

UNITED STATES NAVY



protecting the seas
through **science**



Sailors have a unique relationship with the oceans. Aboard our ships for many months as we travel the globe year round to defend freedom, sailors experience the power and beauty of the sea every day. We have great respect for the marine environment, and view it as a home worth protecting.



Sailor observes wake of U.S. Navy carrier

A UNIQUE RELATIONSHIP WITH THE OCEANS



Dolphins ride bow wave of USS Mt. Whitney

The U.S. Navy's core mission is to meet America's global security commitments at sea. We also conduct humanitarian assistance, disaster relief, anti-piracy, and other operations in support of our national objectives. We recognize that activities at sea could potentially affect marine life.

In order to understand - and ultimately minimize - such effects, the U.S. Navy has developed a robust marine mammal research program.

The U.S. Navy partners 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.



¹Pilot whales surface near the NATO Research Vessel Alliance during a multinational marine mammal research expedition

¹Photo courtesy of Ann Allen, Woods Hole Oceanographic Institution



Navy and Sonoma State University researchers test a live elephant seals' hearing

While the U.S. Navy funds much of this research, most of it is conducted independently by scientists from various organizations. We encourage all Navy-funded scientists to have their work peer reviewed by experts in the same field. This is an important process to help determine whether scientific findings are accurate, reliable, and worthy of publication.

MARINE MAMMAL ECOLOGY AND POPULATION DYNAMICS



Purpose:
to improve understanding of the behavior, seasonal distribution, and abundance of marine species in areas where the Navy conducts testing and training activities.

Humpback whale mother and calf

PROGRAM OVERVIEW

In general, Navy-funded research addresses four broad study areas. This research is expected to provide a biological baseline to be used when assessing the effects of Navy training activities on marine mammals.

| Current Project Highlights |



²Researchers aboard North Atlantic Treaty Organization (NATO) Research Vessel *Alliance* use passive acoustic arrays to monitor marine mammals

- Using animal tagging and passive acoustic monitoring to study behaviors and distributions of animals relative to key environmental factors.
- Developing models to calculate density estimates based on habitat preference data.
- Developing a spatial decision support system to predict probability of animal occurrence based on species preferences related to physical oceanography and other variables.
- Mapping marine mammal food source distribution (“preyfields”) to better understand the distributions of marine mammal species in their habitats.
- Tracking location and behavior of beaked whales and other marine mammals on Navy ranges using satellite tags.
- Investigating marine mammal vulnerability to trauma from emboli (gas bubble) formation.

²Photo courtesy of Odile Gerard, NATO Undersea Research Center

| Future Project Highlights |

- Collecting multi-year, seasonal oceanographic data with marine mammal sighting and acoustic detections to help predict marine mammal presence.
- Developing methodology for predictive modeling to forecast abundance and location of a given marine mammal species based on time of year.



³Researcher prepares to launch passive sonobuoy to localize and detect marine mammals

³Photo courtesy of Marco Ballardini, BluWest

MARINE MAMMAL ECOLOGY AND POPULATION DYNAMICS

CRITERIA AND THRESHOLDS TO MEASURE EFFECTS OF NAVY-GENERATED SOUNDS



Purpose:

to determine the biological effects of natural and manmade sound on marine animal behavior.

Dolphin hearing test at Space and Naval Warfare Systems Command San Diego

| Current Project Highlights |



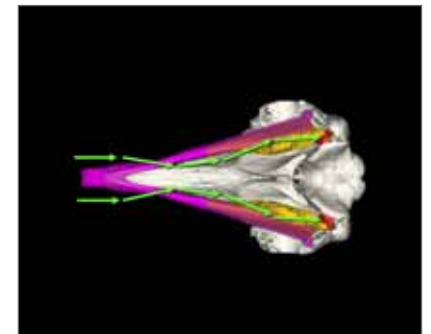
⁴Digital data tag on Blainville's beaked whale

- Developing portable equipment to electronically measure an animal's brain response to sound, thereby establishing its hearing range. Knowing the hearing range of different marine mammal species is important for understanding the effects of different sound sources on those species.
- Refining the current acoustic effects model to more accurately estimate the potential to expose marine mammals to significant levels of acoustic energy.

- Improving data collection tags to record heart, respiration, and fluke rates. These data can be used to evaluate the energy expended by a marine mammal during normal behavior and when exposed to Navy-generated sound.
- Transforming the National Research Council's Population Consequences of Acoustic Disturbance model (a conceptual model that defines levels of potential effects of anthropogenic sound on marine mammals) into a mathematical model structure to better identify meaningful behavioral effects on marine mammals.

| Future Project Highlights |

- Conducting behavioral response studies over the next five years. Researchers will use digital acoustic recording tags and passive hydrophones to collect biological data and track marine mammal reactions to underwater sounds.
- Exploring and evaluating models and computer simulation to create graphic representations of sound through auditory pathways and determine effects on surrounding tissue. This approach may be useful for determining the physical effects of sound source on marine mammals.
- Expanding temporary threshold shift (TTS) experiments conducted over the past decade to better understand how exposures to Navy sound sources might result in temporary (recoverable) hearing loss in certain scenarios.
- Seeking opportunities to improve criteria presently used to assess behavioral effects of marine mammals' exposure to Navy-generated sound.



⁵Computed x-ray tomography scan of beaked whale's head with arrows showing sound pathways

⁴Photo courtesy of Dr. Ari Friedlaender, Duke University

⁵Image courtesy of Dr. Ted Cranford, San Diego State University

IMPROVING MONITORING TECHNIQUES



Purpose:

to develop observation, detection, and classifications approaches for more effective monitoring.

⁶Researcher attaches a digital data tag to a pilot whale off Kona, Hawaii

| Current Project Highlights |



⁷Autonomous underwater glider funded by Woods Hole Oceanographic Institution (WHOI) and the Office of Naval Research

- Developing and testing radar, infrared sensors, and other new hardware for detecting, classifying, and localizing marine mammals.
- Validating data sets of vocalizing mammals detected during passive monitoring.
- Automating data collected through passive monitoring.
- Increasing the capacity of passive acoustic monitoring,

with the goal of differentiating species based on vocalization patterns without human oversight.

- Improving technologies associated with digital tags used to track marine mammals in the wild.

⁶Photo courtesy of Dr. Brandon Southall, formerly with NOAA's Ocean Acoustics Program
⁷Photo courtesy of Dr. Dave Frattoni, Woods Hole Oceanographic Institution

| Future Project Highlights |

- Exploring tools and techniques to improve monitoring through field work at the Atlantic Undersea Test and Evaluation Center (referred to as "AUTEC") and the Southern California Offshore Range (also known as "SCORE"), including use of satellite tags and the ranges' passive acoustic monitoring capabilities.



⁸Three Blainville's beaked whales surface in front of the AUTEC vessel *Ranger*



FLIP ("Floating Instrument Platform") conducts marine mammal monitoring near the Navy's SCORE training range

⁸Photo courtesy of Dr. Ari Friedlaender, Duke University

SOUND FIELD CHARACTERIZATION



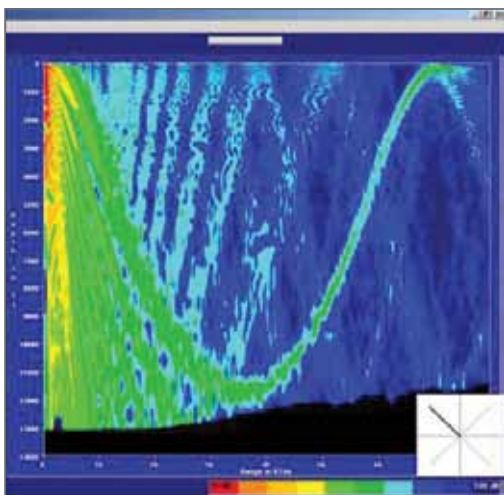
Purpose:

to develop protocols and a model for predicting how sound propagates in water.

Navy aerographer's mate launches a bathythermograph data acquisition system

| Current Project Highlights |

- Developing models that demonstrate how acoustic energy travels through the air and sea.



Underwater sound velocity profile showing a convergence zone at sea

- Developing models to predict the transmission of acoustic energy from multiple small and large explosions in a shallow water environment.
- Developing protocols for when to use coherent (i.e., sonar) and incoherent (i.e., explosives) transmission loss models.
- Integrating the latest propagation models into a standard Navy process. A Navy Acoustics Effects Model (NAEMO) is being developed to provide a

consistent methodology for environmental planners to use when analyzing the potential for acoustic effects from Navy training and testing.

| Future Project Highlights |

- Finalizing a software simulation system (referred to as the Effects of Sound in the Marine Environment or "ESME" Workbench) that will be used by environmental planners to help assess the potential impact of Navy-generated sound on marine mammals.

This effort will include:

- Developing capability for simulating and analyzing three-dimensional sound fields produced by fixed sources.
- Adding capacity to simulate moving sound sources and conduct acoustic footprint analysis.
- Simulating mammalian sound sources with fixed and moving receivers and providing tools for animal detection analysis.
- Adding capacity for simulating single and multiple explosive sources.



Pod of Blainville's beaked whales

- Integrating the simulation system with the NAEMO process.

Over the next five to ten years, the U.S. Navy will continue its commitment to fund marine mammal research required to assess, monitor and mitigate potential effects of sound on marine mammals. Such research will allow us to meet our national security mission, while working with our partners to protect marine mammals.



Navy lookout uses "Big Eye" binoculars to scan for surface contacts at sea, including marine mammals

A LONG-TERM COMMITMENT



Sailor gives positive reinforcement to a Navy-trained dolphin during a Rim of the Pacific exercise

If you would like more information about the U.S. Navy's marine mammal research program, or if you have scientific research you believe may be of value to the U.S. Navy, please contact:

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For additional information about Navy environmental stewardship, please visit <http://www.greenfleet.dodlive.mil>.



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