Behavioral Response Study-2007 (BRS-07)

Cruise Report

January 2008

RV Ranger following beaked whales on the Tongue of the Ocean, Bahamas, during BRS-07
Photo: Ari Friedlaender

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Preface

This is the cruise report of the first behavioral response study to be carried out on beaked and pilot whales in which these animals were exposed to carefully measured doses of underwater sound while their responses were being measured. The study is seen as the first step in a series of similar experiments that are designed to safely identify the behavioral mechanisms that may be involved in the causal chain of events leading from exposure to some types of man-made underwater sound to mass strandings of beaked whales and to test whether this risk extends to other cetaceans.

Many meetings and workshops have been convened during the past few years to discuss the problem presented to marine mammals by anthropogenic sound in the oceans. In every case these meetings have concluded that the data are insufficient to develop anything other than highly precautionary, and in many cases arbitrary, approaches to the management of marine mammals in the face of apparent threats. At times the debate has become heated, acrimonious, and even destructive as different parties have attempted to assert their particular interpretation of the scant information about where the line should lie between preventing an underwater sound-producing activity and permitting it to proceed.

During the late 1990s to the present, a major research program focused on Temporary Threshold Shift (TTS) experiments with the belief that audiometric results could serve as a conservative and safe indicator for identifying exposures that would result in physical injury. The logic was that the inner ear is the organ system most sensitive to sound, and that temporary effects of underwater sound on hearing could be used as a quantitative means of predicting permanent injury from higher-level exposures. Levels of sound sufficient to cause TTS have been measured for a few individuals of a few pinniped and odontocete species. TTS studies have not included beaked whales, though their phylogenetic and morphological similarities to those cetaceans tested would suggest that relatively high levels of sound exposure should be required to cause physical damage to beaked whale hearing systems. The TTS-based injury criteria predict a range of direct acoustic injury just tens of meters from operational sonars. For the strandings that coincided with sonar exercises, there is no information on the initial location of the beaked whales that eventually stranded. However, it seems unlikely that many of the whales observed to strand in some events (*e.g.*, Greece 1996 and Bahamas 2000) would have come so close to large, generally fast-moving sonar sources within such a short time. While fewer than 100 beaked whales are known to have stranded during and in the vicinity of sonar exercises globally, the true magnitude of the problem is generally unknown and may not be limited to just those animals actually detected during stranding events. The causal sequence leading to injury is unknown, and these effects may not be limited to mid-frequency active (MFA) sonar and beaked whales. The effects are almost certainly triggered in certain conditions by exposures below those predicted to result in auditory injury based on

TTS measurements. We need to understand the causal mechanism of these effects using empirical measurements of behavioral responses in situations where received sound exposures are well-characterized.

Most of the reports on marine mammals and underwater sound (National Research Council 1994, 2000, 2003, 2005; the International Council for Exploration of the Seas 2005; and the UK Inter-Agency Committee on Marine Science and Technology 2006) and the report of a technical workshop on beaked whales (Cox et al. 2006) recommended an experimentally-based approach to addressing the need for new and reliable data on how beaked and other whales respond to sonar and other underwater anthropogenic sounds. This Behavioral Response Study (BRS) project was designed to address the problem of beaked whale responses to MFA sonar. However, not only are free-ranging marine mammal species very difficult to study in practical terms, but there has also been resistance to pro-active studies of this problem that involve direct exposure and measurements of behavior. Ironically, the opposition to an empirical approach has come from the very communities that vociferously advocate the broad-scale nature of the problem and the need for extreme precaution in the face of scientific uncertainty. In order to meet these challenges, it was recognized that the kinds of scientific methodologies and appropriate precautions required to conduct the experiments safely, while yielding useful information, would require a team approach. Hence the BRS was conceived and a core team of scientists was assembled to lead the development and implementation of BRS-07, the first phase in a multi-phase effort.

The principal investigators would like to acknowledge the broad range of support, interaction, dialogue, and constructive criticisms and suggestions there have been for this project from across the community of researchers, sponsors, Environmental Non-Governmental Organizations (eNGOs), government agencies and ministries from several countries. All these groups played a vital part in turning this idea into a reality.

We are particularly grateful to our sponsors; the US Navy Chief of Naval Operations' Submarine Warfare Division (Undersea Surveillance), the US Navy Environmental Readiness Division, the U.S. Office of Naval Research, the Oil and Gas Producers Joint Industry Program on Sound and Marine Life, the US Department of Defense Strategic Environmental Research and Development Program (SERDP), and the US National Oceanic and Atmospheric Administration (National Marine Fisheries Service, Office of Science and Technology). They have been both generous in their support and in their patience during the early phases of the study.

The study took place in the Bahamas and we are deeply grateful to the Government of the Bahamas for its generosity in allowing us to conduct this study within its territorial waters and for issuing a research permit to Ian Boyd. The U.S. Embassy to the Bahamas in Nassau was also extremely helpful and supportive in this process. In the same context, the contributions made by the Bahamas Marine Mammal Research Organization were a vital component of the study because of their immense knowledge accumulated over many years of cetacean research in the Bahamas. We are extremely grateful for the pivotal role they played.

Several individuals were critical to ensuring that, from an early stage, this study gained strong independent scientific and sponsor support. We are particularly grateful to Joe Johnson, Darlene Ketten, Bob Gisiner, James Eckman, Roger Gentry, Peter Evans, John Hall, Capt. Robin Brake, Mark Tasker and Douglas Wartzok. Clayton Spikes played a particularly important role in managing the coordination of the study and setting it on a path to success. Numerous personnel in the U.S. National Marine Fisheries Service permits and authorization division were also very helpful in ensuring all appropriate environmental analyses were conducted and that the research was consistent with the requirements of U.S. federal law.

We are also grateful to the eNGO community for engaging with us during the planning stages of the study. We recognize that some had strong reservations about the study, and some have asked to not be characterized as concurring with it. However, despite these reservations, all were willing to listen to our case for conducting the study. Most provided constructive feedback on our plans and we attempted to address and integrate this feedback, where we felt it was appropriate. We found the professional spirit of dialogue among these concerned parties to be a more constructive means of addressing differences of opinion than has often been the case on this issue.

The study took place in the Bahamas' Tongue of the Ocean (TOTO) and the adjacent Atlantic Undersea Test and Evaluation Center (AUTEC) on Andros Island, Bahamas. This is an underwater weapons range operated by the U.S. Navy. We are grateful to the Officer in Command, Commander Jeff Pafford, and AUTEC personnel for their excellent support of the BRS research team throughout the study and also for the close interest they took in our activities and the results.

Finally, we owe the greatest debt of gratitude to our fellow members of the BRS team. They are too numerous to mention individually here but each one brought a unique set of skills which, when merged together, provided a cohesive approach that ensured success. It is important not to understate the technical challenges presented when studying beaked whales, which are some of the most cryptic species on the planet, and the recognized need for a precautionary approach given the animals' expected reactions to the kinds of sounds being used. It took a multi-skilled team to balance these varied challenges. We are grateful to all individuals for playing their part with the utmost professionalism.

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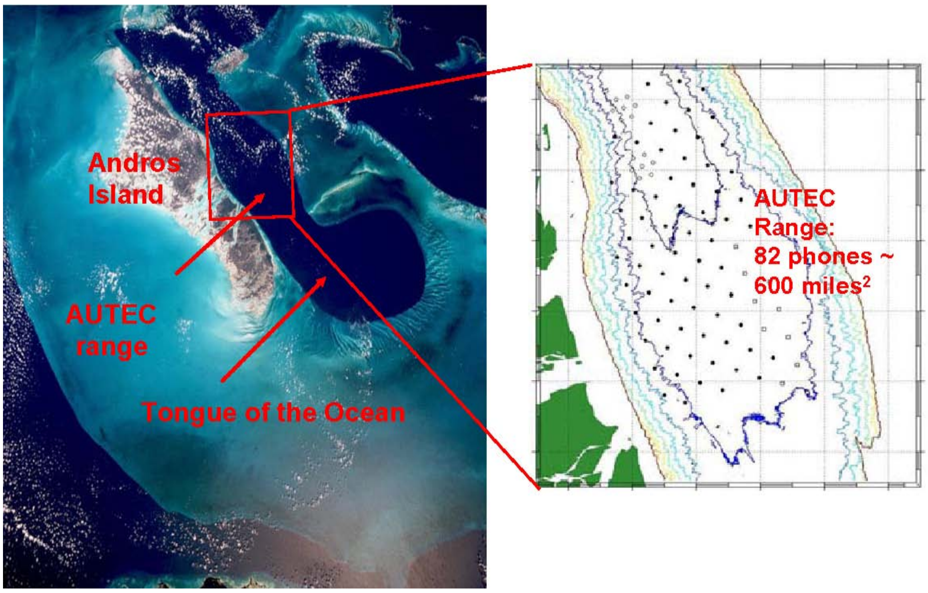
This reports presents preliminary results only. Final reporting of the scientific outputs will be made via the peer-reviewed literature. Please do not quote from this report without first clearing this with the authors.

Executive summary

1. A Behavioral Response Study (BRS-07) took place in the Tongue of the Ocean (TOTO) and at the adjacent Atlantic Undersea Test and Evaluation Center (AUTEC) on Andros Island, Bahamas during August and September 2007 (Summary Fig. 1). AUTEC has a 600-square-mile permanent grid of seafloor hydrophones in the deep ocean canyon of the TOTO where beaked whales are known to occur.



Summary Figure 1: A GoogleEarth image of the southern Bahamas showing Andros Island and the Tongue of the Ocean, a canyon surrounded by shallow reefs in which the AUTEC Range is located (box). The range is shown in the diagram in the right. There is a 2 nm spacing between the hydrophones which are shown as circles or solid dots.

2. The objectives of BRS-07 were to:

- Establish, test and refine new protocols for studying beaked whales using established sound playback experiment paradigms
  - Demonstrate feasibility and safety of study design;
  - Obtain U.S. and Bahamian permits and engage with eNGOs concerning the pros and cons of these specific kinds of playbacks;
  - Collect base-line (control) data to provide a basis for comparison with playback results.
- Define responses of beaked whales, and other species of odontocete whales, to mid-frequency active (MFA) sonar and natural sounds such as those from killer whales. Address the questions:
  - Does the response help narrow the range of hypotheses for the cause of MFA sonar-related strandings?
  - Does the response to MFA sonar differ from the response to killer

whale sounds to test whether whales respond to sonar as if it represented a predator?
  - Can responses be used as a safe predictor of risk of injury/stranding from higher level exposures?
  - Do other species also respond in a way that elevates risk of injury/stranding?

- Measure exposure parameters for sounds that evoke a behavioral response
  - Use an acoustic recording tag as the primary method to measure received level at the animal.
  - Measure ship noise on the AUTEC hydrophones, and input these measures to an acoustic propagation model to predict exposure at the animals.

3. On the whole, these objectives were achieved. The feasibility of the approach was demonstrated, and considerable progress was made with refining the research protocols. As expected, the chance of tagging a beaked whale is highly dependent on weather and wind conditions, as even light winds can make visual detection very difficult. The permitting process in both the U.S. and Bahamas was successfully completed. All the required permits were provided in time for the field effort and the conditions of the permits were compatible with the research plan. Efforts were made to interact with and consult eNGOs in advance of BRS-07 and, while some eNGOs remained resistant to the approach, many were willing to engage in discussions with the BRS team. Many of the comments and suggestions received will continue to be useful in the development of subsequent phases of the BRS.

4. The research protocols used a combination of data sources to measure the behavioral responses of whales to sound. This included: direct visual observation of the whales when at the surface, passive acoustic measurement of whale behavior when they were acoustically active (for beaked whales this was during deep foraging dives), and detailed behavioral and acoustic observations from suction cup tags attached directly on focal individuals. The objective was to play the simulated sounds of MFA sonar, killer whales, and other control sounds to a sample of animals being monitored using these methods. The sound source level was ramped up gradually as a precautionary measure and to allow for each subject the ability to relate the onset of a response to a specific RL. The estimated received level of sound at the animal was always kept well below the level expected to cause temporary threshold shift.

5. Data were collected from 10 tag deployments, 6 on Blainvilles beaked whales and 4 on pilot whales. A total of 109 hours of data were collected from tags, 74 hours from beaked whales and 34 hours from pilot whales. The data collected by the tag included sounds produced by the tagged animal, environmental and anthropogenic sounds received by the animal, details of the animals movements in terms of its diving, swimming speeds, changes in orientation and swimming actions.

6. Playbacks were performed on 3 of the tagged whales, 1 beaked whale and 2 pilot whales. This is a lower total than was anticipated. Long stretches of poor weather incompatible with tagging, especially toward the end of the test period,

meant that effective tagging opportunities were greatly reduced from expectation. However, those playback experiments conducted did demonstrate that these methods could safely be used in these species using MFA and biological sounds to generate very detailed information on received exposures and behavioral responses.

7. Photo-identification of beaked whales in the study region over several years before the study, as well as identification of animals during BRS-07, suggests a degree of residency within the region, with some individuals seen over multiple years.

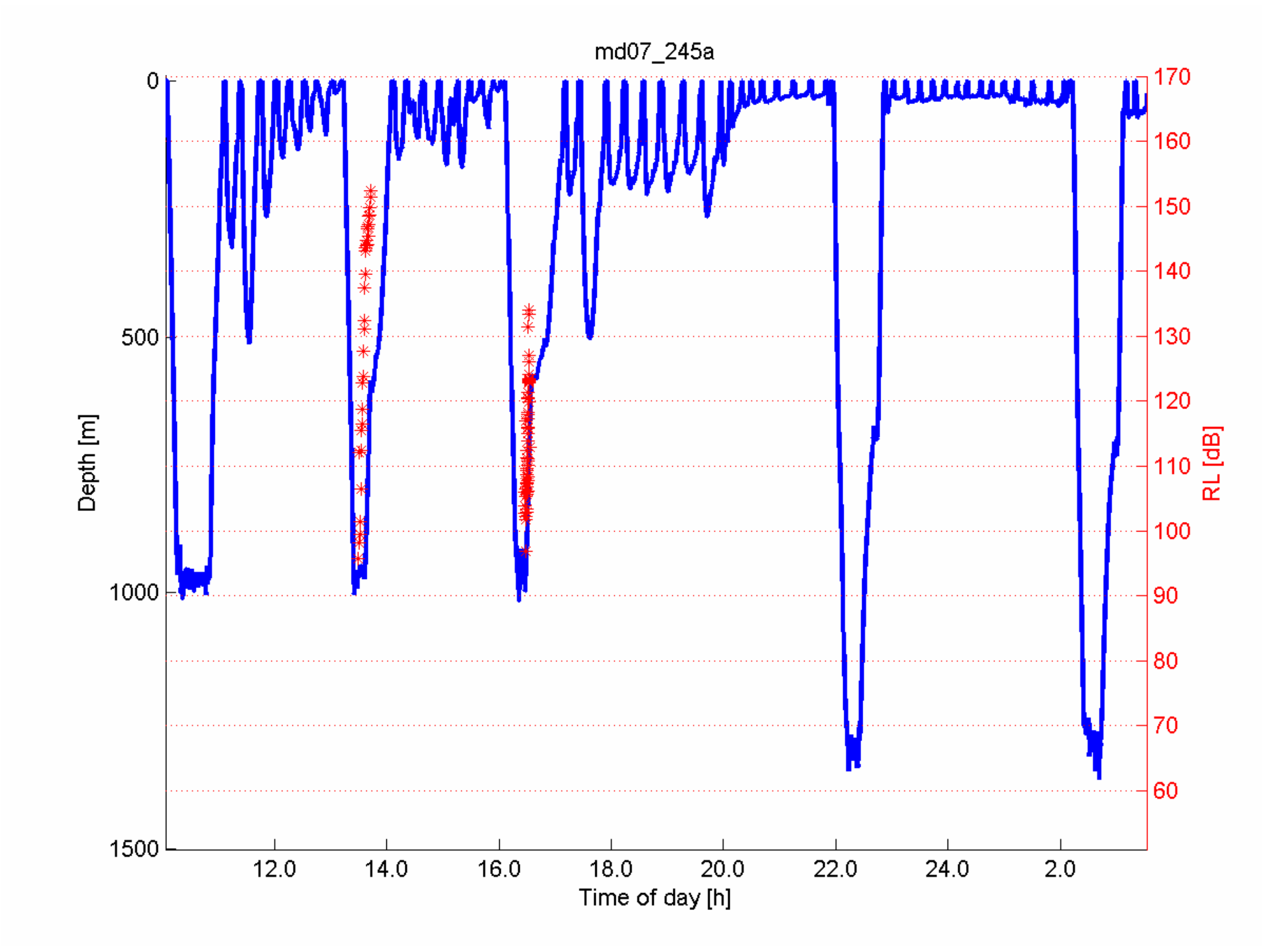
8. At this stage, only the results from the playback to the beaked whale have been analyzed extensively. The following is a preliminary summary of what was observed:

- After a pre-exposure dive, a MFA sonar playback was conducted on a tagged, female adult *Mesoplodon densirostris*.
- The MFA playback started at a source level (SL) of 152 dB[1], a few minutes after the whale began producing ultrasonic clicks. The SL was then increased by 3 dB every 25 s in a ramp-up procedure, reaching a maximum SL of 212 dB after 9 minutes. The MFA signal was then played back at maximum SL every 25 sec for 6 minutes.
- The first ping detected on the tag and for which received level (RL) could be estimated, had an RL of ~95 dB (Summary Fig. 2)
- After 10 min into the playback, the whale appeared to stop clicking earlier than usual, when the RL at the whale was ~145 dB. The playback continued for several minutes once cessation of clicking was confirmed. The maximum RL recorded at the whale was ~152 dB. Because this dive was so short, she had an unusually low number of whale buzzes (very rapid series of clicks) which are indicative of foraging events.
- The whale then ascended more slowly than usual and, as a result, had a longer than normal ascent.
- The whale surfaced, where her behavior appeared normal. After about 2 hours she started another deep foraging dive (Summary Fig. 2). Once she started clicking at depth, a playback of killer whale sounds was started.
- The killer whale playback started at an initial SL of 130-140 dB, a few minutes after the whale began producing ultrasonic clicks. The SL was then increased by about 5 dB about every 30 sec in a ramp-up procedure, reaching a maximum SL of 190-203 dB after 10 minutes. The killer whale playback was stopped several minutes after the whale stopped clicking, before the ramp up process had reached maximum SL.
- The first killer whale sounds detected on the tag for which RL could be estimated had a RL of ~96 dB (Summary Fig 2).
- The whale stopped clicking about 5 minutes into the killer whale playback, a

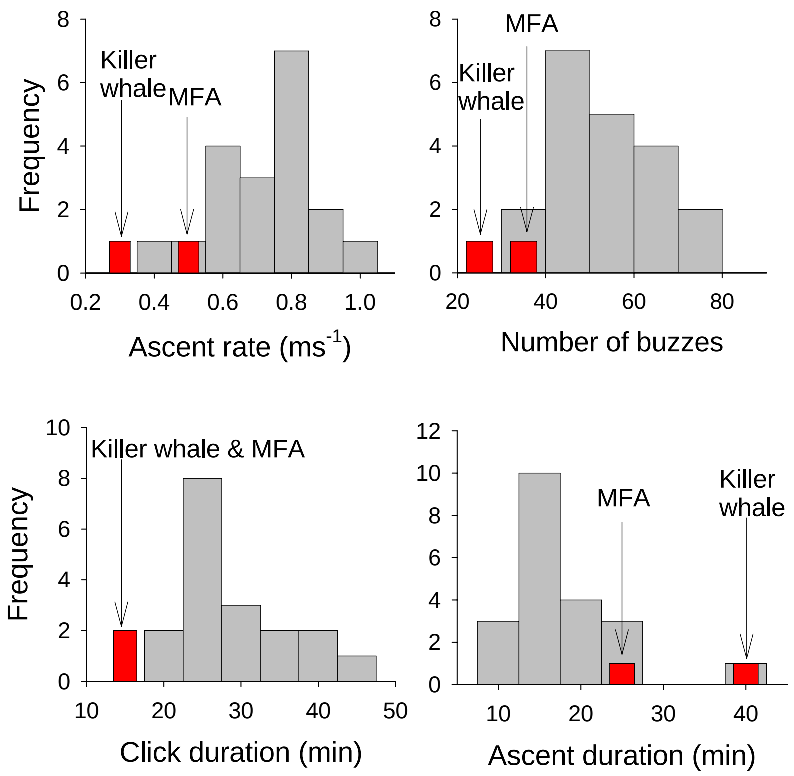
[1] References in underwater sound pressure level (SPL) in this Cruise Report are values given in decibels (dBs), and are assumed to be standardized at 1 microPascal at 1 m (dB re 1 µPa at 1 m [rms]) for Source Level (SL) and dB re 1 µPa [rms] for Received Level (RL), unless otherwise specified

shorter clicking period than usual. The received level of the killer whale sounds recorded on the tagged whale just before she ceased vocalizing was ~117 dB. The sound exposure at the whale continued for several minutes once the cessation of clicking was confirmed. The maximum RL recorded at the whale was ~134 dB.

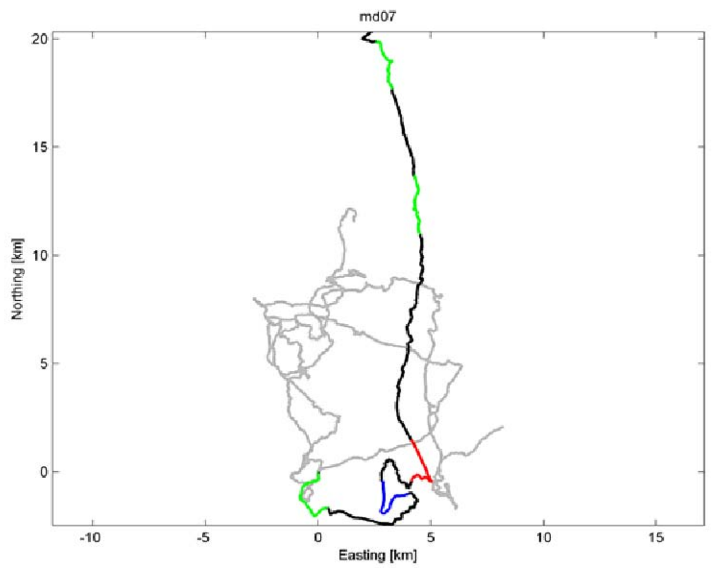
- This exposure dive had the shortest overall clicking period, the lowest number of buzzes, the slowest ascent rate, and the longest ascent among the beaked whale deep foraging dives recorded at TOTO in BRS-07 from 5 individual whales (Summary Fig. 3).
- As soon as the killer whale playback stopped, the beaked whale started swimming away from the location of the sound source and she continued swimming on a much straighter course than usual, although she made two additional deep foraging dives during this movement, the first of which was 4.8 hours after the killer whale exposure dive. This inter-dive interval is longer than any of the other times between deep foraging dives of *Mesoplodon* recorded during the BRS at AUTEC.
- By the time the tag was released from the whale, 10 hours after the end of the dive that contained the last playback, the whale had traveled approximately 20 km (10.8 nm) from the playback location at an average horizontal speed of about 0.5 m/s (1 kt) (Summary Fig. 4). Details of this movement pattern are preliminary and will be improved after the tag data are geo-referenced at several points throughout the record.



Summary Figure 2: The dive profiles of the female beaked whale involved in the playback. This shows the depth of the whale (blue) during the time that the tag was attached. It shows that the whale made 5 deep (>500m) foraging dives. During two of these dives (numbers 2 and 3) she was exposed to a playback of MFA sonar (dive 2) and killer whale (dive 3) sounds. Each of the red stars shows when the tag on the whale received playback sound and the received sound level (dB) as indicated on the right hand axis. It can be seen that the playback sound was ramped up through the deep dive which corresponds to the time when the whales was clicking. The playback was ended in both cases within several minutes of cessation of vocalization.



Summary Figure 3: Histograms showing the frequency distributions of four variables measured across all the deep foraging dives for Blainville's beaked whales within the TOTO. The grey bars show those dives made without playbacks whereas the red bars represent the measurements made for the dives when playback occurred.



Summary Figure 4: The patterns of movement, shown in a two-dimensional plan view, of four tagged Blainville's beaked whales when the whales made repeated deep foraging dives. These tracks are based upon assumptions about the speed of the whale and of currents, and the details of movements will be improved after points are georeferenced throughout the record. The track shown in multiple colors is of the female adult beaked whale involved in the playback, and this is superimposed on three that are in grey in which there was no playback. Each track covers a similar time period. The black parts indicate parts of the track that were not deep foraging dives. The green sections show the pre- and post-playback dive; the blue section shows the track during *the MFA sonar playback and the red section shows the track during the killer whale playback.*

9. These early results have to be interpreted with care because the analyses are preliminary and stem from a single experiment involving the response of one individual. There is also a limited set of baseline data to characterize normal behavior. A greater sample size is required before robust conclusions can be drawn. However, this result helps to narrow the high level of uncertainty about the possible responses of Blainville's beaked whales to sonar and predator calls, and it provides a basis for further experiments to better understand the nature of the response. Nothing in the responses observed to date suggests that the playback experiment presented any risk to the whale. Additional questions that need to be addressed include, but are not limited to:

- Was the prolonged movement away from the sound source after playback of killer whale calls the result of the killer whale stimulus alone or was it influenced by the MFA playback, and the order in which the sounds were presented?
- Do these animals respond in this way to other novel sounds irrespective of whether they simulate MFA sonar or a predator?
- What is the range of acoustic parameters associated with these responses.

10. It is not possible at this stage of analysis to be sure about the pilot whale responses to playbacks, but it is possible that one of the tagged pilot whales responded.

11. BRS-07 has seen a successful progression toward our main objective which is to characterize behavioral responses that could be used to measure the effects of MFA sonars on beaked whales and other species. While further analyses of the data are required, we believe that we have obtained a relatively clear set of behavioral responses by an adult female beaked whale to the controlled playback of MFA sonar and killer whale sounds. The tags were able to quantify the acoustic exposure associated with the onset of the responses. However, it must be noted that this experiment involved two exposures to a single individual with limited baseline information. Now that we have demonstrated that this experimental paradigm can provide useful information, without harm or undue risk to the animals, additional results using a similar paradigm are needed. Additionally, the absence of negative control stimuli for BRS-07 means that this test must be repeated with other stimuli that do not elicit such a response. Such tests would allow us to better understand the sound features that elicit responses.

12. BRS was fully operational on only 25 percent of the days scheduled for the experiment, mainly because of weather conditions that were not suitable for carrying out tagging operations. Activities related to other AUTEC range users had less impact than weather but were an important operational constraint. Tagging was successful on 60 percent of days when weather conditions were suitable for tagging, suggesting that, given appropriate weather, tagging has a high success rate at AUTEC. Historical weather records suggest that BRS had about 50 percent of the opportunities to operate in 2007 that it could have expected based on average measurements of sea state over the previous 7 years.

13. The protocols initially proposed for playbacks were carried through without major in-field modification. However, the detailed action list and control procedures for the playback protocol has been refined and modified as a result of this BRS-07 experience. The experimental procedures were refined throughout the study and the experience of BRS-07 has resulted in a number of recommendations for future research.

14. The post-playback mitigation and monitoring observations, both vessel-based and aerial, were conducted at the start and end of BRS and after both playbacks to ensure that there were no injured or stranded marine mammals in and around a large area surrounding the location of each playback. In some cases, weather and practical considerations extended the periods of time over which this monitoring was conducted, but for all playbacks there was extensive monitoring of both the waters and surrounding shorelines. No distressed, injured, or stranded animals were detected at any time.

1 Introduction

This is the report of a Behavioral Response Study (BRS-07) that took place during August and September 2007 in the Bahamas Tongue of the Ocean (TOTO) and the adjacent Atlantic Undersea Test and Evaluation Center (AUTEC) on Andros Island, Bahamas. The study was developed in response to increasing evidence suggesting that exposure to intense underwater sound may cause certain marine mammal species to strand, and in some situations the stranded animals die. A small percentage of reported marine mammal strandings have been associated in time and space with mid-frequency active (MFA) military sonar transmissions and the study will focus upon the effects of MFA sonar on some of the same species that have previously stranded during sonar exercises. As such, this study is intended to provide some direct, empirical information on a matter of pressing concern and practical importance to the navies, regulatory agencies, scientists, environmental groups, and other concerned parties in many nations. The study was a first step toward developing the methods that required analysis of the effects of sound on beaked whales and other cetacean species. The intention was that this study will be followed by others, but the exact form of these studies will depend on the outcome of this field research (BRS-07). While the early results from the BRS studies must be interpreted with substantial caution for many methodological reasons, the results obtained in the overall BRS effort are expected to significantly enhance the scientific basis for reducing risk of harm to marine mammals from MFA sonar and to help regulators and those involved in generating underwater sounds to assess and predict the risks to cetaceans from activities involving MFA sources.

Beaked whales are very challenging animals to study. They dive for long periods of time (nearly one hour) and they are some of the deepest divers of the cetaceans, reaching depths of over 1,250 m (4,100 ft) (Tyack et al. 2006). Studying these species using casual, surface-based observations yields little data that can inform us about their responses to specific types of sound. It is for this reason it was decided to conduct a study under controlled circumstances, and with instruments, that will provide the greatest possible opportunity to collect sufficient data, and with a sufficient sample size, to begin to draw some statistically valid conclusions about the effects of MFA sonars. The study was designed to allow the BRS team to control as many of the variables as possible while keeping the context as natural as possible. Combining this with a need for extreme precaution in the scientific approach at these early stages – because it was not known how the animals would react - a research protocol was chosen that balanced the need for scientific rigor with practicality, and also the need to ensure the welfare of the animals involved.

The study was carried out under permits and authorizations issued by the Bahamian Government as well as the United States Government.

The field research was carried out by a diverse and experienced international team of scientists. The group was divided into teams – including tagging, visual observation and focal follow, passive acoustic monitoring, acoustic propagation modelling and acoustic sound source operation.

2 BRS Objectives

The general objectives of BRS-07 were

- **Establish, test and refine new protocols for studying beaked whales using established sound playback experiment paradigms**
  - Demonstrate feasibility and safety of study design;
  - Obtain US and Bahamian permits and engage with eNGOs concerning pros and cons of these specific kinds of playbacks;
  - Collect base-line (control) data to provide a basis for comparison with playback results.

- **Define response of beaked whales, and other species of odontocete whales, to MFA sonar and natural sounds such as killer whale**
  - Does response help narrow range of hypotheses for the cause of sonar-related strandings?
  - Compare response to killer whale sounds to test whether whales respond to sonar as if it were a predator;
  - Can response be used as safe predictor of risk for injury/stranding for higher exposures?
  - Do other species also respond in a way that elevates risk of injury/stranding?

- **Measure exposure parameters for sounds that evoke behavioural response**
  - Primary method to measure the received level at the animal used a digital acoustic recording tag. Ship noise was also measured on the AUTEC hydrophone array. Acoustic propagation models will be used with these measurements to predict exposure at the animals.

Further goals of the broader BRS project include:

- **Measure exposure parameters for sounds that evoke indicator response**
  - Define acoustic parameters that elicit the response by testing with negative control stimuli that may not evoke the response
  - Characterize whether and how that response differs between different age/sex/ stages in life cycle/behavioral contexts
  - Build a population-level dose:response relationship to predict the probability of inducing a behavioral response that could lead to stranding

The ultimate goal of the BRS project is to provide a dose:response function for risk of sonar to beaked whales, to test whether other sounds pose similar risks, and to test whether other species are at similar risk from sonar or other sounds.

3 Approach

This study had to find a balance between intentions to not harm experimental subjects and to obtain critically-needed empirical data as rapidly as possible in challenging field conditions. Consequently, the scientific approach throughout was precautionary and adaptive in the sense that the BRS team intended to start by being very sensitive to behaviours that could potentially be interpreted as responses to MFA. Then, as experience was built up as to how the animals react, or don’t react, under each circumstance the BRS team expected to gradually change the experimental conditions to investigate the point at which behavioral responses occur. This kind of adaptive approach, which is generally common in conditions where potentially harmful effects are being investigated and relatively little is known, was applied to individual exposures within the context of the BRS undertaken at AUTEC in 2007 and described in this report, as well as on a broader scale. For example, in 2007 a lower power sound source (deployed from a research vessel) was used than that typical for MFA sonars. The study was conducted in an area where whales are likely to have been habituated to these sounds to some extent, but on an acoustic range where sophisticated listening technologies can be employed in locating and tracking animals. In subsequent years the proposal is to move to using an actual MFA sound source and then also to test animals in an area where they probably had limited or no previous exposure to these sound sources. At each stage in this process the plan will be modified depending upon the results from the latest studies and bearing in mind both animal welfare considerations and scientific progress.

The field research was conducted by a diverse and experienced team of scientists and led by a number of globally-recognized marine biologists and bio-acousticians with responsibility for each component of the study - tagging, visual observation and focal follow, passive acoustic monitoring, acoustic propagation modelling and acoustic sound source operation.

The exposure protocol uses a gradual ramp up in the intensity of exposure over time to a point where there are measurable behavioral reactions that could be used to indicate a biologically significant response. At no stage in this experiment was there any intent to create conditions in which animals are in danger of harmful exposures or stranding. The study is designed to use behavioral indicators as a precautionary metric of possible responses that could lead to these risks.

The BRS-07 study was carried out on the AUTEC range. This site for BRS-07 was chosen from a list of many other candidate sites using a set of requirements including local logistics, weather conditions, accessibility, permitting processes, density of beaked whales and other species, likely exposure history of animals, background acoustic environment and overall likelihood of success. AUTEC was deemed most suitable for BRS-07. AUTEC has particular advantages because it has an array of many hydrophones deployed on the seabed within deep water where beaked whales are known to occur. Beaked whales can be detected and localized using the hydrophone array thus helping the research team to locate whales quickly. Moreover, data from the hydrophones provide important information about both the sound source being used and the reactions of the whales. The AUTEC hydrophone range thus allowed real-time monitoring of whales at depth and greater control of the acoustic environment than other sites.

The protocol for this initial phase of these experiments reported here involved the use of a sound source suspended in the water to a depth of about 50 meters (164 ft). This source was used to transmit signals similar to those produced by MFA sonars. It was also used to transmit killer whale (*Orcinus orca*) calls as a positive control stimulus to test the hypothesis that the responses to MFA were similar to those produced in response to a natural predator. The sound source used for these playbacks was limited to the 2-5 kHz band, so the killer whale sounds were filtered to exclude energy outside of this band. The lack of high frequency components was audible to human ears, yielding a recording that sounded as if it was recorded farther away from the killer whales than the original full bandwidth recordings.

3.1 Playbacks

The objective was to expose beaked whales (and also other odontocete cetaceans, such as pilot whales) to a series of sound stimuli during successive dives. This involved received levels of between 80 and 160 dB, which are well below thresholds that could even cause temporary hearing loss for the durations of exposure used, much less direct physical trauma. The sound source levels were ramped up from a low level during the course of a dive, yielding a slowly increasing received level at the animal. The playback design called for monitoring behavior of the whales in real-time, and ceasing playback when specific behavioral responses were observed. Cessation of vocal activity, measured on passive listening systems, was used as the point at which a behavioral effect has been observed. Visual observations of the whales while they were at or near the surface were also included in the experimental protocol, but there was no opportunity to use surface observations of beaked whales as a real-time response measure for playbacks during BRS-07.

For the initial characterization of how beaked whales respond to sonar, it was essential to measure the actual sound received by the whale and its detailed behavioral response. To achieve this, each focal animal had a non-invasive digital archival tag (Dtag) attached to the skin with suction cups. This tag both measured the sound received by the whale, and details of behavior before, during and after exposure.

3.1.1 Controls

Controls took two forms: (1) control dives in focal whales exposed to playbacks and (2) control tag deployments in which Dtags were placed on the whales but no playback occurred.

3.1.2 Monitoring and mitigation

As a precautionary measure, a stranding response and communications plan was developed (although thankfully this never needed to be used) and the study was accompanied by aerial surveys to check for strandings or animals at the surface in the region. The field research was conducted by a diverse and experienced team of scientists and was coordinated in the field by a Chief Scientist who had oversight of all activities and who was responsible for making decisions in response to changing situations during the course of the study and communicating those decisions to the Principal Investigators and co-PIs.

4 Test Participants and Responsibilities

BRS-07 was sponsored by the US Navy Chief of Naval Operations' Submarine Warfare Division (Undersea Surveillance), the US Navy Environmental Readiness Division, the U.S. Office of Naval Research, the Oil and Gas Producers Joint Industry Program on Sound and Marine Life, the US Department of Defense Strategic Environmental Research and Development Program (SERDP), and the US National Oceanic and Atmospheric Administration (National Marine Fisheries Service, Office of Science and Technology).

The field research was carried out by a diverse and experienced international team of scientists. The group was divided into teams – including tagging, visual observation and focal follow, passive acoustic monitoring, acoustic propagation modelling and acoustic source operation as described in the following sections.

4.1 Permits

The U.S. Scientific Research Permit was obtained by NMFS and held by Dr. John Boreman. The Bahamian Research Permit was obtained and held by Dr. Ian Boyd, Director of Sea Mammal Research Unit, Univ. of St. Andrews, Scotland and the BRS Chief Scientist.

4.2 Responsibilities

The primary organizations and responsibilities for BRS-07 are shown in Table 4-1.

Table 4-1. Organizations and responsibilities for BRS-07.

Name	Position	Organization	Test Site Location
Brandon Southall	PI	NOAA	Command and Control Building
Ian Boyd	co-PI and Chief Scientist	SMRU	Command and Control Building
Diane Claridge	co-PI	BMMRO	R/V Blackfin
Chris Clark	co-PI	Cornell	Command and Control Building
Peter Tyack	co-PI	WHOI	Command and Control Building
Clay Spikes	Test Coordinator	MAI	R/V Ranger
Mark Wilson	Test Coordinator	MAI	R/V Ranger
Marilena Quero	Data Manager	NATO	Command and Control

			Building
Todd Pusser	Visual Observer Team Leader	Independent	R/V Ranger

4.3 Test Team Composition

The BRS-07 participants, organizations, and their functions are shown in Table 4-2.

Table 4-2. BRS07 participants, organizations, and their functions performing the test.

Name	Organization	Function	Location
David Moretti	NUWC	M3R	Command and Control Building
Shawn Kennedy	NUWC	M3R	Command and Control Building
Nancy Di Marzio	NUWC	M3R	Command and Control Building
Ron Morrissey	NUWC	M3R	Command and Control Building
Susan Jarvis	NUWC	M3R	Command and Control Building
Marc Ciminello	NUWC	M3R	Command and Control Building
Tom Fetherston	NUWC	M3R	Command and Control Building
Tom Szlyk	NUWC	M3R	Command and Control Building
Tom Vars	NUWC	M3R	Command and Control Building
Matt Ward	NUWC/ASA	M3R	Command and Control Building
Amanda Hansen	WHOI	M3R	Command and Control Building
Edward Adderley	BMMRO	M3R	Command and Control Building
Robert Barton	NUWC	M3R	Command and Control Building
Adam Frankel	MAI	AIM/Acoustic Monitoring	Command and Control Building
Kathleen Vigness-Raposa	MAI	AIM/Acoustic Monitoring	Command and Control Building
Walter Zimmer	NATO	Acoustic Monitoring/PAM	Command and Control Building
Olivia Patterson	BMMRO	Communication/Visual Recorder	R/V Blackfin

Name	Organization	Function	Location
Nicola Quick	SMRU	Communication/Visual Recorder	R/V Blackfin
Charlotte Dunn	BMMRO	Visual Observer /Photo ID	R/V Blackfin
Alessandro Bocconcelli	WHOI	Tag Boat Driver	R/V Blackfin
Jonathan Balyeat	Ocean Works	Tag Boat Driver	R/V Blackfin
Leigh Hickmott	BMMRO	Tagger	R/V Blackfin
Ari Friedleander	Duke	Tagger	R/V Blackfin
Tom Hurst	WHOI	Tag Technician	R/V Blackfin
Anne Adams	WHOI	Tag Technician	R/V Blackfin
Stephanie Watwood	WHOI	Tag Technician	R/V Blackfin
Sasha Hooker	SMRU	Tag Technician	R/V Blackfin
Douglas Nowacek	FSU	Tag Technician	R/V Blackfin
Lance Walker	NUWC	Source Engineer 1	R/V Ranger
Robert Gabriel	NUWC	Source Engineer 2	R/V Ranger
Eryn Wezensky	NUWC	Source Engineer 3	R/V Ranger
Vince Cermak	NUWC	Source Engineer 3	R/V Ranger
Glenn Mitchell	NUWC	Source Engineer 3	R/V Ranger
Eletta Revelli	IND	Visual Observer 2	R/V Ranger
Federico Pongiglione	IND	Visual Observer 3	R/V Ranger
Gordon Hastie	SMRU	Visual Observer 4	R/V Ranger
Nicolo' Gavazzi	IND	Visual Observer 4	R/V Ranger
Kim Skrupky	MAI	Visual Observer 4	R/V Ranger
Alesha Naranjit	BMMRO	Visual Observer 5	R/V Ranger
Monica Arso	BMMRO	Visual Observer 6	R/V Ranger
Matt Weingartner	Ocean Works	Tag Boat Driver/Visual Observer	18-ft Tag Boat
Sean Sullivan	Ocean Works	Tag Boat Driver/Visual Observer	18-ft Tag Boat
Jim Moir	Ocean Works	Tag Boat Driver/Visual Observer	18-ft Tag Boat
Kiya Gornik	BMMRO	Visual Observer/Photo ID	18-ft Tag Boat

4.4 Resources

NUWC/AUTEC and BMMRO provided the primary facilities resources for BRS-07 as described below.

4.4.1 Naval Undersea Warfare Center (NUWC)

4.4.1.1 AUTEC

The Command and Control Building was used to monitor the whale locations on the acoustic range. AUTEC also provided the R/V Ranger to deploy the acoustic source and provide a platform for the marine mammal observers. These facilities are described below.

4.4.1.1.1 Command and Control Building

Test participants from NUWC, WHOI, MAI, BMMRO, NATO, and SMRU were based in the AUTEC Command and Control Building, In this facility the Marine Mammal Monitoring on Navy Undersea Ranges (M3R) signal processing tools were used to detect and track marine mammals using the AUTEC acoustic range facilities. AIM/Acoustic monitoring, PAM, and data management was also accomplished in this facility.

4.4.1.1.2 AUTEC Acoustic Range

AUTEC acoustic range has a 600-square-mile permanent grid of seafloor hydrophones in the deep ocean canyon of the TOTO that is acoustically quiet and where beaked whales are known to occur. The range consists of 82 operational bottom-mounted hydrophones, spaced approximately 2 nm (3.7 km) apart. The maximum depth of approximately 2,000 m occurs at the north end of the range. The range area is shown in Figure 4-1.

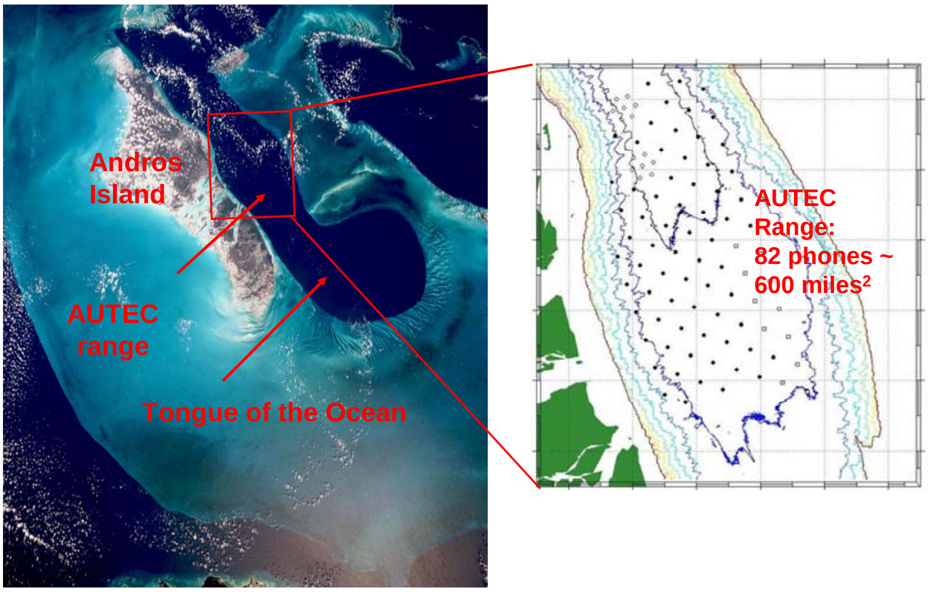


Figure 4-1: A GoogleEarth image of the southern Bahamas showing Andros Island and the Tongue of the Ocean, a canyon surrounded by shallow reefs in which the AUTEC Range is located (box). The range is shown in the diagram in the right. There is a 2 nm spacing between the hydrophones which are shown as circles or solid dots.

4.4.1.1.3 Eryn Acoustic Source

NUWC supplied the Eryn I MFA source (Eryn II as backup) for BRS-07. The source has the ability to transmit MFA sonar like signals and other broadband sounds in the 2-5 kHz band. The maximum SL transmitted was 212 dB which would provide a maximum RL of 155 dB at the animal at 2 km from the source. It provided a symmetrical beam pattern of 360 degrees azimuthally. This source was deployed from the R/V Ranger and had a monitoring hydrophone for transmission confirmation and the ability to record the transmissions. The vertical directionality of the source was measured in the field and is documented in Appendix C.

4.4.1.1.4 R/V Ranger

AUTEC provided the 192 ft R/V Ranger which was used to deploy the acoustic source and provide a platform for visual observers. The R/V Ranger may be seen in Figure 4-2. The visual observers were stationed on the bridge deck where the Big Eye binoculars had been mounted. The Big Eye mount system may be seen in Figure 4-3.

Figure 4-2. R/V Ranger.

Figure 4-3. Big Eye binoculars and mount system on the bridge deck of the R/V Ranger.

4.4.2 BMMRO/Center for Whale Research

BMMRO has been conducting a long-term study documenting the occurrence, distribution, and abundance of marine mammals around the islands of The Bahamas since 1991. It is currently based in Sandy Point on Great Abaco Island. BMMRO provided small support vessels as described below.

4.4.2.1 Blackfin

The Blackfin is a 29 ft Blackfin fibreglass hull ocean cruiser equipped with an aluminium flying bridge, 2-225 hp four-stroke outboard engines. The vessel was used for visual follow, tagging, and photo ID as can be seen in Figure 4-4. The Blackfin also carried an 11 ft RHIB for tagging.

Figure 4-4. R/V Blackfin, visual observers, photo ID and tagging team.

4.4.2.2 18 ft tag vessel

An 18 ft RHIB (18 ft) was used for tagging, visual observation and photo-id. The RHIB was carried by the R/V Ranger.

4.4.2.3 Air Support

BMMRO contracted Sapphire Air in West Palm Beach to do the monitoring and mitigation flights. These flights took place after playbacks to search the beaches and to carry out a search pattern across the Tongue of the Ocean centered on the region of the playback.

4.4.3 Woods Hole Oceanographic Institution (WHOI)

4.4.3.1 Dtag

The sampling method to record whale behavior and sound exposure at the whale included the use of electronic tags developed by WHOI. The Dtag is a miniature solid-state acoustic recording tag that will be used for BRS-07. The outside dimensions (including packaging) of the Dtag are approximately 4.25 in x 1.6 in x 0.9 in (11 x 4 x 2 cm), and weighs approximately 330 g (12 oz) in air, with positive buoyancy. The Dtag has a modular audio acquisition section and can be assembled with a high-performance stereo ADC (24 bits, 192 kHz/channel) suitable for all odontocetes other than *Kogia* and porpoises. The Dtag has a non-acoustic sensor suite including pressure to measure depth, temperature, and three-axis accelerometers and magnetometers to measure pitch roll and heading of the whale. These non-acoustic sensors are sampled at 50 Hz.

The Dtag has a fairing for odontocetes that has been used successfully with beaked and sperm whales. With fairing, Dtag dimensions are approximately 8 in x 4.1 in x 1.4 in (20 x 10 x 4 cm). The Dtag incorporates a digital signal processor capable of real-time detection and compression of audio signals, making efficient use of the 12 GB memory. The sampling rate and compression algorithm used by the tag are fully programmable. All programming and data offload occur through an infrared communications port enabling the entire system to be potted, further increasing the efficiency and robustness of the instrument in the field. Figure 4.5 shows a close up of the Dtag and figure 4.6 shows the Dtag on an animal.

Figure 4-5. Dtag.

Figure 4-6. Dtag on the back of a whale.

4.4.4 Marine Acoustics Inc. (MAI)

MAI provided two Big Eyes binoculars for visual observations from the R/V Ranger. Southwest Fisheries Science Center provided a second pair but one was not functional and was returned. The Big Eyes are Fujinon Polaris 24X binoculars as can be seen in Figure 4-7.

Figure 4-7. Big Eye binoculars used for visual observations from the R/V Ranger.

5 Daily Schedule

Date			**Activities**							
Day (dd-mmm-yy)		**Julian day**	**Ranger**	**Black Fin**	**Tagging**	**Tag Code**	**Species**	**Sex**	**Playback**	**Flights**
13-Aug-07	Monday	225	in port	in port	no	n/a	n/a	n/a	n/a	**yes**
14-Aug-07	Tuesday	226	in port	at sea	no	n/a	n/a	n/a	n/a	n/a
15-Aug-07	Wednesday	**227**	in port	at sea	**yes**	**227**	**Md**	**female**	**no**	**yes (?)**
16-Aug-07	Thursday	228	at sea	at sea	no	n/a	n/a	n/a	n/a	n/a
17-Aug-07	**Friday**	**229**	at sea	at sea	**yes**	**229a and 229b**	**Gm**	n/a	**yes**	n/a
18-Aug-07	Saturday	230	at sea	radio tracking?	no	n/a	n/a	n/a	n/a	**yes**
19-Aug-07	Sunday	231	in port	in port	no	n/a	n/a	n/a	n/a	n/a
20-Aug-07	Monday	232	at sea	in port	no	n/a	n/a	n/a	n/a	**yes**
21-Aug-07	Tuesday	233	in port	in port	no	n/a	n/a	n/a	n/a	n/a
22-Aug-07	Wednesday	234	in port	in port	no	n/a	n/a	n/a	n/a	n/a
23-Aug-07	Thursday	**235**	at sea	at sea	**yes**	**235a and 235b**	**Md**	**male and female**	**no**	n/a
24-Aug-07	Friday	236	at sea	at sea	no	n/a	n/a	n/a	n/a	n/a
25-Aug-07	Saturday	237	at sea	?	no	n/a	n/a	n/a	n/a	n/a
26-Aug-07	Sunday	238	at sea	?	no	n/a	n/a	n/a	n/a	n/a
27-Aug-07	Monday	239	at sea	?	no	n/a	n/a	n/a	n/a	n/a
28-Aug-07	Tuesday	240	at sea	at sea	no	n/a	n/a	n/a	n/a	n/a
29-Aug-07	Wednesday	241	at sea	at sea	no	n/a	n/a	n/a	n/a	n/a
30-Aug-07	Thursday	242	at sea	at sea	yes	n/a	n/a	n/a	n/a	n/a
31-Aug-07	Friday	243	at sea	at sea	yes	n/a	n/a	n/a	n/a	n/a
1-Sep-07	Saturday	244	at sea	at sea	yes	n/a	n/a	n/a	n/a	n/a

2-Sep-07	**Sunday**	**245**	at sea	at sea	**yes**	**245**	**Md**	**female**	**yes**	n/a
3-Sep-07	Monday	246	at sea	at sea	yes	n/a	n/a	n/a	n/a	n/a
4-Sep-07	Tuesday	247	in port	in port	no	n/a	n/a	n/a	n/a	**yes**
5-Sep-07	**Wednesday**	**248**	at sea	at sea	**yes**	**248a and 248b**	**Md**	**female and male**	n/a	n/a
6-Sep-07	Thursday	249	at sea	in port	no	n/a	n/a	n/a	n/a	**yes**
7-Sep-07	Friday	250	at sea	in port	no	n/a	n/a	n/a	n/a	no
8-Sep-07	Saturday	251	in port	in port	no	n/a	n/a	n/a	n/a	no
9-Sep-07	Sunday	252	in port	in port	no	n/a	n/a	n/a	n/a	no
10-Sep-07	Monday	253	in port	in port	no	n/a	n/a	n/a	n/a	no
11-Sep-07	Tuesday	254	in port	in port	no	n/a	n/a	n/a	n/a	no
12-Sep-07	Wednesday	255	in port	in port	no	n/a	n/a	n/a	n/a	no
13-Sep-07	Thursday	256	at sea	at sea	yes	n/a	n/a	n/a	n/a	no
14-Sep-07	Friday	257	at sea	in port	no	n/a	n/a	n/a	n/a	no
15-Sep-07	Saturday	258	at sea	in port	no	n/a	n/a	n/a	n/a	no
16-Sep-07	**Sunday**	**259**	at sea	at sea	**yes**	**259a**	Gm	**male**	**no**	no
17-Sep-07	**Monday**	**260**	at sea	at sea	**yes**	**260a**	Gm	**male**	**no**	no
18-Sep-07	Tuesday	261	at sea	at sea	yes	n/a	n/a	n/a	n/a	no
19-Sep-07	Wednesday	262	in port	in port	no	n/a	n/a	n/a	n/a	no
20-Sep-07	Thursday	263	at sea	at sea	yes	n/a	n/a	n/a	n/a	no
21-Sep-07	Friday	264	at sea	at sea	no	n/a	n/a	n/a	n/a	no
22-Sep-07	Saturday	265	in port	in port	no	n/a	n/a	n/a	n/a	no

Table 5.1 – Daily schedule. RHIB 18 was in port on 13 August, at-sea on 14-15 August, the remainder of the time (16 August – 22 September) it was on the R/V Ranger. Globicephala macrorhynchus (Gm), Mesoplodon densirostris (Md)

6 Methods of Operation

6.1 BRS operational modes

BRS operated in four modes. These were used to help define the routines to be used in each case.

Search and Assessment

Vessels were at sea under guidance from M3R. This included a daily routine involving the manning of M3R from 05.00, a team leader briefing at 06.00 to decide the plan of the day, and the remainder of the day being spent attempting to observe, identify, and tag whales. Search and Assessment Mode moved to Playback Mode when a tag was applied.

Playback

The Blackfin followed focal animals that had been tagged and during a playback sequence.

Monitoring and mitigation

Vessels and aircraft were undertaking post-playback monitoring of the region where the playback took place as well as adjacent beaches. Normally, animals would be followed by Blackfin until she broke off to return to the AUTEC harbor. R/V Ranger was used to search the region where a playback occurred until taking over the focal follow from Blackfin and continuing this through the night using radio direction finding on the tag.

In addition, monitoring flights took place after playbacks to search the beaches and to carry out a search pattern across the Tongue of the Ocean centered on the region of the playback.

Stand-down

Vessels were in port because of weather constraints, range inaccessibility or due to technical difficulties.

6.2 Playback sequence

The following sequential list of actions was developed by the BRS team from their experience of the playback conducted.

1. Start criteria

i) Pre-start preparation
- a) Cast XBT if required to measure sound speed profile
- b) transmit XBT data to acoustic modelers at AUTEC
- c) run propagation loss model
- d) decide on source depth
- e) iterate c and d if necessary

ii) Blackfin follows group of whales

a) Blackfin determines whether a juvenile is in the group, photoidentifies each whale in the group to determine whether any have been exposed before and determines if any adult males are taggable.
b) If group is appropriate, launch tag boat (11 ft inflatable)
c) Once tag boat is in the water, the major Blackfin effort involved putting taggers near whales

iii) Whale tagged
a) retrieve tag boat onto Blackfin
b) photograph tagged whale
c) start focal follow of tagged whale

iv) Chief Scientist to convey playback sequence to R/V Ranger source team. (Blackfin to shut down radio channel used to discuss playbacks)

v) Photo-id continues to confirm as far as possible that:
a) group has not been exposed before
b) for BW, no juvenile in group is less than 3/4 length of adults

iv) Stand-by post-exposure monitoring and mitigation procedure. Options include:
a) inform AUTEC assets (aircraft and ships) of region of special interest and times of desired effort (discuss with AUTEC program manager)
b) arrange for monitoring and mitigation flight from West Palm Beach

vii) Suitable pre-exposure interval (1 dive BW, other species either match to prior BW timing, or >30 min)
a) satisfactory base-line achieved from focal follow assisted by radio beacon on tag and by M3R: confirm from team leaders
b) visual observers on R/V Ranger keep group in sight as far as possible

viii) Position R/V Ranger @1000-2000m from animal <u>during exposure</u> (R/V Ranger to maintain speed < 5 knots while maneuvering). Ensure that the source is at depth <5 min after the start of a deep dive.

ix) Lower source and reference hydrophone to selected depth

x) Check to make sure that subjects are the closest group to R/V Ranger using, 360^{o} visual check from vessel. Inform CS if non-subject group is closer than the focal group.

xi) CS to check “green” from participants based on local status:
a) focal follow (Blackfin)
- Normal behavior
- Weather/sea state okay (i.e. <B4, no squalls approaching)
- Enough daylight left

b) R/V Ranger visual observation team determines suitable radio tracking capability
c) R/V Ranger source team determines source is ready for deployment
d) M3R and, where relevant other AUTEC assets are available.

xii) CS call for playback to begin

a) MFA: Ramp up 3 dB every 25 sec for 10 min then maintain at max level (~212 dB)
b) Orca: use continuous wave file for 10 min ramp up then recycle at max level (~203 dB)

2. *Shutdown criteria*

i) Acoustic (BW only)
   a) Test 1: cessation of clicking
   b) Once team analyzes results of previous tests and agrees that this criterion is safe and necessary, maintain stable RL at cessation of clicking; continue through ascent and first shallow dive.
ii) Visual observers or focal follow call for shutdown based on response from observers and M3R (see Table 6-1).
iii) Focal follow call animal out of sight and not detected (using VHF) for too long following deep dive.
iv) Focal follow cannot maintain follow due to weather, equipment etc.
v) Cetacean sighted nearing 200m zone from R/V Ranger .

Table 6-1. Playback shut-down criteria used during BRS-07.

Monitoring Method	**Animal Responses**	**Go/No-go Criteria**
Passive Acoustic Monitoring (PAM)	• Cessation of clicking determined by M3R PAM • Unusually rapid movement	• Stop on first PB • Once team analyzes results of previous tests and agrees that this criterion is safe and necessary maintain stable RL thru first shallow dive
Visual observers	• Strong and abnormal directed swimming (at surface) • Increased and abnormal surfacing rate and respiration rate • Animal surfacings with pattern(s) of directed movement, especially toward shore • Unusual and abnormal surface/subsurface behavior involving apparent disorientation and confusion or loss of group cohesion • Animal defecation on an unusual scale during or immediately after playback transmission	• Evaluate response and cease transmit if and when CS concerned about risk • Immediate cessation

3. *Post exposure monitoring and mitigation*

Actions are predicated upon operational safety and equipment availability. Actions are advisory and likely to change according to circumstances. In all cases, should any stranding be observed, this must be reported immediately to the CS who will then initiate the Stranding Plan as detailed in the Plan of Experiment and Protocol.

i) Blackfin will track the tagged whale and its associated group with the assistance of M3R until nightfall. If Blackfin cannot track the tagged whale because of sea state then R/V Ranger will take over tracking.

ii) R/V Ranger will survey a region around the exposure site covering a 5 km radius from the exposure. R/V Ranger will use a search pattern that:
   a) takes account of current observational conditions, including sea state, that affect the effectiveness of Bigeyes as a search tool.
   b) allows systematic search of the focal region (e.g., a box pattern) that covers all of the sea area within 5 km radius
   c) takes account of possible drift due to current and wind

iii) At nightfall (around 18.30) stand-down Blackfin.

iv) At nightfall R/V Ranger will switch to tracking the focal group using VHF tracking if available and also using the assistance of M3R, which should set up a night watch if necessary.

v) At dawn deploy Blackfin to help track and recover tag if required.

vi) At dawn R/V Ranger will return to the exposure site to continue monitoring if not completed the previous evening and if no other AUTEC assets are available to achieve this (see ii above).

vii) Deploy any AUTEC assets that are available immediately after playback and through the following day, and direct as much as possible to the focal area and associated coastline. Use additional aerial monitoring if required to cover coastline in the area adjacent to the playback when AUTEC assets not available.

viii) For first beaked whale exposure, complete a full monitoring and mitigation flight of the region, with special focus upon the region of playback and local coastal areas, during the following day and taking account of wind, tide and current speeds.

ix) For situations in which both R/V Ranger and Blackfin cannot track the tagged group or the tag, an aircraft may be used to help localize the tag. Other assets may be deployed to recover the tag as required.

6.3 Sound Stimuli

Three different sound stimuli were used in BRS-07. The propulsion sound of the R/V Ranger (Fig. 6-1) was used in the Ship Noise Evaluation Trials (SNETs, see later section of this report). The other two stimuli are mid-frequency sonar (MFA, Fig. 6-2) and killer whale (Orca, Fig. 6-3) sounds. The mid-frequency sonar sounds used in the BRS were selected from actual waveforms transmitted by US Navy MFA sonars. The killer whale sounds used were a 10 minute-segment recording of wild killer whale calls recorded from the North Atlantic by Sophie van Parijs and from marine mammal-eating (transient) killer whales recorded in southeast Alaska in the North Pacific by Volker Deecke. Where more than ten minutes of transmission were required, this signal was repeated. There are some brief recordings of killer whales recorded in Bahamian waters by the Bahamas Marine Mammal Research Organization, but these were not long enough or of sufficient signal to noise ratio to use as stimuli. Deecke et al. (2002) have shown that harbor seals react to the calls of strange killer whales as a predator, and this is typical for reactions to predator calls, reducing concern about using killer whale stimuli from areas other than the Bahamas.

The MFA and Orca sounds were transmitted through a sound source that was designed to broadcast in the 2-5 kHz frequency band. This was selected to match the frequencies of the MFA stimuli, but was narrower band than the sounds produced by killer whales. This required processing of the killer whale waveform to limit the signal to the 2-5 kHz region and to match the spectrum of the speaker for more accurate re-creation of the 2-5 kHz spectrum of the Orca stimulus. The loss of higher frequencies of the killer whale calls was similar to the frequency dependent attenuation of high frequency calls, leading the playback stimulus to sound as if it came from a more distance higher bandwidth source. This lack of full bandwidth means that the stimulus should probably be viewed as an attenuated killer whale stimulus.

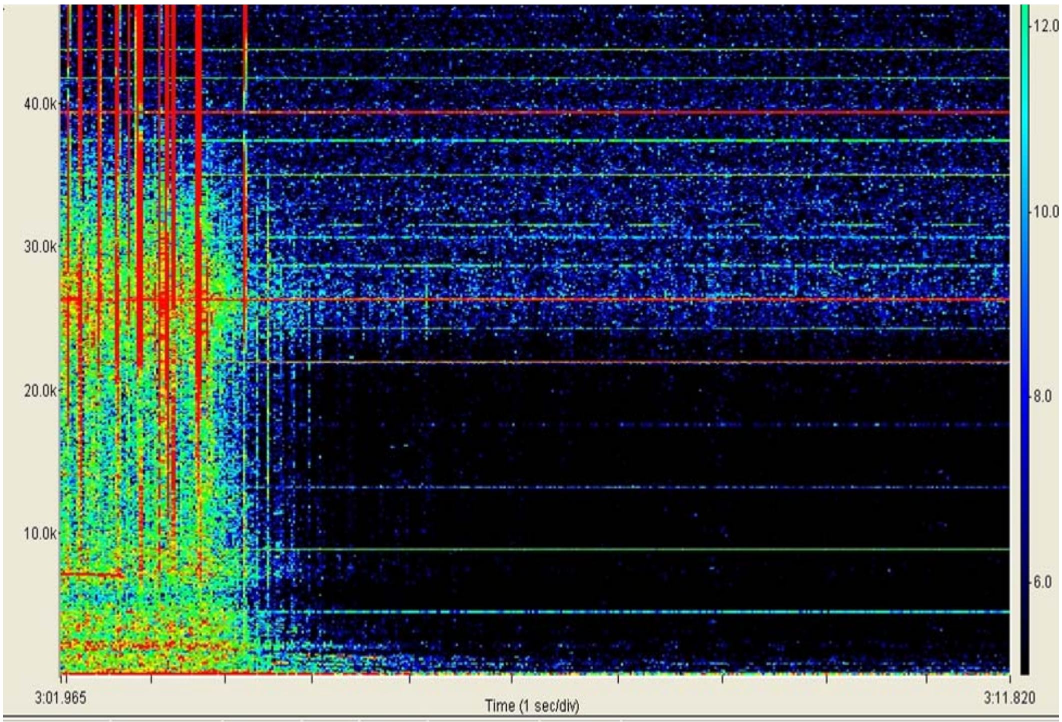


Figure 6-1. Spectrogram of vessel noise from the R/V Ranger.

Figure 6-2. Spectrogram of MFA sonar stimulus as recorded from AUTEC range hydrophones.

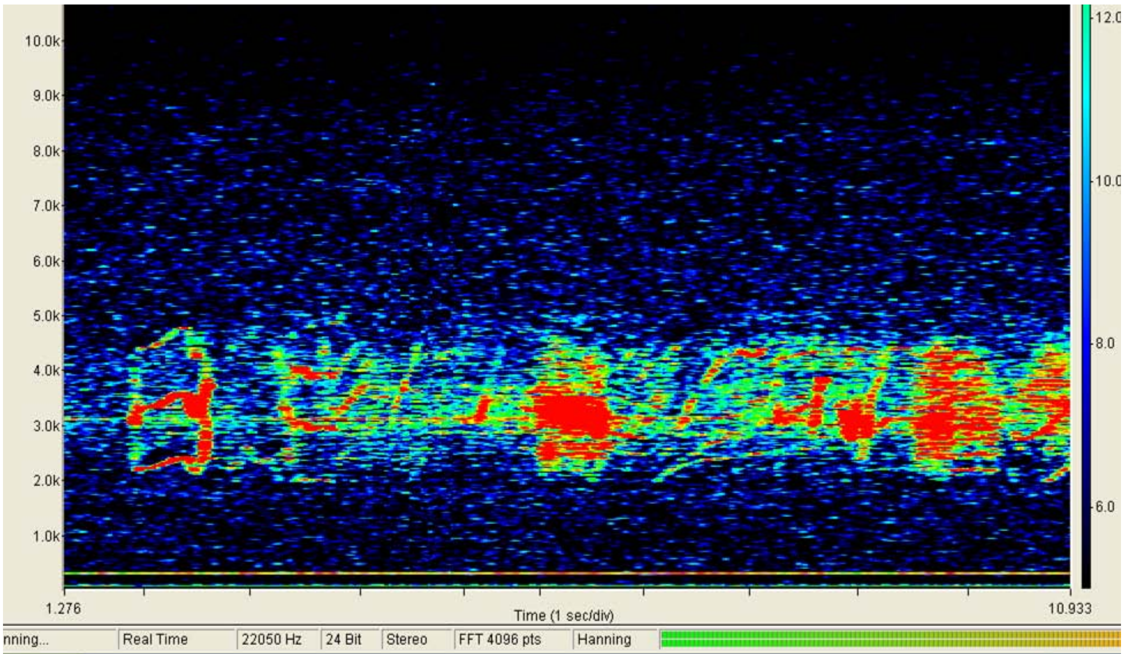


Figure 6-3. Spectrogram of killer whale stimulus filtered in the 2-5 kHz band to match the transmit bandwidth of the source used for the playbacks.

Each of the playback experiments, the first to pilot whales on 17 August (Table 6-2) and the second to a beaked whale on 2 September (Table 6-3) used a ramp up procedure to increase the source level of playback from a level that should have been barely detectable up to a maximum RL below 170 dB. The nominal source depth was 18 m for the pilot whales 45m for the beaked whales.

Table 6-2. Ramp up procedure used for playback experiment on 17 August 2007 to two tagged pilot whales Gm07_229a and b).

TIME	SIGNAL LEVEL IN dB	WAVEFORM	COMMENTS
1458:00[3]	152	MFA 1	Test conductor desired to ramp up to the full level over the whole 20 minute period. This required 2 pings at each level
1458:25	152	MFA 1	
1458:50	155	MFA 1	
1459:15	155	MFA 1	
1459;40	158	MFA 1	
1500:05	158	MFA 1	
1500:30	161	MFA 1	
1500:55	161	MFA 1	
1501:20	164	MFA 1	
1501:45	164	MFA 1	
1502:10	167	MFA 1	
1502:35	167	MFA 1	
1503:00			secured signal at 167 dB to pull source and reposition
1552:00	167	MFA 1	
1552:25	167	MFA 1	
1552:50	170	MFA 1	
1553:15	170	MFA 1	
1553:40	173	MFA 1	
1554:05	173	MFA 1	
1554:30	176	MFA 1	
1554:55	176	MFA 1	
1556:20	179	MFA 1	
1556:45	179	MFA 1	
1557:10	182	MFA 1	
1557:35	182	MFA 1	
1558:00	185	MFA 1	
1558:25	185	MFA 1	
1558:50	188	MFA 1	
1559:15	188	MFA 1	
1559;40	191	MFA 1	
1600:05	191	MFA 1	
1600:30	194	MFA 1	
1600:55	194	MFA 1	
1601:20	197	MFA 1	

[3] All times in this document are local Eastern Daylight Time unless otherwise stated.

1601:45	197	MFA 1	
1602:10	200	MFA 1	
1602:35	200	MFA 1	
1603:00	203	MFA 1	
1603:25	203	MFA 1	
1603:50	206	MFA 1	
1604:15	206	MFA 1	
1604:40	209	MFA 1	
1605:05	209	MFA 1	
1605:30	212	MFA 1	
1605:55	212	MFA 1	
1636:30	>100	ORCA	initial start using ramped signal at 60dB attenuation
1640:00	>100	ORCA	signals extremely low level subtracted attenuation 30 dB step
1642:00	100	ORCA	reduced attenuation by 10dB remainder 20dB
1645:00	100	ORCA	Reduced attenuation by another 10 dB
1650:00	100	ORCA	Reduced attenuation by another 10 dB 0 attenuation from AASP
1652:00	110	ORCA	signal ramping using the preset wave file. Levels still very low
1652:30	110-115	ORCA	signal variable level because of composition
1653:00	0		secured to insert external amplifier into system
1653:10	110-120	ORCA	external amp at 0
1654:00	115-120	ORCA	external amp at 0
1654:35	115-120	ORCA	external amp at 0
1655:00	115-130	ORCA	external amp at +3
1655:25	120-140	ORCA	external amp at +6
1655:50	130-150	ORCA	external amp at +9
1656:15	140-160	ORCA	external amp at +12
1656:40	150-165	ORCA	external amp at +15
1657:05	155-170	ORCA	external amp at +18
1657:30	165-180	ORCA	external amp at +21
1657:55	175-190	ORCA	external amp at +24
1658:20	184-190	ORCA	external amp at +27
1658:45	192-196	ORCA	external amplifier at 29dBv gain

Table 6-3. Ramp up procedure used for playback experiment on 2 September 2007 to one tagged Blainville's beaked whale (Md07_245a).

TIME	SIGNAL LEVEL IN dB	WAVEFORM
1328:30	152	MFA 1
1329:28	155	MFA 1
1329:48	158	MFA 1
1330:12	161	MFA 1
1330:37	164	MFA 1
1331:02	167	MFA 1
1331:27	170	MFA 1
1331:52	173	MFA 1
1332:17	176	MFA 1
1332:44	179	MFA 1
1333:07	182	MFA 1
1333:32	185	MFA 1
1333:57	188	MFA 1
1334:22:	191	MFA 1
1334:47	194	MFA 1
1335:12	197	MFA 1
1335:37	200	MFA 1
1336:02	203	MFA 1
1336:27	206	MFA 1
1336:52	209	MFA 1
1337:17	212	MFA 1
1337:42	212	MFA 1
1338:07	212	MFA 1
1338:02	212	MFA 1
1338:57	212	MFA 1
1339:22	212	MFA 1
1339:47	212	MFA 1
1340:12	212	MFA 1
1340:37	212	MFA 1
1341:02	212	MFA 1
1341:27	212	MFA 1
1341:52	212	MFA 1
1342:17	212	MFA 1
1342:42	212	MFA 1
1343:07	212	MFA 1
1343:34	212	MFA 1
1622:13	130-140	ORCA
1623:00	140-146	ORCA
1623:30	130-150	ORCA
1624:15	140-160	ORCA
1624:37	150-166	ORCA
1625:50	150-170	ORCA
1626:37	160-170	ORCA
1627:04	160-170	ORCA

1627:30	160-170	ORCA
1627:57	160-176	ORCA
1628:30	160-176	ORCA
1628:53	166-180	ORCA
1629:22	170-180	ORCA
1639:03	170-180	ORCA
1630:15	170-186	ORCA
1630:39	177-186	ORCA
1631:06	180-190	ORCA
1631:28	180-190	ORCA
1631:48	186-190	ORCA
1632:02	190-203	ORCA

6.4 Ship noise evaluation trials (SNETs)

6.4.1 Rationale

It became apparent in the early stages of BRS-07 that ship noise may have been a co-variate in the experimental design. The need to maneuver the R/V Ranger close to the focal animals means that vessel noise could be a significant factor in the outcome.

Moreover, it was also apparent that the time available for playbacks on tagged animals was constrained greatly by a variety of factors. The principle factor was weather because wind speeds >5-8 knots meant that tagging became impossible. This meant that there were considerable periods of time available to carry out studies to estimate the effects of ship noise alone.

6.4.2 Approach

The approach adopted involved the use of R/V Ranger (which is a noisy vessel) and M3R during periods of time when conditions were not workable for tagging. This included times when wind speeds were too high but it also included times when operational conditions on the Range precluded tagging.

Multiple tests were proposed in order to achieve a relatively large sample size (n=16) with the aim of examining the response of beaked whales to ship sound.

This complied with the terms of the Bahamian and US Permits (where it was defined as a close approach) so it lay within the experimental permitting procedures adopted to date.

6.4.3 Protocol

M3R was used to guide R/V Ranger to vocalizing beaked whales. This was normally a clearly defined group based upon M3R assessments of beaked whale activity. Ideally M3R had a position on these animals using a multiple hydrophone fix. In practice, this worked best in the northwest portion of the range.

R/V Ranger was positioned as close as possible to the vocalizations and waited for the completion of a surface-dive cycle. Whenever possible, R/V Ranger attempted to gain visual observation of BW while dead in the water (DIW), although in practice this was rarely achieved.

M3R recorded the restart of vocalizations and signalled this to R/V Ranger. About 3-5 min after the re-start of vocalizations, and when M3R were reporting reliable click detection, the CS called for R/V Ranger to select full speed for 1-2 minutes. After 1-2 minutes R/V Ranger was then asked to go DIW.

This procedure was carried out on up to 3-6 consecutive occasions, either during a single dive or during consecutive dives, for any group of whales being followed using M3R.

An alternative approach which was adopted opportunistically while R/V Ranger was in transit involved directing R/V Ranger to pass over groups of vocalizing beaked whales while travelling at 5-11 knots; i.e., normal approach speeds.

The details about the SNETs carried out are shown in Table 6-4.

Table 6-4: SNETs carried out during BRS-07.

SNET#	Date	Start time	End Time	Hydrophones
1	29 Aug	16.21	16.37	80, 83, 71, 72
2	30 Aug	15.40	15.57	26
3	13 Sept	12.43	13.07	8, 9
4	13 Sept	12.43	15.30	11
5	13 Sept	15.11	17.24	8, 26
6	14 Sept	17.02	08.57	29
7	14 Sept	08.40	10.58	29, 33, 32
8	14 Sept	10.25	11.34	8, 10, 11, 26
9	14 Sept	11.10	12.11	25, 26, 6, 7
10	15 Sept	11.40	11.53	15, 26, 6, 3
11	15 Sept	11.23	13.39	18, 21
12	15 Sept	13.15	13.55	6, 7, 4, 25, 3
13	15 Sept	13.39	14.34	23
14	15 Sept	14.11	16.02	28, 39
15	20 Sept	15.35	11.43	28
16	23 Sept	08.58	09.16	49, 43, 42

6.4.4 Analysis and outputs

M3R recorded the raw sound data files, as well as the processed archive files, for the dive sequence at the appropriate hydrophones for subsequent analysis.

The expected response variable will be the early cessation of clicking, the repetition rate of clicking and the frequency band of clicks before, during (if it is possible to discern clicks from background) and after the vessel sound exposure.

7 Data Inventory

Data archiving was carried out at the AUTEC facility. Table 7-1 lists the types of data generated in relation to the platform involved in the data collection. The data management scheme may be found in Appendix D.

Table 7-1: Data type produced by each platform.

Platform	Data Type	Format
R/V Ranger	Visual Team data (sightings, effort, environmental notes, comments)	files *.xls
	Visual Logger GPS navigation file	txt
	(VHF Radio tracking forms)	paper
	Narrative Daily Logs (Visual Team)	files *.doc?
	Narrative Daily Logs (Test Coordinator)	files *.xls
	Source Team Logs (time stamp + level source + alt/long	acii
Blackfin	GPS navigation file	txt
	Visual sightings (access to excell ot MJLogTool)	xls
	Behavioral/Focal follow observation sheet	xls
	Digital Pics (Photo ID)	files
	Photo forms (post analysis - except for tagged whales)	paper
	Narrative Daily Logs	xls
	Effort (from Blackfin bridge logbook)	
	Skin samples (forms with WHOI and Diane's codes and naming description)	
Tagging team (operating on board Blackfin)	Preparation Check list	paper
	Deployment form	paper
	Recovery form	paper
	Off load form	paper
	TAG 2 whale proc	paper
	VHF tracking forms	paper
	DTG file	
	CALs + Tag metafile	
Flights (dedicated BRS or opportunistic AUTEC)	Visual Contacts	*.xls
RIB 18 (not tagging - rib team will help visuals on the R/V Ranger for they are very low in number)	GPS Tracks	*.txt
	GPS Navigation File	
	Visual sightings	
	Behavioral/Focal follow observation sheet	
	Digital Pics (Photo ID)	files
	Photo forms	paper
	Effort/Narrative	
Tag data	Preparation Check list	paper
	Deployment form	paper
	Recovery form	paper
	Off load form	paper
	TAG 2 whale proc	paper
	DTG file	
	CALs + Tag metafile	
	Skin samples (see Black Fin)	paper
	VHF tracking forms	
Prop Loss Modeling	Input mat lab file	*.aim prj
	Output mat lab file	*.ascii

Platform	Data Type	Format
M3R	GPS	
AUTEC data control	HITS tracks	
	XBT	
	CTD	
	METEO	file *.doc ?
CS	Narrative daily logs	

8 Environmental Conditions

The wind speeds experienced during BRS-07 were close to the mean for the time of year (Fig. 8-1b). However, there was a particularly low variance in wind speed during September which meant that there were few calm periods in which tagging could take place (Fig. 8-1a).

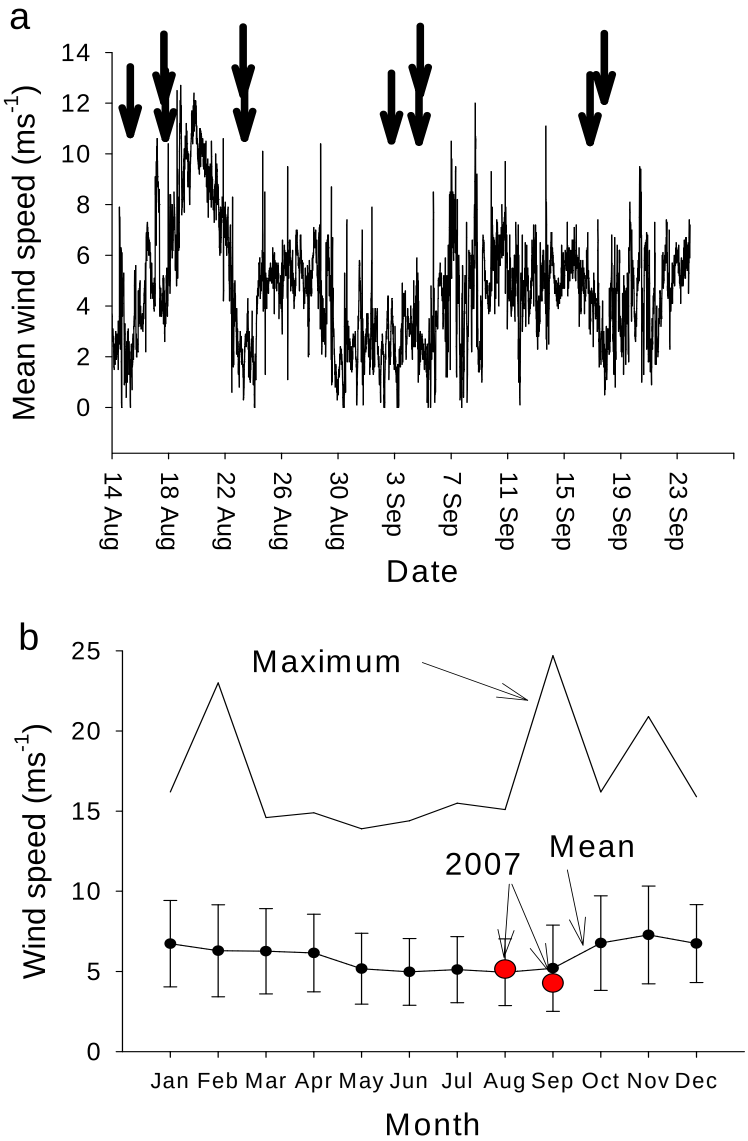


Figure 8-1: (a) The mean wind speed at Site 1 (AUTEC base) throughout BRS-07 (arrows indicate when tagging occurred) and (b) the 5-year mean (±SD) wind speed at Site 1 from 1996-2000 together with the mean maximum wind speed by month through the year. Plotted over this is the mean wind speed experienced during BRS-07.

We also analysed 6 years of data about the wave heights in the Tongue of the Ocean and found that, on average, a sea state of 1 or less was observed most frequently from June through October with the mode in September (Fig. 8-2). During September, on average, it was expected about 45% of days would be available for tagging but in 2007 <20% of days had this sea state.

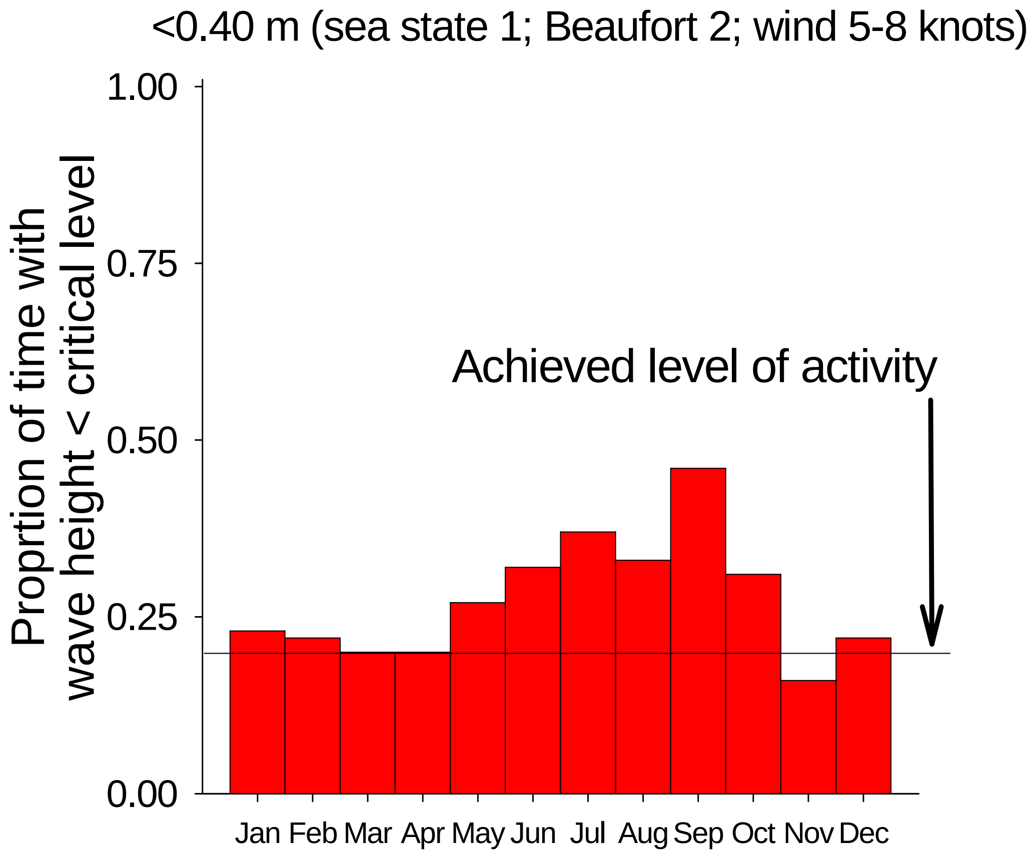


Figure 8-2: An analysis of the wave heights at AUTEC from 1999 to 2005 based or a model using wind speed, direction and bathymetry. This shows that the preferred sea state of 1 or less is available, on average, for about 45% of the time in September when BRS encountered particularly difficult conditions. Sea states are most favorable from June through September.

9 Results Summary

Figure 9-1. The Tagging team poised to place a tag on a Blainville's beaked whale.

9.1 Photo-identification

The Bahamas Marine Mammal Research Organization has been photo-identifying beaked whales and other cetaceans in TOTO since 2002. Figure 9-2 illustrates the kinds of natural markings that can be used to identify individual whales. This whale has a notch at the tip of its dorsal fin, and well defined scars from cookie-cutter sharks[4]. Several new scars are visible in August 2007 that were not present in June 2006, but there are sufficient natural markings for reliable identification of individuals.

Field Effort

A 29-foot (9.5 m) Blackfin ocean cruiser equipped with 2-225 hp four-stroke outboard engines was used for photo-identification and focal follows during BRS-07. The 11-foot (3.6 m) tagging boat was carried on deck and launched when tagging attempts were

[4] Cookie-cutter shark, *Isistius brasiliensis*, also known as cigar shark or luminous shark, is a small, rarely-seen dogfish shark. Its name is derived from its habit of removing small circular chunks of flesh from whales and large fish. It is hypothesized that the shark seizes its much larger prey with its jaws, then rotates its body to achieve a highly symmetrical cut. They are considered parasites.

deemed feasible. A second vessel, RHIB 18, deployed from R/V Ranger, was used opportunistically for photo-identification whilst on transit between AUTEC base and R/V Ranger.

During BRS-07, the Blackfin had 18 days at sea from (15 August – 21 September), during which the Blackfin was vectored to locations where acoustic detections were made by M3R. This effort covered 1188 nm (2198 km) and 151 hours of search, photo-identification, tagging and focal follow effort. The number of observers, which included the tagging team, ranged from 5 – 9 but averaged 8 throughout the field effort.

Marine Mammal Sightings

During BRS-07, there were 32 cetacean sightings made by observers on board the Blackfin and RHIB 18. In all, 49.1 hours were spent during sightings conducting photo-id, focal follows, tagging attempts and radio-tracking of tagged whales. During this time, over 38 hours of focal follow data were collected, including respiration rates and surfacing behaviour. Table 9-1 summarises other data collected during the marine mammal sightings.

The primary target species, Blainville's beaked whales (*Mesoplodon densirostris*), were sighted 19 times, representing 59% of all sightings. Short-finned pilot whales (*Globicephala macrorhynchus*), a secondary target species, were seen on 4 occasions. Other species sighted include pygmy sperm whales (*Kogia breviceps)* which were seen once and Atlantic bottlenose dolphins (*Tursiops truncatus*) which were sighted on 4 occasions inside AUTEC harbour. There were 4 distant sightings during which the species could not be determined.

Group sizes range by species with pilot whales found in the largest groups ranging from 30 – 40 whales. Blainville's beaked whales were found in mean group size of 2.5 whales (range 1 – 6, mode 2, median 2). This is smaller than has been found off Great Abaco Island where the group size has been reported as 4.1 (range 1-11, mode 2, median 4). A total of 219 animals were seen, including at least 23 juveniles or calves. When cetaceans were sighted, close approaches were made whenever possible in order to photograph all individuals in the group. Photographs were successfully obtained of 45 of the 50 beaked whales seen and all of the bottlenose dolphins. Initial analysis of the photographs taken of pilot whales sighted has not yet been undertaken but it is estimated that the BRS team photo-identified approximately 80% of all whales seen.

Skin samples were collected from 8 whales (5 beaked whales and 3 pilot whales) from the suction cups on the Dtag when the tag was recovered. The beaked whale samples will be contributed toward an on-going study of the population structuring of beaked whales in the Great Bahama Canyon.

Figure 9-2: Identification photographs of an adult male (Md517) taken more than 1 year apart showing individually distinctive markings of the same Blainville's beaked whale, Mesoplodon densirostris. This individual was first photographed by BMMRO in Tongue of the Ocean in March 2006 and seen 3 more times during BRS-07. Despite increased scarring between the two dates shown, Md517 is readily recognised by the notch in the leading edge of the dorsal fin and the unique pattern of scars laterally.

Table 9-1: Summary of marine mammal sightings and data gathered during BRS-07. (Preliminary photo-identification analysis has not yet been done for pilot whales.)*

Species	**No. Sightings**	**Mean (SD) Group Size**	**No. Animals Seen**	**No. Animals Photographed**	**No. Animals Tagged**	**No. Tissue Samples**
Blainville's beaked whale	19	2.5 (1.3)	50	45	6	5
Short-finned pilot whale	4	35 (4.1)	140	*	4	3
Atlantic bottlenose dolphin	4	5 (1.8)	20	20	0	0
Pygmy sperm whale	1	2 (NA)	2	0	0	0
Unk. Delphinid	1	1 (NA)	1	0	0	0
Unk. medium cetacean	2	2.5 (0.7)	5	0	0	0
Unk. Mesoplodon species	1	1 (NA)	1	0	0	0

Photo-identification of Blainville's beaked whales

Photo-identification techniques are useful to understand residency patterns and movement of individuals in and out of Tongue of the Ocean, to estimate abundance and to develop individual life histories to quantify reproductive cycles and survival. For these reasons, BMMRO has been compiling a catalogue of individually recognized Blainville's beaked whales from Tongue of the Ocean since 2002.

Photo-identification of individual beaked whales sighted during BRS-07 was also important to ensure that tagging or playbacks were not performed on the same individual more than once. Preliminary analysis of over 2000 photographs found that of the 45 Blainville's beaked whales photographed during BRS-07, there were 30 different individuals identified by their unique scarring patterns (Figure 9-2). This adds substantially to BMMRO's existing catalogue of 23 different individuals compiled prior to BRS-07.

The resighting rate within the BRS field effort for Blainville's beaked whales in Tongue of the Ocean was 0.33. When the BRS-07 data are combined with BMMRO's past data, the overall resighting rate for all Blainville's beaked whales in Tongue of the Ocean is 0.35. Although the majority of individuals were only photographed once during BRS-07, 5 whales were seen twice and 5 whales seen three times during the BRS-07 field effort. These results suggest that there is residency in the area by some whales. The rate of discovery graph (Fig. 9-3) shows that more photographing of new individuals and more field effort is required to better understand residency patterns for Blainville's beaked whales in Tongue of the Ocean.

Table 9-2 summarizes all beaked whales photo-identified by BMMRO in TOTO from 2002 through BRS-07. As more whales have been photographed, the number of resighted individuals increases and the number of new animals decreases.

Table 9-2: Photo-identifications of Blainville's beaked whale, Mesoplodon densirostris taken by the Bahamas Marine Mammal Research Organization in Tongue of the Ocean from 2002-2007.

date	**# animals photographed**	**# new animals**
28-Mar-02	1	1
27-Apr-05	3	3
24-Sep-05	6	6
27-Sep-05	17	17
6-Mar-06	20	18
23-Oct-06	24	22
19-May-07	26	24
15-Aug-07	27	25
23-Aug-07	36	31
30-Aug-07	42	35
31-Aug-07	50	39
1-Sep-07	52	39

date	# animals photographed	# new animals
2-Sep-07	63	43
3-Sep-07	64	44
5-Sep-07	71	46

One can evaluate the rate at which individual whales are re-sighted by plotting the number of animals photographed against the number of new animals identified. The "discovery curve" for these data (Fig. 9-3), has not reached an asymptote, but suggests that there is a relatively resident population of individual beaked whales on the AUTEC range. The number of whales photo-identified on the range (46) is quite close to the average number estimated to be present on the AUTEC hydrophone range (46.125; Moretti et al. 2006).

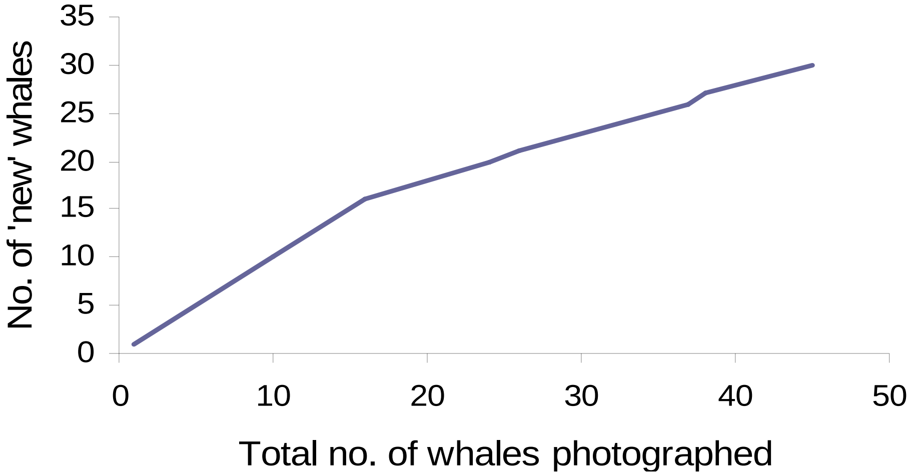


Figure 9-3: Rate of discovery of new Blainville's beaked whales, Mesoplodon densirostris, by Bahamas Marine Mammal Research Organization in Tongue of the Ocean, Bahamas.

9.1.1 Tagging

The method for determining the acoustic exposure at the whale along with its behavioral response in BR-S07 involves attaching a tag (Dtag) to each experimental subject. The tag is designed to record sound and behavior throughout the dive cycle, even when animals are deep and out of view (Johnson and Tyack, 2003). The Dtag has an acoustic sensor that can record calibrated measurements of sound exposure levels at the whale along with the vocal behavior of the tagged and other whales, and non-acoustic sensors that record depth, temperature, orientation and acceleration of the whale. These non-acoustic sensors are sampled rapidly enough to capture fluking and swimming behavior, along with subtle changes in orientation. The record of Dtag deployments is shown in Table 9-3.

Table 9-3: Summary of Dtags deployed during BRS-07.

Species	Number of deployments	Duration of deployments (h)
Blainville’s beaked whale	4	17
Blainville’s beaked whale	2	1.5
Pilot whale	1	17
Pilot whale	1	14
Pilot whale	1	3
Pilot whale	1	1.2

BRS-07 Beaked whale and Pilot whale Tagging Narrative

During BRS07 6 *Mesoplodon densirostris* were tagged. These tags were deployed over a 6 week period, on 4 different days (Table 9-4). A total of 74 hours and 24 minutes of Dtag diving were collected from *Mesoplodon densirostris*. The BRS team was successful in tagging beaked whales only when sea states were 1 or less, and the seas were extremely calm. There was only one visual sighting of a beaked whale in sea states greater than 1 or seas with swell or wave heights greater than 0.5 meters. One full playback experiment with *Mesoplodon densirostris* was conducted on 2 September 2007, and the other tag deployments were used for collecting baseline behavioral and acoustic data.

We also tagged 4 *Globicephala macrorhynchus* during the same 6 week period. A total of 34 hours and 19 minutes of Dtag data were collected from pilot whales (Table 11). An exposure experiment on 2 pilot whales was conducted on 17 August 2007, and the other 2 deployments collected baseline data. Attempts to tag pilot whales only occurred in weather conditions which were not conducive to tagging beaked whales. The BRS team was able to successfully tag pilot whales in sea states up to 4 and with seas around 1 meter.

Table 9-4: Details of the deployments of Dtags carried out during BRS-0(. Globicephala macrorhynchus (Gm), Mesoplodon densirostris (Md))

Date	Tag ID	Tag #	Species	Tag on Time	Tag off Time	Total on Animal Time	Experiment
15-Aug	md07_227a	225	Md	10:47:26	6:15:19	19:27:53	baseline
17-Aug	gm07_229a	227	Gm	13:04:09	2:03:05	12:58:56	playback
17-Aug	gm07_229b	226	Gm	14:15:28	17:28:24	3:12:56	playback
23-Aug	md07_235a	212	Md	13:52:28	14:55:16	1:02:48	baseline
23-Aug	md07_235b	227	Md	14:01:08	14:58:47	0:57:39	baseline
2-Sep	md07_245a	227	Md	10:03:35	3:39:00	17:35:25	playback
5-Sep	md07_248a	227	Md	10:43:48	4:35:39	17:51:51	baseline
5-Sep	md07_248b	229	Md	14:31:23	8:00:22	17:28:59	baseline
16-Sep	gm07_259a	212	Gm	13:50:40	6:41:34	16:50:54	baseline
17-Sep	gm07_260a	210	Gm	10:02:15	11:18:48	1:16:33	baseline

						total	**108:43:54**
						total Md	**74:24:35**
						total Gm	**34:19:19**

Audited dive profiles

For each tag that was deployed on a whale, the audio data were monitored by ear ("audited"), and the times of any beaked whale clicks, buzzes, or playback signals detected were entered into a file. Blainville's beaked whales in TOTO make distinctive long buzzes that are categorized separately from the normal buzz as described by Johnson et al. (2006), and these long buzzes were listed as a category separate from normal buzzes. These times were overlaid on the dive profile obtained from the pressure record in Figures 9-4 to 9-7.

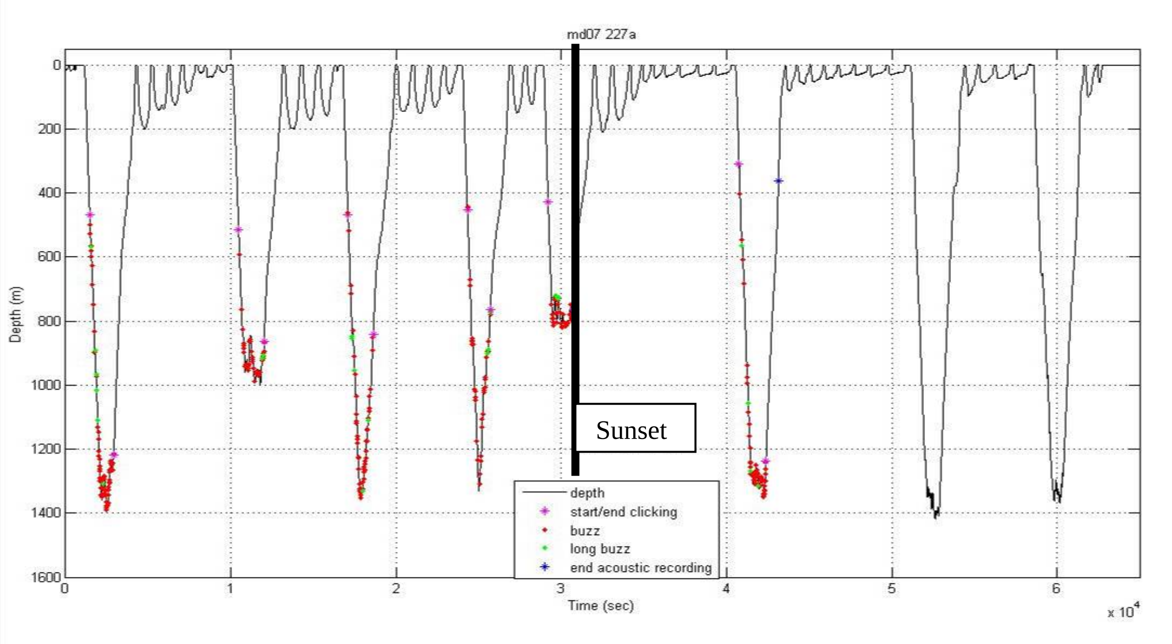


Figure 9-4: Audited dive profile for Mesoplodon densirostris tagged on Julian Day 227 (Md07_227a). Acoustic recording continued through the first six dives, stopping during silent ascent on the 6th dive. The non-acoustic sensors continued to record until the tag released.

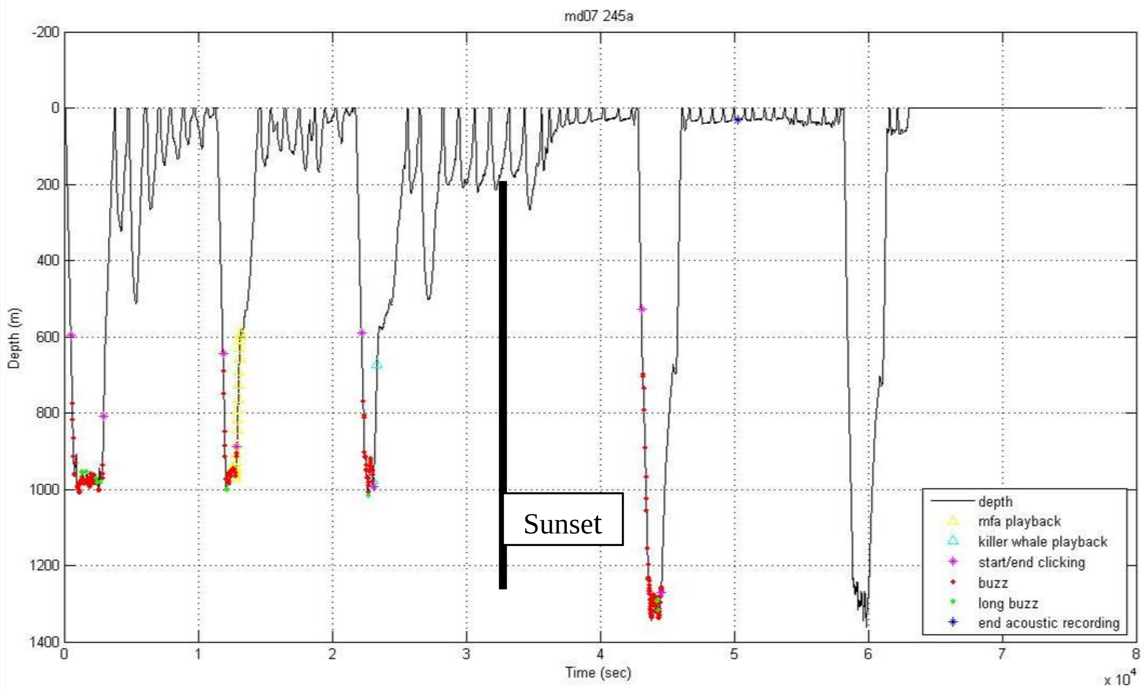


Figure 9-5: Audited dive profile for Mesoplodon densirostris tagged on Julian Day 245 (Md07_245a). Acoustic recording continued through the first four dives, stopping during the shallow dives at Time=50,000 sec. The non-acoustic sensors continued to record until the tag released.

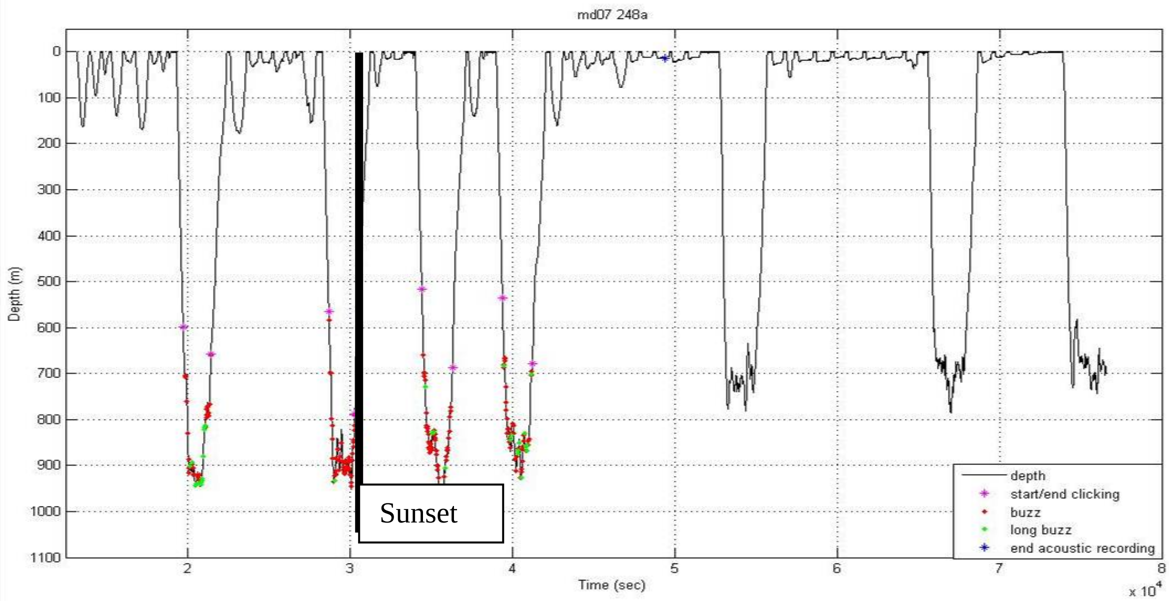


Figure 9-6: Audited dive profile for the first Mesoplodon densirostris tagged on Julian Day 248 (Md07_248a). Acoustic recording continued through the first four dives, stopping during the shallow dives just before Time=50,000 sec. The non-acoustic sensors continued to record until the tag released during the 7th dive.

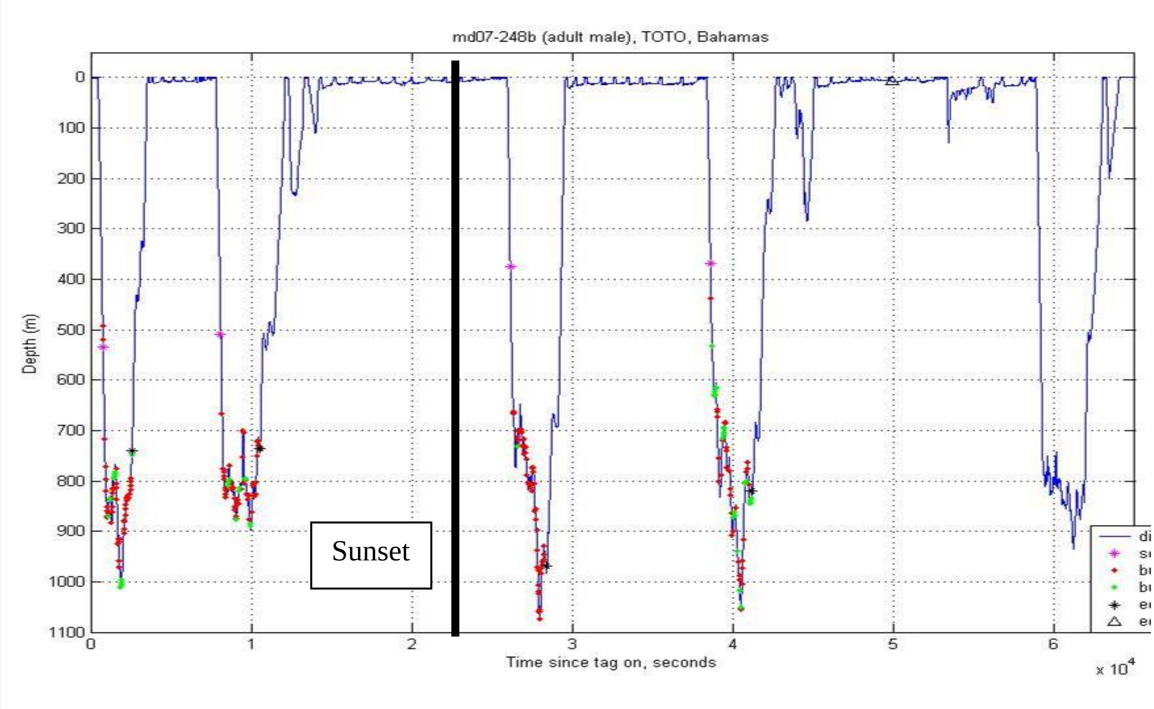


Figure 9-7: Audited dive profile for the second Mesoplodon densirostris tagged on Julian Day 248 (Md07_248b). Acoustic recording continued through the first four dives, stopping during the shallow dives just before Time=50,000 sec (Label "eoar" means end of acoustic recording." The non-acoustic sensors continued to record until the tag released during the 7^th^ dive.

The shallow dives of these whales appear to show a day-night difference, with shallower, more square-shaped shallow dives after. The last whale tagged (Md07_248b) was a large male who made fewer and shallower near-surface dives than the rest of the tagged whales both in TOTO and the Canary Islands (Tyack et al. 2006).

Modeling the movement patterns of tagged whales

Speed estimation

The Dtag is not equipped to measure the animal speed, but both the depth and the pitch of the animal are measured continuously. For this report the speed of the animal through the water was estimated by Kalman filtering according to the motion model:

$$V_Z = V \sin(\beta) \qquad (1)$$

where V_Z is the vertical speed obtained by differentiating the animal depth as function of time, β is the animal pitch, and V is the unknown speed through the water. This method assumes that the animal is moving through the water parallel to the rostral-caudal axes, that is: without any motion-induced lift, and that periods of zero pitch are short enough that the Kalman filter does not diverge.

Figures 9-8 to 9-11 show the resulting speed estimates for the 4 *Mesoplodon densirostris* with long tag attachments. For reference the depth profile is plotted on the top panel indicating the acoustically active time (foraging clicks) in red.

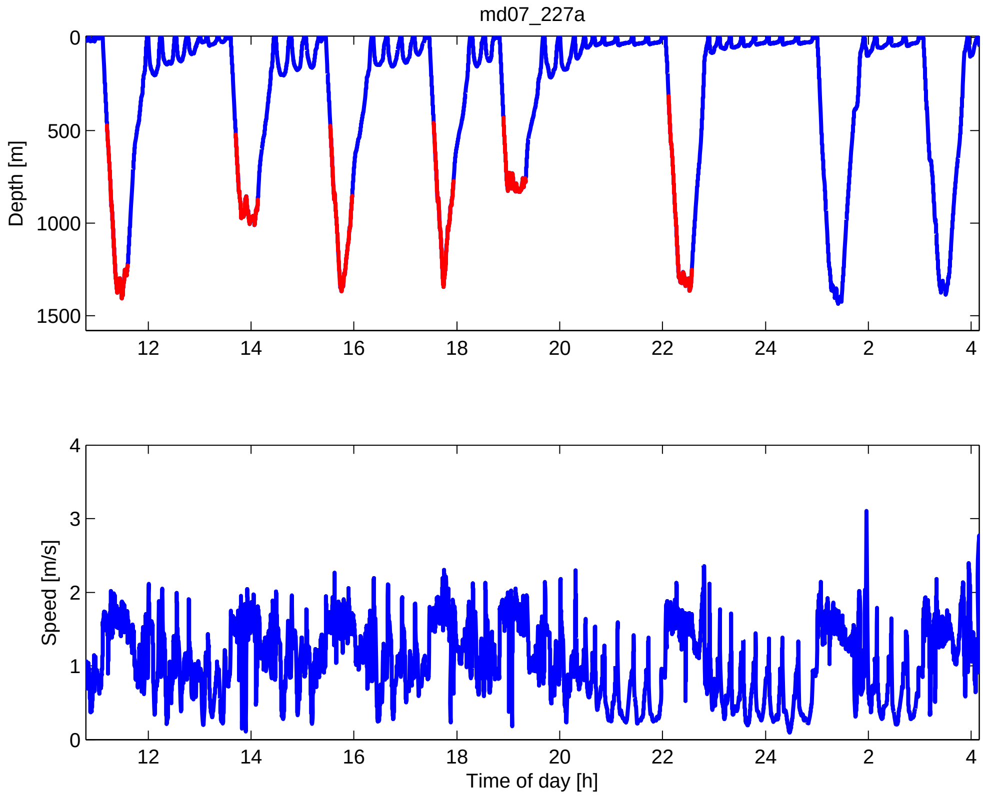


Figure 9-8: Dive profile and estimated speed for Mesoplodon densirostris tagged on Julian Day 227 (Md07_227a). The vocal intervals for the whale are indicated in red on the top cell. The bottom cell indicates the speed estimated by the Kalman filter. The last two dives have no red region because the acoustic record had ended at this later stage of the tag deployment.

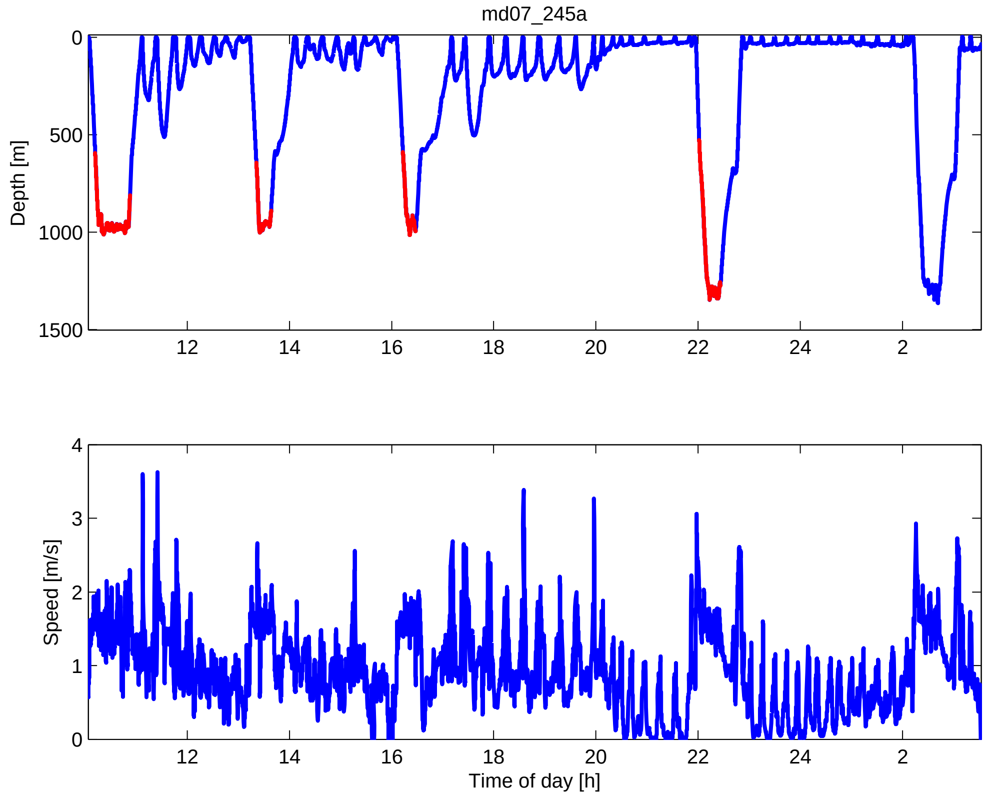


Figure 9-10. Dive profile and estimated speed for Mesoplodon densirostris tagged on Julian Day 245 (Md07_245a). The vocal intervals for the whale are indicated in red on the top cell. The bottom cell indicates the speed estimated by the Kalman filter. The last dive has no red region because the acoustic record had ended at this later stage of the tag deployment.

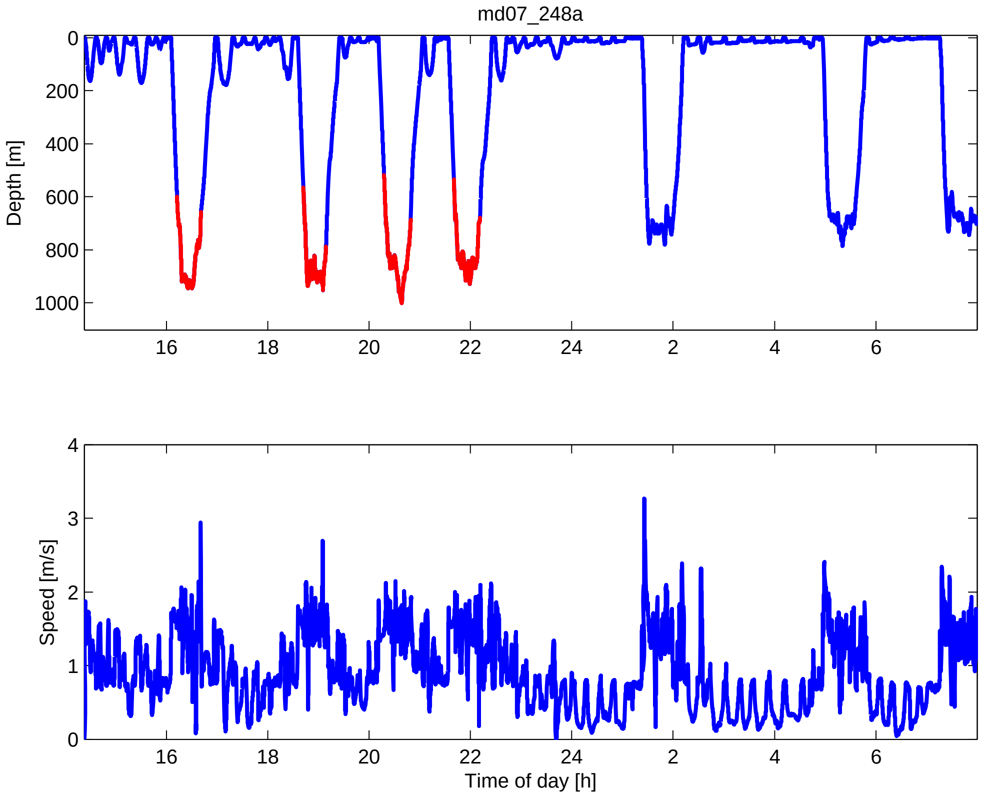


Figure 9-11: Dive profile and estimated speed for the first Mesoplodon densirostris tagged on Julian Day 248 (Md07_248a). The vocal intervals for the whale are indicated in red on the top cell. The bottom cell indicates the speed estimated by the Kalman filter. The last three dives have no red region because the acoustic record had ended at this later stage of the tag deployment.

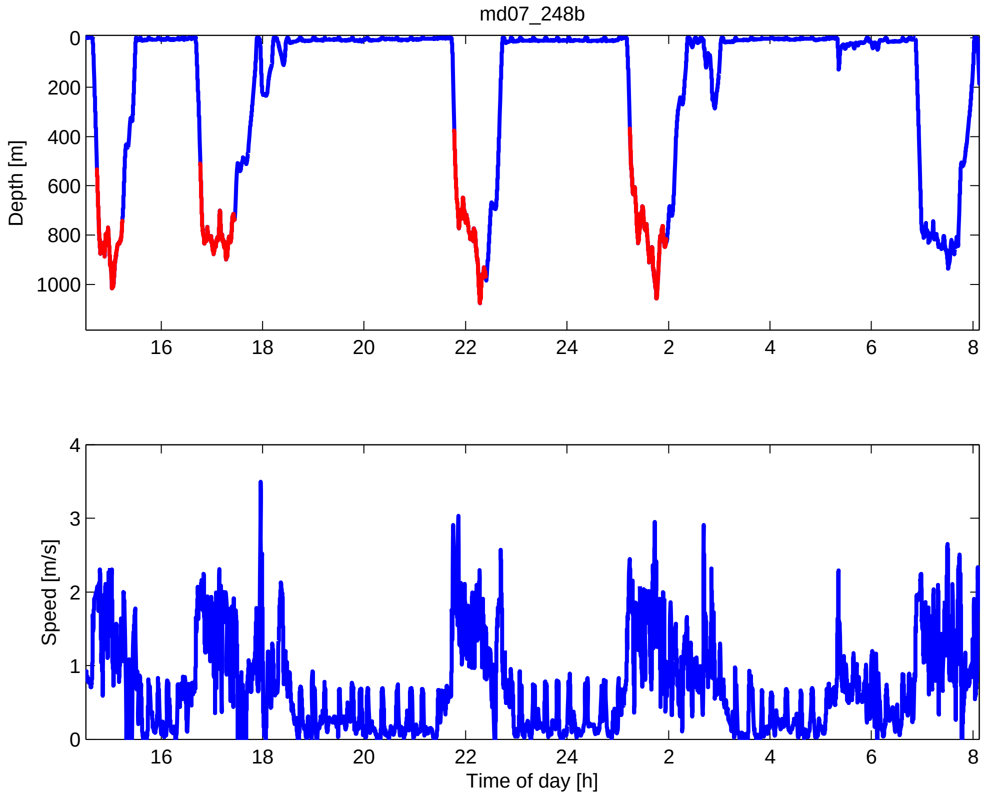


Figure 9-12: Dive profile and estimated speed for the second Mesoplodon densirostris tagged on Julian Day 248 (Md07_248b). The vocal intervals for the whale are indicated in red on the top cell. The bottom cell indicates the speed estimated by the Kalman filter. The last dive has no red region because the acoustic record had ended at this later stage of the tag deployment.

Pseudo-tracks

The three dimensional track of the tagged beak whale can be estimated from the non-acoustic sensors of the tag if one uses an estimate of swimming speed. Pseudo-tracks are estimated from pitch β, heading γ and speed estimation V according to:

$$Tx = V \cos(\beta) \sin(\gamma) \quad (2)$$
$$Ty = V \cos(\beta) \sin(\gamma) \quad (3)$$

where Tx and Ty describe the animal position in easterly and northerly direction. The pseudo-tracks are shown in Figures 9-13 to 9-16.

For md07_245a (Fig. 9-14), the animal exposed with sound, this pseudo-track was corrected so that the surfacing parts of the track correspond to the geographical location of sightings estimated from visual observations in vicinity of the exposure. The correction was done by adding a small constant to the heading (effectively correcting the estimated orientation of the tag on the whale) and by introducing a drift due to water current, so that the last surfacing before the exposure dives corresponds to the observed position of the terminal arching. The beginning of the dive is marked by a small square. Surfacing is marked in magenta. To facilitate the comparison the plots are all on the same scale.

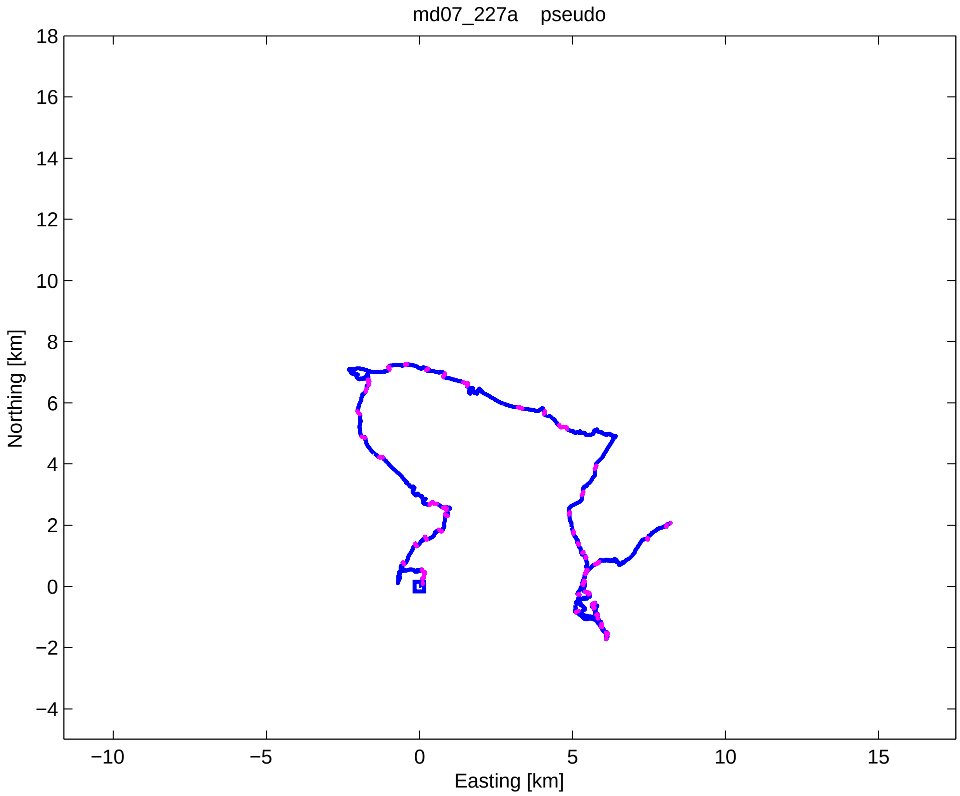


Figure 9-13: Pseudotrack of Mesoplodon densirostris tagged on Julian day 227 (Md07_227a). Periods when the whale was at the surface are colored magenta; dive intervals are colored blue.

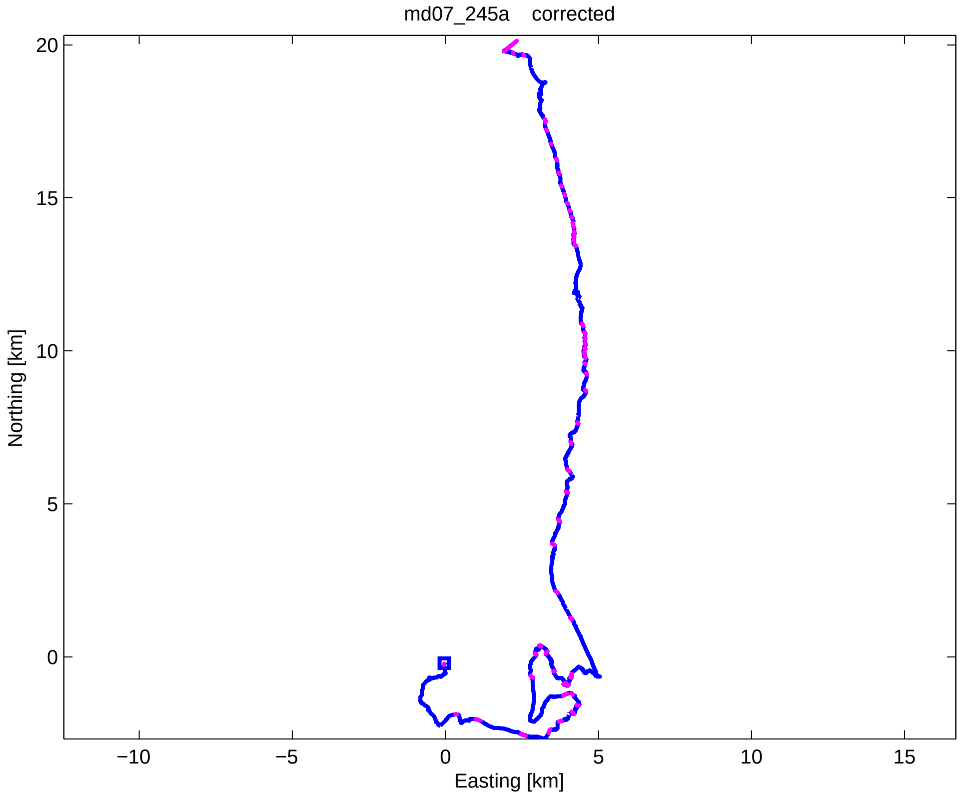


Figure 9-14: Pseudo-track of Mesoplodon densirostris tagged on Julian day 245 (Md07_245a). Periods when the whale was at the surface are colored magenta; dive intervals are colored blue.

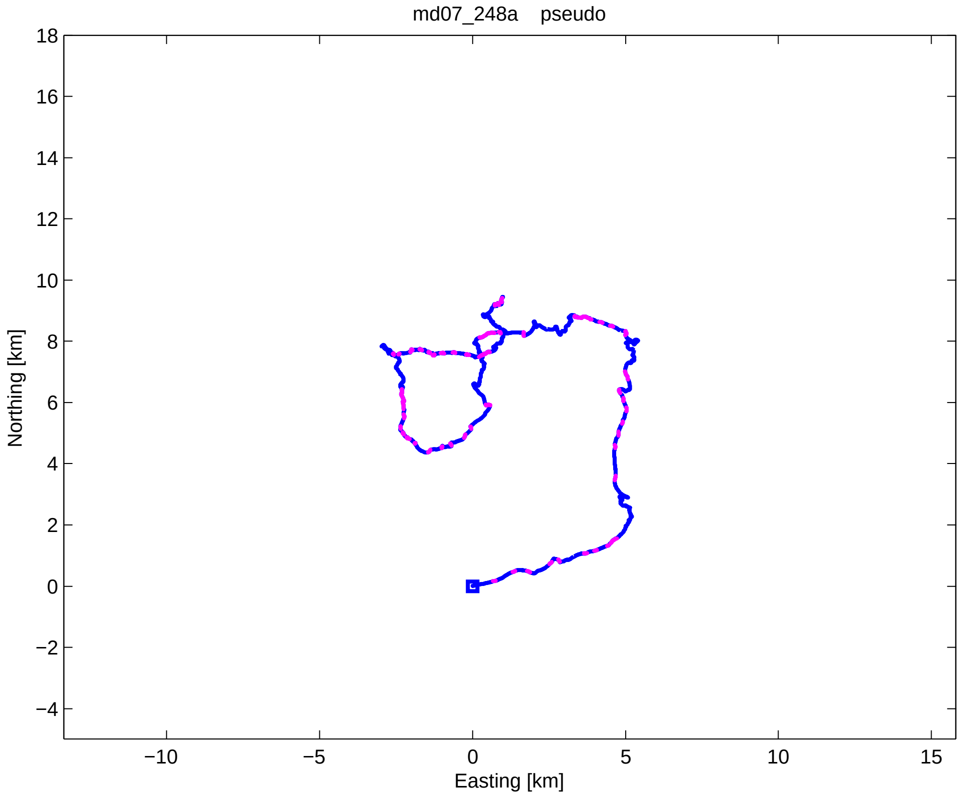


Figure 9-15: Pseudotrack of the first Mesoplodon densirostris tagged on Julian day 248 (Md07_248a). Periods when the whale was at the surface are colored magenta; dive intervals are colored blue.

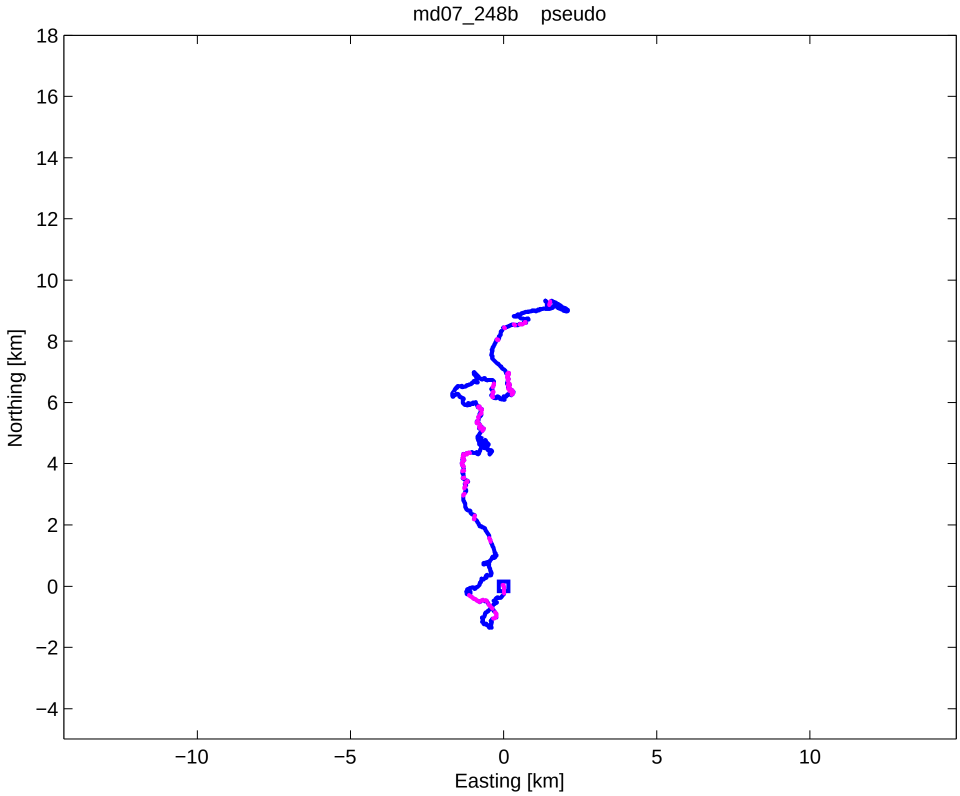


Figure 9-16: Pseudotrack of the second Mesoplodon densirostris tagged on Julian day 248 (Md07_248b). Periods when the whale was at the surface are colored magenta; dive intervals are colored blue.

9.1.2 Playbacks

Mesoplodon densirotris

The characteristics of the source and the characteristics of the playback stimuli are described in section 6.3 called “sound stimuli”. The playback protocol for beaked whales called for obtaining pre-exposure baseline data for the first foraging dive after tagging. Then the goal was to play back one sound stimulus during the next foraging dive and a second sound stimulus during the third dive. This protocol assumes that the subject has ceased a disturbance response if it decides to start a new deep foraging dive. While optimal experimental design would call for randomizing and balancing order of presentation, the top priority for these playbacks was MFA sonar. As the tag could fall off at any time, the decision was made to playback this stimulus first, then killer whale calls as a positive control stimulus. The goal was then to record several more deep foraging dives to measure return to baseline. The design also called for sufficient baseline tag data from the same site and season to test whether the playback dives differed from normal behavior. The beaked whale playback and baseline tagging achieved all of these goals.

An important element of the design was to monitor the tagged whale in real time during exposure. Two options were planned: monitoring clicking during a deep foraging dive, and visual observations of a whale at the surface, which requires flat calm conditions so a vessel can follow the whales during shallow dives. The only option BRS-07 was able to execute was acoustic monitoring during the dive. When a beaked whale descends for a foraging dive, it typically dives more or less vertically. This means that if visual observers can fix the last surfacing, the R/V Ranger would have a good idea of where to position for transmitting to the whale. The average descent rate for *Mesoplodon* is 1.6 m/sec (3.1 kt), and the typical depth at start of clicking is 500 m (1,640 ft) (Tyack et al., 2006), yielding an expected descent duration of about 5 min. Given the short time available to maneuver after the start of the dive, R/V Ranger positioned itself during the series of shallow dives about an hour before the deep foraging dive is expected within 1-2 km (0.54 – 1.08 nm) of the whale.

In order to define the minimum exposure required to evoke a response, the sound source started at a SL corresponding to a RL near predicted audibility and increased slowly until a response was detected (visually monitored if whale at the surface, cessation of clicking for a specified length of time during deep foraging dives) or the maximum received level was reached. Assuming a just-detectable RL at 3 kHz of 80 dB (similar to the *Tursiops* audiogram at 3 kHz (Houser and Finneran 2006) and more sensitive than measured at 5 kHz for *Mesoplodon europaeus* by Cook et al. 2006), the playback was started at a SL of 130-150 dB , at a range of 1 km (0.54 nm), for an RL (estimating -60 dB of TL) of 70-90 dB. The minimum duration of clicking during deep foraging dives in tagged *Mesoplodon* is 18 min (Tyack et al. 2006). With cessation of vocalization used as the response variable being monitored in real time, then the period of time available to cover the full exposure range would be 18 min minus the time required to start the exposure. Assuming that the R/V Ranger was within 1-2 km (0.54 – 1.08 nm) of the whale at the start of descent, and that it could start operating the source within 10 min of the start of descent, then 13 min would be available for exposure. To cover the full range of received level from 80 to 160 dB, BRS-07 increased the level by 3 dB every 25 sec.

On 2 September 2007, Julian day 245, a playback was conducted on the whale Md07_245a whose tagging has been described above. At 0814, hydrophones 35, 10, and 9 started to pick up clicks from what turned out to be the group that contained Md07_245a. Md07_245a was one of two adult whales, one male and one female sighted in the same group. The female was tagged at 1003 near 24 36.152'N, 77 37.261'W. The first deep foraging dive after tagging was a pre-exposure baseline dive. The R/V Ranger measured the sound speed profile, transmitted this information to shore, where a propagation model run predicted a TL = 57-65 dB for 1 km range for a nominal source depth of 45m.. At 1205 a third whale that had joined with the tagged whale and companion was photo identified. At 1222 a second group was reported by the Blackfin to have joined the group with the tagged whale while they were at the surface, but they split up by 1240. At 1319 the group with the tagged whale was heard to start clicking after starting a deep foraging dive. After Md07_245a started clicking on the second foraging dive, a playback of MFA sonar was started using a SL of 152 dB. . The first ping of the MFA playback transmission was made at 1328. The first ping for which a RL at the whale could be measured had a RL in the 80-90 dB range. Figure 9-17 shows the timing of each playback ping overlaid on the dive profile of this whale and Figure 9-18 shows the SL of each transmission. The whale stopped clicking after 17 minutes of clicking and foraging. The playback finished ramp up to a SL of 212dB by 1337, and then continued at this maximum SL until 1343. The MFA sonar playback lasted 15 min. The radio transmitter from the tagged whale was first heard as it surfaced at 1406 and by 1412 visual observers reported seeing normal surfacing behaviour as far as they could see.

The whale started its third foraging dive about two hours after surfacing from the second dive and a killer whale playback was started after it started clicking. The killer whale playback started at 1622 at a SL of 130-140 dB and increased the SL as described in Table 6-3. The whale stopped clicking for this stimulus at a RL of 105-115 dB after 15 min of clicking, early enough in the ramp up process that the source was stopped at 1632 at a SL of 190-203 dB, before the 212 dB maximum SL was reached. The complete duration of the killer whale playback was 10 min. Visual observers sighted the tagged whale at 1856 after hearing a series of radio transmissions. Once daylight failed, the ship tracked the tag by radio transmissions until it released and came to the surface by 0335. The tag was recovered by 0423.

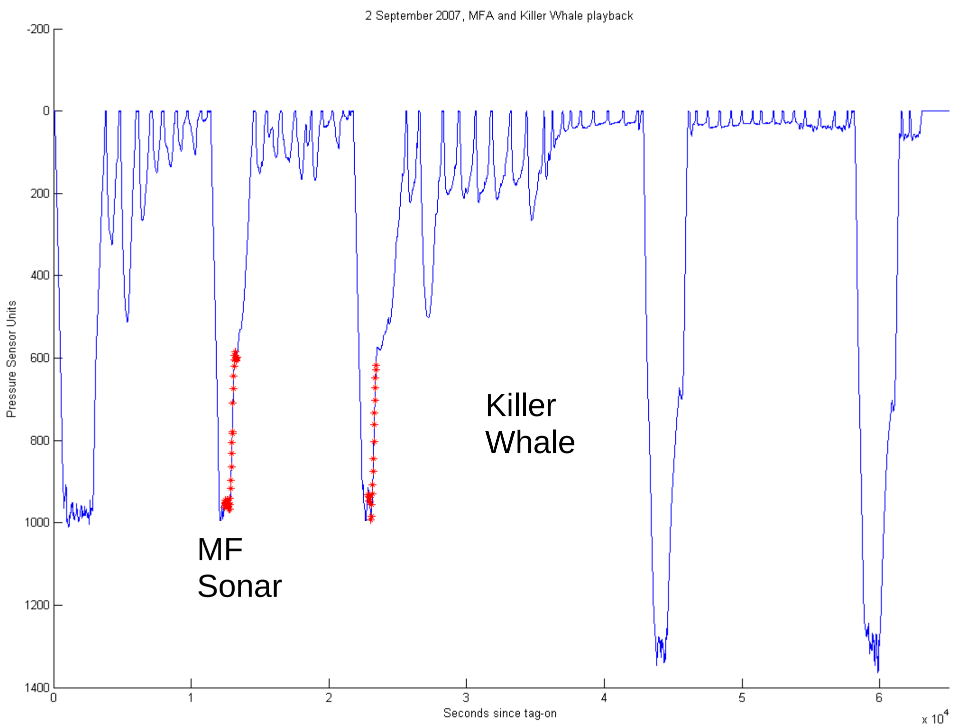


Figure 9-17: Times of mid-frequency (MFA) sonar and killer whale playbacks overlaid on dive profile of Md07_245a.

Table 9-5: Sequence of events for playback (summary extract from the Chief Scientist's log)

Date	Time	Action
02/09/2007	10:00:00	Tagged Beaked Whale, Tag on animal.
02/09/2007	10:05:00	XBT cast from Source Vessel
02/09/2007	10:12:00	Focal Follow Vessel reportsTagged Beaked Whale first terminal dive after being tagged
02/09/2007	10:22:00	Source Vessel reports 85° surface temp, 85' depth for bottom of thermocline, source depth will be 150'
02/09/2007	10:30:00	XBT data sent from Source Vessel
02/09/2007	10:30:00	Source Vessel maintains position, now 500m from Focal Follow Vessel
02/09/2007	10:53:00	Hydrophone 35, Tagged Beaked Whale goes quiet
02/09/2007	11:06:00	Focal Follow Vessel reports Tagged Beaked Whale at surface off of Source Vessel's bow, first surfacing after dive
02/09/2007	11:25:00	Source Vessel reports Tagged Beaked Whale, 175° at 1km
02/09/2007	11:36:00	Sequence of alerts and coordinations with Aerial survey and AUTEC confirmed
02/09/2007	11:43:00	Tagged Beaked Whale, 215° at 840m, Source Vessel
02/09/2007	11:45:00	Propagation loss model run shows TL = 57-65 dB for 1 km range
02/09/2007	12:00:00	Tagged Beaked Whale at surface, waiting until all whale sin the group have been photographed
02/09/2007	12:05:00	Focal Follow Vessel confirms pictures obtained of all whales in group
02/09/2007	12:13:00	Source Vessel, putting source in the water, takes 5 minutes
02/09/2007	12:17:00	Source Vessel, Tagged Beaked Whale at surface at 40° at 500m
02/09/2007	12:31:00	Source Vessel confirms completion of pre-exposure interval
02/09/2007	12:34:00	Source Vessel ca Tagged Beaked Whale 500m range
02/09/2007	12:40:00	Tagged Beaked Whale submerged for 7 minutes
02/09/2007	12:48:00	Tagged Beaked Whale, 331° at 300m from Source Vessel
02/09/2007	13:02:00	Monitoring and mitigation flights confirmed
02/09/2007	13:10:00	Source Vessel reports Tagged Beaked Whale at surface
02/09/2007	13:09:00	Beaked Whales vocalization heard on Hydrophones 13-36-35
02/09/2007	13:13:00	Focal Follow Vessel reports Tagged Beaked Whale makes terminal dive
02/09/2007	13:19:00	Tagged Beaked Whale vocalizing on Hydrophones 13-14-10
02/09/2007	13:23:00	Tagged Beaked Whale vocalizing on Hydrophones 13,36, posit = 33.33 x 35.33
02/09/2007	13:24:00	Source Vessel ready to transmit
02/09/2007	13:28:50	Source Vessel MFA playback commences
02/09/2007	13:34:00	Tagged Beaked Whale, Whales still vocalizing
02/09/2007	13:38:00	Source Vessel, Max SL = 212 dB*
02/09/2007	13:40:00	Tagged Beaked Whale, vocalizations stopped, playback ends*
02/09/2007	13:40:00	Tagged Beaked Whale, posit = 35.316 x 34.787
02/09/2007	13:48:00	Source Vessel retrieving source
02/09/2007	13:57:00	source on deck
02/09/2007	14:00:00	Focal Follow Vessel says they are 0.37 miles from last posit
02/09/2007	14:00:00	Source Vessel says 265° and 1250m from last posit
02/09/2007	14:04:00	Source Vessel whales at surface
02/09/2007	14:06:00	Source Vessel reports VHF tag detected
02/09/2007	14:09:00	Source Vessel reports Tagged Beaked Whale, 320° x 1.4km
02/09/2007	14:11:00	Chief Scientist request for visual observers to assess whales' surfacing

* Timing difference between CS log and table 6.3 is currently under investigation

Date	Time	Action
		behavior
02/09/2007	14:12:00	Source Vessel reports Tagged Beaked Whale, surfacing looked normal so far
02/09/2007	14:15:00	both vessels moving slowly toward the Tagged Beaked Whale
02/09/2007	14:21:00	Source Vessel, Tagged Beaked Whale, 340° at 400m, conditions excellent, winds up a bit 3-5 knots
02/09/2007	15:56:00	Source Vessel, Tagged Beaked Whale, 80° at 1km
02/09/2007	16:06:10	Tagged Beaked Whale, Terminal dive 50m off Focal Follow Vessel's bow, 840m and 90° from Source Vessel
02/09/2007	16:12:00	Source Vessel commence source deployment
02/09/2007	16:12:40	Tagged Beaked Whale vocalizing on Hydrophone 14
02/09/2007	16:18:00	Source Vessel, Start playback of Orca 1; first 10-minutes ramp up to full SL, then next 10-minutes at max level
02/09/2007	16:21:50	Source Vessel, Start Orca playback[4]
02/09/2007	16:24:00	Tagged Beaked Whale vocalizing on Hydrophone 14
02/09/2007	16:30:00	Tagged Beaked Whale vocalizations stop
02/09/2007	16:33:00	Source Vessel stop transmission as Tagged Beaked Whale quiet for 3 minutes[4]
02/09/2007	16:45:00	Source Vessel reports source is dry and secured on deck
02/09/2007	17:13:00	Source Vessel and Focal Follow Vessel detect faint VHF signal from tag at 030°
02/09/2007	17:55:00	Source Vessel another faint series of 14 VHF hits with visual on a surfacing
02/09/2007	18:35:00	Source Vessel still waiting for VHF signal from tag
02/09/2007	18:56:00	Tagged Beaked Whale, 1 km visual. They finally have a visual of tagged animal Maybe terminal dive
02/09/2007	19:40:00	Tagged Beaked Whale, Source Vessel gets VHF signal at 2km due north (They are just east of H7). Loosing light, will go DIW at last position of BW. Will give updates on VHF signals through the night.
02/09/2007	20:02:00	Tagged Beaked Whale, VHF signal to north of position at about Hydrophone 5
02/09/2007	20:08:00	Tagged Beaked Whale, Receiving strong VHF; estimate less than a mile and to WNW
02/09/2007	20:20:00	Tagged Beaked Whale, VHF to NW, Source Vessel NE of H5
02/09/2007	20:30:00	Tagged Beaked Whale, Strong VHF signal NE of position
02/09/2007		Many entries related to tracking the tagged beaked whale using VHF while at the surface
03/09/2007	4:23:00	Tagged Beaked Whale Tag recovered and on board Source Vessel. Current position 48.51 x 37.33.

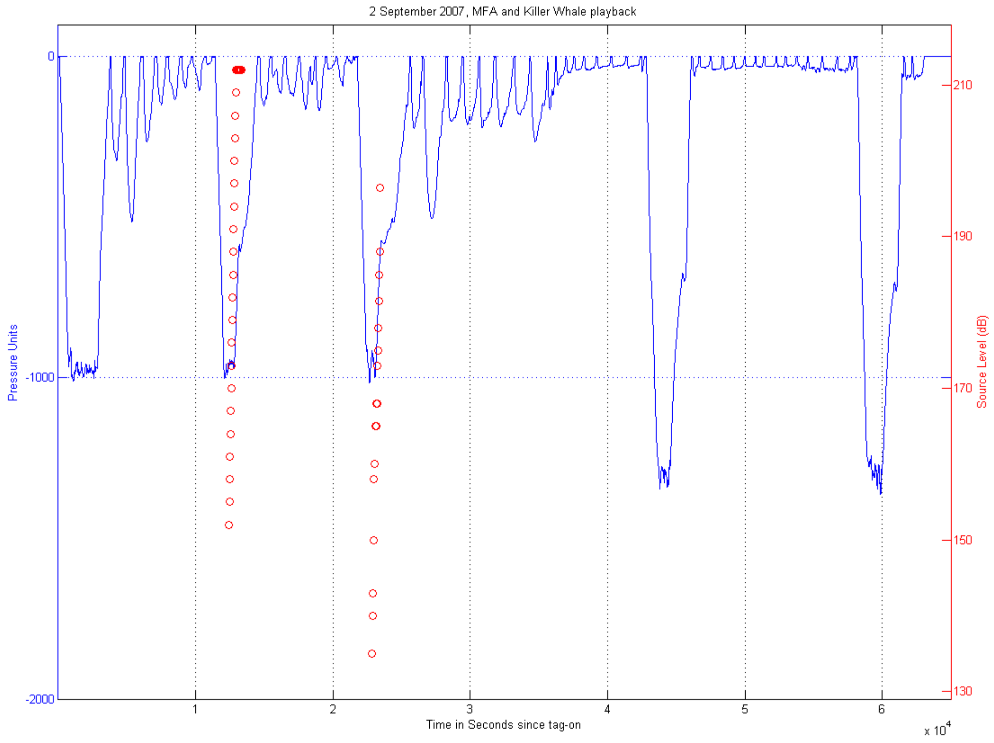


Figure 9-18: Illustration of ramp up process by which Source Level of playback was increased to a maximum level of 212dB and then held until acoustic monitors using range hydrophones detected that the whale had stopped clicking and notified the source engineers to stop transmitting.

Figure 9-18 plots how the SL was increased from 130-152 dB until it reached the maximum source level of 212 dB (MFA sonar) or was stopped during ramp up (Orca) when the whale stopped clicking. These data are also presented in the Sound Stimuli section (table 6.3).

Received level estimation

The RL was estimated by calculating the rms level of energy in a 2-5 kHz band for sonar pings or killer whale calls in the received signal and by subtracting the effective hydrophone sensitivity of -171 dB. Figure 9-19 shows the received level for the MFA sonar and killer whale sound exposures as recorded from the Dtag on the whale as the source ramped up and maintained maximum level. It can be seen that the ramp up process succeeded in slowly increasing RL at the whale from 85 dB up to a maximum of 140-150 dB, starting relatively close to the planned 80 dB RL for the MFA sonar and from 87 dB up to 120-130 dB RL for the Orca playback. The RL estimates from the start of ramp up are faint enough that ambient noise contributes to the estimate. The Dtag is currently undergoing post-cruise acoustic calibration, so these RLs should be viewed as approximate.

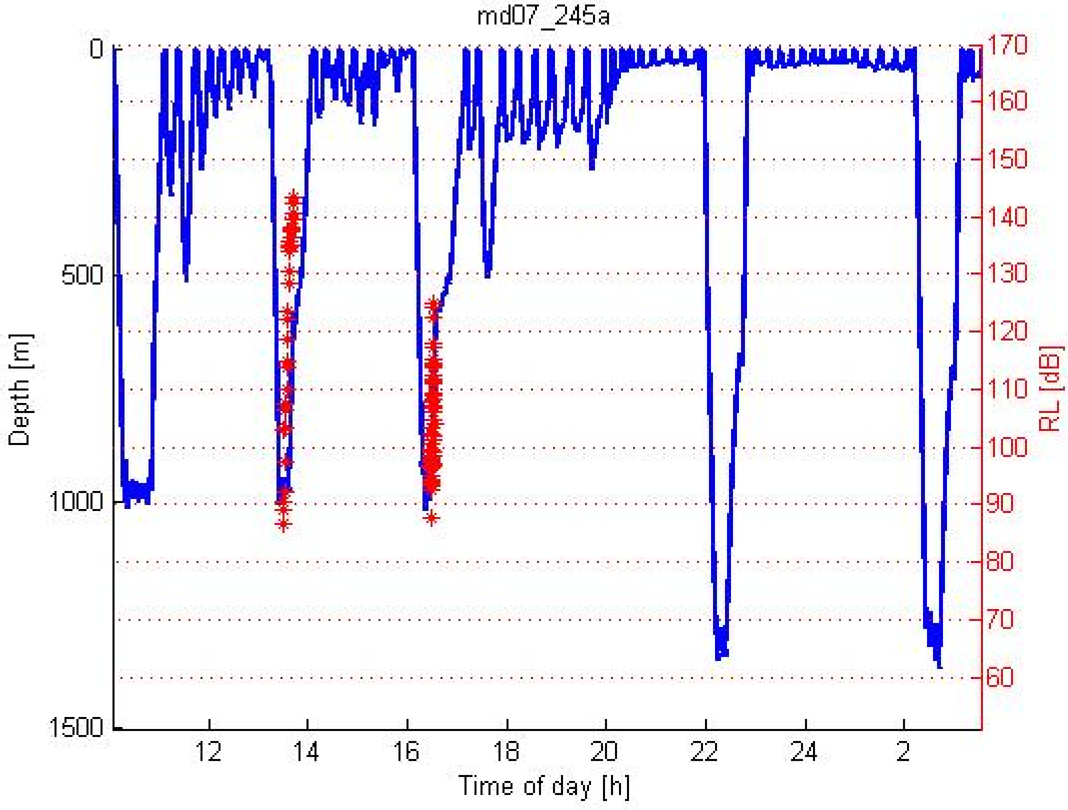


Figure 9-19: Plot of RL measured at the whale Md07_245a for each MFA sonar ping during playback.

Figures 9-20 and 9-21 provide spectrograms of the mid-frequency sonar signals as recorded on the tagged beaked whale Md07_245a.

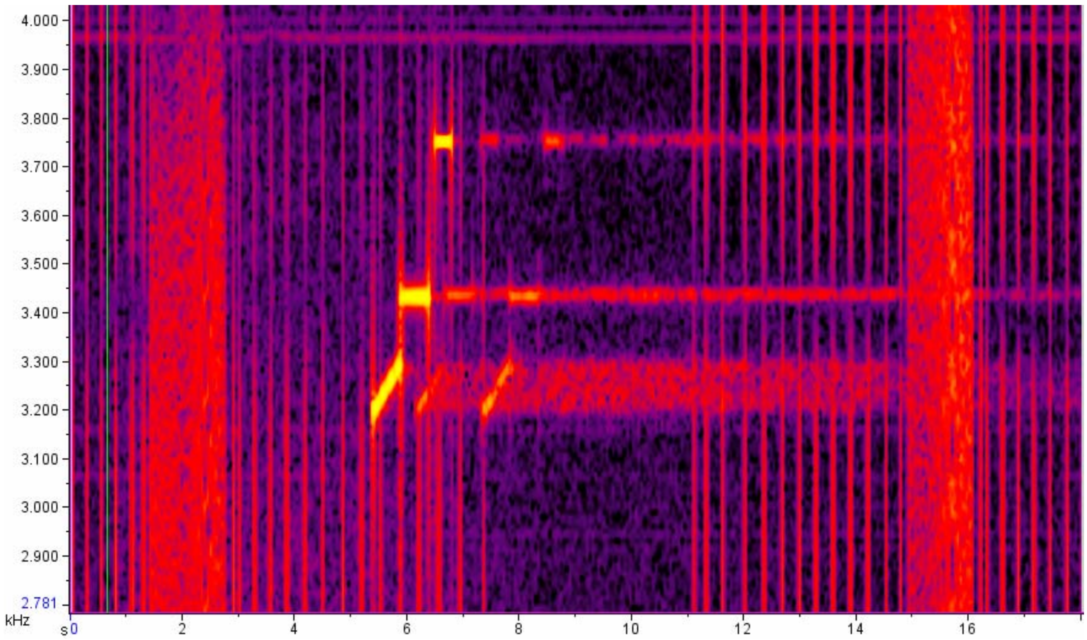


Figure 9-20: Spectrogram of frequency (kHz) on the y-axis vs time (seconds) on the x-axis for sounds recorded on the Dtag during the early part of mid-frequency sonar transmissions to the beaked whale Md07_245a. The vertical lines indicate clicks made by the beaked whale. The red sections from 1-3 and 15-16 seconds indicate buzz sounds made by the whale as it attempts to capture prey. The yellow upsweep at 5-6 seconds and constant frequency signals at 6-7 seconds are the mid-frequency sonar signals. They are followed by echoes as the signals reverberated from the seafloor.

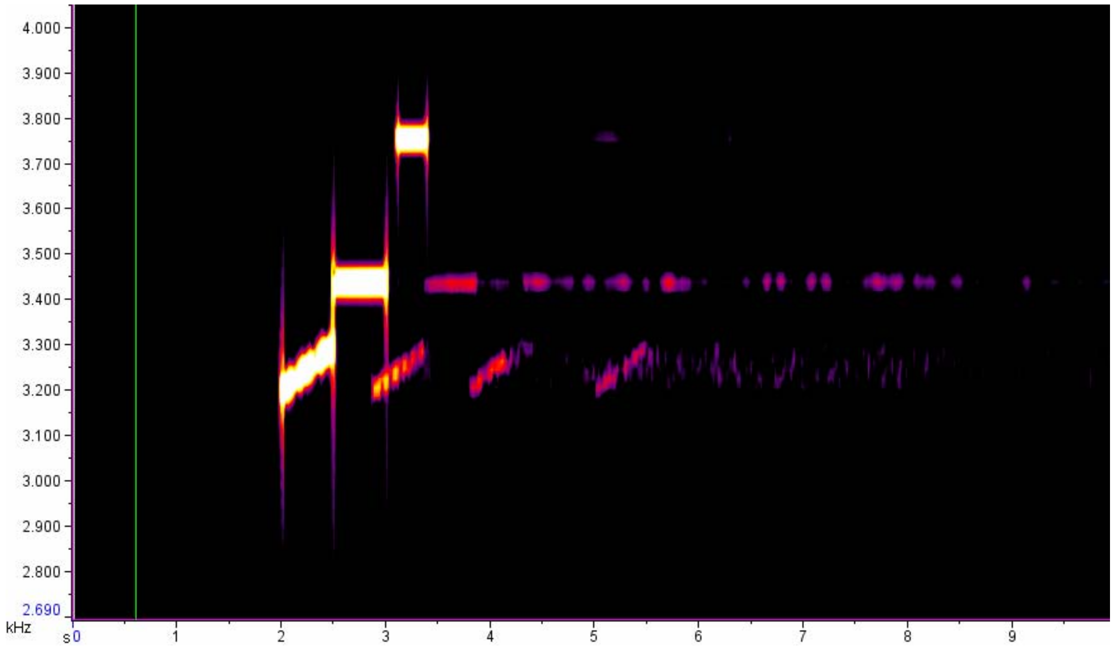


Figure 9-21: Spectrogram of frequency (kHz) on the y-axis vs time (seconds) on the x-axis for sounds recorded on the Dtag during the mid-frequency sonar transmissions to the beaked whale Md07_245a after the whale stopped clicking. The upsweep and constant frequency signals at 2-3.5 seconds are the mid-frequency sonar signals. They are followed by echoes as the signals reverberated from the seafloor.

Three-dimension movement patterns during playback to M. densirostris

The following three diagrams (Fig. 9-22) show the 3-dimensional image of the first 3 dives made by the whale that was subjected to the playbacks (Md07_245a).

Interpretation:

- This result is from a single experiment so a greater sample size is required before any robust conclusion can be drawn;
- Not all dives made by this individual, or by other whales used as controls, have been fully analysed yet, so interpretations need to take account of the preliminary nature of this result;
- These visualisations of the dives in which playbacks occurred relative to the control dive illustrate changes in behaviour perhaps in response to the MFA and the killer whales sounds.
- The whale appears to approach the surface slowly at a low pitch angle increasing the distance from the R/V Ranger in the playback dives but it did not perform these unusual ascents in the control dive.

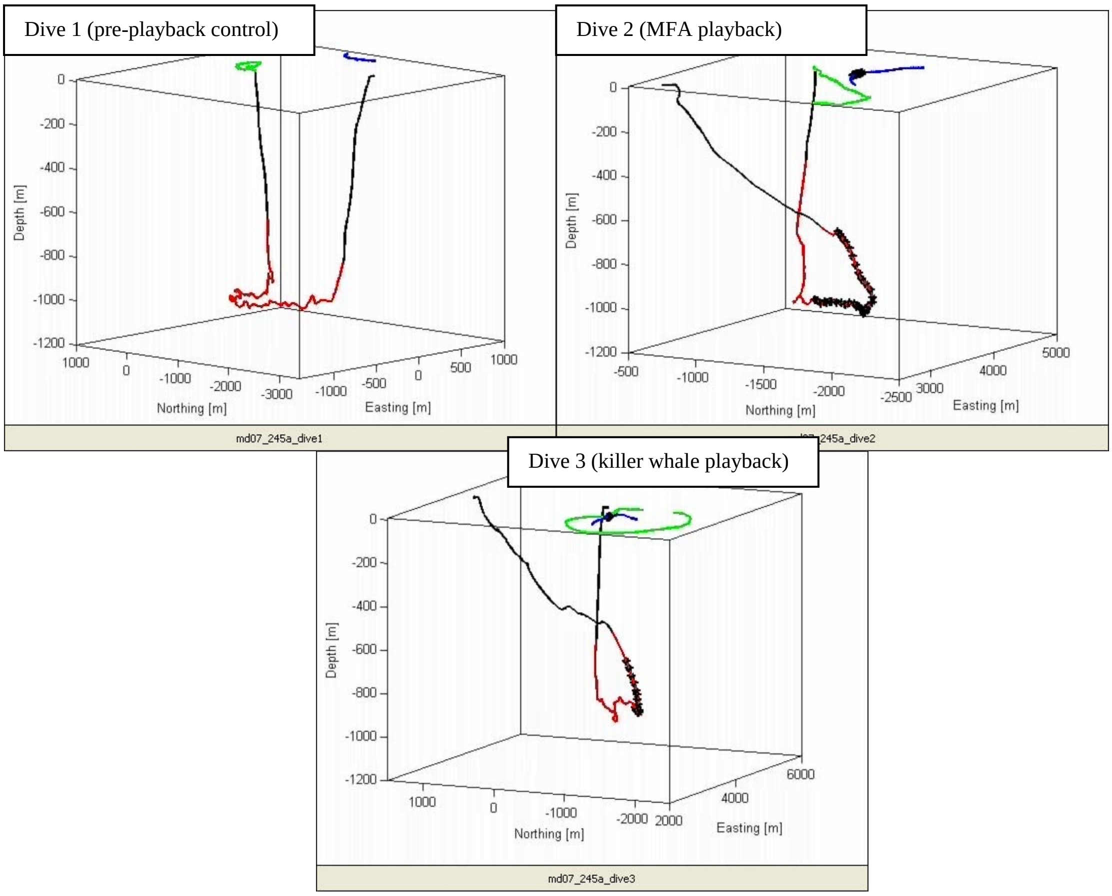


Figure 9-22: Three-dimensional tracks of the md07_245a shown in black and the track of the R/V Ranger in blue. The track of the vessel used to follow the whales is in green. The black crosses on the two dives in which playback occurred show when the playback sound was received by the whale.

Detailed pseudo tracks of md07_245a plotting each dive indicating whale and vessels

Figures 9-23, 9-25 and 9-27 show the horizontal movements during dive 1 (pre-exposure), dive 2 (MFA sound exposure), and dive 3 (killer whale playback) for md07_245a, respectively. The track of the whale is given in black, with surfacing marked in magenta at the beginning and end of the dive. In blue is given the track of the R/V Ranger and in green the track of the observation vessel, Blackfin. Red circles correspond to positions where Blackfin observed the whale. For every sighting, the estimated whale position is plotted as a red star. A red dashed line links whale and observation position. In case of sound exposure, the position of the R/V Ranger is marked by a blue star, and the position of the whale at that time is marked by a black star.

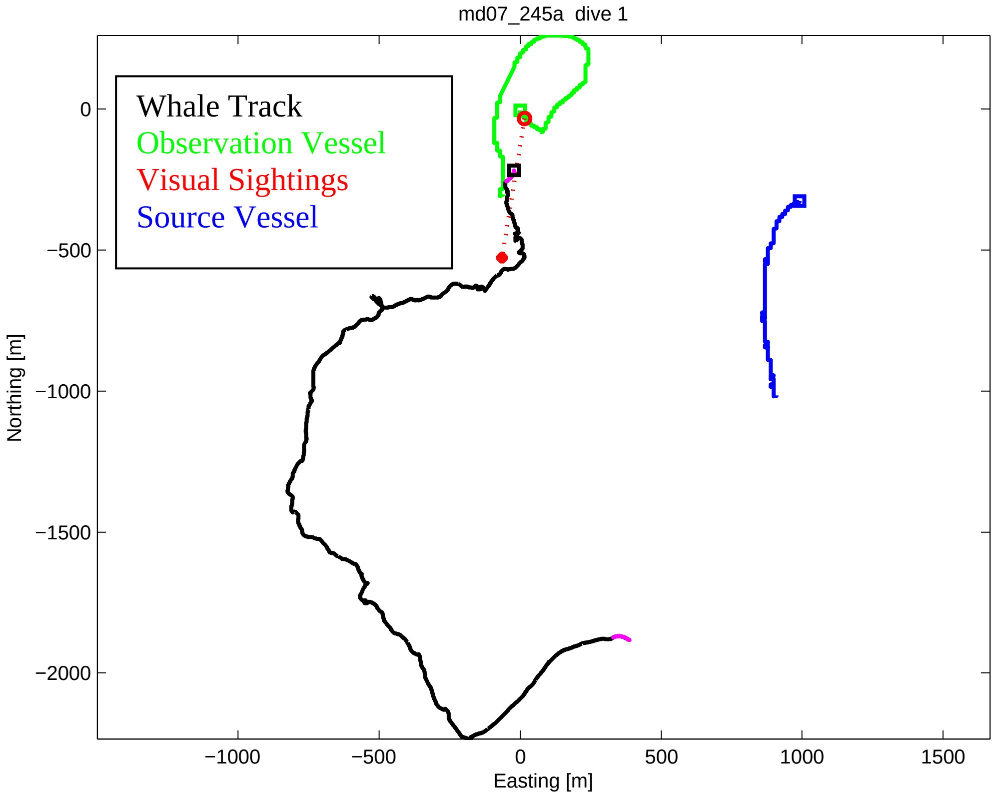


Figure 9-23: Plot of first dive (pre-exposure) for md07_245a along with source and observation vessels. The whale started its dive at (0,0) with the observation vessel nearby. The R/V Ranger maneuvered slowly about 1 km away.

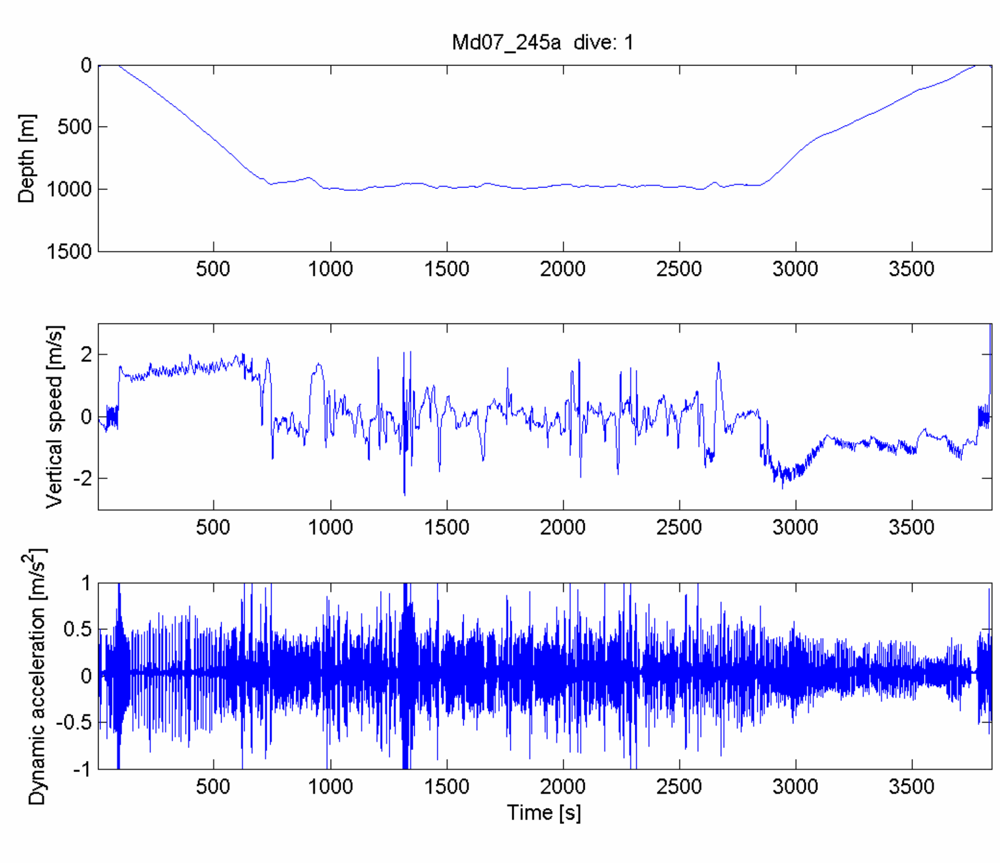


Figure 9-24: Plot of depth and movement for first dive (pre-exposure) for md07_245a.

Figures 9-24, 9-26, 9-28 and 9-29 relate vertical speed and dynamic acceleration of the tagged whale to different phases of the dive cycle of the first 4 dives made by the tagged beaked whale md07_245a. This includes the second and third dives when playback took place. At the start of descent, the whale swims with a relatively high fluke rate (leading to a higher dynamic acceleration signal) to counteract the buoyancy of air in its lungs. As it dives to several atmospheres of pressure and the lungs collapse, the whale becomes less buoyant and it can fluke less hard during the rest of the descent at about 1.5 m/s. While the whale is foraging at the bottom, there are many excursions in vertical velocity and pulses of dynamic acceleration as the whale is feeding. Once the whale started to ascend from dive 1, there was an initial sustained fluking (visible in dynamic acceleration at about 2800-3100 seconds). This was coupled with the highest levels of vertical velocity. Then the final stages of ascent were marked by lower vertical velocity, lower fluking effort, and some glides.

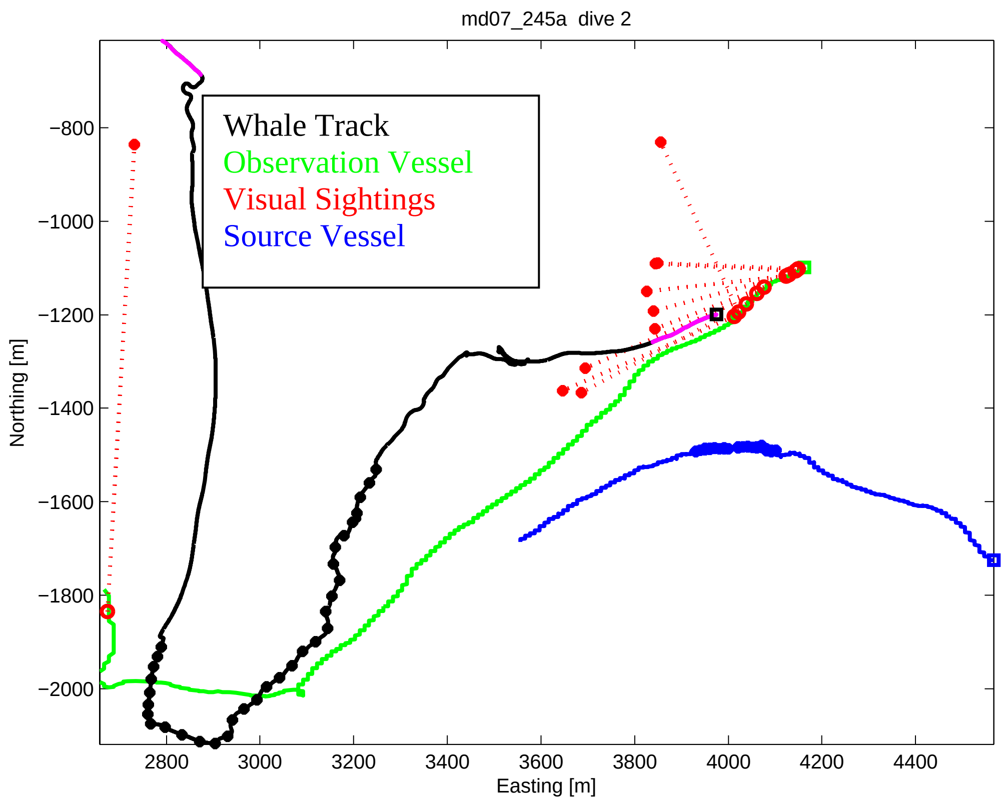


Figure 9-25: Plot of the second dive (MFA exposure) for md07_245a along with source and observation vessels. The whale started its dive near (4000, -1200) with the observation vessel nearby. The red lines mark sightings of the whale from the observation vessel, with the estimated range marked by a closed red dot. The track was fitted to an average of these sightings. The R/V Ranger maneuvered slowly toward the whale and started playback as indicated by the blue asterisks overlaid on the vessel track. Each ping is also overlaid on the track of the whale, indicated with a black asterisk.

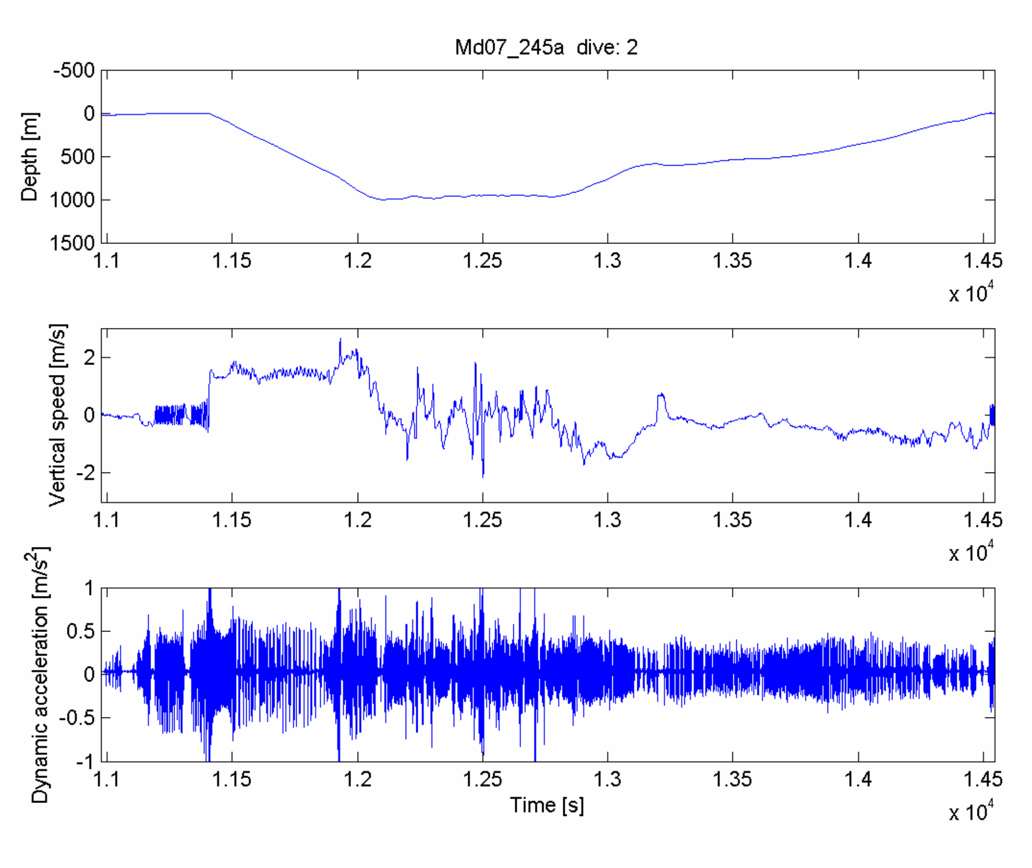


Figure 9-26: Plot of depth and movement for second dive (MFA exposure) for md07_245a.

The initial descent and start of foraging during the second dive of Md07_245a was similar to the pre-exposure dive. However, it stopped clicking and broke off the foraging dive sooner than in the non-exposure dives from TOTO, and its ascent was longer and more gradual than normal. This slow ascent was not characterized by dynamic acceleration values greater than those observed during descent and foraging before the playback started.

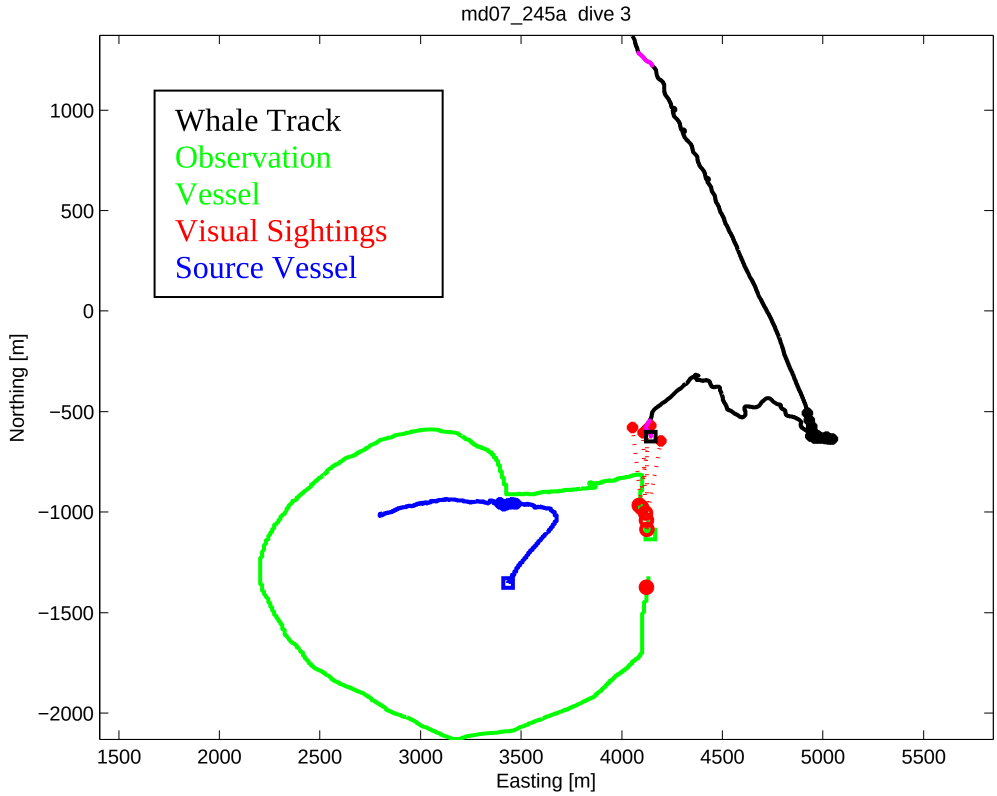


Figure 9-27: Plot of the third dive (Orca exposure) for md07_245a along with source and observation vessels. The whale started its dive near (4100, -600) with the observation vessel nearby. The red lines mark sightings of the whale from the observation vessel, with the estimated range marked by a closed red dot. The track was fit to an average of these sightings. The R/V Ranger maneuvered slowly toward the whale and started playback as indicated by the blue asterisks overlaid on the vessel track. Each ping is also overlaid on the track of the whale, indicated with a black asterisk.

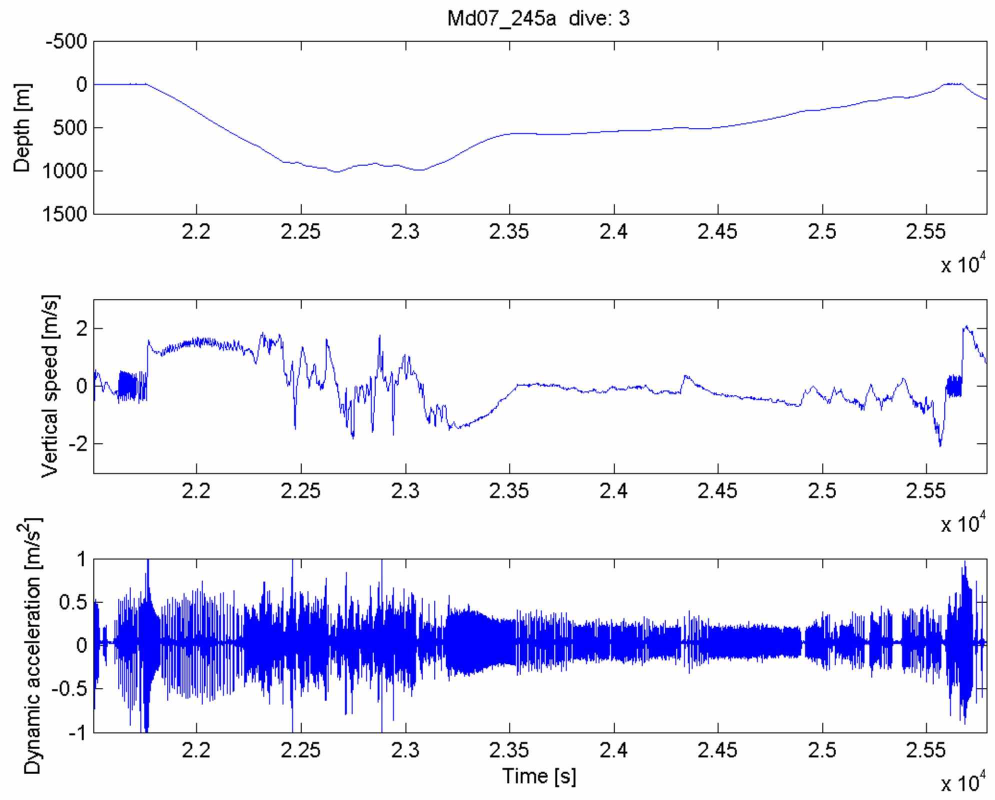


Figure 9-28: Plot of depth and movement for third dive (Orca exposure) for md07_245a.

The initial descent and start of foraging during the second dive of Md07_245a was similar to the pre-exposure dive. However, it stopped clicking and broke off the foraging dive sooner than in the non-exposure dives from TOTO, it had a prolonged burst of fluking from about 23200-23400 s, and its ascent was longer and more gradual than normal. This slow ascent was not characterized by dynamic acceleration values greater than those observed during descent and foraging before the playback started. These differences from normal dives were more pronounced in the Orca playback compared to the MFA playback.

The fourth and fifth dives occurred at night with no visual observations, so it was not possible to produce detailed pseudo-track plots referenced to visual sightings as for dives 1-3, but the dive is presented, with vertical speed, and dynamic acceleration plots for these dives.

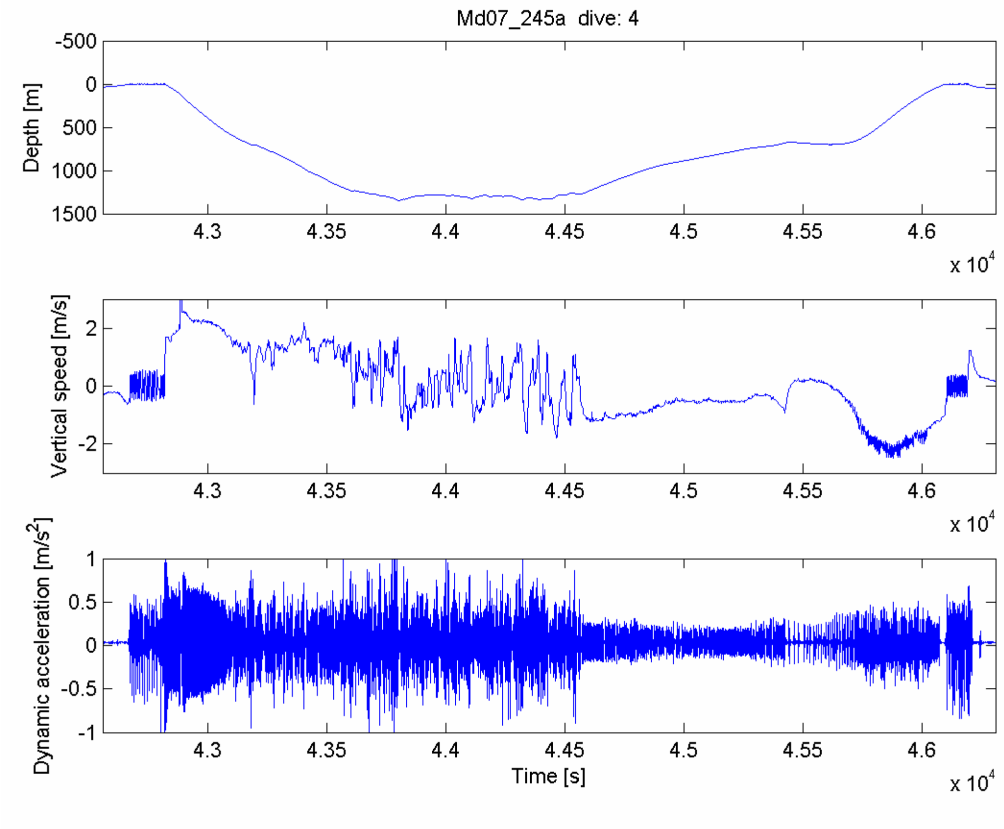


Figure 9-29: Plot of depth and movement for fourth dive (first post-exposure dive) for md07_245a.

Table 9-6 presents dive parameters from all of the beaked whales tagged during BRS-07. The cells marked N/A involve dives with no acoustic data or only partial acoustic data (the tag continues to log data from non-acoustic sensors after it has run out of memory of the acoustic recordings).

Behavior during sequences of dives in M. densirostris with and without playback

Figure 9-30 shows the movements of three Blainville's beaked whales during three tracks when the whales made repeated dives. Superimposed on this is the track of Md07_245a, the beaked whale involved in the playback.

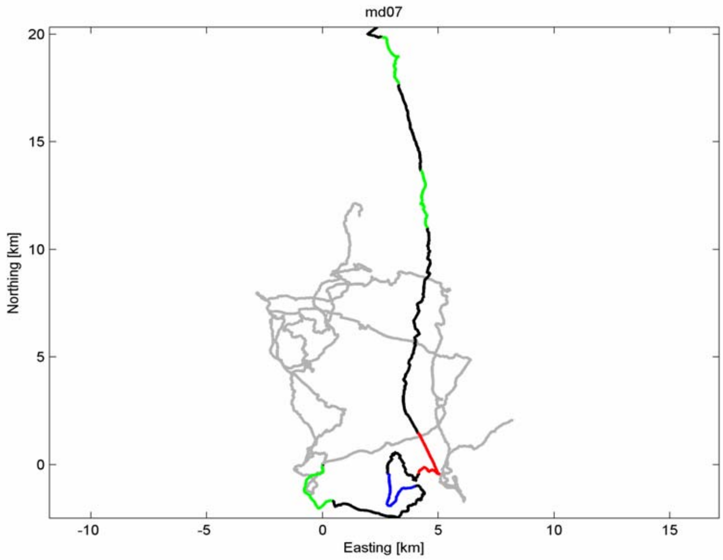


Figure 9-30: The patterns of movement, shown in a two-dimensional plan view, of four tagged Blainville's beaked whales when the whales made repeated deep foraging dives. The track shown in multiple colors is of Md07_245a, the beaked whale involved in the playback, and this is superimposed on three that are in grey. Each track covers a similar time period. The black parts of Md07_245a indicate parts of the track that were not deep foraging dives. The green parts show the pre- and post-playback dives and the blue and red portions of the track show the dive with the MFA playback and the killer whale playback respectively.

Table 9-6: Summary of data from tagged M. densirostris

md07_227a female, baseline tag data

Foraging Dive #	Duration (min)	Depth (m)	Start Click Depth (m)	End Click Depth (m)	Click Duration (min)	# of Buzzes	Buzz/Min	Descent Rate (m/sec)	Duration of Silent Descent (min)	Ascent Rate (m/sec)	Duration of Silent Ascent (min)
1	51.9	1390	467	1218	24.20	74	3.06	1.53	5.10	0.90	22.54
2	50.5	999	514	863	25.80	48	1.86	1.45	5.92	0.76	18.82
3	53.2	1353	467	842	25.50	52	2.04	1.51	5.15	0.62	22.53
4	47.4	1330	453	765	23.30	42	1.80	1.52	4.99	0.67	19.14
5	50.4	821	426	765	25.90	43	1.66	1.62	4.38	0.63	20.09
6	49.7	1350	308	1238	27.20	73	2.68	1.50	3.42	1.08	19.11
7	54.0	1419	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8	51.3	1369	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

md07_245a female, playback

Foraging Dive #	Duration (min)	Depth (m)	Start Click Depth (m)	End Click Depth (m)	Click Duration (min)	# of Buzzes	Buzz/Min	Descent Rate (m/sec)	Duration of Silent Descent (min)	Ascent Rate (m/sec)	Duration of Silent Ascent (min)
1	61.6	1011	519	810	40.91	65	1.59	1.26	6.85	0.98	13.83
2	52.0	1002	642	887	17.37	35	2.01	1.43	7.50	0.55	27.12
3	63.8	1015	589	937	15.00	28	1.87	1.39	7.08	0.37	41.73
4	54.8	1346	527	1272	24.98	84	3.36	2.13	4.12	0.83	25.66
5	57.2	1363	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

md07_248a female

Foraging Dive #	Duration (min)	Depth (m)	Start Click Depth (m)	End Click Depth (m)	Click Duration (min)	# of Buzzes	Buzz/Min	Descent Rate (m/sec)	Duration of Silent Descent (min)	Ascent Rate (m/sec)	Duration of Silent Ascent (min)
1	52.1	945	599	657	28.41	47	1.65	1.41	7.07	0.66	16.61
2	49.1	953	564	787	26.89	53	1.97	1.45	6.51	0.84	15.65
3	52.1	1002	517	687	31.49	61	1.94	1.30	6.62	0.82	13.99
4	51.4	930	535	679	31.00	53	1.71	1.40	6.38	0.81	14.05
5	49.4	781	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6	51.6	786	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

md07_248b male

Foraging Dive #	Duration (min)	Depth (m)	Start Click Depth (m)	End Click Depth (m)	Click Duration (min)	# of Buzzes	Buzz/Min	Descent Rate (m/sec)	Duration of Silent Descent (min)	Ascent Rate (m/sec)	Duration of Silent Ascent (min)
1	51.3	1015	534	740	29.90	63	2.11	1.73	5.13	0.76	16.25
2	72.2	898	509	735	40.59	65	1.60	1.59	5.32	0.47	26.28
3	60.4	1075	375	968	37.09	51	1.38	2.06	3.03	0.79	20.32
4	71.9	1056	368	819	43.13	60	1.39	1.70	3.62	0.54	25.18
5	69.7	936	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

9.1.3 Summary of data from all dives showing the context of the playback to M. densirostris

Combining these results with data from another *Mesoplodon densirostris* tagged at TOTO during October 2006 in a field effort funded by SERDP, Figure 9-31 illustrates how the two exposure dives appear to have peripheral values for four parameters, duration of vocal interval (clicking), number of buzzes, ascent rate and ascent duration. It is premature to conduct statistical tests for this Cruise report, but it appears that where the exposure values differed, the killer whale values are stronger outliers than the MFA sonar values.

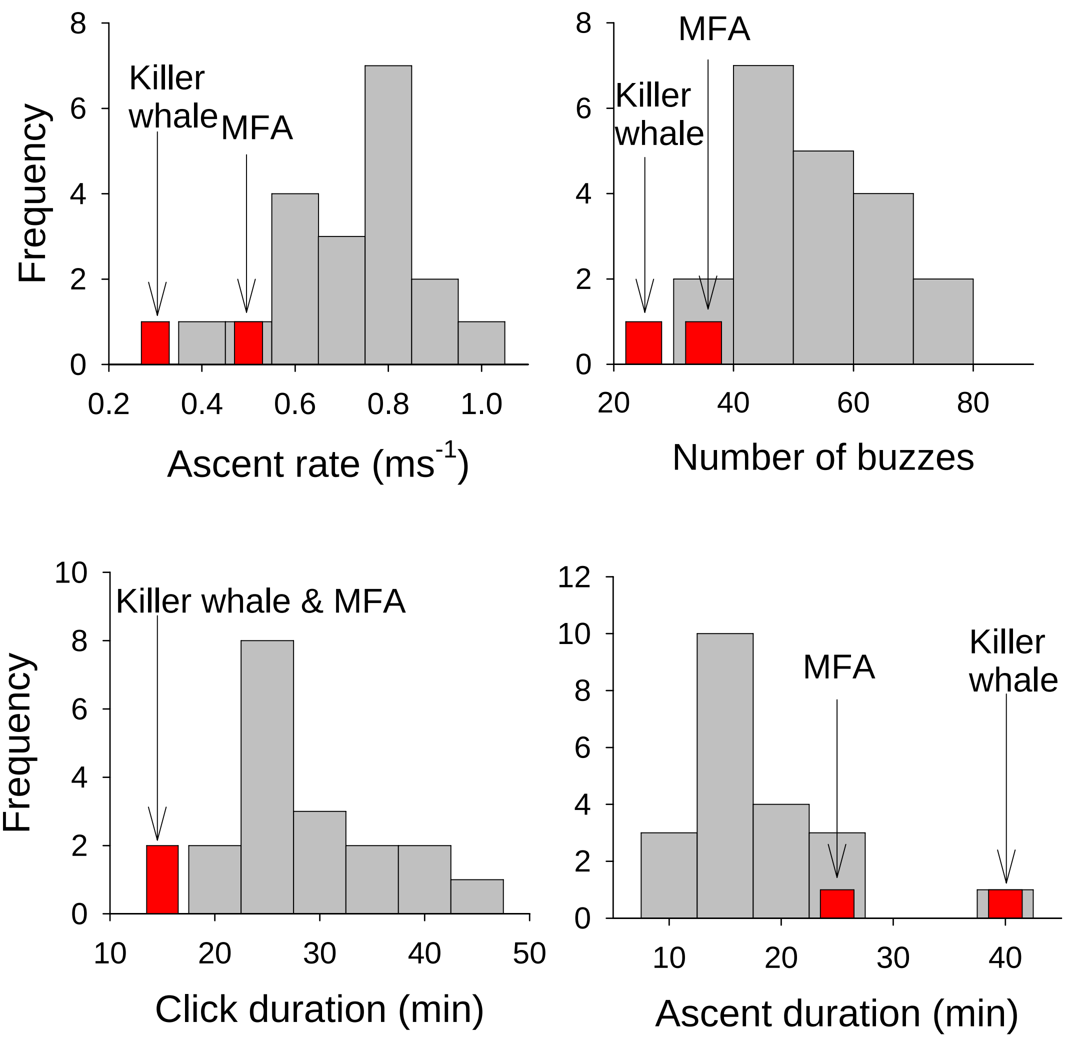


Figure 9-31: Histograms showing the frequency distributions of four variables measured across all the deep foraging dives measured in Blainville's beaked whales within the TOTO. The grey bars show those dives made without playbacks whereas the red bars represent the measurements made for the dives when playback occurred.

To summarize, after a pre-exposure dive, a MFA sonar playback was conducted with a tagged *Mesoplodon densirostris*. The first RL measured at the whale was 85-90 dB, after the whale started clicking at depth. After 15 min with a ping of sonar every 25 sec, the whale appeared to stop clicking earlier than usual, when the received level at the whale was in the 130-140 dB. The playback continued for a few minutes after cessation of vocalization, reaching a maximum RL in the 140-150 dB region. Then the whale ascended on the slow end of normal ascent rates and with a longer than normal ascent. The whale started another deep foraging dive about two hours after surfacing. A killer whale playback was started after the whale started clicking at depth, with the first RL measured at the whale of 85-90 dB. The whale ceased vocalizing at an RL in the 105-115 dB region. The playback continued for a few minutes, reaching a maximum received level of 120-130 dB. This exposure dive had the shortest vocalization period, the lowest number of buzzes, the slowest ascent rate, and the longest ascent among the beaked whale dives recorded at TOTO from 5 individual whales. As soon as the killer whale playback stopped, the whale started swimming directly away from the location of the sound source and it continued swimming on a much straighter course than usual although it made two additional deep foraging dives during this movement. By the time of the was tag release from the whale 10 hours after the end of the dive that contained the last playback the whale had travelled a distance preliminarily estimated at 20 km at an average horizontal speed of about 0.5 m/s (1 kt).

Note that the latter portion of the pseudotrack occurred at night when visual sightings were not possible, so the track cannot be geo-referenced by interpolation between sightings. The accuracy of this track can be improved later using acoustic locations from clicks of the tagged whale as recorded on the AUTEC hydrophone array, but this cannot be completed in time for this Cruise report.

Interpretation:

- This result is from a single experiment so a greater sample size is required before any robust conclusion can be drawn;
- However, in this case the whale appeared to move directly away from the source after the killer whale playback had taken place.
- This movement continued through the two post-playback control dives and the intervening surface period.
- It is not possible to determine whether the movement away from the source after the killer whale playback was due to this playback alone independent of the earlier MFA playback or whether the earlier MFA playback might have influenced this response in some way. However, of the two stimuli, it seems that the response is most closely associated with the killer whale playback.

9.1.4 Pilot whales

On 17 Aug 2007 a pilot whale was tagged at 1304. Tables 9-7 and 9-8 show the sequence of events leading up to and during the playback and tag recovery.

The pilot whale group remained in the area and a second whale was tagged at 1415 between hydrophones 66 and 58 (approx 24.442 N, 77.558 W). The Blackfin started a follow of the group which alternated between traveling, logging, and milling behaviors while preparations were made for playback. A propagation loss model was run with current SVP for a source at 18m. At 1458 a playback of MFA sonar sounds was started at a source level of 152 dB, but this was stopped at 1502 at a SL = 167dB because whales were sighted within 800 m, less than the 1000 m shutdown range. The MFA playback was restarted at 1552 at a range of >2000 m from the focal group and a SL = 167dB. The MFA playback ended at a full power source level of 212 dB re 1 µPa at 1 m at 1606 at a range of 2900 m. Playback of the Orca stimulus started at 1636:30 at a source level of >100 dB. By 1645, the observers on the follow vessel reported that the 2 pilot whale groups had come closer together and were moving towards the R/V Ranger, but were reported to have headed back north by 1648. The Orca playback stopped at 1659 at a SL of 192 - 196 dB. The groups were reported by the Blackfin to have changed direction again by 1709. At 1728 the tag on the second tagged pilot whale (Gm07_229b) came off for a total recording time of 3:12:54. The tag on the first whale tagged (Gm07_229a) did not come off until 0203 the next day the 18th of August for a total time on the whale of 12:58.

Table 9-7. Sequence of events for playback (summary extract from the Chief Scientist's log)

17/08/2007	6:00:00	Recommend RHIB & Blackfin remain Site 1 because of weather. Ranger vectored to H92 for pilot whales
17/08/2007	6:10:00	Weather forecast suggest increased wind speed through the day.
17/08/2007	6:15:00	Instruction to Ranger to carry out mini-cal over H81. Instruct not to tx until signal from In-water. Source in water 07.30
17/08/2007	6:42:00	Confirmed with Ranger SL 155 dB. Require visual observers in place
17/08/2007	6:47:00	XBT dropped
17/08/2007	6:54:00	Ranger reporting position
17/08/2007	7:02:00	Inform Data Control that XBT has been dropped
17/08/2007	7:05:00	Range confirmed green for tx
17/08/2007	7:06:00	In-water confirmed to BW vocals in vicinity
17/08/2007	7:17:00	Confirm range green
17/08/2007	7:17:00	Confirm visual obs green
17/08/2007	7:17:00	Confirm M3R green
17/08/2007	7:22:00	Informed delay in TX from Ranger
17/08/2007	7:23:00	Tx begins
17/08/2007	7:49:00	Mini-cal ends. Ranger requested retain source in water for further 10 minutes
17/08/2007	8:00:00	Ranger requested to stop recording (weapon in water)
17/08/2007	8:01:00	Ranger confirmed stop recording
17/08/2007	8:07:00	Ranger confirm source being recovered
17/08/2007	8:16:00	Beuaf. 3 at Ranger
17/08/2007	8:19:00	Source on deck
17/08/2007	8:26:00	Decision made to transit RHIB & Blackfin to Ranger to work pilot whales
17/08/2007	8:32:00	Ranger moving to H74
17/08/2007	10:07:00	Ranger reporting sighting pilot whales in area of high level vocalizations
17/08/2007	10:32:00	In-water asked Ranger for status readiness for playback - response ready for playback
17/08/2007	10:34:00	Blackfin Requested to program tags for immediate sampling
17/08/2007	11:12:00	Blackfin report on pilot whales. Ranger also with pilot whales.
17/08/2007	11:27:00	Tags re-programmed to start immediately
17/08/2007	11:30:00	RHIB on board Ranger. Cradles delivered
17/08/2007	12:03:00	Blackfin Alongside pilot whales - permission given to tag
17/08/2007	12:10:00	tag boat left Blackfin
17/08/2007	12:10:00	pb sequence agreed
17/08/2007	12:27:00	Tagging attempts on two individuals; 1 adult male, 1 juv. Female
17/08/2007	12:27:00	Reaction scale 0.5, i.e. very slight
17/08/2007	12:27:00	confirmed that have 6 tagging attempts per individual so long as no significant negative reaction
17/08/2007	12:39:00	Blackfin 2.17 km from Ranger
17/08/2007	12:47:00	Official confirmation of WRN clear
17/08/2007	12:50:00	Ranger vectored Blackfin to a different group of pw
17/08/2007	12:56:00	Blackfin alongside a group of pw - probably same group as before
17/08/2007	12:59:00	AF running prop loss model
17/08/2007	13:00:00	Failed tag attempt
17/08/2007	13:05:00 (note discrepancy with Blackfin – use Blackfin timings)	Tag on - focus on one individual. (Right, below dorsol fin) 148.715, 23 59N 77 31 W **[require M3R data for the next 17 h]**
17/08/2007	13:16:00	Permission given for 2nd tag deployment
17/08/2007	13:19:00	Blackfin doing respiration rates on tagged animals
17/08/2007	13:37:00	Ranger still reporting no VHF on pw tag -> likely fault with VHF on

		Ranger
17/08/2007	13:50:00	In-water advise source to be at 60ft, i.e. surface duct
17/08/2007	13:55:00	Failed tagging attempt on 2nd male in group
17/08/2007	13:57:00	Ranger @ 1000 yds from focal animals
17/08/2007	14:06:00	Blackfin requested to break off tagging in 15 min
17/08/2007	14:06:00	Ranger informed 40 min to playback
17/08/2007	14:15:00	Tag on. Between H66 & H58 (approx 24 25N, 77 32W) **[require M3R data for the next 17 h]**
17/08/2007	14:16:00	Playback sequence start @ 14.45
17/08/2007	14:26:00	Blackfin attempting to track gp with 2nd tagged pw
17/08/2007	14:28:00	Prop loss model run for source depth @18 m or 60ft
17/08/2007	14:30:00	Ranger needs to maintain 1000m from the nearest gp.
17/08/2007	14:38:00	Visual on tag 2. Blackfin in group. Positioning for focal follow
17/08/2007	14:46:00	Source in water
17/08/2007	14:51:00	5 min 260 degree scan began, source @60ft, ref hydrophone being lowered
17/08/2007	14:54:00	Blackfin confirm FF green
17/08/2007	14:57:00	EC confirm clear 1 km radius. CS cleared to start playback
17/08/2007	14:59:00	1st ping in the water[4]
17/08/2007	15:04:00	Suspend tx because of whales within 800 m, last tx @167 source level[4]
17/08/2007	15:05:00	Source lifted to reposition
17/08/2007	15:13:00	Ranger requested to position to SW of focal group to avoid BW to NE of focal gp.
17/08/2007	15:15:00	Ranger repositioning
17/08/2007	15:20:00	Ranger 1.5km from Blackfin
17/08/2007	15:23:00	recommence tx @ 15.33 @ break-off tx level
17/08/2007	15:28:00	Ranger advised start up with clear zone of 1000m. Shut-down @ 200m
17/08/2007	15:33:00	Decision not to recommence playback until focal group re-located
17/08/2007	15:47:00	Decision to use closest group for focal follow & PB
17/08/2007	15:51:00	Commencing PB @ 167 dB. Start range 2050 yards[4]
17/08/2007	15:51:00	Signal visible on M3R
17/08/2007	16:02:00	Discussion of proceeding to Orca1 at next PB
17/08/2007	16:02:00	Harmonics observed in signal
17/08/2007	16:04:00	Last ping tx @ 2900 yds; vocalizations from pw focal group stopped clicks when source shut down[4]
17/08/2007	16:10:00	BW started to voc on H66
17/08/2007	16:22:00	Discussion about range - conclusion to retain 1000m range
17/08/2007	16:26:00	Ranger DOW, source being developed
17/08/2007	16:36:00	Clear to start PB of Orca1
17/08/2007	16:36:30	1st transmission
17/08/2007	16:44:00	Play 10 min Orca call x 2 for 20 min
17/08/2007	16:48:00	Blackfin note 180 degree turn of pw
17/08/2007	16:49:00	End 1st pb of Orca1, got to 165dB SL
17/08/2007	16:59:00	Last transmission of Orca1
17/08/2007	16:59:00	BW on H53 stopped during PB
17/08/2007	16:59:00	FF begins
17/08/2007	17:05:00	Focal group moving towards SV
17/08/2007	17:11:00	Decision - end experiment at end of current 10 min mitigation then move to mitigation & monitoring mode for BRS
17/08/2007	17:40:00	Moved to Mitigation and Monitoring
17/08/2007	17:40:00	Ranger heard tag on VHF
17/08/2007	17:55:00	Tag 226 off animal and being tracked
17/08/2007	19:04:00	Tag 226 recovered

17/08/2007	19:15:00	Monitoring flight organized for 10.15 departure 18th from Fresh Creek. Spotter: Hickmott, Ann Allen,
17/08/2007	21:00:00	Tower reports no signal from tag
18/08/2007	6:15:00	VHF check on tower. No tag heard
18/08/2007	7:38:00	Ranger overnight at PB location (H42-H43) on monitoring and mitigation. Advised to develop search pattern northbound from current position. This would follow M3R track of pilot whales until 22.00 yesterday plus projection to 7 a.m. when tag was predicted to detach (latest). Additional drift modelling carried out.
18/08/2007	7:40:00	Aerial survey personnel details passed to Sapphire Air for monitoring flight
18/08/2007	7:46:00	Ranger advised to start search @H17 and to carry out mitigation from current position as well
18/08/2007	7:46:00	Weather: current at Site 1. Heavy electrical storm.
18/08/2007	7:50:00	Contact with Ranger & agreed monitoring and mitigation by northward movement to H17. Force 4 and high sea state will limit mitigation. VHF monitoring will depend on lightning
18/08/2007	8:08:00	Contact with Sapphire Aviation. Telephone number of In-water passed.
18/08/2007	8:23:00	Contact with Sapphire Aviation. Agreed to conduct flight
18/08/2007	8:36:00	Alix Boccancelli checked VHF Site 1 - nothing heard
18/08/2007	9:20:00	Waypoints for Ranger 24 56.29, 77 37.49; 25 00.00 77 44.29
18/08/2007	9:20:00	Ranger current position 24 45.39 77 35.05
18/08/2007	9:20:00	Ranger requested to do search pattern on these waypoints to cover east of range and those areas not covered by searches from Site 1 and Site 2

18/08/2007	9:41:00	Alix Bocanc. Report tag signal from Site 1, ENE in weak signal
18/08/2007	9:48:00	Ranger advised R1000 receiver batteries may need to be changed
18/08/2007	9:50:00	Ranger intends tracking North for 30 min & then west for 30 min
18/08/2007	10:50:00	Ranger reports steering problem & returning to Site 1
18/08/2007	11:01:00	Ranger does not have VHF contact with tag request fro an observer to be put up on tower at Site 1
18/08/2007	12:00:00	Contact with Ranger to discuss tag recovery. Likely Hammerhead deployment
18/08/2007	12:00:00	Site 1 scan showed tag @ c18 miles
18/08/2007	12:25:00	Hammerhead cannot put to sea because of weather
18/08/2007	12:45:00	Tag #2 taken from Ranger for down-load
18/08/2007	13:19:00	Discussion with Marine Ops to deploy a vessel
18/08/2007	13:15:00	Todd Pusser sent to meet flight @ Fresh Creek with radio gear
18/08/2007	14:50:00	Plan A to put Rover to sea. Plan B is to repair Ranger and put her to sea in 4-5 h
18/08/2007	14:45:00	Position of tag relayed from aircraft 24 52.562N, 77 32.329W (24.876, 77.539)
19/08/2007	6:04:00	Overnight. Report from tracking crew north on Andros suggests tag coming ashore Andros. Option to send team north with small RHIB on trailer to spend the day looking for the tag
19/08/2007	6:04:00	Warned Ranger that may be required
20/08/2007	6:36:00	Decision: Ranger stand-by; team sent up coast to search. Weather precludes use of any vessel other than Ranger. 20-30 knots easterly
20/08/2007	6:08:00	In-water manned
20/08/2007	6:15:00	Tag recovery team (TRT) driven north to investigate possibility of recovering tag using small RHIB
20/08/2007	6:15:00	TRT had no success late pm yesterday
20/08/2007	6:20:00	Plan: (i) to wait assessment of TRT; (ii) If recovery not possible deploy Ranger with possibility of using RHIB-18 or Ranger's RHIB
20/08/2007	6:35:00	Suggestion from Ranger that Ranger's RHIB be trailered north & used fro recovery. Authorised to proceed.
20/08/2007	8:18:00	Sending Boston whaler north to Stafford Creek and Masick Point
20/08/2007	13:03:00	Assets available: Ranger - went to sea ~12.45; Aircraft - poss. Available from 15.00; Boston whaler - may be short on radio equipment
20/08/2007	13:42:00	Cessna 182 flight authorised for 15.00
20/08/2007	13:56:00	Contact with Ranger about ship reg. no. and details concerning aerial survey
20/08/2007	14:05:00	Boston Whaler left AUTEC 12.55
20/08/2007	15:07:00	Ranger reported faint signal
20/08/2007	15:07:00	Aircraft launch to go ahead
20/08/2007	16:45:00	Tag located: 24 57.35N 77 56.71W
20/08/2007	21:15:00	Ranger docked
21/08/2007	6:30:00	Search tem departed north with truck & small RHIB
21/08/2007	9:00:00	Team meeting in in-water
21/08/2007	9:00:00	Decision: stand-down because of wind speed. Modify Ranger antenna
21/08/2007	10:45:00	Recovered tag via RHIB - RTB ~4h

Table 9-8. Blackfin sighting data from Gm229.

Date	Time	Latitude	Longitude	Comments
17-Aug-07	7:59:00	24 24.689'N		Sighting from Ranger of pilot whales.
17-Aug-07	10:04:00	24 18.049'N		Sighting from Ranger of pilot whales
17-Aug-07	11:42:00	24 20.742'N		Sighting from Ranger of pilot whales
17-Aug-07	11:46:00			Ari sighted more whales. 300m off the port bow, heading 310degrees, bearing 2 o'clock, aspect 0.
17-Aug-07	12:08:31			magnets off both tags
17-Aug-07	12:19:00	24 21.832'N	77 33.032'W	
17-Aug-07	12:26:00	24 22.128'N	77 33.083'W	tag boat is 300m away from b2.
17-Aug-07	12:35:00			group b. animals traveling fast. Just took off at high speed and dove suddenly they are traveling down windsurfing waves and diving. Few pairs of mom and calf or juvenile. Animals in group are small.
17-Aug-07	12:40:00			tag boat headed to another sub group.
17-Aug-07	12:50:00			Ranger has a group 1 mile off there bow, slow travel.
17-Aug-07	12:55:01	24 23.444'N	77 33.270'W	group c
17-Aug-07	13:03:05			tag boat in midst of group d
17-Aug-07	13:14:09	24 23.702'N	77 33.452'W	tag # 227 on. Position is right side a little low, anterior of dorsal fin. 0 reaction, tag aspect : angled down about 10degrees
17-Aug-07	13:37:00	24 24.694'N		Sighting from Ranger of pilot whales
17-Aug-07	13:38:00			tag boat close to animals and they changed direction
17-Aug-07	13:40:00			In water says prop. Model suggests 55 - 65 dB loss over 1km. Model same of source and receiver at 60 - 150 ft.
17-Aug-07	13:49:00	24 24.194'N		Sighting from Ranger of pilot whales
17-Aug-07	13:52:00			tag boat close approach
17-Aug-07	13:53:27	24 25.553'N	77 33.304'W	animal d3. tag attempt, slip. Ari says this is when the tag should have started so we have about 17 hours from this time.
17-Aug-07	13:58:00	24 25.726'N		Sighting from ranger of pilot whales
17-Aug-07	14:09:00	24 26.386'N	77 33.558'W	Sighting from Ranger of pilot whales
17-Aug-07	14:13:00	24 26.397'N		Sighting from ranger of pilot whales
17-Aug-07	14:15:28	24 26.539'N	77 33.498'W	Tag #226 on whale d5.Reaction scale 2. fluke and dove and so did animal next to it. Tag low on body mid - dorsal, on right sight.
17-Aug-07	14:50:50			change focus from d5 to animal with nick (d6)
17-Aug-07	14:52:00			focal group changes, now is d7 (mom and calf pair)
17-Aug-07	14:52:01	24 27.963'N	77 34.262'W	Sighting from ranger of pilot whales
17-Aug-07	14:57:48			energy to sound source (lab)
17-Aug-07	14:58:06	24 24.902'N	77 33.196'W	first ping in water
17-Aug-07	15:00:47			Di wonders if travelling faster
17-Aug-07	15:04:08			suspend transmission
17-Aug-07	15:05:00			Db up to 167
17-Aug-07	15:21:00			in water has lots of vocal activity on H51, which is 1.5 miles to SE

Date	Time	Latitude	Longitude	Comments
17-Aug-07	15:22:00	24 29.222'N	77 33.484'W	boat position
17-Aug-07	15:24:00			Wind picking up
17-Aug-07	15:33:00			Alex had been hearing tag 226 off the port quarter of Blackfin. Each time more distant. Possibly 5-6 surfacings, dive, then fast swim
17-Aug-07	15:35:00			Ranger visual on group 1400m from the starboard beam
17-Aug-07	15:42:00	24 28.507'N		Sighting from Ranger of pilot whales
17-Aug-07	15:51:15			Commencing transmission. There is another group about 200m past the group nearest us, possibly coming to join
17-Aug-07	15:52:00			Source vessel range to Blackfin 2050 yards starting at 167db
17-Aug-07	15:53:46			Blackfin is 150 m from nearest group
17-Aug-07	16:08:00			Blackfin travel at 012 degrees at 2.6 knots
17-Aug-07	16:30:01	24 31.559'N	77 33.030'W	Sighting from
17-Aug-07	16:32:15			preparing to transmit
17-Aug-07	16:36:22			Order to start Orca playback
17-Aug-07	16:37:18			Transmission has commenced at a low level, started at 16:36.30
17-Aug-07	16:38:01			Animals were in two tight groups and distance between them has decreased. Think we have visual on focal animal, but not getting VHF signal, because animal surfaces low in water
17-Aug-07	16:42:12			1 sub group is at surface, other down
17-Aug-07	16:44:53			Changed direction, now headed towards R/V Ranger
17-Aug-07	16:46:06			162dB right now (SV loud)
17-Aug-07	16:48:00			Animals facing North again
17-Aug-07	16:48:43			have recommended transmission
17-Aug-07	16:54:32			180 db
17-Aug-07	16:59:00			End transmission
17-Aug-07	17:09:00			Group changing direction
17-Aug-07	17:12:00			Weather worsened, rain and wind, unable to remain on fly bridge and lost sight of group.
17-Aug-07	17:13:00			Blackfin heading to site 1, unable to keep focal follow.
17-Aug-07	17:16:00	24 31.757'N	77 34.365'W	Sighting from ranger of pilot whales

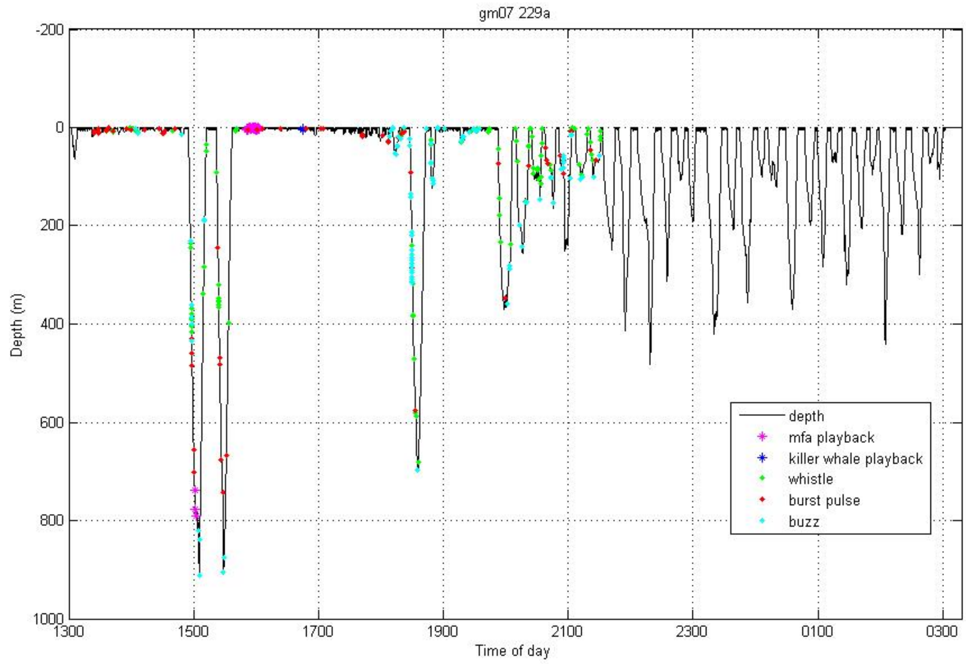


Figure 9-32. Dive Profile of first pilot whale tagged for playback on 17 August 2007.

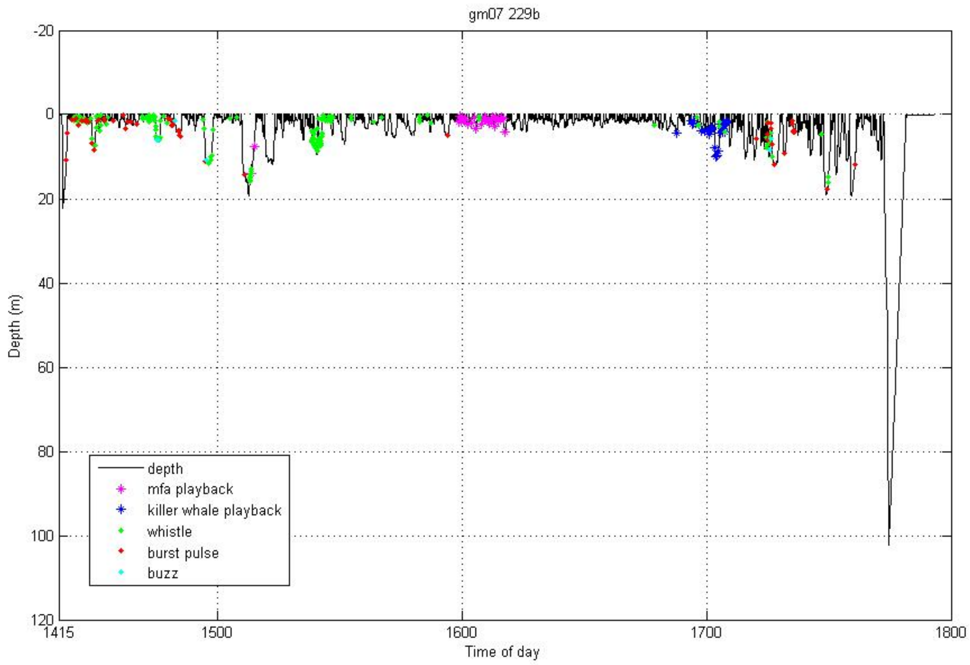


Figure 9-33. Dive Profile of second pilot whale tagged for playback on 17 August 2007.

The dive profiles of the pilot whales (Figs. 9-32 and 9-33) show only short deep dives compared to beaked whales at AUTEC. There appears to be a change in the dive behavior of whale 229a around the time of sunset (2000). The daytime diving behavior involves the majority of the time in the top few tens of meters of depth, with one dive to 100 m for 229 b and several dives to deeper than 600 m for 229a. During the night 229a conducted regular dives to between 100 and 400 m depth. Tags on both pilot whales recorded a diversity of whistles, clicks, burst pulsed sounds and buzzes. This increased variability in diving and vocal behavior of pilot whales compared to the beaked whales complicates analysis of potential diving and vocal responses to the playbacks. Any conclusions will have to wait for more analysis.

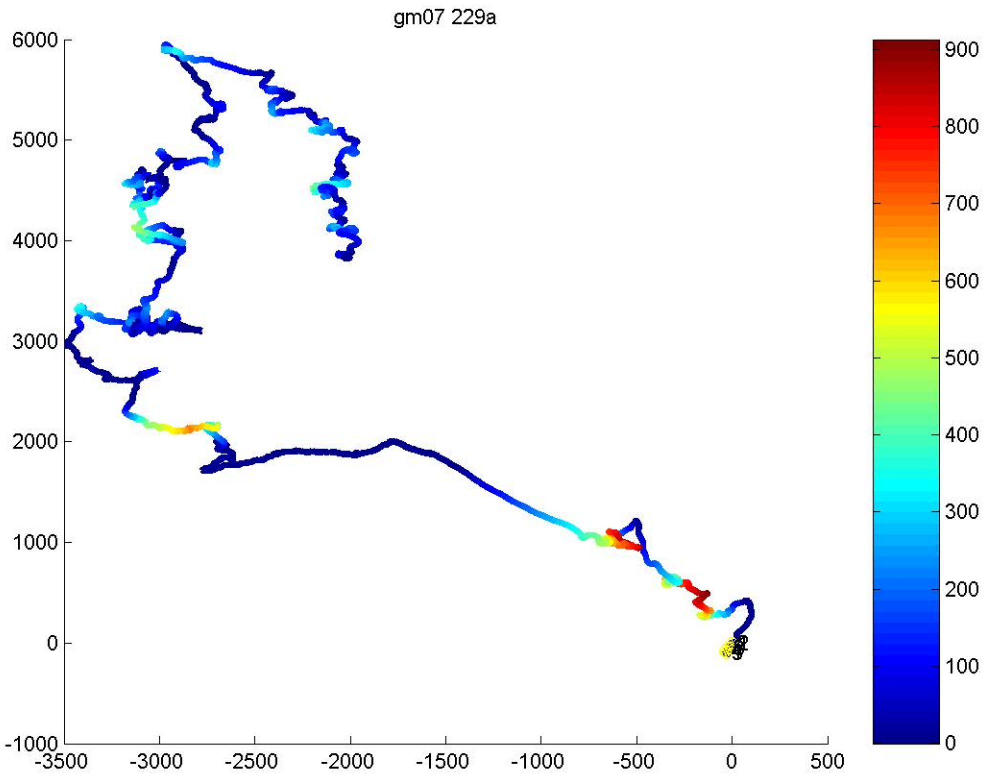


Figure 9-34. Pseudotrack of the 14 hour tag record deployed on the first whale exposed to playback on 17 August 2007. The location at (0,0) marks where the tag was attached. The track is colorized with depth as indicated by the color bar. The pseudotrack assumes a constant velocity for the whale and a constant current profile. Neither assumption is correct. This will be corrected by linkage with sightings and acoustic detection data and should be viewed as only giving a very imprecise picture of how the animal changed heading over time.

The pseudotrack (Fig. 9-34) is not an accurate representation of the actual track of the whale until it can be geo-referenced to sightings and acoustic localizations from the AUTEC hydrophone array. However, this preliminary pseudotrack does give some indication of changes in heading during the tag out. Gm07_229a was exposed to MFA playback during the first deep dive at about (100,-100), and just after the second dive at about (-1000, 1000). The whale was exposed to the Orca playback about halfway in time between the second deep dive and the third one (colorized yellow to orange at -2800, -3000). There is some indication that the track may have been straighter during the period immediately after both playbacks, but it appears to regain the more typical meandering path just before the third dive. It is not possible with such a limited sample size to be sure about responses, and it is critical to point out that this pseudotrack is a very rough approximation of movement data, but it is possible that the tagged whale responded to the playbacks with a straighter course. If so, the resumption of meandering paths suggests that it stopped soon after the killer whale playback. This response would differ from the beaked whale playback in which the whale appeared to continue an avoidance reaction for ten hours until the tag released.

9.1.5 Monitoring and mitigation flights

Seven aerial surveys were flown during BRS-07, as summarised in Table 9-9. Flights were conducted based on differing objectives at the time including pre-BRS surveys, mitigation flights following playbacks and searching for tags. The focus of all mitigation flights was to search the shoreline along the eastern coast of Andros Island, but searches also included the small islands in North and Middle Bight, the bank edge and cays along the east side of Tongue of the Ocean (TOTO), and the coastal areas of New Providence Island. Flights were flown at an altitude of 500 feet and at 90 knots. A total of 16.4 hours of flight time was cumulated covering 1476 nm (2731 km) during the period, during which there were 3 marine mammal sightings.

Table 9-9: Summary of aerial survey efforts during BRS-07.

Date	*Aircraft*	*Type of Flight*	*Area Surveyed*	*Survey Effort (hh:mm)*	*Marine Mammal Sightings*
13 Aug 07	AUTEC helicopter	Pre-BRS survey	East coast of Andros Island – Site 1 to Site 4	00:35	None
15 Aug 07	Sapphire Air	Pre-BRS survey	East coast of Andros Island, line transects across range, east side of TOTO	04:11	6 *Steno bredanensis*
18 Aug 07	Sapphire Air	Mitigation	East coast of Andros Island, line transects across exposure area, North Bight, east side of TOTO	03:55	None
20 Aug 07	Cessna 182	Tag search & Mitigation	East coast of Andros Island	00:30	None
4 Sep 07	Sapphire Air	Mitigation	East coast of Andros Island, southwest coast of New Providence Island	02:10	2 *Tursiops truncatus*
6 Sep 07	Sapphire Air	Mitigation	East coast of Andros Island, North and Middle Bights, east side of TOTO	05:01	3 *Tursiops truncatus*
27 Sep 07	Sapphire Air	Final, post BRS monitoring flight	East coast of Andros Island, North and Middle Bights, east side of TOTO	02:45	? *Tursiops truncatus*

10 Future plans

BRS-07 has always been seen as one part of a series of behavioural response studies to resolve the issue about how sonar and other sounds affect beaked and other whales. The intention was to re-assess the next steps after the end of BRS-07 and, as intended, consideration is being given to the next steps. In summary, the progress made is as follows:

- Overall, BRS-07 demonstrated that the concept works, although rightly there are suggestions for improvements.
- It was determined that there may be measurable behavioural response from beaked whales, and possibly also from pilot whales, that do not necessarily raise concerns about health of the subject.
- BRS-07 vastly increased our knowledge of basic behavior in beaked whales in Tongue of the Ocean and the base-line allows a level of confidence that it is possible to measure responses of animals that are unusual
- The observed response lends more weight to some hypotheses about the causes of strandings in response to sonars than to others, although it does not provide conclusive evidence in any particular direction.
- The ship noise trials provided a starting point to begin developing methods to assess the responses of beaked whales to sound that may lead to a protocol for conducting an experiment without the need to tag all whales

With this progress in mind the intention is to:

- Return to AUTEC in 2008 to increase the sample size of playbacks, concentrating upon beaked whales;
- Build sample size using very similar experimental design but improved, more efficient logistics, probably using a single platform in the form of an ocean-going research vessel;
- Retain the focus on tagging but also develop the capacity to undertake some playback without the need to tag;
- Develop deployed PAM devices to enhance the capacity of M3R and to develop methods for BRS-09 which would probably take place at a location where there is no hydrophone grid available as at AUTEC;
- Carry out playbacks using a real AN/SQS 53C sonar.

Appendix A - References Cited

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Appendix B – Acronyms and Abbreviations

AIM – Acoustic Integration Model
AUTEC – Atlantic Undersea Test and Evaluation Center
BMMRO – Bahamas Marine Mammal Research Organization
BRS – Behavioral Response Study
BW – beaked whale
dB – decibel
CCB – Command and Control Building
CNO – Chief of Naval Operations
CS – Chief Scientist
CTD – conductivity, temperature and depth
CW – continuous wave
DIW – dead in the water
Dtag – digital archival tag
eNGO – Environmental Non-Governmental Organization
FSU – Florida State University
Ft – foot
GB – gigabyte
GIS – Geographic Information System
GPS – Geographic Positioning System
IND - independent
kHz – kilohertz
km - kilometer
kt – knot
m – meter
mm - millimeter
m/s – meters per second
min - minute
MAI – Marine Acoustics Inc.
M3R – Marine Mammal Monitoring on Ranges
METEO - meteorology
MFA- mid-frequency active
NATO – North Atlantic Treaty Organization
NOAA – National Oceanic and Atmospheric Administration
NUWC – Naval Undersea Warfare Center
OIC – Officer in Charge
ONR – Office of Naval Research
PAM – passive acoustic monitoring
PB – playback
PI – Principal Investigator
RHIB – rigid hull inflatable
RL – received level
RUB3 – Range Use Building
RV – research vessel
SD – standard deviation
SERDP – Strategic Environmental Research and Development Program
SL – source level

SMRU – Sea Mammal Research Unit
SNET – Ship Noise Evaluation Trial
SPL – sound pressure level
SV – Source Vessel
TRT – tag recovery team
TL – transmission loss
TOTO – Tongue of the Ocean
TTS – temporary threshold shift
UNOLS – University-National Oceanographic Laboratory System
uPa – microPascal
Unk. - unidentified
VHF – very high frequency
WHOI – Woods Hole Oceanographic Institute
WRN – Weapons Range North
WRS – Weapons Range South
XBT – Expendable Bathy Thermograph

Appendix C – Test Report for Beam Pattern Measurements of Vertical Directivity of Behavioral Response Study (BRS) Transducer

Preface

This report was prepared under the Behavioral Response Study (BRS) project. It represents the findings and conclusions of an in-situ test of the vertical directivity of the active sound source. The sponsoring activities are CNO N-87, N45 and ONR. The technical reviewer was Prof. Kevin B. Smith, affiliated with the US Naval Postgraduate School.

The authors wish to acknowledge the extensive contributions of Lance E. Walker (EG&G) and the crew of the R/V Ranger.

Authors: Adam Frankel, PhD Marine Acoustics, Inc.; Robert Gabriel, BAE Systems; Eryn Wezensky, Naval Undersea Warfare Center, Division Newport

Vertical Beam Pattern Measurements

Introduction

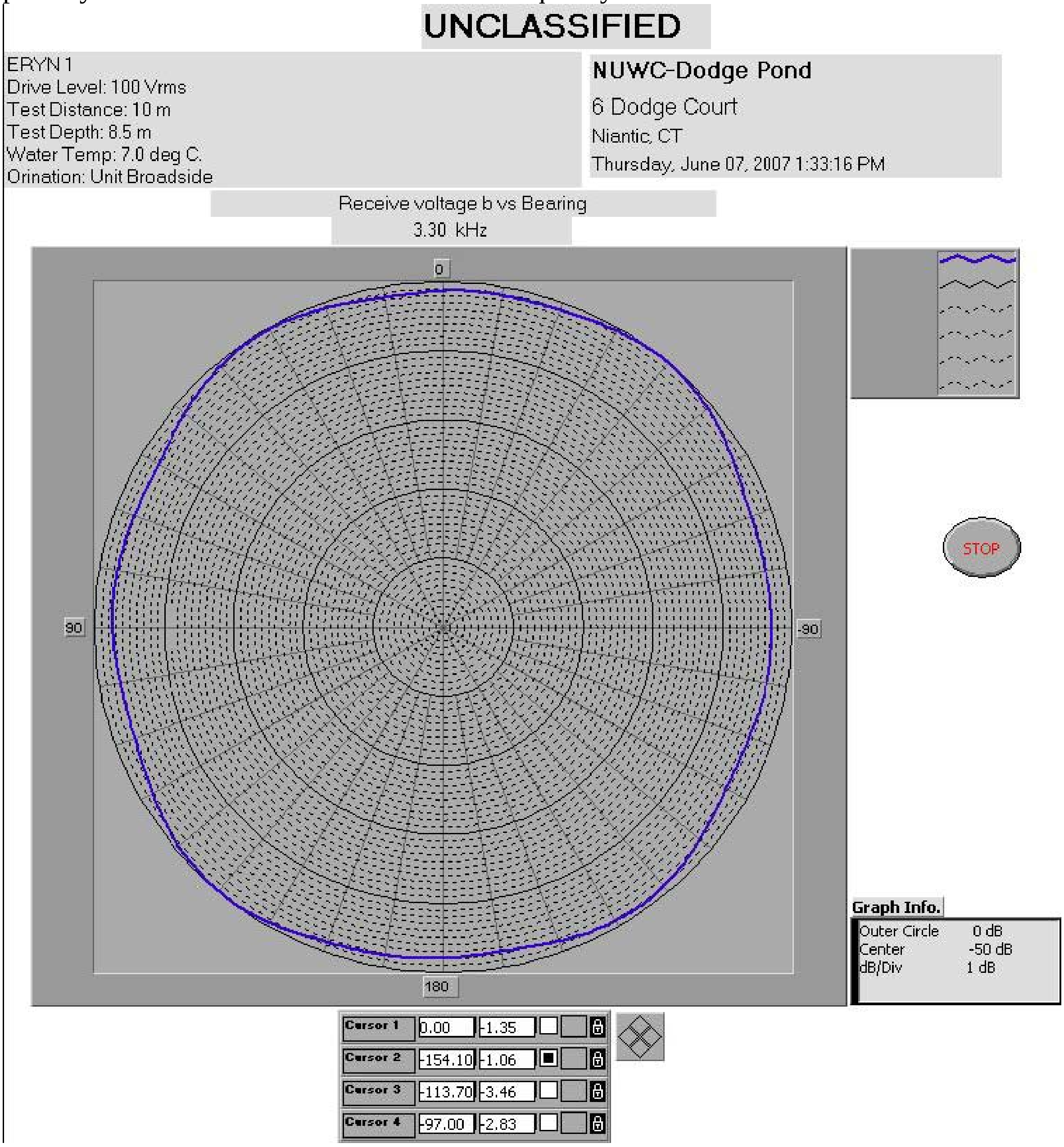
During the Behavioral Response Study (BRS) there was a significant discrepancy, approximately 20dB/μPa/Hz between the predicted levels and the measured levels recorded on the beaked whale Dtag during the playback on 2 September 2007. This was in contrast to the reference hydrophone data which indicated that the intended source levels were being transmitted. The performance prediction tool, Acoustic Integration Model © (AIM), made the assumption that the source behaved as a perfect spherical radiator. The discrepancy in the playback results may be indicative of a non-uniform vertical radiation component. To be able to properly model the sound field generated by the acoustic source transducer requires that the vertical component be measured and those results be entered into the prediction tool. After measuring the actual vertical radiation pattern, the sound field was re-modeled and findings suggested that the tagged beaked whale was positioned near the shadow zone of the acoustic source during the 2 September playback.

Objective

The primary objective of this test is to characterize the vertical radiation pattern of the acoustic sound source. This in turn will provide the information necessary to accurately predict the acoustic environment created by the source transducer. By being able to compute predictions as accurately as possible provides a better likelihood of positioning the acoustic source where required to meet the objectives of the BRS.

Background

On 7 June 2007, the horizontal beam patterns of the acoustic source transducers, primary and backup, were measured at the Naval Undersea Warfare Center, Dodge Pond Facility. The transducers were stimulated throughout the spectrum of its response. The resulting measurements reflected a mostly omni-directional radiation pattern in the horizontal plane. This suggests that the vertical beam pattern of the source will have cylindrical symmetry around the vertical axis. Figure 1 shows the horizontal beam pattern of the primary source transducer measured at the frequency of 3300 Hz.

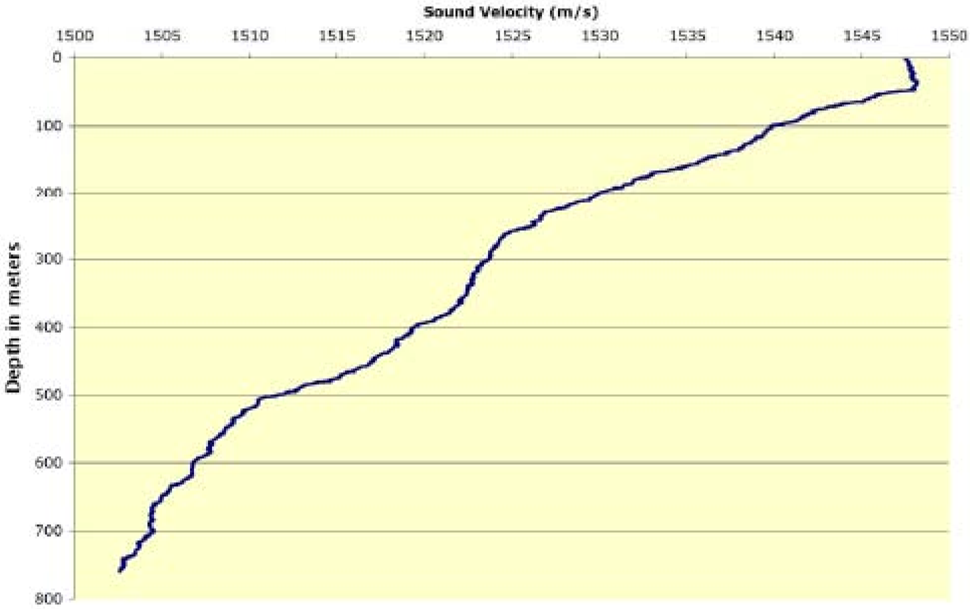


Appendix III Figure 1- Measured 3300Hz horizontal beam pattern

During the testing on 7 September 2007, time limitations required that the measurements be limited to a single frequency. The initial results are considered rough field measurements even though all possible care was taken to minimize the variability of each aspect of the measurement. After completion of these measurements there exists a level of uncertainty in the absolute characterization of the vertical component of the source radiation pattern. For future measurements, the primary and backup source transducer and the measurement hydrophone need to be held rigidly to insure that the relative bearing and distance is known for the entire measurement.

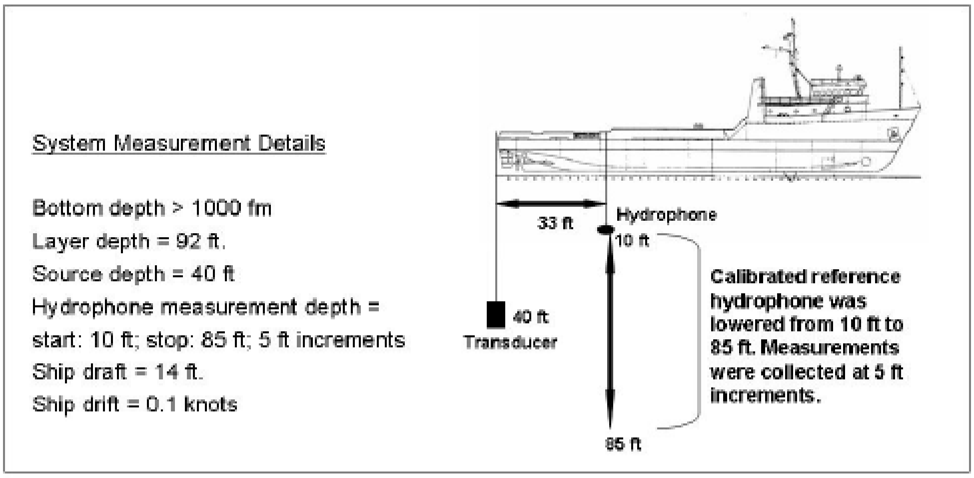
Procedure

The R/V Ranger got underway on 9 September 2007 and proceeded to 24 43.6 N Latitude and 77 41.1 W Longitude where the bottom depth was in excess of 1600m. Once on location, the ship went DIW and secured the main engines. An XBT was deployed and the layer was measured to be at approximately 45 meters, as indicated in Figure 2.



Appendix III Figure 2 - 7 September 2007 XBT measurement

The wind was 5 to 10 knots off the starboard beam. The source was deployed to 40 feet as accurately as possible. The source was set to transmit 3300Hz at 174dB/µPa/Hz @ 1m. The source level was verified using a 1 meter reference monitoring hydrophone. The received level, using an independent calibrated reference hydrophone, was measured and recorded. Figure 3 shows the procedure used for this measurement.



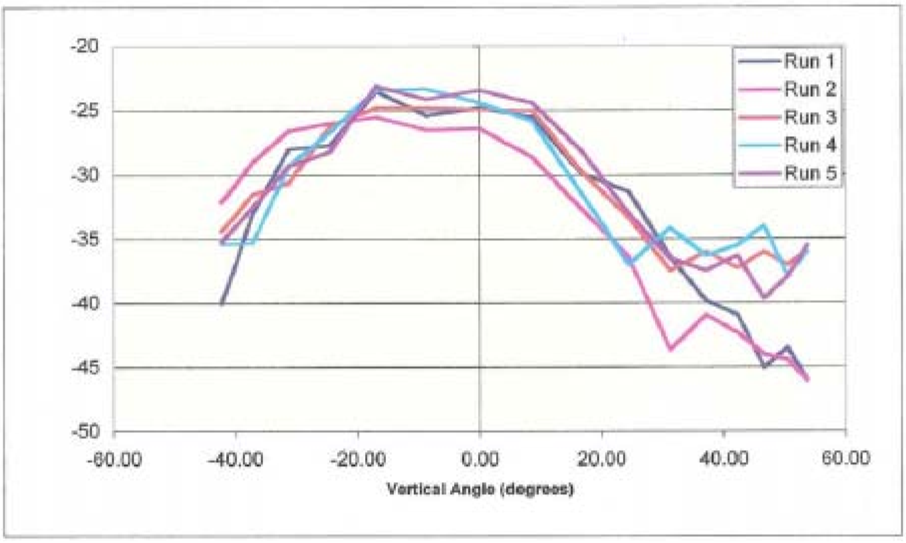
Appendix III Figure 3 – Measurement geometry

The measurements were made every 5 feet while lowering and raising the hydrophone. These levels were acquired using an HP 35665A Spectrum Analyzer. These are relative levels, presented as dBv, and used to identify the effective beam shape in the vertical plane of the source. These measurements are presented in Table 1.

Hydrophone Depth (ft)	Run 1 Stbd side	Run 2 Stbd side	Run 3 port side	Run 4 port side	Run 5 port side	Angle (degrees)	Mean	St Dev
10	-40	-32.1	-34.4	-35	-36	-42.27	-35.47	3.31
15	-35	-29	-31.5	-35	-33	-37.14	-32.2	2.64
20	-28	-26.5	-30.5	-29	-29	-31.27	-28.52	1.71
25	-27.7	-28	-28.2	-27	-28	-24.44	-26.66	0.78
30	-23.5	-25.5	-24.8	-23	-25	-16.65	-24.3	1.02
35	-25.4	-26.5	-24.8	-23	-24	-8.61	-25	1.33
40	-24.9	-26.4	-24.9	-24	-25	0	-25.12	0.67
45	-26.5	-26.5	-25	-26	-24	8.61	-26.22	1.01
50	-29.9	-32.7	-29.9	-32	-30	16.65	-30.87	1.38
55	31.3	30.4	33.3	37	33	24.44	34.5	2.67
60	-38.4	-42.6	-37.4	-34	-37	31.21	-37.9	4.02
65	-39.6	-40.9	-36	-36	-37	37.14	-38.25	2.48
70	-40.9	-42.5	-37.2	-36	-36	42.27	-38.87	3.18
75	-46	-44	-35	-34	-40	45.66	-39.75	5.68
80	-43.5	-44.4	-37	-38	-38	50.47	-40.87	3.81
85	-46	-46	-35	-35	-36	53.74	-41	6.77

Appendix III Table 1 – Actual measured values

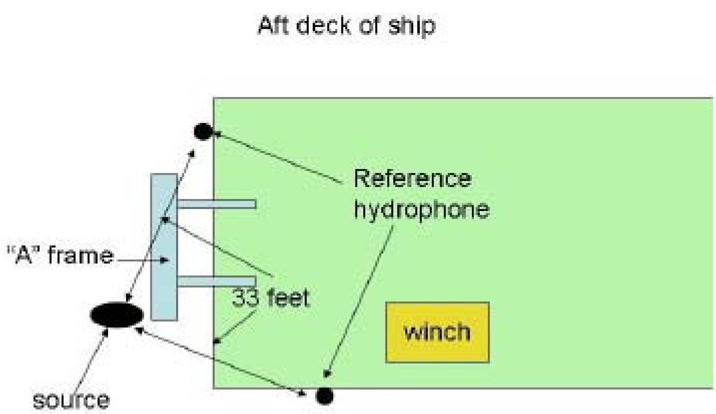
Runs 1 and 2 represent measurements of the outputs with the calibrated reference hydrophone during descent and retrieval on the starboard side, respectively. Runs 3 and 4 represent measurements during descent and retrieval on the port side, respectively. Run 5 was made with the calibrated reference hydrophone starting at 85 feet and retrieved on the port side. Run 5 was made to attempt to quantify the results being measured at the 60 to 85 foot range. The inconsistencies between 60 and 85 feet suggest that the reference hydrophone was moving erratically with relation to its position from the source. Therefore, the measurements provide inconsistent results while at those depths. These results further amplify the need to perform a calibration of the source at the NUWC Lake Seneca facility. The raw values presented in Table 1 are plotted and shown in Figure 4.



Appendix III Figure 4 – Plot of 5 raw data runs

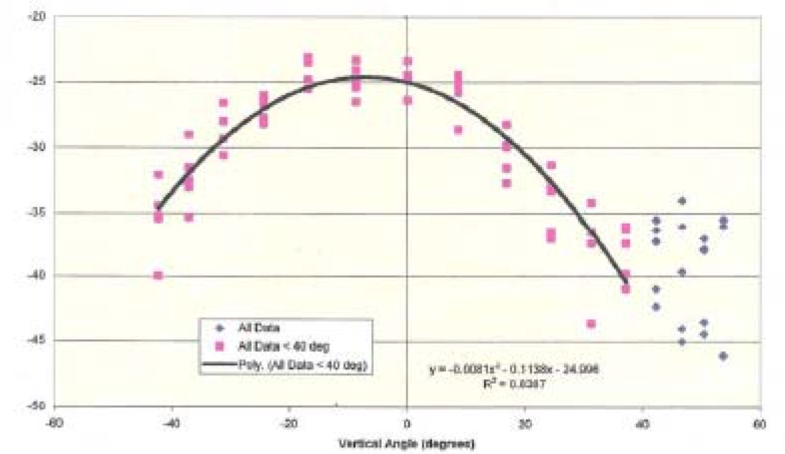
Note in Figure 4 that there is a strong divergence between Runs 1 and 2 and Runs 3-5 starting from 30 to 50 degrees. This trend shows that the deeper the depth, the more divergence in measurement. It is believed that this discrepancy is the result of the both the transducer and reference hydrophone hanging as pendulums and moved independently of each other. This divergence is magnified by the relative movement of the R/V Ranger platform during at-sea conditions. Contributing to the relative movement was the fact that the transducer weighs approximately 550 lbs and is suspended on a 1 inch steel cable weighing 1 pound per foot. The reference hydrophone weighs less than 6 ounces, and is suspended on a cable which was approximately the same diameter as the hydrophone. Its weight was negligible with a 15 pound weight added to it to try to provide some stability during the measurement.

While the measurements were made port and starboard, it was impractical to get a full 180 degrees apart. Therefore, there is some discrepancy in the magnitude of the effect seen between port and starboard measurements. Care was taken to account for any differences caused by these factors by measuring the output levels from a port and starboard aspect. Figure 5 depicts the equipment layout.



Appendix III Figure 5- Layout of the equipment during the measurement

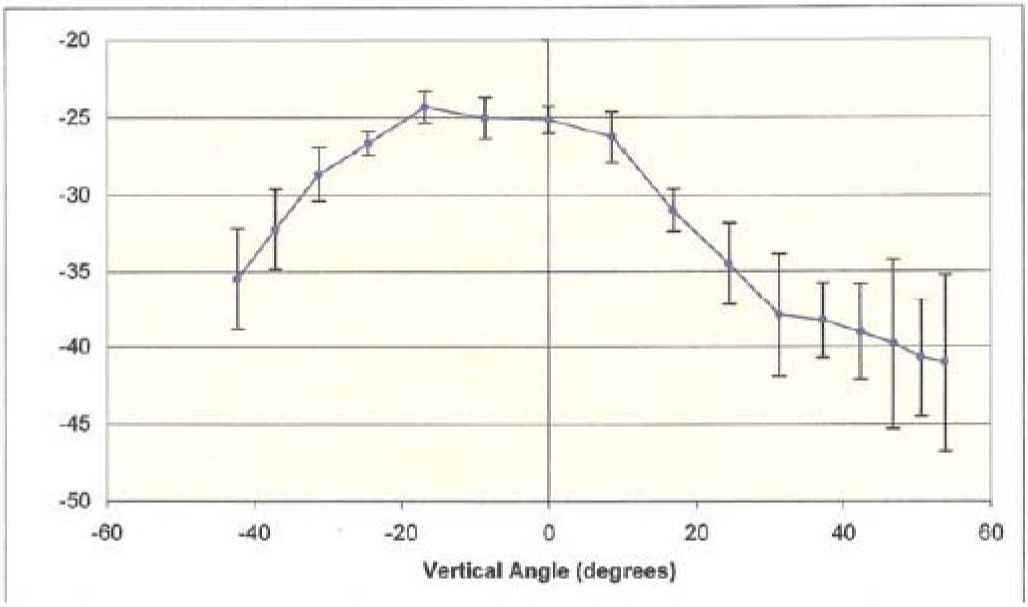
Figure 6 shows a scatter gram of the raw data points combined with a quadratic curve that was fit to data points between angles plus and minus 40 degrees. Data points at higher angles outside of 40 degrees were unreliable and therefore not included in the quadratic equation.



Appendix III Figure 6 – Scatter gram of measured values with a quadratic curve fitted to the data from angles less than or equal to 40 degrees. The quadratic curve components are represented by:

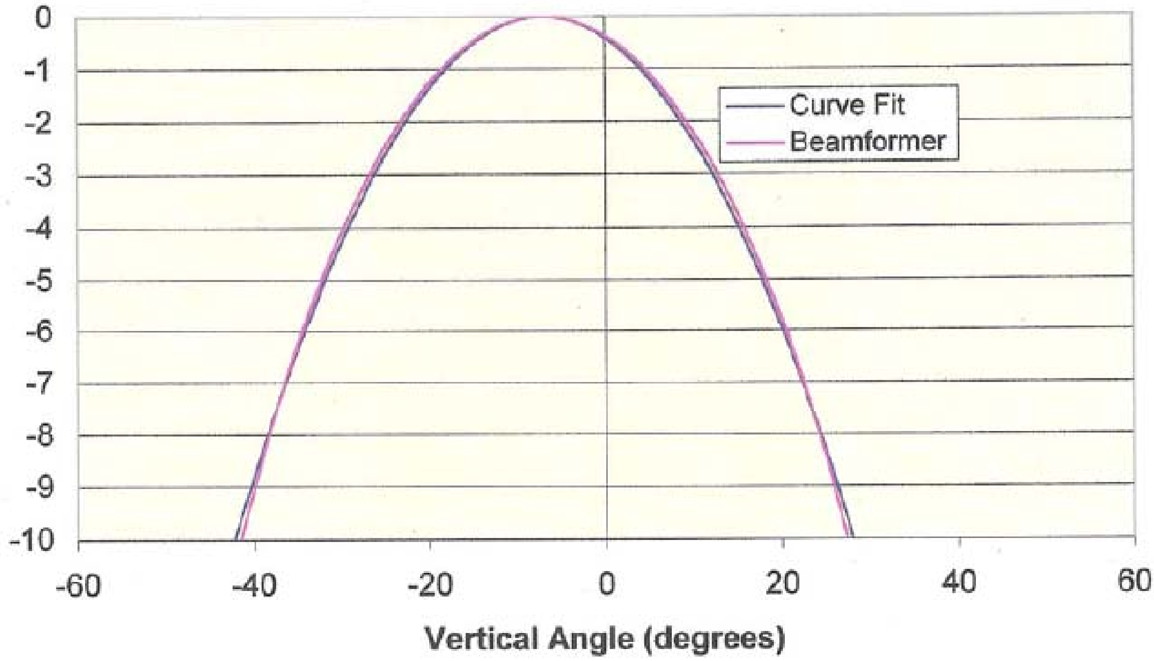
$Y = -0.0081x^2 – 0.1138x – 24.996$
$R^2 = 0.8387$

The mean values for the first four runs are presented in Figure 7. The error bars represent two standard deviations (i.e. +/-1 S.D.). The fifth run was omitted so that there would be equal representation of the values from both measurement locations (port/starboard).



Appendix III Figure 7 - Plot of the standard deviation of the data

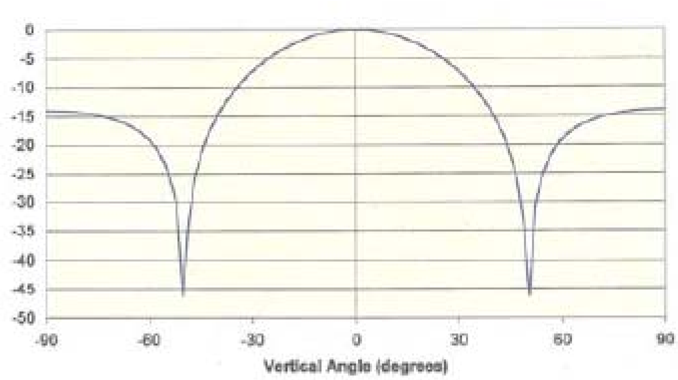
The curve fit described in Figure 5 was used to model a beam pattern using an assumption of a circular piston radiator and computing the theoretical beam pattern with an effective 305 millimeter aperture. This beamformer equation is used in the AIM ©, which in turn is used to make acoustic propagation predictions.



Appendix III Figure 8 - The quadratic curve fit from the data is plotted in blue.

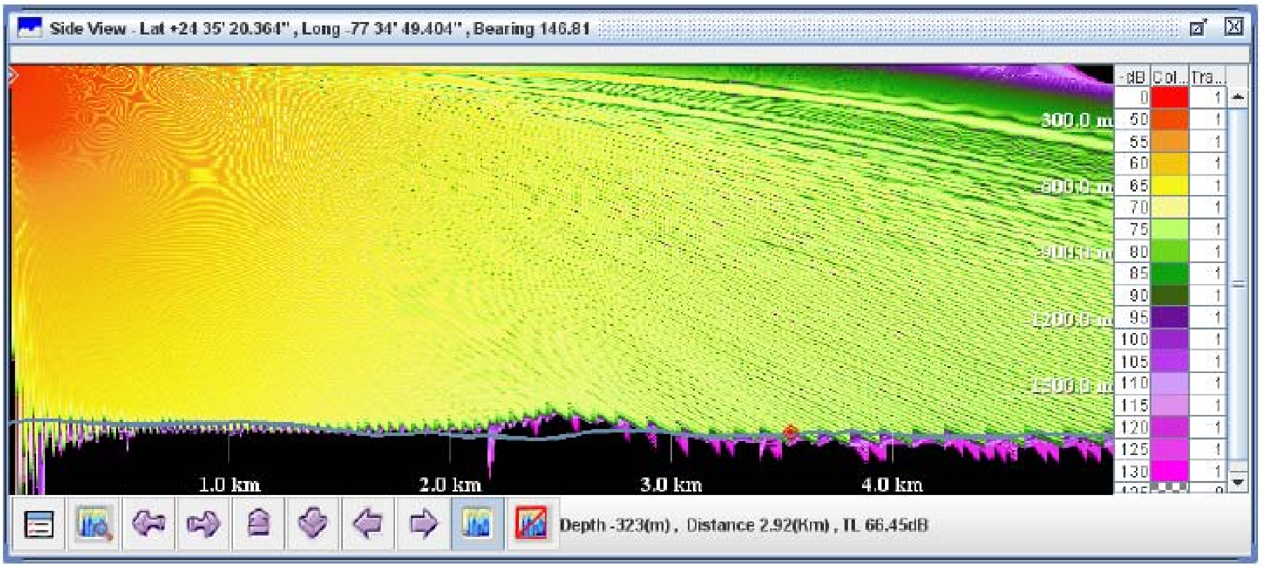
A very close match between the curve fit to the observed data and a beam pattern was obtained with an aperture of 305 millimeters and an upward steering angle of 7 degrees.

It is uncertain whether the steering angle is an artifact of the measurement or actually representative of the radiation pattern of the BRS source transducer. A reasonable assumption would be that the steering angle is an artifact due to the methodology of the measurement and the relative movement between the measurement device and the source transducer. Figure 9 is a theoretical beam pattern of a circular piston radiator of 305 mm diameter transmitting a 3300 Hz tone, and is presented here as a reference.

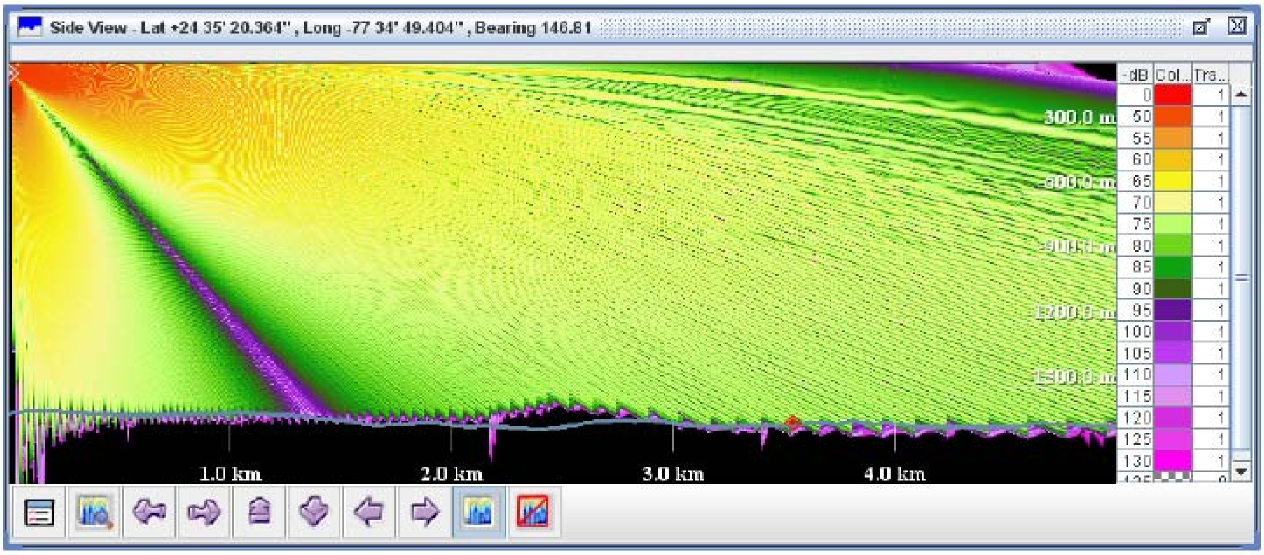


Appendix III Figure 9 - Theoretical beam pattern of a 305 mm circular piston radiator transmitting a 3300 Hz tone

Figure 10 shows the original propagation model using an omnidirectional, CW (3300 Hz) source for the prediction. Figure 11 shows the change after the theoretical beam pattern for a 305 mm circular piston radiator was incorporated. Note the narrow shadow zone that appears in Figure 11. While this shadow zone is deep enough to introduce 20 dB discrepancies, it is highly localized and should not affect the majority of the area of interest, particularly when the full signal bandwidth is considered. More nominal differences of ~5 dB are common throughout the area ensonified.



Appendix III Figure 10 - Propagation modeled for September 2, using an omnidirectional source.



Appendix III Figure 11 - Propagation modeled using the theoretical beam pattern based on the measured values for the main lobe of the beam.

Conclusions and Recommendations

The values measured while at sea are an adequate estimation of the actual performance of the BRS source transducer for the main lobe at 3300 Hz. This measurement should provide guidance for predictions that will enable the team to predict where to place the R/V Ranger and source for the desired acoustic exposure of the beaked whales being monitored during the BRS sea test.

Given the variation in measurements and limitations in controlling environmental current conditions during the on-range testing, as described above, a post-test validation is strongly recommended. This will further validate the measurements made during the BRS.

It is strongly recommended that the overall performance of the transducer's characterization be evaluated with the narrowband and broadband signals transmitted during the BRS test. These should be evaluated for actual vs. expected performance. These measurements should be done in both the near and far fields. This calibration study should also include a Dtag from the experiment, allowing validation of the results while confirming the calibration of the signal levels recorded by the Dtag. Additionally, any signals planned for future tests should also be evaluated at this time to establish the adequacy of the source transducer for those transmissions.

Appendix D– Data Management

Disks used for data archiving:

- "C:" (150 GB)

for archiving all BRS data except for tag team data (way too large for C)

Directory:

C:\BRS-07 Data Archive-no TAG

Subdirectories:

\BRS Software
\Effort
\Environmental
\Google Earth Bahamas
\Inventarium and Paper forms
\Narrative Logs
\Permit Forms
\Positional
\Prop Loss Model
\Sea PAM data
\Source Data
\Visual Sightings data

- "E:" internal data disk (250 GB)

for archiving all BRS data except for tag team data

Directory:

E:\BRS-07 Data Archive-no TAG

Subdirectories:

\M3R data
\Photos

That is to say that the data set for BRS07 no-tag into the main archiving computer is:
BRS-07 Data Archive-no TAG = subdirectories into C: + subdirectories into E:

- "H:" Maxtor RAID (700 GB)

For back up of "C:\BRS-07 Data Archive-no TAG" and for archiving all Tag Team data

Directories:

H:\BRS-07 Data Archive-no TAG
H:\BRS07tag

Subdirectories:

For H:\BRS-07 Data Archive-no TAG see C:\BRS-07 Data Archive-no TAG
For H:\BRS07tag:

\data
\MFA_extracted_from_tag
\paper forms
\Pseudotracks
\tags
\USBIR

- “P:” 'BRS_RAID_A (Brs_raid_a)' WD My Book World Edition (500 GB)

As back up of both “BRS-07 Data Archive-no TAG” and “BRS07tag”

N.B. Tag Data are not available on C:+E: for space problems.
They are available on Maxtor and on My Book WD. Maxtor is an issue: if you load data you might not be able to update them in a later archiving section (message: file or folder not accessible or corrupted). The only solution found to keep using Maxtor was to rename all folders and recopy them. This obviously results in using twice the space that is actually needed! Most recent directories are renamed like “*_1” or “*_2”. The higher the number after the underscore the most recent is the data set.

For more details on data archiving see “Inventarium.xls”
For details on general activities see worksheet “Calendar of Activities” in “Inventarium.xls”.