The head and back of a male dense-beaked whale.
Ari Friedlaender

Principal Investigator for the Navy's Marine Mammal Monitoring Program Outlines Priorities & Projects

SHARING THE SPOTLIGHT for this issue of *Currents* is Dave Moretti, of the Naval Undersea Warfare Center (NUWC) in Newport, RI. Mr. Moretti is the principal investigator for the Marine Mammal Monitoring on Navy Ranges program sponsored by the Chief of Naval Operations Environmental Readiness Division (CNO N45). The focus for this spotlight interview is a study of whale activity in relation to sonar that's being conducted at the Atlantic Undersea Test and Evaluation Center (AUTEC) in the Bahamas.

Tracey Moriarty, N45's Director of Environmental Outreach and Information, conducted this interview on 15 May 2009 during a visit to the AUTEC range. Mr. Moretti modified the original interview transcript to reflect updated information about his research efforts subsequent to that original interview.

CURRENTS: Good morning Dave. Thanks for speaking with us today. Could you provide us an overview on the study you're involved with and its goals?

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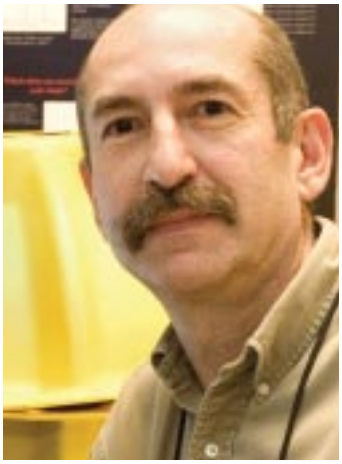

DAVE MORETTI: Yes, what we're attempting to do is use the infrastructure of the Navy ranges that have sensors on the ocean bottom to monitor marine mammals in situ and study their behavior with and without the presence of Navy sonar. We're interested in the overall behavior of these animals juxtaposed against Navy sonar given that these animals have been associated with some stranding events in the past, in particular one in the Northwest Providence Channel in the year 2000.

CURRENTS: You're speaking of the incident in the Bahamas when 17 beaked whales stranded themselves near naval exercises.

MORETTI: Yes. And since that stranding in particular, there's been the perception that sonar is a sort of "death ray." The notion is that these animals when exposed to sonar will immediately be injured or die.

One thing that we do know is that there appears to be a population of these animals at the AUTEC range at densities far higher than anyone anticipated which is counter-intuitive given the perception of sonar and beaked whales. Given that this is an active Navy range where sonar is used, you wouldn't anticipate these species, especially beaked whales, present here if you believe the popular press. It's a good sign that they are here, and it's also a great opportunity to study these animals and their reaction to sonar.

CURRENTS: Are beaked whales the most plentiful species in this area?

MORETTI: There are about 20 species of beaked whales, and we've done a

The Basics About AUTEC

THE ATLANTIC UNDERSEA Test and Evaluation Center (AUTEC), located on Andros Island, Bahamas, provides the Navy with an ideal environment for researching, testing and developing maritime weaponry. "AUTEC serves the United States and our allies in support of Anti-Submarine Warfare, Anti-Surface Warfare, and Overseas Contingency Operations missions," states Harriet Coleman, head of AUTEC's Ranges, Engineering and Analysis Department. "We understand the importance of testing and evaluation and pride ourselves on the accuracy of our data."

AUTEC's Bahamas location, with its semi-tropical climate, quiet acoustic environment, lack of commercial encroachment and extensive capabilities make it an ideal year-round test facility. The location was chosen because of its close proximity to The Tongue of the Ocean (TOTO), a unique, deep water basin, approximately 110 nautical miles long and 20 nautical miles wide, varying in depth from 4,500 to 6,000 feet. The basin floor is relatively smooth and soft, with very gradual depth changes. TOTO is bounded on the west by Andros Island; on the south and east by large areas of shallow, non-navigable banks; and on the north by the Berry Islands. The gradually varying depths of the Berry Islands area make it a particularly suitable location for littoral (close to shore) warfare training exercises. AUTEC also has a second testing facility off the east coast of Florida.

For more information about AUTEC, visit www.globalsecurity.org/military/facility/autec.htm.

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lot of work to identify what species are here. We know that the Blaineville's beaked whale is found on range, which is one of the two species involved in stranding episodes. To a lesser degree, we detect the Cuvier's beaked whale, which is believed to be the most sensitive whale to Navy sonar. Most recently, the Gervais' beaked whale has been detected acoustically and verified by Charlotte Dunn at the Bahamas Marine Mammal Research Organisation (BMMRO).

CURRENTS: The 2000 stranding event took place about 40 miles north of the AUTEC ranges. Why aren't the animals on AUTEC stranding?

MORETTI: It's an interesting question. Given the popular presumption of the reaction of beaked whales to sonar, you wouldn't anticipate finding a population of beaked whales on a weapons range in the Tongue of the Ocean,

when 50 miles north there was a mass stranding event in the year 2000. So one of the questions we have to ask is, "Why did that stranding event occur?"—especially since we haven't seen any mass strandings here (in the Tongue of the Ocean). One of the differences we've considered is the overall size of the range. Although it's 500 square nautical miles, it's relatively small as compared to the overall dimensions of the operations that took place in the Northwest Providence Channel—operations that, by the way, have never been repeated since that 2000 stranding. The AUTEC range is narrower than the Northwest Providence Channel and the overall size is smaller.

Three dense-beaked whales surfacing in front of the AUTEC range vessel Ranger, AUTEC range, Bahamas.
Ari Friedlaender

You wouldn't anticipate finding a population of beaked whales on a weapons range.

Secondly, if you look at operations on range, one of the things that has been postulated is that animals here are "habituated," where animals in the Northwest were naïve. And without doing the long-term tagging of the animals and getting a handle on what their range is, it's very difficult to say whether that's true or not. It may be that the animals that we're seeing in the Tongue of the Ocean move back and forth from the Northwest Providence Channel or they may be residents of the Tongue of the Ocean and they never go out. We just don't know.

The second thing that seems plausible is that if you look at the distance over which ships move during an operation on the AUTEC facility, it's quite a bit smaller than the Northwest Providence Channel. During range operations, ships are confined within the range boundaries. If the animals move off the range in response to the operation, there is little chance of ships inadvertently following behind.

One of the things that was striking in the Northwest Providence Channel, was that the ships started on the east coast and moved through the channel in a westerly direction. But the distance that they covered was significantly larger than the size of the weapons range, roughly four times the distance traveled. So one of the theories that has been postulated is that the animals get out in front of the ships and because of the narrow canyon-like environment, they don't have a way to avoid the ships. The animals may get pushed ahead of oncoming ships with their active sonar engaged.

But again, we really don't know. This is what we're trying to understand. Our methodology has been to study animal movements during these operations on the range and extend that study to include long-term tracking of animals so that we get some notion of their overall range of motion. Perhaps that will help us understand the differences between operations at AUTEC as opposed to what occurred in the Northwest Providence Channel.

David Frome at the Naval Research Laboratory completed a thorough investigation of the acoustics in the Northwest Providence Channel. But if you look at the acoustic propagation in the Northwest Providence Channel and in the Tongue of the Ocean, chances are there are times of the year when they are quite similar. So I'm not sure that acoustic propagation is the difference. At the moment, I can't give you a definitive answer about why the animals at AUTEC aren't stranding. We really don't know. It's one of those puzzles that remain unsolved and something we're actively studying.

CURRENTS: How do you know when there are Naval ships in the area?

MORETTI: Our displays allow us to track ships on range that are equipped with standard U.S. Coast Guard Automatic Identification System (AIS) beacons. However, for Navy operations, the range has very precise ship tracks so that during an operation they know where the ships are at all times—both surface and sub-surface vessels. After the operation, the range has provided ship track data which we are able to combine with marine mammal detection data. Marrying these data sets allows us to better understand how animals react to both the sounds that the ships produce and the movement of the ships themselves.

CURRENTS: Can you describe the different instruments you're using in this study?

MORETTI: The instrumentation we're using includes hydrophones—or underwater microphones—that were installed in the Tongue of the Ocean in the Bahamas to aid in the test and evaluation of undersea vehicles. (See our sidebar entitled, "Satellite Tracking of Whales.") Typically, the Navy will place a "pinger" on an undersea vehicle that emits a known signal at a known repetition rate. The ping is received on multiple hydrophones, detected, and precisely time-tagged, and these data are used to determine the vehicle's position.

We've tried to adapt this technology for the study of marine mammals using passive acoustics, which basically means we listen for vocalizations from the animals. Different animals have different vocalizations, and over the years we've been able to send out trained observers in an attempt to associate these vocalizations with particular species. We've also worked in collaboration with a number of

Satellite Tracking of Whales

UNLIKE THE DIGITAL tags (D-TAGs) used previously in the BRS, the new satellite tags are intended to track a whale's movements. In May 2009, the first batch of these tags was deployed on three species of whales in the AUTEC range.

One of the principal research scientists on the project, John Durban, reported particular success in following one whale before and during AUTEC exercises. "It didn't move very much in the week prior to the exercise," Durban commented. After exercises commenced, "it appears the whale moved a bit further north; away from the range," he said. "It's possible that it's a reaction to exercises that are going on." However, Durban cautioned that it is too early to draw conclusions. "It's very hard to know what one whale is responding to. These tags don't have acoustic capability."

The new tags send a signal to a satellite and the satellite triangulates where the whale is. One thing this tracking system will do it to help explain the mystery of why whales are "going quiet" during exercises. "There are a couple of alternative hypothesizes to explain this: one is that the whales are moving off the range; the other is that they're staying but not foraging using their echolocation," Durban said. "Hopefully this tag will allow us to test between these."

Durban, a research biologist from the Center for Whale Research in Washington State, is working under contract with the National Oceanic and Atmospheric Administration. He has been conducting research on marine mammals for 16 years. Much of his career has been spent working alongside the BMMRO, but working with the Navy is still relatively new to him. "The ability to work on the range with the undersea warfare unit and to have access to real time acoustic detection of beaked whales is invaluable," Durban says. "These guys are really great at directing us to whales. That makes our work that much more efficient."

Durban holds a Ph.D. in Zoology from the University of Aberdeen (UK), and has authored more than 20 research papers on published more than 20 papers on research topics such as the population ecology of killer whales, bottlenose dolphins, right whales and harbor seals, as well as novel techniques for data collection and new statistical approaches for data analysis.

To learn more about NOAA's research involving marine mammals, visit http://swfsc.noaa.gov and click on "research" and "marine mammals."

For more about The Center for Whale Research, visit www.whaleresearch.com.

different scientists at various institutions, including Peter Tyack and Mark Johnson from Woods Hole Oceanographic Institution. They've developed a new recording tag that's attached to animals with suction cups. It records animal vocalizations, along with pitch, roll, depth and heading; which helps reveal their swimming and diving and vocal patterns. Peter [Tyack] and Mark [Johnson] have provided us with clips—different recordings for different animals—that have allowed us to program our equipment for particular species including beaked whales.

We've also worked directly with the BMMRO, which is headed by Diane Claridge. (For more information about the BMMRO, see our sidebar.) They're particularly versed in the different species of animals that reside in the Bahamas. They've been the primary observers on our tests here on the AUTEC range. Under a typical scenario, we use the sensors and hardware and algorithms to localize the animals, then Diane and company will go out and try to find the animal on the surface and identify the species. This gives us the ability to associate the animal with the particular vocalization. By doing that over a number of tests, what we've been able to do is come up with methodologies and tools—both software and hardware—to monitor animals and understand their location both in time and space.

By associating vocalizations with behaviors, we can start to say something about things like foraging behavior especially for beaked whales. We know from the data that Peter [Tyack] and Mark [Johnson] are getting from the tags on beaked whales that they're very deep diving cetaceans. They dive in excess of 1,000 meters.

Every couple of hours they'll execute a deep foraging dive. It's quite fantastic actually. They'll hold their breath for an

The Bahamas Marine Mammal Research Organisation

THE BAHAMAS MARINE Mammal Research Organisation (BMMRO) was founded in 1991 for the purpose of describing the distribution and habitat use of different marine mammal species. "The ultimate purpose of the organisation is to promote the conservation of these species and their habitats," states Diane Claridge, BMMRO's director. A native Bahamian, Claridge has been with BMMRO since its founding.

"We use systematic boat-based surveys for describing the distribution and habitat use of marine mammals," states Claridge, who serves as a field biologist as well as the BMMRO's director. "We use photo identification techniques to investigate patterns of distribution, residency and social structure," she says. The goal is to help assess the whales' vulnerability to noise derived from human activity.

The most unique among the beaked whale species is the Blainville's beaked whale. "This species is the only one of its kind worldwide," Claridge states. The team has identified 165 individuals from over 9,000 photographs taken over the last 11 years.

"We're really on the cusp of what we're going to learn," she says, "because we're just getting into the analysis of all the survey data. We have genetic analysis just starting too. It will be really exciting to see how the beaked whales of the canyon are related to whales elsewhere."

Claridge holds a Master's in Zoology and is completing her Ph.D. in Biology. In addition to being the BMMRO's director, she works as a field researcher, and is the co-principal investigator on the Behavioral Response Study.

For more information about BMMRO, visit www.bahamaswhales.org.

hour and dive to these great depths. And they'll stay at these depths foraging in excess of 30 minutes. Because they only vocalize during foraging, that's when we hear them. So whenever we hear them, we know they're foraging and that they're in deep water.

By monitoring these animals over the entire range, we get an idea of their distribution in time and space, and we can tell when they're foraging. That's the overall goal and objective of the program—to know where the whales are and what their behaviors are when there is no sonar present. So we can compare this to what happens during active sonar operations and afterwards.

CURRENTS: What are the benefits to having this collaborative relationship with other organizations?

Every couple of hours they'll execute a deep foraging dive. It's quite fantastic actually. They'll hold their breath for an hour.

MORETTI: NUWC's core expertise is in acoustics signal processing, which means we develop the systems for detecting and analyzing signals as they travel underwater. In trying to apply acoustic signal processing to the study of marine mammals, we benefit greatly from the expertise of researchers such as Diane Claridge and Charlotte Dunn at the BMMRO, Peter Tyack and Mark Johnson at Woods Hole, Ian Boyd at the University of St. Andrews, John Hildebrand at Scripps, and Chris Clark at Cornell to name a few. We need a collaborative team with expertise in different areas, all of which are necessary to provide a cohesive understanding of the biology of these animals, and the reaction of these animals to sonar.

Diane [Claridge] and the BMMRO have been able to identify species at the surface after we'd detected them on our equipment. They've actually gone beyond that by taking photos of individual whales. Diane can tell the animals apart based on photo identification. By running these tests over and over again, we begin to assemble a catalogue of animals that are present. Diane can then do different types of studies that will allow her to understand whether they are residents or whether they migrate. No one really knows for sure.

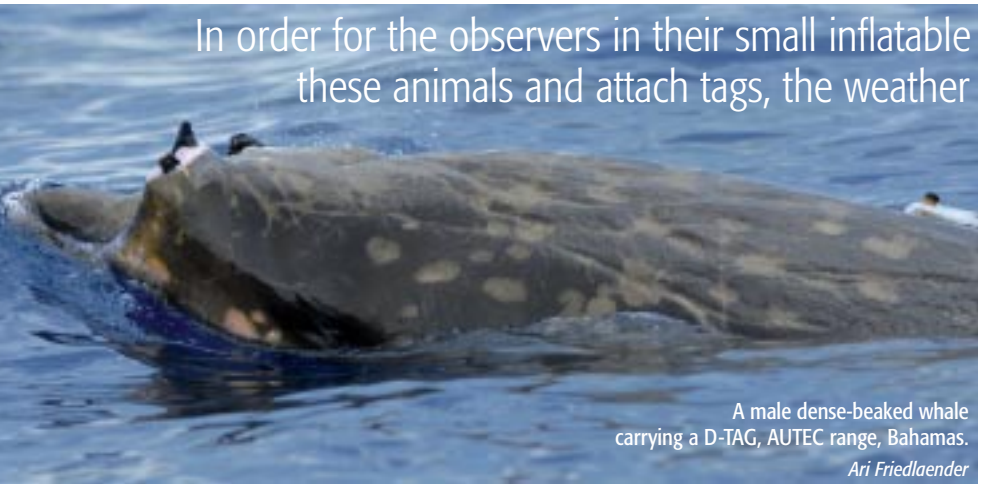
CURRENTS: Can we talk about what animals have been tagged so far? And what kind of information have you been able to gather from them?

MORETTI: Well, first of all, the process of tagging a whale is difficult because it's extremely weather-dependent. In order for the observers in their small inflatable boats to approach these animals and attach tags, the weather conditions have to be ideal. Basically the winds have to be very low and the seas have to be very flat, especially for beaked whales. When they come to the surface, they have a very small profile and spend only minutes above water. So the observers have to be able to find the animals and attach a tag in a very short period of time.

A short-finned pilot whale (*Globicephala macrorhynchus*) mother and calf seen on the AUTEC range.
BMMRO

The "D-Tag", or digital tag, I mentioned earlier gives us a lot of information. In addition to movement, it records sound on a pair of hydrophones. But the tag only stays on for about 19 hours. It's a phenomenal device. Mark Johnson designed it. It's helped immeasurably with the passive acoustics and was an integral part in playback experiments known as the Behavioral Response Study (BRS), the first two phases of which were conducted at AUTEC in 2007 and 2008. That was a collaborative effort that included a number of organizations. We were joined by teams led by Chris Clark from Cornell University, Ian Boyd who heads the Sea Mammal Research Unit at St. Andrews, Peter Tyack at Woods Hole, Angela D'Amico from the Space and Naval Warfare Systems Command, Diane Claridge at BMMRO, and Clay Spikes from Marine Acoustic among others.

That study involved putting the D-Tag on an animal, playing back a particular sound, and recording an animal's



A male dense-beaked whale carrying a D-TAG, AUTEC range, Bahamas.
Ari Friedlaender

In order for the observers in their small inflatable boats to approach these animals and attach tags, the weather conditions have to be ideal.

response. For instance, in 2007, we did a playback study on a Blaineville's beaked whale. During a deep foraging dive, we played a sonar-like signal through the D-Tag. When exposed to the signal, the animal foraged for a time, but then appeared to break off. It ascended to approximately 600 meters, stopped, then moved a significant distance away from the source vessel before surfacing. The animal remained in the area, and about two hours later went on another deep foraging dive. It was then exposed to a playback of orca calls. The animal stopped foraging as soon as the sound was discernable above background noise. It again ascended to the same 600-meter depth, stopped, and again continued to ascend slowly even further from the source vessel. However, upon surfacing, it moved in a straight path north and didn't forage again for nearly four hours, which, based on tag data, is highly unusual.

Because the sonar effect and orca calls were played on successive dives, it is impossible to definitively separate the effect of one from the other.

In 2008, another animal was tagged, but this time during its deep foraging dive it was exposed to a pseudo-random noise signal which featured the same time and frequency characteristics as the sonar signal but sounded nothing like it. As with the sonar-like signal, the animal broke off its foraging dive, ascended slowly to around 600 meters and paused. At this time the tag fell off, but the animal was acquired visually on the surface at a distance from the ship. From the tag and visual data, it appeared that its reaction was similar to that of the year before, suggesting that these animals react to loud sounds regardless of their structure.

The data from these tests, though interesting, are somewhat limited. There is much that we still do not know. For example, it may be that context is important. It is hard to know if for instance the position or movement of the source ship is important.

What the D-Tag doesn't reveal is the range of motion of the animal. The question that we're trying to answer now is, "Do these animals move off range during our operations?"

Marine Mammal Research and the Navy

THE NAVY HAS done more to fund marine mammal research than any other organization in the world over the last five years. For more about the Navy's work in marine mammal research including the use of D-Tags and their role in tracking the movement of marine mammals, see our story entitled "Navy Leads the Way in Marine Mammal Science: Continuing Investments Will Aid Decision Making, Protect Ocean Life" in the winter 2009 issue of *Currents*. You can browse the *Currents* archive and find a digital version of the magazine at the Naval Air Systems Command's environmental web site at www.enviro-navair.navy.mil/currents.

We believe they avoid the sonar and actually move off the range then return after operations are over. We have opportunistic data based on acoustics that strongly supports this theory. But once the animals are off the sensors we really don't know where they go. I can't say definitively that the animals that leave the range are actually the same animals that come back.

We have started using satellite tracking tags which have a longer duration—these tags will last upwards of four months. We are working to tag and track animals with John Durban and Bob Pittman from the National Oceanic and Atmospheric Administration (NOAA) on the AUTEC range, and Greg Shorr and Erin Falcone from Cascadia Research on the west coast. We had a tag that stayed on a Cuvier's beaked whale on the west coast for 121 days. So what we're hoping to do is put these tags on animals that will give us some information on the extent of their movements, both with and without sonar.

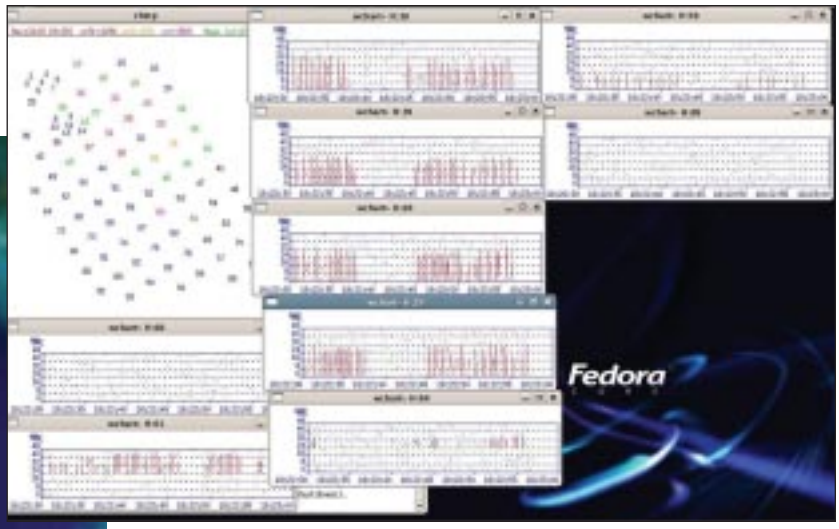
Unlike the suction cup tags, these tracking tags are applied with a dart that is shot into the dorsal fin of the animal. The tag is pretty small so all it provides is position via satellite. To date, three tags have been placed on beaked whales in the Northwest Providence Channel—two were on Blaineville's beaked whales and one is on a Cuvier's beaked whale. Currently in the Tongue of the Ocean, there is a Blaineville's beaked whale which is continuing to provide data. We're hoping it will stay on through the course of an active sonar exercise, which is about to happen in a couple of days. [NOTE: The tagged whale provided data through an active sonar operation and for nearly two weeks afterward. As of November 2009, there were tags on five pilot whales in the Bahamas.]

CURRENTS: Have you come up with any conclusions regarding which animals are residents of the area?

MORETTI: We think these beaked whales are resident but until we complete these studies and get enough data, it's hard to make a definitive statement. The same is true of sperm whales that we see at AUTEC, typically every few weeks when we're here. They seem to come and go within the Tongue of the Ocean. We think they're probably resident within the Bahamas covering a larger territory than beaked whales but we don't know for sure. Again that's where things like the photo identification work that Diane [Claridge] is doing come into play.

CURRENTS: We're looking at some images of computer screens right now that display data from some of the hydrophones. Can you describe what we're looking at?

MORETTI: Sure. There are 91 hydrophones on the range, spaced about two miles apart. We monitor their signals, as they're cabled to shore, with the M3R signal processor. The processor attempts to delineate signals from different animals including clicks from sperm whales or beaked whales and whistles from different types of dolphins. Once we get precise time of detection (on the order of



ABOVE: These graphic displays show information picked up by AUTEC hydrophones. Each chart represents the echolocation clicks recorded by an individual whale.

LEFT: This map shows the M3R localization display. The numbers represent the range sensors, and the red and blue whale icons represent localizations of marine mammal vocalizations.

milliseconds) we can use the data to try to localize the animal. So what we typically look at on our display is a map of the hydrophones, numbered 1 to 91. Then we color the phones based on the number of detections we're receiving at any one time. From there, we're able to click on a particular hydrophone and that will pull up a display that gives us a graphic view of the frequency versus time for a particular hydrophone. Often times, at least in the world of passive acoustics and marine mammals, people prefer to look in frequency versus time because it gives you an indication of the type of signal the animal is producing. So our displays revolve around that concept.

The processor attempts to delineate signals from different animals including clicks from sperm whales or beaked whales and whistles from different types of dolphins.

Many of the displays here were designed and implemented by my colleague Ron Morrissey along with Nancy DiMarzio and Susan Jarvis,. They give us the ability to monitor in real-time a 500-square mile nautical area, and if an animal is present and vocalizing, detect that animal and graphically view the nature of the call. It turns out that with practice you can start to associate the call type with the particular species. At the same time, we've also been developing a classifier tool that will automatically associate call type with species type.

If we're able to localize an animal, we'll put a dot on a screen in a Google Earth display that allows us to track the distribution of individual animals in real time. Today we were trying to put tags on sperm whales. Our passive acoustics tracked the whales during their deep foraging dives, and Diane [Claridge] and company boarded observer boats and took positions where we expected them to surface. And that's basically what happened today. Unfortunately because of the weather, they haven't been able to get tags on animals but they've been following animals for the course of the day.

CURRENTS: What are your next steps?

MORETTI: There are several things that are happening right now. First, we're going to continue the work we're doing at AUTEC. This particular test was intended as a first step—a starting point for us to develop the methodologies

A pantropical spotted dolphin (*Stenella attenuata*) leaps out of the water at AUTEC. *BMMRO*

that will allow us to attach tags and monitor these animals over a longer period of time. But we really need to affix a greater number of tags so we have a large enough set of data with sufficient statistical power to say something meaningful about the movement of these animals once they move off our sensors. Once they move off our sensors, we can't hear the animals and we don't know where they're going or what they're doing.

We need to have a sufficient number of whales tagged so that we can say something meaningful about their movements relative to the sonar.

Out on the west coast, we're doing similar tests on the Southern California Offshore Range (SCORE). We're trying to use our signal processing expertise combined with the skills of our west coast collaborators to understand the animals in their environment—to study them both with and without sonar. We work very closely with Cascadia Research, headed by John Calambokidis. They serve as primary marine mammal observers on SCORE when we do these kinds of tests. In addition, we're working closely with John Hildebrand from the Scripps Institute of Oceanography, who has spent years studying vocalizations and historical acoustics for animals on the west coast. There's a

different set of species present on the west coast that you don't see here and their expertise has been invaluable.

CURRENTS: What other work is being done out there? Or elsewhere?

MORETTI: The folks at Cascadia are doing the same thing as Diane [Claridge] and the BMMRO are doing at AUTEC. They're creating a phone identification catalogue of the animals—studying their calving rates and understanding their social behaviors. And if we can combine these data with data we're providing about things like animal motion relative to sound sources, we'll begin to understand the health of the population long-term. We need to imbed within the facilities the capability to monitor these animals over the long-term so that we have data that point to the overall health of the population.

Also, off Hawaii, NOAA sponsored a fairly large study in concert with the Navy. Satellite tags were placed on multiple individuals from several different species before a large operation.

Within the last ten years, because of the Navy's intense interest, our knowledge of Blainville's and Cuvier's beaked whales has improved immeasurably.

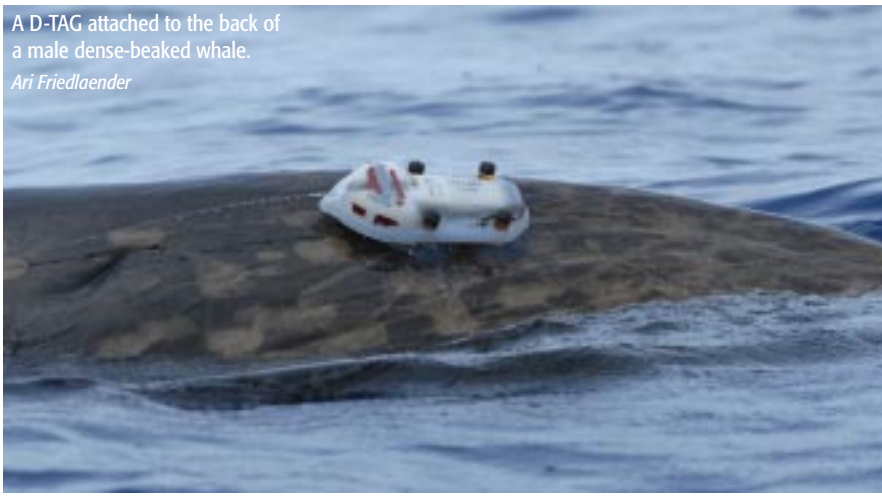
We are also gathering data from our opportunistic study with active sources that lines up with the BRS results. When we look for cases of animals exposed to actual sonar and we estimate the levels of sonar at which beaked whales continue to forage, we find our maximum level was 157 decibels with an average of 130 decibels. This is similar to levels at which animals broke off foraging during the 2007 and 2008 BRS when exposed to pseudo-sonar and pseudo-random noise signal.

Within the last ten years, because of the Navy's intense interest, our knowledge of Blainville's and Cuvier's beaked whales has improved immeasurably. But to some extent, we're playing catch-up to other species—we need to devise better quantitative methods to characterize their behavior.

The hope is that by combining opportunistic studies which provide broad-scale data with fine-grained BRS movement data, we can get a better understanding of how animals move and react relative to active sources. And if we know that, we might be able to avoid conflict situations down the road.

Another factor that is important for the ranges like AUTEC, SCORE and the Pacific Missile Range Facility (PMRF) in Hawaii, is the development of tools to study the health of these populations over the long-term. We'd like to be able to understand the animals that are present, how they move in their environment, and whether the population is stable and healthy over time.

In order to do that, we have to start to combine data from these different studies to come up with a model that helps both predict population health and can be used to study it long-term.



A D-TAG attached to the back of a male dense-beaked whale.
Ari Friedlaender

We need data on animal movement and calving rates and an understanding of predator-prey relationships. For instance there's a study funded by the Office of Naval Research led by Doug Novachek from Duke University that's trying to map prey fields juxtaposed against beaked whales so that we have some understanding of how they relate to their prey. The initial field work for the study took place during the BRS in 2008. Doug was able to produce some pretty interesting statistics on the overall prey field within the Tongue of the Ocean relative to these animals.

In implementing long-term population monitoring, you have to be conscious of environmental data. Changes in population health may have as much to do with changes in the environment as they do with naval operations.

To draw conclusions, we need a fairly comprehensive picture of the environment. That has other benefits

because it helps us understand the environment in which we're operating and allows us to better manage it.

CURRENTS: Regarding the specific projects you mentioned, what's the timeframe for some of them?

MORETTI: We did a test on the west coast on the SCORE range in the summer of 2008 that was similar to the test we ran at AUTEC. The intent of this test was to identify species on range, map the species to their vocalizations, get observers on the animals so we can get data on their behavior relative to their vocalizations and attach tags. So we can monitor the animals long-term both with and without sonar. A tag was placed on an adult Cuvier's beaked whales and four fin whales. The Cuvier's whale moved about 100 miles south and was off the coast of Mexico when the tag stopped transmitting. This was somewhat of a surprise, but we really don't have much data about this species. The fin whales all stayed within a 50-mile radius of the range.

Ultimately, we'd really like to determine the health of the population.

There are two disparate data sets that we're trying to combine. We've accumulated a fairly large data set based on opportunistic monitoring during active sonar operations on ranges. These data show broad movement of populations. What we're observing here at AUTEC are the animals on range—in particular beaked whales. We're able to project or measure the overall movement of populations (not individuals) on and off the range relative to the sources of sound. Remember, when we hear beaked whales, we're hearing a group of them. We know from our observer tests that they tend to associate in groups of three at AUTEC. And they also dive as a group—we know that from surface observations, tags that have been put on the animals. So when we hear them, we're actually hearing a group of animals. So we get broad scale movement, lots of data. Tests like the BRS give you very fine detailed data but those data are very sparse because our ability to get tags on animals is somewhat limited.

For instance, during the six-week studies in 2007 and 2008, there was a single playback each year. Tagging an individual gives you very fine detail of motion, so we got some very significant data but it's sparse.

Ian [Boyd] from St. Andrews championed the idea of combining the abundant opportunistic data with the sparse data from the BRS to produce a model of the animal behavior relative to the sound. If this effort is successful, perhaps it will lay the groundwork for a future tool that planners could use in advance of exercises to predict if there's going to be a problem and to take appropriate steps or choose different sites to avoid such a problem.

Any way that we can combine these data will allow us to say something more significant in terms about how these animals react. We may also gain more insights into the physiological effects of sound on the animals and whether the behavior itself puts these animals in danger or causes secondary effects that lead to these stranding incidents.

CURRENTS: Is that what you see as the ultimate goal of all this research?

MORETTI: Ultimately, we'd really like to determine the health of the population. We'd like to get away from individual animals and focus on how navy operations affect the population as a whole. In order to do that you need several sets of skills—signal processing, passive acoustics, animal biology, and statistical modeling—in particular population modeling.

We hope to incorporate all our data into statistical tools which will allow us to say something about how sound affects long-term population health—that's the Holy Grail. But that's going to take a significant amount of work from our team and scientists at other universities and research institutes that have expertise in these areas.

CURRENTS: Well, thanks for updating us on your work.

MORETTI: My pleasure. ⚓