Biological and Behavioral Response Studies in the Bahamas in 2007-2008 (BRS-07/08)

~ Project Summary ~

~ A Behavioral Response Study in 2007 &2008 (BRS-07/08) was conducted in the Bahamas to study diving behavior and sound production in beaked whales and other marine mammals, including how animals may change their behavior when they hear different sounds. ~

~ Marine mammals face many challenges from human interactions, including overfishing, entanglement, vessel strikes and disturbance from human sounds. Most of these problems are poorly understood; better science is needed to manage and protect marine animals. ~

~ BRS 07/08 included an international collaboration of specialists in marine mammal distribution, diving, and behavior, as well as experts in using underwater sound to find and monitor marine mammals on a specialized U.S. Navy listening range. Controlled exposure experiments to various sounds were carefully conducted to study behavioral responses. ~

~ This was the first controlled study of marine mammal responses to sounds including simulated military sonar and it was conducted safely while yielding important results. Results from the project, when integrated with those from other studies, suggest that beaked whales respond more strongly and at lower sound levels than other marine mammals tested ~

Additional information about BRS 07/08 is available at:

http://www.sea-inc.net/science/#brs

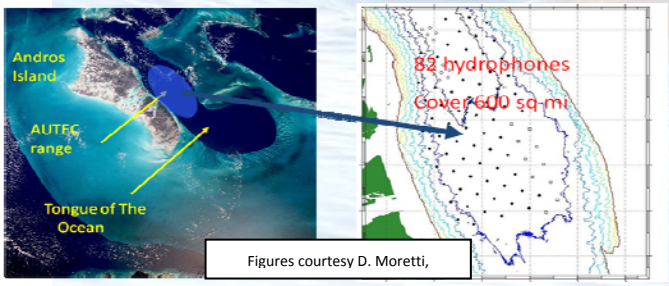
[photo credits: A. Friedlaender, obtained under U.S. NMFS permit #1121-1900]

BRS-07/08 Methods, Results, and Implications

During 2007 and 2008, a marine mammal Behavioral Response Study (called "BRS 07-08") took place in the Bahamas with an international collaboration of inter-disciplinary researchers. Using techniques and tools from related research projects in the Canary Islands, Mediterranean Sea, and various places in the U.S., a specialized, inter-disciplinary team of scientists used specialized acoustic listening and movement sensors[1] attached to marine mammals using suction cups to measure the behavior of four cetacean species (including beaked whales, pilot whales, false killer whales, and melon-headed whales), including how they reacted 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 and other cetaceans 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 exposure experiments (CEEs) to investigate whether and how different species respond to human sounds were possible.

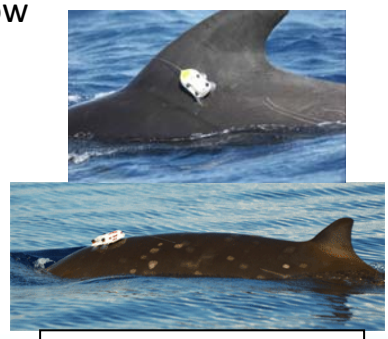


Figures courtesy D. Moretti,

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.

[1] called digital acoustic tags, or "Dtags", developed by Woods Hole Oceanographic Institution

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.



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

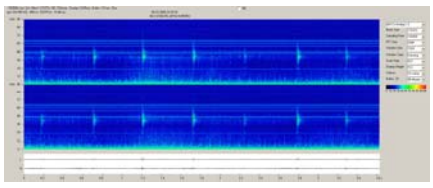
Consequently, precautionary safety procedures, shut-down criteria, and monitoring before, during, and after CEEs were used to ensure test subjects could be studied to get useful information but were not harmed. Additionally, a significant amount of effort was put into studying the baseline diving and 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.

BRS 07/08 included expert marine mammal observers, scientists, and engineers, as well as state-of-the-art tools and technologies to tag and track marine mammals and carefully and safely conduct CEEs. These assets were organized into specialized teams, each serving specific, inter-related functions.

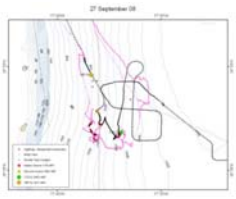
Visual observers were experienced in sighting marine mammals up to several miles away with powerful binoculars. They searched for subjects and, once tagged, monitored animals during CEEs.

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

Passive acoustic observers used different listening systems, primarily the U.S. Navy AUTEC range hydrophones, to detect vocalizing animals and monitor sound exposures and animal responses during CEEs.



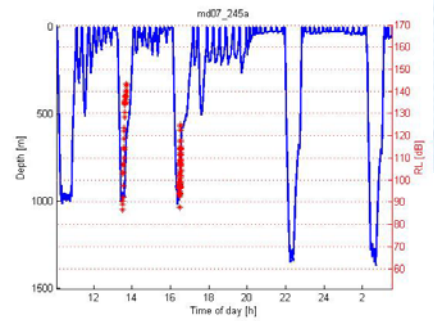
Tagging teams carefully approached marine mammals and deployed DTags with non-invasive suction cups; tag teams also provided visual monitoring of focal groups during baseline dives and CEEs and reported all behavioral observations.

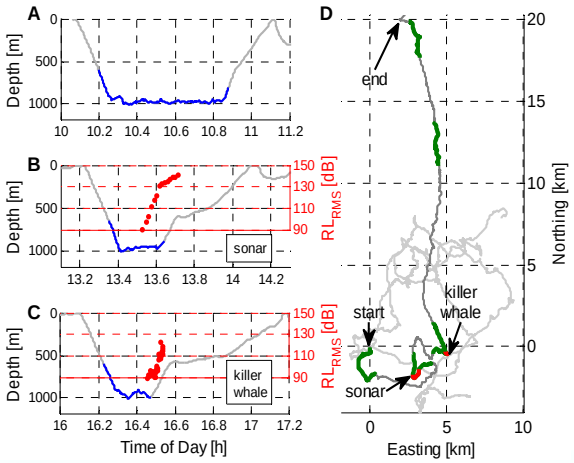


Geographical Information Systems (GIS) engineers integrated information, including vessel position, visual sightings, and environmental data, for real-time presentation on maps and to develop time-synchronized, geospatial archive of all activities.

Sound source technicians operated the specialized underwater speakers used to project experimental sounds during CEEs, controlling signals being projected.

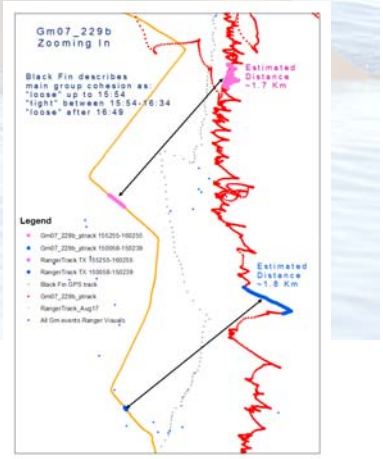
During the course of BRS 07-08, a total of 16 Dtags were attached to individuals of the four focal species. In addition to a large amount of sighting and acoustic detection data and baseline diving behaviour, CEEs were conducted with various combination of simulated military, mid-frequency sonar sounds, 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).

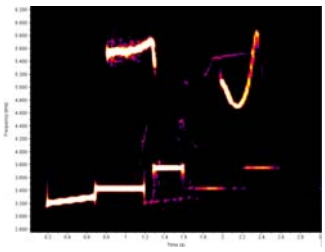




If we blow up the time axis of the first three of these dives to see them in greater detail (A, B, C in figure to right), there are clear differences in behavioural patterns before, during and after sound exposure. The animal came up sooner, made less clicking sounds associated with feeding (highlighted 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, false killer 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 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).

The results, when integrated with recent data from other related studies, suggest that beaked whales may be particularly sensitive to sound exposure. Beaked whales showed consistent disruption of behavior to each artificial sound type at considerably lower levels than pilot whales and other cetaceans. A beaked whale subject also showed sustained avoidance following killer whale sounds whereas other species exhibited social defense responses, suggesting that anti-predator behavior could be a risk factor for strandings. These data provide timely and relevant direct measurements for use by conservation managers and operational military planning regarding the potential impacts of sonar signals on beaked whales and other marine mammals.

However, the results from the Bahamas were limited in the number of CEEs that were obtained, simply because of the extreme limitations on the weather conditions required to do these studies (very calm seas). Additional studies clearly remain needed to identify whether the initial observations made in BRS were generally applicable in other circumstances, and to extend these studies to previously untested marine mammal species, such as the large baleen whales and seals/sea lions. A follow-on study was conducted in the Mediterranean Sea in 2009[2] and a related multi-year study will begin in southern California in the summer of 2010[3].

[2] See: http://med09-expedition.blogspot.com/

[3] See: http://www.sea-inc.net/SOCAL10