LMR Program Holds First In-Progress Review

Researchers Highlight Successes, Management Team Convenes to Steer Future Investments

THE NAVY'S LIVING Marine Resources (LMR) program convened its first In-Progress Review (IPR) to hear about what researchers from across the globe are doing to help the Navy develop, demonstrate, and assess new solutions to protect living marine resources while preserving core Navy readiness capabilities.

Sponsored by the Chief of Naval Operations Energy and Environmental Readiness Division (CNO N45), the LMR program achieves the above mission by:

1. Providing science-based information to support Navy environmental effects assessments for at-sea training and testing.
2. Improving knowledge of the ecology and population dynamics of marine species of concern.
3. Developing the scientific basis for the criteria and thresholds to measure the biological effects of Navy generated sound.
4. Improving understanding of underwater sound and sound field characterization unique to assessing the biological consequences of underwater sound (as opposed to tactical applications of underwater sound or propagation loss modeling for military communications or tactical applications).
5. Developing technologies and methods to mitigate and monitor environmental consequences to living marine resources resulting from naval activities on at-sea training and testing ranges.

In an effort to gain insights into the program's current research portfolio, the LMR program manager convened an IPR of researchers and its management team—the Living Marine Resources Advisory Committee (LMRAC)—at the Naval Facilities Engineering and Expeditionary Warfare Center (formerly the Naval Facilities Engineering Service Center) in Port Hueneme, California on 16-18 October 2012.

Representatives from the program's resource sponsor organization (CNO N45) as well as members of the management team from the LMR's sister research program—the Navy Environmental Sustainability Development to Integration program—joined LMR personnel to evaluate current LMR projects and plan future investments to keep the program properly focused.

LMR researchers, staff and LMRAC members were welcomed to Naval Base Ventura County by CAPT Brant D. Pickrell, commanding officer of the Naval Facilities Engineering and Expeditionary Warfare Center. The meeting was opened with a keynote address by Deputy Assistant Secretary of the Navy (Environment),

Bottlenose dolphins.

Mr. Don Schregardus. A sense of the current program scope and level of effort is provided by the following summaries of major LMR projects:

Marine Mammal Monitoring on Ranges (M3R)

Mr. Dave Moretti, Naval Undersea Warfare Center (NUWC), Newport, RI

The Marine Mammal Monitoring on Ranges (M3R) program is currently being developed and evaluated at three Navy training and exercise ranges equipped with arrays of acoustic sensors that can detect marine mammals:

1. The Atlantic Undersea Test and Evaluation Center (AUTEC) in The Bahamas
2. The Southern California Offshore Range (SCORE) at San Clemente Island, California
3. The Pacific Missile Range Facility (PMRF) in Barking Sands, Hawaii

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At each of these three sites, the M3R team collaborates with local expert marine mammal research teams, which perform visual surveys, photo-identification of marine mammal populations, and animal tagging and tracking to verify and calibrate M3R results and build a multi-sensor picture of animal abundance on the Navy ranges, their habitat use, and responses to Navy activities on the range.

The Atlantic Undersea Test and Evaluation Center

The AUTEC range is home to a sizable population of beaked whales. These whales have lived on the Navy range for an extended time in the presence of active sonar use. The M3R program is assessing animal responses when sonar is active, as well as monitoring baseline usage of the range by beaked whales (and other species) when the range is not in use. Research partners from the National Oceanic and Atmospheric Administration (NOAA) Southwest Fisheries Science Center (Dr. John Durban) and the Bahamas Marine Mammal Research Observatory (Ms. Diane Claridge and her colleagues) verify species identity of animals detected acoustically by M3R and correlate the data from tags placed on the animals with the acoustic data from M3R.

The Southern California Offshore Range

SCORE has many more sensors (about 200 sensors) than AUTEC, but the same basic system architecture, enabling exportation of the M3R technology developed at AUTEC to similar ranges like SCORE and PMRF. With the original data and knowledge from the AUTEC range, researchers have been able to acoustically identify beaked whales and many other marine mammal species on the range. The biggest difference between SCORE and other ranges is the number of animals; the Southern California Bight region is one of the richest marine mammal habitats in the world, both in terms of species variety and absolute numbers of animals per unit area.

This site therefore challenges the M3R acoustic classifier program in ways that the less populous AUTEC site does not. Not only are animals so abundant that the sheer number of calls is uncountable, but many types of sounds, like dolphin whistles, remain very difficult to sort by species. Using the same model of collaboration developed at AUTEC, the M3R team partners with local research experts Ms. Erin Falcone and Mr. Gregg Schorr of the Cascadia Research Collective to visually confirm M3R species identifications, compare abundance estimates from M3R acoustics to visual and photo-identification methods, and confirm animal responses to sound via tagged animals tracked during naval activities on the range.

Pacific Missile Range Facility

PMRF presents its own unique monitoring conditions. The instrumented range is even larger than the SCORE range and covers an area of 1500 square kilometers, from shallow to deep water (200 to 4,000 meters). PMRF

Sperm whale.

marine mammal densities appear to be somewhere between those for SCORE and AUTEC.

During 2011 initial species verification testing was performed, using the same partnership process successfully employed at AUTEC and SCORE. Dr. Robin Baird of the Cascadia Research Collective provides species verification, using visual and acoustic data, photo-identification and tagging. In obtaining baseline data, researchers are looking for seasonal- and/or activity-related movements, just as they do at AUTEC and SCORE.

The goals of M3R are threefold. One goal is to develop automated marine mammal detection, localization, classification and display tools that will enable range staff to perform their own mitigation monitoring without the assistance of expert scientific staff. That transition is the most immediate goal. A second goal is to establish baseline population density, abundance and habitat usage data for Navy risk analyses and permit applications covering fleet activities on the ranges. That capability will also transition soon to operational support for long-term population status and trends monitoring, following completion of calibration evaluations. With multiple calibrated methods (visual, passive acoustic, tagged animal and photo-identification) the Navy will be able to use the mix of methods that provides the best data for the least expense. The third goal is to translate M3R observations of animal responses to Navy activities, including mid-frequency anti-submarine warfare (ASW) sonars, into behavioral response metrics useful in revising regulatory risk criteria for permitting purposes. This work involves integration of M3R data with independently developed data by playback studies (discussed in the SOCAL Behavioral Response Study (BRS) summary below), statistics experts, and modelers. The Office of Naval Research (ONR) plays a vital partnership role in converting M3R observations into integrated models of animal response to sound, and the biological significance of those responses. The goal is to have M3R data provide a significant contribution to improved behavioral risk criteria for the next (Phase III) round of environmental documentation and permitting in the 2014–2017 time frame.

SOCAL Behavioral Response Study

Dr. Brandon Southall, SEA Inc.

Dr. John Calambokidis, Cascadia Research Collective

Dr. Peter Tyack, Woods Hole Oceanographic Institution and University of St. Andrews

Dr. Jay Barlow, NOAA Southwest Fisheries Science Center

Mr. Dave Moretti, Naval Undersea Warfare Center Newport

The SOCAL BRS is a multi-disciplinary team of biologists, acousticians, and technological developers. The objective of this project is to get a better understanding of reactions from marine mammals to Navy sonar by:

- Obtaining baseline behavior for key species for interpretation of responses to sound
- Conducting controlled exposure experiments on a variety of species and under different circumstances (including feeding, socializing, resting and traveling) with different sounds (including 'no sound' control trials)

The Fiscal Year (FY) 2012 approach of the BRS is to evaluate options for smaller, more flexible field teams ('fast and light'), compared to the baseline protocol that requires 12 or more staff deployed on one to two large vessels (40 to 65-plus feet in length) and two small boats (rigid-hulled inflatable boats) used for tagging and focal follow of animals during sound exposure). In 2010, the BRS team adapted and applied the BRS approach to SOCAL species, after prior experience with this research methodology on the AUTEC range and western Mediterranean Sea. The greater number of species available in the Southern California Bight has resulted in an expanded list of species used in playbacks; large baleen whales like blue, fin, humpback and minke whales, and moderate sized toothed whales/dolphins like orcas, Risso's dolphins, as well as larger numbers of animals available to be tagged and included in playbacks. By October 2012, 94 individuals of nine species had been tagged, and 54 of those tagged animals had been involved in a full two to four hour playback study with pre-exposure observations, a 20 to 30 minute controlled sound exposure, and then one to two hours or more of post-exposure monitoring. The goal for 2013 through 2015 is to use Navy ASW sonar-equipped ships in pursuit of the eventual goal of documenting realistic sound exposures under realistic sonar usage scenarios.

SOCAL BRS Tagging Summary

SOCAL-10: 63 TAGS OF 6 TYPES ON 44 INDIVIDUALS OF 8 OR 9 SPECIES		
Scouting & LEG I Tag Summary	**56 tags of 5 types on 37 individuals of 6 or 7 species**	
25 days	Blue Whales	25 total individuals (21 Dtags; 9 Bprobes; 8 MK-10s)
	Fin Whales	7 total individuals (7 Dtags; 1 Bprobe)
	Sperm Whale	1 individual (2 Dtags; 2 MK-10; 1 satellite tag)
	Baird's Beaked Whale	1 individual (1 satellite tag)
	Possible Sei/Fin Whale Hybrid	1 individual (1 satellite tag)
	Bottlenose Dolphin	1 individual (1 TDR)
LEG II Tag Summary	**7 tags of 2 types on 7 individuals of 4 species**	
10 days	Blue Whales	3 total individuals (2 Dtags; 1 ACOUSONDE)
	Risso's Dolphins	2 total individuals (2 Dtags)
	Bottlenose Dolphin	1 individual (1 Dtag)
	Cuvier's Beaked Whale	1 individual (1 Dtag)
SOCAL-11: 38 TAGS ON 4 TYPES ON 35 INDIVIDUALS OF 4 SPECIES		
LEG I Tag Summary	**22 tags of 2 types on 20 individuals of 2 species**	
14 days	Blue Whales	19 individuals (21 Dtags)
	Risso's Dolphin	1 individual (1 Dtag)
LEG II Tag Summary	**14 tags of 4 types on 13 individuals of 4 species**	
14 days	Blue Whales	6 individuals (2 Dtags; 5 MK-10s)
	Risso's Dolphins	6 individuals (5 Dtags; 1 satellite tag)
	Bottlenose Dolphins	2 individuals (2 Dtags)
	Cuvier's Beaked Whale	1 individual (1 Dtag)

Dtag: *A digital tag*

LEG: *Each field effort is divided into approximately "legs" of two weeks each, spanning seasons of interest, allowing for logistic limits of vessels and people and fitting effort in between Navy range closures for various training activities.*

Bprobe: *A type of acoustic recording tag*

MK-10: *A commercially available marine mammal tag that usually includes sensors for time, depth/pressure, temperature and light level*

TDR: *Time-depth recorder*

ACOUSONDE: *See Bprobe. ACOUSONDE is the new and improved model.*

The BRS team is in its third year of sound playbacks to tagged whales on and around the Navy's SOCAL training range. Tagging summaries for the first two years of this effort are provided here. While beaked whales are the priority species, the cost and logistic challenges of this complex at-sea experiment require the researchers to respond opportunistically to any of the many species of whales and dolphins living in the rich habitat of the Southern California Bight. This is the most successful project to date in collecting the behavioral response data needed by the Navy and others to refine models of risk from human sound-producing activities like sonar training.

Researchers from Across the Globe

RESEARCHERS FROM A variety of academic institutions as well as Navy and other federal research facilities participate in the LMR program. Among those institutions and organizations represented at this IPR were the following:

1. Commander, Pacific Fleet
2. Duke University
3. Information Dominance/Director of Naval Intelligence
4. National Marine Fisheries Service
5. National Oceanic and Atmospheric Administration, Southwest Fisheries Science Center
6. Naval Air Systems Command
7. Naval Facilities Engineering Command
8. Naval Post Graduate School
9. Naval Sea Systems Command
10. Naval Undersea Warfare Center Newport
11. Office of Naval Research
12. Office of the Assistant Secretary of the Navy (Environment)
13. Oregon State University
14. San Diego State University
15. Scripps Institution of Oceanography
16. SEA, Inc.
17. Space and Naval Warfare Systems Command
18. The Cascadia Research Collective
19. U.S. Fleet Forces
20. U.S. Geological Survey
21. University of California, San Diego
22. University of California, Santa Cruz
23. University of Hawaii
24. University of St. Andrews, Scotland
25. Woods Hole Oceanographic Institution

Why is so much data needed? It's not just about the acoustic threshold—the received sound level at which animals can be seen to change their behavior. Factors such as species differences, differences in the playback source and its movements, and the behavior of the animal prior to exposure (including feeding, diving, and travelling) all have the potential to produce different outcomes. SOCAL BRS researchers, and the M3R team are collaborating with ONR-funded researchers to develop statistical methods to make the most of the data. The eventual translation of these data into risk metrics like acoustic dose-response functions does not fully express the influences of pre-exposure behavior state and position of the marine mammal at the time the marine mammal is receiving sound.

Obtaining statistically powerful controlled exposure data in a BRS is an expensive methodology. Reducing cost is therefore a high priority as experience in controlled playback methods is gained. Adapting the BRS technique and approach from the big team size and large ship and source down to small team and smaller size source could cut the cost of the project in half if the new methodology is still able to produce a comparable amount of data to the larger scope of effort.

Survey Methods Development & Testing

Dr. Len Thomas and colleagues, Center for Research into Ecological and Environmental Modeling, University of St. Andrews, St. Andrews, Scotland

Dr. Len Thomas and his team have partnered with Dr. Jay Barlow of NOAA Southwest Fisheries and other LMR data providers to adapt the standard statistics for deriving animal density from survey data—called Distance. The Marine Mammal Protection Act requires the Navy to express marine mammal population status, trends and environmental effects in terms of animal density/abundance estimates derived from a variety of survey and sampling procedures, from aerial surveys to ship-based surveys, and largely spaced lines to point sampling and small-area intensive monitoring.

In addition to the LMR-supported survey methods development, Thomas and his team are developing comparable methods for fixed or towed passive acoustic sensor data, under funding from ONR, the interagency National Oceanographic Partnership Program and other sources. To accomplish this task, Dr. Thomas is collaborating with providers of large acoustic data sets under LMR funding, such as the data generated by the M3R program described above, Dr. John Hildebrand at Scripps Institution of Oceanography, as well as Dr. Jay Barlow and Dr. Sophie van Parijs at NOAA's Southwest and Northeast Fishery Science Centers.

The current power of passive acoustic density estimation is limited by the tools needed to automatically detect and correctly classify the sounds of various marine species. The LMR program, as well as ONR and other programs, are therefore investing in advancing the acoustic signal processing tools needed by M3R and other acoustic data collectors.

Anatomical & Modeling Studies of Cetacean Hearing

In addition to behavioral metrics of environmental effects from Navy

activity, Navy and the National Marine Fisheries Service use hearing-based criteria as a higher metric of risk aimed at preventing potentially injurious effects on hearing or other physiological processes. Historically, much of this work was supported by ONR, but a role remains for the LMR program to apply well-tested methods to remaining areas of uncertainty. One of the most challenging topics has been the development of hearing capability data for large whales and beaked whales—species that are difficult if not impossible to maintain in a laboratory setting for testing in the same way sea lions, dolphins and porpoises have been tested.

Using a common standard of scientific investment used by this program and others, LMR has funded two independent teams working in parallel to model hearing abilities based on the anatomy of the ear and associated anatomical structures. Their work is close to completion and will offer Navy planners and modelers improved confidence in risk models for the Navy's Phase III permits process beginning in FY14.

Finite Element Analysis of Hearing Anatomy & Interaction with Sound Energy

Dr. Ted Cranford, San Diego State University

This project has utilized detailed anatomical data from dissections and x-ray computed tomography ("CT scans") to build mathematical Finite Element Analysis (FEA) models of the hearing anatomy and its interaction with sound energy. First of all, the means for scanning large whale heads needed to be developed. Baleen whale heads, the size of a commercial truck or van, are too big for the medical CT scanners found in hospitals and medical research facilities. Dr. Cranford developed the ability to use the Hill Air Force Base large CT scanner used to scan solid fuel rocket motors for bubbles and other defects that might affect the burn rate of the missile.

Among the unexpected discoveries revealed by the anatomical modeling was the finding that the primary sound reception pathway was not where they thought it would be. Rather than sound entering the ear by transmission through the fatty tissues in the jaw, Dr. Cranford and his colleague Dr. Peter Krysl, found that a lot of the acoustic energy enters underneath the lower jaw, which they dubbed the 'gular pathway.' The pathway of sound varies with the frequency of the sound, adjusting the relative loudness of different frequencies before they reach the inner ear, much as the outer ear or pinna of humans and other mammals selectively filters the frequencies of incoming sound to optimize the frequencies of greatest interest for communication and environmental sensing. Another discovery was the role of the middle ear capsule, which houses the malleus, incus and stapes (hammer, anvil and stirrup) that transmits sound from the eardrum to the inner ear. In marine mammals, the eardrum appears to be relatively nonfunctional and the role of activating the middle ear bones is taken over by the walls of the middle ear capsule, which has been thinned and thickened in various places to facilitate sound transmission to the middle ear bones. This anatomical discovery applies to dolphins and other toothed whales, it is not certain that the middle ear works the same way in the large baleen whales. The closing phase of this project will focus on validating the model, to compare it to other measures of whale hearing such as evoked potential audiometry (measuring the electrical activity of

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the auditory nerve and brain), and behavioral responses to sound in their environment.

Modeling Baleen Whale Hearing

Dr. Darlene Ketten, Woods Hole Oceanographic Institution

Mr. Dave Mountain, Boston University

Dr. Darlene Ketten and Mr. Dave Mountain have applied a similar process of anatomically derived Finite Element modeling, but have made more use of existing models of human and general mammalian middle ear and inner ear function. Since mammalian hearing physiology is generally conservative, these are considered reasonable extrapolations, modified for the anatomical differences measured by Dr. Ketten's laboratory. Dr. Ketten offered some preliminary results of modeled baleen whale hearing that will help to hone a number of assumptions about large whale hearing. One is that the lower frequency limit is not that different from humans, elephants and other low frequence 'experts', where sensitivity declines rapidly below 50 to 100 hertz (Hz) and cuts off around 10 to 20 Hz. There is a fuzzy boundary here where the vestibular system, which senses vibration and balance, may augment low frequency perception, but a puzzle remains about the actual functional role for energy in large whale vocalizations that goes as low as 15 to 20 Hz. The other surprise is that baleen whales may have the broadest range of hearing of any mammal, spanning a good eight to ten octaves. Whereas human hearing drops off around 14 to 20 kilohertz (kHz), large whales appear to have good hearing up to as high as 30 kHz. The modeling results have at least some tentative support from behavioral observations of gray whales and other baleen whales clearly reacting to sounds at 20 to 24 kHz or even higher frequencies—well above the limits of human hearing.

Once these and other projects were reviewed, the LMRAC's work continued, reviewing and ranking the statements of research needs submitted by a broad range of Navy activities via the LMR web-based FY13 needs solicitation process. These ranked needs, once approved by CNO N45, will appear on the LMR website sometime in mid- to late-January, to initiate submission of pre-proposals for FY13–14 new starts. The availability of a Broad Agency Announcement will also be announced widely within and outside Navy.

The first annual LMR In-Progress Review was a great success—both in acquainting Navy stakeholders with advances in scientific capability supported by the LMR program, and in acquainting researchers more directly with the Navy's needs for scientific information and technical capability in areas of Navy at-sea environmental compliance. The LMRAC, as representatives of the fleets and system commands affected by at-sea environmental issues like underwater sound, was impressed by the almost overwhelming wealth of information presented to them, but unanimously commended the new LMR program structure that opens up the research and development, test and evaluation decision making process within this program to all interested Navy parties. ⚓

For More Information

FOR MORE INSIGHTS into the LMR program, visit www.lmr.navy.mil.

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