Biological and Behavioral Studies of Marine Mammals in the western Mediterranean Sea ('MED -09')

~ Project Summary ~

~ MED -09 is a research project designed to measure where, why, and how different species of whales and dolphins live in interesting and important biological areas of the western Mediterranean Sea. The study will also include measurements of how these animals may change their behavior when they hear different sounds ~

~ Marine mammals around the world, and particularly in the Mediterranean Sea, face many challenges due to interactions with people, from overfishing and entanglement to vessel strikes and disturbance from human sounds. Many of these issues remain poorly known and we need carefully conducted science to help us manage and protect marine animals ~

~ MED -09 will take place on the NATO research vessel (NRV) *Alliance* from late July to early September in deep canyon-like areas around the Balearic Islands and in the Alboran Sea off the Spanish Mediterranean coast and the Tyrrhenian Sea to the west of the Italian mainland ~

~ The project involves a diverse collaboration of world experts in marine mammal distribution, diving, and behavior, as well as specialists for using underwater sound to find marine mammals and safely measure their responses to controlled sound exposures ~

Additional information about the project is available in the more detailed description that follows – you can also follow our progress and find out more at:
http://www.whoi.edu/expeditions/med09

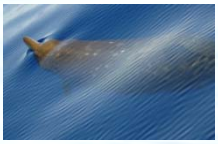
[photo credits: left is courtesy T. Pusser, obtained under U.S. NMFS permit #981-1707; other photos here and watermark are courtesy A. Friedlaender, obtained under U.S. NMFS permit #1121-1900]

Biological and Behavioral Studies of Marine Mammals in the western Mediterranean Sea ('MED -09')

~ *Project Description* ~

Introduction

A biological research cruise (called 'MED -09') will occur from late July to early September in various parts of the western Mediterranean Sea. This multi-disciplinary, multi-national scientific endeavor will provide a wide variety of basic biological data and urgently needed behavioral response measurements. It will contribute to a long-term, integrated research effort that has already involved nine research cruises on the NATO research vessel (NRV) *Alliance* since 1999, and field efforts to tag beaked whales in the Mediterranean, Canary Islands, Bahamas, California and Hawaii since 2001[1].



This coordinated international program addresses many of the priorities identified by The Agreement on the Conservation of Cetaceans in the Black Sea, Mediterranean Sea and contiguous Atlantic area (ACCOBAMS) and other international bodies regarding the understanding and protection of cetaceans from adverse effects of anthropogenic noise. MED -09 will include a diverse array of marine mammal and acoustic experts working on a specialized research vessel. These scientists, acousticians, and engineers come seven countries and a wide variety of participating organizations (shown below).

Specialists from these diverse affiliations have come together for this research project in order to advance our understanding of marine mammals in the Mediterranean Sea, and to gain information about their responses to sound. The results are critically important

[1] **[photo credits for above: (left) courtesy T. Pusser, obtained in the Ligurian Sea in 2006 under U.S. NMFS permit #981-1707 and (right) courtesy A. Friedlaender, obtained in the Bahamas in 2007 under U.S. NMFS permit # 1121-1900]**

to those who produce sounds for a particular purpose (such as the use of military sonar to find submerged objects) that can have unintended negative consequences on marine life and also for regulatory agencies responsible for managing protected species. MED -09 is consequently being supported primarily by several different organizations within the U.S. government that are facing these issues.

Background

Marine mammals use sounds for many important things, such as finding food, raising their young, finding mates, avoiding predators, and finding their way around the large, generally dark, ocean. In many ways, they are primarily acoustic animals whereas we are primarily visual.

Photo courtesy of NOAA National Marine Mammal Laboratory

Photo courtesy of NOAA National Marine Mammal Laboratory

Consequently, sounds in their environment that interfere with their ability to hear signals that are important to them, or sounds that disrupt their normal behavior can negatively affect them and, in extreme cases, can result in injury or death.

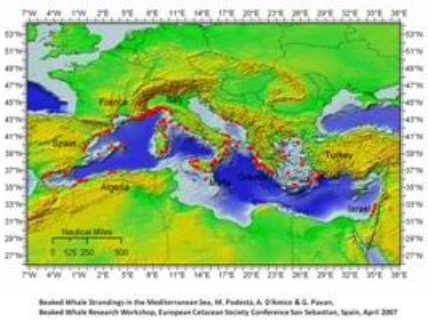
Photo courtesy of NOAA, National Marine Fisheries Service

While much of the concern in a global sense relates to interference (or "masking") of important sounds from industrial sounds such as large ships, we know that isolated intense sounds may harm marine mammals in certain conditions, extreme examples being atypical mass strandings of beaked whales during naval sonar exercises. These events, which seem to be relatively rare given the frequency of such exercises, share a number of similarities in geography, environmental conditions, and the species involved (beaked whales appear to be the most sensitive). However, we lack even a basic understanding of what really causes these events, how common they actually may be,

Photo courtesy of NOAA, National Marine Fisheries Service

and, most importantly, what might be done to reduce the likelihood of subsequent similar events in the future. Better data are sorely needed.

Marine mammals strand on beaches for a wide variety of reasons, many natural, and have been doing so for millions of years since they re-entered the oceans. People have observed these events long before the advent of modern sonar and other industrial sounds, though only recently have detailed records been kept in most areas. The Mediterranean Sea has a relatively high human population density, and compared to many other areas, a relatively long-term, well documented reporting record for marine mammal strandings, including beaked whales. As seen in red symbols, Mediterranean beaked whale strandings have been reported in many areas for several centuries.

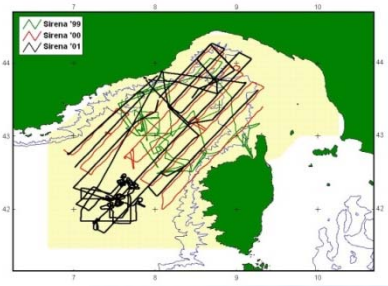


When looking at beaked whale mass stranding events globally, we see that there have been mass stranding events in most of the world's oceans. Many beaked whale mass stranding events have been documented in the Mediterranean Sea since 1961, some of which have been closely associated with and most likely caused by military sonar training exercises. The species of beaked whale most commonly found in the Mediterranean Sea is Cuvier's beaked whale, *Ziphius cavirostris*; this is also the species that is most commonly reported in strandings that coincide with naval sonar exercises in other areas. Thus, this appears to be an important area for studying and understanding the relationship between the use of such sounds and the behavior of potentially sensitive species of beaked whales. Because we know that this species may be quite sensitive to these sounds, we must take great care to avoid inducing harmful responses in studying how these whales respond. Despite the conservation importance of the data that hopefully will be obtained, the MED-09 project would arguably not be advisable, given these concerns, if it were not closely coordinated with considerable early research effort that indicate reduced risk for the approach to be used.

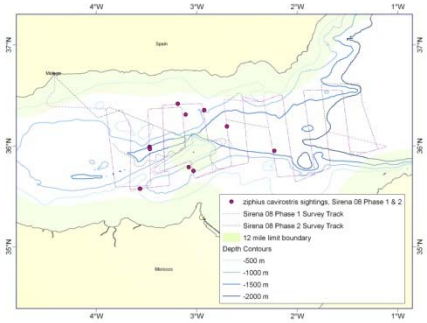
Previous Related Projects

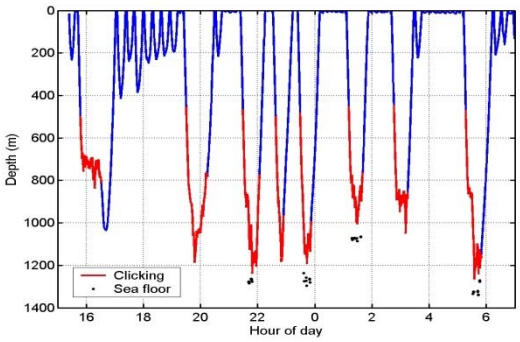
MED -09 is part of a long series of studies with the NRV *Alliance* designed to better understand cetacean populations in the Mediterranean Sea, to test and improve passive acoustic monitoring methods, and to reduce the impacts of anthropogenic sound on marine life. There have been nine such projects since 1999 as part of the NATO Undersea Research Centre's (NURC) Sound and Living Marine Resources (SOLMAR) and Marine Mammal Risk Mitigation. These studies have involved close collaboration since 1999 with Italian scientists from many institutions including Consiglio Nazionale Delle Ricerche (CNR), Istituto per le Scienze Marine (ISMAR), CNR- Istituto per lo studio dell'Oceanografia Fisica (IOF), Istituto Centrale per la Ricerca Applicata al Mare (ICRAM), Universita' degli Studi di Genova (UNIGE), Centro Interdisciplinare di Bioacustica e Ricerche Ambientali (CIBRA) of the Universita' degli Studi di Pavia, Tethys Research Institute, Acquario di Genova, Museo Civico di Storia Naturale di Milano, and Centro Studi Cetacei (CSC).

Sirena 99	Aug 1999
Sirena 00	Aug-Sep 2000
Sirena 01	Sep-Oct 2001
Sirena 02	Jul 2002
Sirena 03	Aug-Sep 2003
CEDAR 05	May 2005
MLJX 05	Sep-Oct '05
Sirena 06	Jul-Aug 2007
Sirena 08	May-Jun 2008
MED 09	*Aug-Sep 2009*



The NRV *Alliance* research efforts have focused on acoustic and visual surveys of cetaceans, collection of relevant oceanographic parameters for predictive habitat modeling, and the development of mitigation measures for the detection, classification, and tracking of marine mammals. Many of these studies have also supported efforts to study whales with tags that can record sound and movements. These tags, called Dtags, were developed at the Woods Hole Oceanographic Institution (WHOI), and have proven an invaluable tool to study species such as beaked whales that dive deep and are seldom visible from the sea surface. The figure to the right



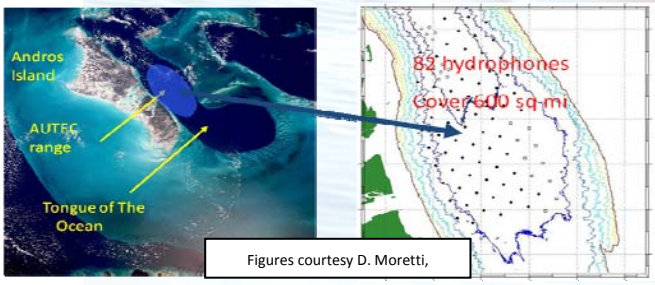


shows a dive record of a Cuvier's beaked whale indicating its depth (occasionally over a kilometer or half a mile!), surface behavior, and when it made clicking sounds associated with feeding and orientation. The Dtags, which are attached using non-invasive suction cups, come off the animals at a pre-set time, float to the surface, and are recovered for analysis. In addition to the NRV *Alliance* studies, the WHOI Dtagging team learned how to tag beaked whales through a collaboration with BluWest, an Italian whalewatching company, in the Gulf of Genoa during cruises each year from 2001 to 2005.

As these scientific projects using the NRV *Alliance* advanced in the Mediterranean, a related effort began on the other side of the Atlantic. During 2007 and 2008, a study (called behavioral response study, or "BRS") took place in the Bahamas. Using techniques and tools from the NRV *Alliance* cruises and other related research projects in the Canary Islands and various places in the U.S., a specialized, inter-disciplinary team of scientists used Dtags to measure the behavior of beaked whales, including how they react to intentional sound exposures.

The UNOLS research vessel *Roger Revelle* was used in BRS-08

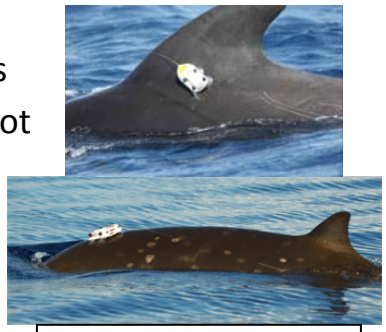
BRS 07-08 sought to learn more about beaked whales in a unique area of the Bahamas called the Tongue of the Ocean, which is a very deep basin to the east of Andros Island surrounded by shallow flats and shoals. This area is home to several species of beaked whales and it also houses a specialized underwater listening range (called the Atlantic Undersea Testing and Evaluation Center, or "AUTEC") used by the U.S. Navy and its allies to train and test new equipment. Scientists and engineers have tuned these listening sensors (called "hydrophones") to track different species of marine mammals over quite large areas using the sounds that they make and began working with marine mammal researchers to track and identify them. The tools had advanced to the point where carefully controlled sound exposure studies to investigate whether and how different species respond to human sounds were now possible.



Figures courtesy D. Moretti,

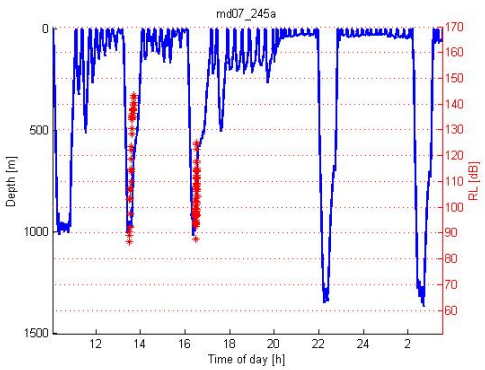
Controlled Exposure Experiments (or "CEEs") are studies in which the behavior of test subjects is measured before, during, and after controlled sound exposures. Different behavioral patterns can be statistically compared without and with different kinds of sounds to identify responses.

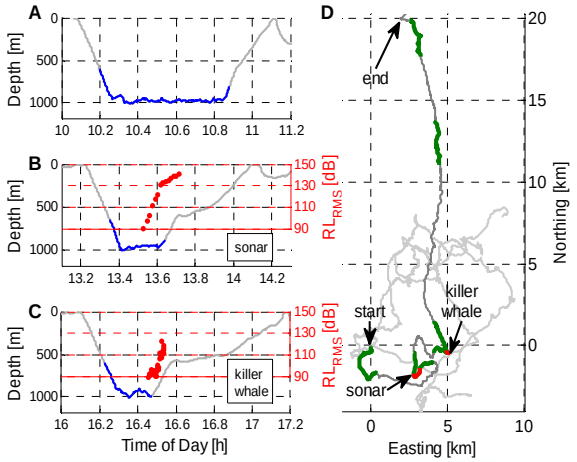
Prior to BRS 07-08 there were no direct studies of how potentially sensitive species such as beaked whales and sounds such as simulated military sonar. Researchers involved wanted to know something about how these animals reacted to these kinds of signals, in order to try and develop ways of reducing the chances of future stranding events, but also did not want to cause injury or strandings in the process of studying them. Consequently, quite precautionary safety procedures, shut-down criteria, and monitoring before, during, and after experiments were used to ensure test subjects could be studied to get useful information but were not harmed. Additionally, a significant amount of effort was put into studying the baseline diving and foraging behavior or these amazing, extreme animals without sound exposure, so that any changes in these patterns resulting from sound exposure could be identified and statistically tested.



[photo credits: A. Friedlaender, obtained under U.S. NMFS permit # 1121-1900]

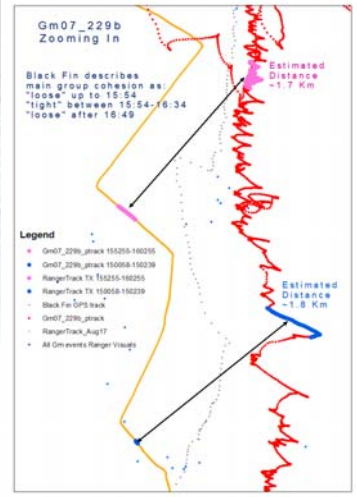
During the course of BRS 07-08, a total of 16 Dtags were attached to individuals of four species (short-finned pilot whales, Blainville's beaked whales, false killer whales, and melon-headed whales). In addition to a large amount of sighting and acoustic detection data and baseline diving behaviour, CEEs were conducted with various combination of simulated military, mid-frequency sonar sounds, killer whale calls, and "control" noises with a total of four pilot whales, two beaked whales, two false killer whales, and one melon-headed whale. During these exposure studies, the Dtags obtained interesting and important results about how the study animals behaved before sounds were played and how they reacted to them while they were on and afterwards. The figure to the right shows a dive record of a beaked whale with one deep dive before any sounds, a second dive with simulated sonar, a third dive with killer whale sounds, and two post-exposure "recovery" dives. Red symbols on the second and third dives indicate sound exposures in terms of the received sound level, or what would be perceived as "loudness", at the whale (units on right axis are underwater sound levels).

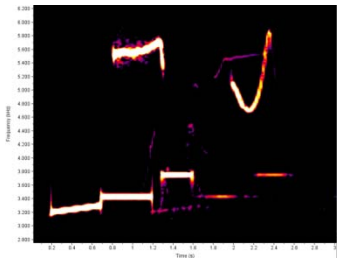




If we blow up the time axis of the first three of these dives to see them in greater detail (A, B, C in figure to right), there are clear differences in behavioural patterns before, during and after sound exposure. The animal came up sooner, made less clicking sounds associated with feeding (highlighted in blue), and returned to the surface slower and at a shallower angle during the exposure dives (B and C) than during the baseline dive before sound (A). If we look at the whole sequence in a plan view (D, as if looking down from high above the whole track of the animal over all dives), we can see the three deep dives highlighted in green and that, following the killer whale sound exposure the beaked whale swam essentially directly away from the site of the experiment for some 20 km until the Dtag detached around four in the morning.

In contrast to this kind of reaction, also generally seen in the other beaked whale CEE using a noise control sound, exposures to pilot whales and the other cetaceans tested yielded much less dramatic kinds of responses. These animals tended to make slight changes in orientation, vocal, and social behavior, but did not exhibit the clear and statistically significant changes in behavior seen in the beaked whales. The figure to the right shows one of the pilot whale CEEs and the track of the whales (in red) was not perceptibly altered during simulated sonar (in blue) and killer whale sounds (in pink), though some changes in social cohesion were observed. Interestingly, on some occasions, pilot whales actually appeared to respond vocally to the sounds played to them underwater, mimicking them as in the case of the figure to the left showing the simulated sonar signal (stepped, three-part tone) and a tone made just afterwards by the whale followed by a whistle.





The data from BRS 07-08 were quite significant in being the first direct measurements of responses of cetaceans, including beaked whales, to simulated

military, mid-frequency sonar signals like those involved in previous stranding events. Additionally, despite the concerns about possible negative impacts, important results (hinting at relatively stronger reactions in beaked whales relative to other species) were obtained without harming subject animals or others in the area (extensive post-monitoring was done and subjects were sighted later behaving normally). But the BRS results were limited in several ways. First, there were fewer CEEs than hoped for, simply because of the extreme limitations on the weather conditions required to do these studies (very calm seas). Second, the behavioral responses were measured in a place (the AUTEC range) where animals hear active sonars of some form or another on a fairly regular basis; their responses may well be different than those of animals who do not live on an active acoustic training and testing range. Additional studies were needed to identify whether the initial observations made in BRS were generally applicable in other circumstances, including in areas where active military sonars are used less regularly and subjects may be less used to them. The advances made in BRS were to come together with the extensive biological and acoustic studies from the Sirena cruises in MED -09.

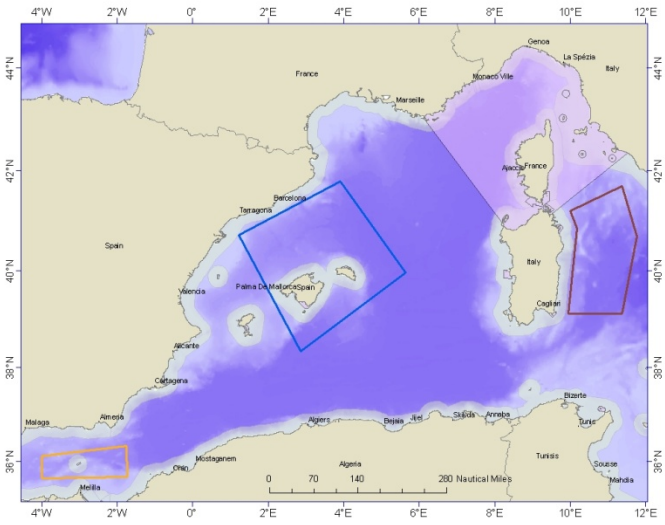
Goals of MED -09

MED -09 builds on the long history of biological studies in the Mediterranean Sea using the NRV *Alliance* with the CEE components of the BRS 07-08 studies in the Bahamas. MED -09 is designed with a number of specific goals, each consistent with the general objectives and recommendations of ACCOBAMS, including to:

- identify and improve the management of habitats that host sensitive species, such as beaked whales;
- map the range of doses of noise to which animals are normally exposed to in the Mediterranean Sea;
- test and improve passive acoustic monitoring tools and techniques for detecting beaked whales, either for mitigation and scientific research;
- develop and/or refine procedures to safely test responses of whales to sound;
- establish sound exposures required to evoke responses in different species; and
- provide a scientific basis for estimating risk and minimizing impact of sound-producing activities to navies and regulators

Timing and Operational Areas

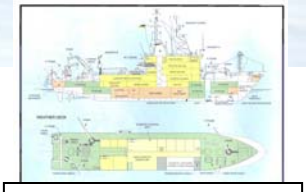
MED -09 will take place on the NRV *Alliance* from late July to early September in deep canyon-like areas in three primary operational areas shown here: around the Balearic Islands to the southeast of Spain (blue box); in the Alboran Sea south of Spain (gold box); and in the Tyrrhenian Sea to the west of the Italian mainland (red box). The NRV *Alliance* will transit through the Pelagos Marine Sanctuary (shaded area) at the beginning and end of the study, but no tagging or CEEs will take place there. The exact timing and location of the NRV *Alliance* during MED -09 will be determined largely by finding the right combinations of good weather and subject animals.



MED -09 Multidisciplinary Teams and Operational Modes

A complex and challenging study such as finding very deep-diving and difficult to detect species such as beaked whales, tracking them over a large area without the sophisticated acoustic range present at AUTEC in the Bahamas, and safely monitoring animals to conduct high-quality CEEs requires a specialized set of skills. MED -09 includes some highly experienced scientists and engineers, as well as some of the most state-of-the-art tools and technologies currently available. These assets are organized into specialized teams either on or deployed from the **NRV *Alliance***, each serving specific, inter-related functions.

Photo courtesy of NURC



Layout of NRV *Alliance*, courtesy: NURC

Visual observers are trained and experienced in sighting marine mammals up to several miles away using high-powered binoculars. They will search for marine mammals and, once they are identified

Visual observer during BRS-07

and tagged, visual observers will monitor target and any other marine mammals during CEEs.

Passive acoustic observers will use multiple different kinds of listening systems towed behind, draped off, or deployed around the NRV *Alliance* to detect vocalizing whales continuously day and night and to monitor sound exposures and animal responses during CEEs.

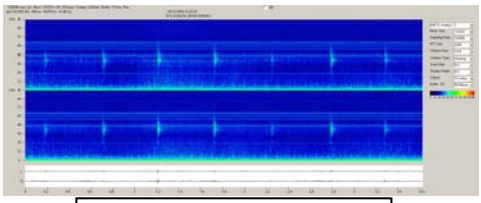


Image courtesy of G. Pavan, CIBRA

Photo identification will be used to catalog and keep track of individuals and groups sighted and involved in CEEs.

Tagging teams will carefully approach and deploy Dtags using non-invasive suction cups; tag teams will also provide visual monitoring of focal groups that have been tagged during baseline dives and CEEs and will report all behavioral observations.

Geographical Information Systems (GIS) engineers will integrate many different kinds of data, including the position of the NRV *Alliance* and small boats, visual sightings and acoustic localizations (or positioning) of animals, and environmental information, for real-time presentation on maps and synchronized archive of all MED-09 activities and measurements.

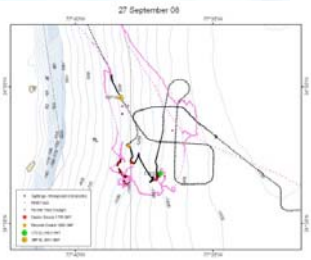


Figure from BRS -08 cruise report

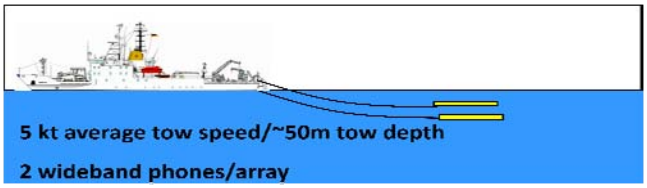
Photo courtesy of NURC

Sound source technicians will operate the specialized underwater speaker (on left before deployment) that will be used to play both artificial and biological sounds during CEEs.

MED -09 will operate in three operational "***modes***" depending on the timing in the study, weather conditions, and whether focal animal species are identified.

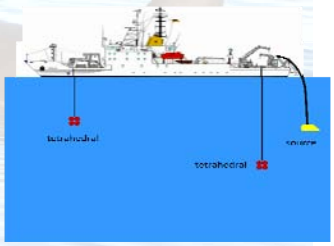
Transit mode involves getting from one operational area to another at cruising speed. Listening arrays of hydrophones will be used day and night for detecting marine mammals and contributing to sighting records. Visual observers will similarly monitor for

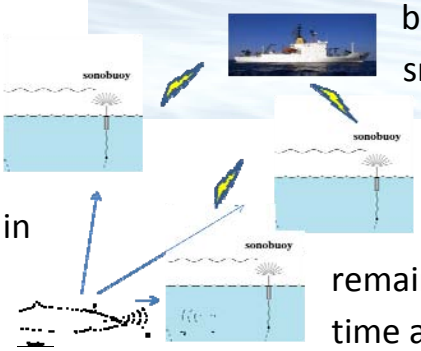
marine mammal presence during daylight hours when conditions permit. Simultaneous oceanographic data will be collected using a variety of sensors, including satellite remote sensing. However, no efforts will be made in transit mode to track or tag marine mammals or conduct CEEs.



During ***survey mode***, the NRV *Alliance* will follow specifically-designed track lines at slower speed in areas of presumed biological interest; multiple track options have been developed to account for variable weather and biological conditions that can be expected. Visual and acoustic surveys will be conducted and various oceanographic data will also be collected. If animals of interest are detected and conditions are appropriate, the NRV *Alliance* may break from survey mode to focus on specific groups.

In ***focal follow mode***, specific focal groups and/or individuals will be tracked and tagging teams will be deployed. Using specific criteria to ensure the safety of researchers and animals, photo identification and/or tagging efforts may be initiated. If successful and conditions permit, CEEs may be conducted in this mode according to very specific protocols. All visual observers on the NRV *Alliance* and small boats will be used during CEEs and all listening capabilities will be deployed. Because MED -09 will not have the luxury of a large listening array of hydrophones on the bottom that BRS 07-08 had, we will approximate this over a small area using directional hydrophones deployed from the NRV *Alliance* and an array of real-time sonobuoys deployed by small boats around the tagged whale that will be involved in the CEE. Focal animals will be followed for as long as Dtags remain attached and will be followed for a reasonable period of time afterwards, as conditions allow. After the baseline tagging or CEE is complete, the NRV *Alliance* will switch back from focal follow to survey and/or transit modes and rapid analysis of the Dtag data will be conducted to inform and/or modify subsequent efforts.





Safety and Stranding Procedures

The first priority with regard to safety is to ensure the health and well-being of scientists and crew involved in MED -09 and the safe operation of the NRV *Alliance*. Extensive standard operating procedures to ensure this priority are in place. MED -09 will operate in compliance with all relevant national and international laws, and has been coordinating with regional interests and agreements including ACCOBAMS during the planning (and will continue to do so during and following execution).

Photos courtesy of NURC

MED -09 also includes specific precautionary procedures to ensure the safety and well-being of marine mammals during the experiment. These include criteria for approaching and/or avoiding marine mammals (*e.g.*, avoiding any endangered species), safety measures and limits for close approaches and tagging of marine mammals from small boats, and specific conditions for initiating and shutting down sound transmissions during CEEs (*e.g.*, turning sound transmissions off when focal subjects cease vocalizing or when any animal is within 200 m of the sound source). Each of these safety procedures has been explicitly detailed and reviewed in applications for a U.S. NMFS scientific research permit (#14241 issued to P. Tyack) and the Institutional Animal Care and Use Committee at WHOI.

Finally, while there is very little reason to believe that MED -09 activities would result in marine mammal injuries or stranding events based on the safe and successful efforts in BRS 07-08, it is only responsible to have specific protocols in place if any are to occur. As noted, marine mammal stranding events have been observed in the Mediterranean Sea for hundreds of years and there is some likelihood of one being observed in the same general time and place as MED -09, even if there is no relationship between the research project and the stranding event. MED -09 has specific response contingencies in place to ensure the rapid detection and reporting of and any stranding event; regional coordinators will ensure effective communication with local marine mammal stranding networks. This will enable the project to:

(1) effectively respond in compliance with all applicable laws and policies;

(2) facilitate the response and investigation of any event and assess whether it was related to MED -09 activities or merely coincidental in the same general area; and

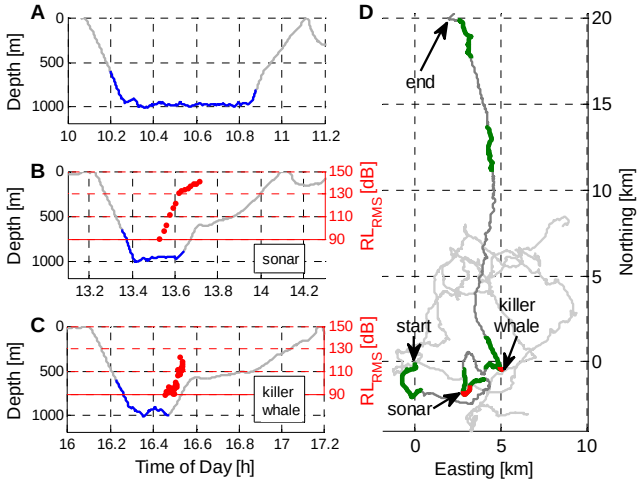
(3) determine whether and when to resume CEEs.

Scientific and Public Impact – Usefulness of Data

MED -09 is committed to the openness and transparency of the project and to the timely and effective transmission of results. The underlying issues, how sound and specifically military sonar signals affect marine mammals including apparently sensitive species such as beaked whales, are timely and controversial issues. And while the underlying methods of controlled sound exposures are well-established in biology and behavioral ecology, some concerns have been expressed about their use in these conditions related to animal welfare. Open discussions, both in public meetings and through exchange of questions and responses, with conservation interests and other scientists has been a healthy and constructive aspect of the planning of MED -09. While there may still be some differences of opinion regarding the best manner of obtaining information to inform conservation management related to human sound, open dialog and transparency in planning and reporting of results is essential.

[photo credit: A. Friedlaender, obtained under U.S. NMFS permit # 1121-1900]

The scientific results that are expected to be generated by MED -09 will contribute to a greater understanding of the biological and oceanographic features of several important areas in the western Mediterranean Sea, particularly regarding whales and dolphins. These data will contribute to, for instance, habitat models to predict where certain species such as beaked whales may occur during different seasons. They will also be made available to local and regional government, conservation, and educational organizations to increase public awareness and appreciation of these valuable areas and species. Additionally, the tagging and CEE results will provide urgently needed



information regarding the baseline behavior of several poorly-known species and how they respond to human sounds. The results will be integrated into the ongoing, international research effort, involving some observational measures around real sonar operations and other directed controlled studies, to understand behavioral responses of marine mammals to sound. The MED -09 results will be provided directly to regulatory and sound-producing organizations internationally and will be made available through scientific presentations and publications in a timely and efficient manner, and through various other public outlets (such as ACCOBAMS) to maximize their utility and impact.

Biological and Behavioral Studies of Marine Mammals in the western Mediterranean Sea ("MED -09")
~ Frequently Asked Questions ~

How will MED -09 contribute to our understanding of the Mediterranean Sea?

Answer: This project will cover thousands of miles of the western Mediterranean Sea with sophisticated oceanographic, acoustic, and visual sensors integrating environmental and biological data. The resulting information will be integrated with previous work of ACCOBAMS and the Sirena cruises and other efforts to expand marine mammal sighting databases and inform predictive habitat models of these biologically important areas.

How can MED -09 identify an appropriate response in real-time to cease CEEs?

Answer: BRS 07-08 identified that when focal animals stop producing echolocation clicks associated with feeding/navigation, it is a reliable indicator of a change in behavior that appears significant but not harmful. MED -09 seeks only to identify the onset of significant behavioral responses rather than more severe reactions that may occur if exposures were sustained or modified. MED -09 will use the same criterion as BRS in terminating CEEs upon identification of focal animals ceasing echolocation clicks.

Without the listening array used in the BRS 07-08 studies, how will MED -09 locate marine mammals acoustically and monitor their responses during CEEs?

Answer: MED -09 will not have the benefit of a real-time wired array covering hundreds of square miles like at AUTEC, but will replicate this capability over a relatively small area around focal animals using a combination of towed hydrophones, directional "bearing" arrays of sensors, and real-time sonobuoys.

Will MED -09 provide definitive answers regarding military sonar and marine mammals?

Answer: Amazingly little is known directly about this issue and MED -09 will contribute to the initial findings made in BRS 07-08. It will be part of a multi-disciplinary, inter-related paradigm of opportunistic and experimental studies to measure how these

animals respond and the exposures required to elicit these responses; the ultimate goal of this overall program is to reduce uncertainty about how and why animals respond to certain sounds and how to minimize negative, unintended effects. Additional studies will be needed, including at some point the use of realistic sound sources in more controlled ways to measure responses directly, but these must be informed by lower-level exposures such as will be used in MED -09.

Why can't the data on marine mammal responses to sonar simply be obtained by tagging marine mammals around on-going military training operations?

Answer: The opportunistic kinds of measurements are ongoing in several areas, including at AUTEC in the Bahamas. They provide useful information, largely because they involve real sources rather than scaled-down exposures through speakers. They are limited, however, in lacking control over the type and kind of exposure on a focal animal and it is very difficult to use more sophisticated acoustic tags like Dtags to measure acoustic dose and behavioral responses in these settings. Both approaches (opportunistically around real operations and experimentally as in BRS 07-08 and MED -09) are useful complements of one another. Eventually, these approaches may converge on one another with controlled exposures using realistic sources.

Will MED -09 results be limited in some way because of small sample size?

Answer: Yes. This kind of work is extremely difficult to conduct – beaked whales are arguably the most difficult large mammals on the planet to study – and limited number of subjects is always an issue in these kinds of studies. While caution must be taken in interpreting results from small numbers of samples, the BRS data have shown that even limited new information can radically improve our ability to understand the situation compared to the utter void of knowledge that existed previously.