The Living Marine Resources Program Report 2014

SCIENCE • STEWARDSHIP • NAVY READINESS

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Please note that any marine mammal photo in this report that does not explicitly include a photo credit/permit number came from a stock photo service.

INTRODUCTION

A Word from the Program Manager

Welcome to the first ever annual report for the Navy's Living Marine Resources (LMR) program. I hope this report provides you with some insights into where we've been, where we're going, and how the research sponsored by the LMR program supports the Navy's at-sea environmental compliance process.

I am honored to be designated as the new manager of the LMR program, which gives me an exciting opportunity to apply my background in bioacoustics, impacts assessments, marine species density estimation, and general marine mammal science—all skills I have been honing since August 2001. As the former head of the Marine Resource Branch at Naval Facilities Engineering Command (NAVFAC) Atlantic, I oversaw a talented group of scientists that supported the analysis and completion of the Atlantic Fleet Training and Testing Environmental Impact Statement and Marine Mammal Protection Act/Endangered Species Act permit applications, and helped to develop the U.S. Fleet Forces Command marine species monitoring program. I am excited about this new assignment and the challenges it will surely present.

Another recent addition to the LMR management team and staff at the Naval Facilities Engineering and Expeditionary Warfare Center (NAVFAC EXWC) is Mandy Shoemaker—a former colleague of mine from NAVFAC Atlantic. Mandy is already contributing wide-ranging technical and compliance expertise to the LMR program. While at NAVFAC Atlantic, Mandy focused on analyzing the potential impacts of Navy training and testing activities on marine species, preparing at-sea environmental compliance documentation, obtaining required permits and consultation documents, and helping to manage and implement the Navy's marine species monitoring program. Please join me in welcoming Mandy to the team.

Among our other accomplishments during Fiscal Year (FY) 2014, was the launch of the following nine new projects:

1. Integrated Real-time Autonomous Passive Acoustic Monitoring System (project no. 2)

2. Simple Performance-characterized Automatic Detection of Marine Mammal Sounds (project no. 3)

3. Demonstration of High-Performance PAM Glider and Profiler Float (project no. 4)

4. Development of Automated Whistle and Click Detectors and Classifiers for Odontocete Species (project no. 5)

5. Database and Metrics for Testing Automated Signal Processing for Passive Acoustic Monitoring (project no. 6)

6. Technology Demonstration for Navy Passive Acoustic Monitoring (project no. 7)

7. Improving the Navy's Automated Methods for Passive Underwater Acoustic Monitoring of Marine Mammals (project no. 8)

8. Electrophysiological Correlates of Subjective Loudness in Marine Mammals (project no. 9)

9. The Effects of Noise on Marine Mammals (project no. 10)

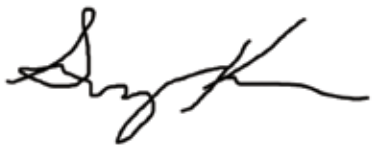
More insights into each of these and other LMR projects are provided in the "Program Investments" section of this report and on our web site at www.lmr.navy.mil.

In addition to these new project launches, we were also able to continue developing and improving internal program processes to better address Navy needs. These improvements will allow the LMR program to better accomplish the overall mission of transitioning the results of applied research for use within the Navy's at-sea environmental compliance and permitting processes.

I would like to thank Dr. Frank Stone, first for giving me the opportunity to develop a career in marine mammal science and serving the Navy, and second for creating this program. If it wasn't for his vision and tenacity in securing funding, we would not have the current state of science to use in the Navy's at-sea environmental compliance process. I would also like to thank Dr. Robert Gisiner, first for being a great mentor and second for transforming the program into its current state, which addresses new needs and a broader Navy community of representatives.

Finally, I would like to thank our resource sponsor, Chief of Naval Operations Energy and Environmental Readiness Division (OPNAV N45) and its representative Danielle Buonantony, and other members of our management team, including the Living Marine Resources Advisory Committee, for all of their efforts to launch and sustain the LMR program over the past two and a half years. Their involvement and support was invaluable during the review of the many proposals we received during this past year. They were also critical participants in our efforts to oversee the ongoing research of the program during our annual review and elsewhere. The program is more transparent and relevant to the Navy mission because they are involved.

Thanks for reading our first effort to document significant program history, our transformation, our more recent investments, and our plans for the years ahead. You'll get additional updates about the program when you subscribe to our quarterly newsletter via our website (www.lmr.navy.mil).



Anu Kumar
LMR Program Manager

PROGRAM OVERVIEW

Program Mission

In its ongoing effort to reduce potential impacts to marine mammals while meeting at-sea training and testing requirements, the U.S. Navy supports both basic and applied research to improve the understanding of marine mammals in regard to occurrence, exposure, response, and consequences. The LMR program is responsible for applied research and works to address the Navy's key research needs and transition the results and technologies for use within the Navy's at-sea environmental compliance and permitting processes, with the goals of improving marine species impact analysis (including marine mammal take estimates), mitigation measures and monitoring capabilities. Key points of the LMR mission statement are:

• Improve the best available science regarding the potential impacts to marine species from Navy activities

• Expand the technology and methods available to the U.S. Navy marine species monitoring program

• Preserve core Navy readiness capabilities.

This mission is accomplished through the following five primary investment areas:

1. Data to support risk threshold criteria
(e.g., hearing studies, sound exposure and behavioral response studies)

2. Improved collection and processing of protected species data in areas of Navy interest
(e.g., new detection and classification algorithms, PAM automated processing tools)

3. Monitoring & Mitigation Technology Demonstrations
(e.g., new passive acoustic monitoring technologies and platforms such as gliders)

4. Standards and Metrics
(e.g., standards for hearing studies, detector and classifier performance analysis standards)

5. Education and Outreach, Emergent Opportunities
(e.g., LMR website and program outreach on investments, other study topics needed by the Navy).

Program History

The LMR program traces its history back to the Navy's earliest efforts to better understand the impact of anthropogenic sound on marine mammals. In 1997, the scientific knowledge needed to establish an appropriate marine mammal monitoring and protection plan for Navy activities did not exist. The Navy initiated the Marine Mammal Research program, managed by Dr. Frank Stone, to partner with other government agencies, universities, and private industry to conduct scientific research required for monitoring and protecting marine mammals during Navy training and testing at sea.

Early on, Navy-funded research addressed broad study areas including marine mammal ecology and population dynamics, sound field characterization, and monitoring methods. The research was targeted to provide a biological baseline that could be used when assessing the effects of Navy training activities on marine mammals.

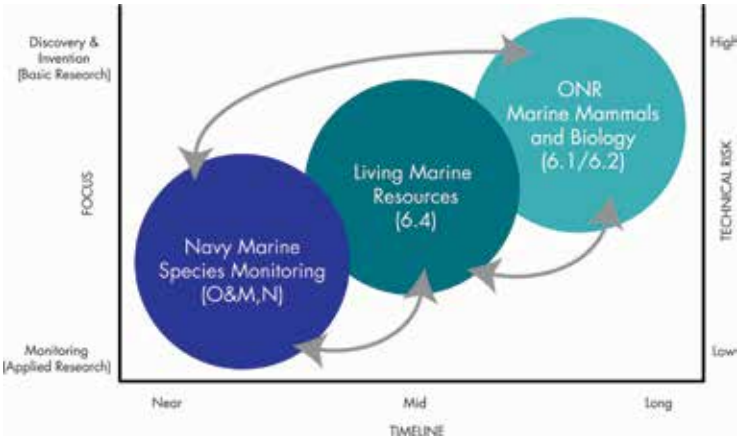
Efforts were expanded in 2000 to include a new focus on the effects of mid-frequency sonar on beaked whales—the species thought to be most sensitive to that sonar.

Between 2000 and 2007, the Navy began work to identify what information would be needed to obtain regulatory agency approvals for its major at-sea training ranges. In 2007, the research efforts were refocused to provide that type of information.

With a significantly expanded knowledge base, the distinctions among basic research (6.1 and 6.2 programs), applied research and testing (6.4 program) and Fleet monitoring applications became more clear. (For more on the distinctions among organizations responsible for marine mammal efforts, see our section "Responsibility and Coordination of

Navy's Research and Monitoring Programs.") Thus in 2012, the LMR program was created as the 6.4 applied research, development, test and evaluation (RDT&E) program and structured to address the Navy's at-sea environmental compliance needs. While OPNAV N45 remained the resource sponsor, controlling the budget and final approval authority, the program needed dedicated management and therefore a program office and manager were established at NAVFAC EXWC in Port Hueneme, California. This location afforded proximity to the Navy Environmental Sustainability Development to Integration (NESDI) program, on which the LMR program is modeled.

With Dr. Robert Gisiner as its first program manager, the LMR program took important first steps to establishing the new program. This included setting up a program office, defining Standard Operating Procedures (SOP), convening an advisory committee (the Living Marine Resources Advisory Committee (LMRAC)), issuing the first formal solicitation for research needs, and holding and documenting the first formal program review. In June 2014, Dr. Gisiner retired from federal service and Anu Kumar was selected as LMR program manager.



Responsibility and Coordination of Navy's Research and Monitoring Programs

Multiple Navy organizations are involved in developing and implementing the means to meet federal permitting requirements for Navy at-sea training and testing activities (see schematic above, Figure 1). To ensure coordinated and efficient efforts, the Navy worked with regulatory agencies, marine experts and Navy personnel to develop an Integrated Comprehensive Monitoring Plan (ICMP). The Navy's ICMP provides the overarching organizing framework for the Navy's research and monitoring efforts to better understand and monitor the potential impacts on marine species. Those efforts, working from basic research to demonstration and validation to monitoring implementation, are coordinated among the following programs:

1. ONR's Marine Mammals and Biology program

2. The LMR program

3. U.S. Navy Marine Species Monitoring program

The Office of Naval Research Marine Mammals and Biology Program

The Office of Naval Research's Marine Mammals and Biology (MMB) program is the Navy's basic (6.1) and early applied (6.2) research program on marine mammals and biology. As a basic research program, this program focuses on new cutting edge research topics, exploratory and developmental technological solutions such as new tag technology, and advancement on the state of the science. This program is credited with some the groundbreaking research that has improved our knowledge of marine species. Outcomes from this program can be transitioned directly to the Navy Marine Species Monitoring program if ready for integration or, for more complex research topics, projects are transitioned to the LMR program to continue to develop, demonstrate and validate solutions.

For more information about the ONR MMB program go to: www.onr.navy.mil/en/Science-Technology/Departments/Code-32/All-Programs/Atmosphere-Research-322/Marine-Mammals-Biology.aspx.

The Living Marine Resources Program

Relative to the Navy's other marine species programs, the LMR program focuses on late stage applied research (6.4) and seeks to develop, demonstrate, validate, and assess data and technology solutions to study living marine resources. The LMR program is structured to be customer focused and to address the needs of the Navy's environmental community. This is accomplished by the program having an advisory committee with representation consisting of Navy end users and other program managers (ONR and the Marine Species Monitoring program). ONR projects may be selected for continued development, demonstration and validation when the project is deemed ready to transition to the next stage of development. In one case, a whole research topic—hearing studies on odontocetes—was transitioned from ONR to LMR because much of the basic development has been accomplished.

For technological solutions, the LMR program is unique in that we have the capability and resources to address successful technology integration into the Navy Marine Species Monitoring program. This can be accomplished by defining technology transition agreements at the initiation of a project and setting up a transition plan that may include patent rights agreements, technological availability, end-user training, and feedback during integration.

U.S. Navy Marine Species Monitoring Program

As part of the regulatory compliance process associated with the Marine Mammal Protection Act (MMPA) and the Endangered Species Act (ESA), the Navy is responsible for meeting specific requirements for monitoring and reporting on military training and testing activities involving active sonar and the use of explosives/explosive munitions. The Navy's Marine Species Monitoring program is a direct outcome of MMPA Letters of Authorization issued to the Fleets and System Commands (SYSCOM).

For more information about the Navy's marine species monitoring efforts go to: www.navymarinespeciesmonitoring.us.

The U.S. Navy Marine Species Monitoring program typically uses tools that have already been developed under the ONR program and field tested/validated or developed by the LMR program. For example, most of the autonomous passive acoustic monitoring devices that are currently being used were developed and tested under research funding

from ONR. This was followed by field demonstrations and refinements to the devices by the LMR program. These devices are now used as a regular component of the monitoring program and represent a successful transition from basic research to the end user.

LMR Program Structure

Our structure was carefully defined to ensure robust communication among Navy commands, other program managers, and the LMR resource sponsor—OPNAV N45. The organization bolsters program communication, accountability and credibility.

Advisory Committees

The LMR program is supported by two committees—the LMR Advisory Committee (LMRAC) and the Technical Review Committee (TRC)—as described below.

LMR ADVISORY COMMITTEE

The LMRAC includes representatives from relevant Navy Fleet and System Command (SYSCOM) activities affected by at-sea issues as well as members of the Navy's research and implementation community. The LMRAC's roles and responsibilities are to:

• Collect, validate, and rank (prioritize) needs

• Obtain external stakeholder input

• Resolve questions about needs and proposals that fall within their purview

• Review and rank pre- and full proposals and provide the recommended rankings to the LMR program manager and resource sponsor (OPNAV N45) via the LMR website

• Participate in project progress reviews, including the review of project status reports, and attend the annual In-Progress Reviews

• Facilitate transition of program products to end users within their respective command structures.

The organizations represented on the LMRAC are as follows:

• Chief of Naval Operations Energy and Environmental Readiness Division (OPNAV N45)

• Office of Naval Research (ONR)

• U.S. Fleet Forces Command (USFF)

• Commander, U.S. Pacific Fleet (CPF)

• Naval Air Systems Command (NAVAIR)

• Naval Sea Systems Command (NAVSEA)

• Naval Facilities Engineering Command Headquarters (NAVFAC Headquarters)

• Naval Facilities Engineering and Expeditionary Warfare Center (NAVFAC EXWC)

• Naval Facilities Engineering Command Atlantic Division (NAVFAC Atlantic)

• Space and Naval Warfare Systems Command (SPAWAR)

• Deputy Assistant Secretary of the Navy for Energy, Installations and Environment (DASN(E))

• Deputy Chief of Naval Operations for Information Dominance (N2/N6).

TECHNICAL REVIEW COMMITTEE

The TRC consists of scientific subject matter experts from within the Navy, other federal agencies, industry or academia, as appropriate. Committee membership changes to ensure that the areas of expertise needed to review submitted proposals are provided. The TRC members are identified and called upon whenever there is a topic that requires expertise beyond the LMRAC's capabilities or there is a need for further input to fully assess the proposals. TRC members provide technical evaluation of the proposals, and advise the LMRAC during their final evaluations.

Program Office

The LMR program is managed by the Naval Facilities Engineering and Expeditionary Warfare Center (NAVFAC EXWC) in Port Hueneme, CA. The LMR program manager assumes the overall responsibility for the execution of the program and has the following specific duties:

• Communicate and address sponsor's funding priorities and make funding recommendations

• Plan and execute the program's finances and budget

• Coordinate with the LMRAC and TRC on needs, proposals, program and project materials, and project reviews

• Coordinate with other Navy research programs and external agency programs to leverage resources and address needs

• Manage projects to address needs, adhere to budget and schedule, and provide successful outcomes that are transitioned to the end users.

• Communicate externally about the LMR program mission, how to participate, our current investments and their outcomes

Resource Sponsor

The LMR program is sponsored by the Chief of Naval Operations Energy and Environmental Readiness Division (OPNAV N45). Through its RDT&E Action Officer, OPNAV N45 serves the following functions:

• Provide annual funding to support the LMR program

• Set policy and guidance for the Navy's environmental research priorities

• Approve the prioritized list of needs and authorize new starts

• Participate in the LMRAC to select new and evaluate ongoing projects

• Coordinate with other agencies.

Program Process

The LMR program follows a formal process each year—from identifying Navy needs to transitioning solutions into the Navy's at-sea environmental compliance process. These steps are described in more detail below.

Identify Navy Needs

The LMR program bases its investments on environmental needs that 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.

Anyone within the Navy may submit needs for consideration by the LMR program (a guide for submitting needs is available at www.lmr.navy.mil under "Needs"). Submitted needs are validated and ranked by the LMRAC, and then recommendations are made to the OPNAV N45 resource sponsor. Selected needs are included in the request for proposals via a Broad Agency Announcement (BAA).

Issue BAA to Solicit Pre-proposals

The program solicits new proposals through the BAA, which is posted in Federal Business Opportunities (www.fbo.gov). Concurrently, the program announces the solicitation both within and outside the Navy via the LMR website and scientific community automatic email distribution lists.

Navy laboratories, academic institutions, businesses, and other qualified public and private sector applicants interested in responding to a statement of need are required to submit a pre-proposal using the web-based template.

Review Pre-proposals & Full Proposals

The LMR program manager distributes the proposals for review by members of the TRC and LMRAC. Proposals are submitted and reviewed as part of a two stage process. Pre-proposals allow for the quicker evaluation of the technical merit, appropriateness, feasibility, and overall budget of the proposed project. If the LMRAC is interested in a pre-proposal, we will request a full technical proposal including a detailed plan and budget. The full proposals are ranked by the LMRAC and selected projects are identified for OPNAV N45 concurrence.

In addition to the Federal Acquisition Regulation criteria requirements, considerations include overall LMR investment portfolio balance, relative impact to the Navy, likelihood of success, and likelihood of successful transition to the Navy's at-sea environmental compliance process.

Initiate Projects

Once the final list of approved full proposals has been agreed upon by the LMRAC and approved by OPNAV N45, the LMR program manager begins the process of initiating the projects. Shortly after funding has been received, a project kick-off meeting takes place to discuss the project management plan, which includes details such as project milestones, spending plan and financial expectations, and reporting requirements.

Regularly Monitor Project Progress

The LMR project manager is responsible for monitoring the cost, schedule, and performance of the project, while the PI is responsible for executing the project on schedule and within budget.
All projects must comply with LMR program reporting requirements. Specific reporting requirements include:

• Project management plan (PMP) – to be completed before work is begun

• Transition plan and associated agreements

• Quarterly project status report on the LMR web site

• In-Progress Review meeting presentation.

Transition/Integrate Solutions

Before the start of a new project, a transition plan is developed to articulate the plan for integrating the results or technology developed for further use within the Navy's at-sea environmental compliance process. When the project results demonstrate that an approach can successfully meet Navy needs, the program works to move the demonstrated solutions out of research and into the hands of the appropriate Navy end-users. This stage represents the final step in the process with continued monitoring by the LMR program of the success and feedback from the integration.

Some of the conditions that define successful integration include:

• Project provides a feasible, desirable solution to the end-user

• Stakeholders or end-users have accepted and integrated the solution

• Funding has been planned for and is in place for transition

• Customer satisfaction has been assessed and documented

• Benefit metrics have been re-assessed and validated.

Mark Deakos; NMFS permit #14451

Management and Communication Tools

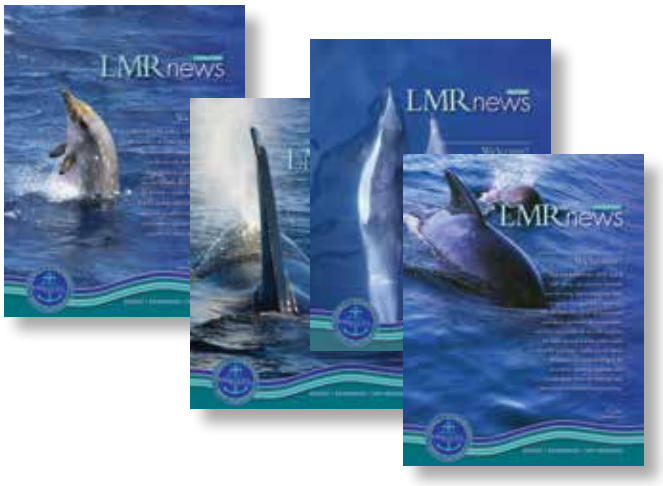
LMR Web Site

The program web site (www.lmr.navy.mil) provides a centralized repository for information pertaining to the management of the program and the execution of our projects. The site promotes the latest information about critical deadlines, project successes and other information essential to key program personnel from across the Navy. The web site also allows personnel from other R&D programs to obtain up-to-date insights into the LMR program's priorities and ongoing projects.

The site includes both a public section and a management section. The public section includes links to program details, defined environmental needs, pre-proposal dates and processes, project highlights, and our newsletter, *LMR News*. The home page also lists program happenings. The management side of the site, which requires a user account login, is a work flow application that serves all aspects of program management. It provides a collaborative interface that program participants can use to review and evaluate needs, proposals and project progress in order to support sound program investment decisions.

Quarterly Newsletters

The LMR program issues a quarterly newsletter, *LMR News*, to provide readers with the latest information about program operations, significant accomplishments, milestones, and future investment areas for the LMR program. The digital newsletter can be viewed at the LMR web site. Subscribers are notified by email when a new issue is available.



Project Fact Sheets

Fact sheets highlighting key aspects of LMR-funded projects offer a quick view into program investments. The fact sheets, available on the LMR web site, provide a summary of the following for each project:

- The need it addresses
- The solution
- The methodology
- The schedule
- Navy benefits
- Transition steps
- Information about the Principal Investigator(s).

In-Progress Review

Each Principal Investigator is required to provide a technical briefing to the LMRAC and invited TRC subject matter experts at the program's annual In-Progress Review (IPR). IPRs are typically held in early fall, after most field season efforts have concluded. The objective of these IPRs is to review project progress, technical issues and accomplishments, integration issues and accomplishments, and to determine if any corrective actions are needed. A template for preparing an IPR presentation is provided on the LMR web site.

Annual Programmatic Review

The LMR program manager delivers an annual programmatic review to the program's resource sponsor, OPNAV N45. The review provides information on the status of the program overall as well as the status of ongoing projects. It notes accomplishments, needs, financial trends, budgeting issues, and the outlook for the future. The review provides the opportunity for the program manager and resource sponsor to confirm priorities and direction, make any mid-course corrections needed, and plan for the future to ensure that the program remains on track to meet the Navy's needs.

PROGRAM INVESTMENTS

The LMR program and its predecessor programs have funded a number of RDT&E efforts to improve the understanding of the occurrence, exposure, response, and consequences to marine mammals relative to Navy at-sea training and testing activities. The following sections give an overview of new initiatives, ongoing projects, partnership projects, and completed projects for FY14.

New Initiatives

The LMR program launched the following nine projects in FY14 (Note: LMR project no. 1 was set aside to track ongoing program management expenditures.) Details about the projects listed below are provided on the following pages.

1. Integrated Real-time Autonomous Passive Acoustic Monitoring System (project no. 2)

2. Simple Performance-characterized Automatic Detection of Marine Mammal Sounds (project no. 3)

3. Demonstration of High-Performance PAM Glider and Profiler Float (project no. 4)

4. Development of Automated Whistle and Click Detectors and Classifiers for Odontocete Species (project no. 5)

5. Database and Metrics for Testing Automated Signal Processing for Passive Acoustic Monitoring (project no. 6)

6. Technology Demonstration for Navy Passive Acoustic Monitoring (project no. 7)

7. Improving the Navy's Automated Methods for Passive Underwater Acoustic Monitoring of Marine Mammals (project no. 8)

8. Electrophysiological Correlates of Subjective Loudness in Marine Mammals (project no. 9)

9. The Effects of Noise on Marine Mammals (project no. 10)

Ernesto Vazquez; NMFS permit #14251, CRC permit #16111

PROJECT NUMBER 2

Integrated Real-time Autonomous Passive Acoustic Monitoring System

Expanding Autonomous Acoustic Monitoring Capabilities

PRINCIPAL INVESTIGATORS: PHIL ABBOT AND VINCE PREMUS

Currently, most Passive Acoustic Monitoring (PAM) undertaken as part of a marine mammal monitoring program is done with single hydrophones. Recently, new sensor array and embedded processor technology has become available that will offer increased detection range performance, spatial resolution, and if successful, improved density estimation. There is a growing need (identified as need N-0006-13) to research, demonstrate, and validate improved PAM using this new technology.

To answer this call, Phil Abbot and Vince Premus from Ocean Acoustical Services and Instrumentation Systems, Inc. (OASIS), are leveraging hardware and software they have developed under the sponsorship of the Office of Naval Research (ONR) over the past five years for the purpose of autonomous acoustic surveillance using Autonomous Undersea Vehicles (AUV).

The IRAP system during a dockside dip test. The LF sensor is coiled and suspended at the vehicle mid-section. The HF sensor is located on the underside of the vehicle a couple of feet aft of the nose.

The OASIS approach utilizes new acoustic sensor and digital signal processing (DSP) technology, as well as existing vehicle hardware developed and maintained by the Woods Hole Oceanographic Institution. These sensor and DSP technologies have previously been demonstrated using Slocum 100 and G2 gliders as an AUV, and have been used to demonstrate real-time detection of humpback whales.

For this project, the team is utilizing a self-propelled AUV known as the REMUS, which has previously been used for underwater mapping and mine detection. The REMUS AUV offers several advantages over the Slocum glider. It can travel faster (up to 3.5 knots), cover a much larger survey area, and it possesses the battery capacity to support sensor and DSP deployment for several days. As it is self-propelled, the REMUS can operate in the presence of currents, following any predetermined course. This stands in contrast to the glider, whose course is often subject to the local current distribution and the density profile of the water column.

The REMUS AUV can operate in the presence of currents, following any predetermined course.

The Integrated, Real-time Autonomous PAM (IRAP) system will consist of a REMUS AUV, integrated with the OASIS low- to mid-frequency (LF/MF) towed sensor and a hull-mounted High Frequency (HF) sensor. Both sensors will include onboard DSPs for the autonomous detection, classification, localization, and tracking (DCLT) of vocalizations from lower frequency baleen whales and higher frequency beaked

whales. DCLT contact reports will be transmitted in near real-time from the vehicle payload when surfaced, to a shore-side command and control facility via satellite. Key to the system is the autonomous processing of raw acoustic data performed by custom software hosted on an embedded, commercial-off-the-shelf computer.

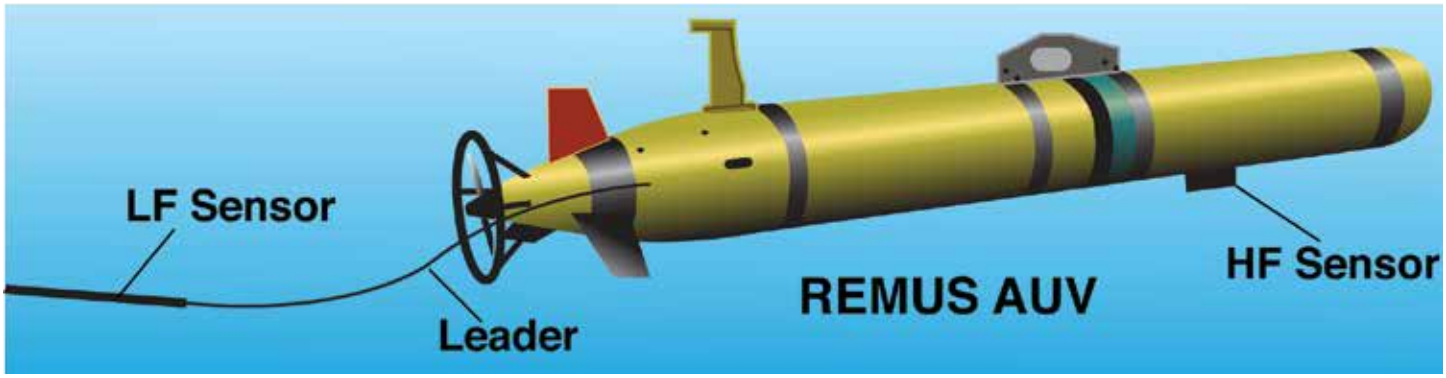
The objective of this project is to integrate and demonstrate the technology over the course of three years. Currently, the focus is on the integration of the LF/MF sensor and the humpback whale classifier (one of the marine mammal-specific classifiers previously developed and demonstrated under ONR sponsorship) into the existing REMUS AUV payload. Concurrent with this, the project team will complete data analyses for the 2013 OASIS HF sensor/G2 sea trials performed at the Navy's Atlantic Undersea Test and Evaluation Center (AUTEC).

In the second year, the integrated LF/MF/HF system will be demonstrated during an operational test as part of a regularly scheduled National Oceanic and Atmospheric Administration marine mammal survey on the East Coast. Also during year 2, a beaked whale classifier will be integrated into the HF sensor's DSP.

In the third year, the beaked whale classifier and OASIS IRAP sensors will be integrated into the REMUS AUV payload and the full IRAP system will be tested in conjunction with a full-scale U.S. Navy fleet test.

Successful demonstration of autonomous DCLT for humpback and beaked whales will provide the basis for future system enhancements such as the integration of autonomous classifiers for a wide variety of other marine mammals, such as dolphins and other odontecetes.

The autonomous system will have the ability to track low-frequency baleen and high-frequency beaked whales while simultaneously monitoring the operation of mid-frequency active sonar, thereby mitigating possible harm to these animals caused by the use of active sonar during at-sea exercises. Due to its mobility and broadband frequency coverage, the IRAP system is expected to improve detection coverage relative to single-channel systems, thus improving the accuracy of existing animal density estimation techniques.



Concept for IRAP system showing the Low-Frequency Towed Array and High-Frequency Hull Mounted Array (HFA) and the Remus 600 vehicle.

PROJECT NUMBER 3

Simple Performance-characterized Automatic Detection of Marine Mammal Sounds

Simplifying the Software

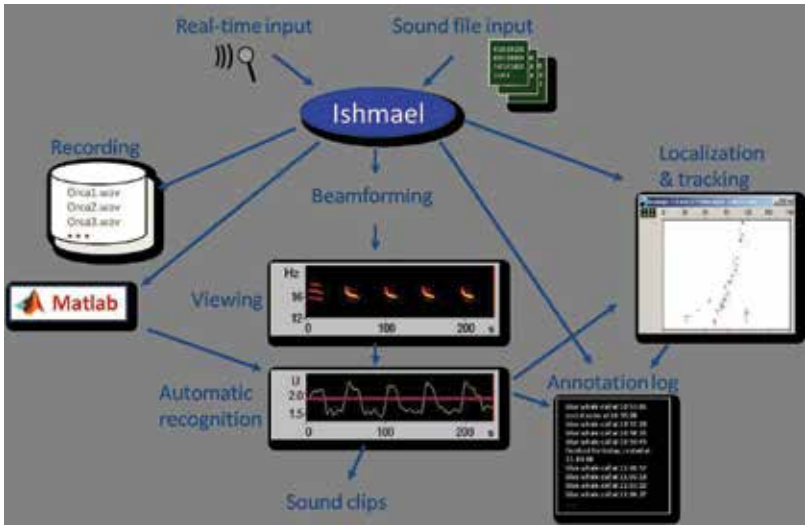
PRINCIPAL INVESTIGATOR: DAVE MELLINGER

As Passive Acoustic Monitoring (PAM) technology has advanced, long-term continuous monitoring systems have created large volumes of data. Interpreting this data is not an easy task, and often requires subject matter experts. A need has been identified within the LMR program (need no. N-0020-13) to develop, test, and evaluate existing or new PAM signal processing systems designed for users with relatively little or no subject matter expertise.

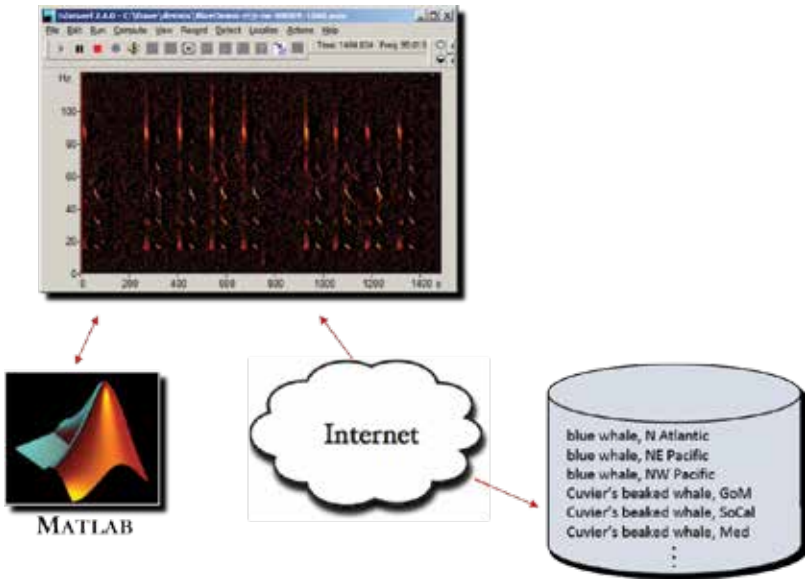
To meet this need, a project team headed by Dave Mellinger of Oregon State University is creating a database of performance-characterized detectors/classifiers for many marine mammal species that can be integrated into the current PAM software package, Ishmael.

The Ishmael program, originally developed by Mellinger with funding from the Office of Naval Research, is one of the most popular bioacoustics programs used in the field today, and has been recently upgraded. It includes displays of sound waveforms and spectrograms, recording capability for real-time input, and several methods for acoustic localization and automatic call recognition.

The detectors/classifiers currently in the PAM system database will be characterized and evaluated by testing them against sound files found in MobySound.org, a publicly accessible archive of sound recordings of over 35 marine mammal species. MobySound recordings have been annotated to indicate where (in time and frequency) each call occurs and what its signal-to-noise ratio is—information crucial to evaluating detector/classifier performance. This broader,



Components of Ishmael.



Ishmael's links to detector/classifier database, and to MATLAB for running the detectors/classifiers.

An online database of detectors/classifiers will be built for sperm, beaked, and baleen whales. (Tim Cole; NMFS permit #775-1600-10)

deeper and easier-to-use signal processing system will enable any Ishmael user to detect sounds coming from a species or subspecies of interest in a specific area.

First, the software interface within Ishmael is being enhanced so that it can communicate seamlessly with MATLAB, a language widely used to easily implement detectors and classifiers. Then, an online database of detectors/classifiers will be built for beaked, sperm, and baleen whales as well as a number of delphinids (small to medium cetaceans, such as pilot whales, dolphins, etc.). These detectors/classifiers will then be tested against the sound files in MobySound to provide performance information for each one. By early 2017, an Ishmael-to-database interface will be created to display detectors and performance data in Ishmael and make it simple to download and install any of the available detectors/classifiers.

A relatively naive user will be able to sit down, choose what species to monitor, and the system will provide detections and other performance measures for those species.

This will be followed by documentation and training for Navy personnel and private (contractor) marine mammal observers as well as regulators who are involved in Navy mitigation issues. Training will be provided by adding a new module to the existing Bio-Waves training course for passive acoustics technicians. Stand-alone training on the new software will also be available.

When this new software is integrated into Ishmael, a relatively naive user will be able to sit down, choose what species to monitor, and the system will provide detections and other performance measures for those species.

Having a system for marine mammal detection that is both straightforward to use and well-characterized will make adoption of acoustic monitoring faster, easier, and therefore more widespread within the Navy, enabling easier compliance with environmental law and practice.

PROJECT NUMBER 4

Demonstration of High-performance PAM Glider and Profiler Float

Toward Autonomous Monitoring

PRINCIPAL INVESTIGATOR: HARU MATSUMOTO

The Passive Acoustic Monitoring (PAM) programs being conducted on Navy ranges employ a variety of platforms, from fixed seafloor hydrophones—which limit the range of detection coverage—to hydrophone arrays that are towed, mounted on platforms, or drifting. There is a need (LMR need no. N-0006-13), to research, demonstrate and validate improved PAM technology.

This project will demonstrate two autonomous PAM platforms based on commercially available gliders and profiler floats; platforms which would allow the Navy to cost-effectively monitor marine mammals anywhere in the world including remote and non-instrumented training areas.

Both platforms will include an acoustic system that was developed by Oregon State University (OSU) with funding from the Office of Naval Research (ONR). The OSU PAM board is based on an advanced digital signal processor (DSP) and low noise pre-amplifier that achieve a signal-to-noise ratio higher than 96 decibels. The electronic noise level of this system is well below the ambient noise level of a typical calm ocean, maximizing the listening range and detection performance in a wide variety of ocean conditions. This system's listening capability covers the frequency range of almost all cetaceans except for porpoises.

The DSP system has already been used in previous work sponsored by ONR with the APEX float from Teledyne Webb Research. This project will compare the APEX float with the Seaglider from Kongsberg. Both platforms are buoyancy-driven, deep-diving vehicles capable of descending to 1,000 meters (glider) and 2,000 meters (float). While gliders can be steered remotely, profiler floats simply drift with the ocean current. The advantage of the float lies in its comparatively low cost, approximately 25 percent of the cost of a glider. Although the two mobile platforms are acoustically quiet, there are differences in body shape, steering mechanism, water flow, pump and motor activities, and internal electronics noise. These differences likely impact the passive acoustic performance of the systems and need to be examined and evaluated.

This system's listening capability covers the frequency range of almost all cetaceans except for porpoises.

Acoustic float descending during the off-Hawaii test. (Photo Credit: Ben Allsup)

Earlier ONR-sponsored tests at the Atlantic Undersea Test and Evaluation Center and the Southern California Offshore Range (SCORE) revealed that the deep operational capability of the APEX float can result in increased beaked whale detection ranges. Therefore, an additional goal of this project is to provide a more robust acoustic data set for the presence, distribution and density estimation of beaked whales.

The first task undertaken under this project, headed by Haru Matsumoto of OSU, was to integrate the OSU PAM board with the Seaglider. After the acquisition of two Seagliders, OSU conducted the first engineering test of a PAM-installed Seaglider off the Oregon coast in October 2014. The test provided valuable data on the system which will be used to enhance its detection capability. In spring of 2015, a two-week test will be conducted to compare the Seaglider's capabilities to those of a bottom-moored High-frequency Acoustic Recording Package (HARP) at the Quinault Training Range in Washington State. Subsequently, both platforms will be demonstrated along with efforts of the Marine Mammal Monitoring on Navy Ranges (M3R) program at SCORE.

At the end of this project, a detailed report will be issued comparing the performance of each system with the HARP and M3R systems. A detailed installation and user's guide will also be developed. This will allow potential end-users, including the Navy, to buy the PAM board and hydrophone and to send it to the corresponding manufacturer for installation on a float (Teledyne Webb) or a Seaglider (Kongsberg).

This technology will enable the Navy to monitor marine mammals cost effectively in real time, in areas of interest where cabled hydrophone arrays are not available or poor weather conditions prohibit ship-based visual observation.

The Kongsberg Seaglider. The hydrophone is located on the orange antenna.

The PAM board installed in the Kongsberg Seaglider.

PROJECT NUMBER 5

Development of Automated Whistle and Click Detectors and Classifiers for Odontocete Species

Tracking Clicks and Whistles

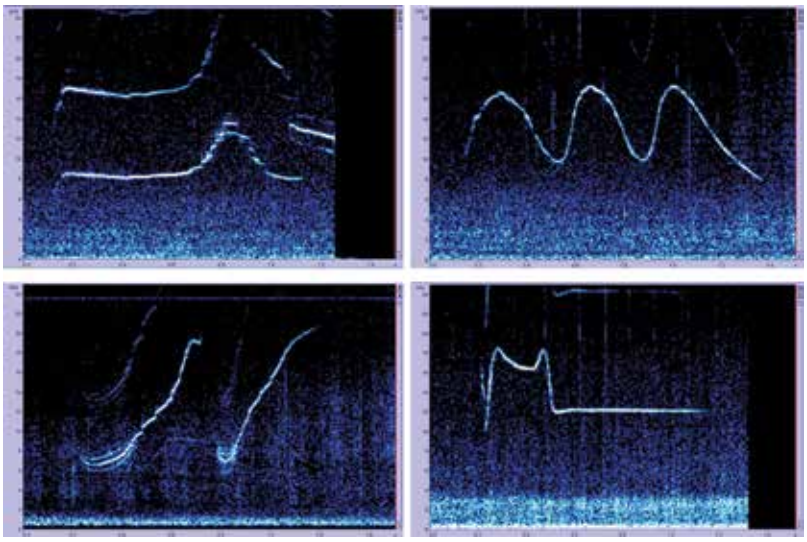
PRINCIPAL INVESTIGATORS: JULIE OSWALD AND TINA YACK

The Navy's current, state-of-the-art Passive Acoustic Monitoring (PAM) systems generate huge volumes (many terabytes/year) of data. In order for this technology to be efficiently utilized; reliable, automated software for detection and classification of sounds produced by marine mammals is needed.

To address this need (LMR need no. N-0020-13), two senior scientists from Bio-Waves, Inc. are advancing the science of automatic detection and classification by adding capabilities to existing software for acoustic analysis by developing a suite of fully automated classifiers to identify sounds produced by odontocetes (toothed whales such as dolphins, beaked whales and sperm whales).

The variability inherent in many sounds produced by odontocetes and the overlap in time-frequency characteristics among species makes it difficult for a software program to automatically detect and classify these sounds. Sounds produced by odontocetes can be grouped into one of two broad categories: whistles and pulsed sounds (i.e. clicks).

Previously, separate whistle and click classifiers have been developed for specific dolphin species. However, not all species produce whistles, or they may only produce whistles or clicks in specific behavioral contexts. Therefore, an automated classifier that includes information from both whistles and clicks would advance the science of automatic classification. In addition, including information about acoustic behavior and the specific location where a recording was made may also increase classification success. A classifier that is able to combine information from different types of sounds as well as information pertaining to behavior and location may be more successful in identifying species than one that only considers one sound-type at a time.



Spectrogram of whistles produced by striped dolphins, illustrating some of the variability that exists in whistle structure.

The Principal Investigators for this project, Julie Oswald and Tina Yack, of Bio-Waves, Inc., are working to develop classifiers that use information from whistles and clicks as well as variables related to location and acoustic behavior to classify acoustic encounters with odontocete species on several naval ranges.

Using acoustic recordings from the Western Atlantic Ocean, the team will first detect/extract whistles using three different automated tonal detectors. The output of the three automated detectors will be tested and compared for accuracy. The detector that exhibits the best performance will then be integrated with the existing whistle classifier software, Real-time Odontocete Call Classification Algorithm (ROCCA), currently available as a module in the marine mammal passive acoustic processing program, PAMGuard. This detector will be used to automatically detect and extract whistle contours to be analyzed with ROCCA's random forest classification algorithm. ROCCA currently includes automated and semi-automated classifiers for

An automated classifier that includes information from both whistles and clicks would advance the science of automatic classification.

The variability inherent in many sounds produced by odontocetes such as striped dolphins makes it difficult to automatically detect and classify them.

whistles produced by some species in the tropical Pacific Ocean and the Western Atlantic Ocean; however, not all species in those regions are currently included and these classifiers do not include click or behavior and location information.

Clicks will be detected and measured using PAMGuard's automated click detector. The click detector will send measurements to ROCCA for classification analysis. Finally, in a related effort funded by the Office of Naval Research (ONR), 'behavior and location' feature vectors will be created and tests will be run to determine how best to include them in the classifier.

When whistle, click and behavior/location feature vectors have been produced, the next step will be training and testing of classifiers that identify encounters to species based on all of the available feature vectors for an encounter. Classification models will be trained and tested during the ONR portion of this project using data from the Northwest Atlantic and Hawaii. The classification approach developed during the ONR portion of the project will then be used to create classifiers for species in the temperate Pacific Ocean. This portion of the project will be funded by the LMR program.
At the end of the project, all new classifiers will be integrated into PAMGuard and another software platform for processing acoustic data, Ishmael. Current users of PAMGuard and Ishmael software will be able to download the updated versions as soon as they are available. At this point, it is hoped that the project will be expanded so that classifiers can be developed for the Mediterranean and/or the Gulf of Mexico region in addition to the three regions discussed above.

The fully automated methods developed under this project will significantly reduce the time and cost required for the processing of PAM data. In addition, adding classifiers for clicks and behavior/location data is expected to enhance the ability to more accurately and completely classify acoustic encounters with odontocete species and provide a more accurate representation of species distribution on and around navy training ranges.

PROJECT NUMBER 6

Database and Metrics for Testing Automated Signal Processing for Passive Acoustic Monitoring

Collecting Data, Building Algorithms

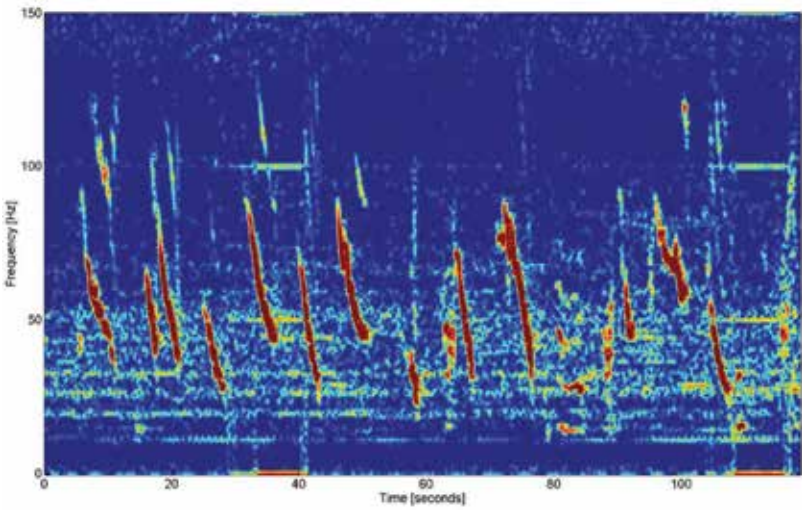
PRINCIPAL INVESTIGATORS: JOHN HILDEBRAND AND ANA SIROVIC

As Passive Acoustic Monitoring (PAM) technology has advanced, long-term continuous monitoring systems have created large volumes of data and the need for concomitant advances in data curation, search, analysis, and visualization. This need has been identified as LMR need no. N-0020-13.

One of these continuous monitoring devices, the High-frequency Acoustic Recording Package (HARP), was co-developed by John Hildebrand, one of the Principal Investigators for this project. The HARP system, currently used on several Navy ranges, stores up to 10 terabytes (compressed storage) of data. (This capacity will increase in the near future. See the related project, "Technology Demonstration for Navy Passive Acoustic Monitoring.")

Processing such a massive amount of data is a difficult and time-consuming task and requires trained users. This project intends to simplify the data management process so that non-expert users can access and process the data gathered by monitoring systems. The current state-of-the art for processing large PAM data sets in the Navy is a hybrid between manual scanning of the data and automatic call detection. This approach allows accurate analysis of large data volumes—and is the baseline against which the efficiency of automatic detection and classification algorithms must be compared.

This project intends to simplify the data management process so that non-expert users can access and process the data gathered by monitoring systems.



This spectrogram is a visual display of a type of blue whale call often made during foraging.

This project will develop metrics for assessing the performance of existing and future data processing algorithms for PAM data. To do so, the team will construct marine mammal sound datasets specific to each naval training area, then compose a standardized set of metrics to assess the performance of both existing algorithms and potential new algorithms.

During the first year, the project team is compiling an extensive set of training and test data based on acoustic recordings already collected at naval training areas on the west coast. In later years, they will examine data from the east coast and central/western Pacific. This work will be undertaken by co-Principal Investigators John Hildebrand, Simone Baumann-Pickering and Ana Širovic of Scripps Institution of Oceanography, and Marie Roch of San Diego State University.

Each dataset will be focused on particular species and signal types, and will sample the range of variability of the signal, the ocean noise environment in which the signals occur, seasonal variables, and the contribution of variations in the recording system. The team is focusing on species that are found across multiple naval training sites, that are relatively ubiquitous, and whose signals are well characterized—such as blue, fin and humpback whales, a variety of beaked whales, and Risso's dolphins. A category of unidentified cetacean signals will also be labeled.

The team will focus on species, such as humpback whales, that are found across multiple naval training sites and have well-characterized signals.

These data will be shared with the marine mammal researcher community for use in developing automatic algorithms related to call detection and classification. This protocol follows the well-developed path of the Advanced Processor Build program utilized in the Anti-Submarine Warfare community.

A parallel effort will engage the marine mammal detection and classification community to develop a standardized set of metrics for evaluating automatic detector and classification outputs. The first year will focus on metrics for baleen whale calls. Later years will consider odontocete (toothed whale) signals. These metrics will then be universally applicable to both existing and potential new automatic detection algorithms for specific baleen whale calls and odontocete signals.

New algorithms can be promulgated to all Fleet PAM operators once they have been demonstrated to provide the necessary recall and precision for a particular species call.

The ultimate goal is to develop a comprehensive dataset of marine mammal calls for use in the development of robust detectors and classifiers.

The ultimate goal is to develop a comprehensive dataset of marine mammal calls for use in the development of robust detectors and classifiers—one that covers the full range of species of interest at every training location. Automated methods to detect and classify marine mammal sounds would simplify data analysis and reduce data processing costs.

PROJECT NUMBER 7

Technology Demonstration for Navy Passive Acoustic Monitoring

New Passive Acoustic Monitoring Interface Will Provide Over Three Times the Data Storage

PRINCIPAL INVESTIGATORS: JOHN HILDEBRAND AND SEAN WIGGINS

The Passive Acoustic Monitoring (PAM) programs being conducted on Navy ranges employ a variety of platforms, from single hydrophones to hydrophone arrays that are towed, mounted on platforms, or drifting. There is a need (identified as LMR need no. N-0006-13) to review the pros and cons of existing systems, analyze their performance and total costs, and if needed, propose alternative PAM systems.

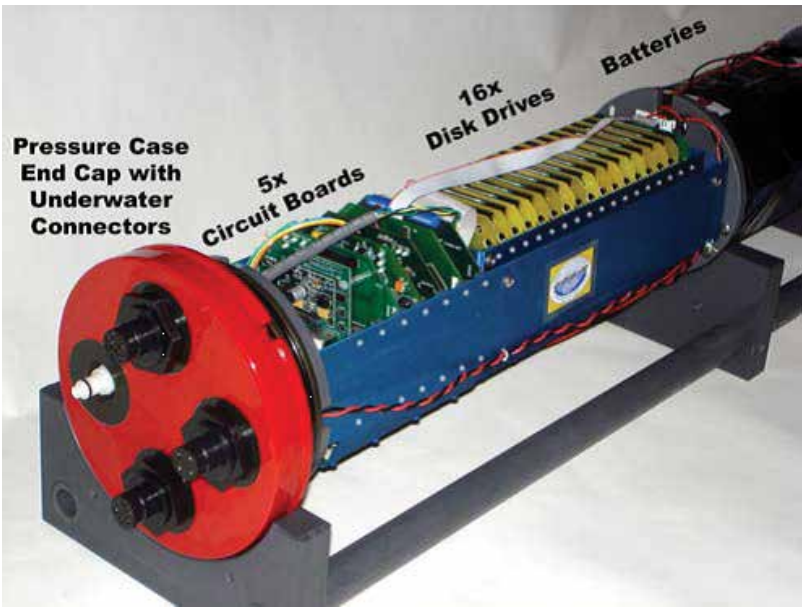
The challenge is designing a PAM system that will collect data at ample bandwidth (greater than 100 kilohertz (kHz)) to detect all marine mammal sounds and with adequate data storage so that sensors may be deployed continuously with infrequent servicing.

The High-frequency Acoustic Recording Package (HARP), currently used on several Navy ranges, is a state-of-the-art recording system that features high bandwidth (up to 160 kHz) and large data storage (5 terabytes (TB)) combined with low power requirements. However, evolving mass storage capabilities have rendered the current HARP storage media obsolete. This project team will modify the HARP for new storage media and thereby increase the storage capacity of the Navy's HARP systems.

Current HARP data storage is based on Integrated Drive Electronics (IDE), a standard electronic interface for disk storage devices. The American National Standards Institute name for IDE is Advanced Technology Attachment (ATA).

More recently the Serial ATA (SATA) interface has become the industry standard. Serial ATA offers several advantages over the parallel ATA interface: reduced cable size and cost, along with faster and more efficient data transfer. The current HARP system has a maximum storage capacity of 5 TB or 10 TB compressed storage. Once the SATA interface is installed, storage capacity will be increased to 16 TB (32 TB compressed) based on currently available hard disk drives. It is anticipated that this capacity will increase as disks with larger capacities become available, as has been the case for this technology throughout the years.

This project team will modify the HARP for new storage media and thereby increase the storage capacity of the Navy's HARP systems.

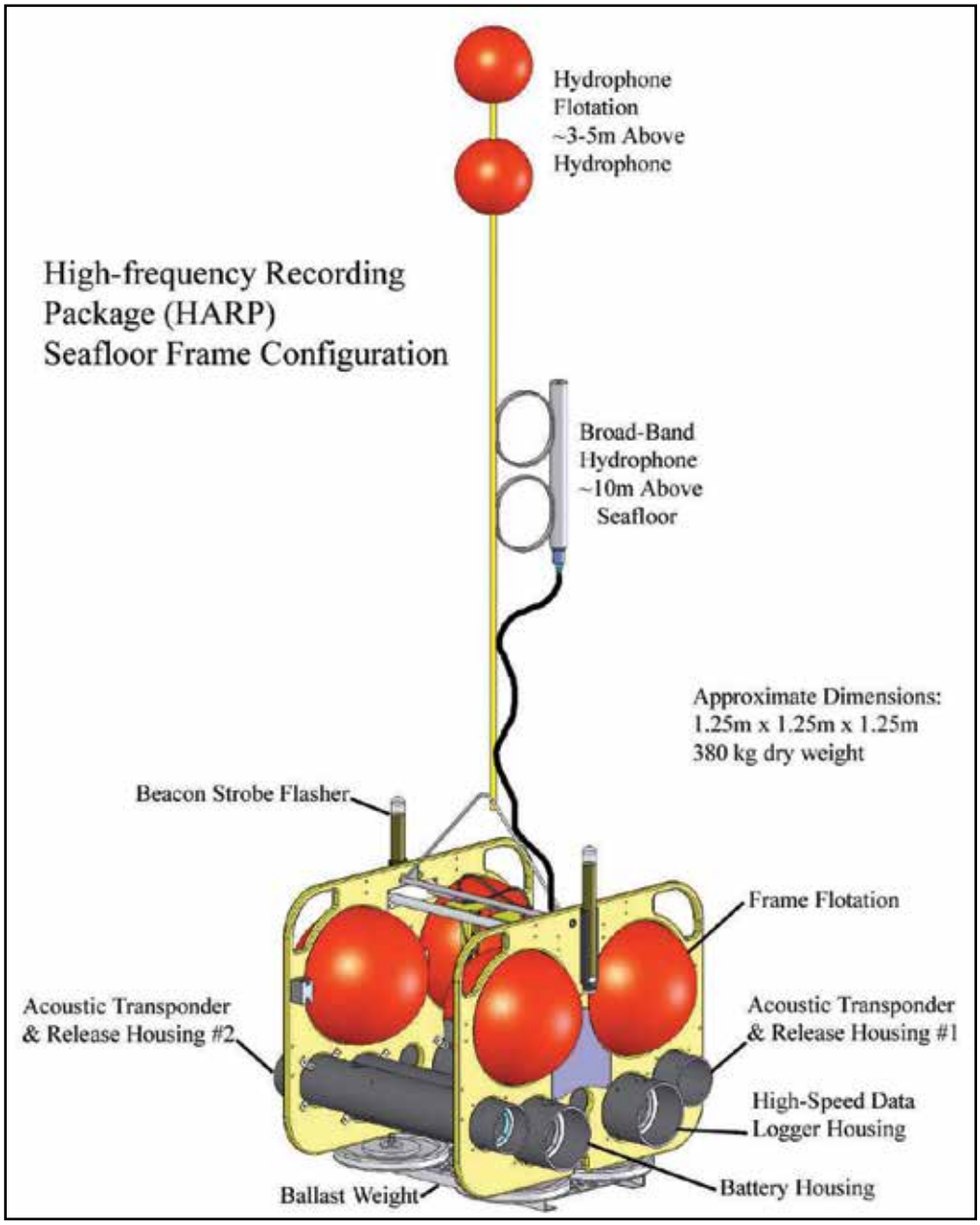


The current HARP data logger electronics attached to a pressure housing endcap with electrical feed-thru connectors. The modular data logger consists of five removable circuit boards to allow for ease in upgrading and repair, and an array of 16 IDE hard disk drives for long-term high-bandwidth data storage. Also shown is a battery pack for autonomous power using either alkaline or lithium primary cells.

This project team, headed by John Hildebrand of the Scripps Institution of Oceanography, will first design the HARP electronic disk interface. Subsequently, it will be installed on a HARP system and tested, first at sea, and then on a Navy range. After a deployment of several months, data from the new system will be analyzed. Assuming acceptable performance, the SATA drives will be installed on all 13 existing Navy HARP systems.

The modular nature of the HARP electronics should allow upgrading by replacement of a select set of electronics boards, rather than the need to replace the entire system.

Upgrade of currently deployed HARPs for SATA disk storage capacity will yield reduced costs per deployment and potentially fewer service trips for sites that are difficult or expensive to access. The project is expected to be completed in the spring of 2016.



The HARP seafloor frame configuration was developed by Sean Wiggins and John Hildebrand at Scripps Institution of Oceanography.

PROJECT NUMBER 8

Improving the Navy's Automated Methods for Passive Underwater Acoustic Monitoring of Marine Mammals

Leveraging Existing Algorithms to Improve Digital Signal Processing

PRINCIPAL INVESTIGATOR: TYLER HELBLE

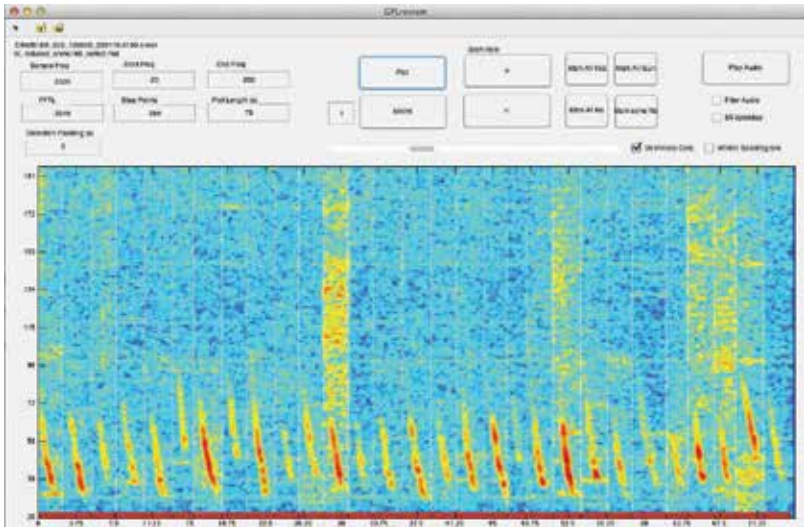
This project is applying the analytical methods and approaches used to develop optimal detectors for signals of interest for active and passive sonar systems to the Passive Acoustic Monitoring (PAM) systems that the Navy uses to monitor marine mammal populations.

As PAM technology has advanced, long-term continuous monitoring systems have created large volumes of data and the need for concomitant advances in data curation, search, analysis, and visualization. This need has been identified within the LMR program (as need no. N-0020-13).

To address this need, a project team headed by Tyler Helble of the Space and Naval Warfare Systems Command, Systems Center Pacific, is tapping into the Navy's larger sonar/radar signal processing community.

The team is focusing primarily on the Generalized Power Law (GPL) processor, the optimal detector for transient signals, or signals with unknown frequency content, location, duration, and strength. The GPL processor has been used with great success in the collection of humpback whale data by autonomous High-frequency Acoustic Recording Packages (HARP) that are currently being used for PAM at several Navy testing and training ranges.

Conventional detection of humpback vocalizations is often based on the assumption that energy (square of the Fourier amplitude) is the



Spectrograms of GPL detections shown in the graphical user interface (GUI) for blue whale foraging calls. The GUI allows the operator to quickly accept/reject detections provided by GPL.

appropriate metric. Power-law detectors allow for a higher power of the Fourier amplitude, appropriate when the signal occupies a limited but unknown subset of these frequencies. Simply stated, sound in the ocean is rarely stationary, and a power-law metric is a more accurate way of isolating and identifying specific sounds.

Raw counts of marine mammal call detections by themselves can be very misleading. They should be corrected for variability in environmental properties before any interpretations can be made. For instance, when ocean noise levels are very low, more humpback whales are detected. However, while the probability of detection rises during these time frames, the animals may very well have been present all along.

Raw counts of marine mammal call detections by themselves can be very misleading.

The GPL processor is able to detect weak transient whale vocalizations in the presence of considerable anthropogenic and biological noise. This has proven to hold true even during periods of U.S. Navy mid-frequency active sonar transmissions typical in U.S. Navy training events. (Advanced Methods for Passive

Acoustic Detection, Classification, and Localization of Marine Mammals (Klay, Mellinger, et al))

Any algorithms developed for GPL processing are constrained by the need for pre-processing adaptation to accommodate the noise environment at each location, as well as noise created by the platform itself. In addition, ocean bathymetry greatly influences PAM readings. For these reasons, the creation of a fully automated system is not feasible. This project will design a system that "calls out" potential signals of interest for examination by a human operator.

Working closely with other LMR-sponsored project teams, the team will first adjust GPL algorithms for use with specific marine mammals and then test and implement these algorithms using data from existing Naval Facilities Engineering Command PAM systems, including the Southern California Offshore Range (SCORE) and the Pacific Missile Range Facility (PMRF) in Hawaii.

To date, the project team has tuned and calibrated the GPL detectors for three species of marine mammals at the PMRF in Hawaii and three species from HARP recordings deployed throughout southern California. Whale track lines have also been provided for humpback whales on the PMRF range. The next step will be to provide calibrated call counts for three species on the HARP recordings, and whale track lines for three species on the PMRF range. The project will be completed by the end of the Fiscal Year 2016.

This project will improve the Navy's PAM capabilities in two critical areas. First, it will implement robust, automated detectors optimized for specific marine mammal species that will

The GPL processor has been used with great success in the collection of humpback whale data.

vastly reduce the time and cost for human operators to manually examine a data set. The use of such detectors also provides an objective, quantifiable basis for measuring performance. This effort will also provide the methods for calibrating the detector output call counts for spatially and temporally varying ocean environmental conditions. This is a necessary step in using passive acoustic data for estimating call densities.

Implementation of this technology at Navy sites will vastly reduce human operator time required to examine the passive acoustic recordings.

The end result of this project will be a software package containing all pre-processing and detection software plus the graphical user interfaces developed in this program. Implementation of this technology at Navy sites will increase computational costs (and may require acquisition of additional computer resources), but will vastly reduce human operator time required to examine the passive acoustic recordings. Therefore, a significant net cost (and time) savings are expected.

PROJECT NUMBER 9

Electrophysiological Correlates of Subjective Loudness in Marine Mammals

What are Marine Mammals Hearing?

PRINCIPAL INVESTIGATOR: JAMES FINNERAN

The LMR need—Hearing and Auditory System Information for Hearing-based Risk Criteria (number N-0012-13)—details the lack of accurate auditory data for marine mammals.

To meet this need, a project team headed by James Finneran of the Space and Naval Warfare Systems Command (SPAWAR), Systems Center Pacific is attempting to improve methods for determining how these animals actually hear.

In humans, noise exposure is quantified by "weighting" sound exposures to emphasize frequencies where auditory sensitivity is high. The weighting functions are obtained from psychophysical tests where human listeners are asked to compare the perceived loudness of one sound to another sound at a different frequency.

To generate marine mammal weighting functions for Navy criteria, a psychophysical experiment was previously conducted at SPAWAR to measure subjective loudness levels in a bottlenose dolphin—the only time such a measurement has been done in a non-human animal (Finneran and Schlundt, 2011). This experiment, sponsored by the Office of Naval Research, consisted of a loudness comparison task, where a dolphin was trained to report which of two sequential tones was louder. The equal-loudness level data were then used to derive equal-loudness contours and design an auditory weighting function. However, the time required to train the subject and collect the data makes future direct measurement of subjective loudness impractical for large numbers of individuals or more exotic species. For these reasons, follow-on studies at SPAWAR have utilized measurements of auditory reaction time as a proxy for loudness.
While simpler, reaction time measurements still require access to trained animals for many weeks to collect the necessary data. This requirement limits the number of individuals and species for whom data can be obtained, forcing extrapolations to estimate weighting functions for untested species.

A bottlenose dolphin wears three surface electrodes embedded in suction cups and positions himself on a "biteplate" for AEP measurements.

The project team is exploring the use of electrophysiological measurements in obtaining hearing data for the design of marine mammal weighting functions. Electrophysiological measurements use non-invasive surface electrodes placed on subjects' heads to measure small voltages (called auditory evoked potentials (AEP)) generated by the brain and auditory nervous system in response to sound.

Previous studies have examined the feasibility of utilizing AEPs to predict perceived loudness in humans. In order to determine whether similar techniques can be used in dolphins and sea lions, a feasibility study was conducted where sounds were delivered to dolphins and sea lions while brain activity was simultaneously monitored via surface electrodes. AEPs were measured at a variety of sound frequencies and levels, and the relationships between acoustic parameters (i.e., frequency and amplitude) and AEP features (i.e., response amplitude and latency) were analyzed. (Note: Response amplitude is a measure of the strength of voltages that are generated by the neurons in the auditory system in response to a sound; response latency is the delay between that sound and the onset of those voltages.) Analyses of these data demonstrated that the AEP methods did not provide a reliable prediction of subjective loudness, especially at low frequencies where data are critical for the design of Navy weighting functions.

Simply stated, loudness is a psychological phenomenon, and this study only measured voltages generated by the brain in response to simple stimuli. While those voltages are clearly related to how the brain later interprets the loudness of a sound, they are only part of the entire story, and simply measuring them with electrodes doesn't appear to provide the complete picture of how they are processed by the brain into the psychological phenomenon of loudness.

Determining the effect of sonar and other underwater sounds on marine mammals is difficult without a thorough understanding of how marine mammals hear.

In the absence of loudness data, low-frequency hearing thresholds are of use for the design of Navy weighting functions. However, previously conducted low-frequency AEP measurements have demonstrated that physical limitations in the delivery of acoustic stimuli and difficulties in recording physiological responses make estimations of low-frequency thresholds difficult.

Current research by the team is therefore focusing on identifying modifications of stimulus and recording parameters that will allow for estimation of low-frequency hearing thresholds in marine mammals, which is a type of data critical to Navy compliance documents. Data collection protocols will also be developed for opportunistic access to novel species including stranding situations.

Determining the effect of sonar and other underwater sounds on marine mammals is difficult without a thorough understanding of how marine mammals hear and the relative effects of sounds at different frequencies. The data gathered in this project will guide the derivation of auditory weighting functions in the acoustic effects analyses sections of Navy environmental documents. The data will be applicable to all Navy environmental documents analyzing acoustic effects of tonal sounds (e.g., sonars) and broadband noise sources, allowing for more realistic predictions of the effects of Navy sonars and explosive sources on marine mammals.

The findings of this project will be disseminated through presentations at scientific conferences and publication in peer-reviewed scientific journals, technical reports, and/or white papers.

PROJECT NUMBER 10

The Effects of Noise on Marine Mammals

Expanding the Knowledge Base

PRINCIPAL INVESTIGATORS:
CHRISTINE ERBE AND DORIAN HOUSER

Currently, the single most cited resource for information on the effects of noise on marine mammals is a book that was published in 1995 (Marine Mammals and Noise, Academic Press, San Diego). This book has been a valuable resource for the Navy, environmental planners, regulators and scientists. However, in the last 20 years the literature related to the issue of marine mammals and noise has expanded greatly and there is more information to consider when assessing effects of noise on marine mammals. There is a pressing need to update this book that is shared by multiple stakeholders who use this resource.

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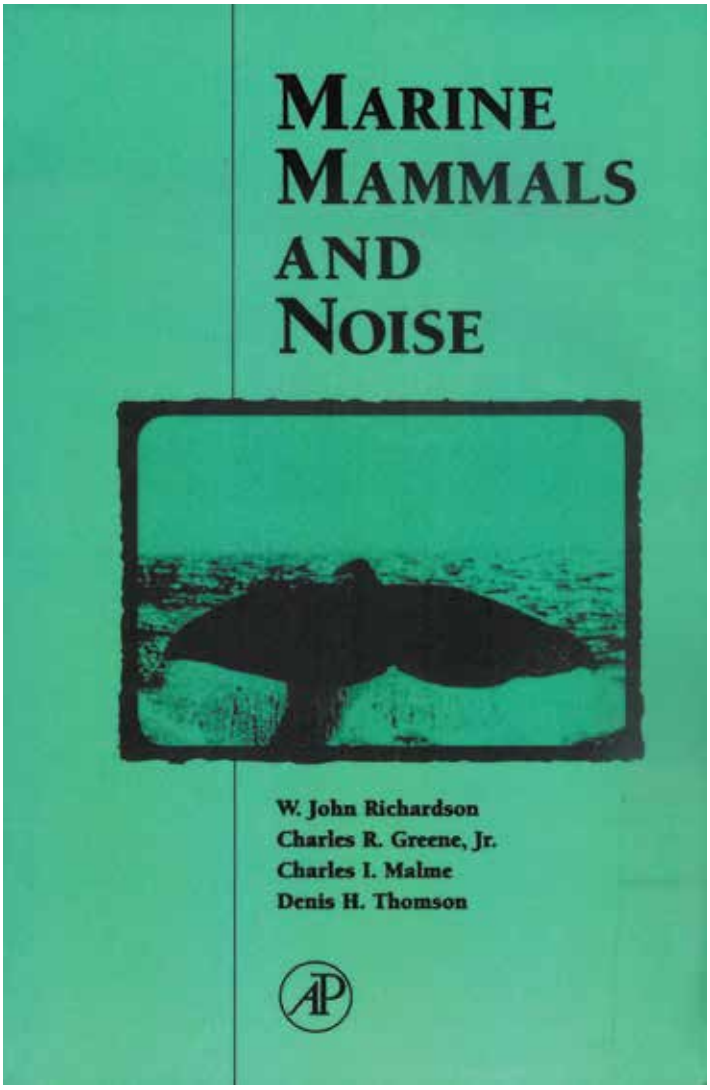
Since there are many stakeholders involved and the effort is so large, this is a leveraged project with funding from the Office of Naval Research, National Marine Fisheries Service, and Joint Industry Program. The LMR component of the project is led by Christine Erbe, Director of the Center for Marine Science & Technology at Curtin University, Australia.



Marine Mammals and Noise, published in 1995, is the single most cited source for marine mammal data. This LMR project will develop an updated source for information on marine mammal bioacoustics.

The tasks to be undertaken during the LMR portion of this effort include:

1. Developing a publicly accessible database of literature on marine mammal bioacoustics

2. Reviewing the literature and publicly available data on the sounds produced by marine mammals and on marine mammal hearing

3. Preparing a subsequent essay on how marine mammal bioacoustic data can inform both conservation efforts and the management of marine resources based on the literature review conducted.

Members of the project team have their own research database from which to gather information. The team will also actively solicit articles and reports from the scientific community, including "grey" literature (reports that were not published in scientific journals). The team members will assemble all relevant information into a publicly accessible database of literature on marine mammal bioacoustics. The information gathered in this project will be summarized into two final reports: one on marine mammal sound generation and one on marine mammal hearing. An essay will also be published summarizing the findings.

Once this project is complete at the end of fiscal year 2016, the team will leverage this work and solicit sufficient additional funds to produce a book compiling the team's findings.

All stakeholders concerned about the impact of anthropogenic noise on marine mammals would benefit from the first single source in 20 years to bring together available research on marine mammal sound production and hearing. It is expected that an updated, authoritative information source would also help alleviate overly conservative values sometimes used by regulators.

This project better enables Navy environmental planners and scientists by consolidating two decades of marine mammal studies relevant to the Navy at-sea environmental compliance process. The project's final essay will provide Navy-specific recommendations.

Gregory S. Schorr; CRC permit #16111

Ongoing Efforts

Marine Mammal Monitoring on Ranges

CO-PRINCIPAL INVESTIGATORS: Dave Moretti, Project Manager (Naval Undersea Warfare Center); Diane Claridge, AUTEC research team (Bahamas Marine Mammal Research Organization); John Durban, AUTEC research team (National Oceanographic and Atmospheric Administration); Erin Falcone, SCORE research team (Cascadia Research Collective); Greg Schorr, SCORE research team (Cascadia Research Collective); Robin Baird, PMRF research team (Cascadia Research Collective); and Daniel Webster, PMRF research team (Cascadia Research Collective)

The Marine Mammal Monitoring on Ranges (M3R) program is a multi-year, collaborative effort that utilizes existing hydrophone (underwater microphone) arrays on Navy ranges to expand our knowledge about marine mammal presence, abundance and behavior using passive acoustic monitoring, visual observation, biological sampling, and satellite tags. As years of marine mammal research have revealed, different species vocalize at different frequencies and have distinguishing types of sounds (clicks, series of clicks, whistles, moans, hums, etc.). These sounds are detected on individual hydrophones as an animal or group of animals moves across the range. The M3R program has developed a signal processor which incorporates developed hardware and software to capture and process these sounds, classify some types of marine mammals by their vocalizations, estimate locations, and display the results in both time and frequency. Real-time detection reports are archived and available for post-analysis.

In parallel, on-water sighting data are being collected to provide a direct measure of physical behavior, group size, and population demographics along with biological sampling to provide insight into population dynamics, prey utilization, and possible stressors through hormone analysis. Satellite tags are also being attached to selected animals to measure both their dive behavior and their movement over the span of months both on and off the range.

These data are then being combined with precise ship tracks and sonar measurements, to investigate the effect of repeated sonar exposure on cetaceans with a focus on deep diving Blainville's (*Mesoplodon densirostris*) and Cuvier's (*Ziphius cavirostris*) beaked whales which have been the predominant species present in stranding incidents related to sonar.

The goals of the M3R program are to:

1. Develop automated passive acoustic marine mammal detection, localization, classification, and display tools and integrated visual and satellite monitoring methods that will enable in-situ visual cetacean monitoring data

2. Provide baseline population density, abundance, and habitat usage data for Navy risk analyses and permit applications covering fleet activities on the ranges

3. Measure animal responses to Navy activities, including mid-frequency anti-submarine warfare (ASW) sonars through the analysis of passive acoustic, sighting, biological, and satellite data with a focus on beaked whales

4. Provide defensible behavioral response metrics which can be used to inform regulatory risk criteria and provide insight in to the cumulative effect of repeated sonar exposure.

The M3R program is currently being developed and evaluated at three Navy undersea ranges equipped with arrays of broadly-spaced (1-4 mi), bottom-mounted hydrophones:

1. The Atlantic Undersea Test and Evaluation Center (AUTEC) in The Bahamas

2. The Southern California Offshore Range (SCORE) at San Clemente Island, California (Figure 1)

3. The Pacific Missile Range Facility (PMRF) in Barking Sands, Hawaii.

These hydrophones are being leveraged both to detect and study marine mammals and to assist scientific experts in their efforts to observe animals in their natural habitat, deploy satellite and recording tags, and collect biological data. During field tests on range, animals are detected and localized using the M3R system and the experts are vectored to vocalizing animals to perform photo-ID surveys, biological sampling, and animal tagging and tracking.

View of AUTEC area and Tongue of the Ocean, one of the three M3R sites.

The combined datasets build a multi-sensor picture of animal abundance on the Navy ranges, their habitat use, and responses to Navy activities on the range.

The combined datasets build a multi-level picture of animal abundance, their habitat use, and responses to Navy activities on the range.

M3R tools and data are contributing to new analyses of cetacean behavior, supporting behavioral risk function analyses and validating new monitoring technologies. As the algorithms are refined, and improved tracking programs developed, researchers have advanced their knowledge of whale dive and vocal behavior with a focus on beaked whales.

Beaked whales are the Olympic divers of the cetacean world, routinely diving to depths in excess of 1,000 feet for durations of over an hour and spending little time at the surface, making them extremely difficult to study. Cuvier's beaked whale tag data collected by this study off the coast of California recorded both the deepest (~9,800 ft) and longest (~1 ¼ hrs) breath hold dive of any mammal.

Collecting precise physical and vocal behavior has enabled the development of passive acoustic population density estimates for Blainville's beaked whales *(Mesoplodon densirostris)* on the AUTEC range. These density estimation methods are being extended to the other Navy ranges. Additionally, for the first time, using advanced algorithms developed with AUTEC data, three Blainville's beaked whales were tracked during a foraging dive feeding at depth. With each advance, the study is expanding the marine mammal knowledge base.

The head and back of a male dense-beaked whale. (A. Friedlaender, NMFS permits: #1121-1900 and #981-1578)

The program is working to transition its monitoring and analysis tools so that they might be run and maintained by Navy range personnel. Because the M3R system and range tracking systems employ similar system architectures, the transition will contribute to maintaining an overall integrated system software repository. It will help to ensure that the M3R algorithms are maintained under the structured source code control implemented for range signal processing systems, thus helping the Navy to protect its long-term investment. It also will ensure that the system meets the current Department of Defense requirements for Information Assurance.

ONR plays a vital role in converting M3R observations into integrated models of animal response to sound, and the biological significance of those responses. M3R data collected under the LMR program are being used to develop improved behavioral risk criteria, the results of which will be applied to the Navy's acoustic impact analysis for Phase III environmental compliance.

As the base M3R technologies are transitioned, the breadth of data will substantially increase, providing a more complete record to help understand cetacean behavior over seasons and years, during training exercises and environmental events. This will provide real-time marine mammal monitoring capabilities in support of range operations.

Behavioral Response Study

CO-PRINCIPAL INVESTIGATORS: Brandon Southall, Chief Scientist (SEA, Inc.); John Calamokidis, Project Manager (Cascadia Research Collective); Peter Tyack, Design & Analysis (Woods Hole Oceanographic Institution/University of St. Andrews); Jay Barlow, Passive Acoustics (National Oceanographic and Atmospheric Administration); and Dave Moretti, Sound Source (Naval Undersea Warfare Center)

The Southern California Behavioral Response Study (SOCAL-BRS) is an interdisciplinary, multi-team, multi-year collaboration designed to increase understanding of marine mammal reactions to sound and provide a more robust scientific basis for estimating the effect of Navy mid-frequency active sonar (MFAS) on marine mammal behavior.

The project began in 2010 and completed its most recent field season in 2014. The overarching approach has included a number of research objectives:

1. Tag a variety of species and obtain baseline behavioral data

2. Conduct Controlled Exposure Experiments (CEEs) to obtain high-resolution measurements of behavioral responses of marine mammals

3. Apply adaptive team configuration to support both simulated MFAS sources and actual military MFAS sources

4. Obtain basic biological, behavioral, and foraging ecology data for marine mammals to support range monitoring efforts and/or habitat models.

The teams conducting fieldwork to measure baseline behavioral data and conduct CEEs include members with wide ranging expertise applying a variety of monitoring and analytical tools. These

include visual observers, tagging teams, sound source engineers and fisheries acoustics biologists who conduct photo identification, passive acoustic monitoring, geographical information system (GIS) tool application, acoustic modeling, and advanced bio-statistical analysis.

Prior to CEEs, tags are deployed on focal animals, underwater acoustical monitoring (towed passive acoustic monitoring and fixed range hydrophones when available) is utilized, and visual observers monitor focal and other animals and determine if

Fieldwork has occurred in coastal areas from San Diego to Santa Barbara and the Channel Islands, as well as an offshore area on and around the U.S. Navy's training range near San Clemente Island.

particularly vulnerable animals (e.g., neonate calves) are present. Controlled exposure experiments involve a simulated sound source, producing pseudo-random sounds and simulated MFAS, as well as actual MFAS sources. All work is conducted within the terms of applicable federal and state permits and various efforts are made to transparently communicate methods and results in scientific meetings and to the public.

As new data are collected and analyzed, the teams refine methodologies as needed to reflect new knowledge, technology and opportunities. For example, utilizing smaller and faster boats improved tagging options, increased flexibility in scheduling, and significantly reduced costs relative to previous methods.

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 in nearly 150 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. Ten peer-reviewed publications of baseline and CEE results to date have been produced by SOCAL-BRS (a dozen more are currently in review or advanced stages of publication), the results of which are being applied to the Navy's behavioral response assessment for Phase III environmental compliance.

The guided-missile destroyer USS Dewey (DDG 105). (U.S. Navy photo)

In the summer of 2013, SOCAL-BRS researchers worked in coordination with the Navy ships USS Dewey (DDG 105) and USS Cape St. George (CG 71) on the Navy's Southern California Offshore Range to conduct the first application of a full-scale operational Navy MFAS system (SQS-53C) within a controlled experiment. Significant new data were acquired on diving, foraging, social, and vocal behavior of focal marine mammal species, using actual MFAS sources. The team tagged two blue whales, two Risso's dolphins, a fin whale and a Cuvier's beaked whale. Navy vessels were positioned using site-specific sound propagation modeling to match received levels specified for focal animals to match those tested with scaled sound sources. Changes in behavior from baseline movement and/or acoustic behavior were measured as a function of sound exposure. Initial evaluation of these data suggests that responses to distant MFA from actual sources were less evident than those from closer scaled sources even though received sound levels were similar.

This was the first-ever use of a full-scale operational Navy mid-frequency sonar system in the context of a controlled exposure experiment.

This was the first-ever use of a full-scale operational Navy mid-frequency sonar system in the context of a controlled exposure experiment.

SOCAL-14 field work was conducted between July and September 2014. Teams deployed 21 tags on four species, including fin, blue, and minke whales as well as Risso's dolphins. Ten scaled source CEEs were completed but actual Navy ship participation was not possible due to a variety of factors. Analyses of collected data are in process.

The SOCAL BRS efforts have built upon previous BRS efforts at the AUTEC in the Bahamas during 2007 and 2008, and in the Mediterranean Sea in 2009.

A university researcher tags a blue whale with a data tag during a SOCAL BRS study. (U.S. Navy photo courtesy of Cascadia Research by John Calambokidis. NMFS permit # 14534)

Auditory Weighting Functions in Dolphins and Sea Lions

CO-PRINCIPAL INVESTIGATORS: Jim Finneran, Project Manager (Space and Naval Warfare Systems Command, Systems Center Pacific (SSC Pacific;)), Jason Mulsow (National Marine Mammal Foundation;), Carolyn Schlundt (Excelis Inc.)

Auditory weighting is the process of accounting for the ear's "sensitivity" to various sound frequencies. Auditory weighting functions are used to emphasize sound frequencies where the listener is susceptible to noise and to de-emphasize those frequencies where sensitivity to noise is low. Weighting functions are used in all Navy acoustic impact analyses.

In humans, weighting functions are obtained from psychophysical tests where listeners are asked to compare the perceived loudness of one sound to another sound at a different frequency. For non-human animals, this is problematic, as a complicated and time-consuming training regimen is required for the participation of subjects (To read more about auditory weighting, see Jim Finneran's companion project, Electrophysiological Correlates of Subjective Loudness in Marine Mammals, on page 32 of this report.)

Instead of training animals to report which of two sounds is louder, work in this area has involved measuring simple auditory reaction time (RT) as a proxy for loudness. Measurement of RT is a relatively straightforward procedure, requiring animals to provide a trained response (e.g., release a switch) upon the detection of a sound. The time required for the animal to provide the response can be used as an indicator of perceived loudness, with shorter RTs corresponding to louder sounds.

The goal of this study was to develop weighting functions for mid-frequency cetaceans (most delphinids) and otariid pinnipeds (sea lions and fur seals) by measuring auditory reaction time in bottlenose dolphins and California sea lions. Testing was conducted at SSC Pacific in 2013-2014. Tonal stimuli were delivered underwater to dolphins using a direct-field transmitter, and in air to sea lions via headphones. A range of sound pressure levels was delivered to each animal. Sea lions were trained to respond upon tone detection by pushing a paddle, while dolphins issued a vocal response.

Sound pressure levels were correlated with RT and frequency to build "equal-latency" curves. These curves, and the weighting functions based on the curves, were generally similar to the frequency-specific threshold curves (audiograms) for sea lions and dolphins. The similarity of the results to audiograms suggested that more easily collected hearing thresholds might provide useful approximations for weighting functions in the absence of equal-latency or loudness data.

A publication summarizing the results of this project is currently in preparation and expected to come out in fiscal year 2015.

Partnerships/Coordination

Working with other organizations on related projects helps to leverage funding, expand investigation options and draw on additional expertise. Examples of partnership efforts are discussed below.

ESTCP: Autonomous Real-time Passive Acoustic Monitoring of Baleen Whales

PRINCIPAL INVESTIGATORS: Cara Hotchkin (NAVFAC Atlantic), Mark Baumgartner (Woods Hole Oceanographic Institution), Sofie Van Parijs and Peter Corkeron (Northeast Fisheries Science Center)

This project is a collaboration between the LMR program and the Environmental Security Technology Certification Program (ESTCP). The overall objectives of this project include:

1. Demonstrating year-round, large-scale near real-time acoustic surveillance of four species of endangered baleen whales (fin, humpback, sei, and right whales) from three different autonomous platforms (Slocum gliders, wave gliders, moored buoys)

2. Validating real-time acoustic detections using audio recorded in-situ and airplane-, ship-, and land-based visual observations

3. Developing best practices for integrating real-time acoustic detections from autonomous platforms into persistent visual monitoring.

Successful demonstration and validation of this technology may provide long-term reduction in analytical effort and improved efficiency of existing monitoring technologies by including real-time detection information.

Sonobuoy Liaison Working Group

The Sonobuoy Liaison Working Group (SLWG) plays an important role in supporting sonobuoy allocations to marine mammal research and monitoring.

The SLWG includes representatives from a large variety of Navy branches and helps to determine how many sonobuoys are made available to the Navy's Non-Combat Expenditure Allocation (NCEA). The Navy's NCEA of sonobuoys includes a quantity of non-expired sonobuoys that can be made available to researchers. Sonobuoys, most often used by the Navy for submarine detection, have proven to be a valuable asset in understanding and locating marine mammals.

The Sonobuoy Liaison Working Group plays an important role in supporting sonobuoy allocations to marine mammal research and monitoring.

In fiscal year (FY) 2013, the evaluation process for marine mammal related requests for sonobuoys was assigned to the LMR program. A number of factors made the LMR program an appropriate venue for evaluating sonobuoy requests. The LMRAC's broad representation, coupled with the LMR's needs and proposal evaluation process, ensures that the main Navy stakeholders on marine mammal issues are involved in solicitations and reviews. The LMR program works with the SLWG on available allocations. LMR was able to allocate over 400 sonobuoys in FY2013 and over 475 sonobuoys in FY2014 to various marine mammal research and population survey projects.

Completed Projects

LMR-funded projects that were completed in FY14 are listed below, along with a brief project description and overview of accomplishments. A partial list of peer-reviewed publications, reports, and conference presentations resulting from work funded by the LMR program can be found in the Appendix.

In addition to these projects, several projects that were initiated as part of the Marine Mammal Research program, prior to the start of the LMR program, were completed prior to FY14. The results of many of these projects have contributed to the progress made in understanding marine mammal behavior, determining new directions in marine mammal work and improving monitoring. However, projects completed prior to FY14 are not listed here.

Constructing Hearing Threshold Diagrams for Marine Mammals: Computational Methods

PRINCIPAL INVESTIGATORS: Ted Cranford (San Diego State University), Petr Krysl (University of California, San Diego)

The purpose of this project was to computationally construct an audiogram (minimum audible pressure graph) in toothed whales. The first goal was to validate the model and process using a common dolphin, and the second goal was to predict an audiogram of a Cuvier's beaked whale. In addition to successfully meeting these two goals, the principal investigators were also able to successfully predict a fin whale audiogram. The data from this project directly support the development of criteria and thresholds used by the Navy to assess the potential impacts from acoustic and explosive sources.

Marine Biodiversity Data Life Cycle: Data Enrollment to Application

PRINCIPAL INVESTIGATOR: Mark Fornwall (United States Geological Survey)

The overall goal of this project was to better integrate U.S. Navy data with the emerging Federal Marine Biological Data Architecture. Some outcomes of this project include:

• Implementing 20 new data terms (an initial subset of the 100 possible data terms identified) into a Visual Line Transect Survey extension within a federal database (OBIS-USA) in order to capture information specific to visual line transect surveys

• Establishing an automated process to transfer data from OBIS-SEAMAP to OBIS-USA

• Developing the Biogeographic Analysis Tool to provide basic geospatial analysis capabilities to data within OBIS-USA

• Providing short-term and long-term recommendations for how the Marine Biogeography Common Terms extension could be modified to consider passive acoustic data.

The work completed under this project set up a plan for existing and future U.S. Navy data to be incorporated and available within OBIS-USA and shared in an efficient manner."

IDEA Training Workshops: Introduction to Density Estimation Using Acoustics

PRINCIPAL INVESTIGATOR: Danielle Harris (CREEM, University of St Andrews, UK)

For this project, the LMR program supported a series of workshops to introduce methods of using passive acoustic monitoring to estimate marine mammal density. Three IDEA courses were delivered at Virginia Beach, San Diego and Honolulu between May and September 2014, with a total of 83 participants. The primary aim of the IDEA courses was to present the latest methodologies for estimating the number and density of marine mammals in an area using passive acoustic data to scientists supporting the Navy's monitoring program. The three specific teaching objectives of the IDEA courses were for participants to understand the issues involved in going from processed acoustic data to animal density, to be aware of the main methods that are currently available to do this, and to understand which method(s) may work for a given scenario. These workshops helped the end users understand the capability, limitations, and experimental design requirements to achieve density estimates from acoustic data. This helped to ensure that future monitoring projects involving the collection of passive acoustic data are properly designed from the outset and take this new knowledge into account.

Measuring Low Frequency Hearing Shifts in the Bottlenose Dolphin

PRINCIPAL INVESTIGATOR: Paul Nachtigall (Hawaii Institute of Marine Biology, University of Hawaii)

The purpose of this project was to measure low frequency temporary threshold shifts (TTS) and recovery in a bottlenose dolphin using (AEP) response methods. Although preliminary data were collected, the project was unable to successfully produce good low frequency TTS and recovery functions. Based on a revised return on investment analysis, this project was discontinued to reduce financial risk.

Measuring the Hearing of Stranded Cetaceans using Evoked Auditory Potentials

PRINCIPAL INVESTIGATOR: Paul Nachtigall (Hawaii Institute of Marine Biology, University of Hawaii)

The purpose of this project was to use stranded cetaceans as subjects for measuring hearing using auditory evoked potential (AEP) response methods. Due to a variety of factors, no stranded animals were able to be tested using AEP methods. Based on a revised return on investment analysis, this project was discontinued to reduce financial risk.

Extending our Capability to Determine Distribution and Abundance of Marine Mammals from Line Transect Data

PRINCIPAL INVESTIGATOR: Len Thomas (CREEM, University of St Andrews, UK)

The purpose of this project was to update existing software (from the Distance project) to extend capabilities associated with collection and analysis of line transect survey data. Specific objectives included incorporation of improved methods for spatial and habitat modeling, analysis methods for dealing with complications such as uncertain species identification and group size, analysis methods for dealing with passive acoustic data complications such as lack of reliable perpendicular distances, and a simulation engine to allow realistic survey planning and optimization. The work completed under this project gives scientists and researchers updated

software tools to plan marine species line transect surveys and analyze the resulting data. Results from these types of analyses are directly used in Navy at-sea environmental compliance documentation to better describe where, when, and how many animals occur within U.S. Navy training and testing study areas. This information allows for better characterization of potential impacts that may result from U.S. Navy training and testing activities.

SOCAL Marine Mammal Studies Using Passive Acoustic Monitoring

PRINCIPAL INVESTIGATOR: John Hildebrand (Scripps Institute of Oceanography)

The overall goal of this project was to study presence and habitat use of vocalizing marine mammals in the Southern California Bight using High-frequency Acoustic Recording Packages (HARPs). Under this project, HARP hardware and Triton software were upgraded to more efficiently monitor for and analyze passive acoustic data. Data collected from the HARPs were analyzed for presence of key mysticete and odontocete species. Results from this analysis were directly used in the Hawaii and Southern California Training and Testing (HSTT) Environmental Impact Statement/Overseas Environmental Impact Statement to better describe where, when, and how many animals occur within the southern California portion of the HSTT study area. This information allows for improved characterization of potential impacts that may result from U.S. Navy training and testing activities.

Using Passive Acoustics to Improve Abundance Estimates and Distribution Data for Marine Mammal Species in the Western Atlantic

PRINCIPAL INVESTIGATOR: Sofie Van Parijs (NOAA Northeast Fisheries Science Center)

This project was part of a larger collaborative effort between the U.S. Navy (ONR and LMR), National Oceanic and Atmospheric Administration (NOAA), U.S. Fish and Wildlife Service, and Bureau of Ocean Energy Management as part of the Atlantic Marine Assessment Program for Protected Species (AMAPPS). The overall goals of the LMR program-funded portion of the project included improved abundance estimates for sperm and beaked whales in the Western Atlantic using towed acoustic arrays, and development and testing of new methodologies for assessing spatial distribution, temporal distribution, and abundance of baleen whales. Results for sperm and beaked whale abundance estimates derived from passive acoustic survey data were approximately twice that derived from visual survey data. In addition, the project compared detection rates between bottom-mounted recorders and visual sightings data to determine benefits of each method for each species. Results from this type of analysis are directly used in Navy at-sea environmental compliance documentation to better describe where, when, and how many animals occur within U.S. Navy training and testing study areas. This information allows for better characterization of potential impacts that may result from U.S. Navy training and testing activities.

LOOKING AHEAD

Looking Ahead

For FY15 the LMR program is going to continue to develop and refine the process to address the Navy's key research needs. There are three key topic areas of recent research interest for the Navy that we will be selecting submitted proposals from:

1. Hearing measurements in a broad range of marine mammal species

2. Density estimation from passive acoustic monitoring data

3. Marine species monitoring data collection toolkit development.

In addition, we are focusing on refining the program process and schedule to be more effective in our management of the program to meet budget requirements. In FY15, we will be restructuring the budget of some existing projects to better fit with current expected timelines, making room for more new starts. We will also continue to work with existing projects to ensure the effective transition of results and technologies to the Navy's at-sea environmental compliance process.

The LMR program continues to collaborate with other programs and agencies on shared interests to more effectively leverage investments to achieve common goals. For the most up-to-date program schedule and information, visit our website at www.lmr.navy.mil

Courtesy of CETOS Research Organization; NMFS permit #1039-1699

LMR Program References

Included here is a list of publications from 2013 and 2014 that were partially or fully funded by the LMR program. The LMR program would like to acknowledge that much of this work was partially funded by the previous OPNAV N45 RDT&E program (Frank Stone) or the ONR program (Mike Weise), and their contributions are greatly appreciated. These publications are of great value to the Navy's at-sea environmental compliance process and directly feed into the National Environmental Policy Act, Marine Mammal Protection Act, and Endangered Species Act compliance documentation.

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2014

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