LMR Program Launches New Project Initiatives

Efforts Continue to Expand the Navy's Knowledge of Marine Mammals

THE LATEST ROUND of Living Marine Resources (LMR) program projects continue to support the Navy's efforts to reduce potential impacts to marine mammals while meeting its at-sea training and testing requirements.

Results will ensure better estimates of potential disturbance and harassment for future naval training and environmental impact statement assessments.

The LMR program is responsible for applied research and works both to address the Navy's key research needs and to transition the results and technologies for use within the Navy's at-sea environmental compliance and permitting processes.

The newly started fiscal year (FY) 2015 projects were selected through a carefully considered process that the program undertakes each year. This process begins with identifying key Navy needs followed by issuing a Broad Agency Announcement (BAA) to solicit pre-proposals to address those needs. The program's advisory committee, the Living Marine Resources Advisory Committee (LMRAC), reviews the pre-proposals and recommends which of those should be expanded into full proposals. Full proposals receive similar scrutiny. Following approval from the LMR program's resource sponsor, the Chief of Naval Operations Energy and Environmental Readiness Division (OPNAV N45), selected proposals are identified for funding.

LMR Investment Areas & Needs

The annual needs identification process is organized within five defined investment areas. (See our sidebar "The Basics About the LMR Program" for more details.) Anyone within the Navy may submit needs for consideration by the program. The needs must fall within the defined investment areas and meet one or more of the following conditions:

- Addresses research challenges being faced by the Navy community
- Identifies an existing gap in knowledge, technology and/or capability
- Is associated with an environmental constraint or regulatory driver.

Submitted needs are validated and ranked by the LMRAC, and then recommendations are made to OPNAV N45. (A guide for submitting needs is available at www.lmr.navy.mil under "Needs.")

For FY15 funding, the BAA requested pre-proposals to address the following three needs:

1. N-0077-15: Population Density Estimation from Passive Acoustic Monitoring Data
2. N-0088-15: Marine Species Monitoring Data Collection Toolkit Development
3. N-0096-15: Hearing Measurements in a Broad Range of Marine Mammal Species

The program received 63 pre-proposals, of which 19 were developed into full proposals. Of those 19,

eight "new start" projects were selected for the FY15 funding cycle.

NEED: Population Density Estimation from Passive Acoustic Monitoring Data

The Navy uses passive acoustic monitoring (PAM) for a number of environmental monitoring needs, including detecting the presence of marine mammals and classifying what species are present. PAM also offers the Navy a potentially powerful and beneficial tool to estimate the density (i.e., number of individuals) for species of concern in situations where other methods (e.g., visual observation) are infeasible or prohibitively expensive. Estimating the number of animals present using PAM data requires a level of data collection planning, metadata collection, and external calibration of detection rates that is not necessarily required for other PAM applications.

Parts of a SSQ-Q53F sonobuoy after being removed from its housing.

From 24 pre-proposals received, three were selected for FY15 funding and are now underway.

Passive Acoustic Density Estimation of Baleen Whales: Using Sonobuoys to Estimate Call-Rate Correction Factors

Project number: 16
Principal Investigator: Shannon Rankin, Southwest Fisheries Science Center

This project will work to improve animal density estimates of baleen whales in the California Current and the Navy's Southern California Offshore Range (SCORE) by combining sonobuoy data with visual sightings to estimate the correction factor needed to convert call density data to whale density data. (Note: The California current is a southward flowing offshore current that traverses the west coast of North America from Canada to Baja California.) The sonobuoys used are equipped with signal processing technology that works in conjunction with PAMGuard, a widely used marine mammal passive acoustic processing program. The density of whales will be compared over the entire study area using visual line-transect survey methods during daylight hours and acoustic point-transect survey methods during night hours.

Sonobuoys offer several benefits as a PAM method. They are used extensively by the Navy, and surplus sonobuoys have proven valuable for detection and localization of baleen whales. Deployment of sonobuoys requires minimal experience and can be conducted from a variety of platforms (airplanes, helicopters, ships of various sizes), which allows for opportunistic monitoring. Data collection can be conducted in real-time, allowing for a short turnaround between identifying a need and obtaining data and density estimates for baleen whales in a given area.

Blue and Fin Whale Density Estimation in the Southern California Offshore Range Using PAM Data

Project number: 17
Principal Investigator: Ana Širovic, University of California San Diego, Scripps Institution of Oceanography

This project focuses on developing spatially and temporally explicit density estimates for blue and fin whales in the Southern California (SOCAL) range to provide the Navy with a realistic, quantitative assessment of levels of impact from Navy training activities.

Team deploying an acoustic and video tag on a blue whale.
A. Allen, NMFS permit 14534

One of the earlier acoustic tags (BPROBE) deployed on a fin whale off Tanner-Cortez Bank in 2003 as part of past study of fin and blue whale calling.

The project team is leveraging results from work completed under the Office of Naval Research (ONR), utilizing data from acoustic tag deployments from the SOCAL Behavioral Response Study (BRS), and will also perform additional acoustic tag data collection, using newly available long-term tags. (For more on SOCAL-BRS, see our sidebar "Two Foundational LMR Projects.") This will allow researchers to evaluate the effect of bias in call-rate estimation from short-term tag deployments, which were the norm during the earlier data collection. The focus of tagging will be on fin whales where existing data are more limited, but will also supplement available blue whale data. Results will ensure better estimates of potential disturbance and harassment for future naval training and environmental impact statement assessments.

DECAF-TEA: Density Estimation for Cetaceans from Acoustic Fixed Sensors in Testing and Evaluation Areas

Project number: 19
Principal Investigator: Len Thomas, University of St. Andrews

Much of the PAM-based density estimation work now taking place occurs on Navy testing ranges where there are pre-existing arrays of cabled hydrophones. However, because a large amount of the Navy's activity takes place away from these instrumented ranges, methods applicable to such non-instrumented areas need to be fully developed, demonstrated and validated.

This project will demonstrate and validate a method for passive acoustic density estimation that can be used across a range of species, environments and temporal scales. The project team will deploy retrievable, bottom-mounted passive acoustic sensors adjacent to or overlapping the Southern California Anti-Submarine Warfare Range (SOAR). Data from these sensors, in conjunction with estimates of vocalization rates from existing and ongoing studies, will be used to estimate density values and create animal distribution maps for two case-study species—the Cuvier's beaked whale and the fin whale. The project team

It is important to understand the difference between an animal hearing a sound and that sound causing an effect.

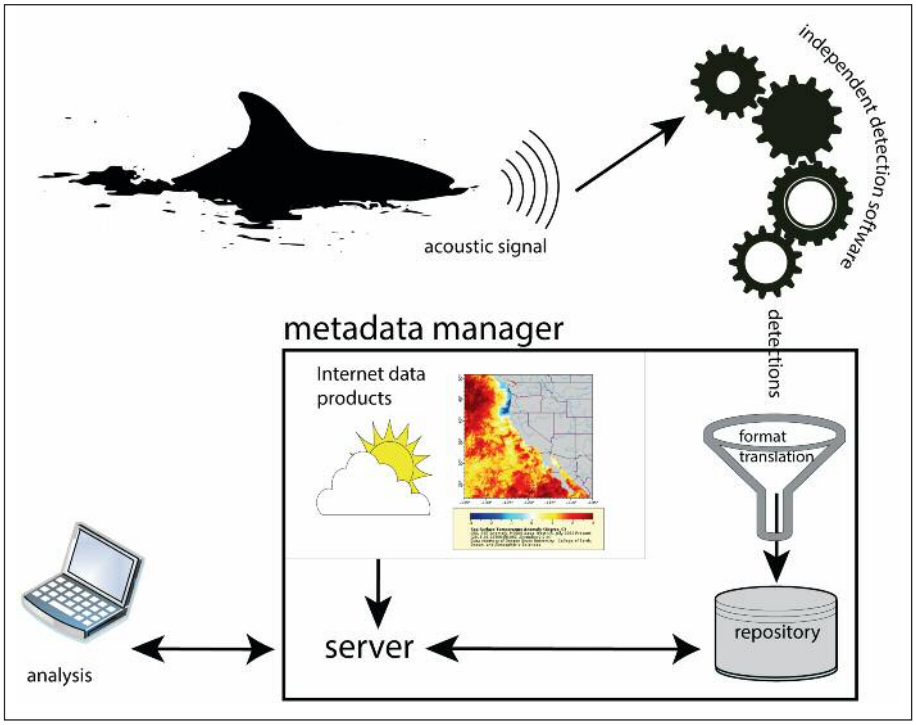
Cuvier's beaked whale.
Gregory S. Schorr, NMFS permit 16111

will leverage fin whale vocalization data obtained in the ongoing SOCAL-BRS. The project is heavily reliant on the Marine Mammal Monitoring on Ranges (M3R) PAM system developed for the instrumented Navy ranges by personnel from the Navy Undersea Warfare Center Newport, Rhode Island who are partners on this project.

The end products will be density estimates and associated animal distribution maps that combine data from both instrumented and non-instrumented ranges. Density estimates will be added to the Navy Marine Species Density Data archive.

NEED: Marine Species Monitoring Data Collection Toolkit Development

Current Navy-funded marine species surveys generate large quantities of data that often are collected using varying monitoring techniques. Data protocols, formats, standards, and quality assurance and control procedures are items that need to be addressed in order to standardize data across the Navy's marine species monitoring program and ensure consistency with generally accepted standards within the scientific community.



Overview of workflow. Raw acoustic signals.
NOAA Southwest Fisheries Science Center, Environmental Research Division

From 10 pre-proposals received, one was selected for FY15 LMR program funding and is now underway.

Acoustic Metadata Management for Navy Fleet Operations

Project number: LMR-15-18
Principal Investigator: Marie Roch, San Diego State University

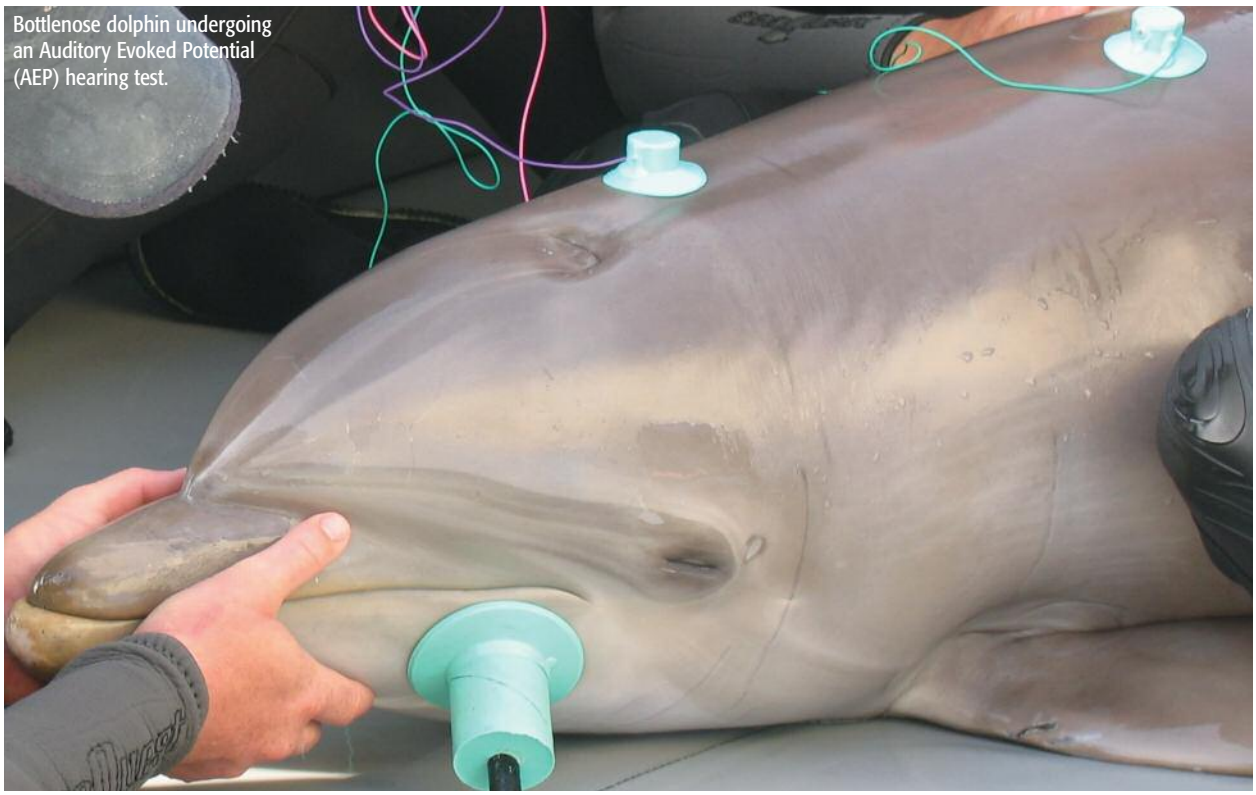
This project will expand development of Tethys, a passive acoustic monitoring metadata database sponsored by National Oceanographic Partnership Program. Tethys incorporates the expertise of PAM personnel at NOAA Alaska, Northeast, Pacific Islands, Southeast, and Southwest Fisheries Science Centers as well as PAM experts at the Scripps Institution of Oceanography and San Diego State University. The system provides a standard that can be implemented on any system, and there is broad interest in transitioning what is becoming a community standard into an official one.

The project team will strengthen the capabilities of Tethys to make it more usable by the Navy. Specific tasks include providing additional data analysis and reporting facilities, identifying bottlenecks in performance as the existing databases continue to grow in size, and further development of the program's schemata for localization. These efforts will improve its utility for long-term Navy monitoring data management and support Navy mitigation efforts.

The project is a collaborative effort among the Navy, NOAA, and BOEM. It builds upon work previously funded by ONR, and portions of the project are currently being funded by the LMR program while others are being funded by BOEM.

NEED: Hearing Measurements in a Broad Range of Marine Mammal Species

For the Navy to minimize the potential adverse effects resulting from exposure to sound, a fundamental need is a more complete understanding of how marine mammals hear and are affected by sound. There are multiple aspects of a sound source that might affect the hearing, behavior and physiology of marine mammals. Improved knowledge of these aspects will help in accurately estimating and predicting the audibility of frequency-related harmonics and other secondary features of sonar signals to different marine mammal species, and the distances at which such sounds can be detected. This information will support more appropriate mitigation measures to minimize the potential adverse effects resulting from exposure to complex anthropogenic sounds.



Bottlenose dolphin undergoing an Auditory Evoked Potential (AEP) hearing test.

Two Foundational LMR Projects

TWO OF THE earliest LMR projects are the Marine Mammal Monitoring on Ranges (M3R) project (no. LMR-12-01) and the Southern California Behavioral Response Study (SOCAL-BRS) (no. LMR-13-02). Several subsequent LMR projects draw from data and techniques developed through these two multi-year projects. Additional details follow.

Marine Mammal Monitoring on Ranges

M3R utilizes existing hydrophone (underwater microphone) arrays on Navy ranges to expand the Navy's knowledge about marine mammal presence, abundance and behavior. The data collected via the hydrophones is combined with other passive acoustic monitoring data, visual observation, biological sampling, and satellite tags. Marine mammal vocalizations are detected on individual hydrophones as an animal or group of animals moves across the range.

The goals of the M3R program are to:

- Develop automated passive acoustic marine mammal detection, localization, classification and display tools using existing Navy undersea hydrophone arrays and integrate visual and satellite monitoring methods to leverage the combination of the methods to study marine mammals on Navy ranges.
- Study and measure animal responses to Navy activities, including mid-frequency active sonar (MFAS), with a focus on beaked whales.
- Provide scientifically defensible behavioral response metrics for sensitive species like beaked whales, which can be used to inform regulatory risk criteria and provide insight into the cumulative effect of repeated sonar exposure.
- Provide baseline population density, abundance, and habitat usage data for Navy risk analyses and permit applications covering training and testing activities on the ranges.

M3R was initiated in 2000 by the Office of Naval Research (ONR). Core components of M3R program development were transitioned from ONR to LMR in 2009. Since then, prototype technologies have been extended and used to study animals on the ranges. M3R now is transitioning its monitoring and analysis tools so that they might be run and maintained by Navy range personnel. During FY15, the project completed significant system updates at three Navy ranges, improved system stability and upgraded hardware, installed packet recorders to archive raw acoustic data, and completed a user's manual.

Southern California Behavioral Response Study

SOCAL-BRS is designed to increase understanding of marine mammal reactions to sound and provide a more robust scientific basis for estimating the effect of Navy MFAS on marine mammal behavior.

The project began in 2010 and completed its most recent field season in 2015. The overarching approach has included a number of research objectives:

- Tag a variety of species and obtain baseline behavioral data.
- Conduct Controlled Exposure Experiments (CEE) to obtain high-resolution measurements of behavioral responses of marine mammals.
- Apply adaptive team configuration to support both simulated MFAS sources and actual military MFAS sources.
- Obtain basic biological, behavioral, and foraging ecology data for marine mammals to support range monitoring efforts and/or habitat models.


Sperm whale.

SOCAL-BRS is providing the Navy with baseline data on movement and acoustic behavior of a variety of cetacean species as well as individual high-resolution measurements of behavioral changes during exposure. To date that has included baseline and CEE data on more than 160 individuals of ten federally protected marine mammals, including two beaked whale species and four endangered species (blue, fin, humpback, and sperm whales). All of these data represent novel measurements for these species. Measurements are providing quantitative insights into the critical importance of exposure context (e.g., distance from source, depth, behavioral state at time of exposure, etc.) in terms of the probability and type of behavioral response.

Data from this study will more than double the number of individual killer whales that have been tested, as well as provide hearing data over a large age range of 12 to 49 years.

From 29 pre-proposals received, four were selected for FY15 funding and are now underway.

Standardization of Auditory Evoked Potentials (AEP) Audiometry Methods to Ensure Comparable Data Inclusion in a National Marine Mammal AEP Database

Project number: 13
Principal Investigator: Dorian Houser, National Marine Mammal Foundation

To understand the natural or baseline hearing in marine mammals, researchers have measured hearing thresholds either by studying behavioral response to sound or by taking an electrophysiological approach. In the latter, they measure voltages produced by the brain in response to an acoustic stimulus. These voltages (AEPs) can be quickly measured in subjects with minimal subject cooperation.

However, different AEP methodologies can result in large differences in threshold estimates for the same species, or even the same individual. Differences may vary on the order of tens of decibels, which has serious ramifications for determining the range of audibility for Navy acoustic sources, as well as for estimating impacts within mid- to low-frequency ranges where variances will be the greatest.

This project standardizes hearing threshold measurement methods used in toothed whales (odontocetes) and increases species representation and sample sizes in hearing threshold estimates to reduce uncertainty in hearing range analyses used by Navy planners. Efforts include developing and promoting a standardized methodology for the collection and reporting of audiometric information from odontocetes through AEP methods. Following completion of the standard, the portable AEP system currently in use, called the Evoked Response Study Tool (EVREST), will need to be reprogrammed according to the consensus methodologies determined through the standardization process.

Data collected from wild odontocetes with the AEP systems, under standardized methods, will be incorporated into the national AEP database and access for queries to the database will be made available to Navy environmental planners.

Behavioral Audiometry in Multiple Killer Whales

Project number: 14
Principal Investigator: Brian Branstetter, National Marine Mammal Foundation

This project provides the first demographic hearing data from killer whales by measuring behavioral audiograms from five to eight participants that vary in age and gender. Additional subjects may become available during the course of the study. Audiograms will be measured using well-established psychoacoustic methods that are regularly employed by the National Marine Mammal Foundation for the testing of hearing in dolphins. Psychophysical hearing tests are the "gold standard" of hearing tests, leading to the most accurate audiometric measurements.

A killer whale positioned on a stationing device while participating in a psychophysical hearing test.

This modeling environment gives researchers the ability to conduct "virtual experiments" to investigate basic mechanisms of hearing and sound production.

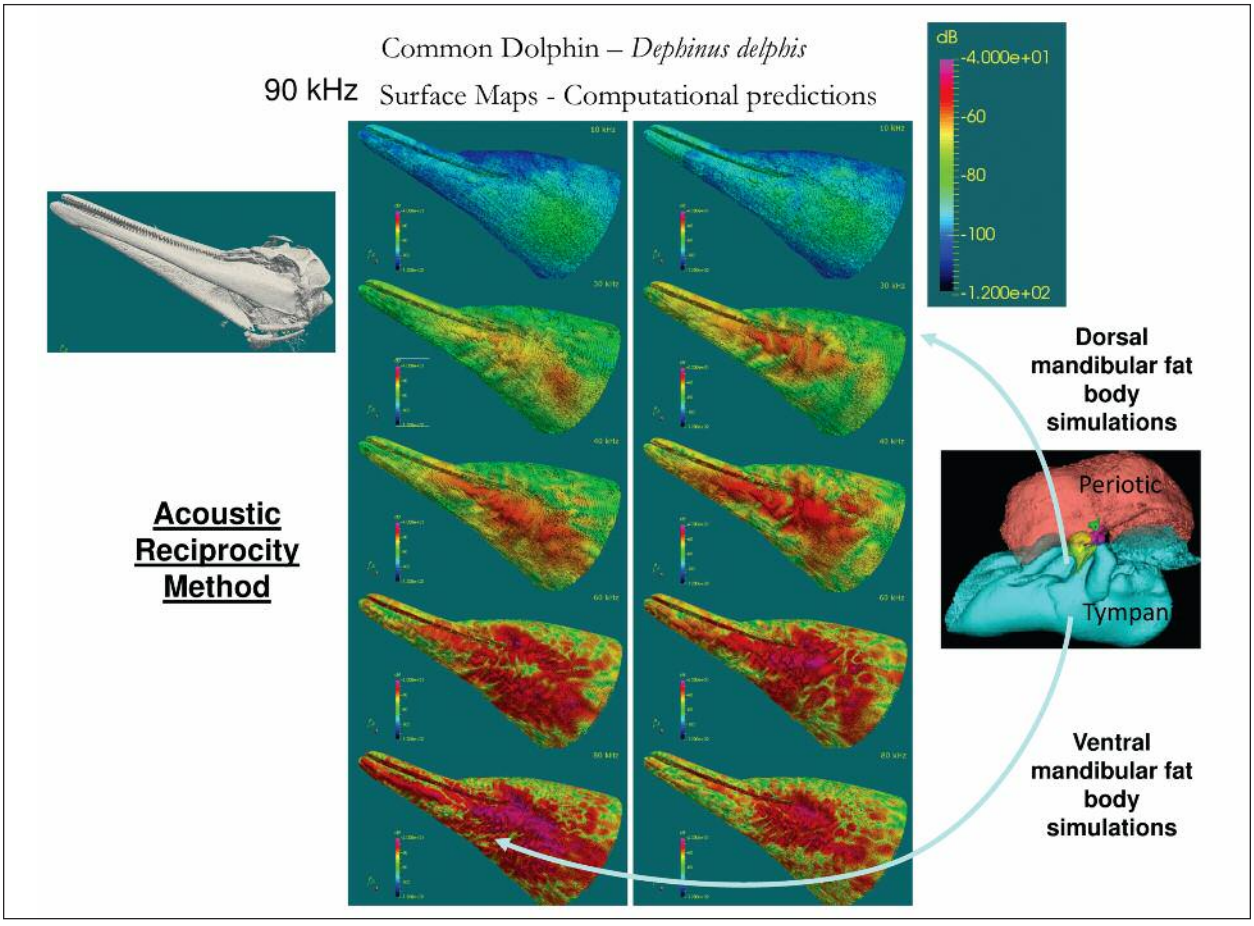
Data from this study will more than double the number of individual killer whales that have been tested, as well as provide hearing data over a large age range of 12 to 49 years. This will help to determine accurate mid-frequency cetacean composite audiograms and weighting functions for Navy at-sea environmental compliance. This work is follow-up to a 2014 cooperative project between Sea World San Antonio and U.S. Fleet Forces Command.

Jawphone Simulations to Maximize the Utility of Psychoacoustic and Auditory Evoked Potential Experiments

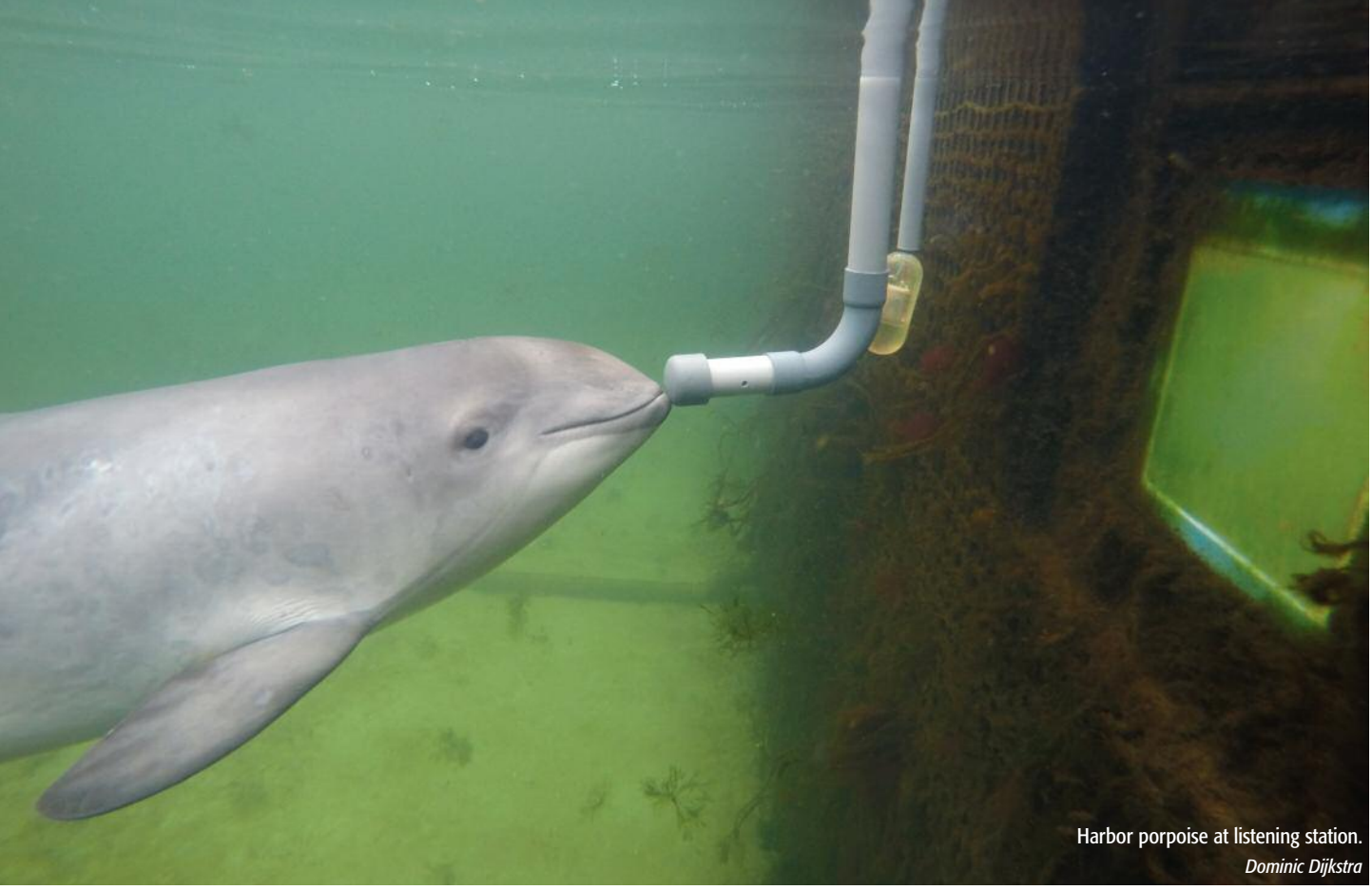
Project number: 15
Principal Investigators: Ted Cranford, San Diego State University; Petr Krysl, University of California, San Diego

Auditory evoked potential can be quickly measured in subjects with minimal subject cooperation. To date, however, basic hearing measures (AEP or behavioral) have only been compiled on a small number of animals, and interpreting AEP results may be more complicated when a device called a jawphone (suction cup containing a transducer) is used. The placement, frequency selection, and other parameters of the jawphone can affect AEP testing results.

In preliminary simulation studies, it appears that jawphones can selectively excite hearing pathways that



Common dolphin surface maps.



Harbor porpoise at listening station.
Dominic Dijkstra

may be different from those used naturally by the animals. Small changes in the placement of a simulated jawphone can cause large amplitude differences (several decibels) by the time the sounds reach the ears.

This project uses a computational approach to identify the mechanism(s) by which jawphones stimulate hearing when they are used to gather data on marine mammal auditory capabilities. The methodology is based on finite element modeling techniques, where high-resolution computerized tomography scan data are combined with measurements of tissue properties and custom-built computer programs to simulate sound propagation into and out of the anatomic complexity of specimens. Model outputs will quantify the acoustic pathways between the jawphone and the ear, which will enable researchers to compile sensitivity maps that identify the optimal locations for jawphone placement in three dolphin species. These maps can be used to design and evaluate AEP-based hearing tests, guiding jawphone placement to minimize errors due to variable response sensitivity to the location of the transducer on the animal's skin.

This modeling environment gives researchers the ability to conduct "virtual experiments" to investigate basic mechanisms of hearing and sound production, and to simulate exposure levels at sound pressures that would be impossible or unethical with live animals. These results will be helpful in the design and evaluation of past and future AEP hearing tests, will significantly reduce lifecycle costs of physical experimentation, and have the potential to reduce environmental impacts.

Behavioral Dose-Response Relationship and Temporary Threshold Shift in Harbor Porpoises

Project number: 20
Principal Investigator: Ron Kastelein, Sea Mammal Research Company Inc.

A variety of Navy sonar sources are audible to harbor porpoises (*Phocoena phocoena*), a small odontocete species that has a wide distribution area, acute hearing, and functional hearing over a very wide frequency range.

It is important to understand the difference between an animal hearing a sound and that sound causing an effect—either a behavioral effect or a physiological effect on hearing, known as a temporary threshold shift (TTS) or permanent threshold shift. Based on the presently available information, neither TTS (especially for frequencies above 7 kilohertz (kHz)) nor behavioral responses can be predicted for harbor porpoises due to exposure to specific signals of U.S. Navy relevance.

This project consists of two study types: a behavioral dose-response study and a TTS study. The behavioral dose-response study consists of two phases:

The Basics About the LMR Program

THE LMR PROGRAM seeks to develop, demonstrate, and assess data and technology solutions to protect living marine resources by minimizing the environmental risks of Navy at-sea training and testing activities while preserving core Navy readiness capabilities. This mission is accomplished through the following five primary focus areas:

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.

The program is sponsored by OPNAV N45 and managed by the Naval Facilities Engineering Command out of the Naval Facilities Engineering and Expeditionary Warfare Center in Port Hueneme, California.

For more information, visit the LMR program web site at www.lmr.navy.mil or contact Anu Kumar, the LMR Program Manager at 805-982-4853, DSN: 551-4853 or anurag.kumar@navy.mil.

1. Establishing the dose-behavioral response relationship for playbacks of 53-C sonar sounds at two duty cycles (2.6 and 90 percent) in quiet conditions.
2. Establishing the dose-behavioral response relationship for playbacks of 53-C sonar sounds at 2.6 percent duty cycle in three Sea State noise conditions (Sea States 0, 4 and 6).

The TTS study also consists of two phases:

1. Establishing which hearing frequency is most affected by several continuous pure tones above 8 kHz (i.e., shows the highest TTS).
2. Establishing TTS growth curves (due to sound pressure level) for each of the tested frequencies (1 hour exposures).

The results of the behavioral dose-response and TTS studies will be used to update the criteria and thresholds for harbor porpoises that are used to estimate potential exposures from Navy training and testing activities.

Refining Knowledge Supports Improved Understanding & Protection

Each of the FY15 new start projects will help the Navy refine its knowledge of how marine mammals might be affected by anthropogenic sounds. Improved data collection, management and analysis are all critical to the permitting process for Navy at-sea operations. Increasing the understanding of how marine mammals hear will inform the Navy about potential effects of different sound sources. With this information, the Navy can employ better monitoring and mitigation techniques.

The LMR program continues to help the Navy meets its training requirements while protecting the species with whom they share the oceans. Fact sheets with more information on the FY15 projects can be found under the "Project Highlights" tab on the LMR web site at www.lmr.navy.mil.

Mandy Shoemaker
Naval Facilities Engineering and Expeditionary Warfare Center
805-982-5872
DSN: 551-5872
mandy.shoemaker@navy.mil