Behavioural response studies of cetaceans to naval sonar signals in Norwegian waters -

3S-2011 cruise report

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English summary

Marine mammals are sensitive to sound in their environment and there is a continuing need to quantify the sensitivity of the animals to behavioural disturbance, and determine how potential behavioural changes may affect biologically significant activities, in order to regulate the use of powerful anthropogenic sound sources and design procedures to mitigate impacts. The $3S^2$-study will produce quantitative information on how cetaceans react to sonar and relevant control sounds. This report summarizes the achievements, activities and data collection of an international research trial conducted in Norwegian arctic waters in June 2011 as part of this project. The overall objectives of the trial were to establish a new *modus operandi* for the 3S-group with our new target species (Minke whales, Northern Bottlenose whales and Humpback whales) in our new field site (Norwegian arctic waters), and to start conducting experiments to investigate behavioural responses of target species to naval sonar signals, including studies of the effectiveness of Ramp-up, sensitization or habituation.

During the 3S-2011 research trial a total of 544 sightings of 1694 individual marine mammals were recorded. We deployed 19 DTAGs, 15 to Humpbacks and 4 to Minke whales, and one CTAG to a Minke whale. These tags recorded a total of more than 145 hours of data. We conducted 3 full Ramp-up experiments on Humpbacks, including collection of pre-exposure baseline data, sonar exposure, and positive- (killer whale playbacks) and negative control experiments (silent approaches). In addition, we have conducted two additional experiments on Humpback whales with baseline data collection and silent approaches only. One single Dose-escalation experiment was conducted on a Minke whale, which included collection of pre-exposure baseline data, silent approach, sonar exposure and playback of broadband noise.

All main elements of our cruise plan have been successfully tested, except tagging and exposing Bottlenose whales. We found and successfully tracked all target species, including acoustic detection and tracking of Bottlenose whales. Baleen whales were found in large numbers, both the target species (Minkes and Humpbacks) and other baleen whales (Blue whale and Fin whales). We have also established the Isfjord Channel as a suitable site where we can work with baleen whales close to the Spitbergen coast and with some protection from the weather. We have gained a lot of experience tagging all target species, and except for the Bottlenose whales, we have also successfully tagged them. We have successfully conducted several Ramp-up experiments and a Dose-escalation experiment according to the established protocols, and using a tag boat (MOBHUS) as the tracker platform. The 3S-11 trial is the first trial in a series of 3 yearly trials. Even though we had exceptionally good weather this year, we did not conduct more than 4 complete sonar exposure experiments. However, we have gained a lot of experience with the new field site, new experimental procedures and new species. Thus, we have established a new *modus operandi*, and should be able to make necessary adjustments to be even more efficient in collecting data in the coming trials in 2012 and 2013.

Norsk sammendrag

Sjøpattedyr er følsomme for lyd i deres miljø, og for å kunne regulere bruken av intense akustiske kilder er det et behov for å kvantifisere hvordan menneskeskapt lyd påvirker deres atferd og hvilken biologisk relevans en slik påvirkning har. $3S^2$-prosjektet har som målsetning å generere kvantitativ informasjon om hvordan hval reagerer på militære sonarpulser og relevante kontroll-lyder. Denne rapporten oppsummerer aktivitetene, data innsamlingen og utfallet fra et internasjonalt forskningstokt som ble gjennomført som en del av dette prosjektet med FFIs forskningsfartøy HU Sverdrup II i norske arktiske farvann i juni 2011. Målsetningen med 3S-11 toktet har vært å etablere en ny *modus operandii* for 3S-gruppen med nye arter (vågehval, knølhval og nebbhval) og områder (Barentshavet), samt gjennomføre eksperimenter for å undersøke atferdseffekter av militære sonarer inkludert effekten av Ramp-up, sensitivering og habituering. Resultatene vil kunne brukes som grunnlag for retningslinjer for sonaroperasjoner. Rapporten inneholder også en rekke vedlegg som detaljerer de eksperimentelle prosedyrene og forklarer bakgrunnen for disse.

Under 3S-11 toktet har vi gjort 544 observasjoner av til sammen 1694 individer av sjøpattedyr i området mellom Bjørnøya og Spitsbergen. Vi har satt på 19 DTAG'er (sensorpakker); 15 på knølhval og 4 på vågehval, i tillegg til en CTAG på en vågehval. Disse sensorpakkene har registrert til sammen 145 timer med data. Vi har utført 3 fulle Ramp-up-eksperimenter på knølhval, inkludert registrering av atferd før under og etter sonareksponering, samt under eksponering til spekkhoggerlyder som spilles til dyrene under kontrollforsøk. I tillegg har vi gjennomført to eksperimenter på knølhval som bare inkluderte registrering av normalatferd og kontrollforsøk. Ett dose-eskaleringseksperiment ble også gjennomført på en vågehval. Dette eksperimentet inkluderte registrering av atferd før under og etter sonareksponering samt under eksponering til et bredbånds støysignal.

Alle elementer av toktplanen ble testet, og med unntak av merking av nebbhval fungerte alle prosedyrer tilfredsstillende. Vi fant og sporet alle målarter, inkludert akustisk sporing av nebbhval med tauet antenne. Bardehvaler ble observert i stort antall, både målartene vågehval og knølhval samt andre bardehvaler som blåhval og finnhval. Vi har etablert Isfjordrenna vest av Spitsbergen som et gunstig område å jobbe i under fremtidige tokt, fordi vi finner mye dyr og litt beskyttelse mot været. Vi har høstet gode erfaringer med merking av målartene og med unntak av nebbhvalen har vi også med suksess merket dem. Vi har gjennomført eksperimenter i tråd med planer og protokoller, inkludert sporing av hvalene fra lettbåt. 3S-11 er det første planlagte toktet i en serie på 3 årlige tokt. Vi har hatt eksepsjonelt godt vær i år, men har likevel ikke gjennomført mer enn 4 fulle eksperimenter med sonareksponering. Vi er likevel godt fornøyd med årets tokt fordi den erfaring vi har høstet med nye arter og områder vil gjøre oss i stand til å gjøre nødvendige korreksjoner for å øke utbytte av fremtidige tokt planlagt i 2012 og 2013.

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Preface

In the modern western world, widespread concern is felt about the effects that anthropogenic sound, like active sonar, can have on marine life. Many forms of marine life rely on the use of sound for feeding, avoiding threats, communication and navigation; exposure to loud sounds may interfere with these activities. The concern on the effects of sonar was initiated by incidents involving multiple stranded whales after military sonar exercises.

The use of active sonar is operationally required, an alternative technology enabling detection of underwater objects is not foreseen. "Responsible use" of these systems is necessary, and many navies, including the US Navy, the Royal Norwegian Navy and the Royal Netherlands Navy realize that the protection of marine life by the responsible use of sonar should be part of everyday routine. However, implementation of concrete measures is not easy. Often the necessary knowledge is insufficient, especially the knowledge on sensitivity of marine mammals to specific sonar sounds. Research over the last fifteen years has provided us with a growing fundamental understanding of how sound may affect marine life. Our improved understanding shows us that direct effects by affecting the hearing capabilities of individual animals may happen in some cases. However, it is much more relevant that marine life may be affected by complex and subtle impacts like behavioural responses that may influence populations and eco-systems. There is an urgent need for the navies to obtain knowledge on these effects, to identify risk and tailor mitigation measures. Behavioural response studies (also sometimes called controlled exposure experiments) are an important approach for studying the response of animals to potential stressors. An international and multidisciplinary approach is necessary to carry out this form of research: sea-going experiments are complex and expensive and should not be performed by a single country. For this reason US, Norwegian, Netherlands and UK institutes embarked on the 3S project in 2006 and successfully executed sea trials that resulted in a large and already used dataset on a number of marine mammals (Killer whales, Sperm whales and Long-Finned Pilot whales) and fish (Herring).

In the new $3S^2$ project, we aim to expand this dataset to include other marine mammals like Northern Bottlenose whales and Minke whales, animals that can be found in many naval operating areas and are potentially sensitive, so navies urgently need data on actual risk to populations. There is also an operational need to verify the efficacy of an often used mitigation measure, Ramp-up (or Soft-start), which will be done on Humpback whales which we know we can approached and tag with the existing systems.
The $3S^2$ project is foreseen to carry out three sea trials- the first trial in 2011 should not only bring the first data, but this also the trial where all issues preventing data acquisition should be identified so that these can be dealt with before we go to sea again. In this 3S-11 cruise report an overview of activities and achieved experiments is given.

Group photos: *The most important components of the trial; the scientific team (left) and ship's crew (right). Scientific team (from bottom right): Filipa, Charlotte, Eva, Fleur, Lise, René, Machiel, Mark, Rune, Leigh, Thomas, Patrick, Petter, Lars, Sander, Paul and Frans-Peter. Ship's crew (from right): Terje, Jon, Liv, Erling, Olav, Jonny and Henning.*

The 3S-11 research team consisted of 17 scientist from 7 different countries (Norway, The Netherlands, USA, Portugal, UK, Denmark and France) representing the different research organisations involved. In addition the research vessels had a regular crew of 7. The research group included people with background in biology, underwater acoustics, oceanography, electronics, mechanical engineering, environmental science and operational sonar use. It is clear that the main goals of this first of three sea trials are achieved- this motivated group of people has succeeded in executing experiments in open waters far North, in sometimes difficult conditions, and it has been shown that the knowledge that is urgently needed by the navies can actually be collected.

LCdr René P.A. Dekeling

Netherlands Defence Materiel Organisation

Underwater Technology

The trial started with a very special astronomical phenomena, a midnight sun solar eclipse! The picture is taken shortly after midnight, 1 June 2011

Photo: René Dekeling

Introduction

Marine mammals are sensitive to sound in their environment and there is a continuing need to quantify the sensitivity of the animals to behavioural disturbance, and determine how potential behavioural changes may affect biologically significant activities, in order to regulate the use of powerful anthropogenic sound sources and design procedures to mitigate impact. This study will produce quantitative information on how cetaceans react to sonar and relevant control sounds. Behavioural responses to naval sonar are thought to be a factor in cetacean stranding events, which have included two of our target species, Minke whales and Northern Bottlenose whales. Allied navies have a shared responsibility to address this environmental issue, although specific regulations and species of concern will vary nation by nation.

Recent research conducted in Norwegian water by our 3S research group, and by the BRS team at AUTEC and SOCAL have established that behaviour of individual animals and the groups in which they live can be studied in very fine detail during controlled sonar exposure experiments which involve the use of tag devices and visual and acoustic monitoring. These studies are currently providing critical data on behavioural reactions thresholds of several different species. Such data are needed to quantify the risk of sonar exposure to cetaceans and to establish safe operating procedures. The "Ramp-up" procedure already implemented by some navies, implies a gradual increase of source level upon start of transmissions, in order to allow animals to evacuate the immediate vicinity of the source before it reaches dangerous levels which might injure them. Thus, this procedure is assuming that the animal responds to the sonar signals by an avoidance response and that this response lowers the risk of more severe effects such as hearing impairment. Although intuitively useful, this procedure has been controversial between scientists, environmental groups and naval operational decision makers, because it's mitigating effect has never been documented and it might influence the effectiveness, realism and fidelity of the training.

This report summarizes the achievements, activities and data collection of an international research trial conducted in Norwegian arctic waters in June 2011. The data collected are currently being analysed and final results and recommendations which are expected to be the outcome of the trial will be published in suitable formats later.

1.1 Cruise objectives

The overall objective of the trial was to:

1. Establish a new *modus operandi* for the 3S group which will, within the planned three field seasons, enables us to conduct enough controlled exposure experiments on our new target species (Minke whales, Northern Bottlenose whales and Humpback whales) in our new field site (Norwegian arctic waters) using the financial, logistical and personnel resources available to us.

2. Investigate behavioural responses of target species to naval sonar signals, including studies of the effectiveness of Ramp-up, sensitization or habituation, in order to establish mitigation measures for sonar operations.

1.2 Cruise tasks

The objective of the trial will be met through the execution of the following specific primary and secondary tasks:

1.2.1 Primary tasks

1. Establish a new *modus operandi* for the 3S group which enables us to conduct enough controlled exposure experiments on our new target species (Minke whales, Northern Bottlenose whales and Humpback whales) in our new field site (Norwegian arctic waters) using the financial, logistical and personnel resources available.
2. Tag Minke whales and Northern Bottlenose whales with DTAG and record vocal-, movement- and surface behaviour, and thereafter carry out sonar Dose-escalation experiments where the tagged animals are exposed to LFAS sonar signals and control experiments without any active transmissions.
3. Tag Humpback whales with DTAGs and record vocal -, movement- and surface behaviour, and thereafter carry out sonar Ramp-up experiments where the tagged animals are exposed to LFAS sonar signals and control experiments.

1.2.2 Secondary tasks

4. Tag animals and record natural undisturbed behaviour of target species
5. Carry out control experiments where tagged animals are exposed to a playback of killer whale sounds and a reference sound (broad band noise)
6. Collect group behavioural data to investigate the effect of tagging
7. Retrieve information about the acoustic environment of the study area by CTD or XBT measurements, and do acoustic propagation modeling
8. Carry out pilot tagging (DTAG) and collect baseline data on possible new species (Fin whales, blue whales, bowheads) to be added to the target species list of coming exposure trials.
9. “Tag” dolphins with paint ball coloration and establish procedure for data collection with the aim to add dolphins to the target list for coming sonar exposure trials.
10. Test the use of the next generation DTAGs (DTAG3) on our target species including ARTS-launching it on to the animals.
11. Use of other tags to support data collection (GPS tags, CTAG, speed sensor tag, sponge tag)
12. Biopsy sampling of target species.
13. Collection of bio-acoustic data using towed arrays

The primary tasks had a higher priority than the secondary tasks. However, we tried to accomplish as much as possible also with the secondary tasks, and some of them were even incorporated in our regular experimental protocol. However, secondary tasks were given a lower priority if they interfered with our ability to accomplish the primary tasks.

1.3 Collaborating organisations and sponsors

The 3S-11 research trial is conducted by the 3S-consortium as part of the $3S^2$-project. The main partners of the $3S^2$-project conducting the 3S-11 trial are:

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

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

- Institute of Marine Research (IMR), Norway
- LKARTS-Norway, Norway
- Kelp Marine Research (KelpMR), The Netherlands

The main sponsors of the $3S^2$ research project are:

- The Norwegian Ministry of Defense
- The Dutch Ministry of Defense
- Office of Naval Research, USA

In addition WWF, Norway and Total Foundation are also contributing to specific part of the project.

2 Overview of operation

The 3S-11 research trial took place between Tromsø and Svalbard, 70°-80° northern latitude and 3°-18° eastern longitude, between June 1. and 30. 2011 using the Norwegian military research vessel H.U. Sverdrup II. The operation area and period were chosen based on a thorough evaluation where target species abundance and expected weather conditions were the two must important factors considered (Appendix G). 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 very weather dependent. We consider sea state 0-2 to be working conditions, whereas during sea state 3 the tagging and tracking become very difficult. At sea states above 4, we are non-operational. A main reason for choosing this field site is the typical Arctic high pressure cells which tend to be very stable and give good weather conditions in the early summer. Of the 30 days of operation we were docked for 5 days, mainly for installation, de-installation and a mid sail port call to get supplies in Longyearbyen. Of the remaining 25 days we had good working conditions for 18 days, borderline or difficult working conditions for 5 days and non workable conditions for only 2 days. Table 2.2 summarises the weather situation during the trial.

Table 2.1. Main activities during the trial. Dates are all June.

Date	Area	Main Activities
01.	Tromsø	Installation. Joint dinner with local food, midnight sun, great view and solar eclipse.
02.	Malangen	Continued installation, test of equipment and drill of operation.
03.	Tromsø	Remaining installation and testing, bunkering and ready the ship. Sail off at 21:00.
04.	Tromsøflaket	Transit from Tromsø towards Humpback Ridge, NW of Bear Island.
05.	NW of Bear Island	Searching southwards in Humpback Ridge area. Sightings of numerous Fin whales and White Beaked Dolphins along the shelf break. Occasionally also Minkes and Humpbacks.
06.	NW of Bear Island	Tagged a Humpback. Executed successfully a full Ramp-up experiments on a solitary animal under difficult weather conditions.
07.	W of Bear Island	Sightings of several travelling Humpbacks in relatively shallow water. Tagging attempts on feeding animals. Two tags on one animal. Execute the silent run, before tags falls off.
08.	W of Bear Island	Search westwards off the shelf and then back NE to the shelf break. Sightings of several Humpbacks, but constant travelling behaviour made tagging difficult.
09.	NW of Bear Island	Spotted group of 4 resting Humpbacks. Two tags on one animal but one falls off after a few hours. Executed a full Ramp-up experiment. Transit to South Cape.
10.	South Cape Canyon	De-brief of yesterdays experiment. Search from shallow water westwards into deep water in the South Cape Canyon. Some baleen whales sighted in the shallow part and sperm whales in the deep part, but no sightings of target species.
11.	Spitsbergen	Search north along shelf break off Spitsbergen. Suboptimal weather condition, no sightings of target species. Switch over to search closer to the coast.
12.	Isfjord Channel	Good conditions in Isfjord Channel. Sightings of numerous Minke whales, blue whales and Fin whales. Tagging attempts on Minkes with the ARTS results in a good tag contact, but the tag comes off within the first dive. Another tagging attempt with the hand held pole gave the same results.
13.	Isfjord Channel	Perfect conditions for Minkes during the night and morning. Two more good tag contacts, one with pole one with ARTS, but both come off within the first dive again. Decide to switch to CTAG.
14.	Isfjord Channel	Trying to tag Minkes with CTAG, but fewer sightings of Minkes in the Channel. Sightings of Humpbacks, tagging attempts with cantilever pole results in two tags on, but both come off after 4 hours. New tag attempts, three DTAGs deployed on the two animals. Ramp-up experiment conducted. Tags off and recovered. One tag lost due to VHF failure.
15.	Longyearbyen	Searching for lost tag in Isfjord Channel. Brake off search and transit to Longyearbyen to get supplies and look at engine problems.
16.	Isfjord Channel Fram Strait	Search westwards through the fjord, listening for the lost tag again. Search visually for the tag from position of *"tag not seen on animal"* to *"tag last seen on animal"*. Find the tag by miracle and recovered it. Search further off shore into deeper and steeper waters for Bottlenose whales.
17.	Fram Strait	Continuing the search for Bottlenose whales 50-100 nmi off Spitsbergen focusing the search in the historical catch site for Bottlenose whales between 77-79°N 3-8° E and around bathymetric features like steep slopes, canyons and sea mounts.
18.	Fram Strait	Continue to cover the central and northern part of the historical catch ground, but no sightings. Visual conditions detoriates with increasing northern wind.
19.	Forlandet	Return to the coastal areas searching along the deep slopes off Forlandet. Tag a Minke whale with CTAG and conducted Dose-escalation experiment.
20.	Isfjord	Increasing wind near the end of the Minke whale experiment, recover the tag and transit to Isfjord to seek protection during the resting period.
21.	Isfjord Channel	Search for Minkes and Humpbacks in the Channel and towards the shelf break. A few sightings and tagging attempts, but conditions are difficult.
22.	Isfjord Channel	Return to the Isfjord Channel, still difficult conditions.
23.	Isfjord	Search for, and find, Belugas in the fjord. Searching westwards towards the shelf break. Numerous sightings of baleen whales but conditions are too rough to tag.
24.	Shelf break off Spitsbergen	Searching southwards along the shelf break off Spitsbergen. Sightings of Humpbacks, animal tagged, and experimental protocol initiated. Tag off after 7 hrs of baseline.
25.	Knipovitch Ridge	Continue to sight several Humpbacks on the shelf break of Spitsbergen. Tagged another animal and initiate the experimental protocol. Again tags come off during the baseline period. Transit westwards towards the Knipovich Ridge and search southwards for Bottlenose whales. Sighting of a small group of Bottlenose whales, visual and acoustic tracking of the group, initiated tagging attempts, but not successful.
26.	Knipovitch Ridge	Continue search southwards along the Knipovich Ridge. Sighting of another small group of Bottlenose whales, initiated tagging attempts, but not successful.
27.	Knipovitch Ridge	Continue search southwards along the Knipovich Ridge to 43.5°N. Sighting of numerous groups of Bottlenose whales. No more time left to work with them, but continue to survey for future planning purposes.
28.	Tromsø-banks	No working condition. Sonar transmissions on FFI array as a target of opportunity during transit to Tromsø.
29.	Tromsø	Transit to Tromsø. Arrived Tromsø at 08:00. De-installation, de-mobilization, de-briefing, celebration!
30.	Tromsø	Off loading, disembark.

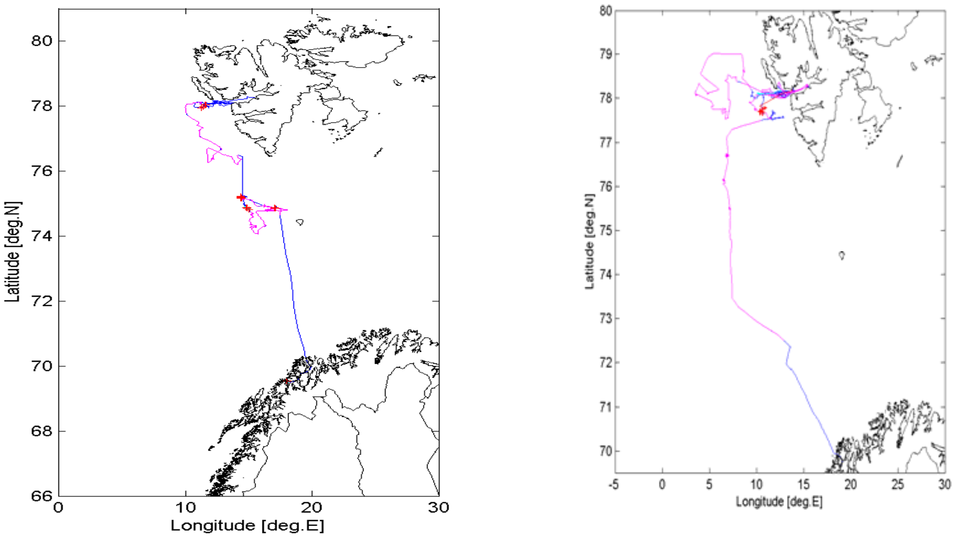


Figure 2.1 Sailed track of HU Sverdrup II for leg 1 (left) (June 1-15) and leg 2 (right) (June 16-30). Sonar transmissions of Socrates system are depicted in red. The pink colored part of the track is where the Delphinus array is being towed, while the cyan colored part is where the CAPTAS array is being towed. Daily tracks can be found in Appendix B.

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

Date	Area	Wind	Weather	Sea state
01.	Tromsø	docked	docked	Docked
02.	Malangen	SW 2	changing cloud cover	1
03.	Tromsø	Docked	Docked	Docked
04.	Tromsøflaket	SW 7	Clouded	5
05.	NW of Bear Island	SW 3	Clouded	3
06.	NW of Bear Island	W 4	changing cloud cover	3
07.	W of Bear Island	NE 2	Clouded	2
08.	W of Bear Island	NE 3	changing cloud cover	2
09.	NW of Bear Island	N 1	Clouded	2
10.	South Cape Canyon	E 2	Clouded	2
11.	Spitsbergen	N 4	Clouded	3
12.	Isfjord Channel	SE 2	clear sky	1
13.	Isfjord Channel	NE 2	clear sky	1
14.	Isfjord Channel	NW 1	clear sky	1
15.	Longyearbyen	docked	Docked	Docked
16.	Isfjord Channel-Fram Strait	NW 2	changing cloud cover	1
17.	Fram Strait	NW 2	Clouded	2
18.	Fram Strait	N 4	Clouded	2
19.	Forlandet	NW 1	changing cloud cover	2
20.	Isfjord	NW 4	changing cloud cover	3
21.	Isfjord Channel	SW 2	Clouded	1
22.	Isfjord Channel	N 5	changing cloud cover	2
23.	Isfjord	SE 5	changing cloud cover	2
24.	Shelf break off Spitsbergen	SE 2	changing cloud cover	3
25.	Knipovitch Ridge	NW 3	changing cloud cover	2
26.	Knipovitch Ridge	E 1	Clouded	2
27.	Knipovitch Ridge	NE 2	Clouded	1
28.	Tromsø-banks	E 5	Clouded	4
29.	Tromsø	docked	Docked	docked
30.	Tromsø	docked	Docked	docked

3 Equipment and data collection

3.1 Equipment

Conducting controlled sonar exposures on free ranging cetaceans at sea requires a variety of sophisticated equipment. Detailed description of ship, tag boats, tagging equipment, tags, sonar source and towed acoustic arrays are given in the cruise plan (Appendix E).

3.2 Protocols

Protocols for the search for target species visually and acoustically, tagging target animals, collecting surface and group behaviour data, tracking the animals, conducting the exposure experiment, collecting necessary environmental data and eventually checking and securing all data in the end of each experiment are all described in the cruise plan (Appendix E). Additional details on the protocol for collection of group behaviour data can be found in Appendix D, and additional material on the experimental design of the Ramp-up experiment can be found in Appendix F.

3.3 Summary of experimental procedures

The operation goes through different phases; a search phase, a tagging phase, a pre-exposure phase, an exposure phase, a post-exposure phase, and then after a data checking and resting phase we return to search phase. The default timing of the different experimental phases is illustrated in the figure below.

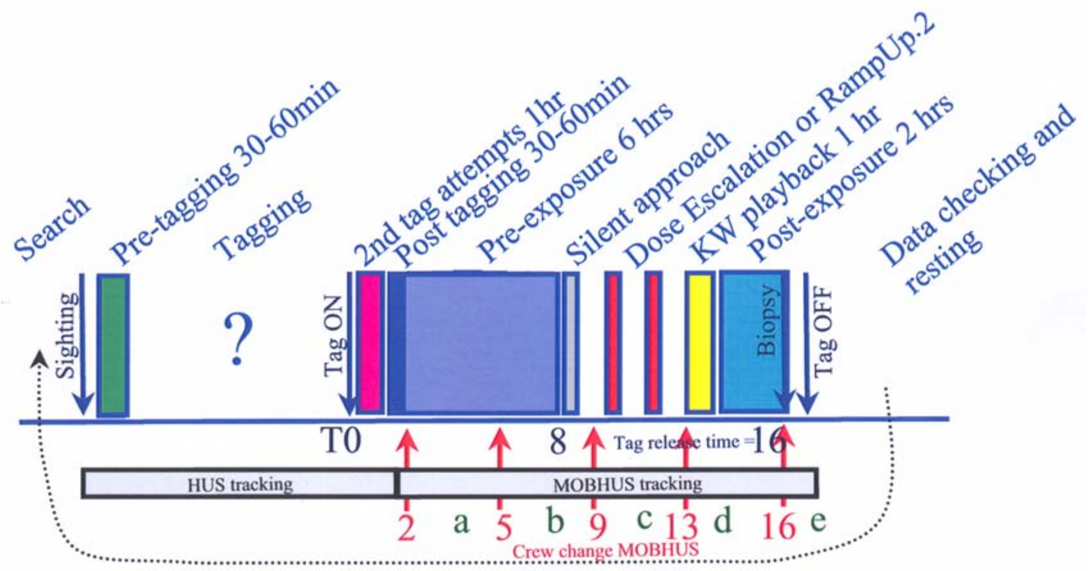


Figure 3.1. Default timing of the different phases of the experiment. The red bins are either Dose-escalation LFAS-exposures on Bottlenose whales and Minke whales or Ramp-up exposures on Humpbacks. The red arrows indicate the timing of crew changes on the observation boat (MOBHUS).

Search for target species were done using a visual team on the elevated platform on the roof of the bridge of the Sverdrup and an acoustic team operating a towed array (Delphinus or CAPTAS). When a target species was detected, group and surface behavioural observations were initiated with the visual team for 30-60 min before a tag boat team was launched to deploy a tag on the animal. If the target animals were Humpback whales or Northern Bottlenose whales attempts were made to deploy the non invasive (suction cups) DTAGs, while if it was Minke whales, several unsuccessful attempts to deploy DTAGs to Minkes showed that suction cups does not attach to the skin of this species and therefore, attempts were made to deploy the invasive CTAG (see section 4.7.1 for details). Collections of group and surface behavioural observations continued also during tagging and for 30-60 min after tagging stopped to look for effect of tagging. After a successful tag deployment, attempts were made to put on a second tag on the same animal for 1 hr before tagging ceased and the tag boat team returned to Sverdrup. The tagged animal was initially tracked visually by the marine mammal observer team on Sverdrup using a VHF digital direction finder (DDF, ASJ Electronics Design/LKARTS, Horten, Norway) to track the radio beacon of the tag. After about 2 hours a visual team was deployed in a specially equipped Man Over Board boat (MOBHUS) with an observation platform in the aft with space for two observers and tracking equipment. Until tag recovery the tagged animal was tracked from MOBHUS and visual observations of surface and group behaviour were recorded from there. Every 3-4 hr the 4 people on MOBHUS were replaced by a new and rested team.

Fleur Visser *Machiel Oudejans*

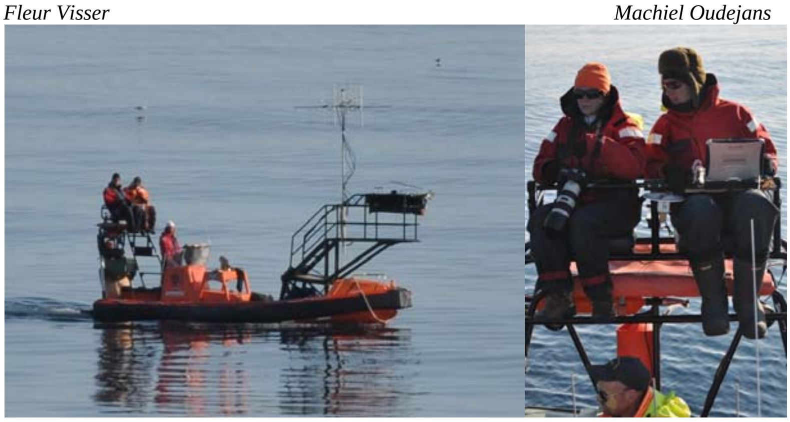


Figure 3.2. The observation platform during the focal follow was an 8 m long water jet propulsion Man Over Board boat (MP800 Springer) (MOBHUS) (left), equipped with an elevated observation platform (right) and antennas for radio tracking of the tag. This boat was also used for tagging using the ARTS system and therefore also had an elevated shooting platform in the bow (section 4.7).

After a period of 6 hrs collecting pre exposure data on the behaviour of the tagged animal, the first approach by the source vessel was initiated. The first approach was a silent approach where the source vessel approached the animal with the towed sonar source deployed but without any active transmissions. During the second and third approach the source ship transmitted a 1.3-2.0 kHz hyperbolic up-sweep signal. Time between approaches was at least 1 hr. If the tagged animal was a Humpback whale, a Ramp-up procedure was used during the approaches, while if it was a Minke whale a Dose-escalation procedure was used. No experiments were conducted on Northern Bottlenose whales because we struggled to find them and they were never successfully tagged.

During the Ramp-up experiments conducted on Humpbacks the source vessel approached the animal at a speed of 8 knots on an estimated intercept course to achieve a closest point of approach (CPA) of 0m. Transmission started 5 min before the estimated CPA and no course changes were allowed after start of transmission. At CPA the transmitted source level reached maximum level (214 dB re 1µPa @ 1m) and transmissions continued for another 5 min while the source ship still continued on the same course. The specific Ramp-up scheme used was carefully chosen based on simulations of the potential outcome (Appendix F).

During the Dose-escalation Experiment conducted on Minke whales the source ship approached the animal at a speed of 8 knots from a distance of 4.3 nmi. Transmission started with a Ramp-up, increasing source level from 152 dB to 214 dB in 10 min, and continued with full power transmissions until 5 min after CPA. The initial course was set to intercept the animal, and the course could be changed to approach the animal head on until a distance of 1000m after which the course was locked.

After completion of the sonar exposure and a 1 hr post exposure period, the animal was exposed to playbacks of killer whale sounds and a reference noise signal. Around the time of tag release attempts were made to collect a biopsy sample of the tagged animal. After tag recovery, the MMO team on MOBHUS returned to Sverdrup. All collected data were subsequently downloaded, checked and backed up before we returned to search mode to look for the next target animal as soon as the crew were reasonably rested.

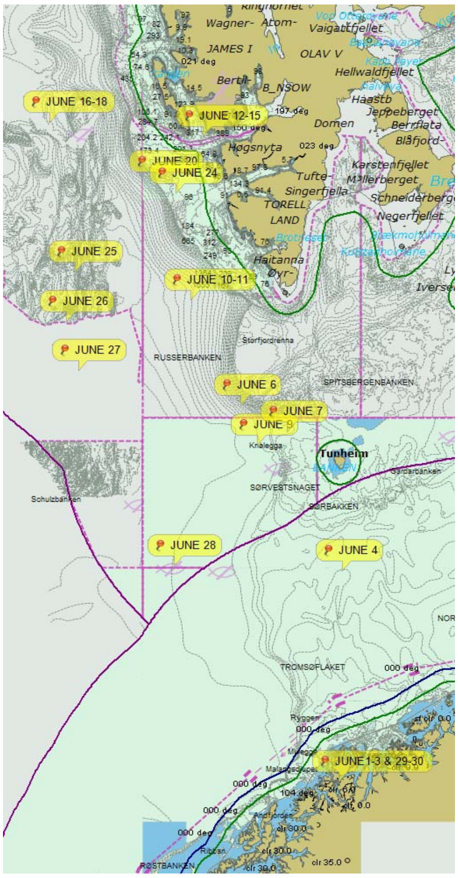
All animal experiments were carried out under permits issued by the Norwegian Animal Research Authority (Permit No. S2011/38782), in compliance with ethical use of animals in experimentation. The research protocol was approved by the University of St Andrews Animal Welfare and Ethics Committee and Woods Hole Oceanographic Institution's Animal Care and Use Committee. In accordance with the permit, mitigations observers were placed on the source ship to assure that no marine mammals were too close to the source and were exposed to sound pressure levels over 180 dB re 1µPa, as required by the permit. The stand-off range between source and animals during full power transmission was 50m. An emergency shut down procedure was implemented and exercised, to immediately stop transmissions if any animals were approaching this safety zone or if any animal showed any signs of pathological effects, disorientation, severe behavioural reactions, or if any animals swam too close to the shore or entered confined areas that might limit escape routes. During 3S-11, no emergency shut down was necessary.

Details of the experimental protocols are given in the cruise plan (Appendix E), and wherever we deviated from the protocol this is stated under each subsections of chapter 4 (Data collected)

4 Data collected

4.1 Overview of achievements

During the 3S-2011 research trial we successfully established a new *modus operandi* in the study area, and a *"fair"* amount of data was collected. Fig 4.1. summarises the main events of the trial and a complete data inventory is give in Appendix A. The marine mammal observers recorded a total 544 sightings of 1694 individual marine mammals (fig 4.2, table 4.1). The acoustic team recorded a total of 6 Tbytes of data, including acoustic detections of at least 6 different species (section 4.10). We deployed 19 DTAGS, 15 to Humpbacks and 4 to Minke whales, and one CTAG to a Minke whale section 4.7). These tags recorded a total of more than 145 hours of data. We conducted 3 full Ramp-up experiments on Humpbacks, including collections of pre exposure baseline data, sonar exposure, and positive- (killer whale playbacks) and negative controls (silent approaches) (section 4.3). In addition, we have conducted two additional experiments on Humpbacks with baseline data collection and silent approaches, as well as collected baseline data only for 1 animal.



Date	Main events of 3S-11 trial
June 1-3	Installation in Tromsø, test and exercise of operation.
June 4	Transit across shelf in bad weather.
June 6	Ramp-up experiment on Humpback
June 7	Baseline data and silent run on Humpback
June 9	Ramp-up experiment on Humpback
June 10-11	Searching for target species in South Cape Canyon
June 12-15	Four DTAG deployments to Minkes, Ramp-up experiment to Humpback.
June 16-18	Search for Bottlenose whales in historical catch area.
June 20	CTAG deployed and Dose-escalation experiment conducted on Minke whale
June 24	Humpback tagged, baseline data collected
June 25-26	Bottlenose whale sightings, tracking and tagging attempts
June 27	Bottlenose whale detections, but gradually decreasing numbers
June 28	Transit to Tromsø
June 29-30	De-mobilization

Figure 4.1. Geographical locations of main events of the 3S-11 trial.

The reason that these two experiments were not completed according to protocol was that the tag came off the animal prematurely. One single Dose-escalation experiments was conducted on a Minke whale, which included collection of pre exposure baseline data, silent approach, sonar exposure and playback of broadband noise (section 4.3). Details of all experiments are given in Appendix C, and example of data from the experiments is given below. No experiments were conducted on any Northern Bottlenose whales. The reason for this is that we only found this species so late that there was not time for sufficient tagging attempts on them. However, we did manage to get some experience tracking them both acoustically and visually, and also some initial tagging attempts were made.

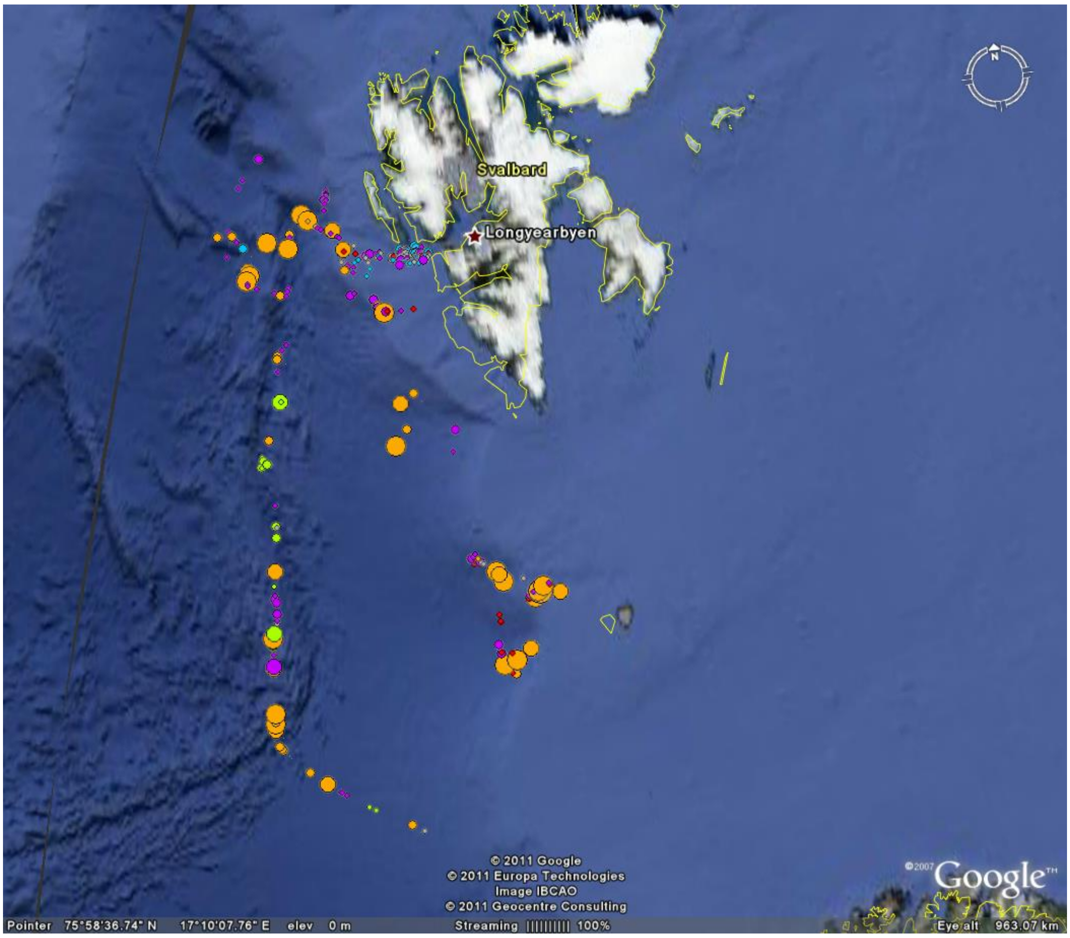


Figure 4.2. Initial sightings of marine mammals from RV HU Sverdrup II during 3S-11. The size of the dots indicate a relative size of the group. Blue whales (•), Fin whales (•), Humpback whales (•), Minke whales (•), Northern Bottlenose whales (•) and White Beaked dolphins (•). Some unidentified cetaceans and some seals are not shown (table 4.1)

4.2 Establishing a new 3S *modus operandi*

A main objective of this trial was to establish a new *modus operandi* for the 3S-group in a new field site, working with new species and somewhat new methodology compared to previous 3S-trials (Kvadsheim et al. 2007; Kvadsheim et al 2009). The main difference being that we planned to use one of the tag boats (tag boat 2/MOBHUS) deployed off the source boat as the tracker boat and observation platform during the experiments instead of a dedicated second vessel. Since we only had one vessel, the scientific crew was significantly smaller than during previous trials. In addition the Ramp-up protocol implied a mush stricter and tighter geometry during the approaches. Much effort was spent prior to the trial to collect as much information as possible about the field site, both in terms of weather conditions and abundance of target species (Appendix G), and to prepare and test the equipment and protocols (cruise planning meeting at sea). However, in the start of the trial there were still uncertainties about our ability to find some of the target species and track them acoustically, especially the Bottlenose Whale, and our ability to tag and conduct controlled exposures on them with the protocol defined and with the equipment available. We were quite comfortable about our ability to find Minke whales and Humpbacks, based on existing data (Appendix G) and our own experience in the area, but very little information existed on Northern Bottlenose whales (Appendix G). We therefore spent a significant amount of time simply surveying large areas to search for Bottlenose whales. The survey was focused in areas which were traditional catch sites for Bottlenose whales up until the early seventies, and in areas with steep and deep bathymetry where this species are typically found.

Table 4.1. During the 3S-11 trial 544 sightings of 16 different species were recorded, with a total number of 1694 animals (best estimate).

Species	Latin name	Sightings	Low[1]	Best[2]	High[3]
Whitebeaked dolphin	*Lagenorhyncus albirostris*	59	536	709	919
Atlantic white-sided	*Lagenorhychus acutus*	1	1	1	1
Unidentified dolphin		17	81	137	176
Minke whale	*Balaenopetera acutorostrata*	98	101	102	102
Sperm whale	*Physeter macrocephalus*	16	17	17	17
Fin whale	*Balaenoptera physalus*	132	161	169	176
Humpback whale	*Megaptera novaeangliae*	40	48	54	57
Blue whale	*Balenoptera musculus*	37	44	44	46
Bottlenose whale	*Hyperoodon ampullatus*	19	42	45	52
Sei whale	*Baleanoptera borealis*	1	1	1	1
Beluga	*Delphinapterus leucas*	1	15	30	40
"Big" cetacean		29	33	34	35
Unidentified whale		70	78	82	85
Unidentifyed beaked		1	8	10	12
Harp seal	*Pagophilius groenlandicus*	8	60	80	95
Hooded seal	*Cystophora cristata*	1	1	1	1
Unidentified seal		14	134	178	211

[1] Lowest estimated number of animals in sighting
[2] Best (most accurate) estimated number of animals in sighting
[3] Highest estimated number of animals in sighting

All main elements of our cruise plan have been successfully tested, except tagging Bottlenose whales. We have found and successfully tracked all target species, including acoustic detection and tracking of Bottlenose whales. Baleen whales have been found in large numbers, both the target species (Minkes and Humpbacks) and other baleen whales (Blue whale and Fin whales). We have also established the Isfjord Channel as a suitable site where we can work with baleen whales close to the Spitbergen coast and with some protection from the weather. We have gained a lot of experience tagging all target species, and except for the Bottlenose whales, we have also successfully tagged them. We have successfully conducted several Ramp-up experiments and a Dose-escalation experiment according to the established protocols, and using a tag boat (MOBHUS) as the tracker platform. The 3S-11 trial is the first trial in a series of 3 yearly trials. We have had exceptionally good weather this year and still have not conducted more than 4 sonar exposure experiments. However, we have gained a lot of experience with the new field site, new experimental procedures and new species. Thus, we have established ourselves with a new *modus operandii*, and should be in good shape to make necessary adjustments to be more efficient in collecting data in the coming trials planned for 2012 and 2013.

Fleur Visser

Figure 4.3. A total of 6-7 days was spent surveying in typical habits of Northern Bottlenose whales. Black dotted circles indicate the covered areas. The survey was initially focused along the deeper part of the steep continental shelf break and in the traditional catch site for Bottlenose whale west of Spitsbergen. However, no Bottlenose whales were ever sighted there. Near the end of the trial, we eventually found them in quite large numbers (20-40 animals) in groups of 2-10 animals along the Knipovich Ridge further off shore (green dots).

4.3 BRS on cetaceans

Two types of experiments were conducted. Ramp-up experiments to Humpback whales and a dose-escalation experiment with one Minke whale. The procedures for the two types of experiments differ in only minor ways. In both cases, tags are attached and the experimental protocol detailed in Fig. 3.1. were followed. The teams on the observation platform conduct identical tracking and behavioural observation tasks in both types of experiments. The only difference was the specific way in which the sonar exposure was conducted. For the dose-escalation experiments, the exposure began with a Ramp-up at a target distance of 6-8 km from the whale and the source vessel then approaches the whale during full-level exposure. This created a slow escalation of the sonar dose received by the animal, and our experiments were designed to enable us to identify the thresholds at which responses begin to occur. For the Ramp-up experiments, the source boat was already approaching the whale at the start of the Ramp-up sequence. The goal was to create a realistic situation in which a whale was in the location close to where full-level transmissions would start to be made by the source. Thus, for Ramp-up experiments, both the approach course and the specific timing of the start of transmissions needed to be carefully carried out, making the Ramp-up procedure more challenging than the dose-escalation procedure. In both cases the sonar exposure was conducted twice – with the goal to quantify within-individual variability in response thresholds and any order effect. Also, in both cases a silent pass was made before any sonar passes (negative control), and the goal was to conduct playback of killer whale sounds after the final sonar pass.

3S-11

Figure 4.4. Humpback whale tagged with two DTAGs to improve VHF tracking capability, and to increase the chance that at least one DTAG stays on for the entire duration of the experiment (16 hrs). The DTAGs both have an extra GPS-tag attached to them.

4.3.1 Ramp-up experiments on Humpback whales

The experimental design of the Ramp-up experiment on Humpback whales required that the source vessel was navigated towards the animal in an identical fashion between Silent runs, Ramp-up sonar runs, and Full Power sonar runs (the latter type of approach was not conducted this year, but possibly will be in future trials). Because of the importance of navigation the Ramp-up approaches were conducted using two separate intercept calculators to advise the experimental coordinator on which approach path he should choose; 1) the MARIA software used by the Norwegian Navy, and RUtool specially designed by Paul Wensveen (Fig 4.5). The positions of the whales, as reported by the MOBHUS tracking it, was fed into the tools which then calculates the best sailing path of the source ship in order to intercept the whale closely during the approach. The two tools used somewhat different logic. The movement of the whale is often unpredictable, and while Wensveen's tool predicts the future movements of the whale based on the last few sightings, the MARIA tool uses the movement of the tracking boat (MOBHUS), which is usually within 100m of the whale, and then the operator makes manually corrections to compensate for the offset between the whale and the MOBHUS. It turned out the Maria tool was most useful in the initial positioning of the source vessel, and approach, while RUtool was most useful in timing the start of transmission so that we reached full power at CPA, as required by the experimental design. Ultimate decisions on course changes and start of transmission were always done by the experimental coordinator based on all available information.

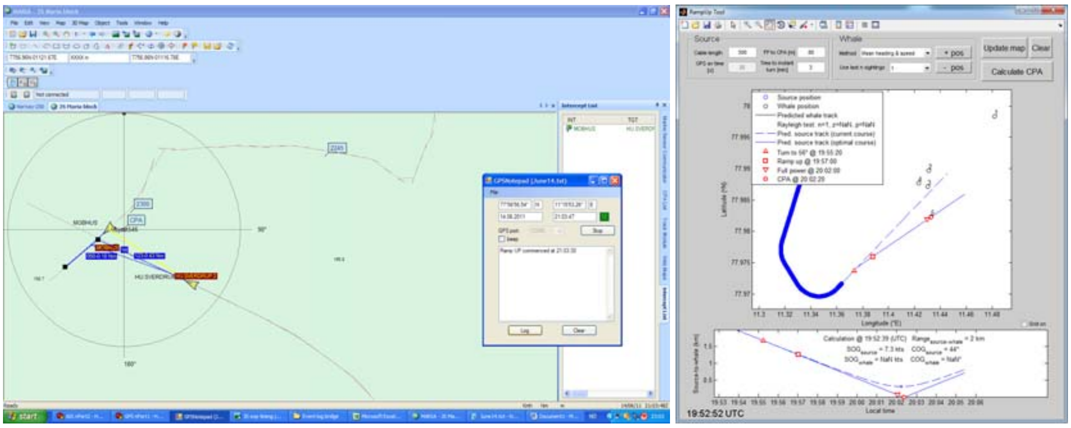


Figure 4.5. The screenshot to the left is from the MARIA software used by the Norwegian Navy and the screenshot to the right is from a tool specially designed by Paul Wensveen (RUtool). Both tools were used to advise the experimental coordinator about navigational decisions during the Ramp-up approaches.

The Humpback whale tracks showed good correspondence between the tracks produced by the GPS tag attached to the DTAG and the tracks generated by sightings from observers on both MOBHUS and HU Sverdrup (Fig 4.6). Although no severe behavioural responses were observed by the marine mammal observers during the Sonar or Silent approaches, there were some indications of more subtle horizontal and vertical avoidance responses by the animals after plotting the horizontal tracks and dive profiles. Different time-domain approaches (e.g. brake point analysis) will be explored during the data analysis phase to quantitatively combine all the information from the different high-resolution data streams that were recorded during the Ramp-up experiments.

Other data streams such as the depth and 3D-accelerometer data recorded with the DTAG provide crucial information about the behaviour of the animal and will also be included in the quantitative analysis approach. For example, Figure 4.7 shows how the dive behaviour of the two Humpback whales changed after the second Sonar run which is not evident from the horizontal tracks of that same experiment (Fig 4.6).

The vertical positions of the animal are also valuable in understanding observed patterns in the sound exposure levels that the Humpbacks received during vessel approaches with active sonar.

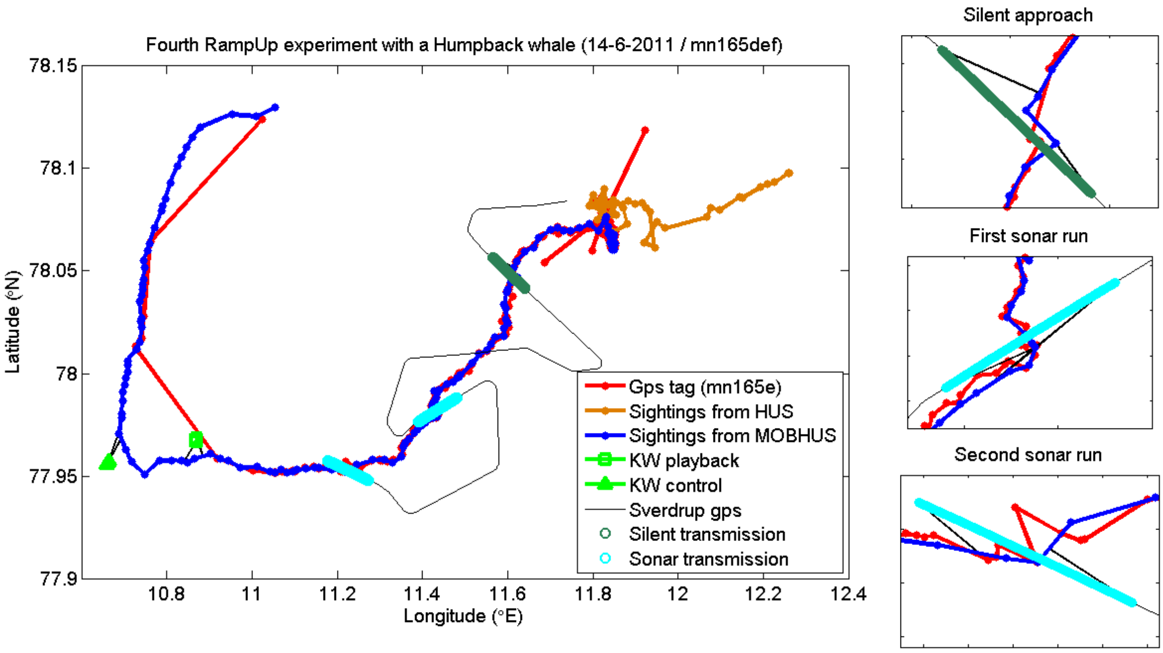


Figure 4.6. Example of tracks from the 14th June Ramp-up experiment on two Humpback whales travelling side by side. The DTAG on the whale had a GPS tag attached to it, and the GPS track is overlaid the track generated from the sightings made by the marine mammal observers. Except for occasional drop outs of the GPS sensor late in the deployment, the two tracks are very similar. Zoomed-in views of the Silent run and two Sonar runs are shown on the right.

One of the assumptions behind the Ramp-up procedure is that the animal will receive a lower total acoustic dosage because it will start to avoid the source when the sound levels are slowly increased. The sound levels on the Humpback whale were measured directly as all focal animals were tagged with sound-recording DTAG sensors. Similar as in the first 3S project (Miller et al 2011) the maximum Sound Pressure Level (with 200-ms rms averaging time) and cumulative Sound Exposure Level of the sonar signals were calculated using CEE-analyser (Fig 4.8). A custom Matlab program was written so that the sonar pings could be extracted from the (sometimes noisy) DTAG audio recordings with relative ease and this approach ensured that the sound levels were quantified according to a strict set of rules.

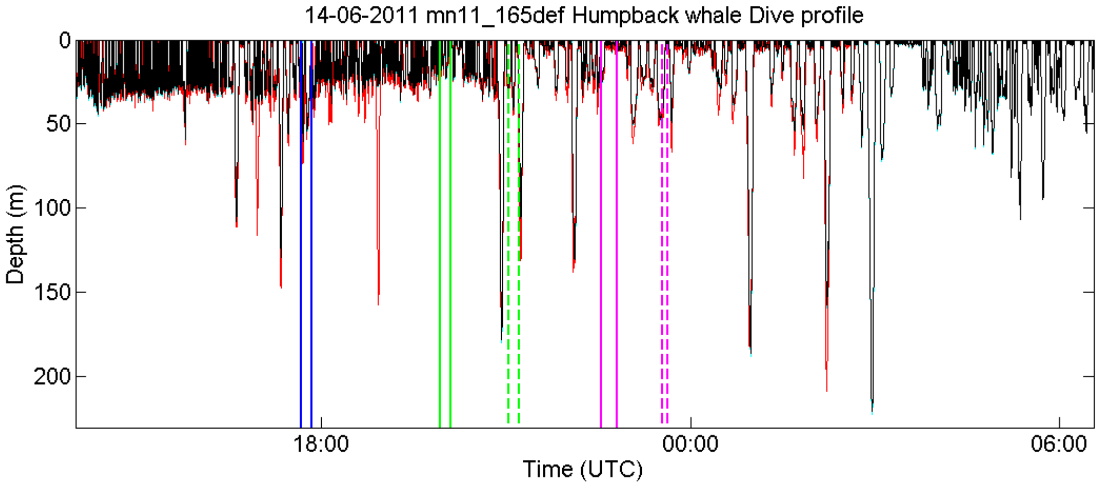


Figure 4.7. Example of dive records (black and red lines) of two Humpback whales travelling together during the Ramp-up experiment conducted on the 14th of June. Horizontal lines indicate the start and end of the Silent run (blue), first and second sonar runs (whole and dashed green lines, respectively) and playbacks of killer whale sounds (whole magenta) and the noise control sound (dashed magenta).

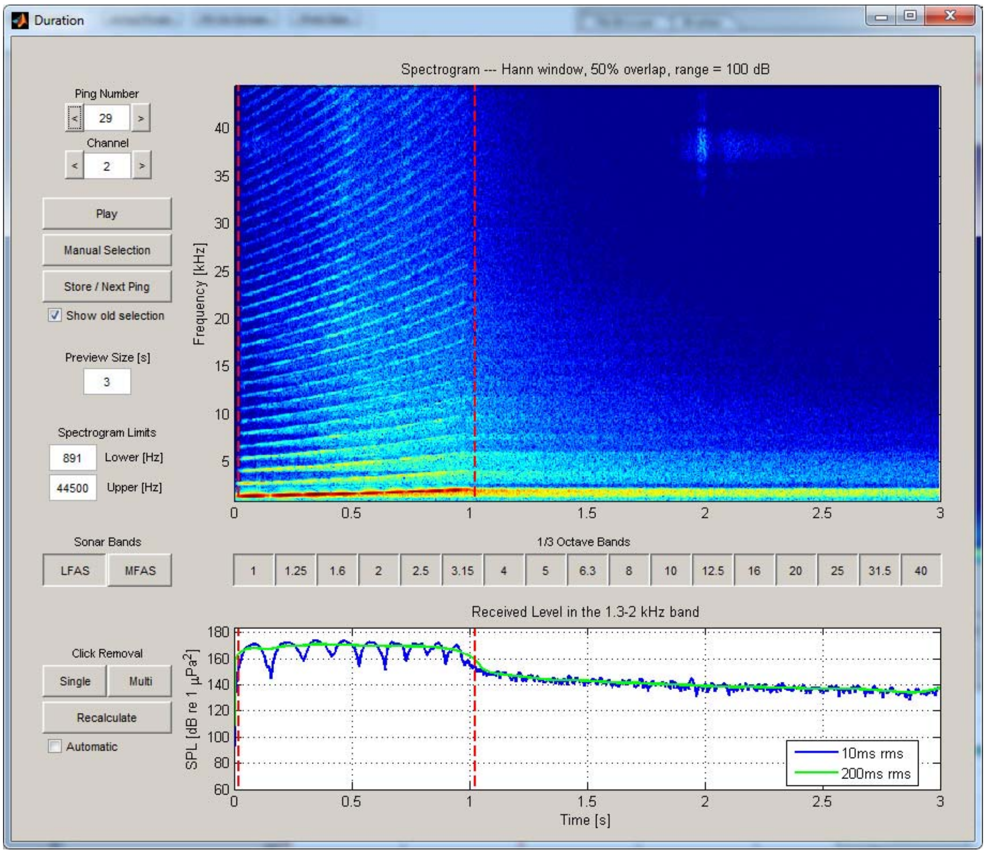


Figure 4.8. Screenshot of CEE-analyser showing example of LFAS ping recorded on the DTAG during a Ramp-up experiment. The maximum received pressure level of this ping is more than 170 dB re 1µPa).

4.3.2 Dose-escalation Experiments on Minke whales

A CTAG (Fig 4.9 and 4.17)) was attached to a subadult Minke whale around 15:30:00 on June 19th, and started recording at 16:00:00 (local time, UTC + 2), and recorded until 11:21:16 (local time) on June 20th.

Patrick Miller

Figure 4.9. Picture of Minke whale with CTAG attached.

The animal quite clearly responded to the tagging, and both the tag boat and Sverdrup lost contact with the animal for a short while. However, the animal soon returned to normal behaviour and the pre-exposure phase was conducted with good tracking from MOBHUS according to protocol. The silent run was conducted with a closest point of approach of about 300 m without any obvious responses to the approaching ship. Before starting sonar transmissions, the whale was reported to feed close to the surface (skim feeding), as is seen by the shallow dives before onset of transmission (Fig 4.10). Shortly after start of Ramp-up, the dive behaviour changed to deeper dives down to 40-50 m, and the animal sped up and started moving on a constant course away from the ship (Fig 4.12). Using transmission loss estimates (Fig 4.11) it looks as the initial response of the whale was to dive in and out of the sound channel, maybe as an orientation response or to keep track of the position of the sound source. A close look at the dive record reveals that the animal does multiple of these dives without going to the surface. Approximately half way into the run, the animal again changed to shallower diving, and sped up to a horizontal speed faster than the approaching source ship, which was doing 8.5 knots. Such shallow diving is probably a more efficient way of rapid horizontal travelling. Since the response to the sonar at this point was obvious, and the source ship was not closing in on the fast moving whale, the source ship locked it's course prematurely at a distance of 3 km instead of 1km as usual. After a while the animal gradually turned north and the closest point of approach was only 2.5 km. Total exposure time was 1 full hour of full power transmission. After the end of the transmissions the animal apparently returned to normal dive behaviour, but since the response to the sonar was so clear and the exposure session lasted unusually long, the decision was made to cancel the second sonar exposure run, extend the post exposure observation period, and then move on to the killer whale playback.

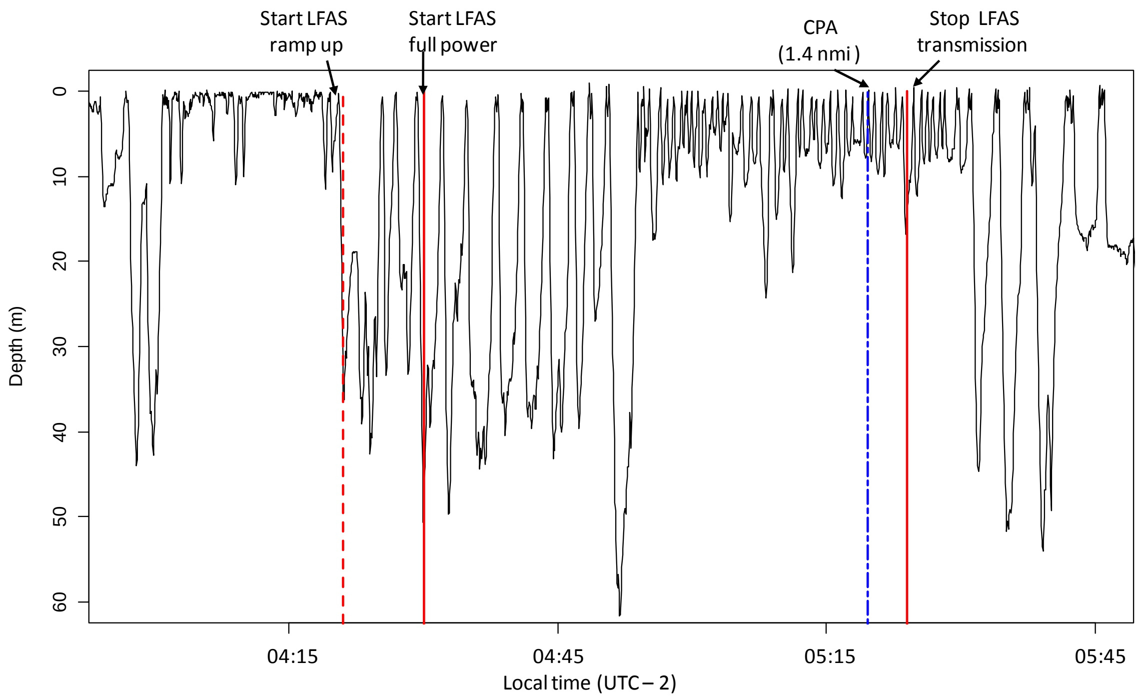


Figure 4.10. Dive record of Minke whale with experimental conditions indicated.

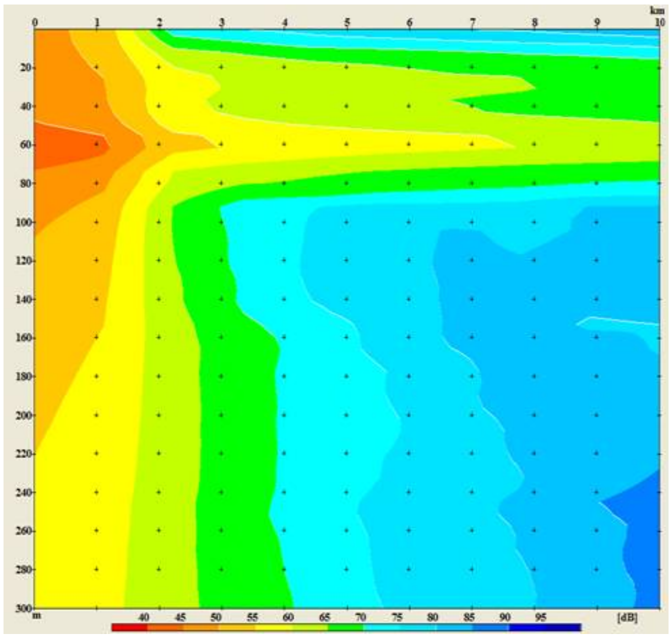


Figure 4.11. Transmission loss plot generated by Lybin based on the transmission characteristic of Socrates and sound speed profiles collected in the area of transmission. The source started transmitting at a distance from the whale of 8km, and at CPA the distance was still 2.6 km. There was a prominent sound channel between 40-80 m in the area of the experiment.

Since the CTAG does not have an acoustic sensor the exposure levels have to be reconstructed using transmission loss modeling (Fig 4.11) in combination with data on vertical (Fig 4.10) and horizontal movement of the whale and source (Fig 4.12), all of which is recorded. In addition received levels were recorded on the VD-array towed by the MOBHUS which was usually within 100 m of the whale during exposure (table 4.2).

Table 4.2. The table shows all the acoustic recordings on VD array during the trial. The recording made during the Minke whale sonar exposure and killer whale playback look good without clipping.

Date	Start Time (GMT)	Filename	Duration	Comments
09/06/2011	09:01:02	VDARRAY_09062011_090102 (test)	01m48s	Test
09/06/2011	09:13:02	VDARRAY_09062011_091302 (sonar exposure to Humpback)	12m36s	Clipped levels
09/06/2011	10:34:12	VDARRAY_09062011_103412 (sonar exposure to Humpback)	11m27s	Clipped levels
14/06/2011	19:46:38	VDARRAY_14062011_194638 (sonar exposure to Humpback)	20m06s	Clipped levels
14/06/2011	21:00:38	VDARRAY_14062011_210038 (sonar exposure to Humpback)	15m38s	Clipped levels
14/06/2011	22:31:33	VDARRAY_14062011_223133 (KW playback to Humpback)	17m46s	-
14/06/2011	23:16:23	VDARRAY_14062011_231623 (KW control to Humpback)	22m49s	-
20/06/2011	01:57:25	VDARRAY_20062011_015725 (sonar exposure to Minke)	1h38m08s	-
20/06/2011	06:08:39	VDARRAY_20062011_060839 (KW control to Minke)	0h38m50s	-

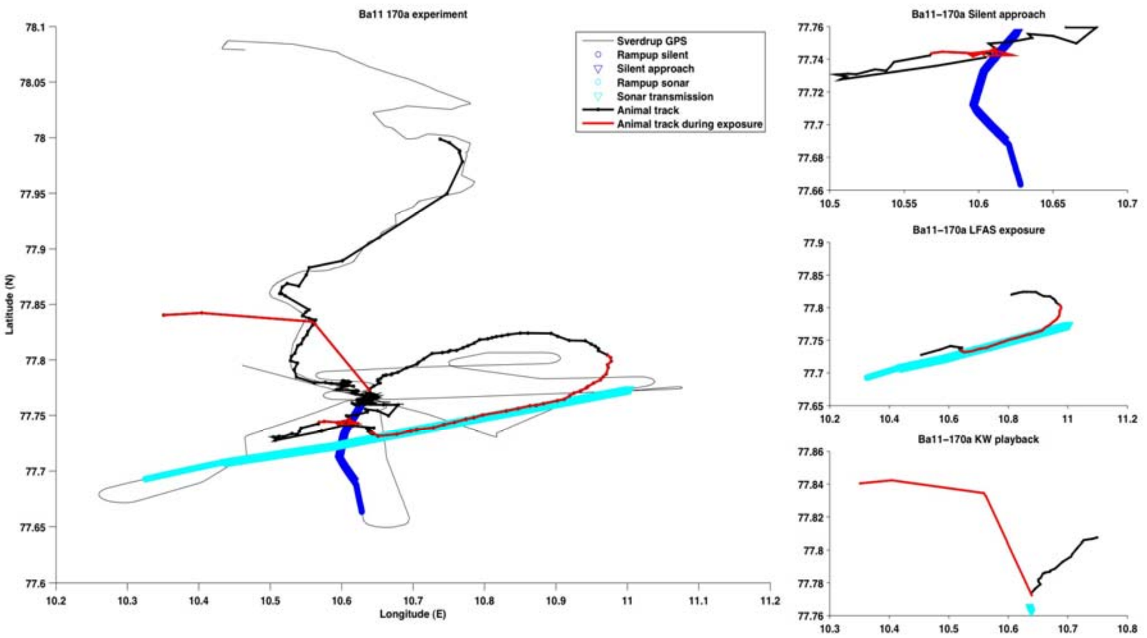


Figure 4.12. The horizontal movement of the Minke whale and the source ship during the exposures.

4.3.3 Killer whale playbacks

Playback experiments were performed on 2 target species; Humpback whales and Minke whales. Each experiment of killer whale playbacks was performed from tag boat 1 and roughly required 1.5 hour. Two sound stimuli were played back in random order; 15 min noise or 15 min Killer whale sounds, with 30 min between exposures. The broad band noise signal was used as a negative control. The signal is a sequence of background noise selected from previous recordings (2005), amplified up to get the average RMS power equal to the Killer whale stimulus, and repeated until getting the same duration as the stimulus (15 min). The Killer whale vocalizations used was a recording from transient mammal-feeding Killer whales. It was recorded in 2005 in a behavioural context of foraging (DTAG acoustic recordings). All acoustic signals have a similar average RMS power and duration of 15min. To avoid pseudoreplication, we used 3 different sets of killer whales stimuli and 3 different noise stimuli. For all experiments, playback started at a distance of 800m (estimated) at an angle of around 90° from the direction of travel of the focal animal. Actual position relative to the focal animal will be checked later with tracking data.

Table 4.3. Summary of the 4 playback experiments performed during the trial

	Date and time of playback session			**Acoustic signals & comments on responses**	
	Date	*Time of Start (UTC)*	*Time of End (UTC)*	*Acoustic signals*	*Comments*
Humpback whale	06 June	11:40:40	11:56:51	1- KW 2- Noise	Changed direction in response to Killer whale sounds. No visible response to noise.
Humpback whale	09 June	12:14:48	12:30:13	1- KW 2- Noise	Changed direction in response to Killer whale sounds. No visible response to noise.
Humpback whale	15 June	12:13:00	12:29:00	1- KW 2- Noise	Changed direction in response to Killer whale sounds. No visible response to noise.
Minke whale	20 June	13:03:43	13:19:42	1- Noise	Strong reaction to noise: fast travel away from the source almost immediately after the start of playback

There was no obvious response to noise for the three tested Humpback whales, while the animals changed direction and reduced number of surfacings in response to the Killer whale sound. The Minke whale started a fast travel away from the source almost immediately after the start of the noise playback. We did not have time to perform playback of Killer whale sounds to the Minke whale.

4.4 Visual tracking

Visual tracking was successfully conducted from two platforms during 3S-11 (see the cruise plan, Appendix E for details); HU Sverdrup II (HUS) and tag boat 2 (MOBHUS). Searching for animals was conducted from the Sverdrup using the naked eye, hand-held binoculars and big-eye binoculars, when weather conditions allowed. Once a target species was sighted, tracking of the animal started to evaluate the possibilities to tag it. Pre-tagging, tagging and post-tagging phases of observations were conducted from the Sverdrup. The tracking platform was then transferred to MOBHUS and all observations were then conducted from that platform.

Sightings and re-sightings were entered into the Logger software and stored as Microsoft Access tables. This software has specific fields for species ID, range to animal, bearing to animal, and animal aspect relative to the direction of the boat. Using this information the software displays a map with the sighting location relative to the track of the observation vessel in real time, which is extremely useful to help guide the observation vessels and for real-time checking of the data entered. Additional user-specified fields were added to record behavioural observations.

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Figure 4.13. Naked eye, baby Big Eyes and binoculars were used from the marine mammal observer platform on HUS. The MOBHUS platform is shown in figure 3.2.

On the Marine Mammal Observer (MMO) platform of the Sverdrup (HUS) a total of 450 h, 56 min of visual effort, with 2.7 persons on average doing observations was recorded. During the searching phase, 2.97 persons were on average observing, while during tagging and tracking an average of 2.85 persons were observing. During experiments, the main visual effort was conducted from MOBHUS (tag boat 2), with a reduced visual effort of average 1.8 persons doing visual observations from HUS.

Total visual effort from the MOBHUS platform exceeded 75 hours, divided into tracking and biopsying activities as shown in the table 4.5. A total of 874 re-sightings of tracked individuals were made from the MOBHUS platform.

Table 4.4. Daily visual effort on HUS. Given in the table is total time (duration) of visual observations, and the average number of MMOs doing observations (visual effort). This is given as total effort for the day, and for three categories of activities; Searching, Tagging/tracking and Observation.

	Daily total		Searching[1]		Tagging/tracking[2]		Observation[3]	
	duration	visual effort	duration	visual effort	duration	visual effort	duration	visual effort
05.06.2011	15:33:59	2.5	13:35:56	2.5	02:05:47	2.3	05:06:13	1.6
06.06.2011	15:01:12	1.6						
07.06.2011	19:53:50	1.75	07:24:19	2.2	05:49:57	1.75		
08.06.2011	19:23:25	3.14	14:33:44	3.425	05:05:07	2.625		
09.06.2011	15:13:35	1.35			01:16:29	3	13:57:06	1
10.06.2011	17:42:04	3.14	23:59:59	3.14				
11.06.2011	23:59:59	3	23:54:35	3	00:05:24	3		
12.06.2011	23:59:59	3.02	14:28:18	2.081273148	15:56:40	3.0375		
13.06.2011	23:59:59	2.7	20:32:27	2.88	03:27:32	2.5		
14.06.2011	23:59:59	2.16			02:22:50	3	21:37:09	2.18
15.06.2011	08:04:23	2					08:04:23	2
16.06.2011	08:35:36	2.3	08:35:36	2.3				
17.06.2011	23:59:59	3.14	23:59:59	3.14				
18.06.2011	23:59:59	3.3						
19.06.2011	23:59:59	2.83	03:15:33	3.25	07:12:31	2.83	03:42:36	1.75
20.06.2011	08:51:20	1.71					08:51:20	1.71
21.06.2011	19:32:46	3.35	23:09:35	3.33	00:50:24	3.5		
22.06.2011	23:59:59	3.32	23:59:59	3.32				
23.06.2011	23:59:59	3.33	23:59:59	3.33				
24.06.2011	23:59:59	3.05	05:17:31	3	12:34:35	3.155	06:07:53	2.5
25.06.2011	15:04:31	3	11:47:31	3.17			03:17:00	2
26.06.2011	23:59:59	3.4	17:19:03	3.326	06:40:56	3.525		
27.06.2011	23:59:59	3.14	23:59:59	3.14				

[1] Includes all visual effort when searching for animals

[2] Includes all visual effort during tracking of animals from HUS, during pretagging, tagging and post tagging, as well as before MOBHUS takes over during experiment.

[3] Includes all visual effort from HUS during experiments, when MOBHUS is doing the main tracking of the focal animal(s).

Table 4.5. Visual effort of MMO platform on MOBHUS.

	Time (hh:mm)
Total Track	75:58
Tracking	72:57
Biopsying	03:01

4.5 Group and surface behaviour

Group behavioural data was collected for Humpback whales, Northern Bottlenose whales and (briefly) for Minke whales. The protocol for data collection was identical to the group behavioural protocols used during the 3S-09 trial (Kvadsheim et al 2009), with some additions. For all focal whales, it was now recorded whether they were associated with a calf for all sightings and re-sightings. In addition, display event fields were added to account for the different surface behaviours of the new target species. Added display events were: bubblenet feeding, fluke out, rolling and lunging, as well as fields for birds associated and dolphins associated. Synchrony was measured by the number of whales in the focal group surfacing while the focal animal was visible at the surface. Combined sampling of group behaviour and tracking of the focal whale was established well from both the HUS and the MOBHUS observation platform during all encounters. New platforms and new species were introduced during the 3S-11 trial, however, the experienced research team succeeded in collecting high quality tracking and group behaviour data throughout the trial. Pre-, during- and post tagging group behaviour data was collected from the HUS observation platform. Group behaviour data during pre-exposure (baseline), exposure, post-exposure and biopsy phases were collected from the MOBHUS observation platform.

4.5.1 Humpback whales

We collected 6 tracks for Humpback whales (5 experiments, 1 tagging; table 4.6, fig 4.14). Group behavioural sampling was established during pre-tagging and continued to the end of tracking for all experiments. The focal whale remained the same throughout each of the experiments. In total 100 hours of combined tracking and group behavioural sampling data was collected, of which 38 hours of tagging data, 31 hours of baseline data, 3,5 hours of exposure data and 3 hours of biopsy sampling data.

Humpback whales were observed generally alone or in pairs, forming larger groups, up to 8, and aggregations, up to 11, during feeding bouts. Feeding was characterized by an erratic track with little net horizontal movement, showing lunges, fluke outs and rolls. Birds (kittiwakes) were always associated during feeding events, while white beaked dolphins were associated mainly in the offshore areas off Bear Island. Often, Fin whales were feeding in the same area as the Humpback whales. Feeding was observed for all focal animals, alternated with bouts of resting and travelling of variable duration.

4.5.1 Minke whales

We collected 17 tracks for Minke whales (1 experiment, 8 tagging, 8 baseline) with a total duration of 34 hours (tables 4.6. and 4.7). Without a tag, individual Minke whales could be tracked for 7 minutes up to 2:28 hours, with a mean duration (± SD) of 55 ± 45 minutes. Visual tracking of Minke whales required very calm conditions, sea state 0-1. During the experiment, following tag on, tracking could be performed well from MOBHUS from the baseline phase throughout the end of the exposure. During the playback session the wind picked up and the tracker team became dependent of the direction finder to follow the tagged whale and retrieve the tag upon release.

Minke whales were generally observed alone, sometimes shortly associated with other large baleen whales (mostly Fin whales), sometimes in an area with several other Minke whales, and once, again briefly, feeding together with another Minke whale. Observed behavioural states were mostly travelling and feeding. Once skim feeding was observed, for the focal whale of the experiment. While group behaviour sampling was very much limited for Minke whales, alternatively, surface behaviour parameters, such as the number of surfacings per surfacing bout, direction changes and skim feeding activity were collected systematically. The frequency of data collection was altered from once per 2 minutes to once for each surfacing, to better capture the movement and dive pattern of the focal whale.

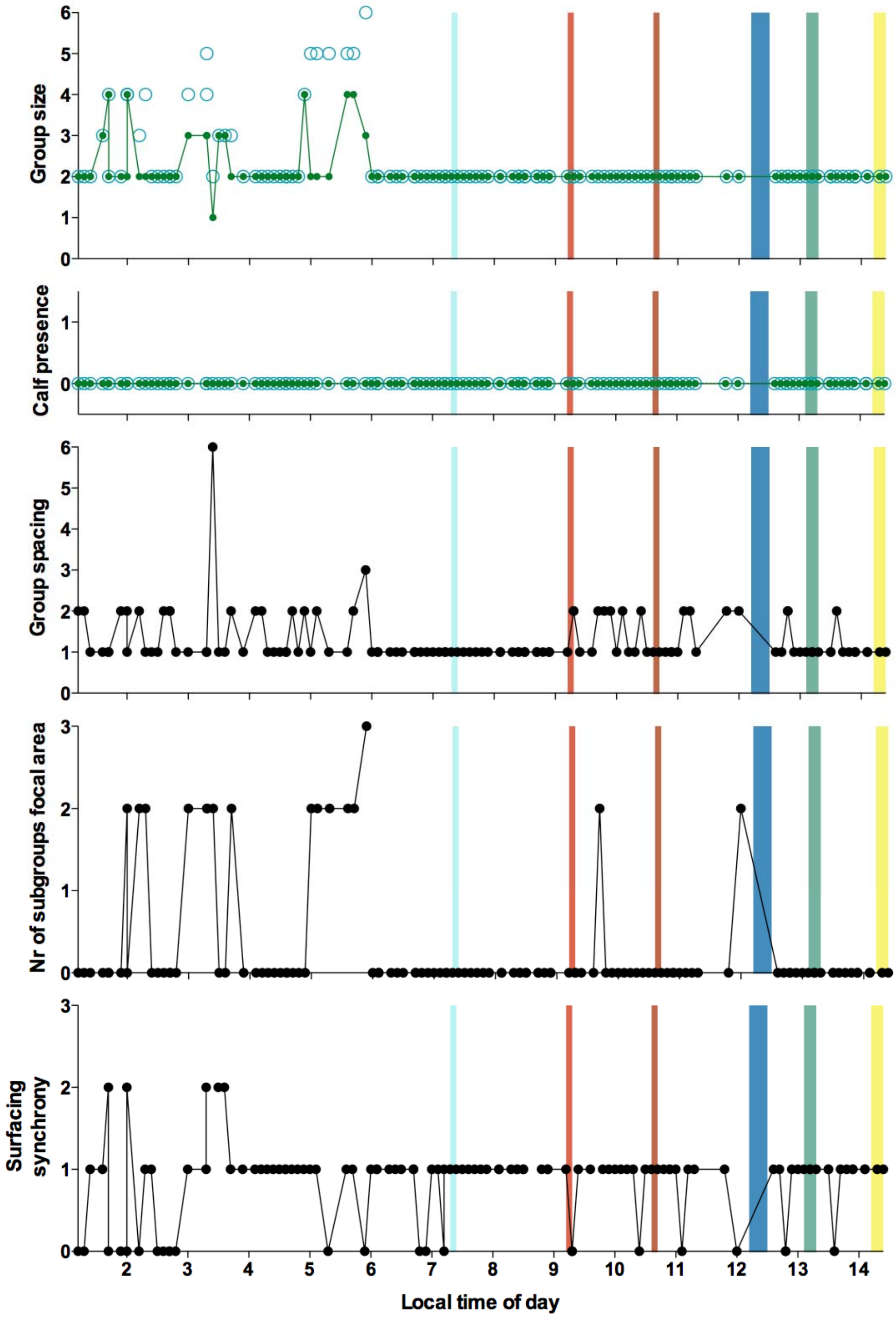


Figure 4.14. Example of Humpback whale group behaviour sampling data collected June 9th from the MOBHUS observation platform. The experiment time-line consecutively shows baseline (white), silent Ramp-up (turquoise), Ramp-up I (red), Ramp-up II (brown), killer whale playback (blue), noise playback (green) and biopsy sampling (yellow). Pre-, during and post-tagging data for this experiment was collected from the HUS observation platform

Table 4.6. Group behavioural sampling effort during experimental phases for Humpback whale and Minke whale. Effort listed as the duration of combined tracking and group behavioural sampling during each phase. Data collected from HUS from pre-tagging to post tagging and from MOBHUS from pre-exposure to Biopsy.

Species	Date start	Experiment nr	Exposures	Pre-tagging	Tagging	Post-tagging	Pre-exposure	Sonar Exposure	Biopsy	Total tracking	First - last sighting
Humpback	June 5	1	SIL - Ramp-up - Ramp-up - KW PB - NOISE	01:07	00:50	01:22	06:43	01:02	01:03	18:04	18:13
Humpback	June 7	2	SIL	00:47	02:30	01:24	06:05	00:10	-	11:42	11:42
Humpback	June 8	-	-	01:58	01:53	01:03	-	-	-	04:54	04:54
Humpback	June 8	3	SIL - Ramp-up - Ramp-up - KW PB - NOISE	00:56	01:59	00:10	03:43	01:02	00:41	17:05	17:47
Humpback	June 13	4	SIL - Ramp-up - Ramp-up - KW PB - NOISE	01:03	1:10 and 6:53	0:45 and 0:17	4:06 and 2:23	01:00	01:17	27:13	27:58
Humpback	June 24	6	SIL	01:08	03:32 and 04:35 and 1:11	00:26 and 1:02 and 0:10	05:13 and 2:55	00:10	-	21:13	23:28
Minke	June 19	5	SIL - DOSE ESC - NOISE	00:13	00:59	01:00	05:33	02:06	-	19:53	19:53
Total - Humpback		**5**		**06:59**	**24:33**	**06:39**	**31:08**	**03:24**	**03:01**	**100:11**	**104:02**
Total - Minke		**1**		**00:13**	**00:59**	**01:00**	**05:33**	**02:06**	**-**	**19:53**	**19:53**

Table 4.7. Group behavioural sampling and tracking effort (duration of tracking) outside of experiments for Minke whale and Northern Bottlenose whale. Total tagging effort for both species and group size characteristics of the tracked whales are also given.

Species	Nr of tracks	Min-max (Mean) duration (minutes)	Tagging periods	Time spent tagging	Time spent tracking	Tags on	Mean gr size
Minke	17	7-148 (55)	6	17:51	15:30	3 (4)	1
N Bottlenose whale	6	10-228 (116)	5	08:44	11:36	0	3.2 (1-10)

4.5.2 Northern Bottlenose whales

We collected 6 tracks of Northern Bottlenose whales (5 tagging, 1 baseline), with a total duration of 11,5 hours (Table 4.7). During 4 tracks, acoustic detections were recorded by the TNO Delphinus array (section 4.10). Northern Bottlenose whale groups or aggregations were tracked for 10 minutes up to 3:48 hours, with a mean duration (± SD) of 116 ± 86 minutes. While we could not distinguish with certainty between different groups in the same area, consecutive recordings of Northern Bottlenose whales, which are recorded as the same group, may be different individuals. Therefore, we cannot yet describe dive cycle characteristics for these whales with certainty. However, one deep dive, recorded both visually and acoustically, had a duration of 45 minutes, during which the whales were recorded acoustically for 22 minutes, starting 2-3 minutes following the last sighting. Acoustic recordings suggest 18-23 minute duration of clicking during dives.

Group behavioural data was collected during all encounters, following the protocol. The whales remained at the surface generally for one minute or less, were (very) tightly grouped with medium to high synchrony, and milling events. Sampling of surface behaviour was extended with the recording of the number of blows observed and any visible alterations of movement pattern, such as directional changes, milling and higher arching/increased lifting of upper body.

4.5.3 Considerations for future group behaviour data collection

The 3S-11 trial was the first trial in a series of three, for the first time investigating three new target species in a new area. With the exception of the Northern Bottlenose whales, the 3S-11 target species generally form smaller, less stable social groups than are observed for pilot whales and killer whales (previous 3S target species), for which the group behavioural protocols were initially developed. While the group behaviour protocols developed for 3S-09/3S-10 were applicable and worked well, it is recommended to further incorporate the additions made to the protocol in the field, to account for the surface active behaviours and association with other species of the new target species. In addition, re-assessment of the size of the focal area (200 m from focal whale) for Humpback whales may be of value, given that, for example, Humpback whales feeding in the same general area, at distances larger than 200 m, may well be considered associated to the focal whale and part of its focal area. Humpback whales were well visible up to a range of 500-750 m from both platforms.

Generally, even for solitary whales, the recording of surface-active behaviour, included in the group behaviour sampling protocol, can be of value in the interpretation of dive data recorded from the tags. Feeding activity of both Humpback and Minke whales could be clearly visible from surface-active behaviour and events and could be correlated to the dive pattern from the tags, in analysis to distinguish between dive characteristics during feeding, resting and travelling.

It would be valuable, both for consistency of data collection and the resulting quantity of data, to extend the planned duration of the pre-tagging and post-tagging phase to one hour, a process which happened naturally during the trial without compromising the other phases of the experiment.

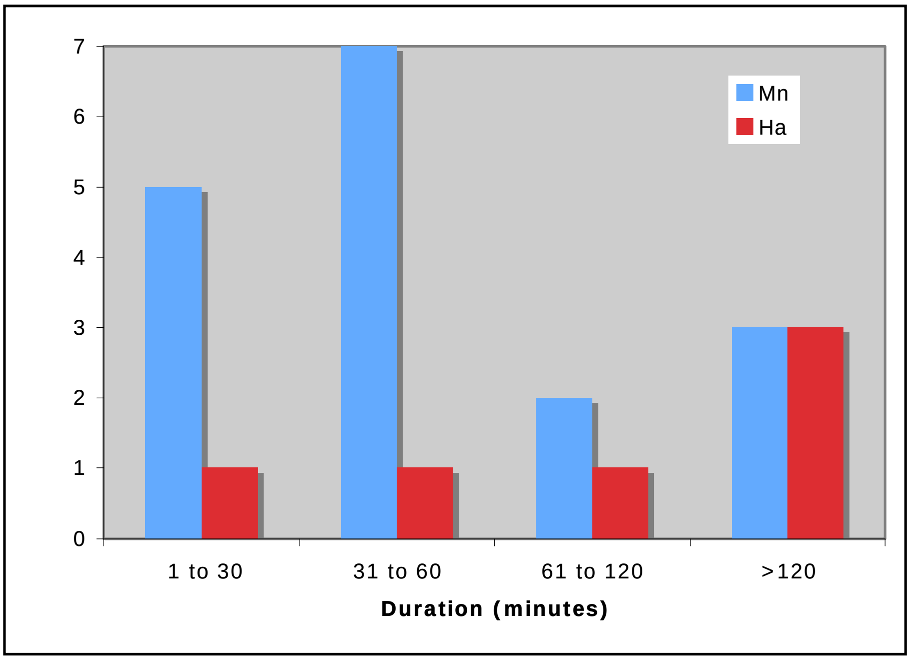


Figure 4.15. Duration of visual tracking of un-tagged Minke whales (blue bars) and Northern Bottlenose whale (red bars).

4.6 Effect of tagging

4.6.1 Humpback whale

Pre, during and post tagging data was collected from the HUS observation platform for 6 Humpback whale focal groups. The HUS observation platform performed well for both tracking and group behaviour sampling observations. Data collection of the focal animal without a tag on was established and maintained throughout the tagging phases, with relatively more ease compared to our experience with pilot whales in previous 3S trials. In one case the focal animal was periodically lost during tagging, due to limiting weather conditions and the presence of 7 Fin whales and 3 other Humpback whales in the same area. The duration of pre-tagging ranged from 0:47 – 1:58 hours, generally longer than was aimed for in the protocol (30-60 minutes). In total 7 hours of pre-tagging data was collected (table 4.6). The longer duration was a natural result of the start of tracking and group behaviour sampling at first sighting, the relative ease of tracking one focal animal without a tag and time needed to deploy the tag boat(s).

The duration of the tagging phase(s) was variable, dependent on the behaviour of the focal whales. Tag boats were deployed for tagging Humpback whales for periods of 0:50 – 6:53 hours (table 4.6). Tracking and group behavioural sampling were continued throughout the tagging phases. In total 24:30 hours of tagging data were collected. For two experiments, multiple tagging phases were conducted for the same focal whale(s) due to early tag offs. In case of multiple tagging phases, pre-tagging data was collected for the first phase only.

The duration of post-tagging phases was 00:10 – 1:24 hours, and generally 45 minutes or longer for the first post-tagging phase. In total 6:40 hours of post-tagging data were collected (table 4.6). One post-tagging phase was shorter than 30 minutes, resulting from the shift of the observer team from HUS to MOBHUS following the end of the tagging phase.

4.6.2 Minke whale

Tagging data was also collected for one Minke whale focal individual (table 4.6). However, the pre-tagging phase was relatively short, with few records (13 minutes) and the whale was only tracked via VHF from the tag during the period of post-tagging. Additional tracking during tagging phases was performed for several Minke whales, during which tags were deployed, but did not stick, and no experiment was performed (table 4.7).

4.6.3 Northern Bottlenose whale

During 5 of the 6 tracking sessions of Bottlenose whale groups, tagging effort was performed, and recorded in tracking and group behavioural sampling data (table 4.7). While no tag was deployed, we obtained useful experience on how to track and tag these animals. During the final tagging phase, both tag boats had relatively close encounters with Bottlenose whales.

4.7 Tagging

4.7.1 Minke whales

During the planning of 3S-11, the Minke whale was considered to be the most available target species within the research area. Even though available, very little is known about the effectiveness of small boat operations close to this species. The initial tactics of tagging operation on this species was to work with animals in feeding aggregations, or at least multiple encounters on very calm waters. Both tag boats would be used, where tag boat 1 was setup with the hand pole and tag boat 2 had a setup with the ARTS system. When HU Sverdrup II entered the Isfjord Channel on the night of the 11 of June, tag boat 2 was launched after multiple registrations of Minke whales from the visual observers. The weather was excellent with calm seas and gentle wind, and thus ideal for tagging attempts on Minke whales. The tag boat team had good help initially from the MMOs on HUS to find the whales, and then successfully started to work. The tag boat team experienced encouraging close encounters with 5 Minke whales during a period of 6 hours, whereas in 2 of these encounters the animals were typical "seekers" which came over to check out the boat. For the three other occasions the animals were less interested in the boat but made circles around it. In general these whales where sub-adults, and all seemed to be in a slow moving modus. A total of five Minke whales were approached with tag attempts using the ARTS-DTAGv2. The ARTS launching details are given in table 4.8.

René Dekeling *Leigh Hickmott*

Figure 4.16. DTAGs being deployed to Minke whales using the ARTS (left) and a hand-held pole (right). Despite repeated good contact between whale and suction cups, the tag detached within the first dive cycle. This is probably due to the loose epidermal skin of the Minke whale.

In summary, the launching distances where mostly in the range from 10-12 meters, and the launching pressure was always at 10 bar. This distance and pressure was at the same level as when successfully tagging killer whales and pilot whales with DTAGv2 during 3S-2009 (Kvadsheim et al 2009). On two occasions the DTAGv2 attached to the back of the animal, but slipped off the whale early during the first dive. Unfortunately, there is no photo documentation of these attempts to reveal any details of these events. The tag-boat team had a small brief rest, and then launched again. Tag boat 1 was also launched in parallel in the same area. After 4 hours a “new” Minke whale approaches us and we had another close encounter while driving at low speed. These two periods of tagging events of 6 and 4 hours illustrates clearly very different successes rates with different whales, and it probably reflect different behavioural modes of the whales. All the whales during these periods were sub-adults.

On the night of the 12 of June, the weather was still perfect for this type of tagging and tag boat 1 was launched to try to tag Minke whales with a four section hand held pole (Fig 4.16). A sub-adult Minke whale was sighted and approached. The tag boat remained in gear at it’s slowest speed possible (slow idle). The whale began ‘seeking’, showing it’s belly. It continued to approach the boat coming within 8 metres. The pole tagger made a tagging attempt that was short, hitting the water near the whale. It reacted, but then returned to ‘seeking’ on it’s next surfacing. This continued until it again surfaced ahead of us in tagging range. The whale was tagged high on the back, forward of the dorsal fin. It was a good strong tag contact, but the tag came off as the whale dived away. We were able to re-approach this animal and were able to get within 15 meters, but not close enough to tag again. Later we approached another whale and as it turned towards tag boat 1, we slowed from 2.5kts to slow idle, the whale approached and began ‘seeking’, we slowly circled keeping our speed constant, the whale surfaced around the boat and then within tagging range, just ahead of the bow. The tagger attempted to tag, the tag hit the whale well, high on the back, forward of the dorsal fin. The suction cups did not attach and the tag partially remained within the robot. On inspection the cups were full of a transparent gelatinous material from the skin of the whale. This organic material prevented tag attachment. The whale was re-sighted but could not be approached close enough for tagging.

3S-11 *3S-11*

Figure 4.17. The DTAG (left) and CTAG (right) ready to be launched with the ARTS. Note the green shock absorbers used to reduce impact power on the DTAG. The DTAG was also equipped with an extra VHF transmitter when being deployed to Minke whales. This transmitter has a pulse repetition rate 3 times that of the normal DTAG, and this makes it easier to track the fast surfacing Minke whales. The CTAG is invasively attached and releases by a galvanic time release. It is only the front end (in front of the antenna) which attaches to the animal, the carrier releases upon impact.

After this major effort with the DTAGv2 on Minke whales, we decided to change to the CTAG which has an invasive anchor attachment (Fig 4.17). First tagging attempt with the CTAG was on the 14 of June, however, this solitary Minke whale was not approachable, and both tag boat 2 and the MMOs on Sverdrup lost visual contact with the animal after 30 minutes. On the night of the 14th June, tag boat 1 attempted to tag Minke whales in an area offshore from Isfjorden. We approached a single adult Minke at slow idle speed, it approached and surfaced within 25 metres of the tag boat. We were close to the animal on some surfacings, but never within tagging range. While tracking the above Minke we spotted another approaching animal, we decided to switch our efforts to this whale. Within 150 meters of it we slowed from 2.7 knots to slow idle, keeping the rpm the same. The animal approached and began ‘seeking’ behaviour, we did tight circling moves and the animal re-approached a number of times. Closest distance was approximately 12 meters. After a number of surfacing’s the animal lost interest and returned to travelling behaviour.

As a result of failed tagging attempts due to the nature of Minke whale skin, Patrick Miller with mechanical assistance from the ship’s crew developed a “scraper tag” method. The design and attachment method seemed good and robust. On tagging the scraper hits down onto the whale, a pin is released and the scraper pulled back along the whale’s body via release of tension in two rubber straps. Almost instantaneously the tag is delivered to the area of body that has been “scraped”. The technique has been tested and proven to work well in the lab, however, no successful attempts were made to deploy DTAGs on an animal during the trial. Thus, it requires further field testing on live or freshly dead Minke whales.

Table 4.8. Tagging table for Minke whale tagging attempts.

Date June	Species	Position	Tagboat/ System	Tagger/ driver/ID	Tag	Range/P	Tag position	tag duration
11.	Minke whale	78.09.904N - 11.23.891E	TB2/ARTS/ ARTSCarrier	Lars/ Thomas	DTAG2	10m/10bar	Miss	
11.	Minke whale	78.09.904N - 11.23.891E	TB2/ARTS/ ARTSCarrier	Lars/ Thomas	DTAG2	12m/10bar	Miss	
11.	Minke whale	78.09.904N - 11.23.891E	TB2/ARTS/ ARTSCarrier	Lars/ Thomas	DTAG2	12m/10bar	hit top back	20s, Tag On-Tag Off after short dive
11.	Minke whale	78.07.804N - 11.09.421E	TB2/ARTS/ ARTSCarrier	Lars/ Thomas	DTAG2	14m/10bar	Miss	
11.	Minke whale	78.07.804N - 11.09.421E	TB2/ARTS/ ARTSCarrier	Lars/ Thomas	DTAG2	12m/10bar	Miss	
12.	Minke whale	78.04.732N - 11.50.535E	TB2/ARTS/ ARTSCarrier	Lars/ Thomas/ Rune	DTAG2 +vhf4bip	10m/10bar	Hit top L back	20s, Tag On-Tag Off after short dive
12.	Minke whale	77.57.321N - 12.58.946E	TB2/ARTS/ ARTSCarrier	Rune/ Lars/ Mark	DTAG2+ vhf4bip	7m/10bar	Miss	
12.	Minke whale		TB1/ Handpole	Patrick/ Lee	DTAG2	Pole	Hit	Short attachement, slided off on the first dive
12.	Minke whale		TB1/ Handpole	Patrick/ Lee	DTAG2	Pole	Hit	DTAG did not release from the robot
13.	Minke whale	77.57.926N - 12.58.746E	TB2/ARTS	Lars/ Thomas/ Rune	CTAG	no attempts		
19.	Minke whale	78.04.858N - 10.27.994E	TB2/ARTS	Lars/ Thomas/ Rune	CTAG	7m/9bar	LDR	19h, successfull experiment

On the 19th of June the weather was favorable again and the MMOs on Sverdrup reported several Minke whale sightings in the area, and both tag-boats where launched. The team on tag boat 1 was testing out a new tagging technique using the scraper tag while tag boat 2 was setup with the CTAG and the ARTS. The team on tag boat 2 encountered quickly a Minke whale, and it appeared to be a “seeker”. They attached the CTAG at a distance of 7 meters using 9 bars of barrel pressure, after less than 30 minutes. The CTAG carrier touched the whale in the waterline, and this was probably why the whale initially swam away with the carrier. However, on the next visual encounter the carrier had released from the tag, and the CTAG was transmitting VHF signals. The CTAG was set up with a galvanic time release for a window of 16-22 hours, and it released after 19 hours and was recovered.

Rune Roland Hansen

Figure 4.18. Successful deployment of CTAG to a Minke whale despite the tag hitting the water in front of the animal. The carrier seen detaches upon impact leaving only the small tag on the whale.

Table 4.9 Data table for CTAG deployments

Species	**Dataset/tag**	**Date – Location**	**Deployment Position**	**Duration (tag on animal)**	**System – boat Release**	**CEE/ Baseline**
Minke	Ba170_Ctag	June 19th 15:33	78.04.858N - 10.27.994E	19:04	ARTS – TB2 GTR-release (A1/1day)	CEE 1h

4.7.2 Humpback whales

Prior to the start of the trial, two of the DTAG2 housings were slightly altered and additional flotation added in order to attach a Sirtac FL2 GPS logger to the DTAG (Fig. 4.4 and Fig 4.19). The Sirtrac loggers had been pressure tested to 400m. Substantial testing of the flotation and operation of the combined devices and the radio-beacons was made before the combined DTAG-GPStag was deployed on a Humpback whale. No issues were identified, and all systems worked well in the subsequent deployments.

DTAGs were attached to Humpback whales using a 15m cantilevered pole system, equivalent to the system used with sperm whales and many other species of large baleen whales, operated off tag-boat 1. The attachment required some modification of the DTAG-attachment robot to provide sufficient clearance for the GPS logger. The standard 3S protocol is to attempt to tag more than one individual in social groups of animals to increase the chance that one tag will remain attached for the entire experiment duration. Because

Humpback whales in foraging grounds are thought to be largely solitary, it was deemed too risky to tag different individuals, so instead we attempted for one hour to attach a second tag to the tagged whale (Fig. 4.4 and Fig 4.20), assuming it did not react too strongly to the initial tag attachment. In fact, reactions to all tag attachments were minor or none. In addition to increasing the likelihood of one tag remaining attached for the entire experiment period, the attachment of more than one tag improved our ability to radio track the animal and provides a mean to cross-validate the accuracy of DTAG measurements.

A total of 14 DTAGs were deployed to 7 different Humpback whales (Table 4.10), of which 9 also had a GPS-tag attached (Table 4.11). Tags were generally attached within 1-4 hrs of launching tag-boat 1, except in 2 cases in which animals proved difficult to approach. Only four deployments remained attached for the full duration: deployments mn11_157a and mn11_160as both stayed attached for the full duration and Ramp-up experiments were conducted; Tag mn11_165d fired after the full release time and an experiment was conducted, but the VHF transmitter had failed, and the tag was recovered by a fortunate sighting of the floating tag by Lars Kleivane. The whale was successfully tracked with the aid of tag mn11_165f, which remained attached until the scheduled release time. Deployment mn11_165c had a fault within the tag, and the released fired immediately after attachments.

Lars Kleivane *Lars Kleivane*

Figure 4.19. DTAG with GPS-tag attached to it (left) being deployed to a Humpback whale using a cantilever pole system (right).

The experimental protocol (Fig. 3.1) was designed to enable collection of baseline data as well as experimental data. Thus, it was critical for tags to remain attached until the release time for full experiments to be conducted (Fig. 4.20). In 4 of the 7 tag deployment sessions with a Humpback, tags detached prematurely, which made it only possible to collect baseline data and in 2 cases to conduct the silent pass. Field observations indicated that tags deployed prematurely when animals were surface active (breaching or lunging), often within closely-spaced groups. Inspection of the tag data suggested strong thrusting or acceleration forces, consistent with high-speed activity, just before tag detachment.

Filipa Samarra

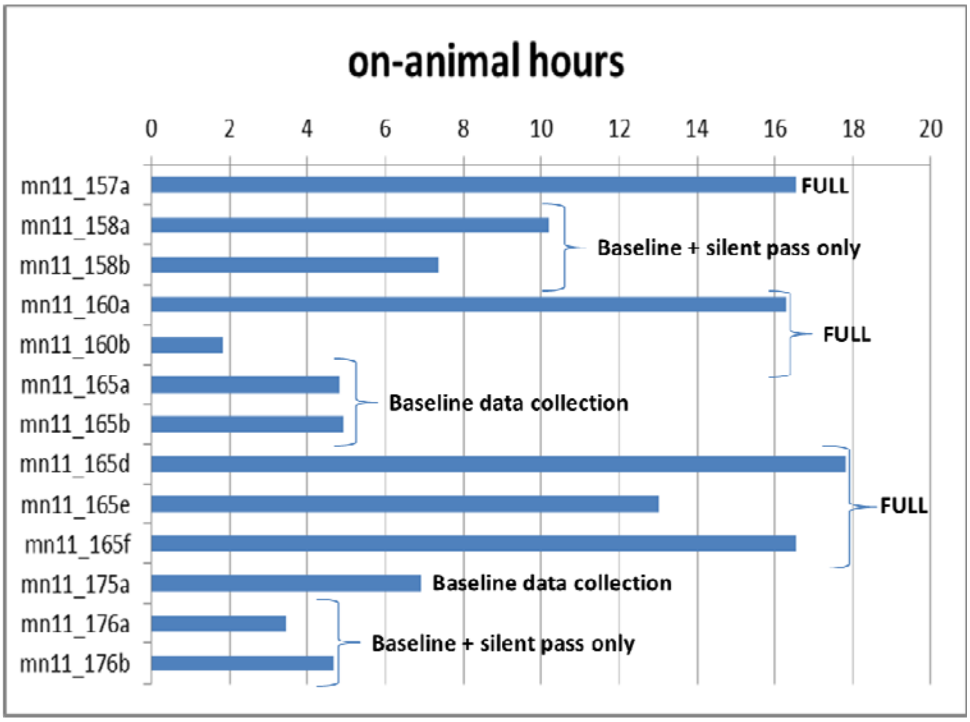


Figure 4.20. A total of 14 DTAGs were deployed to 7 different Humpback whales, and 9/14 deployments also had a GPS-logger attached to it. Most animals were double tagged to improve radio-tracking and to reduce the risk of having to terminate an on-going experiment due to premature tag detachment. Tags mn11-165a-f were attached to a strongly-associated pair of whales. Tag attachment time varied from ~2-18 hrs, only 4 tags stayed on until the release fired, during which it was possible to conduct experiments (labelled as 'FULL'). In other cases, baseline and silent pass data was collected.

Table 4.10. Data table for DTAG deployments

Data set	Species	Date and Time	Deployment Location	On-animal Time	Tag system and Tag boat	Release	Skin sample and Biopsy	GPS-tag	CEE
Mn11_157a	Humpback	06.06.2011-00:25:15	75 08.569-14 37.932	16h 33 min	Pole TB1	Release fired	No/Yes	Yes	Yes
Mn11_158a	Humpback	07.06.2011-11:21:23	74 49.818-16 36.762	10h 12 min	Pole TB1	High acc.	No/No	Yes	Yes silent
Mn11_158b	Humpback	07.06.2011-11:33:52	74 49.915-16 40.255	7h 21 min	Pole TB1	High acc.	No/No	No	Yes
Mn11_160a	Humpback	09.06.2011-00:54:00	74 36.648-15 17.633	16h 17 min	Pole TB1	Fired	No/No	Yes	Yes
Mn11_160b	Humpback	09.06.2011-02:14:00	74 37.993-15 15.770	1h 49 min	Pole TB1	High acc.	No/No	No	Yes
Ba11_163a	Minke	12.06.2011-03:17:04	78 38.273-12 52.431	13 sec	ARTS TB2	High acc.	No/No	No	No
Ba11_163b	Minke	12.06.2011-08:43:15	78 38.273-12 52.431	17 sec	ARTS TB2	High acc.	No/No	No	No
Ba11_163c	Minke	12.06.2011-18:27:00	78 38.273-12 52.431	9 sec	Pole TB1	High acc.	Yes/No	Yes	No
Mn11_165a	Humpback	14.06.2011-02:48:12	78 10.192-12 19.101	4h 48 min	Pole TB1	Sliding during high acc.	No/No	Yes	No
Mn11_165b	Humpback	14.06.2011-03:02:07	78 10.200-12 17.332	4h 56 min	Pole TB1	High acc.	No/No	No	No
Mn11_165c	Humpback	14.06.2011-12:37:00	78 06.152-12 58.644	-	Pole TB1	Fired early	No/No	No	No
Mn11_165d	Humpback	14.06.2011-13:18:25	78 05.893-12 15.534	17h 49 min	Pole TB1	Fired	No/No	No	Yes
Mn11_165e	Humpback	14.06.2011-15:40:20	78 05.012-11 05.070	13h 1 min	Pole TB1	Breach	No/No	No	Yes
Mn11_165f	Humpback	14.06.2011-15:59:51	78 05.040-11 48.680	16h 32 min	Pole TB1	Fired	No/No	No	Yes
Mn11_175a	Humpback	24.06.2011-09:50:05	77 33.947-11 31.241	6 h 55 min	Pole TB1	High acc.	No/No	Yes	No
Mn11_176a	Humpback	25.06.2011-00:14:45	77 33.284-11 59.920	3 h 27 min	Pole TB1	High acc.	No/No	Yes	No
Mn11_176b	Humpback	25.06.2011-00:36:11	77 33.455-12 03.294	4h 41 min	Pole TB1	High acc.	No/No	No	Yes silent

Table 4.11 Data table for SirTrac GPS logger deployments

GPS Tag #	GPS raw data File name	.pos OK?	TB1 track filename	DTAG code / Boat only?	Time deployed	# Re-Sight	Placement Pictures?	Comments
29409	Obs020611_115718	Y	Sverdrup	No deploy				
29409	Obs020611_151337	Tbp	Sverdrup	No deploy				
29409	Obs020611_163139	Y	Sverdrup	No deploy				
29409	Obs050611_094425	Tbp	Sverdrup	No deploy				
29409	Obs050611_172825	Tbp	Sverdrup	No deploy				
29409	Obs070611_221029	Y	TB1_trk_07-Jun-2011a	mn11_158a	11:21:23 local	339/340	Low placement, left side behind dorsal	
29409	Obs080611_195050	Tbp	TB1_trk_08-Jun-2011a	No deploy				
29409	Obs090611_213428	N!!	TB1_trk_09-Jun-2011a	Mn11_160a	00:34:03 LOCAL	377/379	Left side below dorsal	clock was exactly 4hrs off - send to Sirtrac Mn11_160b was simultaneously attach
29409	Obs130611_041024	Y	TB1_trk_13-Jun-2011a	No deploy				
29409	Obs130611_144953	Y	TB1_trk_13-Jun-2011c	No deploy				
29409	Obs140611_083847	Y	TB1_trk_14-Jun-2011a	mn11_165a	02:48:12 Local	556/557	Good placement. Data look good with lots of satellites	Simultaneously on same whale with Obs140611_084036
29409	Obs150611_060432	Y	TB1_trk_14-Jun-2011c	mn11_165e	15:40:20 LOCAL	561	High on dorsal, slid at breach to worse position at	
29409	Obs190611_195848	Y	TB1_trk_19-Jun-2011b	No deploy				
29409	Obs210611_224901	Y	TB1_trk_21-Jun-2011a	No deploy				
29409	Obs220611_032707	Y	TB1_trk_22-Jun-2011a					
29409	Obs240611_112146	Y	TB1_trk_24-Jun-2011a	No deploy				

29409	Obs240611_225523.	Tbp	TB1_trk_24-Jun-2011b & c	No deploy				
29409	Obs250611_060147	Tbp	TB1_trk_25-Jun-2011a	Mn11_176a	00:14:45 local		Lower left flank under dorsal fin	Having trouble finding time offset
29420	Obs020611_105216	Y	Sverdrup	No deploy				
29420	Obs020611_141027	Tbp	Sverdrup	No deploy				
29420	Obs020611_162941	Y	Sverdrup	No deploy				
29420	Obs060611_173148	Y	TB1_trk_05-Jun-2011a	mn11_157a	00:25:15	315/316	Good, anterior to dorsal fin, center	
29420	Obs120611_200450	Y	TB1_trk_12-Jun-2011a	No deploy				
29420	Obs140611_084036	Y	TB1_trk_14-Jun-2011a	mn11_165b	03:02:07 local	557	Low on animal	
29420	Obs140611_150046	Y	TB1_trk_14-Jun-2011b	Mn11_165c	12:57:00 local	561	Good, high on back	No DTAG data – DTAG failed
29420	Obs220611_123731	Y	TB1_trk_22-Jun-2011a	No deploy				
29420	Obs240611_174411	Y	TB1_trk_24-Jun-2011a	Mn11_175a	09:50:05 local		Low on left flank	

4.7.3 Northern Bottlenose whales

Bottlenose whales were only sighted near the end of the trial during an offshore search during transit South from Spitsbergen (see Fig. 2.1). Both tag boats were deployed on several occasions to attempt to tag a Bottlenose, but limited time was available for tagging attempts so close to the end of the trial. Visual observers on the Sverdrup sighted and tracked surfacing whales, and helped the tag boats to position in good locations to be close to the whales. In fact, however, no tagging attempts were ever possible. In one case, a single whale approached tag-boat 1 for roughly 5 minutes, but did not come close enough for a tagging attempt.

4.8 Photo ID and Biopsy

Genetic analysis of the biopsy samples collected will provide valuable information of the sex and identity of the animal. In addition, since full blubber profiles were collected, biochemical analysis of the blubber layer will give information on health and body condition as well as reproductive status. The equipment applied during biopsy sampling was either the Finn Larsen Gun (FLG) using a 40mm biopsy tip, or the whale-tag launcher ARTS using a 100mm biopsy tip with the new ARTS biopsy dart (LKDart). Successful sampling was achieved for all attempts on Humpback whales, however only samples of 3 whales were collected. No biopsy attempts were preformed on Minke whales or Bottlenose whales.

Table 4.12. Table of biopsy sampling

Date	Position	System	Range/ Pressure	Photo ID	Comments
6. June.	75.12N-014.46E	ARTS	35m/9bar	Yes	LKDart,100mm FL tip, 100mm sample, LL, no reaction
15. June	78.57N-010.49E	ARTS	20m/9bar	Yes	LKDart,100mm FL tip, 100mm sample, LR, no reaction, the larger animal
15. June	78.57N-010.49E	ARTS	20m/9bar	Yes	LKDart, Dart stuck for about 2h (water hit), dart lost, pictures, no reaction
15. June	78.57N-010.49E	LG	20m/green	Yes	FLdart, 40mm FL tip, 40mm sample, LL, swift reaction-tail slapping

To reduce the possibility of re-tagging Humpback whales, photo ID pictures were collected throughout the survey. Using fingerprint techniques of the flukes we can rule out the possibility that tagged animals have been tagged and exposed before. No re-sightings were registered in the field. Retrospective analysis will be performed to confirm this. During 3S-11 a total of 21 photo ID pictures were collected mainly in the areas in the inlet of Isfjorden, and in the area NW of Bear Island around “Kveithola”. Collected photo id pictures will also be transferred to the

Norwegian national database at IMR. No pictures were taken for photo id purposes on Minke whales or Bottlenose whales.

Lars Kleivane

Figure 4.21 The pictures demonstrate characteristic fluke markings of a Humpback whale used to recognized individual animals directly in the field and during retrospective analysis.

4.9 CTD/XBT measurements and transmission loss modelling

When conducting sonar exposure experiments oceanographic measurements of temperature, salinity and density through the water column were made. The primary reason for doing this is to convert these measurements into depth profiles of sound speed and use these sound speed profiles as input to transmission loss models. Such models are used to calculate how the sound propagated through the water column from the source to the animal. The DTAG has acoustic sensors which are used to measure the received sound level on the animal. The CTAG did not have acoustic sensors, and received levels therefore have to be estimated based on sound propagation modelling. In addition, the DTAG only measures the levels on the animal, not what would have happened if the animal responded differently, or not at all. The propagation of the sonar sound is therefore also used in analysis of potential sonar avoidance, of the exposed animals.

During each sonar exposure run, an XBT was taken using Sippican 77 XBTs. In addition, after the end of every sonar exposure experiment, a CTD profile was taken along the transmission path using SAIV SD200. Sonar transmissions were conducted in two very different oceanographic environments (Fig. 4.22); in deep water at high sea west of Bear Island, and in shallow costal waters of Spitsbergen (Isfjord Channel).

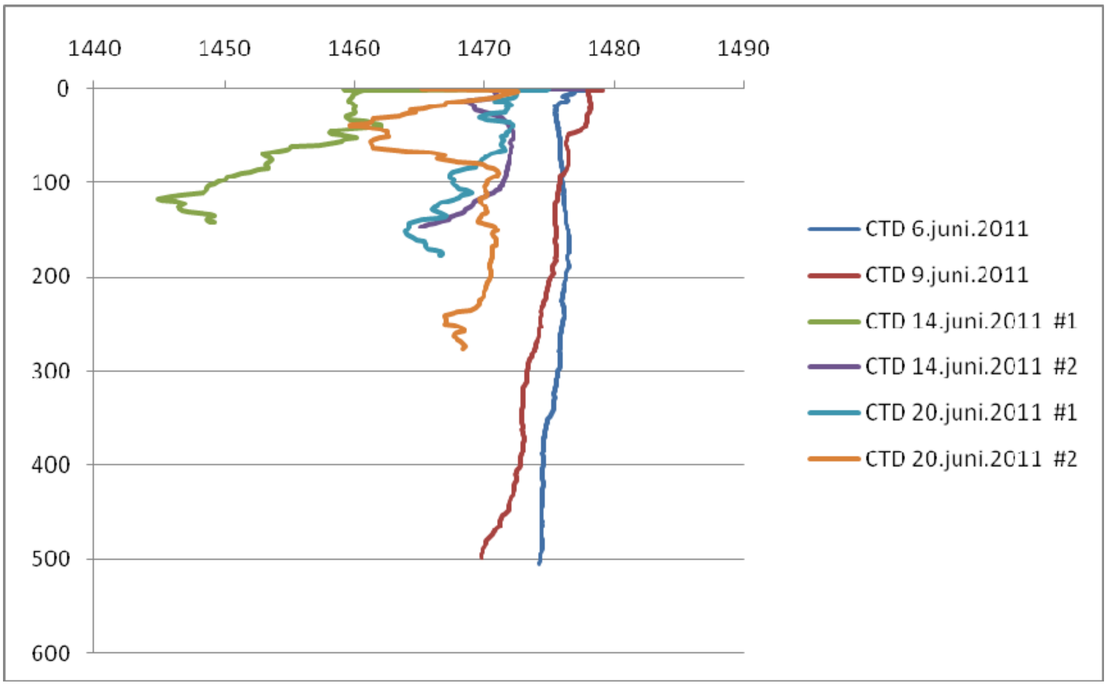


Figure 4.22. Sound speed profiles taken during the trial. CTDs on June 6th and 9th were taken in the off shore aeras west of Bear Island while profiles taken on June 14th and 20th were taken in the coastal areas off Spitsbergen.

In the deep (1000-1500 m) offshore areas off Bear Island where the first two experiments were conducted, transmission conditions were dominated by an almost constant salinity profile and a linear temperature profile with warmer water (6-7°C) at the surface gradually decreasing to 4°C below 500m. This gave a slowly downward refracting sound propagation, but within the range relevant to us, the propagation conditions were essentially omnidirectional (Fig 4.23).

In the more shallow (100-300m) costal waters, propagation conditions were much more complex and variable (Fig 4.23), and therefore two CTD profiles were collected along the transmission path instead of only one. In this environment the sound picture will also be more influences by bottom reflections.

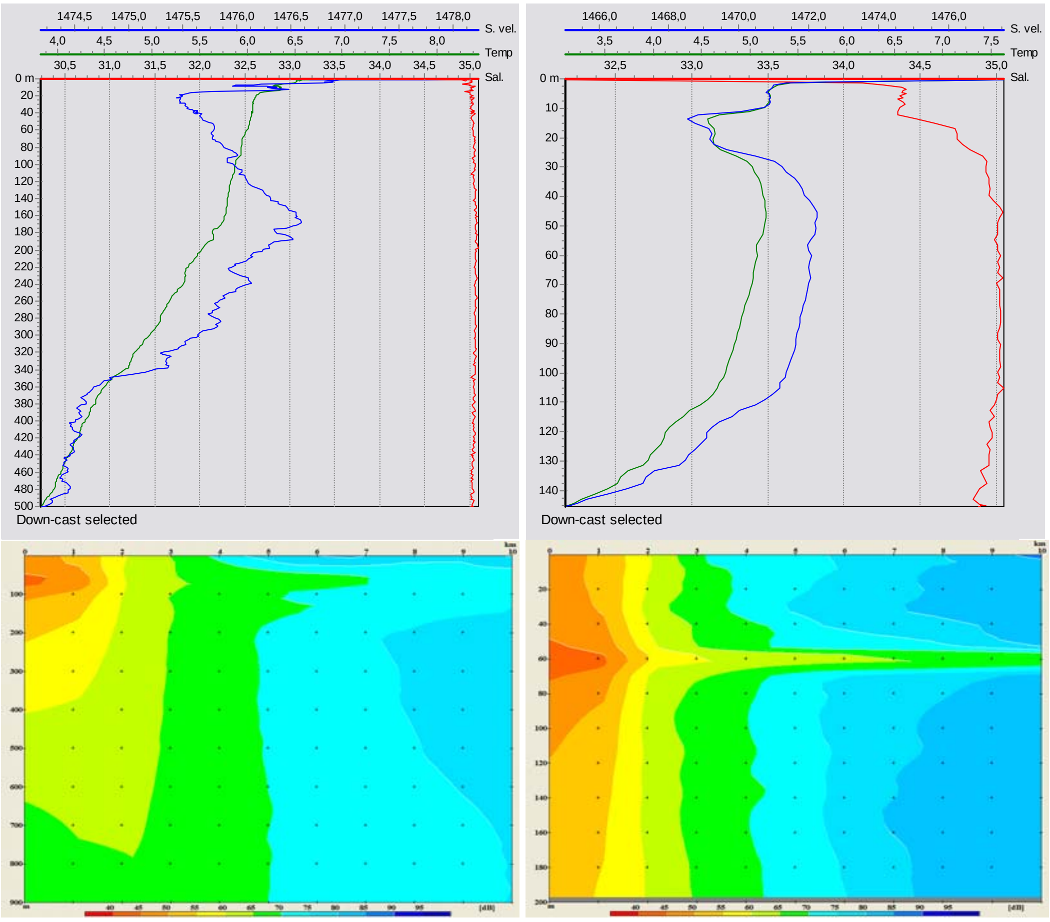


Figure 4.23. Upper pannel; temperature (green), salinity (red) and sound speed profiles (blue) from CTDs taken on June 6th in the off shore aeras west of Bear Island (left) and on June 14th in the coastal areas off Spitsbergen (right). Lower panel; tranmission loss from sound propoagation modell Lybin based on the transmission characteristics of the SOCRATES source and measured sound speed profiles from June 06 off Bear Island (left) and June 14 in Isfjord Channel (right).

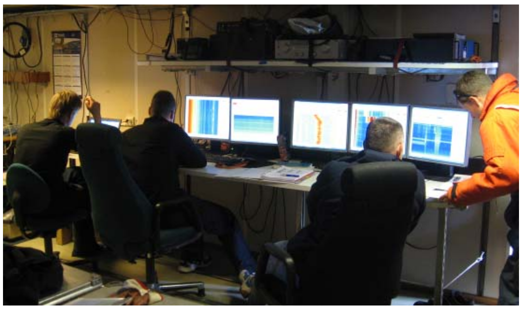
4.10 Passive acoustic monitoring

In addition to the VD-array towed off the MOBHUS and used to measure the sonar levels near the tagged whale (described in section 4.3.2) , two different towed arrays were available for towing by HU Sverdrup II. Apart from the upgraded Delphinus system, also an operational CAPTAS array with triplet-hydrophones was available. Both systems are described in detail in the cruise plan (Appendix E).

All recordings of both towed arrays are shown in table 4.13. In total more than 6 Tbyte of acoustic data has been collected, containing 227 hour of recording time. Because high frequency sounds could only be detected by the Delphinus system, this system was towed most of the time during surveying mode (search phase). Only when the presence of beaked whales could be excluded (on the shelf, mostly during operations with baleen whales) we were towing the CAPTAS system. However, in several cases the (very) shallow depth and required maneuverability were limiting the possibilities for towing any array, explaining the limited amount of CAPTAS data retrieved.

Both systems (CAPTAS and Delphinus) performed well. Some striking examples are demonstrated below. The experimental module of the Delphinus system did not work satisfactory. At the start of the cruise, the triplet was not providing proper data. At the start of the last week of the cruise, the new module caused interference with other acoustic output, and was taken out of the array on June 22nd.

During the cruise, a collection of processing software was available for monitoring passive acoustic recordings. Processing was running on two dedicated computers with five screens in total, supported with another laptop for additional analysis. This was set up in the laboratory of Sverdrup (Figure 4.24). In addition a terminal (with two screens) was running in parallel on the bridge of Sverdrup. This terminal could also display part of the passive acoustic recordings remotely from the bridge. This was done in some cases during exposure runs, when also the Socrates source was operated remotely from the bridge, in order to minimize radio traffic.



Sander van IJsselmuide

Mark van Spellen

Figure 4.24 Picture of setup of acoustic station in laboratory of Sverdrup (left) and acoustic terminals on the bridge (right).

The processing software was ranging from more experimental prototypes to existing operational software. In this report we will not provide a full overview of all functionality on board during 3S-11. In total about 10 displays and four audio channels were available for Delphinus and CAPTAS systems. This output was supported by geographical screens, to present acoustic detections on a map, in some cases combined with ship traffic (AIS). Some examples of acoustic detections are given below.

The following species was detected acoustically during 3S-11:

- White beaked dolphins
- Sperm whales
- Belugas
- Northern Bottlenose whales
- Seals
- Blue whales

During a system test (Feb.2011) along the Norwegian coastline, the Delphinus system already demonstrated its capability to detect high-frequent porpoise clicks (130 kHz). Moreover, during 3S-11 an unidentified scattering layer appeared to be present. Some typical examples of acoustic detections are presented below.

4.10.1 White-beaked dolphins

During large parts of the cruise, but especially at the beginning, large groups of white-beaked dolphins were seen and heard. A large variety of different types of vocalization is recorded covering a wide frequency range. A nice example is given in Fig.4.25, where a group of dolphins could be tracked for a long period of time.

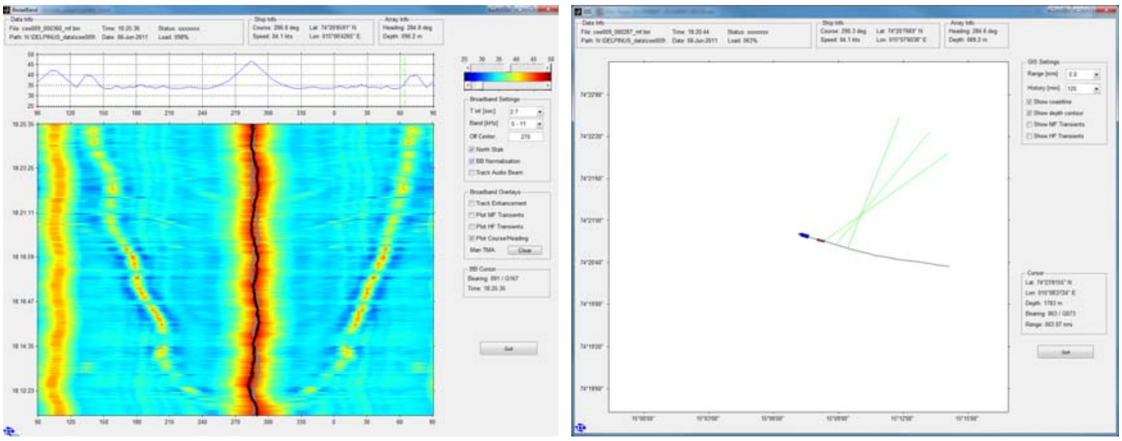


Figure.4.25 Track of white-beaked dolphin detections on June 8th, about 0.5 nautical mile on starboard-side of Sverdrup. Left graph shows about 14 minutes of acoustic beamformed data as displayed with the broadband waterfall display. Right graph demonstrates the coupled TMA-display (Target Motion Analysis) in a lat-lon geographical (lat-lon) frame. In this example the Sverdrup (depicted in blue) travels in WNW-direction, towing the Delphinus array (depicted in red) and recently sailed track (120 minutes in this example) in black.

4.10.2 Sperm whales

At many moments during the cruise sperm whales could be detected. Because the loud clicks produced, most detections were acoustic without visual confirmation. At the beginning of the cruise (6 June, 21:20 UTC) a loud clicking sperm whale was estimated (with TMA-display) to be at 5 nautical miles distance. Another example of a sperm whale track is shown in Fig 4.26. This example shows how the left-right ambiguity of the array can be resolved with the TMA-display. After a change of the heading of the Sverdrup, the sperm whale (estimated range 3 nautical miles) appears to be at port side.

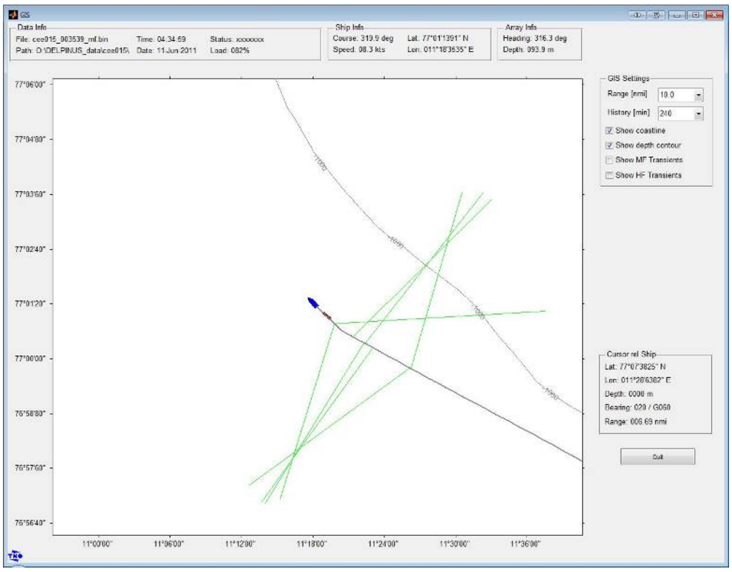


Figure 4.26. Sperm whale track on 11 June 11, 03:49 UTC. Bearings of detected sperm whale clicks from broadband after the change of course are only consistent at the port-side of the vessel.

4.10.3 Belugas

In the morning of 23 June during unfavorable weather conditions offshore, we were sailing in Isfjord. Whistles were detected around 7:30 UTC. In this area Belugas were reported earlier while sailing to Longyearbyen June 15th. After sailing back and forth, the group of belugas could be confirmed visually around 11:00. The pod was located very close to the shore at the southern side of the fjord.

4.10.4 Baleen whales

Due to the low frequency vocalization, if they vocalize at all, baleen whales are very hard to detect acoustically. During the cruise monitoring of very low frequency sound (VLF) was optimized and some occasional vocalization could be detected. If they were vocalizing, we expect to be able to detect Humpback whales singing, and since no such detections were recorded (while we sighted many Humpbacks), it appears they do not vocalize much in this area. In some examples visual confirmation of the vocalizing animal was difficult because several species were in the vicinity of the vessel (at one moment Humback-, Fin- and Blue whale) at the same time when vocalization was detected. Most VLF detections are probably Blue whale calls. An example is given in Figure 4.27, recorded with the (high frequency!) Delphinus system.

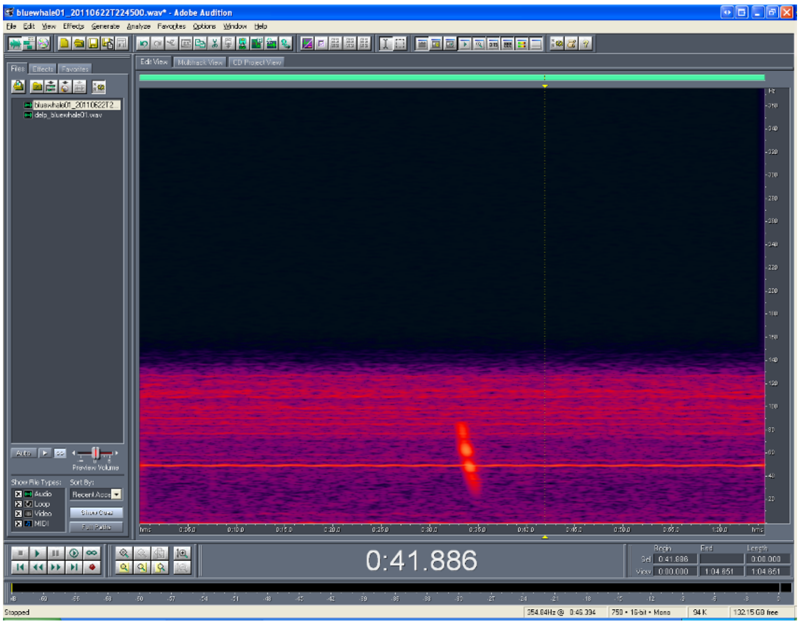


Figure 4.27. Blue whale call as recorded with Delphinus system, 22 June 22:45 UTC. Frequency range of the call is approximately from 30 to 90 Hz.

4.10.5 Northern Bottlenose whales

Only near the very end of the cruise (25-27 June) Northern Bottlenose whales were observed. In two occasions, the acoustic detections were prior to visual observations. First acoustic detections occurred on 25 June. During 2 dives clicks from the animals could be detected while sailing around the diving location. See Figure 4.28 for some examples and details. It appeared that the lower frequency clicks (5-10 kHz) were recorded at the beginning of the dive, while later on higher frequency clicks and buzzes (20-70 kHz) were observed. These data need further analysis to identify the details. Halfway through the second dive the animals were lost.

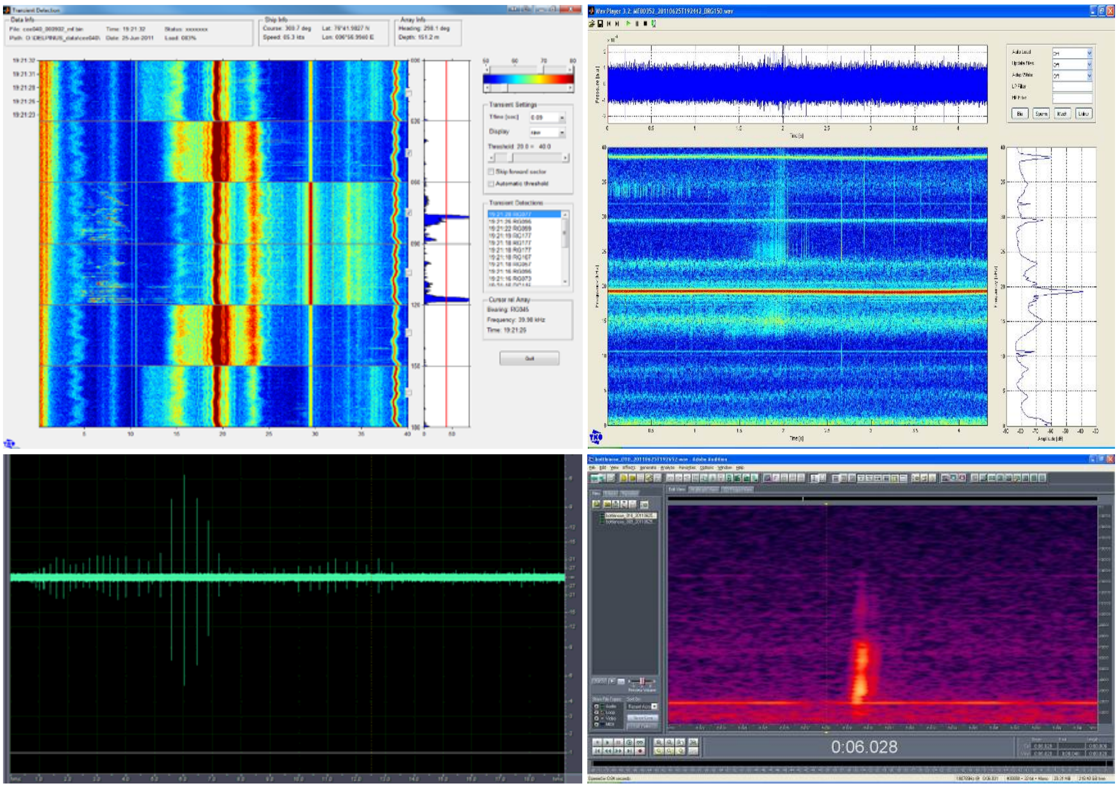


Figure 4.28. Example of clicks of Northern Bottlenose whales, 25 June. Top left: Clicks were detected on the Delphinus array at 19:21 UTC, 2-5 minutes after visual dives were reported from the observation deck. Here the clicks are visible in the MF-display for the two middle beams (060-120 degrees) in the frequency band 5-10 kHz. Beamforming is actually possible for this frequency range. Upper right: Spectrogram of higher frequency buzz some minutes later (19:24:42) as recorded with one of the UHF hydrophones of the array. Lower left: Time series of click sequence showing inter click intervals of 0.2s. Lower right: Frequency characteristics for a single click, showing most energy is contained between 20 to 70 kHz.

Later that day and during the following two days more Bottlenose whales were encountered, both visually as well as acoustically. On 26 June 18:12 UTC detections were made on the high frequency hydrophones, of animals which had a slightly different inter-click interval of about 0.6 seconds. Systematic tracking of the animals appeared to be difficult. Later on several scattered individuals were observed, and they appear to be in travelling mode (without long deep dives with foraging clicks). Tagging attempts were also not successful at this occasion.

Table 4.13. Overview of Delphinus and CAPTAS recordings during 3S-11.

Exp Name	Systems	Start Time	Stop Time	Duration	Size [GB]	Summary	Acoustic	Visual
Minke Dinky	Delphinus	02-06-2011 16:44	02-06-2011 17:39	00:55	22	System test	None	None
Minke Dinky	CAPTAS + SOC	02-06-2011 18:49	02-06-2011 22:12	03:23	29	System test	None	None
Cee001	Delphinus	05-06-2011 07:32	05-06-2011 16:33	09:01	201	Survey	White beaked dolphins Sperm whales	White beaked dolphins Sperm whales Minke whale
Cee002	Delphinus	05-06-2011 16:53	06-06-2011 04:39	11:46	265	Survey	White beaked dolphins Sperm whales	White beaked dolphins Sperm whales Fin whale Humpback whale
Cee003	CAPTAS + SOC	06-06-2011 05:58	06-06-2011 12:28	06:30	63	Rampup exp on Humpback.	None	White beaked dolphins Fin whale Humpback whale
Cee004	Delphinus	06-06-2011 20:44	07-06-2011 03:30	06:46	191	Survey	White beaked dolphins Sperm whales	White beaked dolphins Sperm whales
Cee005	Delphinus	07-06-2011 03:39	07-06-2011 15:49	12:10	342	Survey	White beaked dolphins Sperm whales	White beaked dolphins Sperm whales Humpback whale
Cee006	Socrates	07-06-2011 18:30	07-06-2011 19:40	01:10	1	Rampup exp on Humpback.	-	White beaked dolphins Humpback whale
Cee007	Delphinus	07-06-2011 21:09	08-06-2011 04:59	07:50	176	Survey	white beaked dolphins sperm whales	No effort
Cee008	Delphinus	08-06-2011 05:00	08-06-2011 18:00	13:00	369	Survey	White beaked dolphins Sperm whales	White beaked dolphins Sperm whales Humpback whale

Exp Name	Systems	Start Time	Stop Time	Duration	Size [GB]	Summary	Acoustic	Visual
Cee009	Delphinus	08-06-2011 18:00	09-06-2011 04:33	10:33	235	Survey	White beaked dolphins Sperm whales	White beaked dolphins Sperm whales Fin whale Humpback whale
Cee010	CAPTAS + SOC	09-06-2011 06:20	09-06-2011 11:41	05:21	52	Rampup exp on Humpback.	None	White beaked dolphins Fin whale Humpback whale
Cee011	CAPTAS	09-06-2011 12:38	09-06-2011 13:22	00:44	7	Killer whale playback (noise only).	None Tag boat + noise playback	Humpback whale
Cee012	Delphinus	10-06-2011 05:37	10-06-2011 17:32	11:55	343	Survey	White beaked dolphins Sperm whales	White beaked dolphins Sperm whales Fin whale
Cee013	Delphinus	10-06-2011 17:40	10-06-2011 22:00	04:20	122	Survey	White beaked dolphins Sperm whales Unknown (shrimp/krill?)	White beaked dolphins Sperm whales
Cee014	Delphinus	10-06-2011 22:05	11-06-2011 00:35	02:30	56	Survey	white beaked dolphins sperm whales	White beaked dolphins
Cee015	Delphinus	11-06-2011 00:36	11-06-2011 04:52	04:16	121	Survey	White beaked dolphins Sperm whales	White beaked dolphins
Cee016	Delphinus	11-06-2011 04:56	11-06-2011 07:56	03:00	85	Survey	None	None
Cee017	Delphinus	11-06-2011 07:57	11-06-2011 12:02	04:05	85	Survey	None	None
Cee018	Delphinus	11-06-2011 12:47	11-06-2011 18:25	05:38	113	Survey	None	Blue whale Fin whale Minke whale
Cee019	Socrates	14-06-2011 17:00	14-06-2011 21:15	04:15	1	Rampup exp on Humpback.	-	Humpback whale Fin whale Minke whale

Exp Name	Systems	Start Time	Stop Time	Duration	Size [GB]	Summary	Acoustic	Visual
Cee020	Delphinus	16-06-2011 11:20	16-06-2011 20:24	09:04	132	Survey	Sperm whales Seals	Blue whale Minke whale Seals
Cee021	Delphinus	16-06-2011 20:35	16-06-2011 22:49	02:14	38	Survey	Sperm whale	Sperm whale Fin whale
Cee022	Delphinus	17-06-2011 02:28	17-06-2011 04:34	02:06	48	Survey	White beaked dolphins Sperm whales	White beaked dolphins Sperm whales
Cee023	Delphinus	17-06-2011 04:42	17-06-2011 11:15	06:33	150	Survey	White beaked dolphins Sperm whales	White beaked dolphins Sperm whales Seals
Cee024	Delphinus	17-06-2011 11:16	17-06-2011 18:10	06:54	159	Survey	Sperm whales Seals?	White beaked dolphins Fin whales
Cee025	Delphinus	17-06-2011 18:11	18-06-2011 02:00	07:49	179	Survey: sperm whales	Sperm whales	White beaked dolphins Fin whales Sei whale
Cee026	Delphinus	18-06-2011 02:10	18-06-2011 11:22	09:12	208	Survey	Sperm whales	White beaked dolphins Fin whales Seals
Cee027	Delphinus	18-06-2011 11:23	18-06-2011 18:25	07:02	158	Survey	None (except strange 53kHz signal)	Fin whales
Cee028	Delphinus	18-06-2011 18:27	19-06-2011 05:34	11:07	254	Survey	Sperm whales	White beaked dolphins Fin whales
Cee029	Socrates	19-06-2011 23:30	20-06-2011 04:00	04:30	1	Exposure:Minke whale	-	Blue whale Fin whale Minke whale
Cee030	CAPTAS	21-06-2011 22:10	22-06-2011 06:25	08:15	80	Survey	Blue whale	Blue whale Fin whale Humpback whale
Cee031	Delphinus	22-06-2011 10:30	22-06-2011 18:45	08:15	120	Survey	None	Blue whale

Exp Name	Systems	Start Time	Stop Time	Duration	Size [GB]	Summary	Acoustic	Visual
Cee032	Delphinus	22-06-2011 18:47	23-06-2011 06:06	11:19	164	Survey	Blue whale	Blue whale
Cee033	Delphinus	23-06-2011 06:08	23-06-2011 12:49	06:41	97	Survey	Beluga Seals	Minke whale Beluga Seals
Cee034	Delphinus	23-06-2011 13:05	23-06-2011 22:36	09:31	138	Survey	Seals?	White beaked dolphins Fin whales Seals
Cee035	Delphinus	23-06-2011 22:57	24-06-2011 00:04	01:08	16	Survey	Dolphins? (one click train)	Fin whales
Cee036	Delphinus	24-06-2011 00:05	24-06-2011 07:15	07:11	145	Survey	None	Fin whale Humpback whale White beaked dolphins
Cee037	Delphinus	24-06-2011 07:17	24-06-2011 07:43	00:26	6	Survey	None	Fin whale Humpback whale
Cee038	Socrates	25-06-2011 03:00	25-06-2011 04:00	01:00	1	Rampup exp on Humpback.	None	Fin whale Humpback whale Seals
Cee039	Delphinus	25-06-2011 08:00	25-06-2001 18:18	10:18	1	Survey	Sperm whales White beaked dolphins	Fin whales Bottlenose whale White beaked dolphins
Cee040	Delphinus	25-06-2011 18:19	25-06-2011 23:44	05:25	109	Survey	Bottlenose whale	Bottlenose whale
Cee041	Delphinus	25-06-2011 23:44	26-06-2011 05:27	05:43	118	Survey	White beaked dolphins	Fin whales White beaked dolphins
Cee042	Delphinus	26-06-2011 05:35	26-06-2011 09:52	04:17	88	Survey	Sperm whales Bottlenose whale	Bottlenose whale
Cee043	Delphinus	26-06-2011 09:55	26-06-2011 20:13	10:18	209	Survey	Sperm whales Bottlenose whale	Minke whale Bottlenose whale
Cee044	Delphinus	26-06-2011 20:15	27-06-2011 03:48	07:33	155	Survey	Sperm whales Bottlenose whale White beaked dolphins	Fin whales Bottlenose whale White beaked dolphins

Exp Name	Systems	Start Time	Stop Time	Duration	Size [GB]	Summary	Acoustic	Visual
Cee045	Delphinus	27-06-2011 03:49	27-06-2011 11:15	07:26	153	Survey	Sperm whales	Sperm whales Fin whales Bottlenose whale
Cee046	Delphinus	27-06-2011 11:16	27-06-2011 18:05	06:49	138	Survey	Sperm whales White beaked dolphins	Fin whales White beaked dolphins
Cee047	Delphinus	27-06-2011 18:06	28-06-2011 00:12	06:06	124	Survey	Sperm whales	Sperm whales
Cee048	Delphinus	28-06-2011 00:14	28-06-2011 03:26	03:12	66	Survey	Sperm whales White beaked dolphins	Sperm whales Minke whales White beaked dolphins
Total				227:13	6134			

5 Recommendations and future plan

5.1 Recommendations

There is a strong tradition within the 3S-group to engage the entire team in a group process to assess what did not go according to plan and where should we change plans and procedures to improve safety and successful data collection during future trials. Table 5.1. summarizes the issues raised by the team during the de-brief meeting on the last day of the trial. Some additional issues were also raised at the post cruise meeting in The Hague in September 2011, where again most of the 3S-team was gathered. During the post cruise meeting the group also discussed which of these issues should be followed up, how they should be followed up, who should be responsible and what would be appropriate deadlines for specific actions on the matter.

Table 5.1. List of issues raised by the 3S team to further improve safety and data collection. Actions, responsibility and deadlines of how to follow up these issues are also listed.

Issue raised by 3S-team ↓	**Comments/Follow-up/actions** ↓	**Responsibility** **Deadline** ↓
SAFETY		
Install AIS/VHF also in tag boat 1. This is safer if boats are working wide apart.	*Should be installed if feasible*	FFI 3S-12 (06/12)
The people going on tag boats should get a course in survival at sea	*This is employers responsibility*	Employers 3S-12 (06/12)
The people going in tag boats should be instructed on safety issues in tag boats and this should be 'enforced' during the trial.	*Will be implemented in cruise plan, and executed as planned*	Cruise leader 3S-12 (06/12)
Tag boat 1 suffered engine problems. Ensure that problem is fixed before next trial	*Will be fixed*	FFI 3S-12 (06/12)
FIELD SITE		
During the trial we struggled to find target species. A dedicated field site assessment was made by FFI (Appendix G), but target species distribution should be assessed in more detail.	*All available data sources on species distribution within the field site have been emptied. Change of field site will be assessed after each trial based on our experience.*	3S-group (Chief Scientist) Cruise planning meeting (02/12)
	Assess possibility of scouting trips using coast guards or marine patrol aircraft prior to next trial.	FFI Cruise planning meeting (02/12)
We found ourselves in an area together with a whaler. It would be better to ensure that we are not mutually interfering, can data about position of whalers be obtained?	*Accurate information is not available before trial, but activity can be monitored during trial*	FFI 3S-12 (06/12)
Marine mammal observers (MMO)		
The Logger screen on HUS can be used to keep the expected orientation of the animal when combining visual and acoustic tracking.	*During combined acoustic and visual tracking of Bottlenose whales, someone should be dedicated to this. This will be implemented in the MMO protocol*	MMO-leader 3S-12 (06/12)

It is not yet clear whether acoustic "boxing" will work. A more detailed protocol for tracking should be made.	*Both acoustic and visual tracking should be further tried in combination but we should avoid bad compromises. Contact Gianni Pavan and Peter Tyack to evaluate procedures.*	TNO Cruise planning meeting (02/12)
Investigate whether we can remove the search lights on the MMO-platform of HUS. They are blocking some sectors for the Big Eyes.	*It will be investigated if this is possible, with the intention of having them temporarily removed.*	FFI 3S-12 (06/12)
Wind shield which covers the entire front of the HUS MMO-platform will improve conditions.	*Should be installed*	FFI 3S-12 (06/12)
Make more use of the top mast of HUS as an observation platform	*Should be implemented*	MMO-leader 3S-12 (06/12)
TAGGING/TRACKING		
Many tags deployed on Humpback whales came off prematurely. We should assess if tags themselves can be improved.	*The premature releases of tags on Humpbacks seem to be caused by the animal's behaviour with rapid swimming, breaching or rubbing against other animals. SMRU will verify if this impression is consistent with tag data.*	SMRU Cruise planning meeting (02/12)
	WHOI will make available old white suction cups, since there is an indication that they stay on longer	WHOI 3S-12 (06/12)
Putting a second tag on the same animal does not seem to solve the problem of premature tag release in Humpbacks, since both tags tended to come off at the same time. This should therefore not be prioritized.	*The cost and risk of a second tagging attempt on the same animal is low. A second tag on another animal increases risk to the tag if animals split up. Procedures remain unchanged.*	No action
The actual position of the tag on the animal could be a factor influencing premature tag release.	*Investigate if tag-on-animal-time correlates with position of tag.*	SMRU Cruise planning meeting (02/12)
Use of the ARTS-system on Humpbacks was not done. It could be explored if this will further increase tagging efficiency.	*This should be tried, but require modifications on the ARTS carrier robot to fit the GPS sensor*	FFI/SMRU 3S-12 (06/12)
The ARTS-robot should be adapted to accommodate the new version DTAGs (DTAG3)	*A dedicated effort is already working on this (ARTS-DTAG3-project)*	WHOI/FFI 3S-12 (06/12)
The efficacy of the scraper tag should be evaluated	*Investigate if there is any opportunity to do this.*	FFI Cruise planning meeting (02/12)
Improve the CTAG so that it can be activated upon deployment. This will make it easier to opportunistically tag single Minke whales when an opportunity is offered.	*This requires modifications to the Star Oddi sensor package. We should contact them and ask if this is feasible or consider a different sensor package*	FFI Cruise planning meeting (02/12)
Consider what is the optimal sensor package for the CTAG	*Based on data from the first experiment it will be assessed which sensors are useful, and if the sensor package should be changed. This consideration will have to include an assessment of what is economically feasible and also the size of tag in relation to deployment range.*	FFI/IMR Cruise planning meeting (02/12)
Explore if the CTAG can include an acoustic sensor, or other sensors	*Available acoustic sensors are big, but this will be followed up. The preferred solution is to modify and use the DTAG also for Minke whales.*	FFI Cruise planning meeting (02/12)

Increase the power output of the VHF-transmitters of the CTAGs to DTAG standard	*This can be important when tag is placed low on the animal or floats low on the water. Should be followed up.*	FFI 3S-12 (06/12)
Increase the pulse repetition time of the VHF-transmitters in the DTAG to CTAG standard (4 pulses pr second)	*This increases the safety margin of being able to track Minke whales ans should thus be followed up.*	WHOI 3S-12 (06/12)
Explore if DTAGs can be modified to be attached with invasive techniques.	*This is the preferred solution to the Minke whale tagging problem, and thus will be followed up. First step is that FFI will write a report to WHOI on the events of 3S-11 Minke whale tagging and the scientific reasons for accepting invasive methods.*	WHOI/FFI Step 1 by 09/11. Final plan by 02/12.
Sometimes tagging attempts continued longer than seemed effective. The MMO-team has the best view to oversee this and should make recommendations to tag teams.	*This procedure will be added to the MMO- and tagging protocol.*	MMO-leader 3S-12 (06/12)
The optimal tagging strategy for Minke whales is still not perfectly clear. When single animals are spotted, consider to launch tag teams quickly and try tagging shortly.	*This procedure will be implemented in the tagging protocol. However, it may require training of a second ARTS operator.*	FFI 3S-12 (06/12)
The new digital direction finders proved to be a significant improvement, but we experienced black out on two units. This must be investigated and corrected. We should also have an extra unit on board for back up.	*We think the black out was due to insufficient protection of electrical circuits. This will be corrected, but we should still bring a spare one.*	FFI 3S-12 (06/12)
EXPOSURE PROTOCOL		
Consider to collect shorter baseline periods, which will enable more exposures to be completed before tag comes off.	*Will be discussed and concluded at 3S-12 cruise planning meeting*	3S-group (PI) Cruise planning meeting (02/12)
The maximum exposure duration should be stated in the protocol.	*In the Minke whale exposure 60 min was used, this is adapted as the max exposure time and will be implemented in the exposure protocol before the next trial*	PI 3S-12 (06/12)
Decide if source ship should change course towards the animal, also after it has clearly responded.	*Will be discussed and concluded at cruise planning meeting*	3S-group (PI) Cruise planning meeting (02/12)
Consider to change exposure protocol for Minke whales and commence exposure at larger ranges than 4nmi to achieve lower initial received levels.	*Confirm from data at what received levels the Minke whale responded, and based on that adapt protocol. Will be discussed and concluded at cruise planning meeting*	IMR Cruise planning meeting (02/12)
Keep a strict minimum distance between source ship and tagged animals after first exposure.	*Min distance should be 1nmi, preferred distance >2nmi.*	Cruise leader 3S-12 (06/12)
If using invasive tags on Minke whales in the future, consider to change protocol to extend the duration of experiments (e.g. 24 or even 48 hrs)	*Will be discussed and concluded at cruise planning meeting*	3S-group (PI) Cruise planning meeting (02/12)
Consider to change the order of sonar and killer whale playback exposures in Minke whales	*This can compromise the sonar exposure, having the highest priority .The current order (silent-sonar-sonar-Killer whale playback) will be tried at least once more before considering to change it.*	Chief scientists 3S-12 (06/12)

Consider to change the exposure protocol for Bottlenose whales to comply with SOCAL and BRS.	*Will be discussed and concluded at cruise planning meeting*	3S-group (PI) Cruise planning meeting (02/12)
CRUISE MANAGEMENT		
Explicit representation of the MMO-team at the daily planning meeting.	*All team members will be invited to express ideas and concerns in the beginning of the chief scientist meeting. Generally communication should follow chain of command within each team. MMO-team leaders are especially encouraged to give short updates on the status of the work and teams.*	Cruise leader 3S-12 (06/12)
MMO-team leader and the CO on watch should plan the shift and recruit personnel from other teams if available and needed.	*This is mainly how things were done already, but this will be formalized more in the next trial.*	MMO-leader / CO 3S-12 (06/12)
Consider to change species priority for future trials if TNO funding for 3S-13 is not granted	*Formal decision on TNO funding is expected primo 2012. If TNO can not participate in 3S-13, the logical consequence is to reduce the scope of the project and reduce the numbers of target species.*	3S-board Cruise planning meeting (02/12)
Issue raised by 3S-team ↑	**Comments/Follow-up/actions** ↑	**Responsibility** **Deadline** ↑

Many of the issues raised by the team are procedural issues such as suggested changes to the experimental protocols. These will be discussed and concluded at the cruise planning meeting prior to the next 3S-trial. This meeting is planned for February 2012. There are also some minor technical or practical details to be sorted out before the next trial, which will potentially also improve our performance. The most challenging issues which must be addressed before the next trial, is related to our ability to find Bottlenose whales and to tag Minke whales.

We will carefully assess options of changing field site, but don't expect to find new information to base such assessment on. We did find Bottlenose whales during the trial, but too late to achieve much. We will therefore assess the possibility of getting real time information of the whereabouts of Bottlenose whales just prior to the next trial, by sending our MMOs on scouting expeditions on ships or airplanes.

It seems as if the current version of the DTAG can not be used with Minke whales, since the suction cups do not attach to the animals. We therefore have to either change the attachment of the DTAG or use the CTAG instead, in the future. The preferred solution is to use the DTAG. The data recording rate of the motion sensors in the DTAG enable us to study potential responses of the animals in much greater detail then with any alternative sensor packages known to us. The acoustic sensor of the DTAG also enables us to measure the received level of sound on the animal. The use of DTAG will also make the results of the Minke whale experiments easier to compare to results of experiments on other species, since the DTAG is used in most exposure experiments to date. Our preferred plan of action is to start working with the DTAG -group to develop an invasive attachment for the DTAG as soon as possible. This attachment should of course be specified to be minimally invasive. A major challenge will also be the release mechanism of the tag. The alternative course of action for us is to start looking at the CTAG and on how to improve the sensor suite of this tag.

5.2 Future plans

There are already plans to conduct a second full scale sonar exposure trial in 2012. The funding is already in place for this trial for all involved partners. The crew and logistics will be mostly the same as during 3S-11. The 3S-12 trial is preliminary scheduled for June 2012 and the field site will be the area between Bear Island and Spitsbergen, but will be extended westwards off the shelf, based on our sightings of Bottlenose whales this year. The current decision is that the target species will be the same three as during 3S-11, but this list might be expanded or compressed depending on the prospect of future funding. A cruise planning meeting will be held in St.Andrews in February 2012 to finalize the plans for the 3S-12 trial.

The 3S-group also has plans to conduct a third full scale sonar exposure trial and a baseline trial in 2013. Details of these trials are pending decisions on funding for some of the partners.

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Appendix A Data inventory

The data inventory contains a complete list of all data, files and folders collected and generated during the trial and uploaded to the central database at the end of the trial. The inventory is structured according to the participating institutions.

A.1 Data inventory FFI

Folder	**Subfolders/files**	**Content**
Daily work plans	1 file for each day (JuneXX.doc)	Daily plans
Cruise leaders summary	Cruise leaders summary	Cruise leaders daily report, summary of events and weather report
Briefings	.ppt files	Briefings
	1.xls file	Drill of operation
CTD 3S211	CTD_log3S 201.xls	CTD log
	Raw data CTD files	Raw data CTD files (SD2) and software to read and convert files. (SD200W.exe)
	Lybin	Lybin runs. Transmission loss model output in .doc file.
	Manual	Manuals for CTD software and probe
CTAG	Calibration	Ctag data file from CTD cast with CTAG attached
	3S2011Minkejun20	Ctag data file from Minke whale Dose-escalation experiment
Event log bridge	One text file for each experimental day	Text files with logs of events during experiments recorded from the bridge of source ship
Maria files		Reference points and screen dumps from navigation tool (Maria) on bridge)
3S cruise plan final		3S cruise plan with attachments
Pictures and videos	Rune-pictures Lars-pictures Rune-video Lars-video	Pictures and videos of tagging and experiments, people and animals.
Tagging	ARTS and CTAG log	ARTS log CTAG log Biopsy log Humpback photo id log

A.2 Data inventory TNO

Folder	Content
belle_wav	Selection of finest acoustic detections during the trial.
Documents	Logbook and overview of recordings.
GPS_log	Complete ship track of H.U. Sverdrup II
Photos	Pictures and videos, including a selection from SMRU and Fleur Visser
plot_tracks	Pictures of totla ship and daily tracks.
Screenshots	Screenshots from acoustics
Socrates Logs	Socrates source log.
XBT_logs	XBT data

A.3 Data inventory SMRU

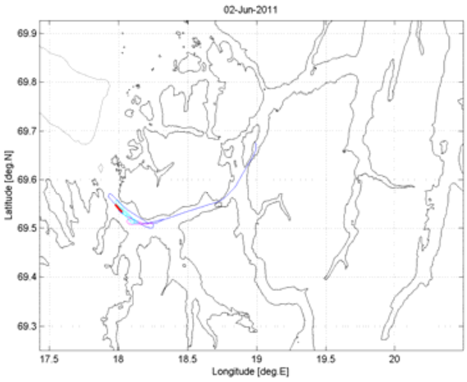
Directory	Size	Content
3S-11_TB_tracks	1.09 MB	Tracks of tagboats from Garmin GPS
DTAG data	250 GB	Uncompressed DTAG data
Gps_tag	3.83 MB	Gps tag deployments and tests
HUS_logger_backup	87.3 MB	Sverdrup logger database
MOBHUS logger backup	122 MB	MOBHUS logger database
Photo_id	39.4 GB	All photo
Playbacks	4.05 GB	Playback stimuli and recordings
vd_array	7.70 GB	Recordings on VD array on MOBHUS
Videos	22.7 GB	Various video recordings of operations

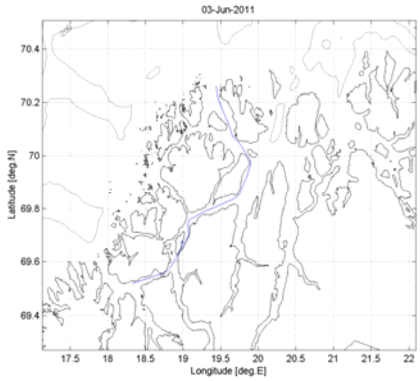
A.4 Data inventory Kelp Marine Research

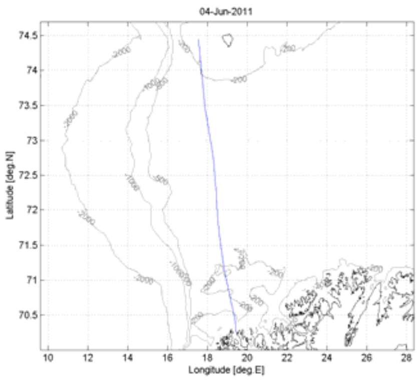
File	Content
Experiment timeline	Timelines for all experiments and tracks (start/end tracking, tagboat effort, tag on/off/recovery, sighting numbers, exposures, experiment phases, notable events, etc. (KMR / FFI)
3S goes young / P&P working group minutes	Minutes of first meeting of 3S postdocs and Paul, with chief scientists
Overview data collected	Descriptive overview of all data types collected, respective location and folder where files are saved, data-gatekeeper/contact person
Logbook shifts	Descriptive summary of shifts with tracking from HUS and MOBHUS (KMR / FFI)

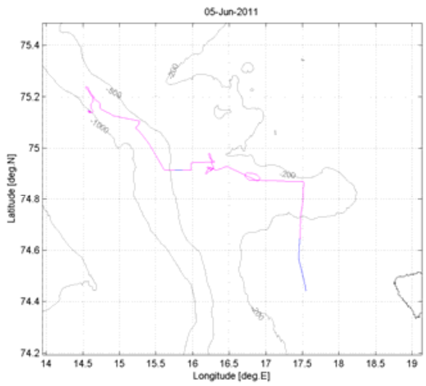
Appendix B Daily sailing tracks of Sverdrup (HUS)

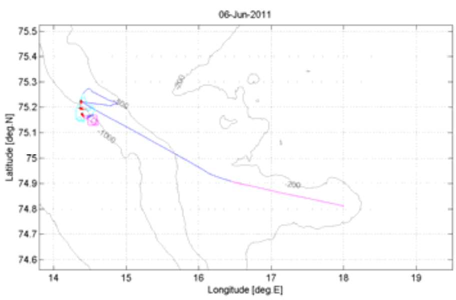
Depicted below is the daily sail track of HU Sverdrup II. The blue part of the track indicates that no sonar (passive of active) systems are operational. Sonar transmissions by the Socrates system are indicated by a red track, operation of the Delphinus array by a pink track and the Captas array by a cyan colored track.

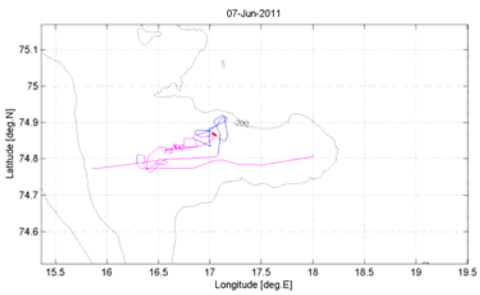


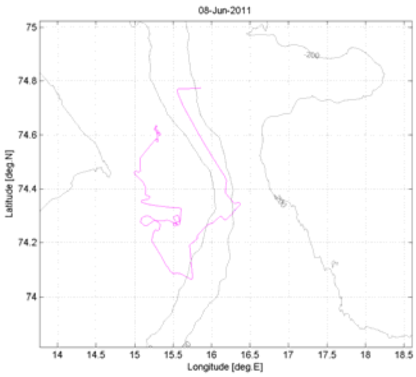








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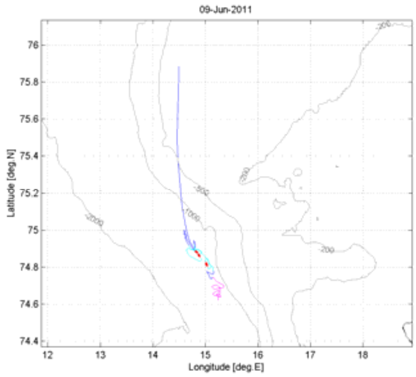
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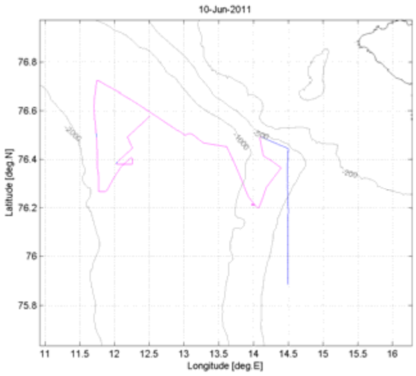
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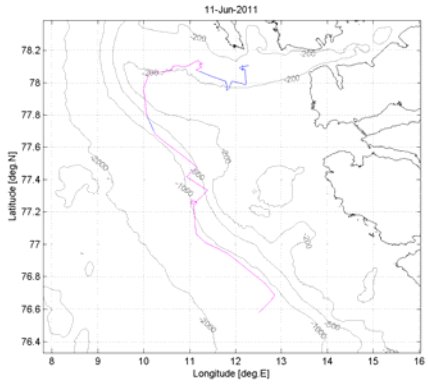
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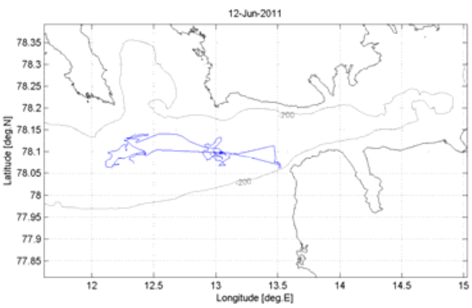
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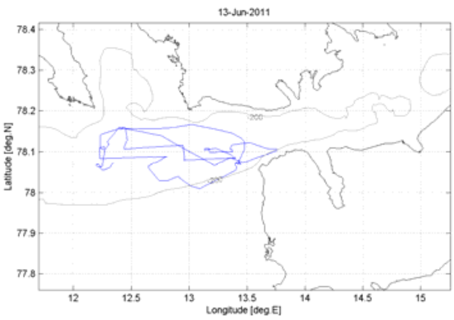
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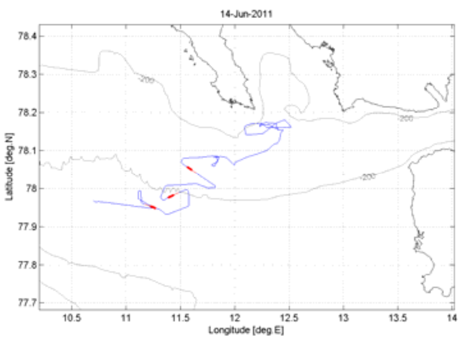
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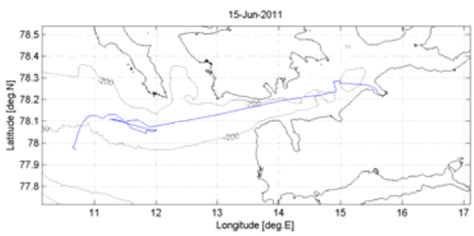
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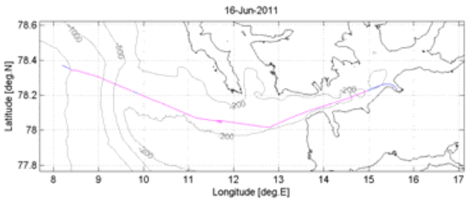
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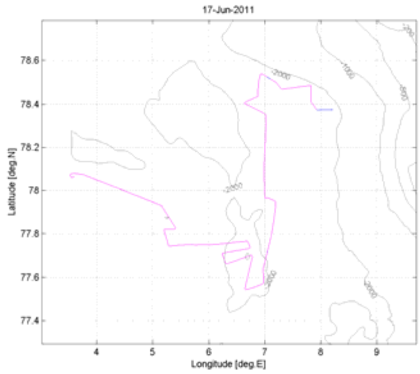
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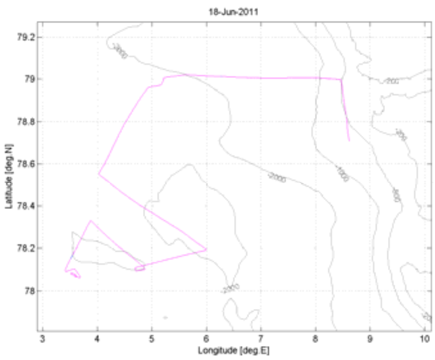
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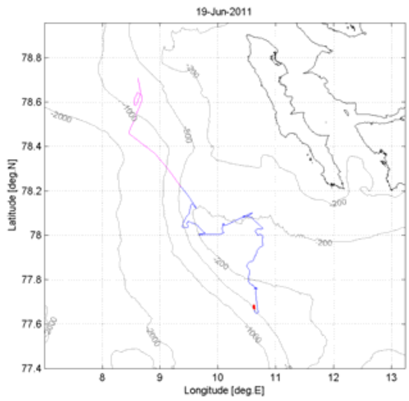
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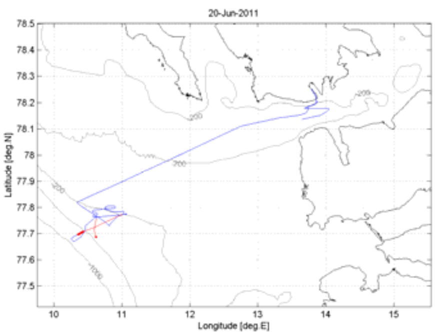
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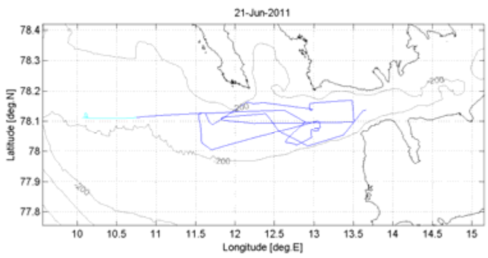
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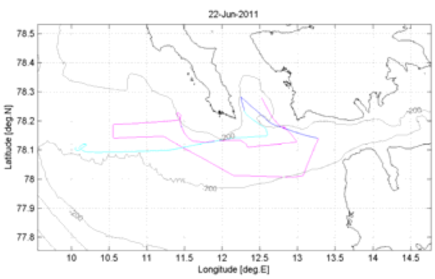
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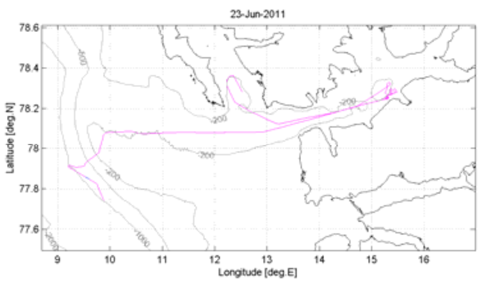
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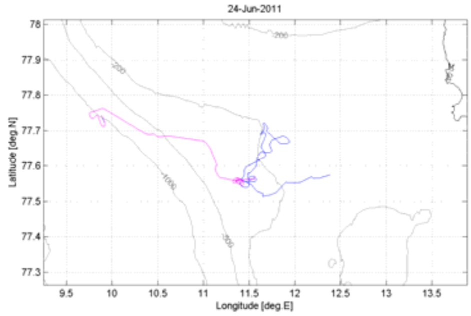
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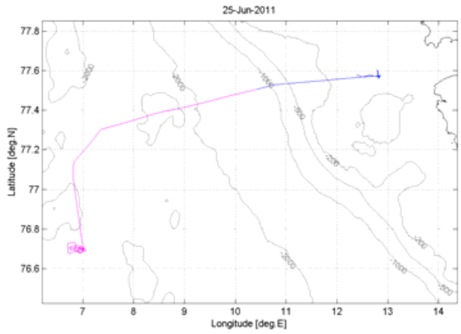
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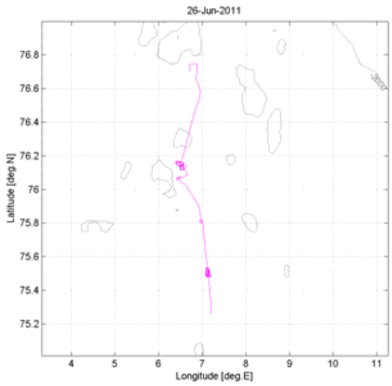
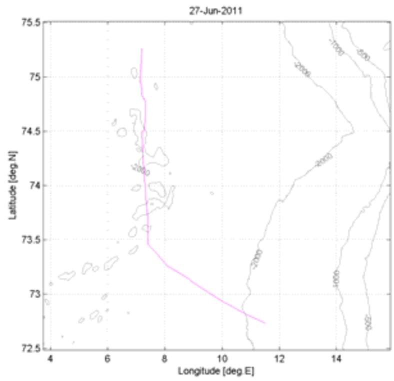
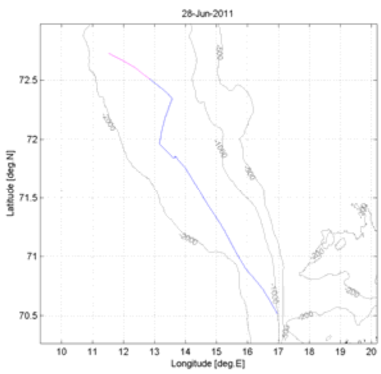
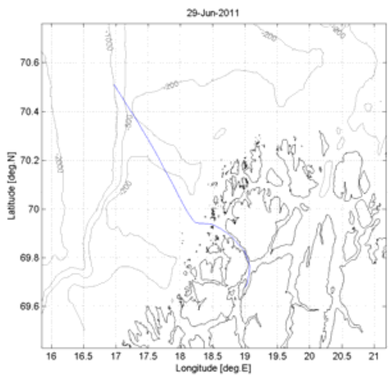

26-Jun-2011
Latitude [deg.N]
Longitude [deg.E]


27-Jun-2011
Latitude [deg.N]
Longitude [deg.E]


28-Jun-2011
Latitude [deg.N]
Longitude [deg.E]


29-Jun-2011
Latitude [deg.N]
Longitude [deg.E]

Appendix C Details of experiments

All times are given as hh:mm (or hh:mm:ss) in Local/UTC time (unless stated otherwise)

Deployment: mn11_157a

Date: 06-Jun-2011
Species: Humpback whale (*Megaptera novaeangliae*)
Experiment code: Cee003
Logger sighting number: 316 (once tag is on)

Whale ID, tagging attempt and tag on pictures

Photos by Rune Hansen, Rune Hansen and Leigh Hickmott (in clockwise order)

Description of events:
22:55 (05-Jun-2011)/**20:55** (05-Jun-2011) - Visual detection from HUS (sighting number 315)
22:55 (05-Jun-2011)/**20:55** (05-Jun-2011) – Start pre-tagging;
00:02 (05-June-2011)/**22:02** (05-June-2011) – Tagboat 1 launched; Start tagging;
00:18 (06-June-2011)/**22:18** (05-June-2011) – Start tagging approach;
00:25/22:25 – TAG ON (sighting number 316)

00:52 (06-June-2011)/**22:52** (05-June-2011) – Tag boat 1 returns; Post-tagging observations begin;
02:14/00:14 – Post tagging ends;
02:25/00:25 – Change platform, start tracking from MOBHUS
09:08/07:08 – Start of SILENT RAMP-UP approach (3S-2011_TNO_Final/Socrates Logs/20110606_0709_locator_cee003_rampup_exp1/transmission.log)
09:18/07:18 – End of SILENT RAMP-UP approach
09:58/07:58 – HUS taking over tracking during crew change
10:09/08:09 – MOBHUS transits back to HUS for crew change due to engine failure of tagboat 1; tracking is handover to HUS
10:35/08:35 – Resume tracking from MOBHUS
11:23/09:23 – Start of RAMP-UP (3S-2011_TNO_Final/Socrates Logs/20110606_0922_locator_cee003_rampup_exp2/transmission.log)
11:28/09:28 – Full power of RAMP-UP
11:33/09:33 – End of RAMP-UP
12:46/10:46 – Start of RAMP-UP II (3S-2011_TNO_Final/Socrates Logs/20110606_1045_locator_cee003_rampup_exp3/transmission.log)
12:51/10:51 – Full power of RAMP-UP II
12:56/10:56 – End of RAMP-UP II
13:40/11:40 – Start of KW playback
13:56/11:56 – End of KW playback
14:14/12:14 – Start of Noise playback (control)
14:30/12:30 – End of Noise playback (control)
16:04/14:04 – Start of biopsy
16:34/14:34 – Biopsy attempt
16:58/14:58 – TAG OFF
17:02/15:02 – Biopsy attempt
17:07/15:07 – Successful biopsy
17:10/15:10 – End tracking
17:14/15:14 – Tag recovery

Visual tracking summary:
Pre-tagging started at **22:55/20:55** (05-Jun-2011) – sighting 315
Tagging began at **00:02/22:02** (05-June-2011)
Post-tagging started at **02:14/00:14**

DTAG information

Tag on time: 00:25 (06-June-2011)/22:25(5-Jun-2011)
Tag on location: 75º 08.569 – 14º 37.932
Tag off time: 16:58/14:58
Tag recovered time: 17:14/15:14
Tag recovered position: 75º 12.728 – 14º 47.065
VHF frequency: 148.263
System: Cantilever
Operator: Patrick Miller
Images of tagging: YES
Images of tag on animal: YES
Tag position on animal: High on back, forward of dorsal
Characteristics of animal: Humpback feeding with ~10 fin whales
Range: long pole
Comments: No reaction at all, kept feeding
Data Recorder on tag boat: PM
Sea state: 1-3 m swell
Reaction level: 0
Tagging team members: Rune Hansen (photo-id), Leigh Hickmott (driver) and Patrick Miller (tagger)

On-animal Time: 16h33min
DTAG#: 241
DTAG code version: 2
Release fired: YES
Reason for release: Release fired
Programmed released time: 16h
Skin sample: NO
Audio sampling rate: 96 kHz
Channel: 1 & 2
Gain: 0 &12
NBITS: 16
Compression: YES (Audio 1,875)
Housing damage/Observations: None

DTAG reported start time: 06.06.2011 00:25:15 (local)
Start chip/block: 1:6
End chip/block: 3:7647
# of chips: 3
On-animal chips: 3
Current tag offset to GPS Time (Tag time-GPS time): Unknown

GPS tag information

Tag #: 29420
Sampling rate: 30 s
GPS raw data filename: Obs060611_173148
.pos file ok? YES
Time deployment: 00:25(06-June-2011)/22:25(05-Jun-2011)
Detailed picture of GPS tag with DTAG on animal: YES
Comments: Good placement, anterior to dorsal fin

Biopsy sampling

Biopsy sample number: 0132
Tip length: 100mm Finn Larsen tip
Biopsy system: ARTS/LKDART
Number of misses: 2
Reaction level (0-3): 0
Reaction description: No observed response
Location on animal: Behind and below dorsal on left side
Biopsy time: 17:07:49/15:07:49
Biopsy location: 75º 12.432 N; 14º 46.096 E;
Section of sample: 100 mm sample
Division of sample: ½ skin sample in DMSO; ½ skin sample + blubber
Comments: None

KW playback

Playback stimulus name (playback order): Mammal eating killer whale_stim1 (1)
Playback start time: 13:40:40/11:40:40
Playback start position: 75º14.142 N; 14º27.420 E
Playback end time: 13:56:51/11:56:51
Playback end position: 75º14.155 N; 14º28.187 E
Noise stimulus name (playback order): Noise_5 (2)
Noise start time: 14:14:48/12:14:48
Noise start position: 75º15.028 N; 14º28.896 E
Noise end time: 14:30:13/12:30:13
Noise end position: 75º15.070 N; 14º29.281 E
Playback origin: oo06_181_a_11to22min (sequence #9)
Source depth: 8m

Gain setting on hydrophone amplifier: 31.6 mV
Gain setting on amplifier (for speaker): Gain 1=20; Gain 2=20;
Distance of monitoring hydrophone (from source): 1m
Approximate distance from focal individual: 800 m (estimated)
Playback operator: Charlotte Curé
Crew: Charlotte Curé, Sander v Ijsselmuide, Leigh Hickmott

Deployment: mn11_158a

Date: 07-Jun-2011
Species: Humpback whale (*Megaptera novaeangliae*)
Experiment code: Cee006
Logger sighting number: 339 (for mn158a) and 340 (for tag mn158b)

Tagging attempt, tag on and whale ID pictures

Photographs in clockwise order by Rune Hansen, Rune Hansen and Leigh Hickmott

Description of events:

07:57/05:57 – Visual detection from HUS (sighting number 333)
09:52/07:52 – Start of pre-tagging;

10:38/08:38 – Tag boat 1 launched; start tagging;

11:21/09:21 – TAG ON (tag mn158a VHF 148.263; sighting number 339)

11:23/09:23 – Tag mn158b (tag b VHF 148.403) touches water
11:51/09:51 – Tag mn158b on
11:54/09:54 – Tag mn158b off (tag fell off)

12:48/10:48 – TAG ON (tag mn158b VHF 148.403; sighting number 340)

13:08/11:08 – tag boat returns; start post tagging (tracking of 340 as 339 is for tag down in the animal so we got no beeps; shift to number 339 when tag b comes off; 339 and 340 are the same focal animal)
14:24/12:24 – MOBHUS launched;
14:32/12:32 – MOBHUS takes over tracking; post tagging ends
17:34/15:34 – tag boat 1 launched for crew change on MOBHUS
17:54/15:54 – tag boat 1 returns from crew change

20:09/18:09 – TAG OFF mn158b

20:22/18:22 – tag mn158b recovery
20:37/18:37 – Start of SILENT RAMP-UP approach (3S-2011_TNO_Final/Socrates Logs/20110607_1836_locator_cee006_rampup_exp1/transmission.log)
20:47/18:47 – End of SILENT RAMP-UP approach
20:49/18:49 – Tag boat 1 launched for crew change
21:10/19:10 – Tag boat 1 returns from crew change

21:33/19:33 – TAG OFF mn158a

21:41/19:41 – Tag mn158a recovery
21:56/19:56 – End tracking
21:57/19:57 – MOBHUS returns to Sverdrup
22:20/20:20 – End of effort

Visual tracking summary:
Pre-tagging started at **09:52/07:52** – sighting 333
Tagging began at **10:38/08:38**
Post-tagging started at **13:08/11:08**

DTAG information

Tag on time: 11:21/09:21
Tag on location: 74º 49.818 N; 16º 36.762 E;
Tag off time: 21:33 (from tag data)
Tag recovered time: 21:41/19:41
Tag recovered position: 74º 52.477 N; 17º 01.882 E;
VHF frequency: 148.263
System: Cantilever
Operator: Patrick Miller
Images of tagging: YES
Images of tag on animal: YES
Tag position on animal: Low on left side of tale stock
Characteristics of animal: -
Range: long pole
Comments: Minor reactions possible from tag boat approach but no reactions during actual tagging attachments or attempts;
Data Recorder on tag boat: Patrick Miller
Sea state: 3 – confused sea with swell, difficult conditions

Reaction level: 0
Tagging team members: Rune Hansen (photo-id), Leigh Hickmott (driver) and Patrick Miller (tagger)
On-animal Time: 10h12min
DTAG#: 238
DTAG code version: 2.4
Release fired: NO
Reason for release: -
Programmed released time: 16h
Skin sample: NO
Audio sampling rate: 96 kHz
Channel: 1 & 2
Gain: 0 & 12 dB
NBITS: 16
Compression: YES (Audio1,928)
Housing damage/Observations: None

DTAG reported start time: 06.07.2011 11:21:23 (local)
Start chip/block: 1:6
End chip/block: 2:7813
# of chips: 2
On-animal chips: 2
Current tag offset to GPS Time (Tag time-GPS time): -1 seconds

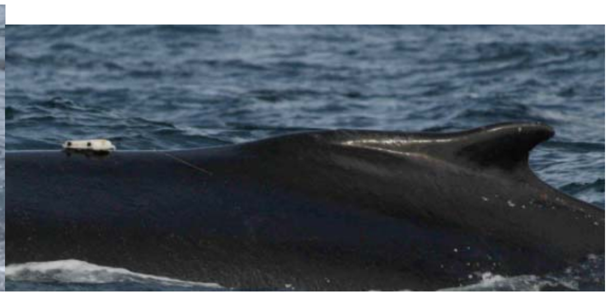
GPS tag information

Tag #: 29409
Sampling rate: 30 s
GPS raw data filename: Obs070611_221029
.pos file ok? YES
Time deployment: 11:21/09:21
Detailed picture of GPS tag with DTAG on animal: YES
Comments: Low placement, on the left side behind dorsal

Deployment: mn11_158b

Date: 07-Jun-2011
Species: Humpback whale (*Megaptera novaeangliae*)
Experiment code: Cee006
Logger sighting number: 339 (for mn158a) and 340 (for tag mn158b)

Tagging attempt, tag on and whale ID pictures



Pictures in clockwise order by Rune Hansen and Leigh Hickmott

DTAG information

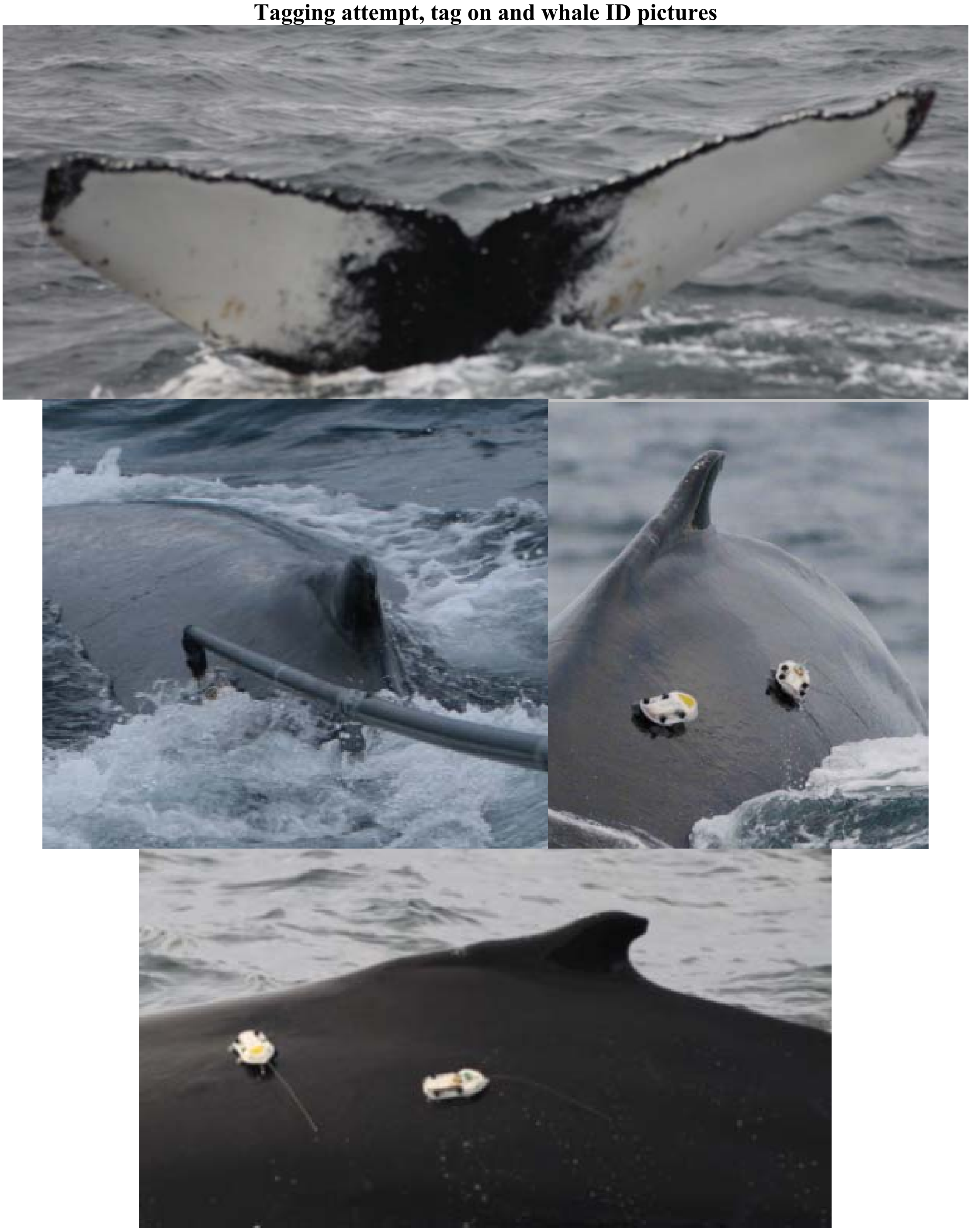
Tag on time: 11:33/09:33
Tag on location: 74º 49.915 N; 16º 40.255 E
Tag off time: 18:54/16:54
Tag recovered time: 19:41/17:41
Tag recovered position: 74º 52.729; 17º 04.719 E
VHF frequency: 148.403
System: Cantilever
Operator: Patrick Miller
Images of tagging: YES
Images of tag on animal: YES
Tag position on animal: on the back behind the dorsal
Characteristics of animal: -
Range: long pole
Comments: Minor reactions possible from tag boat approach but no reactions during actual tagging attachments or attempts;
Data Recorder on tag boat: Patrick Miller
Sea state: 3 – confused sea with swell, difficult conditions
Reaction level: 0
Tagging team members: Rune Hansen (photo-id), Leigh Hickmott (driver) and Patrick Miller (tagger)
On-animal Time: 7h21min
DTAG#: 237
DTAG code version: 2.4
Release fired: NO
Reason for release: High acceleration
Programmed released time: 16h
Skin sample: NO
Audio sampling rate: 96 kHz
Channel: 1 & 2
Gain: 0 & 12 dB
NBITS: 16
Compression: YES (Audio 1,933)
Housing damage/Observations: None

DTAG reported start time: 06.07.2011 11:33:52 (local)
Start chip/block: 1:6
End chip/block: 2:5078
# of chips: 2
On-animal chips: 2
Current tag offset to GPS Time (Tag time-GPS time): -1 seconds

Deployment: mn11_160a

Date: 09-Jun-2011
Species: Humpback whale (*Megaptera novaeangliae*)
Experiment code: Cee010
Logger sighting number: 377 (for mn160a) and 379 (for tag mn160b)

Tagging attempt, tag on and whale ID pictures



Photos by Filipa Samarra, Rune Hansen, Leigh Hickmott and Filipa Samarra (in clockwise order)

Description of events:
23:24/21:24 – Visual detection from HUS (sighting number 376)
23:40/21:40 – Start of pre-tagging;
00:20/22:20 – Tag boat 1 launched; Start of tagging;
00:55/22:55 – TAG ON (tag mn160a VHF 148.263; sighting number 377)
02:14/00:14 – TAG ON (tag mn160b VHF 148.403; sighting number 379)
02:19/00:19 - Tag boat 1 returns; Start post-tagging;
00:47/00:47 - End of post-tagging;
02:41/00:41 – MOBHUS launched for tracking;
03:12/01:12 – MOBHUS takes over tracking;
04:03/02:03 – TAG OFF mn160b
04:15/02:15 – tag mn160b recovery;
06:45/04:45 – tag boat 1 launched for crew change;
06:56/04:56 – tag boat 1 returns from crew change
09:16/07:16 – Start of SILENT RAMP-UP approach (3S-2011_TNO_Final/Socrates Logs/20110609_0715_locator_cee010_rampup_exp1/transmission.log)
09:26/07:26 – End of SILENT RAMP-UP approach;
10:03/08:03 – tag boat 1 launched for crew change;
10:20/08:20 – tag boat 1 returns from crew change;
11:01/09:01 – Start of track 002 in VD array;
11:13/09:13 – Start of track 003 in VD array;
11:14/09:14 – Start of RAMP-UP (3S-2011_TNO_Final/Socrates Logs/20110609_0912_locator_cee010_rampup_exp2/transmission.log)
11:19/09:19 – RAMP-UP full power;
11:24/09:24 – End of RAMP-UP;
12:34/10:34 – Start of track 004 in VD array;
12:36/10:36 – Start of RAMP-UP II (3S-2011_TNO_Final/Socrates Logs/20110609_1034_locator_cee010_rampup_exp3/transmission.log)
12:41/10:41 – RAMP-UP II full power;
12:46/10:46 – End of RAMP-UP II;
13:12/11:12 – Tag boat 1 launched for killer whale playback;
14:13/12:13 – Start of KW playback
14:29/12:29 – End of KW playback;
15:03/13:03 – Start of noise control of KW playback;
15:19/13:19 – End of noise control of KW playback;
15:30/13:30 – Tag boat 1 back from KW playback;
15:43/13:43 – Tag boat 1 launched for crew change;
16:05/14:05 – Tab boat 1 returns from crew change;
16:12/14:12 – Start of biopsying
16:50/14:50 – End of biopsying (no successful biopsy because whale was lost – no beeps heard due to batteries failing on speaker)
17:11/15:11 – TAG OFF mn160a
17:12/15:12 – End tracking;
17:15/15:15 – tag mn160a recovery;
17:20/15:20 – End effort;

Visual tracking summary:
Pre-tagging started at **23:40/21:40** – sighting 376
Tagging began at **00:20/22:20**
Post-tagging started at **02:19/00:19**

DTAG information

Tag on time: 00:54 (09-Jun-2011)/22:54 (08-Jun-2011)
Tag on location: 74º 36.648 N; 15º 17.633 E
Tag off time: 17:11/15:11
Tag recovered time: 17:15/15:15
Tag recovered position: 74º 58.484 N; 14º 36.640 E
VHF frequency: 148.263
System: Cantilever
Operator: Patrick Miller
Images of tagging: YES
Images of tag on animal: YES
Tag position on animal: on left side of animal a bit behind dorsal
Characteristics of animal: -
Range: long pole
Comments: Tag hit water at 00:33 (local);
Data Recorder on tag boat: Patrick Miller
Sea state: 3 – confused swell
Reaction level: 0
Tagging team members: Leigh Hickmott (driver), Patrick Miller (tagger) and Rune Hansen (photo-id)
On-animal Time: 16h17min
DTAG#: 238
DTAG code version: 2.4
Release fired: YES
Reason for release: fired as programmed
Programmed released time: 16 h
Skin sample: NO
Audio sampling rate: 96 kHz
Channel: 1 & 2
Gain: 0 & 12 dB
NBITS: 16
Compression: YES (Audio 1,968)
Housing damage/Observations: None

DTAG reported start time: 06.09.2011 00:34:03 (local)
Start chip/block: 1:6
End chip/block: 13:6459
# of chips: 7
On-animal chips: 7
Current tag offset to GPS Time (Tag time-GPS time): 0 seconds

GPS tag information

Tag #: 29409
Sampling rate: 30s
GPS raw data filename: Obs090611_213428
.pos file ok? NO
Time deployment: 00:54:03/22:54:03
Detailed picture of GPS tag with DTAG on animal: YES
Comments: Left side below dorsal

KW playback

Playback stimulus name (playback order): Mammal eating killer whale_stim2 (1)
Playback start time: 14:13:00/12:13:00
Playback start position: 74º54.039 N; 14º44.911 E
Playback end time: 14:29:00/12:29:00
Playback end position: 74º54.108 N; 14º44.071 E

Noise stimulus name (playback order): Noise_7 (2)
Noise start time: 15:03:43/13:03:43
Noise start position: 74º55.323 N; 14º45.885 E
Noise end time: 15:19:42/13:19:42
Noise end position: 74º55.416 N; 14º44.789 E
Playback origin: oo06_181_a_11to22min (sequence #9)
Source depth: 8m
Gain setting on hydrophone amplifier: 100 mV
Gain setting on amplifier (for speaker): Gain 1=20; Gain 2=20;
Distance of monitoring hydrophone (from source): 1m
Approximate distance from focal individual: 800 m (estimated)
Playback operator: Charlotte Curé
Crew: Charlotte Curé, Sander v Ijsselmuide, Leigh Hickmott

MOBHUS Acoustic data

Original filename (start time; duration): track 002 (11:01:02/09:01:02; 00:01:48.224); track 003 (11:13:02/09:13:02; 00:12:36.298); track 004 (12:34:12/10:34:12; 00:11:27.104);
New filename: VDARRAY_09062011_090102; VDARRAY_09062011_091302; VDARRAY_09062011_103412
Sampling rate: 96 kHz
Number channels: 2
Gain setting on recorder: 3.5
Comments: Clipped levels during sonar pings!!!

Deployment: mn11_160b

Date: 09-Jun-2011
Species: Humpback whale (*Megaptera novaeangliae*)
Experiment code: Cee010
Logger sighting number: 377 (for mn160a) and 379 (for tag mn160b)

Tagging attempt, tag on and whale ID pictures

Photo by Rune Hansen

DTAG information

Tag on time: 02:14/00:14
Tag on location: 74º 37.993 N; 15º 15.770 E;
Tag off time: 04:03/02:03
Tag recovered time: 04:15/02:15
Tag recovered position: 74º 40.456 N; 15º 12.854 E
VHF frequency: 148.403

System: Cantilever
Operator: Patrick Miller
Images of tagging: YES
Images of tag on animal: YES
Tag position on animal: on left side under back of dorsal
Characteristics of animal: -
Range: long pole
Comments: Tag hit water at 01:14 (local)
Data Recorder on tag boat: Patrick Miller
Sea state: 3 – confused swell
Reaction level: 0
Tagging team members: Leigh Hickmott (driver), Patrick Miller (tagger) and Rune Hansen (photo-id)
On-animal Time: 1h49min
DTAG#: 237
DTAG code version: 2.4
Release fired: NO
Reason for release: -
Programmed released time: 16 h
Skin sample: NO
Audio sampling rate: 96 kHz
Channel: 1 & 2
Gain: 0 & 12 dB
NBITS: 16
Compression: YES (Audio 2,004)
Housing damage/Observations: None

DTAG reported start time: 06.09.2011 01:17:20 (local)
Start chip/block: 1:6
End chip/block: 1:7558
# of chips: 1
On-animal chips: 1
Current tag offset to GPS Time (Tag time-GPS time): -1 seconds

Deployment: mn11_165a

Date: 14-Jun-2011
Species: Humpback whale (*Megaptera novaeangliae*)
Experiment code: Cee019
Logger sighting number: 556 (when tag mn165a is on), 557 (when tag mn165b and mn165d is on), 561 (when tag mn165e is on)

This animal has deployments mn165a, mn165b, mn165d and mn165f

Tagging attempt, tag on and whale ID pictures

Photos by Leigh Hickmott (top) and Filipa Samarra (bottom)

Description of events:
01:03/23:03 – Visual detection from HUS (sighting number 556);
01:03/23:03 – start pre-tagging;
02:06/00:06 – both tagboats launched; start tagging;
02:48/00:48 – TAG ON (tag mn165a VHF 148.263; sighting number 556)
03:02/01:02 – TAG ON (tag mn165b VHF 148.863; sighting number 557)
03:14/01:14 – tag boat 2 returns;
03:16/01:16 – Start post-tagging observations;
04:01/02:01 - End of post-tagging;
04:07/02:07 – MOBHUS launched;

04:22/02:22 – MOBHUS takes over tracking;
07:36/05:36 – TAG OFF (tag mn165a);
07:38/05:38 – Tag recovery (tag mn165a);
07:58/05:58 – TAG OFF (tag mn165b);
08:04/06:04 – tag recovery (tag mn165b);
08:21/06:21 – HUS takes over tracking while new tags are deployed;
09:24/07:24 – Tag boat launched for re-tagging; start of tagging (no pre-tagging when animals are being re-tagged)
12:58/10:58 – TAG ON (tag mn165c VHF 148.863; sighting number 559)
13:18/11:18 – TAG ON (tag mn165d VHF 148.952; sighting number 559)
13:41/11:41- TAG OFF (tag mn165c)
13:55/11:55 - tag recovery (mn165c)
15:40/13:40 – TAG ON (tag mn165e VHF 148.263; sighting number 561)
15:59/13:59 – TAG ON (tag mn165f VHF 148.203; sighting number 559)
16:15/14:15 – tag boat 1 returns to Sverdrup; start of post-tagging;
16:32/14:32 - post-tagging ends;
17:11/15:11 – MOBHUS launched for tracking;
17:17/15:17 – MOBHUS takes over tracking;
19:40/17:40 – Start of SILENT RAMP-UP approach (3S-2011_TNO_Final/Socrates Logs/20110614_1740_locator_cee019_rampup_exp1/transmission.log)
19:50/17:50 – End of SILENT RAMP-UP approach;
21:11/19:11 – Tag boat 1 launched for crew change;
21:31/19:31 - tag boat 1 returns from crew change;
21:46/19:46 – Start track 001 in VD array;
21:56/19:56 – Start RAMP-UP (3S-2011_TNO_Final/Socrates Logs/20110614_1955_locator_cee019_rampup_exp2/transmission.log)
22:01/20:01 – RAMP-UP full power;
22:06/21:06 – End of RAMP-UP;
23:00/21:00 – Start track 002 in VD array;
23:03/21:03 – Start of RAMP-UP II (3S-2011_TNO_Final/Socrates Logs/20110614_2102_locator_cee019_rampup_exp3/transmission.log)
23:08/21:08 – RAMP-UP II full power;
23:13/21:13 – End of RAMP-UP II;
23:51/21:51 – Tag boat 1 launched for KW playback;
00:31/22:31 – Start track 003 in VD array;
00:33/22:33 – Start of KW playback;
00:48/22:48 – End of KW playback;
01:16/23:16 – Start track 004 in VD array;
01:22/23:22 – Start of noise KW playback;
01:37/23:37 – End of noise KW playback;
01:53/23:53 – Tag boat 1 back from KW playback;
02:11/00:11 – Tag boat 1 launched for crew change;
02:34/00:34 – Tag boat 1 back from crew change;
04:01/02:01 – Start biopsying;
04:10/02:10 – Successful biopsy on larger of two animals;
04:32/02:32 – Biopsy attempt on smaller animal;
04:36/02:36 – Biopsy attempt on smaller animal;

04:41/02:41 – TAG OFF (tag mn158e – time calculated from time on animal)

04:43/02:43 – Biopsy on smaller animal but dart was stuck on animal;
05:18/03:18 – End of biopsying;
05:18/03:18 – Handover tracking to Sverdrup so that MOBHUS could recover tag off; tag off time unknown;
05:33/03:33 – Tag recovery (tag mn158e)

07:07/05:07 – TAG OFF (tag mn158d – time calculated from time on animal)

08:32/06:32 – TAG OFF (tag mn158f)

08:59/06:59 – Tag recovery (tag mn158f)
10:03/08:03 – tag mn158d not seen on animal and no beeps
10:10/08:10 – transit to last position where tag mn158d (VHF 148.952) was seen to check for beeps as this tag was never recovered;
18:49/16:49 (16-Jun-2011) – Tag recovery (tag mn158d)

Visual tracking summary:
Pre-tagging started at **01:03/23:03**– sighting 556
Tagging began at **02:06/00:06**
Post-tagging started at **03:16/01:16**

DTAG information

Tag on time: 02:48/00:48
Tag on location: 78º 10.192 N; 12º 19.101 E
Tag off time: 07:36/05:36
Tag recovered time: 07:38/05:38
Tag recovered position: 78º 15.527 N; 12º 13.301 E
VHF frequency: 148.263
System: Cantilever
Operator: Patrick Miller
Images of tagging: NO
Images of tag on animal: YES
Tag position on animal: High on back, anterior to dorsal
Characteristics of animal: smaller of 2 animals
Range: long pole
Comments: No reaction during feeding
Data Recorder on tag boat: Patrick Miller
Sea state: 0
Reaction level: 0
Tagging team members: Patrick Miller (tagger), Leigh Hickmott (driver), Filipa Samarra (photo-id)
On-animal Time: 4h48min
DTAG#: 238
DTAG code version: 2.4
Release fired: NO
Reason for release: -
Programmed released time: 16 h
Skin sample: NO
Audio sampling rate: 96 kHz
Channel: 1 & 2
Gain: 0 & 12 dB
NBITS: 16
Compression: YES (Audio 1,917)

Housing damage/Observations: None

DTAG reported start time: 06.14.2011 02:48:12 (local)
Start chip/block: 1:6
End chip/block: 1:8121
# of chips: 1
On-animal chips: 1
Current tag offset to GPS Time (Tag time-GPS time): Unknown

GPS tag information

Tag #: 29409
Sampling rate: 30s
GPS raw data filename: Obs140611_083847
.pos file ok? YES
Time deployment: 02:48:12 (local)
Detailed picture of GPS tag with DTAG on animal: YES
Comments: simultaneous on same whale with Obs140611_084036

Biopsy sampling

Biopsy sample number: 0332
Tip length: 40 mm Finn Larsen tip
Biopsy system: Finn Larsen gun
Number of misses: Unknown
Reaction level (0-3): 1
Reaction description: Swift reaction, tail slapping
Location on animal: Lateral left
Biopsy time: Unknown
Biopsy location: Unknown
Section of sample: 40 mm sample
Division of sample: ½ skin sample in DMSO; ½ skin sample + blubber
Comments: First biopsy was at 16:43:33/14:43:33 in position 78º 07.45 N; 10º 54.42 E using LKdart but it hit water before and got stuck 60-70% inside animal for about 2h; there are pictures of it stuck on the animal; there were 2 misses before;

KW playback

Playback stimulus name (playback order): Mammal eating killer whale_stim3 (1)
Playback start time: 00:33:00/22:33:00
Playback start position: 77º58.094 N; 10º52.189 E
Playback end time: 00:48:01/22:48:01
Playback end position: 77º58.000 N; 10º52.165 E
Noise stimulus name (playback order): Noise_6 (2)
Noise start time: 01:22:13/23:22:13
Noise start position: 77º57.444 N; 10º39.799 E
Noise end time: 01:37:19/23:37:19
Noise end position: 77º57.351; 10º39.597 E
Playback origin: oo06_181_a (mix of sequences #1, 7 and 9)
Source depth: 8m
Gain setting on hydrophone amplifier: 100 mV
Gain setting on amplifier (for speaker): Gain 1=20; Gain 2=20;
Distance of monitoring hydrophone (from source): 1m
Approximate distance from focal individual: 800 m (estimated)
Playback operator: Charlotte Curé
Crew: Charlotte Curé, Sander v Ijsselmuide, Leigh Hickmott

MOBHUS Acoustic data

Original filename (start time; duration in hh:mm:ss): track 001 (21:46:38/19:46:38; 00:20:06.293), track 002 (23:00:38/21:00:38; 00:15:38.364), track 003 (00:31:33/22:31:33; 00:17:46.261), track 004 (01:16:23/23:16:23; 00:22:49.365)

New filename: VDARRAY_14062011_194638; VDARRAY_14062011_210038; VDARRAY_14062011_223133; VDARRAY_14062011_231623
Sampling rate: 96 kHz
Number channels: 2
Gain setting on recorder: 3.5
Comments: Clipped levels during sonar pings!!!

Deployment: mn11_165b

Date: 14-Jun-2011
Species: Humpback whale (*Megaptera novaeangliae*)
Experiment code: Cee019
Logger sighting number: 557

Tagging attempt, tag on and whale ID pictures

a) b) c)

Photos by Leigh Hickmott (a) and Filipa Samarra (b and c)

DTAG information

Tag on time: 03:02/01:02
Tag on location: 78º 10.200 N; 12º 17.332 E
Tag off time: 07:58/05:58
Tag recovered time: 08:04/06:04
Tag recovered position: 78º 15.725 N; 12º 13.057 E
VHF frequency: 148.863
System: Cantilever
Operator: Patrick Miller
Images of tagging: YES

Images of tag on animal: YES
Tag position on animal:
Characteristics of animal: Smaller of 2 animals, possibly offspring
Range: long pole
Comments: No reaction during feeding; tagged animal had white on leading edge of dorsal
Data Recorder on tag boat: Patrick Miller
Sea state: 0
Reaction level: 0
Tagging team members: Patrick Miller (tagger), Leigh Hickmott (driver), Filipa Samarra (photo-id)
On-animal Time: 4h56min
DTAG#: 241
DTAG code version: 2.4
Release fired: NO
Reason for release: -
Programmed released time: 16 h
Skin sample: NO
Audio sampling rate: 96 kHz
Channel: 1 & 2
Gain: 0 & 12 dB
NBITS: 16
Compression: YES (Audio 1,959)
Housing damage/Observations: None

DTAG reported start time: 14.06.2011 03:02:07 (local)
Start chip/block: 1:6
End chip/block: 1:7665
# of chips: 1
On-animal chips: 1
Current tag offset to GPS Time (Tag time-GPS time): Unknown

GPS tag information

Tag #: 29420
Sampling rate: 30s
GPS raw data filename: Obs140611_084036
.pos file ok? YES
Time deployment: 03:02/01:02
Detailed picture of GPS tag with DTAG on animal: YES
Comments: simultaneous on same whale with Obs140611_083847, low on animal

Deployment: mn11_165c

Date: 14-Jun-2011
Species: Humpback whale (*Megaptera novaeangliae*)
Experiment code: Cee019
Logger sighting number: 559 (when tag mn158c is on) and 561 (when tag mn158e is on)

This animal has deployments mn165c and mn165e

Tagging attempt, tag on and whale ID pictures

Photos by Lars Kleivane

No data on DTAG!!!

DTAG information

Tag on time: 12:58/10:58 (camera time)
Tag on location: 78º 06.152 N; 12º 58.644
Tag off time: 13:41
Tag recovered time: 13:55/11:55
Tag recovered position: recovery location was not recorded
VHF frequency: 148.863
System: Cantilever
Operator: Patrick Miller
Images of tagging: YES
Images of tag on animal: YES
Tag position on animal: High on back, anterior to dorsal
Characteristics of animal: Larger of 2 animals, possibly mother
Range: long pole
Comments: animal moved away after tagging
Data Recorder on tag boat: Patrick Miller
Sea state: 0
Reaction level: 1
Tagging team members: Patrick Miller (tagger), Lars Kleivane (photo-id) and Leigh Hickmott (driver)
On-animal Time: Unknown
DTAG#: 241
DTAG code version: 2.4
Release fired: YES
Reason for release: Burned the release
Programmed released time: 16 h
Skin sample: NO
Audio sampling rate: 96 kHz
Channel: 1 & 2
Gain: 0 & 12 dB
NBITS: 16
Compression: NA
Housing damage/Observations: The tag had burned the release wires, just a few hours into the deployment, but was still blinking double green when retrieved

DTAG reported start time: NA
Start chip/block: NA
End chip/block: NA
# of chips: NA
On-animal chips: NA
Current tag offset to GPS Time (Tag time-GPS time): NA

GPS tag information

Tag #: 29420
Sampling rate: 30s
GPS raw data filename: Obs140611_150046
.pos file ok? YES
Time deployment: 12:57:00/10:57:00
Detailed picture of GPS tag with DTAG on animal: YES
Comments: Good placement, high on back but no DTAG data because DTAG failed

Biopsy sampling

Biopsy sample number: 0232
Tip length: 100 mm Finn Larsen tip
Biopsy system: ARTS/LKdart
Number of misses: 0

Reaction level (0-3): 0
Reaction description: No reaction
Location on animal: Lateral left below dorsal
Biopsy time: 16:10:33/14:10:33
Biopsy location: 78º 05.66 N; 10º 48.66 E
Section of sample: 100 mm sample
Division of sample: ½ skin sample in DMSO; ½ skin sample + blubber
Comments: None

Deployment: mn11_165d

Date: 14-Jun-2011
Species: Humpback whale (*Megaptera novaeangliae*)
Experiment code: Cee019
Logger sighting number: 559

Tagging attempt, tag on and whale ID pictures

a)

b)

c) 

Photos by Leigh Hickmott (a) and Lars Kleivane (b and c)

DTAG information

Tag on time: 13:18/11:18
Tag on location: 78º 05.893 N; 12º 15.534 E
Tag off time: 07:07/05:07 (15-Jun-2011)
Tag recovered time: 18:49/16:49 (16-Jun-2011)
Tag recovered position: 78º 03.360 N; 11º 40.730 E
VHF frequency: 148.952
System: Cantilever
Operator: Patrick Miller
Images of tagging: YES
Images of tag on animal: YES
Tag position on animal: Very low on right rear side
Characteristics of animal: Smaller of 2 animals, possibly offspring
Range: long pole
Comments: None
Data Recorder on tag boat: Patrick Miller
Sea state: 0
Reaction level: -
Tagging team members: Patrick Miller (tagger), Lars Kleivane (photo-id) and Leigh Hickmott (driver)
On-animal Time: 17h49min
DTAG#: 242
DTAG code version: 2.4
Release fired: YES
Reason for release: release wire burned
Programmed released time: 16h
Skin sample: NO
Audio sampling rate: 96 kHz
Channel: 1 & 2
Gain: 0 & 12 dB
NBITS: 16
Compression: YES (Audio 1,946)
Housing damage/Observations: The VHF beacon failed shortly after deployment; the wires from the battery on the VHF were sticking out of the epoxy and made the battery die when in contact with saltwater.

DTAG reported start time: 14.06.2011 13:18:25 (local)
Start chip/block: 1:6
End chip/block: 3:7061
# of chips: 3
On-animal chips: 3
Current tag offset to GPS Time (Tag time-GPS time): Unknown

Deployment: mn11_165e

Date: 14-Jun-2011
Species: Humpback whale (*Megaptera novaeangliae*)
Experiment code: Cee019
Logger sighting number: 561

Tagging attempt, tag on and whale ID pictures

Photos by Lars Kleivane

DTAG information

Tag on time: 15:40/13:40
Tag on location: 78º 05.012 N; 11º 05.070 E
Tag off time: 04:41/02:41 (15-Jun-2011)
Tag recovered time: 05:33/03:33 (15-Jun-2011)
Tag recovered position: 78º 12.379 N; 10º 89.707 E
VHF frequency: 148.263
System: Cantilever
Operator: Patrick Miller
Images of tagging: NO
Images of tag on animal: YES
Tag position on animal: High on dorsal – hit back
Characteristics of animal: Larger of two animals (possibly mother)
Range: long pole

Comments: High on dorsal, good stick
Data Recorder on tag boat: Patrick Miller
Sea state: 0
Reaction level: 0
Tagging team members: Patrick Miller (tagger), Leigh Hickmott (driver) and Filipa Samarra (photo-id)
On-animal Time: 13h01min
DTAG#: 238
DTAG code version: 2.4
Release fired: NO
Reason for release: -
Programmed released time: 16 h
Skin sample: NO
Audio sampling rate: 96 kHz
Channel: 1 & 2
Gain: 0 & 12 dB
NBITS: 16
Compression: YES (Audio 1,952)
Housing damage/Observations: None

DTAG reported start time: 06.14.2011 15:40:20 (local)
Start chip/block: 1:6
End chip/block: 13:2884
# of chips: 3
On-animal chips: 3
Current tag offset to GPS Time (Tag time-GPS time): Unknown

GPS tag information

Tag #: 29409
Sampling rate: 30s
GPS raw data filename: Obs150611_060432
.pos file ok? YES
Time deployment: 15:40:20/13:40:20
Detailed picture of GPS tag with DTAG on animal: YES
Comments: High on dorsal, slid at breach to worse position

Deployment: mn11_165f

Date: 14-Jun-2011
Species: Humpback whale (*Megaptera novaeangliae*)
Experiment code: Cee019
Logger sighting number: 559

Tagging attempt, tag on and whale ID pictures

Photos by Lars Kleivane, Filipa Samarra and Lars Kleivane (from top to bottom)

DTAG information

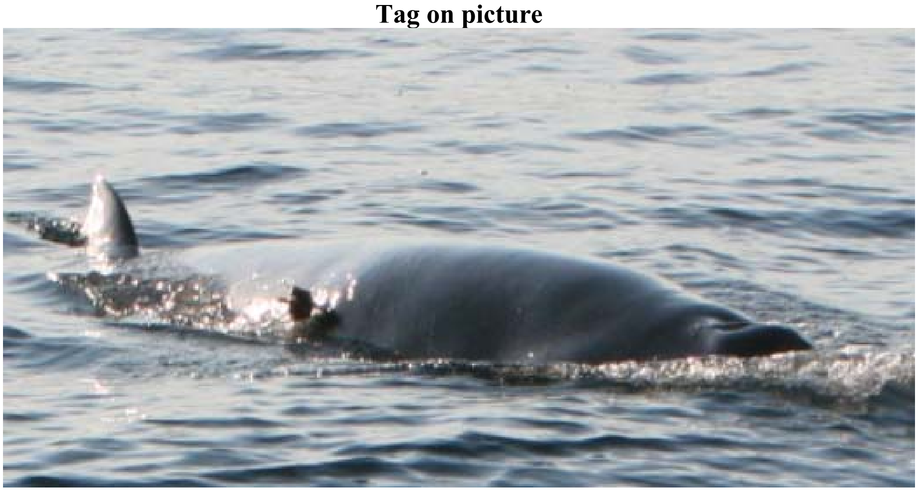
Tag on time: 16:00/14:00
Tag on location: 78º 05.040 N; 11º 48.680 E
Tag off time: 08:32/06:32 (15-Jun-2011)
Tag recovered time: 08:59/06:59 (15-Jun-2011)
Tag recovered position: 78º 03.219 N; 11º 48.249 E
VHF frequency: 148.203
System: Cantilever
Operator: Patrick Miller
Images of tagging: YES
Images of tag on animal: YES
Tag position on animal: High on back, good stick
Characteristics of animal: Smaller of two animals (possibly offspring)
Range: long pole
Comments: None
Data Recorder on tag boat: Patrick Miller
Sea state: 0
Reaction level: 0
Tagging team members: Patrick Miller (tagger), Leigh Hickmott (driver) and Filipa Samarra (photo-id)
On-animal Time: 16h32min
DTAG#: 235
DTAG code version: 2.4
Release fired: YES
Reason for release: release wires burned
Programmed released time: 16 h
Skin sample: NO
Audio sampling rate: 96 kHz
Channel: 1 & 2
Gain: 0 & 12 dB
NBITS: 16
Compression: YES (Audio 1,921)
Housing damage/Observations: None

DTAG reported start time: 06.14.2011 15:59:51 (local)
Start chip/block: 1:6
End chip/block: 3:7651
# of chips: 3
On-animal chips: 3
Current tag offset to GPS Time (Tag time-GPS time): Unknown

Deployment: ba11_170a

Date: 19-Jun-2011
Species: Minke whale (*Balaenoptera acutorostrata*)
Experiment code: Cee029
Logger sighting number: 672

Tag on picture



Photos by Patrick Miller

Description of events:
15:04/13:04 – both tag boats launched; start tagging;
15:33/13:33 - TAG ON
16:03/14:03 – Start of post-tagging (but tag boats were still in the water trying to establish VHF tracking)
20:19/18:19 – Start tracking focal animal from MOBHUS
01:52/23:52 – Start of SILENT DOSE-ESCALATION (3S-2011_TNO_Final/Socrates Logs/20110619_2349_locator_cee029_rampup_shallowwater_exp1/transmission.log)
02:02/00:02 – End of SILENT DOSE-ESCALATION RAMP-UP
02:33/00:33 – End of SILENT DOSE-ESCALATION
03:57/01:57 – Start track 005 in VD array;
04:20/02:20 – Start of DOSE-ESCALATION RAMP-UP (3S-2011_TNO_Final/Socrates Logs/20110620_0216_locator_cee029_rampup_shallowwater_exp2/transmission.log)
04:30/02:30 – DOSE-ESCALATION FULL POWER
05:30/03:30 – End of DOSE-ESCALATION
08:08/06:08 – Start of track 006 in VD array
08:13/06:13 – Start of noise control KW playback;
08:28/06:28 – End of noise control KW playback;
10:37/08:37 – TAG OFF

10:44/08:44 – Tag recovery
10:44/08:44 – End of tracking;

Visual tracking summary:
No Pre-tagging
Tagging started at **15:04/13:04**
Post-tagging started at **16:03/14:03** but both tag boats were still in the water to establish VHF tracking

Ctag information

Tag on time: 13:33/11:33
Tag on location: 78º 04.858 N; 10º27.994 E
Tag off time: 10:37/08:37
Tag recovered time: 10:44/08:44
Tag recovered position: 77.83828 – 10.23535
VHF frequency: 148.606 (NB: tag frequency drift, probably 148.6055)
System: ARTS – LK carrier
Data logger: Star Oddi DTS magnetic (9J0477)
Operator: Lars Kleivane
Images of tagging: YES
Images of tag on animal: YES
Tag position on animal: High on back, anterior to dorsal closer to flipper
Characteristics of animal: Small Minke whale
Depth sensor sampling rate: 4 s
Movement sensor sampling rate: 4 s
Range: 7-8 m
Comments: no reaction to hit but moved away at moderate/high speed after tagging;
Sea state: 1
Reaction level: 1
Tagging team members: Rune Hansen (photo-id), Thomas Sivertsen (driver) and Lars Kleivane (tagger)
On-animal Time: ~19h
CTAG#: 2010 sensor package DTS magnetic, VHF (ATS MM110)
Release: GTR (A1) 24h (-2 to +4°C)
Reason for release: active GTR
Estimated release time: 16-22 hrs from deployment
Comment: weight balance broken, resulted in antenna pointing down after release

KW playback

Playback stimulus name (playback order): -
Playback start time: -
Playback start position: -
Playback end time: -
Playback end position: -
Noise stimulus name (playback order): Noise_7 (1)
Noise start time: 08:13:20/06:13:20
Noise start position: 77º45.939 N; 10º38.150 E
Noise end time: 08:28:03/06:28:03
Noise end position: 77º45.734 N; 10º38.323 E
Playback origin: -
Source depth: 8m
Gain setting on hydrophone amplifier: 100 mV
Gain setting on amplifier (for speaker): Gain 1=20; Gain 2=20;
Distance of monitoring hydrophone (from source): 1m
Approximate distance from focal individual: 800 m (estimated)
Playback operator: Charlotte Curé

Crew: Charlotte Curé, Leigh Hickmott
MOBHUS Acoustic data
Original filename (start time; duration in hh:mm:ss): track 005 (03:57:25/01:57:25; 01:38:08.074); track 006 (08:08:39/06:08:39; 00:38:50.240); **New filename:** VDARRAY_20062011_015725; VDARRAY_20062011_060839; **Sampling rate:** 96 kHz **Number channels:** 2 **Gain setting on recorder:** 1 (in VDARRAY_20062011_015725); 3.5 (in VDARRAY_20062011_060839) **Comments:** None

Deployment: mn11_175a

Date: 24-Jun-2011
Species: Humpback whale (*Megaptera novaeangliae*)
Experiment code: Cee038
Logger sighting number: 752

Tagging attempt, tag on and whale ID pictures

Photos by Lars Kleivane

Description of events:

06:14/04:14 – Visual detection from HUS (sighting number 746)
06:14/04:14 – Start pre-tagging;
07:22/05:22 – Tag boat launched; Start tagging;
09:50/07:50 – TAG ON (tag mn175a VHF 148.263; sighting number is 752);
10:54/08:54 – tag boat returns; start post-tagging;
12:02/10:02 – MOBHUS launched;
12:20/10:20 – MOBHUS takes over tracking;
12:50/10:50 – Fecal sample collected;
15:08/13:08 – Tag boat 1 launched for crew change;
15:21/13:21 – Tag boat 1 returns from crew change;
16:45/14:45 – TAG OFF (tag mn175a)
16:48/14:48 – tag recovery (tag mn175a);
17:33/15:33 – End tracking from MOBHUS;
18:33/16:33 – HUS takes over tracking;
00:14/22:14 – TAG ON (tag mn176a VHF 148.863; sighting number 759 – this is the same animal as 752)
00:37/22:37 - TAG ON (tag mn176b VHF 148.203; sighting number 759 – this is the same animal as 752)
00:56/22:56 – tag boat 1 returns;
02:03/00:03 – MOBHUS launched;
02:22/00:22 – MOBHUS takes over tracking;
03:44/01:44 – TAG OFF (tag mn176a)
03:46/01:46 – tag recovery (tag mn176a);
05:17/03:17 – TAG OFF (tag mn176b)
05:23/03:23 – Start of SILENT RAMP-UP (3S-2011_TNO_Final/Socrates Logs/20110625_0322_locator_cee038_rampup_exp1/transmission.log)
05:32/03:32 – Tag recovery (tag mn176b);
05:33/03:33 – End of SILENT RAMP-UP;
05:46/03:46 – End of tracking from MOBHUS;

Visual tracking summary:
Pre-tagging started at **06:14/04:14**
Tagging started at **07:22/05:22**
Post-tagging started at **10:54/08:54**

DTAG information

Tag on time: 09:50/07:50
Tag on location: 77º 33.947 N; 11º 31.241 E
Tag off time: 16:45/14:45
Tag recovered time: 16:48/14:48
Tag recovered position: 77º 42.3660 N; 11º 44.6106 E
VHF frequency: 148.263
System: Cantilever
Operator: Patrick Miller
Images of tagging: YES
Images of tag on animal: YES
Tag position on animal: On left side, forward of dorsal
Characteristics of animal: large animal
Range: long pole
Comments: Flinch and arch out, seemed to respond to follow-up approach
Data Recorder on tag boat: Patrick Miller
Sea state: 3 – confused seas
Reaction level: 1
Tagging team members: Patrick Miller (tagger), Leigh Hickmott (driver), Lars Kleivane (photo-id)
On-animal Time: 6h55min
DTAG#: 238
DTAG code version: 2.4
Release fired: NO
Reason for release: High acceleration
Programmed released time: 16 h
Skin sample: NO
Audio sampling rate: 96 kHz
Channel: 1 & 2
Gain: 0 & 0 dB
NBITS: 16
Compression: YES (Audio 2,035)
Housing damage/Observations: None

DTAG reported start time: 06.24.2011 09:50:05 (local)
Start chip/block: 1:6
End chip/block: 2:2138
# of chips: 2
On-animal chips: 2
Current tag offset to GPS Time (Tag time-GPS time): -1 seconds

GPS tag information

Tag #: 29420
Sampling rate: 30s
GPS raw data filename: Obs240611_174411
.pos file ok? YES
Time deployment: 09:50/07:50
Detailed picture of GPS tag with DTAG on animal: YES
Comments: None

Deployment: mn11_176a

Date: 25-Jun-2011
Species: Humpback whale (*Megaptera novaeangliae*)
Experiment code: Cee038
Logger sighting number: 759

Description of events for this deployment is in mn11_175a!!!

Tagging attempt, tag on and whale ID pictures

Photos by Frans-Peter Lam

DTAG information

Tag on time: 00:14/22:14 (24-June-2011)
Tag on location: 77º 33.284 N; 11º 59.92 E
Tag off time: 03:41/01:41
Tag recovered time: 03:46/01:36
Tag recovered position: 77º 33.8574 N; 12º 49.2426 E
VHF frequency: 148.863
System: Cantilever with 2 DTAGs
Operator: Patrick Miller
Images of tagging: NO

Images of tag on animal: YES
Tag position on animal: Low on left side under dorsal
Characteristics of animal: large animal
Range: long pole
Comments: New robot rig with two DTAGs
Data Recorder on tag boat: Patrick Miller
Sea state: 1
Reaction level: 0
Tagging team members: Patrick Miller (tagger), Leigh Hickmott (driver), Frans-Peter Lam (photo-id)
On-animal Time: 3h27min
DTAG#: 242
DTAG code version: 2.4
Release fired: NO
Reason for release: Possibly loosened by high acceleration
Programmed released time: 16 h
Skin sample: NO
Audio sampling rate: 96 kHz
Channel: 1 & 2
Gain: 0 & 0 dB
NBITS: 16
Compression: YES (Audio 2,226)
Housing damage/Observations: None

DTAG reported start time: 06.25.2011 00:14:45 (local)
Start chip/block: 1:6
End chip/block: 1:6958
# of chips: 1
On-animal chips: 1
Current tag offset to GPS Time (Tag time-GPS time): Unknown

GPS tag information

Tag #: 29409
Sampling rate: 30s
GPS raw data filename: Obs250611_060147
.pos file ok? NO
Time deployment: 00:14/22:14
Detailed picture of GPS tag with DTAG on animal: YES
Comments: needs to be processed

Deployment: mn11_176b

Date: 25-Jun-2011
Species: Humpback whale (*Megaptera novaeangliae*)
Experiment code: Cee038
Logger sighting number: 759

Tagging attempt, tag on and whale ID pictures

Photos by Frans-Peter Lam (top) and Leigh Hickmott (bottom)

DTAG information

Tag on time: 00:36/22:36 (24-Jun-2011)
Tag on location: 77º 33.455 N; 12º 03.294 E
Tag off time: 05:17/03:17
Tag recovered time: 05:32/03:32
Tag recovered position: 77º 34.482 N; 12º 48.398 E
VHF frequency: 148.203
System: Cantilever with 2 DTAGs on one pole
Operator: Patrick Miller
Images of tagging: YES
Images of tag on animal: YES
Tag position on animal: Right side of body under the dorsal
Characteristics of animal: large animal
Range: long pole
Comments: New robot rig with two DTAGs
Data Recorder on tag boat: Patrick Miller
Sea state: 1
Reaction level: 0
Tagging team members: Patrick Miller (tagger), Leigh Hickmott (driver), Frans-Peter Lam (photo-id)
On-animal Time: 4h41min
DTAG#: 235
DTAG code version: 2.4
Release fired: NO
Reason for release: High acceleration during a dive
Programmed released time: 16 h
Skin sample: NO
Audio sampling rate: 96 kHz
Channel: 1 & 2
Gain: 0 & 12 dB
NBITS: 16
Compression: YES (Audio 1,902)
Housing damage/Observations: None

DTAG reported start time: 06.25.2011 00:36:11 (local)
Start chip/block: 1:6
End chip/block: 1:8118
# of chips: 1
On-animal chips: 1
Current tag offset to GPS Time (Tag time-GPS time): Unknown

Appendix D Group behaviour sampling protocol for behavioural response studies

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D.1 Protocol scope and objective

This behaviour sampling protocol was designed to provide a generic and quantitative sampling method for the study of cetacean social behaviour, allowing for comparison of data across species, studies and areas. The protocol focuses on the group as the level of observation. It was designed specifically to target cetacean species forming relatively stable, small to medium-sized groups (<30), potentially within larger aggregations. The protocol was developed, tested and used within the 3S project, alongside sampling of behaviour of focal individuals using suction-cup tags and tracking methodology.

D.2 Step 1. Focal group selection

Focal group selection is determined by the presence of a focal individual. The focal individual is selected at the start of the observation. When a tag has been deployed, the focal whale will be the tagged individual. The focal group is structured around the focal whale; it is defined as the selection of individuals most closely associated with the focal whale. Association is defined by the relative distribution of individuals in the vicinity of the focal whale. For example, in figure 1, a group of 5 individuals (including the focal whale) is tracked (left). When, during tracking, the focal group changes its association by forming 2 relatively more closely associated clusters, the focal group size is reduced to the size of the cluster holding the focal individual (top right). If the focal group changes its association by becoming more widely spaced, while maintaining an even distribution between members, focal group size remains unaltered (bottom right).

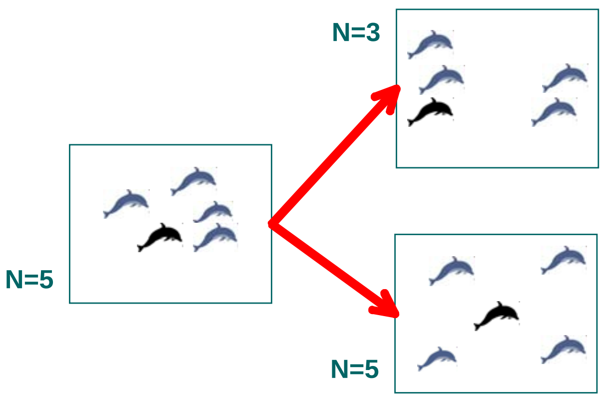


Figure 1. Example of focal group size selection. The focal individual is indicated in black. N gives focal group size.

This definition for the focal group allows for the tracking of the same focal whale and its associated individuals throughout the full duration of a focal follow observation. It also facilitates tracking of smaller subgroups within larger aggregations, allowing for fine-resolution sampling of group behaviour parameters. In addition, it provides a definition for a focal group which is comparable between species, behavioural states, areas and studies.

D.3 Step 2. Group behaviour sampling parameters

Sampling takes place at regularly spaced time-intervals (2 minutes). The following group behaviour parameters are sampled at each (re)sighting of the focal group:

A) Geographical location and travel path
- Radial distance: estimated distance to the focal individual
- Estimated angle: angle of sighting to the focal individual
- Aspect: heading/direction of swimming of the focal individual

B) Group size and composition
- Calves presence: record presence / absence of calves in the focal group
- Group size Low – Best – High: record low, best and high estimate of group size
- Nr of subgroups in focal area: record nr of groups within 200m of focal group, including the focal group itself
- Nr of animals in focal area: record nr of individuals within 200m of focal individual, including the focal group itself
- Group spacing: record group spacing of the focal group (categorical parameter);
    - categories:
      GS1 spacing <1 body length (BL)
      GS2 spacing 1-3 BL
      GS3 spacing >3-15 BL
      GS4 spacing >15 BL
      GS6 solitary
- Surfacing synchrony: record the number of individuals surfacing <5 seconds of the focal individual (exclude focal whale in number counted)
- Milling index: record the % of surfacings in the focal group which have a different aspect than the surfacing of the focal individual (no milling = 0%)
- Distance: record the distance to the nearest other group or individual not part of the focal group.
- Line: record if the focal group is lined up
- Display events: record presence of observed events
- Birds associated: record whether birds are associated
- Other sp. ass: record whether other cetacean species are associated
- Comments: record behavioural state; any valuable comment

Appendix E 3S-11 Cruise plan

3S-2011
Cruise Plan

The 3S-11 research trial is conducted by the 3S-consortium as part of the 3S^2-project

CONTENT

PROJECT OBJECTIVE

Investigate behavioral responses of cetaceans to naval sonar signals, including studies of the effectiveness of Ramp Up, sensitization or habituation, in order to establish mitigation measures for sonar operations.

CRUISE TASKS

Primary tasks:

1. Tag minke whales and northern bottlenose whales with DTAG and record vocal-, movement- and surface behavior, and thereafter carry out sonar dose escalation experiments (SDE) where the tagged animals are exposed to LFAS sonar signals and control experiment without any active transmissions.
2. Tag humpback whales with DTAGs and record vocal -, movement- and surface behavior, and thereafter carry out sonar Ramp UP experiments where the tagged animals are exposed to LFAS sonar signals and control experiment.

   The three main target species (Northern Bottlenose whales, Minke whales and Humpback whales) all have equal priority at the start of the trial. Prioritization will be reassessed during the trial, as we make progress (or not).

Secondary tasks:

3. Tag animals and record natural undisturbed behavior of target species
4. Carry out control experiments were tagged animals are exposed to a playback of killer whale sounds and a reference sound (broad band noise)
5. Collect group behavioral data to investigate the effect of tagging
6. Retrieve information about the acoustic environment of the study area by CTD or XBT measurements, and do acoustic propagation modeling
7. Carry out pilot tagging (dtag) and collect baseline data on possible new species (fin whales, blue whales, bowheads) to be added to the target species list of coming exposure trials.
8. "Tag" dolphins with paint ball coloration and establish procedure for data collection with the aim to add dolphins to the target list for coming sonar exposure trials.
9. Test the use of the next generation DTAGs (DTAG3) on our target species including ARTS-launching it on to the animals.
10. Use of other tags to support data collection (GPS tags, CTAG, speed sensor tag, sponge tag)
11. Biopsy sampling of target species.
12. Collection of bio-acoustic data using towed arrays

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

COLLABORATING ORGANIZATIONS

The main partners of the $3S^2$-project conducting the 3S-11 trial are:

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

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

- Institute of Marine Research (IMR), Norway
- LK-ARTS, Norway
- Kelp Marine Research (KelpMR), The Netherlands

The $3S^2$ 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>June</u>

01. 08:00 - Embarkment of scientific crew on RV HU Sverdrup II (HUS) in Port Breivika, Tromsø. Technical installation of equipment commences.
14:00 - Brief of ship's crew
16:00 - Brief of scientific crew
19:00 - Joint dinner in town.

02. 08:00 - Continued installation and testing of equipment. Please observe that this is a bank holiday in Norway and all stores are closed.
14:00 - Transit to Malangen (2hrs) for engineer tests and drill of operation. Transit back to Tromsø at night.

03. 08:00 - Final preparations. If no more preparations are needed, we could leave 08:00.
14:00 - Departure Tromsø. Safety brief. Transit through Malangen towards operation area. Final drill and tests.
20:00 - Fully operational upon passage of Hekkingen. Regular watch plan implemented.

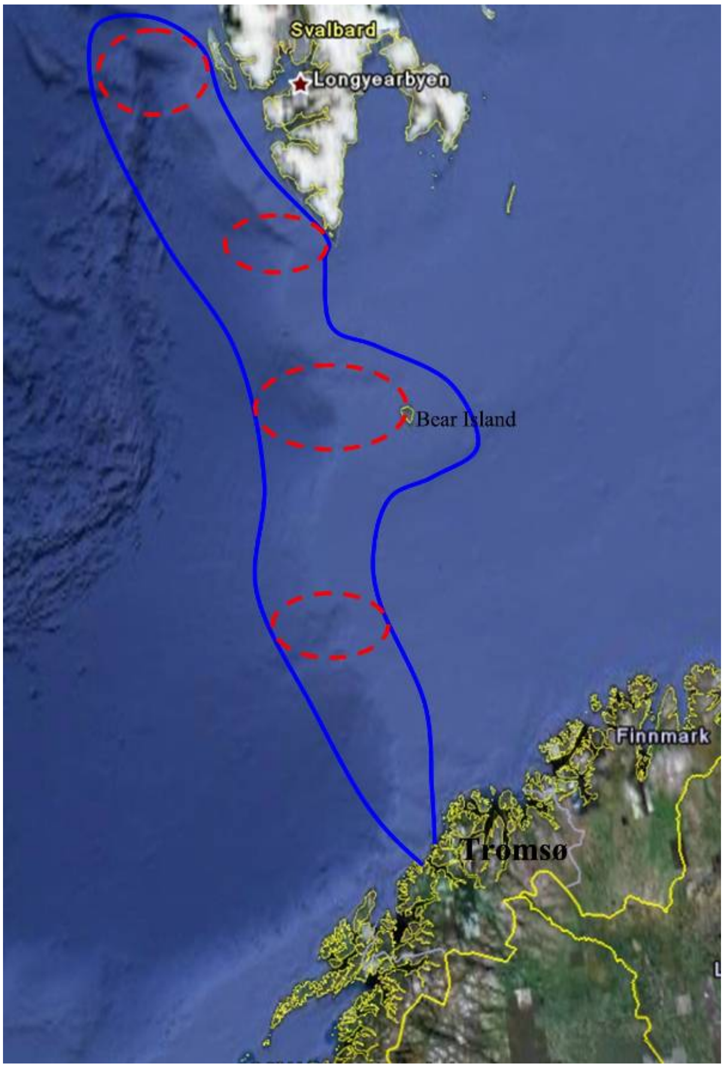
04-28. Regular 3S-operation, no scheduled port calls.

29. Transit to Tromsø, cruise report and packing, arrival at 16:00. De-installation, de-brief and celebration. Change of the ship's crew.

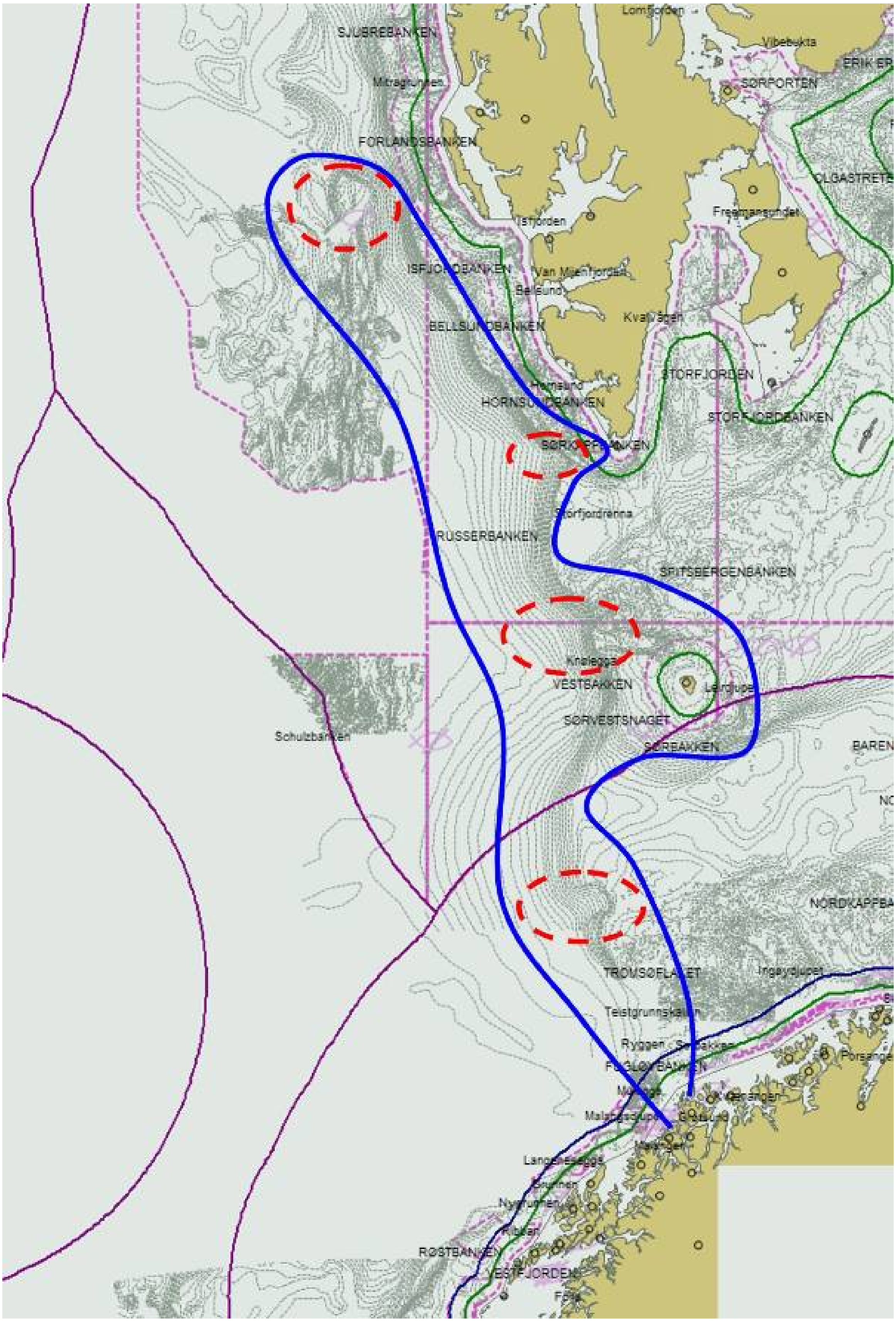
30. Off loading and dissembarkment.

OPERATION AREA

The operation area and period is determined based on a thorough analysis of availability of target animals and weather condition (FFI 2011B). Our operation area will be in open ocean primarily along the continental shelf break between Tromsø and Svaldbard (70°N_18°E - 79°N_10°E). The distance from the southern to the northern part of this area is 600 nmi, and thus we are not going to cover all part of the area equally thorough. Based on historical sightings, catch statistics and knowledge of habitat preference of our target species, four sub-areas are determined which will be surveyed particularly careful. These areas are all characterized by steep underwater canyons, which tend to attract the Northern Bottlenose whale, but where we also expect to find the other target species. We might occasionally leave the shelf break and search further east upon the shelf, where Humpbacks and Minke whales might be found in large numbers, especially around Bear Island. However, due to operational restrictions of the Socrates system we cannot operate in waters shallower than 200-300m. The weather in this area is quite stable in the summer, and statistically we will have 15-25 days of working conditions. Decision on where within the operation area we will be at any given time, will depend on weather, and reports of marine mammals sightings.



Overall operation area along the shelf break (in blue), and the areas within it which will be surveyed particularly thorough (in red). From south to north these are entitled, Guillemot Canyon (Teistskallan), The Humpback Ridge (Knølegga), The South Cape Ridge (Sørkappegga) and the Svalbard Hole. Detailed map below.



Detailed map of operation area.

MAIN LOGISTICAL COMPONENTS

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

Length: 180 feet
Max speed 13 knots
Crew: 7
Scientific crew: 17
Phone: +47 95138992 (Cruise leader)

Captain**;** Jonny Remøy.
First officer**;** Terje.
Chief engineer; Erling
Matros; Henning.
Matros; Jon.
Steward**;** Bernt.
Catering assistant**;** Liv

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

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

Tagging boats

Two tag boats can be deployed from HUS. Tag boat 1 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. In the tagging phase they will carry tagging gear (ARTS, pole, tags with necessary accessories), documentation sheets, GPS, camera and communication gear (VHF). The tag team will usually consist of three people; a driver, a tagger and someone in charge of photo id/documentation.

Tag boat 1 will primarily be used for hand pole and long pole tagging. It will therefore be equipped with a cantilever swivel in the bow. Tag boat two will primarily be used for ARTS-tagging, and are therefore equipped with an elevated platform in the bow.

Tag boat two will also be used in the tracking phase. It will therefore be outfitted with an observation platform in the aft with space for two observers. It will also be equipped with VHF-tracking antennas and DDF receiver in addition to compass, binoculars, range finders and a data recording systems which consist of a fully ruggedized laptop running the Logger software. It will also be towing a small acoustic array (the VD-array of SMRU) which records the sonar levels and vocal activity close to the tracking boat. During tracking the crew will consist of 4 people, a driver, a data recorder and two marine mammal observers.

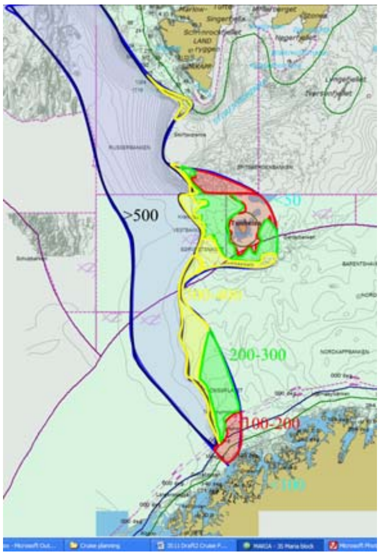
Tag boat 1 (left) and Tag boat 2 (right). The lifting arrangement on Tag boat 1 will be modified to enable us to pick it up with the David crane. Tag boat 2 will be modified with a 2 person elevated MMO-station behind the driver.

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 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 (TNO 2011A). During towing of Socrates the ship can turn once at a rate of 15deg pr. min (TNO 2011A).

Because of risk of cavitation and damage to the source, it must stay below cavitation depth during operation. Cavitation depth depends on the transmitted source level and on sonar frequency. It drops from 100m at 1000 Hz to only 60 m at 1300 Hz, when the source is operated at full power (214 dB). Tow depth will depend on the speed of the ship, and is regulated by changing the cable scope (TNO 2011A). According to operational restrictions for the SOCRATES system (TNO 2011A), a critical water depth is specified for different configurations of the system (transmitted frequency band, source level and cable scope). In order to maintain the operational relevance of our experiments and to expose the fast swimming targets species whales in accordance with our protocol, we have to maintain full source level and a speed of at least 8 kts. The full band LFAS (1-2 kHz) pulse at 214 dB source level and 8 kts speed gives a critical water depth of 280m. This implies that the entire area on the continental shelf is too shallow (see figure below). This is not a problem when working with beaked whales, which are found in deeper water anyway, but becomes an unacceptable limitation for the work on baleen whales, which could very well appear in shallower water on the shelf. A shallow water pulse having a reduced bandwidth (1.3-2.0 kHz) is therefore specified. It has a critical water depth of only 180m @ 214 dB and 8 kts. To be able to compare the experiments on the deep diving northern bottlenose whales with the previous 3S-experiments on the deep diving sperm whales, we will stick with the full band LFAS pulse during sonar exposures of northern bottlenose whales. However, during exposures of the shallow water baleen whales (minke whales and humpback whales), we will use the reduced bandwidth signal.



Depth contours for the operation area. Red area = 100-200m. Green areas = 200-300m, yellow areas = 300-400m, blue areas = >500m. $LFAS_{shallow}$ (1.3-2.0kHz) can be used in all areas except the red area, while $LFAS_{deep}$ (1.0-2.0kHz) can only be used in the yellow and blue areas.

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

During exposure experiment two types of signals will be used, $LFAS_{deep}$ and $LFAS_{shallow}$ as specified in the table.

Prior to full power transmission a ramp up procedure will be used, starting at 152 dB and increasing to full power within 10 min. 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 be used. It will be deployed from the Sverdrup to primarily acoustically search for marine mammals. The Delphinus is a single line array, 74 metres long with an outer diameter of 65 mm. The middle section of the array contains 18 LF hydrophones used for the detection and classification of marine mammal vocalization up to 20 kHz. Three UHF hydrophones with total baseline of 20m are used for the detection, classification and localization of marine mammal vocalizations up to 160 kHz. Additionally there is a single triplet (consisting of 3 UHF hydrophones), which can be used to solve the left-right ambiguity for the localization solution. The array is also equipped with a depth sensor and a combined heading-roll-pitch sensor.

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

Software of Delphinus system includes the (near) real-time display of detected signals and tracking of those detections in a broadband display. Recently, a GIS display has been added to provide the operator with geographical co-ordinates in real-time, aiming to follow detected whales while diving under water.

Delphinus/CAPTAS needs to be deployed before Socrates and Socrates will be recovered out of the water before Delphinus/CAPTAS. When a CTD sensor is used to measure the sound speed profile Socrates, Delphinus and CAPTAS need to be out of the water. More information about sailing and deployment restrictions can be found in (TNO 2011A).

Acoustic array – CAPTAS

During the trial, a second array will also be available. It will also be deployed from the Sverdrup to search for vocalizing baleen whales. However, Delphinus and CAPTAS can not be towed at the same time. The Delphinus array will be used as default during search for target species because it also covers the frequency band of the northern bottlenose whales. The CAPTAS array will however be used during search for animals in shallow areas where we don't expect to find beaked whales, but only the baleen whales which vocalizes within the frequency band covered by this system. During exposure experiments the Delphinus array will be used during experiments on bottlenose whales and the CAPTAS array during experiments with the baleen whales.

The typical feature of the CAPTAS array is that it uses hydrophone triplets in order to obtain direct Port/Starboard discrimination. In a way, it combines three antennas in one hose. The total receiving array consists of:

- 1 Vibration Isolation Module (VIM) of 20 m length
- 1 CAPTAS 20D module of 63 m length with acoustic section of 23 m
- 1 tail rope of 100 m length and a diameter of 12 mm.

The acoustic section consists of 64 equispaced hydrophone triplets spaced at ½λ for the design frequency of 2080 Hz. This results in a triplet spacing of d=360 mm. The triplets are fixed at this distance by a rigid construction. The hydrophones in a triplet are placed on a circle with a diameter of 50 mm and spaced at 120°.

Processing software and displays are not identical, but have similar features. The advantage of the CAPTAS array over the Delphinus array is its longer aperture as used for beamforming, which allows for a better detection and localization of the low frequent baleen whale vocalizations. The disadvantage is its more limited frequency band of 10-2100 Hz compared to the 10-160000 Hz of the Delphinus array. Both arrays come with recording and processing software for the detection, classification and localization of marine mammal vocalizations. More information about sailing and deployment restrictions can be found in TNO 2011A.

Acoustic array - The CODA array

The CODA array will be used as backup if the Delphinus system fails, and possibly also in periods where the Sverdup is used to track animals, because the CODA array does not restrict the ship's maneuverability as much as the Delphinus and Captas arrays. Thus, the CODA array will also be towed off the Sverdrup, but not together with the other systems. The CODA array is 400m long, with two sensor sections at 200m and 400m. The sensor section at 200m contains 2 elements, while the sensor section at 400m contains 3 elements. The system includes a 50m deck cable. The system can be deployed either 1) using the entire length of cable, which is most useful for searching phases and cross beam range determination, or 2) using a much shorter section with only the distant 3 elements in the water. The shorter deployment will restrict the movement of the source vessel less than the full length deployment. Recordings from the array will be made onto a dedicated laptop using PamGuard, which can also run real time detection and angle-of-arrival calculation.

Acoustic array - VD-array

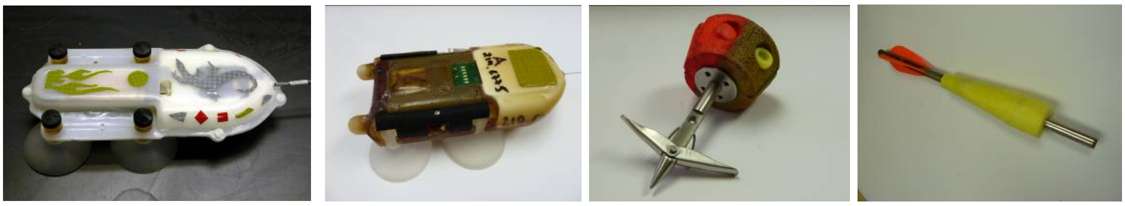
The VD array was built by Volker Deecke (VD) of the Sea Mammal Research Unit. It is composed of a 60m tow cable, with 2 Benthos AQ4 hydrophones separated by 96cm. The array plugs into a rugged, self-standing pelican case which contains a breakout box and a Marantz recorder at 96 kHz. The VD array will be used from the observation boat (tag boat 2 or MOBHUS). It's primary function will be to record sonar transmissions near the tagged whale. However, if memory and battery capacity is sufficient, recordings may be made throughout the observation period.

Directional hydrophone operated from tag boat

To increase the effectiveness of beaked whale tagging, we will try to use a directional hydrophone system ("Pickle") consisting of a plate-shaped baffle with a hydrophone on either side. Each hydrophone will be connected to one channel of a Micro-track recorder, and monitored using headphones. Alternatively, heterodyne-transformed signals will be monitored to bring the high-frequency clicks of beaked whales into the range of human audibility. In combination with directions provided by acoustic team on Sverdrup, the tag boat will use the system to fix the direction of, and subsequently approach, nearby clicking beaked whales so that the tag boat will be close to the animals when they surface.

Whale tag – DTAG2

The version 2 DTAG is the main tool used to record the behavior of the whales. 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 of 16 hrs the vacuum is released from the suction cups and the tag floats to the surface. The tag contains a VHF transmitter used to track the tagged whale during deployment and to retrieve the tag after release. All sensor data are stored on board the tag and the tag therefore has to be retrieved in order to obtain the data. DTAGs record sound at the whale as well as depth, 3-dimensional acceleration, and 3-dimensional magnetometer information. DTAG audio will be sampled at 96 kHz and other sensors at 50 Hz, allowing a fine reconstruction of whale behaviour before, during, and after sonar transmissions.



DTAG2 (left), DTAG3, CTAG and Biopsy needle.

Whale tag - DTAG3

WHOI is developing a new version DTAG, the DTAG3. This tag will be smaller and lighter than DTAG2, and will also have a higher data storing capacity. In the future new sensor such as GPS and heart rate sensors will also be implemented. This tag is still in a developing phase, and we will not use them for the exposure experiments. However, we may try to do some testing with dtag3 dummies, and deployments of them using the ARTS-system.

Whale tag - CTAG

Previous attempts to tag minke whales with suction cups tags has shown that this might be very difficult. It's difficult to get within tagging range, and their skin appears to be very slippery so that the tag falls off. We have therefore developed a small and light invasive tag, to be used as back up if DTAGing turn out to be too difficult. The CTAG (C=sea and C=combined tag) is developed to be deployed using the ARTS system at distances up to 15m. Compared to the DTAG the CTAG contains a simpler set of sensors; a VHF-transmitter, and a Star Oddi DST Magnetic with time depth recorder, 3D magnetic and tilt sensors. It is attached to the whale by a small barb (5 cm long) which penetrates the skin and anchors in the blubber. The tag is released from the animal using a mechanical galvanic time release. The tag does not contain acoustic sensors. The CTAG will therefore be used as an alternative only after initial tagging attempts with DTAGs has failed, and if the conditions or animals make further DTAG approaches unserviceable.

Whale tag - GPS tags

This field season the primary tag, DTAG version 2, does not contain GPS. However, it is expected that the final version of the next generation DTAGs, DTAG 3, will be the primary tag used from the 2012 onwards, and that this tag will have a GPS logger built into it. Thus, the 2011 season will be the only season under the $3S^2$-project without detailed GPS-track of the tagged animals. To compensate for that this year, and to make the total $3S^2$ dataset more consistent, we are attempting to build a separate tag containing a GPS, VHF, and a timer release. The units we will attempt to deploy are SirTrak ZF2G 134A Fastloc 2 devices. This tag will be placed on a robot arm together with the DTAG on the long pole, and both tags will be deployed simultaneously. Alternatively, we will evaluate whether the small GPS device can be attached to the Dtag directly. The humpbacks are the only species suitable for long pole tagging, and thus the double tagging procedure will only be used with this species. Humpbacks are also big enough to presumably not be bothered by the drag of two tags. Accurate positioning of the animal is also considered particularly important during the RampUp experiments with humpbacks.

Whale tag - Dolphin sponge tag

White beaked dolphins are often encountered in large groups in the operation area. As a secondary objective we might decide to do some preliminary attempts to work on this species. Dolphins are difficult to tag, but are on the other hand quite easy to track visually. However, the problem is often to track individual animals within a large group. We will therefore tag, one or two individuals with a colored cream to enable this. The paint will be deployed using the ARTS system, by launching a cork with a sponge on the tip which is soaked with the paint. The current permit does allow for this, but not sonar exposure of dolphins. The idea is just to develop procedures and protocols to possibly expand the scope of the project in coming years.

Whale tag – Speed sensor tag

To gain more information on the energetics of locomotion, biomechanics, and performance of swimming of the target species, we will attempt to deploy some tags that contain speed sensors. The loggers to be used are Little Leonardo 3MPD3GT and PD3GT loggers, which are multi-sensor archival tags that have been designed to continuously record speed and other data including depth, 3-axis accelerations, external temperature and 3-axis magnetometers (3MPD3GT tag only). These tags are small, lightweight, non-invasive tags that are attached to whales with suction cups, and have VHF beacons and release devices that were substantially tested during the 3S-2010 baseline trial. These tags will be deployed on a 'not-to-interfere' with Dtag deployment basis, either as secondary or tertiary tags attached simultaneous to Dtag attachment or at the end of a Dtag follow during biopsy sampling attempts. Minimal tracking is needed for these tags, with fixes only required every 20-30 minutes to aid in tag recovery.

Biopsy sampling

In the end of the experiment, after sonar exposure but before the tag detaches, a biopsy sample will be taken from the experimental animal. A standard Finn Larsen biopsy tip will be used for this. It is a hallow and sharp needle, which samples a small piece of skin and blubber tissue from the back of the animal. The biopsy tip is 8mm in diameter and penetrates 40mm into the blubber. The tissue is used to sex and i.d. the animals, to assure that they have not been exposed before. Tissue samples will be made available for other projects to look at e.g. biochemical composition, presence of environmental pollutions or for genetic analysis. Since the biopsy sample is taken before the tag detaches, we will use the stored data to also look at possible behavioral changes related to the biopsy sampling.

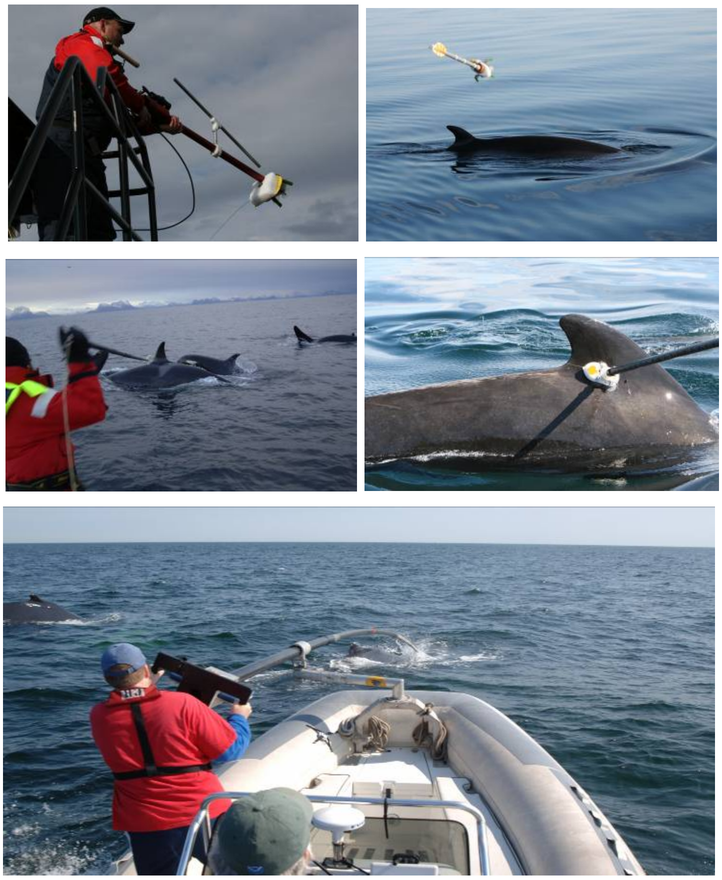
Tag deployments

The tags will be deployed using three different techniques, the ARTS-system, the hand held pole and the long cantilever pole.

The ARTS pneumatic tag launcher launches the tags through the air on to the animals. It was developed to be used with the DTAG during the 3S-project to enable longer tagging ranges and rapid changes of directions. With the new tag carrier developed last year the ARTS-DTAG system is a well tested and fully operational technique. During this trial it will primarily be used to tag minke whales, where tagging distances are expected to be long, and bottlenose whales, which have been reported to respond by escaping when they see the tagging poles. In addition the ARTS system will be used to deploy the CTAGs, the sponge tags and for biopsy sampling.

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 pole is a 7m long carbon fibre windsurfer board mast, with the tag placed on a straight robot arm in one end. The limitation of this system 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. The hand held pole will be used for deployments of DTAGs on bottlenose whales and minke whales.

The cantilever long pole technique is also well established technique used in many previous trials. The pole is 15 m long and placed on a swivel in the bow. Because of the length, the pole it is counterbalanced and placed in a bracket. This technique is most suitable for use on slow moving large animals and will only be used to tag humpbacks with DTAGs and GPS tags.



Deployment of DTAG using the ARTS system (upper panel), the hand held pole (middle panel) and the cantilever pole (lower panel). When deploying the tag with the ARTS the tagger shoots from the elevated platform in the bow of tag boat 2. The pole techniques will primarily be used from tag boat 1.

Tracking and data collection

To visually search for animals in the search phase, and to observe the behavior of the animals during tagging and tracking, a marine mammal observer platform will be installed on the roof of the bridge of Sverdrup. This platform will be equipped with two baby big eyes, a wind shield, binoculars, protractor, intercom to the bridge, a ruggedized computer running Logger and a VHF digital direction finder system.

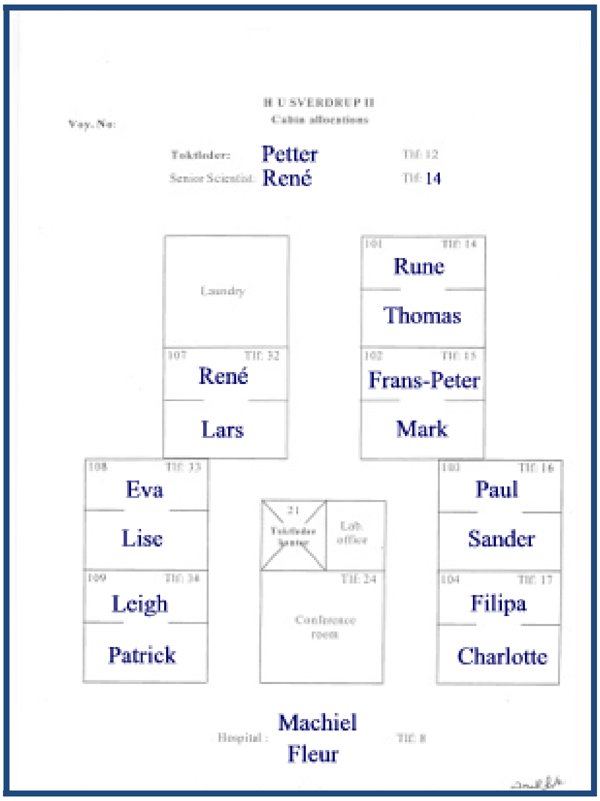
On tag boat 2 there will be a small elevated station for two observers, and space for a data recorder beneath them. This platform will be equipped with intercom between the observers and the data recorder, binoculars, laser range finders, compass, protractor, VHF direction finder, and a fully ruggedized computer running Logger. The Logger software is used on both Sverdup and on tag boat 2 to record the position of the animals and social behavior based on the input of the marine mammal observers. As a back-up system for data collection the IMR voice recorder or paper notes will also be used.

Detailed instruction for the marine mammal observers are found in the 3S-Observer Handbook (SMRU & KelpMR 2011).

CREW PLAN

There will be no scheduled crew changes during the trial. The total number of scientific crew is 17 people:

Name	Main role	Secondary roles	Affiliation	Nationality
Petter Kvadsheim	Executive chief scientist (CO)	MMO	FFI	NOR
René Dekeling	Executive scientist (XO)	Sonar/MMO	RNLN	NL
Patrick Milller	Principle investigator	Tagger, MMO	SMRU	US
Frans-Peter Lam	Chief scientist sonar	MMO	TNO	NL
Mark van Spellen	Sonar operator	Hardware engineer	TNO	NL
Sander van IJsselmuide	Sonar operator	Software engineer	TNO	NL
Lars Kleivane	Tagger	Tag boat driver/MMO	FFI/LKARTS	NOR
Leigh Hickmott	Tag boat driver	Tag technician/MMO	SMRU	UK
Thomas Sivertsen	Tag boat driver	MMO	FFI	NOR
Eva Hartvik	Tag technician	MMO HUS	WHOI/SMRU	DAN
Lise Doksæter	Lead MMO HUS	tag technician/data manag	IMR	NOR
Fleur Visser	Lead MMO MOBHUS	data management	KelpMR	NL
Rune Roland Hansen	MMO	Photo id./data manag	FFI	NOR
Machiel Oudejans	MMO	data management	SMRU	NL
Filipa Samarra	Lead MMO MOBHUS	Photo id./data manag	SMRU	Portuguese
Paul Wensveen	MMO/Sonar	Data management	SMRU	NL
Charlotte Curé	MMO	Killer whale playback	SMRU	French



Cabin plan

Responsibilities:

FFI

Personnel: Cruise leadership, marine mammal observers, local knowledge, oceanographic measurements, tag-boat drivers, ARTS tagging.

Equipment: Research vessels with crew, 2 tag boats, gas for tag boats, 2 CTD's, 2 VHF-tracking system with antennas and cables, power supply for tag boat, digital video camera, CTAGs, 2 ARTS-canons, ARTS-DTAG carriers and robots, VHF-communication equipment. Moving Vessel Profiler, ruggedized computer, rifles.

SMRU

Personnel: PI, DTAG-technician, pole tagger, marine mammal observers, photo id/documentation, acoustic recordings.

Equipment: VD-array, coda array, digital cameras, VHF receiver (148-150 MHz), VHF cables, hand-held GPS, killer whale playback equipment, Logger software for two platforms, tracking equipment (laser range finders, compass, protractor etc), hand held tagging poles, cantilever tagging poles.

WHOI

Personnel: Tag boat driver

Equipment: 3 LF DTAG2s + 3 HF DTAG2s, DTAG accessories, cantilever handle and yard arm, 2 DTAG robots straight, 2 DTAG robots 90º, VHF receiver and ADF and DDF, 2 baby big eyes.

TNO

Personnel: Software and hardware operators and technicians for Socrates, Delphinus and Captas, marine mammal observer.

Equipment: Socrates, Delphinus, Captas array, XBTs, Ruggedized computer, Radio data link.

KelpMR

Personnel: Marine mammal observer

Equipment: Ruggedized computer

IMR

Personnel: Marine mammal observer

Equipment: Voice recorder

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 different platforms (Sverdrup, Tag boat 1 and Tag boat 2), depending on which phase of the operation we are in. The operation goes through different phases which requires very different staffing from the different teams. The main 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 does 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.

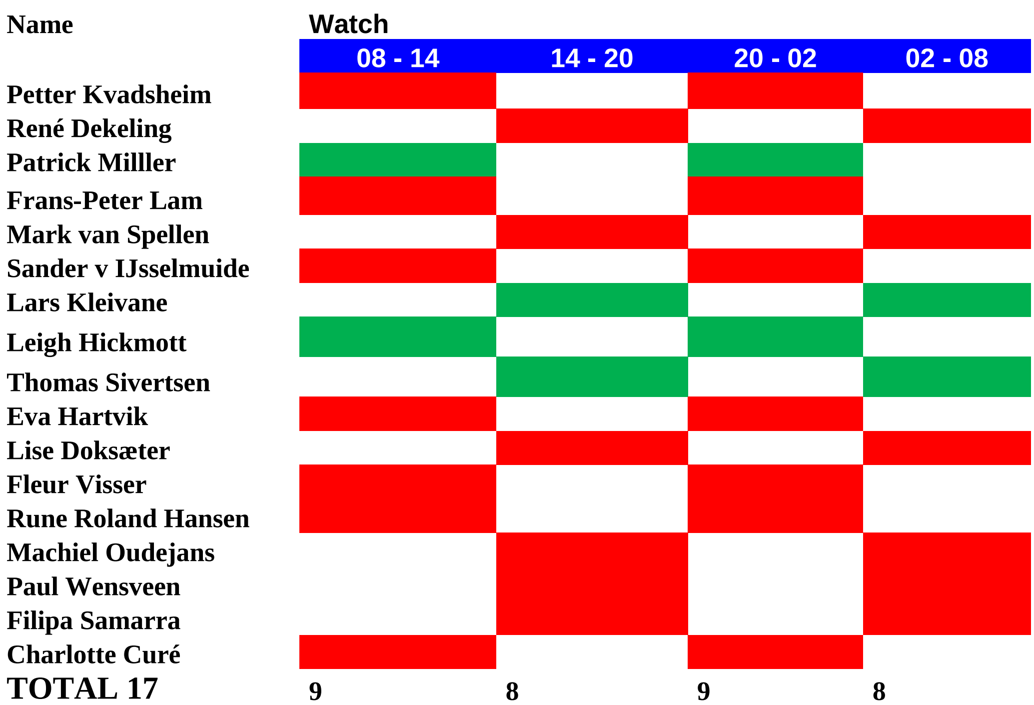
The complexity of all this requires a structured watch plan, which considers a minimum staffing requirement from the different teams, but we also have to be flexible when the operation moves into the more labor demanding experimental phases. It also requires a well defined chain of command and communication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

Planning meetings

Every morning before breakfast (0700), the chief scientist from the main 3S partners (Kvadsheim, Lam, Miller, Dekeling) 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 board on board. Every evening at 1900, the chief scientist will meet again to make adjustments to the daily plan, and plan activities for the coming night. Occasionally, the cruise leader may call for a plenum meeting with the entire scientific crew.

Watch plan

The entire crew will follow a basic regular seamen's watch plan of 6 hrs on and 6 hrs off, with change of watch at 8 and 2 am and pm, coordinated with the meals on-board. This will cover the basic staffing requirement during the search phases and tagging 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 an animal has been tagged and until the tag is recovered (pre-exposure, exposure and post-exposure phase), extra manpower is needed, and therefore a separate watch plan will be implemented. In the 16 hrs from tag on to tag off, the tagged animal will be tracked from MOBHUS. A watch plan of two MMO-teams of minimum 4 people, which takes turned and rotate every fourth hour between MOBHUS and resting duty will be established. In addition separate watch plans for the remaining MMOs who should stay on the Sverdrup as well as for the acoustic team be established.



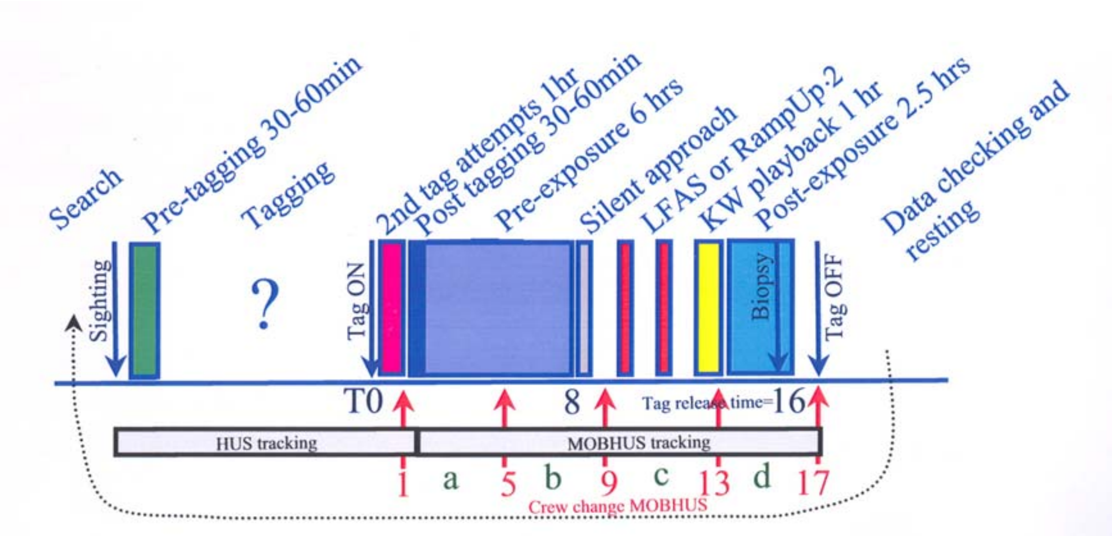
Basic watch plan used in the survey phase. The entire crew will follow a regular 6 hrs on and 6 hrs off seamen's watch plan. The tag boat team members (green) will be allowed to be more flexible.

Watch	Time	MOBHUS	Resting	HUS	Resting	SOCRATES	Resting
a	T0+1-5	MOBHUS T1	MOBHUS T2	HUS T1	HUS T2	SOC T1	SOC T2
b	T0+5-9	MOBHUS T2	MOBHUS T1	HUS T2	HUS T1	SOC T2	SOC T1
c	T0+9-13	MOBHUS T1	MOBHUS T2	HUS T1	HUS T2	SOC T1	SOC T2
d	T0+13-17	MOBHUS T2	MOBHUS T1	HUS T2	HUS T1	SOC T2	SOC T1

Watch plan used in the experimental phase from tag on until tag recover. As soon as a tag is successfully deployed on an animal, it will be determined who is on which teams for the coming experiment.

Operational phases

The operation goes through different phases; a search phase, a tagging phase, a pre-exposure phase, an exposure phase, a post-exposure phase, and then after a data checking and resting phase we return to search phase. See detailed description of the different phases above. The default timing of the experimental phases is illustrated in the figure below.



Default timing of the different phases of the experiment. The red bins are either dose escalation LFAS-exposures on bottlenose whales and minke whales or Ramp up exposures on humpbacks. The red arrows indicate the timing of crew changes on MOBHUS.

Operational status

In extended periods of good weather, and if we are successful in finding 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 the ship.

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

DATA COLLECTION

Search

From the Sverdrup we will be able to access online AIS information covering the entire Barents seas through an AIS-satellite service. Based on this we will contact other ships (fishing vessels, whalers, research vessels and coast guard vessels) in the area and request information about possible marine mammal sightings. Weather forecast and knowledge of sightings (historical or current) 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 around the clock.

The Sverdrup will search for whales in the specified locations using towed array acoustics and visual observations. When a target species marine mammal is detected, a decision will be made whether or not to attempt tagging. If yes, the tag boat(s) will be launched with taggers and photo-id capability.

Northern Bottlenose whales, minke whales and humpback whales are primary target species. However, we may opportunistically also try to tag white beaked dolphins with sponge tags. A rule whether or not to attempt to tag and do an experiment for each species will be made the day prior.

Pre-tagging, tagging and post-tagging

Pre tagging observation should be initiated from the MMO platform on Sverdrup as soon as the sighted animals are approached using the established protocol described in the *3S MMO Observer Handbook* (SMRU & KelpMR 2011). When tracking animals from Sverdrup, a tracking distance of about 1000 m from the animals should be maintained. Before the tag boats are allowed to approach the animals and start tagging attempts the visual observers on Sverdrup will collect group behavior data for 30-60 min. However, during the first approach with each species the tag boats are allowed to start tagging attempts as soon as possible, but the MMOs should nevertheless opportunistically do pre-tagging observations.

During tagging, the MMOs on Sverdrup should continue to track the focal animal and collect group behavior data according to the established protocol (SMRU & Kelp MR 2011). In addition they should also provide support to the tag-boats. For safety reasons the tag boats should stay within 3 nmi of the Sverdrup at all times, depending on visibility and sea conditions.

During initial tagging attempts, the DTAG should be used. With humpback whales the primary technique will be the cantilever pole form tag boat 1, with minke whales the primary technique will be the ARTS-DRAG system from tag boat 2. With bottlenose whales one or two tag boats will be used depending on group structure and spacing. The hand held pole will be used in tag boat 1 and the ARTS-DTAG system will be used in tag boat 2. If initial tagging efforts on minke whales are unsuccessful, but approaches closer than 20m seems likely, we will attempt to deploy a CTAG instead.

Once a tag has successfully been deployed on an animal, the 2nd tag boat will move to the tagged animal and attempt to tag a 2nd animal. Tag boats will take photo-identification photographs and track the tagged animal initially, until tracking is picked up by HUS using the VHF digital direction finder system. Tagging might continue for a maximum of 1hr, attempting to tag more animals. The other tag boat should move to assure that it is working with the same group of animals as the tagged animal. If we manage to deploy more than one tag, 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 from the pre-exposure time. 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. When Sverdrup has 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. The MMOs on Sverdrup should continue to collect post-tagging group behavioral observations until the end of the 1hr post tagging period. If pre-tagging and tagging phase observations have been successful, but tag-deployment has not been successful after one hour, the tag boat will leave the 'effects-of-tagging' group for ½ hr to enable post-tagging data collection. Detailed tracking and behavioural observations will cease after post-tagging data has been collected, but sightings will be recorded to support the tagging teams.

Once the tracking from the Sverdrup is reliable and tagging efforts cease, tag boat teams will transfer back to Sverdrup. Care will be needed during the recovery not to loose the tagged whale. At this point, the first MOBHUS team should prepare the boat and equipment for tracking, while the first HUS team keeps tracking the focal animals.

Pre-exposure

When one or two animals have been tagged and the decision is made to stop tagging, both tagging teams will transfer back to HUS. After a half-hour of post-tagging observations, an MMO team of at least four people will then be re-deployed in MOBHUS, and take over tracking the tagged animals and also do the group behavior data recording, until the tags are recovered in the end of the experiments. The reason for not doing the tracking from Sverdrup is that our experimental protocol with a moving source, does not allow tracking from the source ship during exposures. In order to collect a dataset which is consistent from pre- to post exposure, we therefore have to do the tracking from MOBHUS also in the pre-exposure period. The MMO team on MOBHUS will consist of four people, a driver, a data recorder and two MMOs. They should alternate between these roles. Every fourth hour the entire MMO team on MOBHUS will be replaced. Tag boat 1 will be used to transfer the MMO teams between MOBHUS and Sverdrup. When MOBHUS has taken oven tracking of the animal, the MMO team on the Sverdrup will be relived. However, there should be a reduced effort on the

Sverdrup as well to serve as back up in case the MOBHUS team loose contact with the tagged animal. The MMOs on Sverdrup should also make sure they continue to record sightings of other animals, since they have a better view of the larger picture of animal activity in the area. It is very 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 last 2-8 hours depending on the need for baseline data from the specific species and behavioral context.

Dose escalation experiments (SILENT-LFAS-LFAS)

When minke whales or bottlenose whales are tagged, the dose escalation (Silent-LFAS-LFAS) protocol should be used for the sonar exposure. The MMO team on the MOBHUS will continue to track the tagged animals visually and using the VHF-direction finder throughout the experiments. Miller with be a 5th MMO on the MOBHUS during hours 9-13 to act as mitigation observer. In preparation for the exposure, the Socrates will be deployed and HUS will distance itself from the observation vessel (MOBHUS) and the tagged animals. During the exposure phase, 4 different exposure runs will be carried out in a consistent sequence (SILENT-LFAS-LFAS-Killer whale playback with control sound). After a ramp-up, the HUS will approach the position of the tagged animals, as reported from the MOBHUS, head on at 8 knots from a distance of 3nmi. The primary goals of the start location are to place the source to the side or in front of the whale's direction of movement. The final decision to start sonar transmission is made by Kvadsheim after consultation with Miller and the Socrates operator. 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 MOBHUS, 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. The second exposure will start one hour following the end of the first exposure, once the source vessel is in a new acceptable location. All protocols will be identical for the first, second and third exposures. One hour after the final exposure tag boat 1 will be deployed to conduct a playback of killer whale sounds to the animals. However, if the animals clearly respond strongly to the sonar, the killer whale playbacks are cancelled to allow for a longer post exposure period. The exposure phase will last 5-6 hours.

Exposure schedule dose escalation:

Four different exposures will be transmitted as part of the normal cycle:

1.) SILENT: silent vessel approach with Socrates deployed but not transmitting.
2.) LFAS: hyperbolic Up-sweep of 1000ms duration with 20s PRT.
3.) LFAS: hyperbolic Up-sweep of 1000ms duration with 20s PRT.
4.) Playbacks of killer whale sounds and broad band noise signal

If the target species for the experiment is bottlenose whales, the $LFAS_{deep}$ signal (1-2 kHz) will be used, while if it's minke whales the $LFAS_{shallow}$ signal (1.3-2.0kHz) will be used. The silent control approach is always conducted first to avoid sensitizing the animal towards the source ship. The two repeated LFAS sonar exposures allow us to look at possible sensitization or habituation to the sonar. Prior to full power transmission a 10 min ramp up is transmitted starting at 152dB. This ramp up is longer than during the ramp up experiment because in addition to being a mitigation measure for non focal animals in the area, it is also part of the dose escalation. The playback of killer whale sound are always conducted last and will be cancelled if the animals respond strongly to the sonar to allow for a longer post exposure period.

Ramp Up Experiment

When humpback whales are tagged, the Ramp Up protocol should be used. After tagging and a post tagging and pre-exposure period the tagged animal will be exposed to the following experimental conditions:

Exposure schedule Ramp Up:

Four different exposures will be transmitted as part of the normal cycle:

1.) SILENT: silent vessel approach with Socrates deployed but not transmitting.
2.) RampUp using $LFAS_{shallow}$ (1.3-2.0kHz).
3.) RampUp using $LFAS_{shallow}$ (1.3-2.0kHz).
4.) Playbacks of killer whale sounds and broad band noise signal

The silent control approach is always conducted first to avoid sensitize the animal towards the source ship. The two repeated RampUP exposures allow us to look at possible sensitization or habituation to the sonar. The playback of killer whale sound are always conducted last and will be cancelled if the animals respond strongly to the sonar to allow for a longer post exposure period.

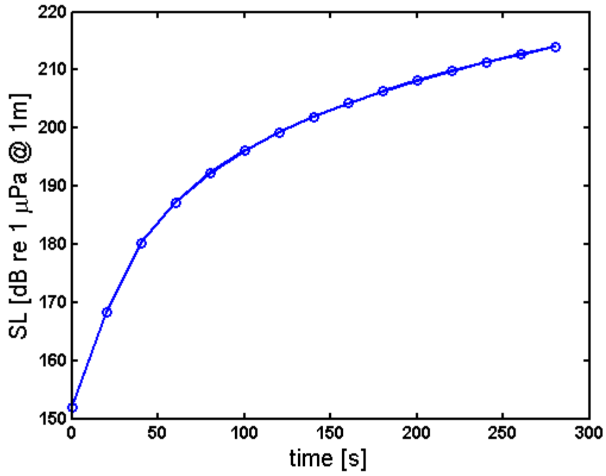
Time between exposures will be 1 hr and each exposure will have a duration of 10 min. During the Ramp Up approach, sonar transmissions will be initiated approximately 1250m from the tagged animal, and the source ship will approach at 8 knots on a straight and constant course while gradually increasing the transmitted source level from a minimum level of 152 dB to the maximum level of 214 dB at the closest point of approach, and then continue to transmit for another 5 min while moving away from the animal after passage. A CPA of 0m will be estimated based on the moving pattern of the animal in the pre-exposure phase. From the point of first ping and throughout the transmission scheme the source ship will maintain a constant course independent of the animal's movement.

To reduce the number of experiments needed, a digital test bed has been established to simulate the effectiveness of the Ramp Up procedure in minimizing risk to marine mammals during sonar operations (TNO 2011B). The model makes assumptions on how the animal might respond, and this model is then used to generate specific hypothesis to be tested. Thus, the test bed is used to find an optimal ramp scheme to be tested so that we only have to test one. The transmission scheme to be transmitted by Socrates during the experiments is defined as:

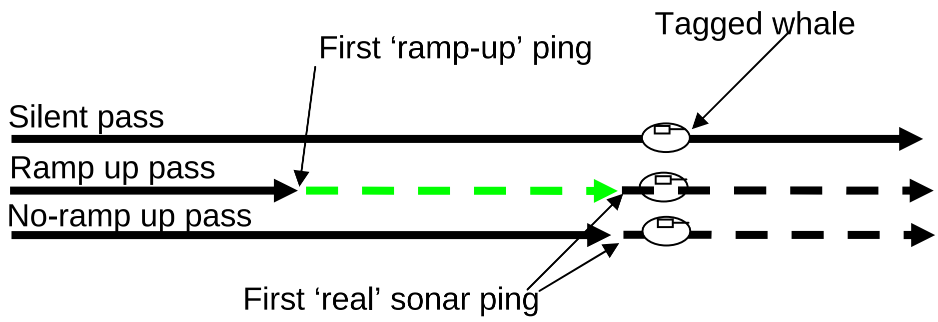
Ramp Up transmission scheme:

RAMP UP; Pulse duration = 500 ms, Pulse Repetition Time = 20s, Vessel speed = 8 knots, Source depth = 60-100m, Ramp up time = 5min (1250m transect), Steepness factor of increase of SL = 4, Initial source level = 152dB, Maximum source level = 214 dB, Signal= $LFAS_{shallow}$ 1.3-2.0 kHz hyperbolic up-sweep.

FULL POWER; Pulse duration = 1000 ms, PRT = 20s, Vessel speed = 8 knots, Source depth = 50m, Duration = 5 min (1250m transect), Signal= $LFAS_{shallow}$ 1.3-2.0 kHz hyperbolic up-sweep.



Transmission scheme for Socrates during the Ramp up experiment.



Conceptual diagram of the Ramp Up experimental deign. The oval represents a tagged subject whale, and the pointed lines represent the source vessel course. In all three runs the animal is approached as directly as possible, and the course of the vessel is fixed at a pre-determined distance, before the planned start of ramp-up signals. In the silent pass, no sonar transmissions are made. In the ramp-up pass, a ramp-up sequence is transmitted in addition to full-level signals. In the no-ramp-up pass, transmission starts with the first full level ping at the closest point of approach. The no-ramp up run will not be executed because the outcome can be simulated using transmission loss models and the silent approach (TNO 2011B).

Killer whale playbacks

The killer whale playbacks will require 1 hr to complete. Two stimuli will be played as part of each playback as follows (15 min noise, 30 min gap, 15 min orca). 'Orca' stimulus contains natural vocalizations of mammal eating killer whales, recorded in similar behavioral contexts, i.e. when the killer whales were foraging. 'Noise' (as a negative control) is a sequence of background noise selected from previous recordings (2005), amplified up to get the Average RMS Power equal to the stimulus, and repeated until getting the same duration than the stimulus (15 min). All acoustic signals have a similar Average RMS Power and duration of 15±2 min. Amplitude is low at the beginning of the stimulus and progressively increased up to its normal value to simulate better KW approaching. At the end of the stimulus, amplitude progressively decreases to simulate KW leaving.

Setting for Lubell speaker system is: source depth = 8m; gain setting on Amplifier = 200 mV; hydrophone Amplifier GAIN1 = 20dB; hydrophone Amplifier GAIN2 = 20dB; Distance speaker-monitoring hydrophone = 90cm.

The playback will be done from tagboat 1, with the transmission starting slightly ahead and to the side of the tagged whale, at a planned distance of 800m. The playback operator (Curé) may first join MOBHUS to see the whale track in order to plan the position of the playbacks.

Post-exposure

After termination of the exposure phase, we will go back to an operational modus similar to the pre-exposure phase. The tagged animals will still be tracked from MOBHUS. Towards the end of the post exposure phase, when tag release is just 30 min away, a biopsy team on MOBHUS will try to sample a biopsy of the tagged animal(s), and possibly attempt to attach a 2ndary tag for post-experiment monitoring. The post-exposure last 3-4 hrs. The total duration of tag deployment will usually be set to 16 h before the tag releases. When all tags have been retrieved, the MMO team will transfer back to HUS to download and secure the data. Visual and behavioral data will also have to be checked, corrected and secured (backed up). Then after at least a 6 hr period of resting the troops, we return to the search phase.

Mitigation during transmission

During transmissions, MMOs on Sverdrup will assure that no whales are close enough to the source that they might be exposed to sounds over 180 dB re 1μPa as required by the permit. The stand off range between source and animals during full power transmission is 50m. If any animals are approaching this safety zone an emergency shout down of sonar transmission will be ordered. Transmission will also be ceased immediately if any animal shows any signs of pathological effects, disorientation, severe behavioral reactions, or if any animals swim too close to the shore or enter confined areas that might limit escape routes. The decision to stop transmission outside the protocol is made by Kvadsheim or by the PI (Miller) observing the whales from the MOBHUS. For efficiency of communication, a VHF radio protocol should be established to allow for Miller and Kvadsheim to speak directly to each other on the radio.

Sound speed profiles (CTD) and LYBIN

If possible, a CTD or XBT profile should be collected when tag boats are deployed so that is can be used to plan possible acoustic transmission, when tags are deployed.

Sound speed profiles should be taken whenever acoustic transmissions (sonar signals or killer whale playback) have been used in an area. CTD profiles will be taken form the Sverdrup, but Sverdrup cannot reduce speed beyond 3 knots when towing Socrates or Delphinus. Sverdrup is equipped with a Moving Vessel Profiler (MVP), which can sample vertical sound speed profiles while the ship is moving, but the MVP can not be used when towing Delphinus due to the risk of entanglement.

After an exposure experiment, Socrates and Delphinus (or CAPTAS) are usually recovered on the Sverdrup, which allows Sverdrup to collect CTD profiles along the exposure path using the MVP or a regular CTD probe.

CTD profiles should also be collected on a routine basis (e.g. 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 (e.g. LYBIN).

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.

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 (TNO 2011A). Final decisions on issues related to the safety of Socrates and Delphinus are made by the chief scientist of TNO (Lam).

Scientific issues

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

COMMUNICATION PLAN

In all phases of this trial the crew will be split in different groups (acoustic teams – marine mammal observation teams – tag teams - coordination/management) and platforms (Sverdrup – 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 spare one. Cell phones are of no use, we will be out of range!

The radio call signals for the different units will be:

"Sverdrup"	Sverdrup (HUS) bridge (HQ)
"Tag boat I"	4 stroke outboard engine work boat
"Tag boat II"	Water jet propulsion MOB (MOBHUS)
"Socrates"	Sonar operator on Sverdrup (Socrates and Delphinus)
"Obs deck "	Marine mammal visual observation deck on Sverdrup

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

During the tagging phase, communication to and from the tagging teams must be limited. Tag boats should stand by on the main channel (A), while communication between the other stations, with little imminent relevance to the tag boat teams, should happen on the alternative channel (B). "Sverdrup" will monitor both channels at all time. Messages to the tag boats, which is not urgent, should be channeled through the "Sverdup", who will relay the information when appropriate. An intercom channels between Sverdrup and Socrates and Obs deck will be implemented.

Tag boats must report in to "Sverdrup" to confirm communication lines every hour! We are mostly operating in open ocean, and this safety procedure is an invariable rule. Tag boat teams who fail to comply with this will be called back and recovered without further warning.

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

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

RISK MANAGEMENT AND PERMITS

FFI has obtained necessary permits from appropriate civilian and military authorities for the operation described in this document. The operation area is entirely within Norwegian territorial waters or the exclusive economic zone of mainland Norway or Svalbard, thus all under Norwegian jurisdiction. The operation is considered a military activity under the jurisdiction of Norwegian military authorities. RV HU Sverdrup II will carry a Royal Norwegian Navy Ensign and be placed under command of government official from The Norwegian Defense Research Establishment. 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 2011/38782) acquired by Petter Kvadsheim (FFI 2011A). The permits include tagging (DTAG and CTAG) and acoustic exposure of minke whales, bottlenose whales and humpback whales according to the protocol described here. Permits also allow biopsy sampling of target species. In addition the current permit allow some initial attempts to tag white beaked dolphins with colored paint and track them visually, but does not include permit to expose them to sound. 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 operators and will be responsible for permit compliance in the field.

Procedures to mitigate environmental risk will be implemented as described in this document and in the permit documents. Risk to humans should be minimized through the regular safety regime implemented for all relevant working operations on board. The cruise leader is primarily responsible for these risk issues. A separate risk management plan, to mitigate risks to expensive equipment, such as the SOCRATES system the towed arrays, has also been specified (TNO 2011A). All personnel involved in handling this equipment, including navigators, must be aware of the content of this plan. Risk involved in the handling and operation of this equipment is the primary responsibility of the TNO chief scientist.

PUBLIC OUTREACH AND MEDIA

During the cruise, all media contact should be referred to the cruise leader (Kvadsheim) who will coordinate with the 3S-board members (Miller, Lam, Tyack) 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.

TRAVEL AND ACCOMMODATION

Travel

Port in/out Tromsø:

There are frequent direct flights from Oslo to Tromsø with SAS and Norwegian Airlines. Tromsø airport is a 15 min taxi drive from both port terminal and from down town Tromsø.

Hotel

If you need to organize with hotel accommodation in Tromsø, our recommendation is:
Clarion Hotel Bryggen +47 77 78 11 00 - Sjøgata 35/37 Tromsø
http://www.clarionbryggen.no/

If you refer to the arrangement with Norwegian MoD (Forsvarsavtalen) you will be given a discount. Just refer to the fact that you are visiting the country to attend a research trial on collaboration with FFI. If you prefer another hotel, the same will apply to other hotels in the Choice Hotel chain. There are several alternatives in Tromsø. http://www.choicehotels.no/

SHIPPING

For loading and off-loading Sverdrup will be docked at Breivika port terminal in Tromsø.

For shipping equipment to Tromsø, coordinate with FFI, and use this address:

HU Sverdrup II
c/o Steinar Sørensen
Bring Logistics Tromsø AS
Terminalgaten 42 Breivika
NO-9261 Tromsø

Phone +47 77 64 80 90

GENERAL ADVICE

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

Weather conditions will be the most limiting factor during the cruise. In June the air temperature will still be relatively cold at sea in these Arctic oceans (0-15 ºC). Make sure you bring high quality clothing for all layers. Floatation suit is mandatory for everybody working on the tag boats. However, it's what you wear under the suit which keeps you warm. A hat, gloves and shoes which keep you dry are your most important tools.

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

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

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

The food on the Sverdrup is known to be good. However, on a cruise of this duration without port calls, we will run out off fresh food such as fruit, dairy products and vegetables. It might be a good idea to bring you favourite food goodies (*e.g.* tea, coffee, chocolate, cookies, etc.).

Prepare yourself mentally that we might be at high sea without even sight of land for weeks at the time. We will be out of cell phone range most of time. Warn the people at home that you are still alive, even if you don't pick up their calls. You will be allowed to call home, but not unlimited, due to the limited number of satellite based phone lines. The ship has continuous satellite based internet connection and internal wireless network. There are a few available computer stations on board, but these have to be shared. You are welcome to bring your laptop and connect to the network.

Be prepared!   ENJOY!   Good luck!

Petter Kvadsheim (cruise leader)

REFERENCES

The following list of other internal documents within the 3S-group also has relevance to the conduction of the trial.

FFI 2011A Permit from Norwegian Animal Research Authority – *"3S^2 Behavioral response studies of cetaceans to naval sonar signals in Norwegian waters"*. Available from Petter Kvadsheim at phk@ffi.no

FFI 2011B *"3S^2 2011-2013 Evaluation of alternative field sites within Norwegian waters"*. Available from Petter Kvadsheim at phk@ffi.no

TNO 2011A "*Deployment, operation and recovery of SOCRATES-, Delphinus- and the CAPTAS-system"*. Available from Frans-Peter Lam at frans-peter.lam@tno.nl

TNO 2011B *"3S2 Ramp-up experiment - experimental protocol and theoretical ramp-up design"*. Available from Frans-Peter Lam at frans-peter.lam@tno.nl

SMRU & Kelp MR 2011 - *"3S-Observer handbook"*. Available from Patrick Miller at pm29@st-andrews.ac.uk

SMRU and WHOI 2010 - Research proposal to ONR "*3S^2 Behavioral response studies of cetaceans to naval sonar signals in Norwegian waters"*. Available from Patrick Miller at pm29@st-andrews.ac.uk

Appendix F 3S^2 Ramp-up experiment - experimental protocol and theoretical Ramp-up design

Please cite this document as:

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$3S^2$ Ramp-up experiment

experimental protocol and theoretical ramp-up design

A.M. von Benda-Beckmann, M.A. Ainslie, P.A. Wensveen, F.P.A. Lam,
P. Miller, P. Kvadsheim, P. Tyack

06 May, 2011 - Version 1.0

1. Introduction

Ramp-up (or soft-start) schemes are widely used as an attempt to mitigate the impact of sonar sound to marine mammals. During ramp-up, source levels are gradually increased prior to the onset of full-power transmission, which is thought to give nearby animals time to move away before sonar transmissions reach maximum levels. So far, it has not been demonstrated that ramp-up is actually effective in reducing the risk of harm of sonar to marine mammals. Therefore, one of the research goals of $3S^2$ is to conduct a directed study of the effectiveness of ramp-up as a mitigation method.

This document describes the motivation for the set-up of the ramp-up experiment. A ramp-up scheme is designed based on theoretical considerations, which is to be tested during the experiment. This document is intended for sharing and discussing ideas about ramp-up design and experiment among members of the 3S group, so please add any thoughts you think are useful!

The humpback whale is selected to be the subject species for the 3S experiment. Humpback whales are expected to be a) abundant both in the coastal waters SW of Svalbard and around Bear Island during the trial period (June), and b) relatively straightforward to Dtag. Based on the humpback audiogram of relative hearing sensitivity predicted from anatomical data (Houser et al., 2001) and the frequencies of their own vocalizations (e.g., Zoidis et al., 2008), humpbacks are also expected to be sensitive to low frequency sonars like the LFAS 1-2 kHz sonar available in the Socrates system. We will use only LFAS up-sweep signals to ensure we obtain a sample size large enough to make the necessary statistical comparisons.

The outline of this document is as follows. First, a working definition for the objectives of ramp-up is provided in Section 2 and 3 to make sure all members agree on the aim of the experiment. The aim of the experiment is to demonstrate that the ramp-up scheme can significantly reduce the risk of direct injury of sonar sounds to marine mammals. The remainder of this document is divided into two sections: Section 4 contains the theoretical framework that is used to optimize the ramp-up design to test during the $3S^2$ experiments. Section 5 contains general information about the ramp-up design and the experimental protocol. The results are summarized in Section 6. Chapter 7 and 8 list key elements that need to be decided upon before the protocol can be finished. Under "Decision points: ramp-up scheme" (chapter 8) you will find the variables that are the input of the ramp-up simulations. For this category of parameters (ping duration, ramp-up time, etc.), we only need to limit the range of values at this point, and we use a sensitivity analysis to investigate their effects on the risk of impact (see Section 4).

2. Purpose of ramp-up

For the purpose of this work the aim of the ramp-up is to lower risk of physical **injury** to marine mammals. Injury is defined here as direct auditory tissue effects (Southall et al. 2007) commonly expressed in terms of a permanent threshold shift (PTS)[*]. A PTS can be incurred by a maximum received level of a single sonar transmission (expressed here in terms of maximum peak pressure), or through the cumulative effect of multiple transmissions (expressed in SEL). The onset values for PTS in marine mammals are unknown, but temporary threshold shift (TTS) is generally used as a conservative limit, which lies approximately 15 dB below PTS (Southall et al. 2007).

Two approaches can be adopted:

1. When no prior knowledge about the presence of marine mammals in the area of operation is available, the average number of animals affected can be estimated by product of the affected area A by PTS/TTS and the number density n. The risk level in this work is assumed to scale with the number of animals affected by PTS, and TTS, respectively.
2. When prior knowledge is available about the presence (and absence) of a particular animal, a ramp-up can be designed to minimize the impact on the animal at highest risk of being injured. In the case of the $3S^2$ experiment, the CPA can be chosen such that the risk will be high if the animal is not responding.

The first approach is probably the most operationally relevant. However, the second approach is more comparable to the situations we are likely to encounter during $3S^2$. The modeling work in Section 4 considers both scenarios, and considers both the maximum received peak pressure as well as cumulative SEL.

A decrease of risk to injury by a ramp-up procedure comes at the expense of more animals being disturbed. It is difficult to quantify the risk of behavioral disturbance. In this work, the increase in area where behavior is predicted to be affected is also presented along with the decrease in risk to injury.

[*] Note that *indirect* damage that involves something like preventing a panic reaction that caused DCS requires completely different evaluation of the ramp-up efficacy. Since the mechanisms that cause DCS are still unknown, only the increase in number of animals whose behavior is affected is addressed here.

3. Objective

The objective of the 3S ramp-up experiment is to test the hypothesis that a ramp-up allows a humpback whale to move away from the source, thereby significantly reducing the risk of direct physical injury compared to when no ramp-up is prior to the operation. Conclusions about the overall effect on the population will be drawn using model results. The assumptions made in the behavioral model will be verified using the ramp-up experiment results.

4. Modeling ramp-up efficacy

This section briefly discusses a ramp-up parameterization that can be used to minimize the exposure of a sonar operation in the case of a moving LFAS source. In particular, we focus on a ramp-up designed for humpback whales, to be tested during the 3S[2] experiments.

Operational scenario

Two phases are defined for the sonar operation. First, a ramp-up phase, in which the sonar is transmitting pulses specifically designed to cause a response of the animal. Second, the operation phase in which the sonar is transmitting operationally relevant transmission schemes. In this work, the sonar source is considered to be moving at constant speed v_s in a straight line along the x-direction at $y = 0$ for the duration of the operation (taken to be $T_{op} = 1$ hr). The operation starts at ($x = 0$, $y = 0$) at time $t = T_{ramp}$. The ramp-up starts at a position ($-T_{ramp} \cdot v_s$, $y = 0$) at time $t = 0$.

Ramp-up Parameterization

The ramp-up is parameterized by the following function

$$SL_{rmp}(t) = SL_{\min} + (SL_{\max} - SL_{\min})\left(\frac{t}{T_{ramp}}\right)^{n_{ramp}} \quad \text{for } t < T_{ramp} \qquad (1)$$

Where SL_{rmp} and SL_{max} are the source level during ramp-up and full-power transmission, respectively, and steepness n_{ramp}, and the ramp-up duration T_{ramp}, are free parameters. Here the ramp-up time is not included in the total operation time. This function is sampled at an interval of constant pulse-repetition time *PRT*. The ramp-up starts at a SL_{min} of 152 dB re 1 μPa @ 1m (minimum possible SL for Socrates 2 in the LFAS band).

Sound Impact on Marine Mammals

As risk measures, the impact areas A_{TTS} and A_{PTS} are calculated. The entire area is discretized in surface elements with a resolution of $dx = 100$ m, and $dy = 100$ m. Each grid-cell considers a potential starting position of a whale encountered during the operation. The impact areas are calculated by summing all starting positions of the whale(s) that lead to a SEL or peak pressure exceeding the TTS and PTS threshold. The SEL is calculated by the product of the sum of sound pressure level *P* over all pings with the duration of the pulse

$$SEL = \sum_{\text{ping}=1}^{\text{N}} T_{\text{sig}} \cdot P$$

The SPL is related to the peak pressure a factor

$$P = 20 \log(P_{peak}) - 3.0 - F_{mp} \qquad (2)$$

the first factor of 3.0 dB is the ratio between peak and *rms* pressure for an LFM or CW waveform, expressed as a level, and the second is a factor F_{mp} = 20 log 2[*] to take into account possible increases in peak pressure due to multipath interference or other distortion (note that we are currently modeling propagation loss by 20 log R). Depth effects are not considered yet in this work. A minimum distance of 0.75 m is applied, corresponding to the radius of the sonar source.

TTS onset threshold

For humpback whales, the SEL value of 195 dB, given in Southall et al. 2007, is the level at which statistically significant TTS occurred in Finneran et al. 2005 (3 kHz, 2 animals) and also the mean level from Schlundt et al 2000 (7 animals, 3-20 kHz; but possibly masking at >3 kHz). Nachtigall et al 2004 found TTS at 193-194 dB for 50 min octave-band noise. Mooney et al. found that long duration sounds require less SEL, with a minimum SEL of 187 dB inducing TTS (3 dB TTS, 30 min duration). Finneran & Schlundt (2010) present model fits for SEL as function of induced TTS measured 4 min after exposure (1 animal). For a 3 kHz tone, 6 dB of TTS_4 (an often used criterion) is induced at SEL of 191 dB according to this model. For 20 kHz, the same threshold is 10 dB lower. These results however were published as a Letter to the editor, and labeled preliminary by the authors. Lucke et al. 2009 induced TTS in a harbor porpoise at 164 dB SEL.
The SEL value of 195 dB is often used and based on multiple animals and signal types. However, some argue this threshold is rather high, and recent studies of other species have shown lower TTS onset levels than quoted by Southall for the harbour porpoise.
A SEL of 195 dB is adopted for humpbacks as the TTS level. The PTS level is assumed to be TTS + 20 dB.

In the simulations no recovery from TTS is assumed to occur throughout the operation, but in reality recovery of hearing will occur during the time intervals between the pings

[*] The best way to be sure is to look at the measurements, but from what I have seen so far M.A. suspects a value of 3 (for the ratio between the peak pressures) is more realistic than 2.

(see Mooney et al. 2009). This implies higher cumulative SELs would be required to induce TTS. Therefore there are arguments both for using both a higher threshold than the 195 dB from Southall et al. 2007 and for choosing a lower one.

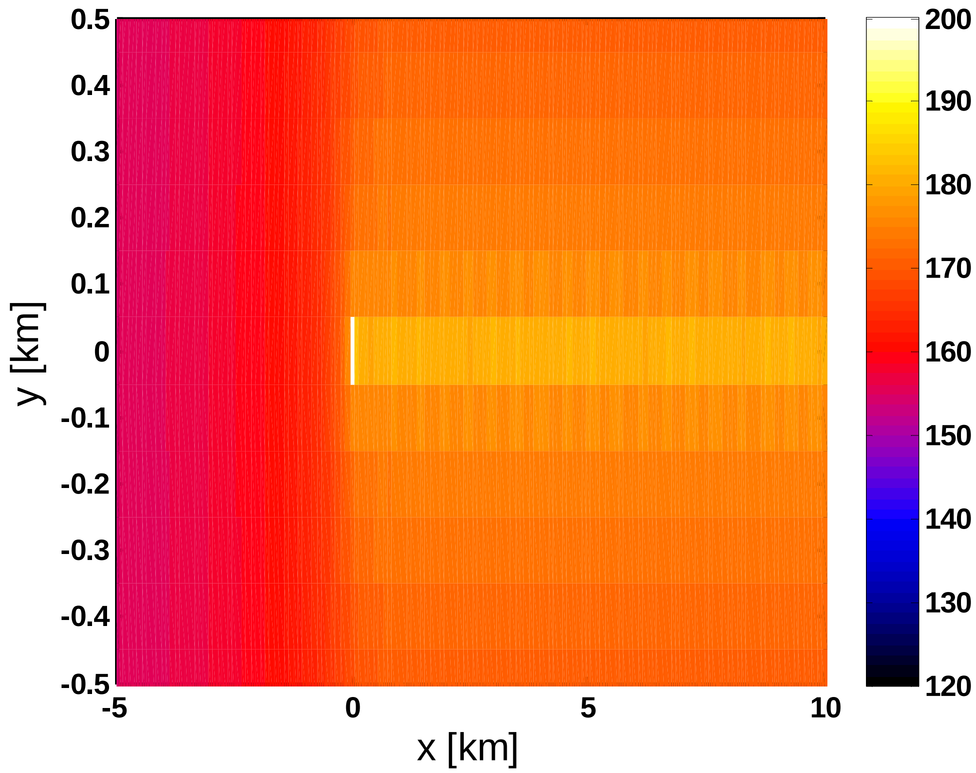


Figure 1 : Example of exposure map (colors indicate total SEL experienced by animal starting at position (x,y), and moving in the y-direction) for an operation without ramp-up (T_{ramp}=0). The ship transmitting at full-power starts at position (0,0) and continues in positive direction over the x-axis at a speed of 4 m/s (~ 8 knots). The black contours indicate the TTS = 164 (porpoises, Lucke et al 2009), 183 (pinnipeds, Southall et al 2007), and 195 (low- and mid-frequency whales) dB re 1 $\mu Pa^2 s$. This example uses a step-function as avoidance threshold (in this case RLav = 165 dB re 1 μPa^2).

Behavioral response

We assume that a behavioral response is elicited at a predefined avoidance threshold RL_{av}, expressed in received sound pressure level (Tables 15 – 21 in Southall et al. 2007). The animals in the area are assumed to swim away perpendicularly from the path of the ship once their received sound pressure level exceeds the avoidance threshold.
The only studies reviewed by Southall et al with humpbacks and ‘nonpulse’ (as defined by Southall 2007) sound in which avoidance occurred are Baker et al 1982 and McCauley et al 1996 (both on responses to vessel noise). According to Appendix C in Southall et al, Baker et al 1982 indicate some avoidance when RL was 110-120 dB and clear avoidance at 120-140 dB (these data may be difficult to reproduce). Part of this spread in noise level

is due to the methodology, as levels were not measured directly but noise signatures were estimated from the size of the vessels.
McCauley et al. 1996 qualitatively scored 8 hours of behavioural data of humpbacks in the presence of boats, and report 6 instances of behaviour distinctly correlating with maneuvering boat noise (out of 11 correlations in total). The mean of the measured maximum SPL over the 6 instances was 118 dB (range 113-123 dB). These authors recommended speed limits for vessels designed to keep the noise exposure below 120 dB.
Wintering humpback whales responded during controlled playbacks of 3.3 kHz sonar pulses by increasing their distance to the source, and more acutely to playbacks of 3.1-3.6 kHz sonar sweeps by increasing their track linearity (Maybaum, 1989). The latter was a direct function of increasing sound level (Fig 2). There are two conference abstracts available but the work was never published in a peer-reviewed journal (figure from the master's thesis).
A set of calculations is performed for a range of avoidance thresholds (RL_{av} = 80 – 200 dB re 1 μPa^2, in steps of 5 dB) for the following set of parameters. The effect of the choice of RL_{av} is discussed in Section 3.1.1.

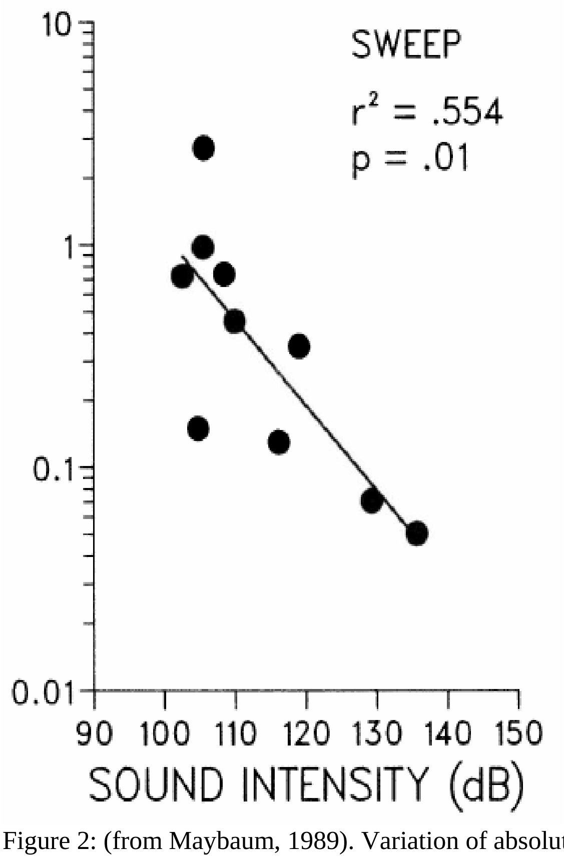


Figure 2: (from Maybaum, 1989). Variation of absolute angle of deviation (AAD) with sound intensity.

Optimizing the ramp-up

To optimize the ramp-up, a set of 72 ramp-up scenarios are computed, and compared to a no-ramp up scenario. The parameters adopted for this study are summarized in Table 1-3. Table 1 contains the parameters for the operation that are fixed.

Table 1: Operation

parameter	values used
T_{op}	1 h
SL_{op}	214 dB re 1 µPa^2m^2s (@ 1m)
PRT_{op}	20 s
T_{pulse}	1 s
v_s (ship speed)	4 m/s (~ 8 knots)

Table 2: Ramp-up fixed parameters

parameter	values used
SL_{max}	214 dB re 1 µPa^2m^2s (@ 1m)
SL_{min}	152 dB re 1 µPa^2m^2s (@ 1m)
v_s (ship speed)	4 m/s (~ 8 knots)
v_m (mammal avoidance speed)	1 m/s (~2 knots)
T_{pulse}	0.2 s
escape direction	*y*-axis

The following parameters are varied (see Eq. 1):

Table 3: Ramp-up variable parameters

parameter	values used
T_ramp (ramp-up time)	0, 60, 300, 600, 1200, 3600 s
n_ramp (steepness)	1, 2, 3, 4
PRT (pulse-repetition-time)	5, 10, 20 s

4.1 Impact due to SEL on whole population

Figure 3 shows the area affected with PTS (resp. TTS) for each ramp-up scenario (combination of steepness, PRT, and ramp-up time, see Table 3) as function of avoidance threshold RLav. Note the steep change at high avoidance thresholds of ~ 170 dB, which is due to the fact that the ship is moving beyond the area that it affects between two pings (and hence operation/ species dependent!). In this regime, the ramp-up starts to become much more inefficient. This point can be influenced by changing the PRT during the operation. However, for typical ASW operations, the PRT is directly linked to the detection ranges by two-way travel time. Hence, an operational scenario should consider long PRT during the operation phase of the experiment.

Note that the PTS impact area of humpback in terms of maximum peak pressure is smaller than 100^2 m (simulation resolution), and is not depicted here.

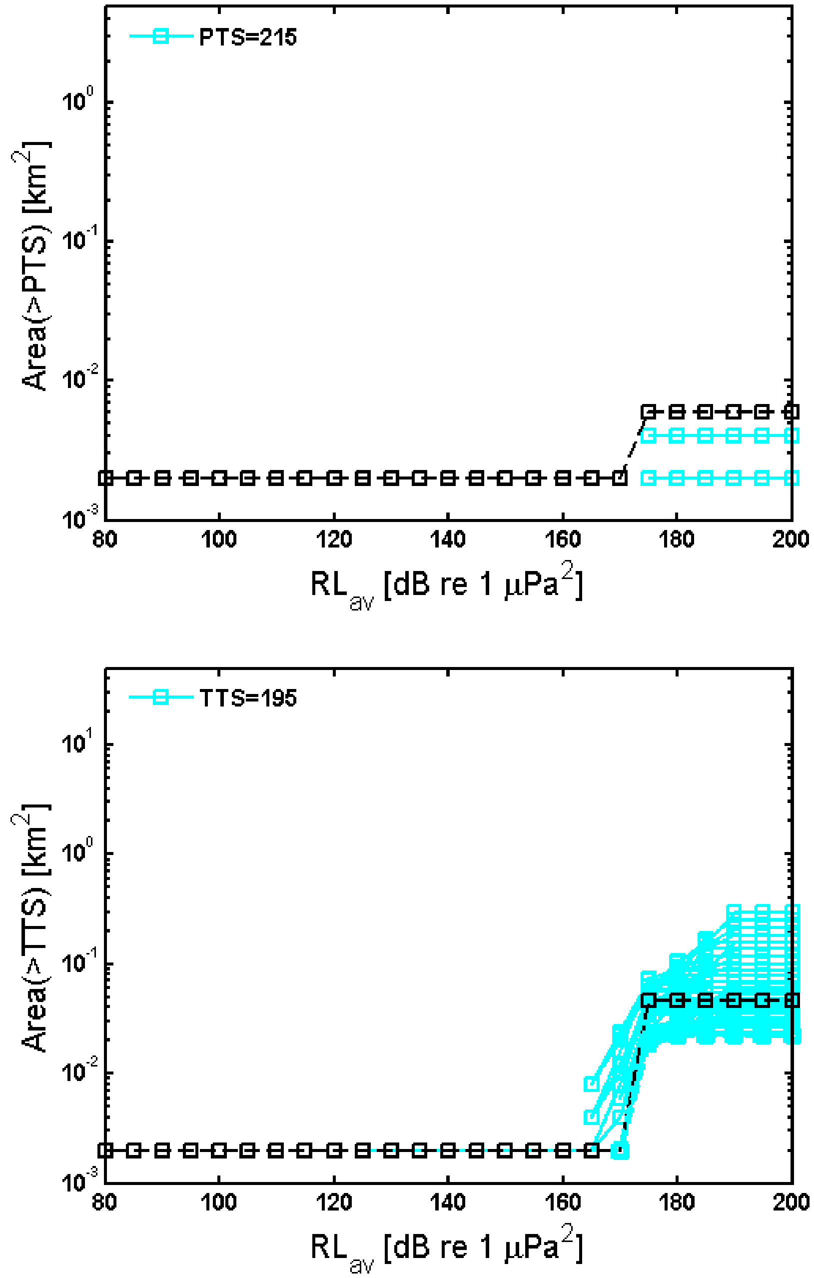


Figure 3: The impact area as a function of response threshold RLav. Each curve indicates a single ramp-up scenario. The impact areas are defined for humpback whales, with SEL exceeding a PTS (*top*) and TTS (*bottom*) level of 215 (195) (low-, and mid-frequency cetaceans; Southall et al 2007) in dB re 1 μPa2s. Solid black lines indicate a no-ramp-up scenario.

4.1.1 Weighting by Dose Response

To take into account the variability in avoidance onset, we adopt a dose-response methodology. We characterize this uncertainty in terms of a cumulative dose-response curve, where we follow Miller et al. 2011.

$$p_{resp}(< RL_{av}) = \frac{1}{1+e^{-(a+b\cdot RL_{av})}} \tag{3}$$

with *a* indicating the steepness of the curve, and *b*, the position of the turn-over point.

The total risk is obtained by weighting the risk of each of the calculations by the derivative w.r.t. the avoidance threshold P_{av} of Eq. 2.

$$w_{resp}(RL_{av}) = \frac{-b\cdot e^{-(a+bRL_{av})}}{\left(1+e^{-(a+b\cdot RL_{av})}\right)^2} \tag{4}$$

The weighted impact area is then the weighted outcome of each run with a particular avoidance threshold, summed over all (a wide range of) avoidance thresholds

$$\overline{A}_{TTS} = \frac{\int_{-\infty}^{\infty} A_{TTS}\cdot w_{resp}(RL_{av})dRL_{av}}{\int_{-\infty}^{\infty} w_{resp}(RL_{av})dRL_{av}} \tag{5}$$

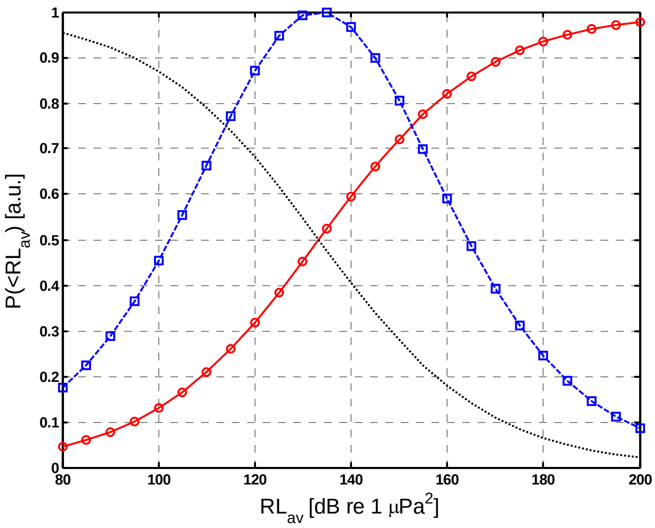


Figure 4: Example of a dose response (in red), its inverse (in black), and the derivative (weighting factor, in blue). Values were adopted from Miller et al 2011. Note that the weighting factor is scaled to unity for illustrative purposes only.

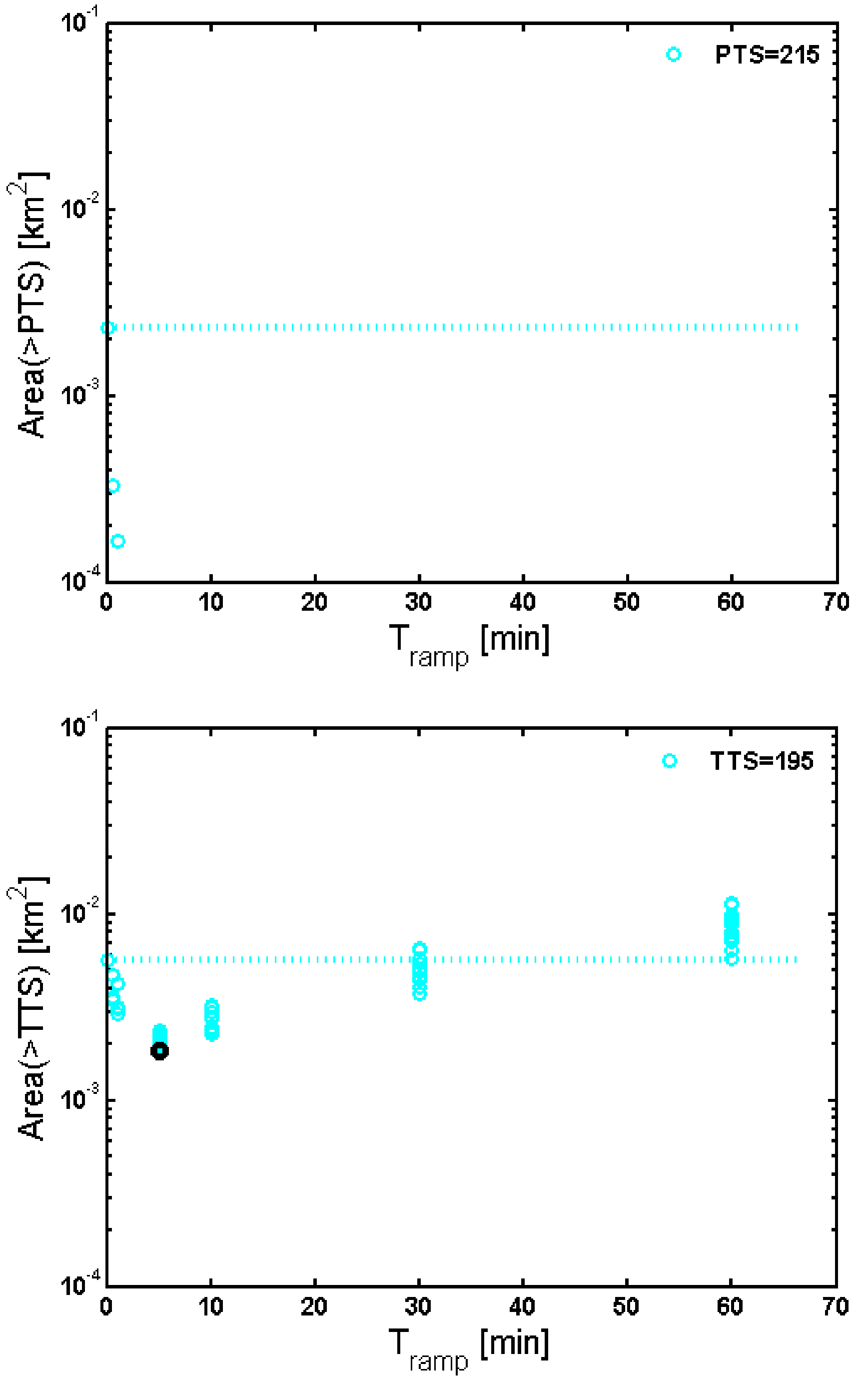


Figure 5: Weighted Impact area as a function of ramp-up time. The impact areas are defined for SEL exceeding levels representative for humpbacks: a PTS (*top*) and TTS (*bottom*) level for 215 (195) (cyan, low-, and mid-frequency cetaceans; Southall 2007) in dB re 1 µPa2s. Dashed lines indicate a no-ramp-up scenario. The vertical spread at each ramp-up time indicates the spread in impact due to change in ramp-up parameters, such as *PRT* and n_{ramp}. Note that the ramp-up scenarios tend to have a minimum at a ramp-up time of 5 minutes (indicated by the black circle).

We adopt for the dose-response relationship, values for a = -7.6 and b = 0.057 taken from Miller et al. 2011 for killer whales (illustrated in Figure 4). This curve peaks at somewhat higher levels than expected for the humpbacks (135 vs 120 dB), however covers the range of avoidance levels expected for humpbacks (110 – 140 dB). The final weighted impact areas with SEL levels exceeding PTS/TTS as function of ramp-up time are depicted in Figure 5 for all scenarios.

The parameters for the ramp-up scheme with the lowest impact area $A(TTS>195)$ are listed in Table 4.

Table 4: Optimal ramp-up variables for the 3S2 experiment with humpback whales

parameter	**values used**
T_ramp (ramp-up time)	300 s
n_ramp (steepness)	4*
PRT (pulse-repetition-time)	20 s

4.1.2 Impact due to maximum peak-pressure on whole population

Figure 6 considers the impact in terms of maximum peak-pressure. This is estimated from the maximum received SPL according to Eq. 2. The impact area of humpback whales is smaller than 100^2 m (simulation resolution).

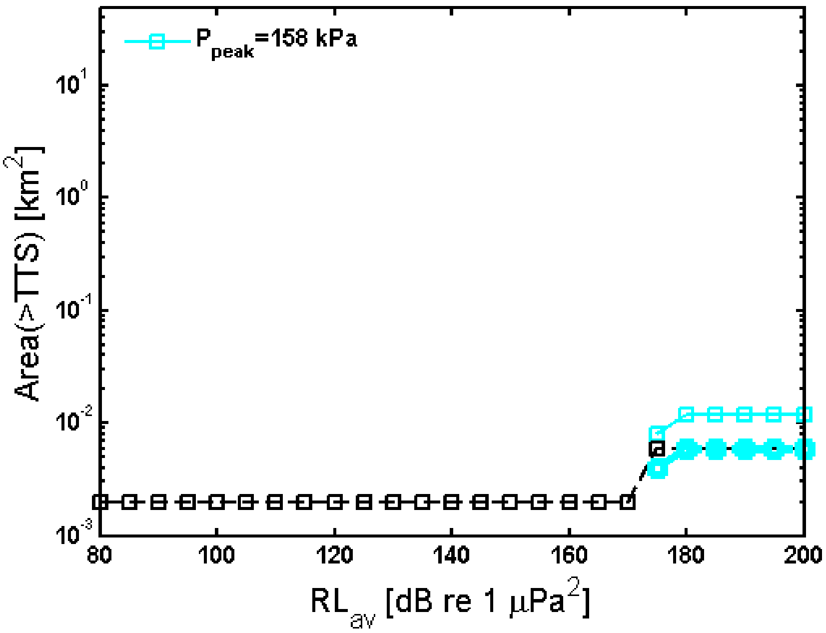


Figure 6: The impact area as a function of response threshold RL_{av}. Here impact area is determined in terms of peak pressure exceeding a threshold of TTS level for three TTS onset thresholds 158 kPa (cyan, low-,

* We also included steepness of n_{ramp} = 5, 6, and 7 because n_{ramp} = 4 was at the border of parameter space. Still n_{ramp} = 4 provided the minimum risk, although the difference was minor compared to n_{ramp} = 5.

and mid-frequency cetaceans; Southall et al 2007)*. Note that in terms of PTS the impact area of humpback whales is smaller than 100^2 m (simulation resolution).

4.2 Single animal

In the case that the ramp-up is focused at a single animal with known location, instead of a population where no prior knowledge is available, it makes sense to look at a single starting point. Figure 7 and 8 consider the SEL and max SPL for three different whale starting locations along the ship track line with distances of r = 0, 100, and 500 m from the point where the source starts at full power. The dashed lines indicate the results for the optimal ramp-up scheme listed in Table 4. For the single animal a drop of 10-15 dB can be measured between the no-ramp-up case and the optimal ramp-up. Some ramp-up appear to give a lower SEL and SPL for the single animal. These scenarios are for long ramp-up which provide the animal with more time to respond. This is illustrated in Figure 9 that shows the SEL at a reaction threshold of 120 dB (typical for humpbacks) for different ramp-up times. The SEL level is decreasing with increasing ramp-up time.

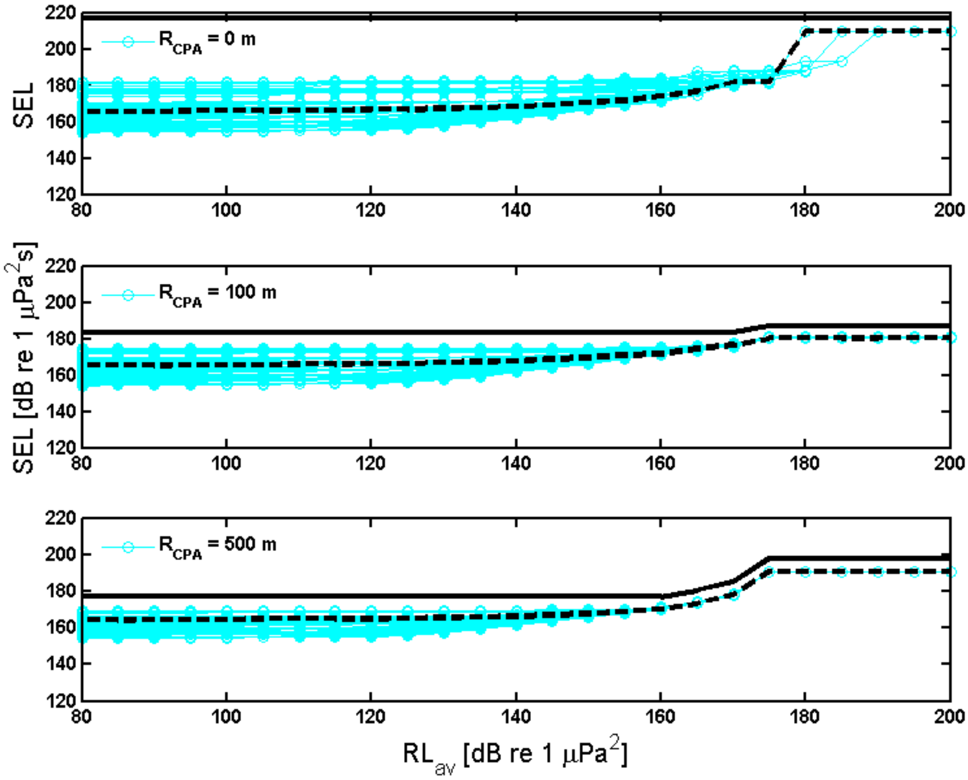


Figure 7: Total SEL (*top*) a function of reaction threshold for a single animal starting at (CPA) r = 0 m (top), 100 m (middle), and 500 m (lower) away from the point at which the source starts at full power. The

* These values of peak pressure are not quoted by Southall, but are inferred by assuming that “peak SPL” is equal to 20*log_10(peak pressure). See ‘Principles’ p563.

distance is along the track of the ship. The black solid lines indicate the no-ramp up scenario. The dashed black line indicates the optimal ramp-up (in terms of area affected with TTS>195 dB).

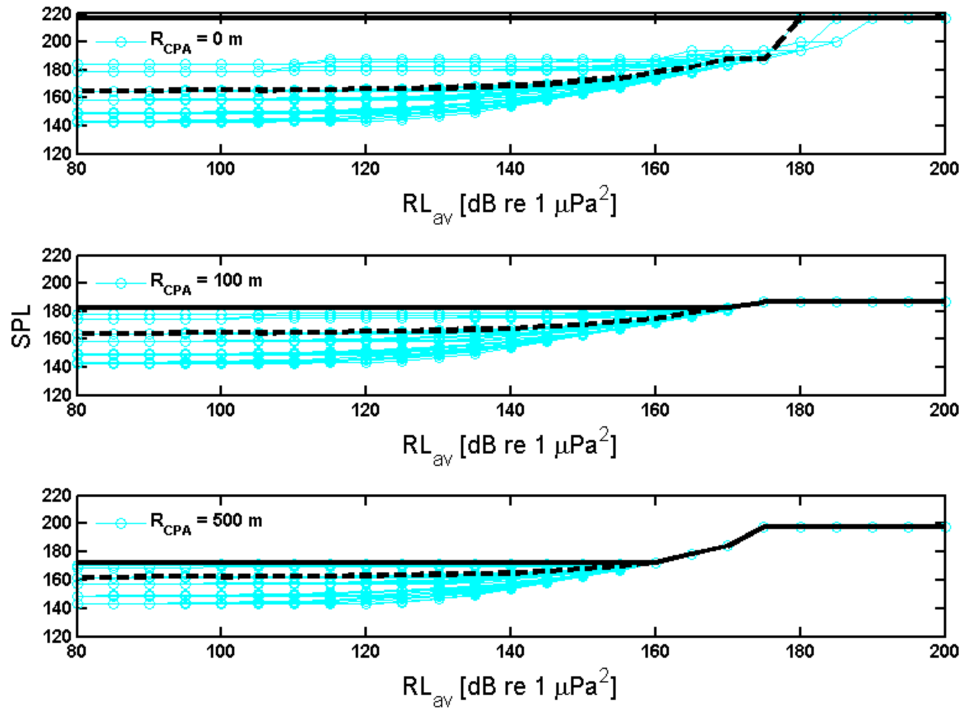


Figure 8: Total SPL (*top*) as a function of reaction threshold for a single animal starting at (CPA) r = 0 m (top), 100 m (middle), and 500 m (lower) away from the point at which the source starts at full power. The distance is along the track of the ship. The black solid lines indicate the no-ramp up scenario. The dashed black line indicates the optimal ramp-up (in terms of area affected with TTS>195 dB).

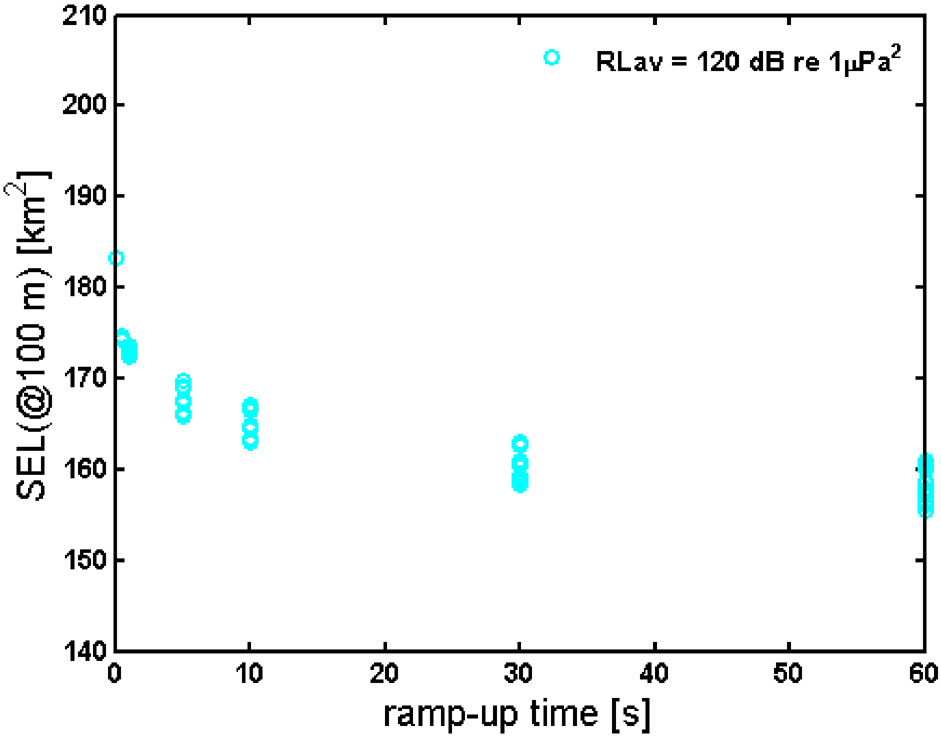


Figure 9: The figure shows the sound exposure level for a single animal starting at 100 m CPA on the trackline, for a reaction threshold of 120 dB. The SEL is strongly decreasing for increasing ramp-up time. The minimum SEL is for a ramp-up time that is operationally not relevant (on same order as total operation).

4.3 Area of avoidance

The increase in area where avoidance is elicited is plotted in Fig. 10 below. The optimal ramp-up is superimposed (gray dashed line) and is almost the same as the no-ramp-up scenario. This means that there is little extra risk on indirect injury in the case of the optimal ramp-up: i.e. most of the avoidance is elicited during the exercise itself.

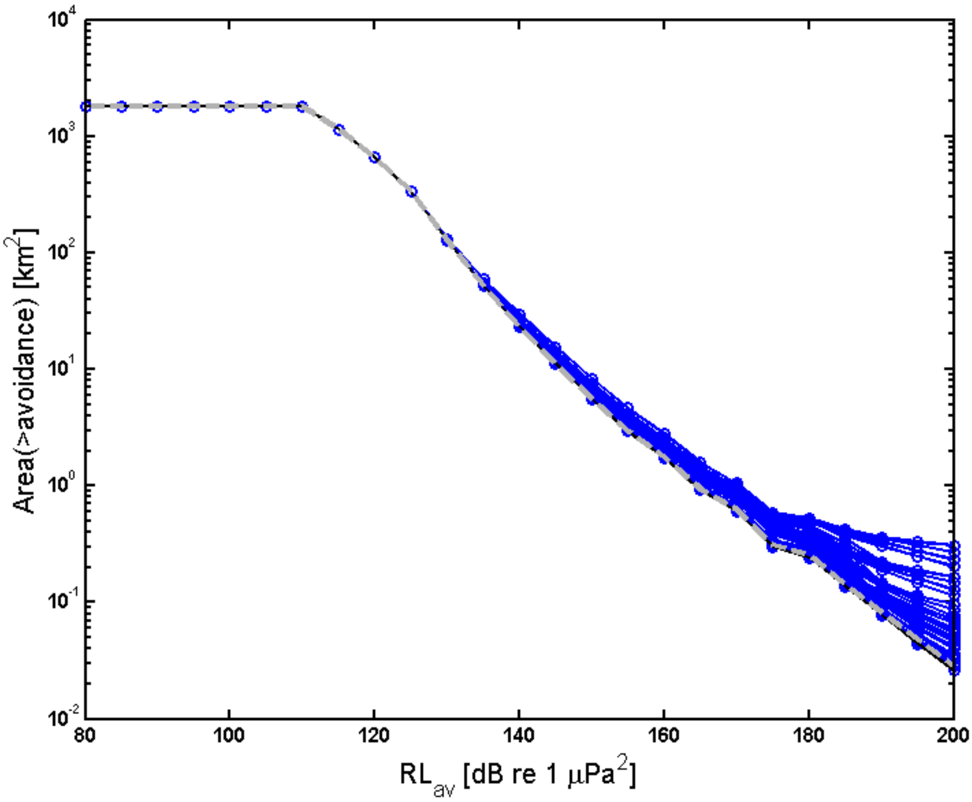


Figure 10: Area where avoidance is elicited for different avoidance thresholds. Each blue line indicates a ramp-up scenario from Table 3. Note that the flattening at RL = 80 – 115 dB is artificial due to the finite size of the model grid. The extra area due to the ramp-up is negligible for most ramp-up scenarios. Only for high avoidance thresholds, the extra area affected can be differing from 10% to 80%. The dashed gray line indicates the most efficient ramp-up scheme. For this scheme the area where behavior is not significantly increased.

5. General description experimental protocol

We will perform the experiments to test 2 distinct hypotheses. The first hypothesis is that animals will avoid the sound source, and that avoidance starts during the ramp-up period. We will use the procedures already proven in 3S to test whether or not avoidance occurs and at which sound pressure level. The second hypothesis is the *central hypothesis* of this work: that ramp-up leads to lower total sound exposure level and maximum sound pressure level because it is effective in allowing animals to move away from the path of a moving source, despite the fact that additional sound is transmitted into the ocean. We will measure both cumulative levels and the level of the single most intense ping, as both of these metrics may be useful predictors of behavioral effects and risk of injury (Southall et al., 2007).
Note that ultimately one would like to demonstrate the beneficial effect on the entire population (or all possible starting positions). This is beyond the scope of the 3S2

experiments. However, the results of the experiments will be used to validate or adopt the assumptions in the behavioral model (response thresholds, duration of the pulse, pulse type, speed, direction and duration of response) presented in Section 4 and the model will then be used to assess the effect on the entire population.

Our proposed method is to simply experimentally recreate the two scenarios shown in figures 11 and 12, below. This protocol entails a process of tag attachment and vessel approach similar as in the other 3S experiments. We will monitor the movement and behavior of Dtagged subjects throughout, starting with a pre-exposure period and then by a silent source vessel passby to control for any immediate effects of the source vessel. It is expected that the vessel approach itself should not cause strong reactions by the tagged animal(s), but the silent passby is critical to conduct first to test how reactive humpbacks might be to the vessel itself. Our experiences in the 3S experiments conducted to date indicate that animals may become more sensitive to the vessel following a sonar exposure. While such an observation is interesting, it is not central to our study to fully describe an order effect of silent (with a non-transmitting sonar) vessel approach. Rather our goal is simply to test whether the vessel itself, in the absence of sonar transmission or history of sonar transmission from the vessel, causes avoidance reactions. Thus, the silent passby should be conducted first in all cases, and not randomized.

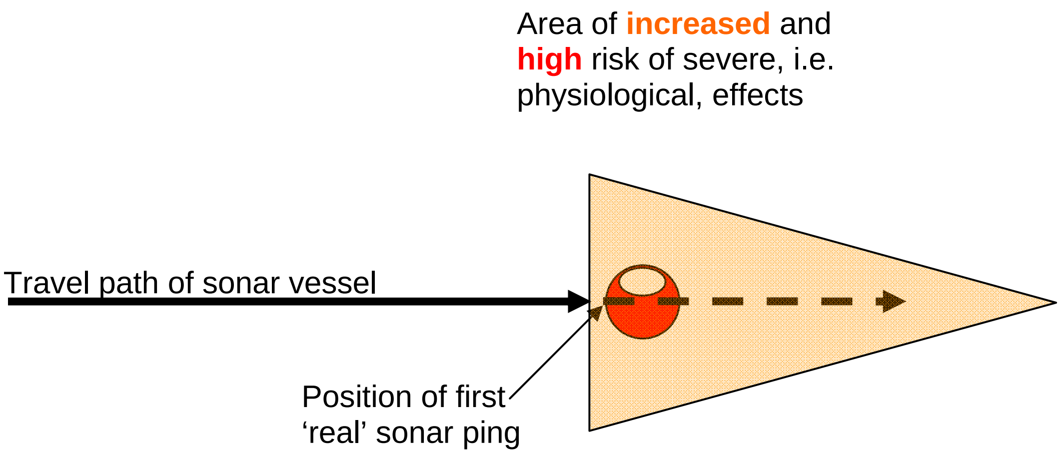


Figure 11. Animals placed near (but *ahead* of) the position of the first full-power sonar transmissions are at a higher risk of hearing injury.

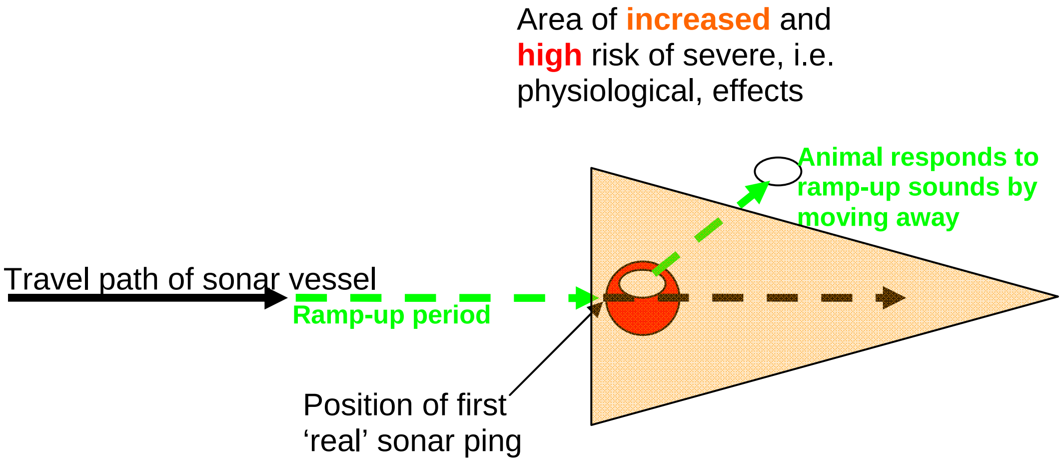


Figure 12. Sonar sounds are started earlier at lower levels and are gradually increased to full power at the planned position. These additional ramp-up transmissions increase the total amount of sound energy transmitted into the ocean, but have the potential to reduce risk by giving animals in the zone of increased risk time to move away.

Following the silent (non-transmitting sonar) passby, two additional passes including transmissions of the 1-2 kHz LFAS will be conducted, one with ramp-up and another without ramp-up (Fig. 13). The order of the two types of passes with transmissions will be changed for each new subject. Each approach will be conducted in precisely the same fashion, with the playback coordinator (blind to the specific exposure signal) maneuvering the vessel so that the Dtagged subject is directly in the path of the vessel. Replicates will be needed to control for the inevitable variation in the location of the Dtagged subject(s) relative to the sonar transmissions. It is expected that we can collect 4-5 of these ramp-up tests per 4-week trial, for a minimum total of 12-15 tests, which should be sufficient to provide advice on the effectiveness of ramp-up.

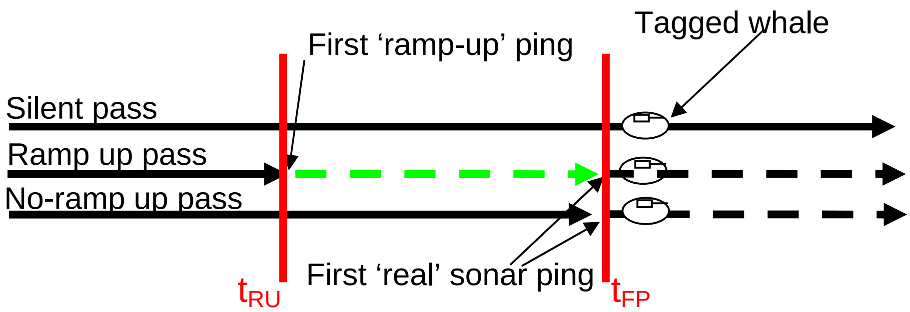


Figure 13. Conceptual diagram of the approach-exposure protocol to be used in the test of the effectiveness of ramp-up. The oval represents a tagged subject whale, and the pointed lines represent the source vessel course. In all three types of pass, the animal is approached as directly as possible, and the course of the vessel is fixed at a pre-determined distance, before the planned start of ramp-up signals. In the silent pass, no sonar transmissions are made. In the ramp-up pass, a ramp-up sequence is transmitted in addition to full-level signals. In the no-ramp-up pass, transmission starts with the first full level ping.

The two red lines in figure 13 indicate two crucial points in space: 1) the distance from the animal when the ramp-up period starts (or would start, in the case of silent or no-rampup passes), and 2) the distance from the animal where the full-power transmission starts (or would start, in the case of a silent pass). To make the passes as similar as possible, the course of the source vessel should not change after t_{RU} (time of ramp-up start) is reached, unless the course imposes a risk of collision. As the speed of the vessel will be fixed, the time and distance from CPA will be related to each other in a straightforward matter.

The following protocol is adopted for approaching the tagged animals:

- see chapter 8

6 Summary

6.1 Conclusions

We investigated the efficacy of ramp-up during an LFAS sonar operation by modeling the risk of direct physical injury. The ramp-up was specifically designed for humpback whales that are target species for the 3S2 trials. From the simulations we conclude the following for the experimental set-up:

- The ramp-up can significantly decrease the risk both in terms of PTS as well as TTS for a population of humpback whales as well as the risk for a single animal with known location.
- For humpbacks the general risk of actual direct physical injury (PTS) is very low (practically zero), unless the full power start is close (~10 m) to the animal and animals are unresponsive (RL_{av} > 160-170 dB re 1 μPa^2). Typical avoidance thresholds from the literature appear to be well below these values (RL_{av} ~ 120 – 140 dB)
- An optimal ramp-up was chosen based on the impact area of TTS for humpback whales. This choice was made because the risk on PTS is below simulation resolution.
- For a single animal at CPA = 100 m, the optimal ramp-up (in terms of Area(TTS) for the humpbacks) provides a drop in SEL and maximum SPL of approximately 10-15 dB compared to the no-ramp-up scenario. These are the actual values that are expected to be measured during the 3S ramp-up experiment.
- The difference in SEL/SPL between ramp-up/no-ramp-up can be increased for a single animal by increasing the ramp-up time. However, the ramp-up time becomes too long to be operationally relevant, and also increases the exposure to the total population (more animals affected).

- The optimal ramp-up leads to only a small increase (~1%) in area where animals are affected. I.e. the *increase* of risk of inducing *indirect* injury through e.g. DCS is likely to be small.

6.2 Ramp-up scheme for use during the 3S2 experiments

Based on our operational limitation and considerations of naval operational relevance as well as the above analysis we arrive at the following ramp-up scheme to be tested on humpbacks during the 3S-trials. This ramp-up was found to theoretically minimize the overall risk on receiving TTS (and PTS) to a humpback population under the conditions of the experimental set-up.

The transmission program during the ramp up experiments is depicted in Figure 14. Tables 5 – 6 summarize the parameters adopted for the experimental set-up.

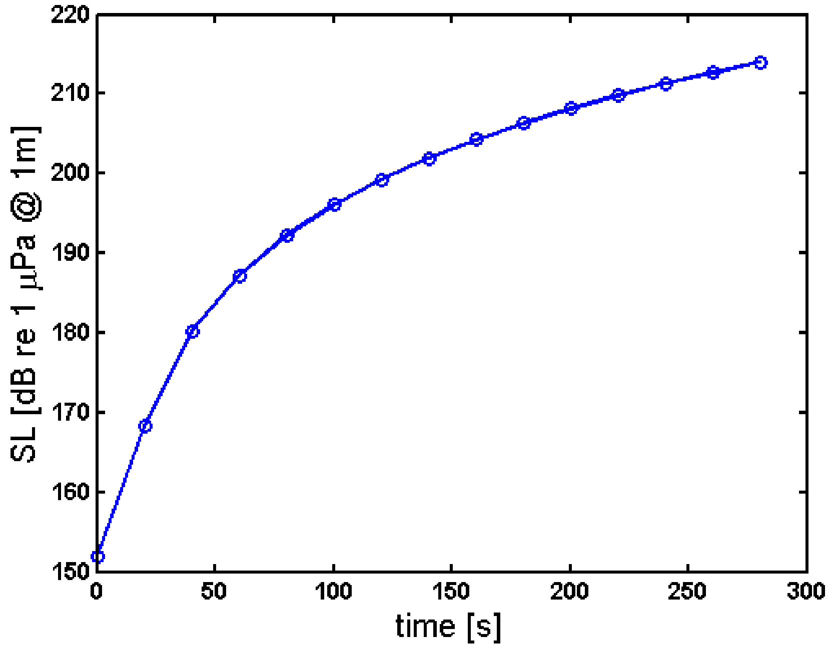


Figure 14: Optimal ramp-up scheme for 3S2 experiment with humpback whales.

Table 5: Ramp-up parameters for the 3S2 experiment with humpback whales

Parameter	**values used**
T_{ramp} (ramp-up time)	300 s
n_{ramp} (steepness)	4
PRT (pulse-repetition time)	20 s
T_{pulse} (pulse duration)	500 ms
HFM up-sweep	1.3-2 kHz
SL_{max}	214 dB re 1 μPa^2m^2s (@ 1m)
SL_{min}	152 dB re 1 μPa^2m^2s (@ 1m)
v_s (ship speed)	4 m/s (~ 8 knots)
v_m (mammal avoidance speed)	1 m/s (~2 knots)
T_{pulse}	0.5 s

After the ramp-up we will immediately switch to full power, still considering operational relevance:

Table 6: Operation

parameter	**values used**
T_{op}	5 min*
SL_{op}	214 dB re 1 μPa^2m^2s (@ 1m)
PRT_{op}	20 s
T_{pulse}	1000 ms (including two 50 ms ramps)
v_s (ship speed)	4 m/s (~ 8 knots)
HFM up-sweep	1300-2000 Hz
tow depth	Minimal 60 m, because of cavitation limitations

7 Decision points: experimental protocol

- ✓ Tagging

We will tag as many animals per tagging period as is practical. Whether we decide to stop tagging after a tag-on depends mainly on 1) the quality of the attachment, and 2) our ability to track the animal(s).

* the experiment will stop 5 minutes after reaching full power. The 1 hr is what the model assumed when assessing the reduction in risk.

How long post-tagging before start approach? What is the logic?

- if DTag 3 GPS not available, GPS tags + DTag would be useful (critical?) for tagging multiple animals, given that tracking boat is untested.
- Use 1 hrs principle for post-tagging if multiple individuals can be tracked.
- Probably long pre-exposure good to characterize movement.
- Post-exposure less critical in ramp-up experiment?

<u>CPA estimation</u>

The times t_{RU} and t_{FP} are based on the estimated closest point of approach (CPA) of the vessel to the whale. Therefore, the CPA has to be known before t_{RU} is reached. As the CPA will depend on the sightings of the whale, we will determine the CPA while we are approaching the animal (as we have been doing during regular 3S experiments).

The predictability of the movements of the tagged animal is important to get a reliable CPA. We can decide to base the method of CPA estimation on the behavioral state of the animal, or decide to only start an experiment when animals are showing (or not showing) a certain type of behavior. For instance, when animals are feeding on one location (e.g. while bubble-net feeding), the last sighting of the whale before t_{RU} can be used as CPA. When animals are travelling between feeding areas, or migrating, and are on a very directional path, it could be most useful to estimate CPA from the speed and heading of the whale. We are also likely to encounter whales that forage on euphausiids (Stevick, 2006). Because such animals may show more ‘patchy’ feeding behavior, it may be necessary to break off approaches or make extra turns before starting the final pass.

- we need a tool to predict the future position of the whale based on previous sightings.

- in both runs (no-ramp up/ramp-up) full power starts at this CPA position at t_{FP}.
- The position of the whale is estimated by extrapolating the last whale sightings forward in time to t_{FP}.
- The CPA = 0 m position is estimated as the most-likely location of the whale at start of full power t_{FP}. Due to the uncertainties in whale movement, it is unlikely that the whale will be at exactly that location, but will optimize the proximity to the whale at t_{FP}.
- at t_{RU} minutes the ship heading is fixed toward the location where it is expected that CPA will be obtained at t_{FP}.
- collision and sonar mitigation procedures should be in place for the case when the source closely approaches the whale by $R < R_{mit}$.
- the no ramp-up approach will not be performed in the first year (or only at the end?). The results from the ramp-up experiment from the first year will be used to assess the risk of doing the no ramp-up approach.

Distance to whale at full power

The ramp-up procedure is designed to reduce the risk of causing injury in nearby animals, thus we want to be fairly close to the whale and approaching it at this point during the "no ramp-up" pass. We do not want the whale to actually receive levels that can cause injury, however this seems unlikely because the SPL @ 100 m from the source is down to ~174 dB (based on SL=214 dB and 20 log R). At these short distances, it is important to think in terms of distance from the source and not from the ship..

When we consider cumulative SEL to be more important than maximum SPL, it may be worse for the animal to have full power transmission starting before CPA. Another argument to start slightly before is that, because we are moving towards the animal, starting pinging behind the animal (due to uncertainty in whale position) would cause a much lower maximum level. Thus the variation in maximum level received will thus be larger in the full power dataset.

- ✓ Angle of approach

As before in 3S, our goal is to approach the subject animal head on because then avoidance behavior is the most clear. Because the direction of movement of foraging humpbacks may be less predictable, we do not consider approaching head on to be an absolute requirement.

- ✓ Whale swim speed

For travelling humpback whales, the reported mean horizontal speed is typically between 3 and 5 km/h (0.83 – 1.39 m/s). For example, 4 km/h for non-singing humpbacks migrating along the coast of Australia (Noad & Cato, 2007), 3.6-5.4 km/h for humpbacks migrating along the East coast of South-Africa (Findlay 1994), 2.6-4.0 km/h in the presence of commercial shipping in Alaska (Baker et al 1993), and 3.0 and 4.5 km/h in the absence and presence of whale-watching vessels off the coast of Ecuador (Scheidat et al., 2004).
We will use a swim speed of 1 m/s in the ramp-up modelling work and for other initial calculations, but this value will be updated based upon our data collection in 2011.

- ✓ Surface-active behavior

Humpback whales are famous for their surface-active behaviors (e.g., Stamation et al 2010 for a list). Some of these may be related to vessel presence, sound exposure, annoyance, etc. The observer protocols will be updated to include surface-active behaviors that are specific for humpbacks.

Dual tow

The Captas or Delphinus array may provide useful information on the whale location or potential vocal responses, but also may limit maneuverability and our ability to work in shallow water (array needs to be below the source).

Duration of full power transmission

We maintain a 5 min rule (stop transmission 5 min after passing the animal).

Collision safety procedure

t.b.d.

8 Decision points: ramp-up scheme

A ramp-up scheme must be defined according to its; total duration, speed of source ship, signal bandwidth, signal waveform, signal duration, pulse repetition time, initial source level, and rate of increase of source level.

Pulse duration
The hearing integration time of most mammals for tones of ~1 kHz is about 200-500 ms, meaning that longer signals have more energy but will not be perceived as louder. If avoidance is mostly related to loudness or SPL, but injury is related to sound energy or SEL, shorter signals may be less likely to cause injury.
During the experiment, a pulse duration of 500 ms will be adopted. This choice is adopted because

> 1) 200ms is based on the detection of pure tones (1 critical band) while the 1-2 kHz signal covers multiple bands. This may increase the integration time needed to obtain the same level of loudness. The detection threshold of a harbor porpoise for a LFAS signal was higher than for 1 or 2 kHz pure tones, possible because of this mechanism (unpublished).
>
> 2) For the same harbor porpoise integration times of 277-629 ms were found

These integration times are indeed for hearing threshold levels; temporal integration (or 'summation') of loudness above threshold is possibly slightly faster (for humans - unknown for cetaceans) but is still comparable. A pulse duration below 200 ms would be unwise because there is a good chance the loudness will be affected. We chose 500 ms to be on the safe side (and because results from human studies are not unambiguous).
The simulation results were performed for 200 ms pulse lengths. However, the results scale with the pulse duration, and we do not have to redo the simulations. The results will lead to 3dB (~factor 2) extra SEL. This translates to a factor of roughly $10^{3/20}$ ~ 1.4 in impact range.

Pulse-repetition time
There is a tradeoff between short and long PRT. If a short PRT is adopted, animals will not have the time to move a significant distance between two transmissions and the energy will only add to the SEL without being beneficial. If the PRT becomes too long,

animals may not respond to previous transmissions, and will not contribute to the position at the start of the operation.

A PRT of 20 sec resulted in the lowest predicted exposure,, given the modelling assumptions.

Note however that the model considers a mximum of PRT = 20 sec. Larger PRT may lead to even lower risk, however the price of breaking the information flow to the animal is not included in the model, so a maximum of 20 sec is chosen to be on the safe side.

Vessel speed and direction

Influences among others the time of CPA (and thus t_{RU} and t_{FP}) and the uncertainty of the whale position at CPA. A fixed velocity is desirable to keep the approaches as similar as possible. A speed below 10 knots reduces the risk of collision (Vanderlaan & Taggart, 2006).

We will use a vessel speed of 8 knots and fixed direction.

Source depth

Technically not part of ‘ramp-up’ scheme but dependent on vessel speed. Because the speed is fixed we have to be extra precise in determining the length of the tow cable (figure 4).

In sound channel (if any)

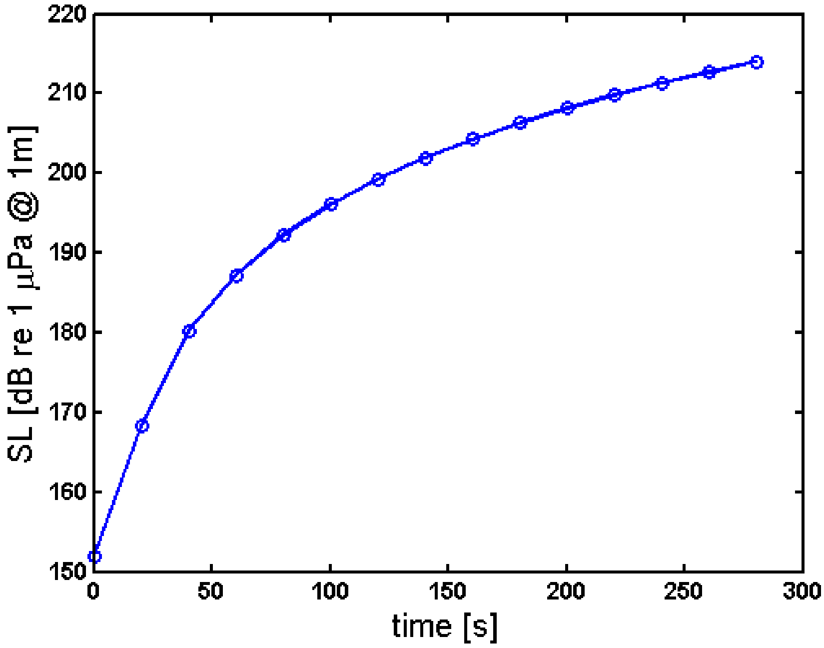
Ramp-up time/duration

Depends directly on which distance we want to start the ramp-up. A long ramp-up increases the uncertainty of the CPA, which means the full-power point has to be further away from CPA.

A ramp-up time of 5 minutes provides lowest risk.

Rate of increase of source level (shape of ramp-up)

n_{ramp} = 4, this gives the following ramp-up scheme:



Initial source level

We will use as an initial source level the lower limit of the Socrates system, SL_{in} = 152 dB re 1 µPa @ 1m.

Signal bandwidth

LFAS (1.3-2 kHz)

Signal shape

Hyperbolic upsweep

Appendix G 3S^2 2011-2014 evaluation of alternative field sites within Norwegian waters

Please cite this document as:

Kleivane et al. (2011). 3S^2 2011-2014 evaluation of alternative field sites within Norwegian waters. In: *Kvadsheim et al. (2011). Behavioural response studies of cetaceans to naval sonar signals in Norwegian waters* **-** *3S-2011 Cruise Report. FFI-rapport* ***2011/01289***

$3S^2$ 2011 – 2013

EVALUATION OF ALTERNATIVE FIELD SITES AND PERIODS WITHIN NORWEGIAN WATERS

Kleivane, Nordlund and Kvadsheim (FFI, March 2011).

One of the $3S^2$-target species the minke whale "captured" during 3S-2009 by Paul Ensor.

Introduction

The 3S group has conducted three research trials (2006, 2008 and 2009) in Norwegian waters to investigate behavioural reactions of killer whales, pilot whales and sperm whales to naval sonar signals. With the additional study of baseline behaviour planed for 2010, we can hopefully draw conclusions on the effects of sonar on these species. Following up the previous success, the 3S consortium has initiated a proposal to conduct similar CEE trials on three new species in the period 2011-2013 ($3S^2$). The $3S^2$ will focus on the baleen whale species minke whale and humpback whale, due to their biology and the lack of knowledge related to behavioural responses to sonar signals, and the northern bottlenose whale which belongs to the Ziphiidae family and therefore might be particularly sensitive to anthropogenic noise, as some of the other species of this taxonomic group.

Conducting behavioural response studies is an expensive and complicated operation involving heavy logistics, operation of sophisticated equipment and arduous collection of behavioural data of the target species. Limiting factors in these operations are availability of animals of the target species, daylight and weather condition. The aim of this note is to summarise the available information of weather condition and target species abundance as a basis for decisions on the optimal choice of field site and period for the upcoming $3S^2$-trials in 2011-2013.

Decision Criterion

The optimal $3S^2$ field site and period will be decided based on (in order of importance);

a) expected abundance of targets species in area/period.
b) weather condition, particularly wind in area/period.
c) number of daylight hours in area/periods
d) sailing distance to area from mainland port.
e) expected external logistical support (repair, supplies, crew change etc) in area.
f) other supporting activities in area/period (research, whale watching, whaling, fishing etc).

Methods

Period

The experience from 3S-06 implies that at these latitudes daylight hours becomes a critical factor in the winter. In addition, all three target species have a seasonal migration patterns which implies that their appearance in Norwegian waters is more or less limited to the summer months (April to September). The analysis is therefore limited to the April to September period.

Areas

Knowledge of bottlenose whale habitats in Norwegian waters is limited. We therefore consider this a particularly critical factor to consider. Benjaminsen (1972) presented bottlenose whale catch statistics from Norwegian whalers in the period 1938-1972, and the main catch areas are typical bottlenose whale habitats. We have therefore chosen to use the traditional bottlenose whale catch areas described in Benjaminsen (1972) to define potentially good field sites for bottlenose whale studies. The four areas, Tromsø, Møre, Jan Mayen and Svalbard, are analysed as candidates for the $3S^2$-trials (fig.1).

Animal abundance

General information of feeding areas of the target species is collected from SONATE, but originates from the Institute of Marine Research (IMR). In addition available sighting data of the target species is also compiled. These data is primarily collected from the national (Norwegian) database of marine mammal sightings kept by IMR. This database contains all recorded sightings, including whale surveys, from the period 1967 to 2008. In addition, since minke whale is a target species, minke whale catch data from the period 1993 to 2007 is collected from the Directorate of Fisheries. For Bottlenose whale we have also collected sighting data from the Icelandic sighting database. By compiling all datasets together we have achieved the best available monthly overview from April to September of target species abundance in the different potential $3S^2$-field sites. However, catch and sighting data are not effort corrected and this might bias the representation of animal abundance in the different field sites, and this is very important to keep in mind.

Weather

Sea state, wind and visibility are limiting factors in whale tagging operations. We have collected weather statistics from shore stations of the Norwegian Metrological Institute (fig 1). The weather prognoses are based on 10 years of measurements from the weather stations close to the potential field sites (fig 1). However, these stations are unprotected shore stations while the operation areas are mainly off-shore. This might limit the reliability of the analysis but it still the best available basis for weather prognosis. The wind speed is assumed to reflect sea state, and 0-5m/s is considered good working conditions, 5-10m/s difficult working conditions and >10m/s no working condition. The visibility often changes from the shore towards open ocean and thus, shore station observations are not a good predictor of off-shore conditions.

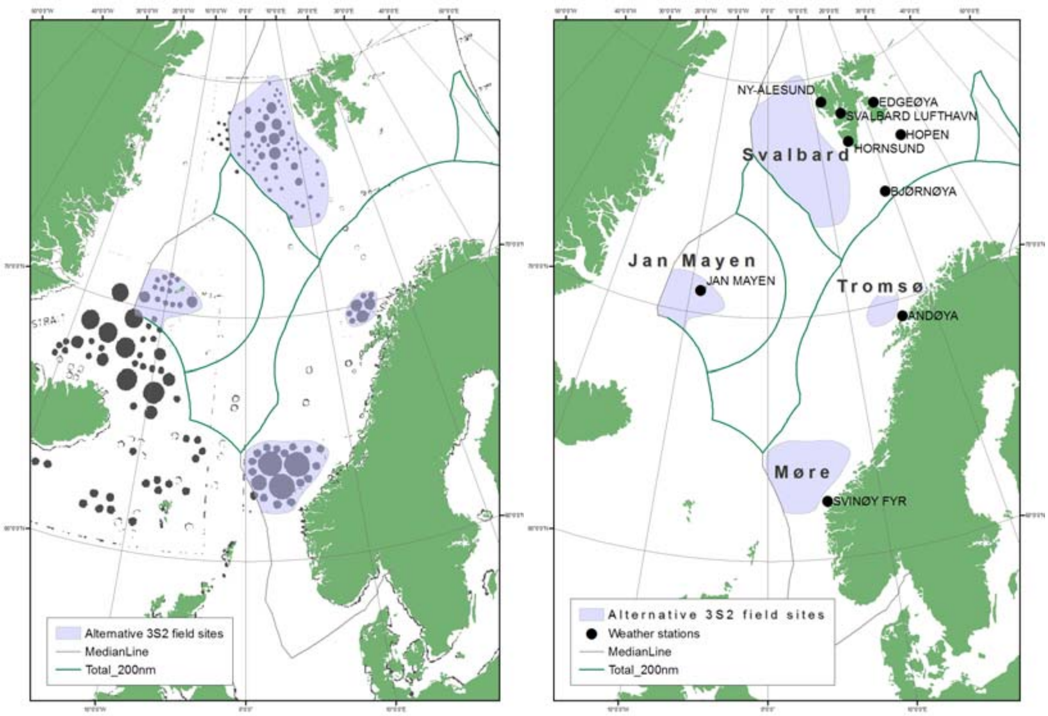


Figure 1. Left: Black dots represent bottlenose whale catch data 1938-1972 from Benjaminsen (1972). Based on the catch statistics four potential 3S² field sites are defined (blue shaded areas). The Norwegian jurisdiction zone is also indicated and limits the extent of some of the sites. Right: The 3S² field site candidates indicated in blue shading and the positions and names of the weather stations used in the analysis of weather prognosis.

Supporting activities

Information on fishing activity and whaling is collected from SONATE, but originate from the Norwegian Directorate of Fisheries. This type of activities in the operation area, might constitute a valuable real time sighting network, which could support us in finding animals on site.

Other factors

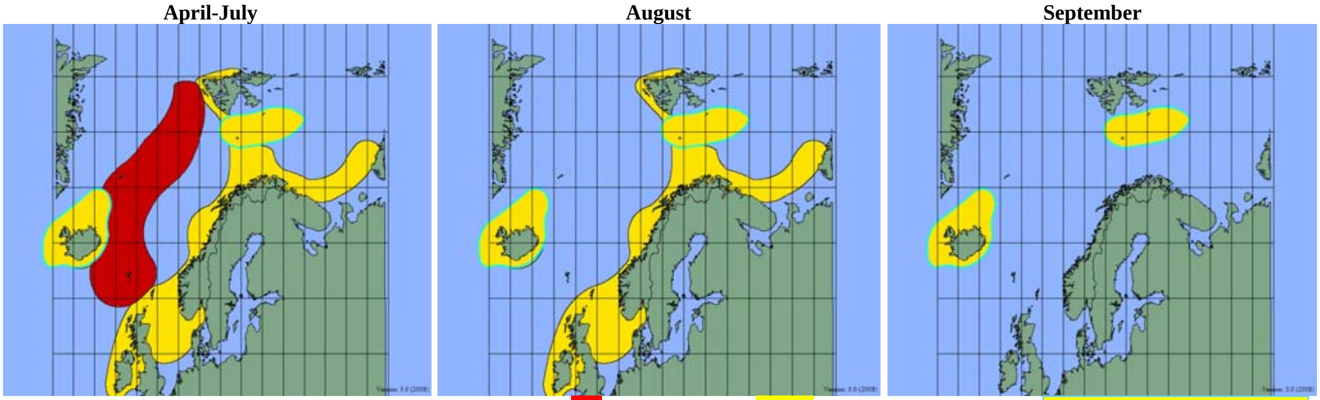
The sailing distance from a mainland port to the operation area, the availability of local ports for crew changes, supplies and logistical support is also considered as part of the evaluation, but with less emphasise than animal abundance and weather condition.

Results

All data available have been compiled and structured in monthly records from April to September.

Animal abundance

April-July August September



<u>Figure 2.</u> Current known feeding areas of Bottlenose whales (red), minke whales (yellow) and humpback whales (yellow with turquoise border)

<u>Minke whale</u>

Of our three target species, the best available documentation is on the minke whale. This baleen whale is the most abundant whale in North East Atlantic waters, arriving Norwegian waters in early spring during northwards feeding migrations, and leaving higher latitudes in autumn. This implies increasing numbers of animals from April to June and decreasing numbers in August and September (Fig. 3-5). Although the minke whale usually is a solitaire animal, feeding aggregations are often documented during their northwards migration, and they are likely to be found both off the continental shelf in deep waters and in coastal waters. They have a prey preference for herring and capelin in Norwegian waters and abundance of these prey species would be a good indirect indicator of potential presence of minke whales. In the catch records, the majority of animals caught in Jan Mayen and in Svalbard waters are adult females, while the catches from the Vestfjorden area are smaller and juvenile animals. Off Tromsø and Møre the catch records show mixes of sexes and ages. Juveniles are known to actively seek boats more frequently than adults, and might also be easier to tag. The Vestfjorden area would be available as a back up area if operating in the Tromsø area, but with a significant sailing transit compared to the 3S-trials.

<u>Northern Bottlenose whale</u>

The historical date on the catches of the Northern bottlenose whale (Benjaminsen and Christensen, 1979) indicate a northward seasonal feeding migration from Icelandic waters starting in April. This implies increased records off Jan Mayen from late April to early June (fig 3-5), continuing with increasing registrations northwest of Bear Island and west of Spitsbergen during May and June. However, from July few recordings of the northern bottlenose whale have been documented from these northern waters, and Benjaminsen concluded also that the majority of northern bottlenose whales seemed to leave Svalbard waters before the end of June. Minor catches have been made off the coast of Norway, in the Tromsø and the Møre sites in

September, October and November, indicating that evidently some individuals postpone their southward migration out of the Norwegian Sea to later in the autumn. The northern bottlenose whale avoids shallow waters such as the continental shelf, the Barents Sea and the North Sea, and prefers waters deeper than 1000 meters. In the North Atlantic the squid Gonatus fabricii seems to be the main diet of the northern bottlenose whale, and a recent publication (Bjørke, 2001) indicate concentrations of this prey during summer at old catching areas outside Tromsø and Møre. There are also registrations of this squid west of Bear Island and north of Jan Mayen. However, there are no indications of Gonatus fabricii at the right size west of Svalbard.

The bottlenose whales are most frequently seen in groups of 2-4 animals, however, according to Munsterhjelm (1915) they were seen mainly as single animals or pairs in waters west of Svalbard in May, but the number of whales in each group increased trough the summer. Apart from historical catching data of 5043 northern bottlenose whales in the period from 1938 to 1972, there are relatively few recordings of this species in North Atlantic waters during the last 4 decades.

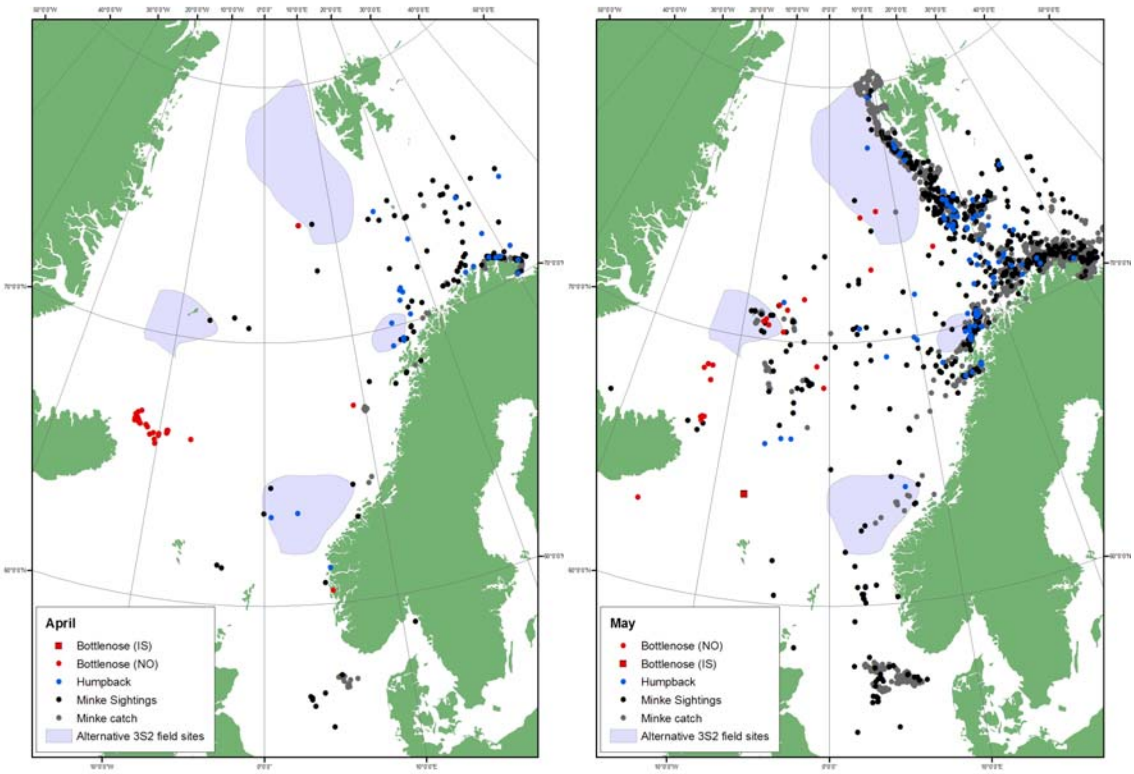
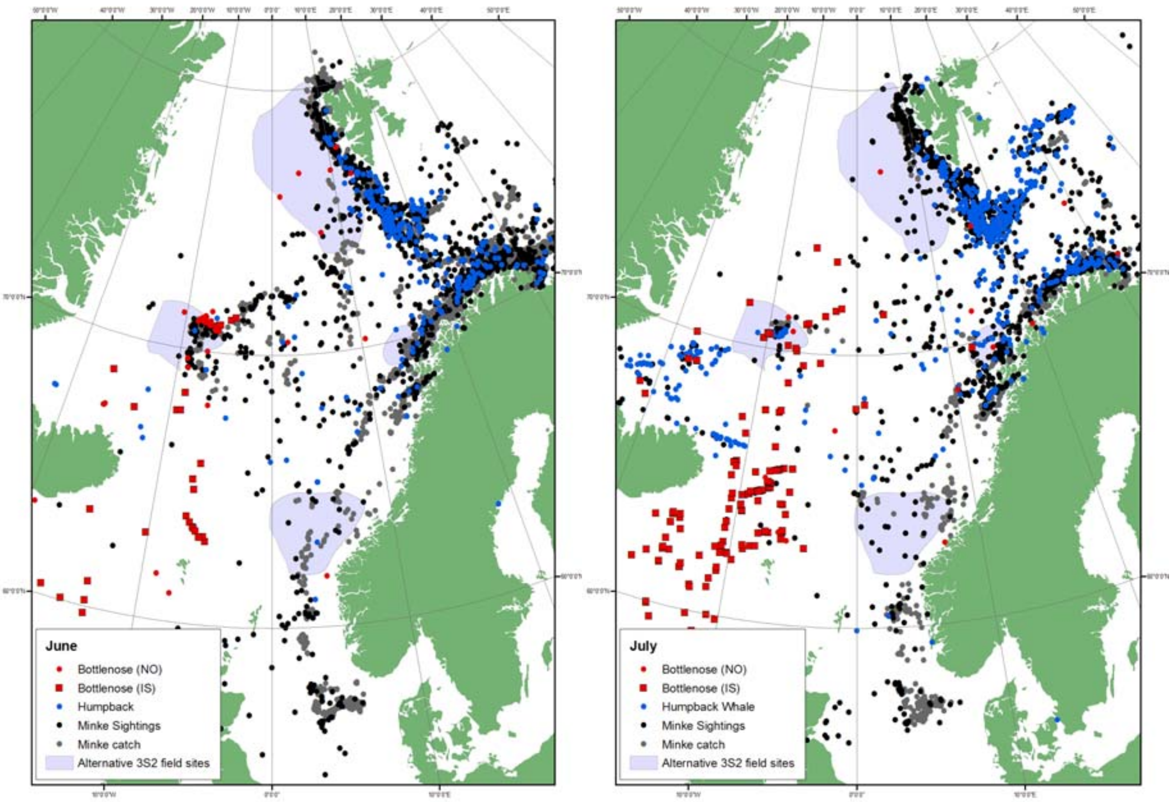


Figure 3. Recorded positions of Minke whale catches, and sightings of Bottlenose whales, Humpback whales and Minke whales. Bottlenose whale data are collected from both Norwegian and Icelandic records. Left; April. Right; May.

Humpback whale

The humpback whale is also a migratory species arriving in Norwegian waters in late spring. As for the other two species little information on their large scale migration is available. However, compared to the minke whale it seems like the humpback whale have a more eastern migration route into higher latitudes, with increasing records both in coastal waters of northern Norway, around Bear Island and SW of Svalbard, from May to June (Figure 3-5). Moving into July and August, the highest numbers of humpback whales have been recorded in waters around Bear Island, north to Svalbard and further NE of Bear Island north to Hopen Island and further east into the Barents sea. Feeding aggregations have been associated with the copepod *Calanus finmarchicus* and capelin, and the migration and presence of older age classes of capelin is a probable key factor in the autumn movements of humpback whale in the Barents Sea.



<u>Figure 4.</u> Recorded positions of Minke whale catches, and sightings of Bottlenose whales, Humpback whales and Minke whales. Bottlenose whale data are collected from both Norwegian and Icelandic records. <u>Left;</u> June. <u>Right;</u> July.

Weather

According to the weather prognosis of the Bear Island area and the waters west of Svalbard the number of days with wind forces less than 5m/s is increasing from April to July, and then decreasing again (fig. 6). During June the prognoses indicate 50% or more of these excellent conditions. However both May, June, July and August are comparable and thus the period May to August is expected to offer good working conditions in the Arctic field site (Fig. 6). Compared to the Arctic areas both the coastal field site off Tromsø and Jan Mayen offers less favourable conditions. However, the summer months of June to August still offer acceptable weather conditions in these areas, while the risk of long term bad weather appears to be much higher in the Møre area.

Sailing distance and logistical support

The sailing distance from mainland ports were the installation of the heavy equipment have to happen is obviously much shorter for the coastal field sites (Tromsø and Møre) than for the Svalbard and Jan Mayen alternatives. The sailing distance from the port of Tromsø to Bear Island is about 24 h, but to Jan

Mayen it is almost twice this distance. The opportunity for logistical support during the operation will also be much better in the coastal field sites, than for the remote ones. After leaving the installation port, no external logistical support could be expected if we are operating in the Jan Mayen area. Neither crew changes. In utter needs or emergencies, Icelandic ports could be used. At Svalbard there is an airport with regular every day flights (Longyearbyen), and thus there is the possibility of doing crew changes or having equipments shipped in during the operation. However, if operating in the southwestern part of this operation area, we will loose almost 48 hrs on a trip to Longyearbyen.

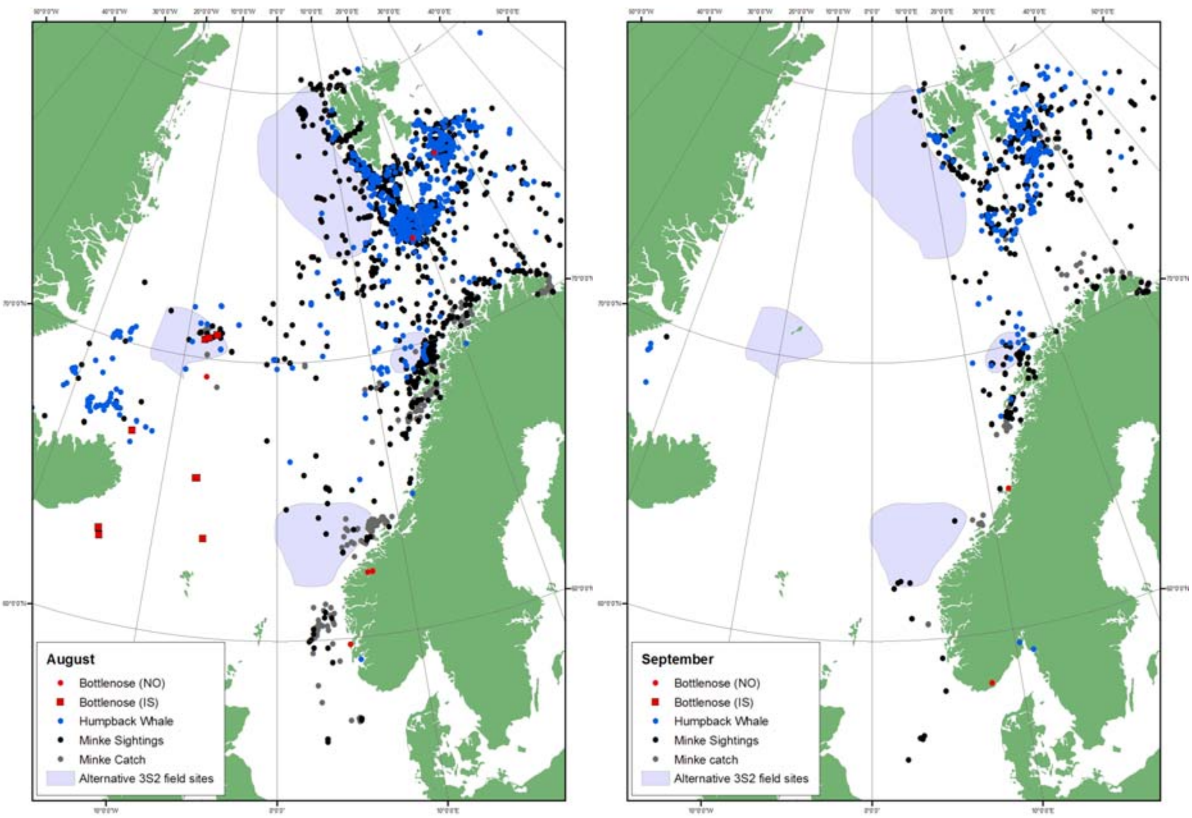


Figure 5. Recorded positions of Minke whale catches, and sightings of Bottlenose whales, Humpback whales and Minke whales. Bottlenose whale data are collected from both Norwegian and Icelandic records. Left; August. Right; September.

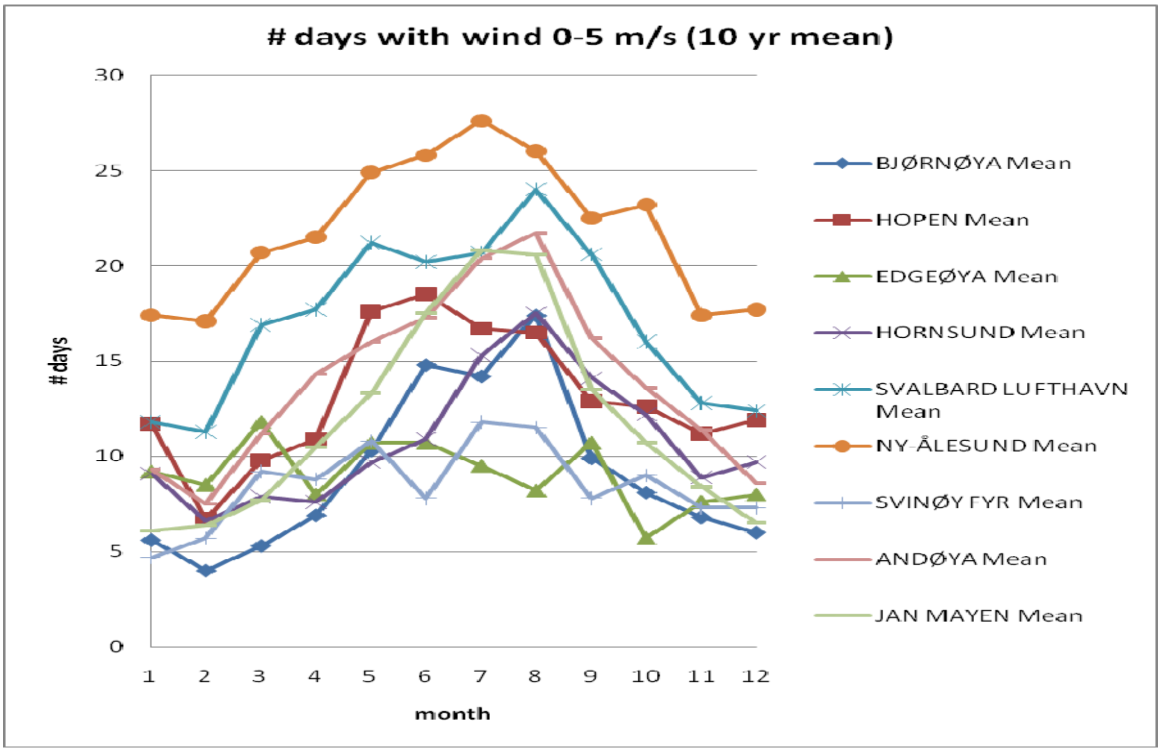
Numbers of daylight hours

Table 1. Number of daylight hours at different months and in the different alternative field sites.

Period	Møre 63°N	Tromsø 70°N	Jan Mayen 71°N	Svalbard 72°N	Svalbard 80°N
Mid April	15 h	16 h	16 h	17 h	24 h
Mid May	18 h	21 h	24 h	24 h	24 h
Mid June	20 h	24 h	24 h	24 h	24 h
Mid July	19 h	24 h	24 h	24 h	24 h
Mid August	16 h	17 h	18 h	20 h	24 h
Mid September	12 h	13 h	13 h	13 h	13 h

Other supporting activities

In the coastal area off Tromsø there is both whale watching, whaling and a relatively high numbers of fishing vessels which could be used to establish a sighting network to support the search for whales. In the Møre area there will also be a limited numbers of fishing vessels which could be used in a similar manner. In the Bear Island and Svalbard area there is usually a fleet of about 10-15 whaling vessels and a few off shore Norwegian coast guard vessels, which could be requested to assist in finding whales. Other than this, we are mostly left alone in this large open ocean. Sailing to Jan Mayen,…..is to be alone!



<u>Figure 6.</u> No of days with average wind less than 5m/s (good working conditions) from weather stations close to the potential field sites (fig. 1). Data are given on a monthly basis and are presented as mean values from the past 10 years.

FFI's evaluation of alternative field sites

The main purpose of this document is to present the best available and relevant information as a basis for a decision within the 3S-group on the optimal selection of field site and period for the $3S^2$-trials. However, we here present our judgments as a starting point of this discussion.

The decision factors are listed on page 2 (abundance of targets species, weather condition, number of daylight hours, sailing distance, external logistical support and other supporting activities in area). The most important factors are the abundance of target species and weather condition. For all alternative field sites and months the factors are classified as best solution, second best solution, acceptable solution and non acceptable solution (table 2).

Periods

Because of the late arrival of the baleen whales into Norwegian water, and the early sortie of the bottlenose whales, April and September is considered to have non acceptable numbers of one or several of the target species. This is also the months with the most unstable weather and fewest numbers of daylight hours. May and June appears to be the best compromise to optimize animal abundance of the different target species in most areas, and this is also the best weather months in most areas.

Areas

Jan Mayen in June might the best solution for bottlenose whales, and even though it is not the first choice, this area is expected to also have acceptable numbers of minke whales. The biggest concern with Jan Mayen is the availability of humpbacks, as well as more unstable weather conditions than other sites. In addition to wind, Jan Mayen is also famous for it's fog. When the wind finally calms down the fog often thickens instantly. Other factors such as sailing distance and support also speaks against Jan Mayen.

Table 2. Evaluation of field sites and periods. Each of the four sites and each of the 6 alternative months are for each decision factor categorized as the best solution (B1), the second best solution (B2), an acceptable solution (A) or a non acceptable solution (Non).

	Jan Mayen						Møre						Adenes						Svalbard					
Criteria	April	May	June	July	Aug	Sept	April	May	June	July	Aug	Sept	April	May	June	July	Aug	Sept	April	May	June	July	Aug	Sept
Minke whale	Non	A	A	A	A	Non	Non	A	A	A	A	Non	Non	A	B1	A	A	Non	Non	A	B2	A	A	Non
Humpback whale	Non	Non	A	A	A	Non	Non	Not	A	A	Non	Non	Non	A	A	A	A	Non	Non	A	A	B1	B2	Non
Bottlenose whale	Non	A	B1	A	Non	Non	Non	A	A	A	Non	Non	Non	A	A	A	Not	Non	Non	A	B2	A	Non	Non
Weather	Non	Non	A	A	A	Non	Non	Non	Non	Non	Non	Non	A	A	A	A	A	A	A	A	B2	B1	A	A
Logistical suport	A	A	A	A	A	A	B2	B2	B2	B2	B2	B2	B1	B1	B1	B1	B1	B1	A	A	A	A	A	A
Sailing distance	A	A	A	A	A	A	B2	B2	B2	B2	B2	B2	B1	B1	B1	B1	B1	B1	A	A	A	A	A	A
Supporting activities	A	A	A	A	A	A	B2	B2	B2	B2	B2	B2	B1	B1	B1	B1	B1	B1	A	A	A	A	A	A
Total	Non	Non	A	A	Non	Non	Non	Non	Non	Non	Non	Non	Non	**A**	B2	A	Non	Non	Non	**A**	B1	A	A	Non

Møre is expected to have acceptable numbers of all target species in June and July, but is not the first choice for either. The numbers of recent bottlenose whale sightings are also few. Møre is favoured by the secondary factors such as sailing distance and support. The biggest concern with this area is the weather condition which appears to be more unstable than for any of the other alternative sites. Møre is also the only area without 24 hours of working daylight even at summer solstice.

Tromsø is expected to have acceptable numbers of all target species in May to July, and this area in June is considered the best solution for minke whales. The priority of this area before the arctic area, which is expected to have a high density of minkes as well, is primarily the presence of smaller minke whales in this area, and the assumption that these animals are easier to tag than the larger animals further north. However this assumption might only be true in the Vestfjorden basin, not the off shore area 50-150 nmi off the coast, which is were we expect to find bottlenose whales. The Tromsø area is also the most favourable one regarding sailing distance and support.

Svalbard has highly acceptable numbers of all target species between May and July. This area is however, also the largest area considered, extending over 300 nmi from NW to SE. It consists partly of relatively shallow areas on the Barents Sea shelf, and partly of very deep areas off this shelf West of Spitsbergen and Bear Island. The area around Bear Island is probably the best solution for humpbacks. The timing of arrival of humpback whales in the Bear Island area may be critical, and resent findings indicates later arrivals of this species into both July and August. However, most data indicate that the majority of northern bottlenose whales have left higher latitudes in late June, and we therefore compromise on June as the optimal period for the $3S^2$ trials. This area and period is also a very good solution for minkes. Considering all three species this area in June is probably the optimal compromise between the different periods and areas. However, bottlenose whales are expected to be found in highest numbers in the deep western part of this area, whereas humpbacks are found in highest numbers in the more shallow eastern part. Minkes are expected to be found throughout the area. It is therefore probably necessary to move about within this large area to optimize chances of finding all the target species. A more detailed strategy of how to utilize this area in an optimal way and how to balance species priorities need to be established. More details of the dynamics of important prey species (*Gonatus fabricii, Calanus finmarchicus* and capelin) would be important input to this discussion. In the summer months, this arctic area is also the area were the weather condition is expected to be most favourable and stable, but local variations in weather conditions within the area is another important factors determining the operational strategy. Svalbard also has acceptable conditions in terms of sailing distance and support.

Conclusion

The best choice of field site and period is different for all three target species. However the large Arctic field site from Bear Island to Svalbard offers the most favourable weather conditions and it is the second best choice for all three species (table 2). Since all three target species is given the same priority, this area is therefore the optimal compromise to maximize target species abundance. Minkes are found in highest numbers in this area in May-July. Humpbacks arrive in numbers increasing through the summer months, whereas Bottlenose whales appears to leave these higher latitudes at midsummer. In terms of timing, the best compromise is therefore to conduct these trials in June. The period could be stretched two weeks in both directions, but mid May and mid July might offer reduced numbers of Humpbacks and Bottlenoses, respectively. July might however offer better weather than May.

FFIs Recommendation – FFI propose that the $3S^2$ trials are conducted in the area from Bear-Island to the area west of Spitsbergen (Svalbard) in June. The outer limit of the trial period should be mid May to mid July, unless species priority is reconsidered. We propose that the best alternative is the area 100-200 nmi west of Tromsø in the same period, using the Vestfjorden as a back up area

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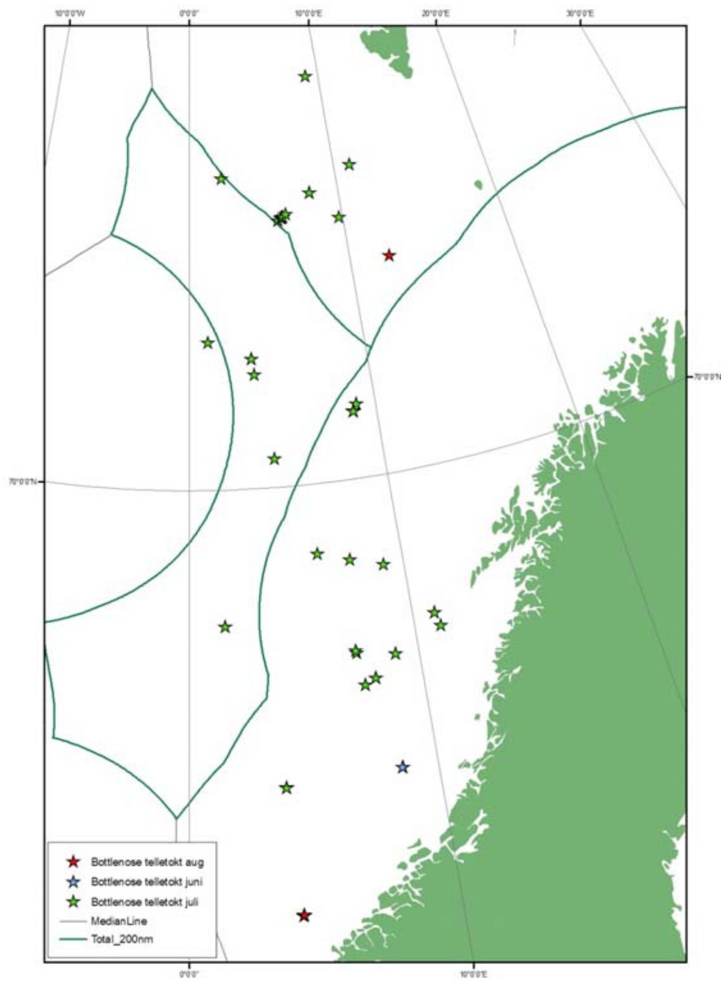
Decision Procedure within the 3S group

The above analysis and FFIs recommendations were presented to the 3S group at the meeting in St.Andrews in February 2010. The group there decided to adopt the recommendation as a preliminary decision. The tentative plan was therefore to conduct the $3S^2$-trials in the area along the continental shelf brake between Bear Island and Spitsbergen in June with Minke whales, Humpback whales and Northern Bottlenose whales as the target species. However, the group requested more data on sightings of bottlenose whales, if available.

At the 3S group meeting in The Hague in September 2010, FFI presented the updated analysis with some additional data on bottlenose whale sightings from the IMR line transect surveys (fig 6). Most of these sightings where from July and August, while the general understanding of the biology of this species is that it is most numerous in the Arctic regions in May-June. The group therefore did not change the original point of view regarding the plan for the $3S^2$-trials.

3S final decision – At the 3S-11 cruise planning meeting on the Sverdrup in February 2011, the 3S group made the final decision that the $3S^2$ trials will be conducted in June in open ocean, primarily along the continental shelf brake, between Tromsø and Svaldbard (70°N 18°E - 79°N 10°E) in June. The three primary target species, Humpback whales, minke whales and Norhern Bottlenose whale, will have equal priority.



<u>Figure 6.</u> Bottlenose whale sightings from IMR line transect surveys.

The distance from the southern to the northern part of the operation area is 600 nmi, and thus we are not going to cover all part of the area equally thorough. Based on historical sightings, catch statistics and knowledge of habitat preference of our target species, four sub-areas are determined which will be surveyed particularly careful. These areas are all characterized by steep underwater canyons, which tend to attract the northern bottlenose whale, but where we also expect to find the other target species. We might occasionally leave the shelf brake and search further east upon the shelf, where humpbacks and minke whales might be found in large numbers, especially around Bear Island. However, due to operational restrictions of the Socrates system we cannot operate in waters shallower than 200m. The weather in this area is quite stable in the summer, and statistically we will have 15-25 days of working conditions. Decision on where within the operation area we will be at any given time, will depend on weather, and reports of marine mammals sightings.

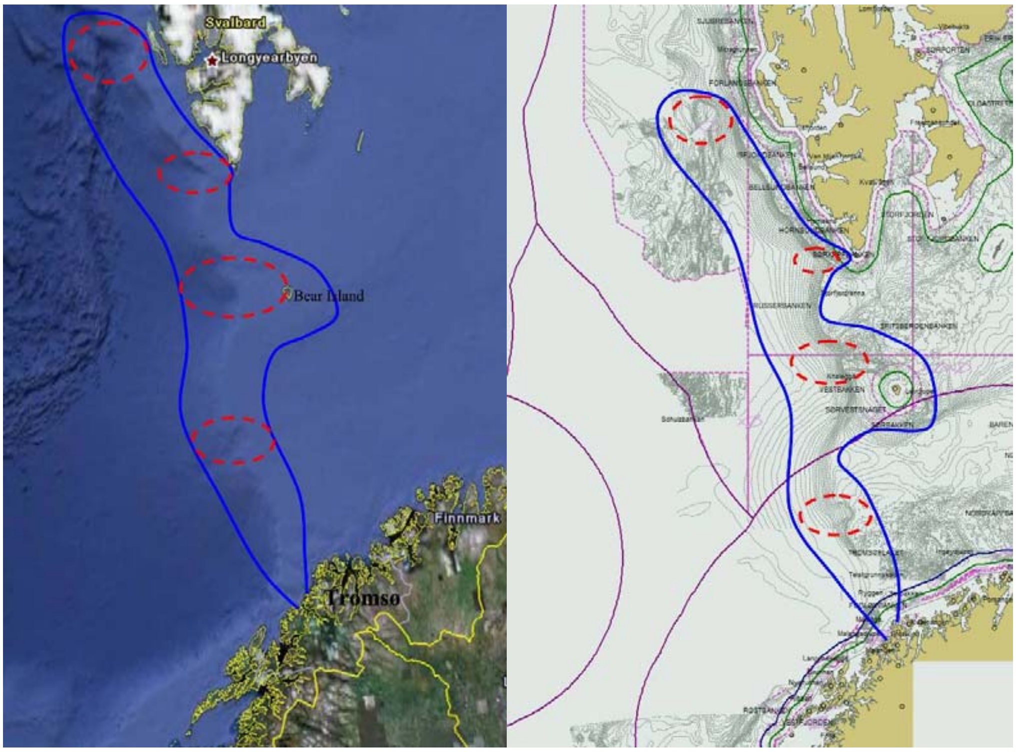


Figure 7. Overall operation area along the shelf brake (in blue), and the areas within it which will be surveyed particularly thorough (in red). From south to north these are entitled, Guillemot Canyon (Teistskallan), The Humpback Ridge (Knølegga), The South Cape Ridge (Sørkappegga) and the Svalbard Hole. Detailed map below.