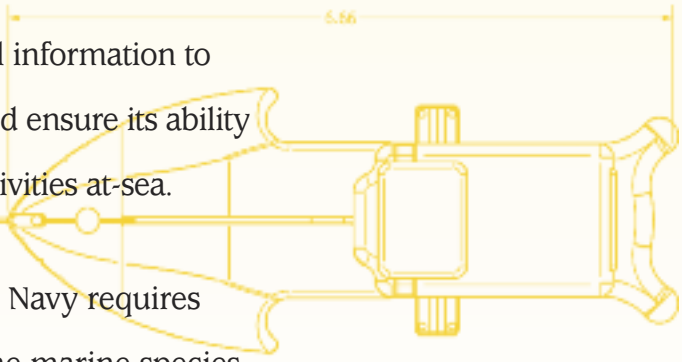
Navy Advances

MONITORING TAG

SCIENCE, DEVELOPMENT & TRANSITION

Technology Provides Foundation for Sound Operation of Training & Testing Ranges

The U.S. Navy's ongoing efforts to advance the state of monitoring tag technology is providing vital information to support its environmental compliance efforts and ensure its ability to utilize Navy ranges for training and testing activities at-sea.



To keep its at-sea training ranges operating, the Navy requires knowledge about and ongoing monitoring of the marine species that are present on or travel through its ranges. Animal telemetry devices, also called monitoring tags, are relatively small but valuable tools in providing the data needed. These devices, in their various forms, open a view below the ocean surface and polar ice packs. They provide critical data on where animals go, how they move within their world and how they react to anthropogenic inputs.

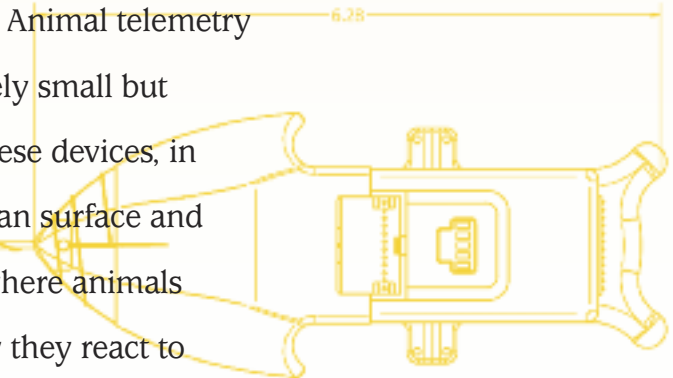


Photo by Cordelia Shea
Illustration by Alex Shorter

HiSTORY

Scientists have long sought to better understand the movements of marine mammals. In early years, the questions centered around where they go, how deep they dive, and how long they can stay submerged. Additionally, scientists recognized that these animals could reach places difficult for humans to study and, with specialized equipment, they might be able to collect information from those deep and distant places. As the list of questions has expanded over time, technology has also changed.

In the early 1960s, Gerald Kooyman, then a graduate student at the University of Arizona, attached a rudimentary time-depth recording device to Weddell seals in Antarctica, producing the first seal dive profiles. Kooyman's device depended on physical access to the seals to be able both to attach and retrieve the device. During those years, other researchers, including William Watkins and William Schevill at the Woods Hole Oceanographic Institution (WHOI), were working to develop radio telemetry devices (tags) and attachment methods to track right whales without needing to capture the whales. Their early efforts succeeded at attaching a tracking device to a whale by projecting the device from a helicopter to the whale, but damage to the tag prevented them from tracking the whale.

During the late 1960s, engineers at the Ocean Applied Research Corporation also were designing and testing radio tracking devices for marine mammals. Their presentation to the 1971 Engineering in the Ocean Environment Conference discussed "the design of the radio transmitter and receiver system, frequency, power, packaging and antenna requirements, and discusses data on respiration rate, pattern and maximum depth of dive collected from several instrumented cetaceans."

Other types of marine mammal tag devices were being developed specifically to collect oceanographic data. One device developed by the Sea Mammal Research Unit (SMRU) at the University of St Andrews collected conductivity, temperature and depth (CTD) data. This large device was attached to and retrieved from elephant seals. Elephant seals often served as early testers of these devices because of their large size and because their haul-out locations are generally known.

Another early 1970s effort sponsored by the Naval Undersea Research and Development Center in San Diego, California successfully used "instrumented marine mammals to measure selected environmental parameters and to relay data on these parameters to tracking aircraft." The researchers proposed that the next step would be transmitting data to satellites.

While work in the 1960s and 1970s generally employed radio telemetry, the focus in the 1980s and 1990s shifted toward satellite transmission and laying the groundwork for including Global Positioning Systems (GPS) capabilities. Equipment developed by the SMRU team was among the

Tracking Marine Mammals by Satellite

When the Argos satellite-based data collection and location system was added to National Oceanic and Atmospheric Administration (NOAA) polar orbiting satellites in the late 1970s, it opened new opportunities for tracking many types of animals, including marine mammals. The Argos program began as a joint effort of NOAA and the French Space Agency, in agreement with the U.S. National Aeronautics and Space Administration (NASA). Other international space agencies have joined the system over the years.

For marine mammal tracking, monitoring devices equipped with Argos-compliant platform transmitter terminals (PTT) are attached to an animal. When an animal surfaces and the transmitters are able to connect to one of the Argos-equipped polar orbiting satellites, the transmitter uploads a burst of environmental and location data collected by the monitoring tag. As described by Argos:

> *"A platform transmits periodic messages characterized by the following parameters:*
>
> *Transmission Frequency (401.650 Megahertz (MHz) ± 30 kilohertz (kHz)), the repetition period, which is the interval of time between two consecutive message dispatches, varying between 90 and 200 seconds according to the extent to which the platform is used, the platform identification number, and the volume of data collected.*
>
> *The transmission of each message takes less than one second."*
>
> *(Source: www.argos-system.org/argos/how-argos-works)*

Data from the satellite are then transmitted to receiving stations for processing and transmission to the user for analysis.

first to successfully transmit temperature and salinity readings collected from an animal-borne tag to the Argos satellite-based system.

Significant technological advancements during the subsequent decades accelerated what tags could do and how they could be used. Satellites and GPS connections improved, electronic components continued to shrink, and digital data collection, storage and transmission became more widely available.

Tag crew practicing the use of the tag pole before heading out to sea.
Rune Roland Hansen

Monitoring tags and other animal telemetry devices were increasingly providing researchers with new ways to see and understand marine animal behavior and the environment they inhabit. The devices offered views into previously obscure ocean areas, motivating more and more innovation in the devices. Continued advancements open whole new possibilities for understanding not only marine species and their environment, but also how human activities might be affecting them.

The following sections provide an overview of some of the new tag technologies, the Navy's contributions to moving those technologies forward and the important role monitoring tags play in keeping Navy at-sea ranges available for training. Along with changing technology of the tags themselves, the research community continues to explore other key components of using monitoring tags. These include optimal attachment methods, potential effects on the animals, how to store and make available the substantial quantities of data collected, and guidelines for appropriate and ethical use of monitoring tags.

NAVY ROLE IN ADVANCING TAG TECHNOLOGY

The Navy has long needed to monitor the ocean and its inhabitants. Naval Oceanography collects and analyzes data on oceanic and atmospheric conditions to support Navy operations throughout the world. Collecting environmental data, including CTD data, have helped to reveal important hydrographic features and oceanographic processes that improved navigation safety. Animal-borne devices offered new ways to collect these environmental data. In the time since the Navy first began listening for submarines it has needed to be able to distinguish between human-generated sounds and those from animals, including whales. And with whale strandings in the early 2000s being attributed to sonar transmissions, the Navy has expanded its investments in research on potential effects of sonar on cetaceans.

The Office of Naval Research's Marine Mammals and Biology (ONR MMB) program has steadily worked to push biologging and biomonitoring technology forward. Beginning in the early 1990s, the ONR Physiology and Marine Mammal Biology program (a predecessor to the ONR MMB program) funded researchers at various universities and institutions to add sensor capabilities to tags and increase tag lifespan. Different sensors incorporated into monitoring tags can record the pressure (depth), acceleration, direction, location and other movement of a marine mammal. These capabilities provide insights on animal distribution, abundance and habitat use.

For decades, underwater acoustics have been a Navy interest. Navy funding helped William Watkins and William Schevill from WHOI develop what became an extensive collection of marine mammal sounds—a library of sound that the Navy has used to train sonar operators. Watkins developed the first tape recorder for recording

The Office of Naval Research's Marine Mammals and Biology program has steadily worked to push biologging and biomonitoring technology forward.

For smaller, faster species like the pilot whale, a hand-held pole is used to deploy the DTAGs. Tags need to be placed high on the back so that researchers can track the whale using the VHF signals given off by the tag when at the surface.
Rune Roland Hansen, Norwegian Animal Research Authority permit 2015/223222

marine mammals at sea. Creating his own hydrophones, he eventually crafted a portable underwater recorder. Over time, Watkins developed a library of marine mammal sounds that the Navy has used to train sonar operators. As Robert (Bob) Gisiner, then with ONR, shared at the time of Dr. Watkins death, ''Bill was the one who opened our ears to what was going on under the ocean."

Despite these advancements, incorporating acoustic recording capabilities into a compact, animal-borne data logger faced technological hurdles. During the 1990s ONR and others worked with researchers from institutions including the University of California Santa Cruz, WHOI and the Monterey Bay Aquarium Research Institute to support initial experiments into acoustic recorders on elephant seals. Subsequent funding and work led to two primary acoustic recording devices—the digital acoustic recording tag (DTAG) from WHOI and the Bioacoustic Probe (later redesigned into what is now the Acousonde™) from Greeneridge Sciences.

Watkins, Schevill and the U.S. Navy: Exhibition at the New Bedford Whaling Museum

In September 2017, the New Bedford Whaling Museum (NBWM) in Massachusetts opened an exhibition, *Whales Today*, that presents two significant collections related to the cetacean acoustics research of William Watkins and William Schevill along with a U.S. Navy interactive exhibit *Stewards of the Sea: Defending Freedom, Protecting the Environment.*

The NBWM is the repository of two significant collections—the *William A. Watkins Collection of Marine Mammal Sound Recordings* and *Data and the William A. Watkins and William E. Schevill Collection of Images and Instruments*. The museum received these collections in 2014 from WHOI, where Watkins and Schevill spent decades conducting their work. Significant portions of Watkins and Schevill's work was possible through U.S. Navy funding of marine acoustics research.

The Watkins collection includes 20,000 sound files of marine mammal vocalizations, and the Watkins and Schevill collection includes photographs, whale radio tags and recording, playback and interpretive instruments related to the audio material.

For more on the NBWM and the *Whales Today* exhibition, visit www.whalingmuseum.org/explore/exhibitions/whales-today.

Tags are deployed using a cantilever operated carbon fiber pole extending from the bow of a small boat. The boat carefully approaches the whale and when enough of the whale's back is visible, the tag team attaches the tag with suction cups.

Rune Roland Hansen, Norwegian Animal Research Authority permit 2015/223222

The DTAG, funded by the Strategic Environmental Research and Development Program (SERDP) and the ONR MMB program, incorporated both a hydrophone for recording sounds and other sensors that could record animal movements. In 1999, this first DTAG was used on northern right whales. The next version, DTAG-2, has been in use since 2002. Version 2 can include up to four hydrophone channels and has 16 gigabytes (GB) of memory—a significant improvement over the 400 megabytes (MB) possible in the first version. Its sensor suite includes tri-axial accelerometer, magnetometer, pressure and temperature sensors, all of which provide detailed data on where and how an animal moves. (Note: Many of these sensors are now standard in modern smartphones.) The latest DTAG upgrade, the DTAG-3, includes 32 to 64 GB of memory, a more powerful processor and can be fitted with varying sensors as needed.

The Bioacoustic Probe development, funded by the ONR MMB program, focused on making bio-acoustic technology more readily available as an off-the-shelf technology. The probes were used both as tags and in arrays. In 2006, ONR funded a redesign to expand the probe's recording bandwidth and include other features. The redesigned produc—the Acousonde—includes hydrophones and sensors to record depth, attitude and orientation, which can monitor the animal's behavior in response to sound.

While both the DTAG and the Acousonde record acoustic data, they each provide different sensor combinations, sound sensitivity and manufacturing capacity. These tags reflect ongoing efforts to add more features in smaller packages. Funding from the ONR MMB program has helped to support improved and consistent manufacturing and field reliability of the devices.

The improvements and refinement of these acoustic tags also demonstrates the Navy's process of working from basic research to demonstration and validation to monitoring implementation. Following ONR's support of early

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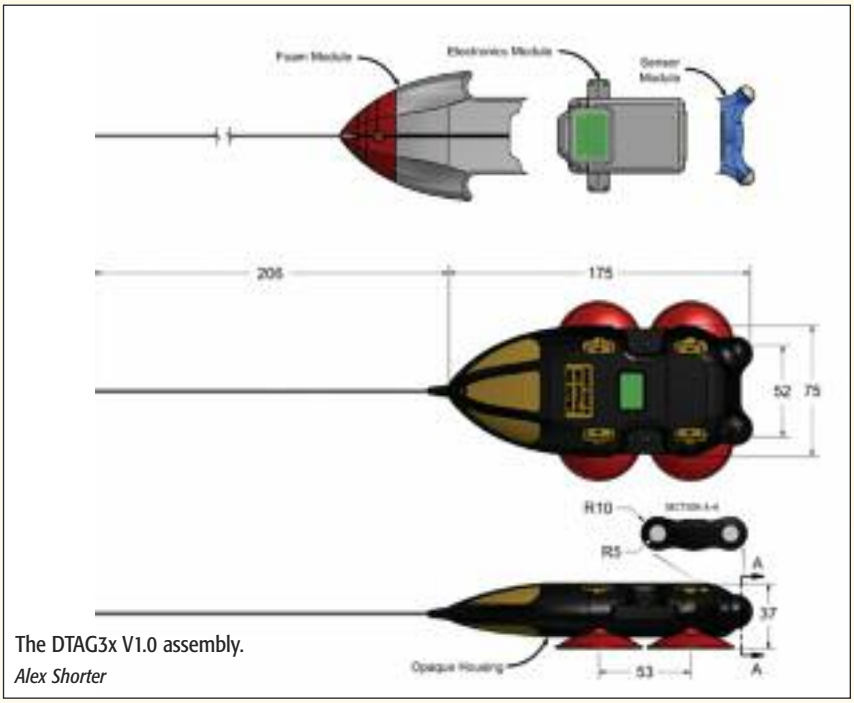
acoustic tag development and refinement, the devices were used in field work funded by the Navy's Living Marine Resources (LMR) program. With researchers providing field-tested feedback, tag developers have continued to make improvements. The Navy's Marine Species Monitoring program currently uses versions of the tags in their monitoring work.

In addition to furthering tag technology, the ONR MMB program also works to coordinate efforts among tag developers and users. ONR co-sponsored a 1992 workshop (Workshop on Tagging and Tracking Technology (February 1992)) and another in

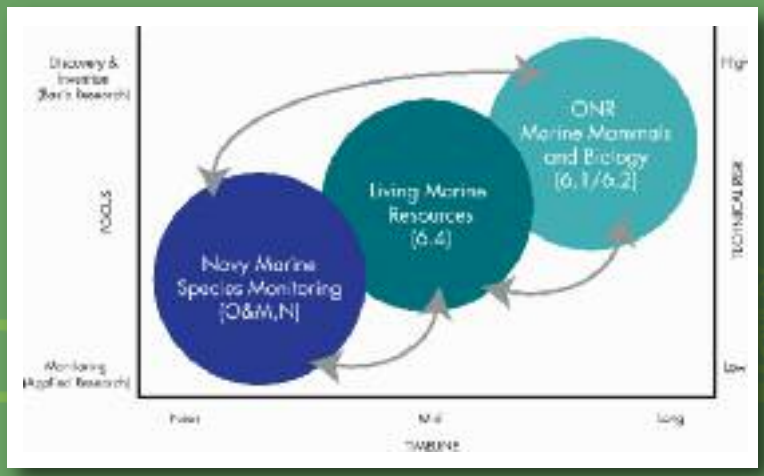


The DTAG3x V1.0 assembly.
Alex Shorter

Responsibility and Coordination of the Navy's Research & 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. The Navy conducts 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 three programs:

1. The ONR MMB program
2. The LMR program
3. The U.S. Navy Marine Species Monitoring program



The ONR 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. Outcomes from this program often are transitioned to the LMR program to continue to develop, demonstrate and validate solutions.

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 at-sea environmental compliance community.

The U.S. Navy's Marine Species Monitoring program conducts the monitoring and reporting for the Navy's regulatory compliance process associated with the Marine Mammal Protection Act (MMPA) and the Endangered Species Act (ESA). The Marine Species Monitoring program typically uses tools that have already been developed under the ONR MMB program and field tested/validated or developed by the LMR program.

Attaching tag to a North Atlantic right whale. The tag is equipped with a new type of suction cup for longer attachment times. *Permit 14791*

1998 to bring parties together to review the status of tags and discuss needs. A third workshop, held in 2009, focused on:

1. Identifying needs related to further development of tag attachments.
2. Identifying research required to evaluate physical, physiological and behavioral effects of tags on cetaceans.
3. Determining if there was community interest to develop and establish 'Guidelines for Cetacean Tagging Studies,' including best practices for conducting cetacean tagging.

Recommendations from this third workshop resulted in several studies to improve tag attachment and to assess the behavioral, physiological and demographic effects of tags on cetacean populations.

A subsequent workshop in September 2017, co-sponsored by the ONR MMB program, the International Whaling Commission Scientific Committee and NOAA's Marine Mammal Health and Stranding Response Program, was held to review results of the studies funded following the 2009 workshop.

A final summary of the 2009 workshop, Cetacean Tag Design Workshop, can be downloaded at www.onr.navy.mil/en/Science-Technology/Departments/Code-32/All-Programs/Atmosphere-Research-322/Marine-Mammals-Biology/Marine-Mammal-Biology-Thrusts. (Look for the link under the "Sensing and Tag Development" header.)

WHAT DO TAGS CAPTURE?

As tag technology continues to advance, the data they capture help to refine the insights into marine animal behavior, moving away from generalized guesses to increasingly informed knowledge. Importantly, on-animal tags provide views that shipboard, seafloor arrays or anchored buoy receivers can't. The tags go where the animal goes rather than relying on where researchers have been able to go. As tag technology has advanced, the information about marine mammals and their behavior has mushroomed. Early efforts revealed where an animal went, how deep it could dive, how long the dives lasted and some oceanographic information. With new sensors and growing understanding of marine mammal sound, newer tags can offer on-animal insights to how the animals use and respond to sound, how they forage and how they interact with their habitats.

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Tags come in various shapes and sizes with different types of sensors depending on their use. Depending on the suite of sensors packaged in a given tag, it might collect data on:

1. Animal location
2. Animal movement, direction and speed and orientation in space
3. Dive depth and duration over time
4. Environmental conditions (e.g., conductivity, temperature, depth and light)
5. Sound, both made by and received by the animal

This type of information helps the Navy monitor for marine mammal presence, abundance and behavior, particularly on its at-sea ranges.

The tag selected and its combination of sensors primarily depends on the goal of the monitoring and the species being monitored. Other questions influencing tag types and sensor packages selections can include:

- Will data be stored, requiring the tag to be retrieved?
- Will data be transmitted via satellite?
- How frequently will data be collected (i.e., sampling frequency)?
- Over what time period will data be collected (e.g., a few hours, a few days)?

Answers to these types of questions influence tag size, retrieval method, battery life and attachment types.

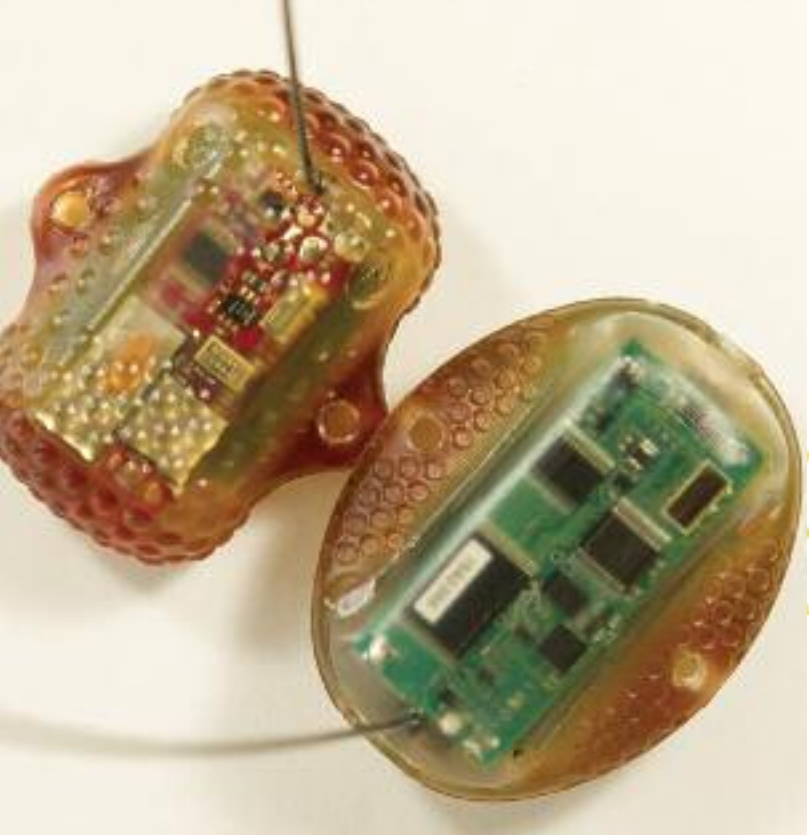
Types of Monitoring Tags

Monitoring tags go by many names and serve many different functions. Early tags were often called data loggers or radio telemetry devices. Biologging is another way to refer to monitoring using tags. In their 2009 meeting report, New Frontiers in Bio-logging Science, Christian Rutz and Graeme Hays defined biologging as "the use of miniaturized animal-attached tags for logging and/or relaying data about an animal's movements, behaviour, physiology and/or environment. Animal telemetry is another term often used to refer to tracking and monitoring animals, both marine and terrestrial.

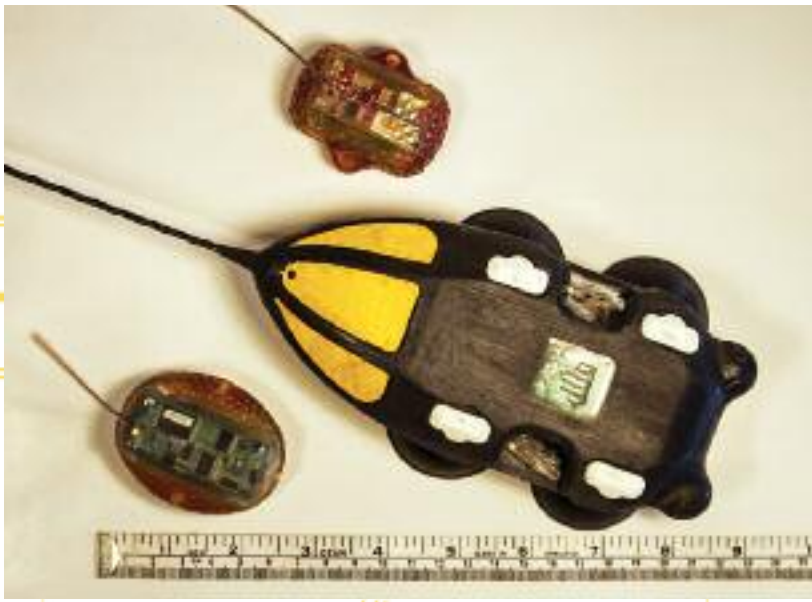
While there are several types of monitoring tags (or data loggers, biologgers or animal telemetry devices) and there is overlap in capabilities, tags generally fall into one of three broad categories:

1. **Archival Tags**
   Archival tags are, as the name suggests, a type that stores (archives) the data collected. Depending on the amount of built-in memory, these tags can collect and store larger quantities of fine-scale data. The tags must be retrieved to collect the data, which influences how they are used. Early tags required locating the tagged animal. This works well with animals such as seals, that often return to known locations. More recent models designed for whales and other aquatic animals that cannot be captured for retrieval include flotation and a beacon to help track and recover the tag. Some of the retrievable versions also are configured to allow researchers to signal tag release. These tags typically are larger to accommodate data storage, flotation and beacons.
2. **Satellite Tags**
   These tags are configured to send collected data to the Argos system aboard NOAA polar orbiting satellites. They have the benefit of not requiring retrieval of the physical tag and provide near real-time location data anywhere in the world. Some tags can store limited amounts of data prior to transmission. Limitations of satellite tags include that connection and transmission can only occur when the animal surfaces and the satellite is available; the types and amount of data that can be transmitted through relatively minimal bandwidth during the brief connection are necessarily restricted; and connection to polar orbiting satellites is less robust in ocean areas distant from the poles.
3. **Acoustic Tags**
   There are two general types of acoustic tags—active transmitters and passive recorders. Active transmitters allow an animal, such as a fish, to be tracked over long periods. The devices can be small enough to be carried inside a salmon smolt. The second type of tag—an acoustic recording tag—is attached to an animal and captures sound made by the animal and/or surrounding sounds. These acoustic recording tags traditionally include only onboard data storage and require retrieval.

The amount of data that can be captured by a given tag depends upon onboard storage capacity, sampling frequency, battery power and life, as well as how long the tag stays on the animal. Attachment mechanisms vary by tag.



Two Low Impact Minimally Percutaneous Electronic Transmitter (LIMPET) tags that have been used in Navy-funded monitoring are the SPOT6 (left) and SPLASH10 (right) from Wildlife Computers.
Cordelia Shea



Size comparison of tags: SPOT6 location tag (top), DTAG-3 acoustic and multi-sensor (middle) and SPLASH10 location and dive data tag (bottom).
Cordelia Shea

For example, studies focused on where an animal goes and how it moves might use smaller satellite tags, similar to the Wildlife Computers' SPOT6 and SPLASH10 tags. The smaller SPOT6 (left in photo) is location only, using an Argos satellite-based connection. The somewhat larger ovoid SPLASH10 (right in photo) has sensors to collect data on diving behavior. The additional types of data and tag size comes at a cost of shorter battery life, less frequent data transmission and a higher price tag.

Another tag developed for the purpose of studying diving behavior is the Advanced Dive Behavior (ADB) tag. This tag has been used with success on large whales including sperm, fin and blue whales. One of its developers, Bruce Mate, describes the tag as "a spatially explicit, high resolution (1-Hertz (Hz)) data logger for large whales capable of staying attached for intermediate time periods (weeks to more than a month)." Funding for this tag came from International Association of Oil and Gas Producers and ONR. The tag has been used in work supported by the U.S. Navy Pacific Fleet under the U.S. Navy's Marine Species Monitoring program.

When studying sound (the sounds an animal makes, what it hears and how it affects its movement), a DTAG or Acousounde tag might be employed. The ability to capture sound does come with costs. Acoustic tags are larger, more expensive, require more power to operate and, typically, do not stay on the animal as long as the smaller, non-acoustic tags.

HOW MONITORING TAGS HAVE BEEN USED ON NAVY AT-SEA RANGES

For many years, the Navy has funded studies on its at-sea training ranges to improve knowledge about what animals are present, when they are present, how they use the areas and how they respond to sound, including mid-frequency active sonar (MFAS). Some of the projects are funded by the ONR MMB program to test new technologies. Other projects funded by the Living Marine Resources (LMR) program support validation of equipment and monitoring methods. U.S. Navy Marine Species Monitoring program efforts focus on range

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permit compliance requirements that arise from a suite of environmental laws and regulations that apply to the marine environment, including the Marine Mammal Protection Act (MMPA) and the Endangered Species Act (ESA).

In general, multiple approaches are employed to locate, identify, listen for and track cetaceans on the ranges. Techniques have included:

1. Visual surveys

   Observers watch for animals from boats and planes and try to follow identified animals. These have been supplemented by photographic surveys to help researchers track individual animals.

2. Acoustic surveys

   Technicians monitor range hydrophone arrays, such as those installed on multiple Navy at-sea ranges, to identify signals of whale vocalizations. Particular signals captured on the arrays can be used to provide preliminary detection, classification and location of cetaceans on the range. (This approach is followed by the Marine Mammal Monitoring on Ranges (M3R) program.)

3. Tagging

   Researchers in boats attach tags to whales to collect data on behavior, including dives, travel, sounds made and sounds to which they are exposed.

Overview of Marine Mammal Monitoring on Ranges Program

Navy at-sea training ranges are equipped with sea-bottom hydrophones (underwater microphones) to track sounds across the range. Marine mammal sounds can also be detected by the hydrophones. As years of marine mammal research have revealed, different species vocalize at different frequencies and have distinguishing types of sounds (clicks, whistles, moans, and hums), of which some allow species identification from sounds alone. These sounds are detected on individual hydrophones as an animal, or group of animals, vocalizes within the range. The M3R program was initiated to determine how equipment on Navy ranges might be used to monitor for marine mammals. The goals of the M3R program are to:

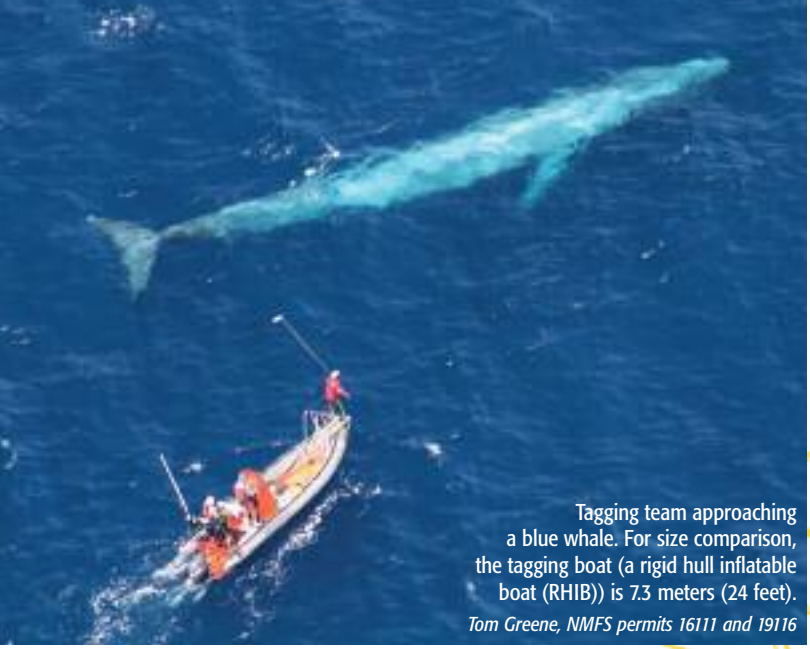
1. Develop automated passive acoustic marine mammal detection, localization, classification and display tools using existing Navy undersea hydrophone arrays and integrate visual and satellite monitoring methods to leverage the combination of the methods to study marine mammals on Navy ranges.
2. Study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

To verify the passive acoustics data, on-water sighting data were collected to provide a direct observation of species identification, physical behavior, group size and population demographics along with biopsy sampling and prey mapping. During focused field efforts during the year, satellite tags are also attached to selected (focal) animals to measure both their dive behavior and their movement over the span of months both on and off the range. When possible, these data are evaluated along with precise ship tracks and sonar received level measurements, to investigate the effects of repeated sonar exposure on cetaceans. The real-time passive acoustic monitoring capability of the M3R program has proved to be a significant aid to the tagging field team to find focal species.

The M3R program is currently being integrated at three Navy undersea ranges equipped with arrays of broadly-spaced (1-4 miles), 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
3. The Pacific Missile Range Facility (PMRF) in Barking Sands, Hawaii

A fourth undersea range, the undersea warfare training range (USWTR) under development off of Jacksonville, Florida, had a prototype three-node system installed in 2016.



Tagging team approaching a blue whale. For size comparison, the tagging boat (a rigid hull inflatable boat (RHIB)) is 7.3 meters (24 feet).
Tom Greene, NMFS permits 16111 and 19116

The Navy has sponsored and/or participated in many long-term projects involving these and other techniques. Examples include the following efforts.

Southern California Behavioral Response Study (SOCAL BRS)

SOCAL Range Complex

Initiated in 2010, this project was designed to increase understanding of marine mammal reactions to sound and provide a more robust scientific basis for estimating the effect of Navy MFAS on marine mammal behavior. Co-funded by the ONR MMB and LMR programs and SERDP, the project included annual on-water efforts to identify species present, tag individual animals and collect data on animal responses to sound. Researchers used high-resolution, multi-sensor tags that provided direct measurements of potential behavioral responses. During the study timeframe researchers were able to make use of new technology as it became available. Acoustic tags with multiple sensors, including DTAG-2, DTAG-3 and Acousounde tags, collected on-animal data of sound both received and made by the animal, dive depths and duration, acceleration, pitch and roll and water temperature.

Distribution and Demographics of Marine Mammals in the Southern California (SOCAL) Range Complex

SOCAL Range Complex

This series of surveys has been conducted within the SOCAL Range Complex to define marine mammal occurrence in relation to the M3R system detections. Survey methods include attaching satellite tracking tags to a variety of species, taking photographs taken for use in photo identification and taking biopsies when possible.

Baleen Whale Tagging in Support of Marine Mammal Monitoring Across Multiple Navy Training Areas

SOCAL Range Complex

Researchers deployed Wildlife Computers' SPOT5 and Mk10-PATF (advanced dive behavior) tags to monitor blue and fin whale use of Navy training areas. Researchers evaluated whale movement across and residence times within training areas in support of Navy compliance with regulatory requirements.

Fin whale.
Jeff Foster, NMFS Permit 16111

Analysis of Monk Seal Behavior Relative to Navy Activities in the Hawaii Range Complex

Hawaii Range Complex

In the collaborative two-year study, SMRU GPS telemetry tags were deployed on several Hawaiian monk seals. Initial studies monitored monk seal habitat use in the main Hawaiian Island areas, including their home range and foraging areas. Subsequent work investigated potential impacts of naval activities on seal behavior. Seal location data were compared to hull-mounted sonar ship locations in order to estimate potential exposures and responses. No abnormal behavior was detected.

The projects summarized here reflect a small sub-set of efforts underway, but offer a glimpse of the important role monitoring tags play in securing critical data for Navy regulatory compliance.

Hawaiian monk seal.
Morgan W. Richie

Multi-species Odontocete Research off Lanai, Hawaii

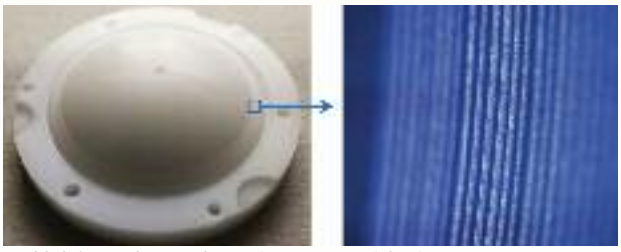
Hawaii Range Complex

The U.S. Pacific Fleet and National Marine Fisheries Service's Pacific Island Fisheries Science Center incorporated multiple approaches to understand odontocete (toothed whale) distribution, habitat use and population structure in a four-island area off Lanai. Approaches included visual sightings, photo identification, genetic analyses of biopsy samples and satellite tagging.

Tagging and Tracking of Endangered North Atlantic Right Whales in Florida Waters

Jacksonville Range Complex

North Atlantic right whales use the coastal waters off Florida and Georgia during the winter months. These winter calving grounds are adjacent to the U.S. Navy's planned undersea warfare training range (USWTR) off the coast of Jacksonville, Florida. A targeted tagging program is underway to collect such data as horizontal movement, dive profile and vocal behavior from individual whales. These data are needed to inform monitoring and mitigation techniques and reveal the potential for disturbance to right whales as the USWTR construction and training operations commence. Devices employed for monitoring include suction cup tags (anticipated tag duration from one to 36 hours) with Fastloc GPS technology, time depth recorders (TDR), three-dimentional movement measurement and acoustic recording capability.



Mold (left) used to produce micro texture (right) into the edge of tag suctions cups.
A. Cannon

North Atlantic right whale.
Georgia Department of Natural Resources, permit 15488

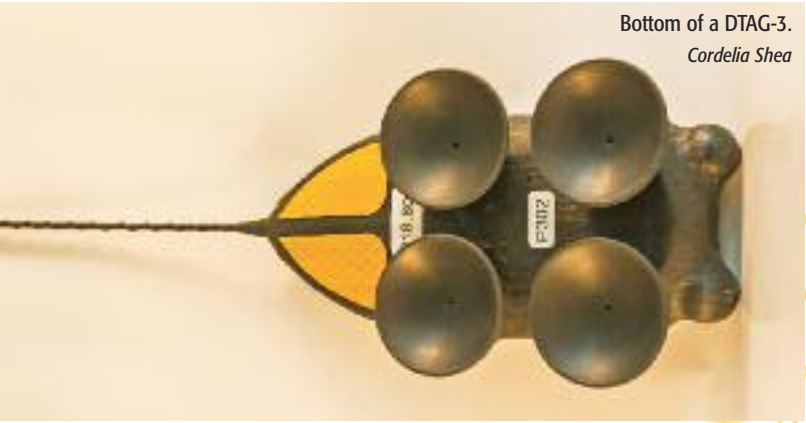
The goal is to attach tags to right whales of all ages and sexes to assess their movement patterns. This effort also includes testing new micro-texture and biocompatible glues for suction cup tag attachments.

Humpback Whale Tagging and Tracking in the Mid-Atlantic

Near-shore Mid-Atlantic

This project is collecting baseline occurrence and behavior data for humpback whales in the Hampton Roads mid-Atlantic region. Collection efforts include visual surveys with associated photo identification, biopsy sampling and tagging using Smart Position and Temperature (SPOT-6) Argos-linked satellite tags in the LIMPET configuration. The data will inform steps to mitigate potentially harmful effects on the species from U.S. Navy training and vessel transiting activities off the coast of Virginia. (Note: A video about this work can be found at www.navymarinespeciesmonitoring.us/news/humpback-whale-tagging-and-tracking-mid-atlantic.)

Humpback whale.
NOAA/NMFS



Bottom of a DTAG-3.
Cordelia Shea

Atlantic Behavioral Response Study

Cape Hatteras Study Area

This project is generating BRS data in a new geographic area and increasing the currently limited sample size of the behavioral response of key species to Navy tactical sonar. The effort will expand the temporal and spatial scales of previous BRS efforts by combining satellite-linked time-depth recording tags (SLTDR) (e.g. SPLASH tags) and short-term, high-resolution DTAGs in the same controlled exposure experiments.

The projects summarized here reflect a small sub-set of efforts underway on or near Navy at-sea training ranges, but offer a glimpse of the important role monitoring tags play in securing critical data for Navy regulatory compliance. For more on these and other Navy monitoring efforts, visit the LMR website (at (http://greenfleet.dodlive.mil/lmr) and the Navy Marine Species Monitoring program website (at www.navymarinespeciesmonitoring.us).

COORDINATING THE DATA: THE ANIMAL TELEMETRY NETWORK

Monitoring tags, also called animal telemetry devices, are used by numerous researchers on a wide range of aquatic species, generating significant quantities of data that could provide detailed insights into the oceanic ecosystem. Until fairly recently researchers have retained all the collected data, publishing scientific reports from their analyses. Not only does this potentially limit broader analysis of data but also risks loss of data over time. Having data centrally located and widely available could potentially lead to new views into how aquatic animals move through and interact with their environment, as well as ensuring that data are preserved.

The U.S. Integrated Ocean Observing System (U.S. IOOS), a national-regional partnership, initiated an Animal Telemetry Network (ATN) to facilitate collaborations among all federal and non-federal entities conducting animal telemetry research. The intent is to provide long-term archive of real-time data on animal movement and behavior and to integrate this with multiple sources of environmental data to better assess the drivers for animal behavior and distribution. Such integrated bio-physical observations can provide critical scientific information to support the management of marine fisheries and endangered and protected species, assess the potential effects of anthropogenic disturbances and improve ocean modeling and forecasting.

One key component is the Animal Telemetry Network Data Assembly Center (ATN DAC). The ATN DAC was coordinated by the U.S. IOOS and the ONR MMB program in cooperation with Stanford University, University of California Santa Cruz and NOAA's Southwest Fisheries Science Center Environmental Research Division. Several other universities and public and private partners participate. The ATN DAC is a web portal and access point for data and, in the future, data products. Currently, the DAC provides access to different species such as sharks, sea turtles, seals, whales, tuna and squid with deployment dates ranging from 2000 to 2017. The goal of the data

Advances in monitoring tags have been central to ensuring the Navy's ability to utilize its ranges for training and testing activities at-sea.

center is to ensure that biological and physical monitoring data are well maintained and widely available. Having a central repository promotes consistent data organization, providing reliable and accurate data.

For an up-to-date inventory of ATN data sites and other information, visit http://oceanview.pfeg.noaa.gov/ATN.

Navy programs that collect or fund collection of animal telemetry data require that the data be added to the ATN DAC.

THE ROLE OF MONITORING TAGS IN KEEPING THE NAVY AT-SEA

Advances in monitoring tags have been central to providing information to support the Navy's environmental compliance efforts and ensuring the Navy's ability to utilize its ranges for training and testing activities at-sea.

As noted in a previous section, the U.S. Navy is required to comply with a suite of environmental laws and regulations that apply to the marine environment, including the MMPA and the ESA. Both statutes require agencies to quantify the effects of their actions on protected marine species. The Navy utilizes acoustic modeling to quantify the potential effects of its training and testing activities on marine species. Detailed information about marine species is required to support these modeling efforts. Just a few of the types of information required include:

1. Spatial and temporal distribution and density of marine species
2. Movement, diving behavior and group size of marine species
3. Criteria and threshold for predicting effects to marine species

Monitoring tags are integral in supplying these types of data.

Tagging efforts on a variety of marine species have illuminated the ways these animals utilize the underwater environment for feeding, breeding, resting and other important life history functions. Monitoring tags have helped the Navy understand which marine species inhabit specific geographic areas, where and how long they are present in those areas, how their activity levels vary throughout the day/night and what their diving capabilities are among others things. Many of these parameters are used in acoustic modeling. The use of these parameters helps the Navy more accurately estimate the potential for marine species to be exposed to the stressors associated with Navy activities based on the location of the activity both geographically and within the water column and how that correlates to a species' known preferences.

The DTAG provides an example of how vitally important tag technology is to the Navy's ability to understand the behavioral responses of marine mammals to sound. The fine scale information that DTAGs can record on the animal's location and movement, coupled with the tag's ability to record the sound level of noises that the tagged animal experiences in its environment, has enabled researchers to identify parameters that influence an

The U.S. Integrated Ocean Observing System

The U.S. IOOS, one of the coordinating organizations of the ATN, is a national-regional partnership working to provide new tools and forecasts to improve safety, enhance the economy, and protect our environment. The U.S. IOOS was authorized by the Integrated Coastal and Ocean Observation System Act of 2009 with NOAA designated as the lead federal agency. It is a partnership of 18 Federal agencies, 11 regional associations, the Alliance for Coastal Technologies and the U.S. IOOS Coastal and Ocean Modeling Test bed. A national ATN through the U.S. IOOS will provide integrated data on aquatic ecosystems from species to environment. This network will complement existing ocean observing assets and will inform ecosystem-based management, fisheries and biodiversity, marine planning, ocean modeling and forecasting and National Ocean Policy priority objectives.

For more on the U.S. IOOS, visit https://ioos.noaa.gov.

A sperm whale surfaces immediately after being tagged with a suction cup DTAG. The DTAG will capture detailed data on the whale's movements, dives, and received sound levels.

Rune Roland Hansen, Norwegian Animal Research Authority permit 2015/223222

animal's behavioral response to sound. For instance, comparisons of DTAGs that have recorded exposures to scaled sonar sources versus real-life tactical sonar have shown that responses are not directly correlated to the received sound pressure level an animal hears and may be influenced by other contextual factors. These other factors include the distance from the sound source and the behavior the animal is engaged in at the time of exposure (i.e., feeding versus resting). DTAGs have enabled the Navy to develop behavioral risk functions to help predict those parameters that may result in the animal behaviorally responding to sonar or other sounds.

Other significant contributions from monitoring tags include reducing the cost of data collection to the Navy and opening new avenues to collect previously unobtainable data. Prior to monitoring tags, studies examining the behavior of marine mammals could only be obtained through techniques called "focal follows" in which researchers in boats or on aircraft followed the animals to observe behavior. The high cost of vessel and aircraft time limited the extent of such studies. Additionally, the amount of information that could be gleaned was limited to what observers could visually detect at the surface. Given that marine mammals can spend up to 90 percent of their time below the water's surface, it was only possible to collect data on a small percentage of their complete behavioral repertoire.

Tagging has also enabled the Navy to collect data in remote areas or at a time of the year in which conditions may not be suitable for other methods or would be highly cost prohibitive. For instance, researchers are using animal-borne tags in the Arctic and Antarctic to collect data on the water column and the acoustic propagation of under sea ice environments. Such data collection would not be possible during certain times of year due to extreme weather conditions or would require expensive equipment capable of withstanding harsh environmental conditions.

Navy investments in tag technology have helped the Navy, regulators and the public better understand how marine mammals utilize the undersea environment.

THE FUTURE OF MONITORING TAGS

New questions about the ocean, its inhabitants and the effects humans can have in the ocean environment will continue to push for new ways to acquire data. It is anticipated that the Navy will continue to invest in improving and expanding monitoring technology. Some projects already underway or of possible interest are noted below.

Sound and Motion Recording and Telemetry (SMRT) Tag

The amount and type of information from monitoring devices falls along a wide spectrum. Tags like the DTAG and Acousonde can capture large amounts of many types of data, but trying to transmit so much data via satellite poses limitations. Only a limited quantity of data can be transmitted within the brief time a link is established. Location-only tags can more quickly connect and transmit their data, but the range of data types is limited. An ONR MMB program-funded project is working to address these limitations.

Video Tags

Video is offering new views on how animals use their habitat but tag size and battery life pose issues. One project, jointly funded by the ONR MMB program and other organizations, is supporting tests of archival tags that combine a high-definition video camera with motion and environmental sensors to expand data on animal location, movements and foraging. Developed by Customized Animal Tracking Solutions (CATS), the tags include tri-axial accelerometers, magnetometers and gyroscopes that record motion as well as sensors that measure depth, temperature and light. The large volumes of data collected by these tags are prohibitive for satellite transfer. Tag performance, attachment and release mechanisms and utility for measuring foraging behavior of marine species are being evaluated.

The tags attach to the whale using minimally invasive suction cups, which stick to the whale for up to 24 hours. After tagging, the whale is tracked visually and acoustically, and using VHF signals given off by the tag itself when at the surface.
Lucia Martin, Norwegian Animal Research Authority permit 2015/223222

Motes

To address some of the challenges posed by satellite-linked tags—limited opportunities to establish connections, limited bandwidth for data transmission and limited coverage area away from the polar regions—the ONR MMB program is working with Wildlife Computers to evaluate the effectiveness of land-based receiving stations (called "Motes") that can receive, log and relay messages from devices transmitting on the Argos frequency. Motes that can capture most of a tag's data burst could make it possible to get more information from a tag.

CubeSat Nanosatellites

CubeSats are a type of nanosatellite (small satellites that fall within the one to 10 kilogram size) that are of a standard size and format. With their small size and lower cost than standard satellites, it might become possible to deploy more of them. Although not currently within the Navy monitoring methods, these devices may offer opportunities to improve transmission coverage and increase throughput of tag data.

CONCLUSION

As improvements in tag technology have enabled the collection of more accurate, fine-scale information across a wider array of species, the Navy continually refined the assessments of the potential effects that Navy training and testing activities may have on marine species. This provides decision makers, both within the Navy and at regulatory agencies, with the information they require to make informed decisions about those potential effects. Data from monitoring studies using tags also helps the Navy understand ways to monitor for or mitigate those potential effects. Lastly, Navy investments in tag technology have resulted in important contributions to the overall state of knowledge and have helped the Navy, regulators and the public better understand how marine mammals utilize the undersea environment. ⚓

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