Underwater Acoustics for Everyone

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Discovery of Sound in the Sea (www.dosits.org) makes underwater acoustics accessible for everyone from grade school students to reporters, the public, and natural resource regulators.

Introduction

Seawater scatters and absorbs beams of light, making it difficult to see objects clearly and at far distances underwater. Light penetrates only a few hundred meters into the ocean, and trying to see underwater is similar to looking through fog on land. Sound travels faster under water than in air (1500 meters per second (m/s) versus 300 m/s), providing information after much shorter delays (for the same distance in air). Since sound travels far greater distances than light under water, sound is often used to accomplish many activities by both animals and people. Oceanographers, submariners, whales, dolphins, fishes, in short, all working or living in the ocean, use sound to sense their surroundings, to communicate, and to navigate underwater.

For example, humpback whales have learned to utilize sound in a unique feeding behavior, which researchers have studied using acoustic tools. Bubble-net feeding is a coordinated foraging technique in which multiple whales emit bubbles from their blowholes to restrict the movement of the forage fish. Whales then lunge from the seafloor through the column of bubbles to the sea surface with a mouth full of food (Figure 1). Researchers have designed digital suction cup tags that are attached to animals to measure their pitch, roll, heading, depth, and sound production (Johnson and Tyack, 2003). These tags were placed on feeding humpback whales to provide insight into the underwater behaviors associated with bubble-net feeding (Wiley et al., 2011). When and where in the behavior bubbles were produced were identified using sound, which allowed researchers to identify the habitat characteristics that constrain this unique feeding behavior.

While underwater sound is universally utilized for a wide variety of tasks, the science of sound can be complex and difficult to grasp. Children learn at an early age that by banging a spoon on a metal bowl, they are able to make wonderful sounds that garner attention. A love of music is also developed and hopefully encouraged throughout a child's life. A fundamental presentation of the science of sound and how it is described is often presented to students in 3rd or 4th grade in U.S. schools and again in physical science classes in 7th or 8th grade. However, beyond these rudimentary introductions, the study of the science of sound is not typically included in traditional public school curricula.

To provide consolidated resources on underwater sound, the Discovery of Sound in the Sea project (DOSITS; www.dosits.org) has been designed to provide accurate scientific information at levels appropriate for all audiences, including the general public, K-12 teachers and students, college students, regulators and policy-makers, and professionals in industry, education, and the media (Vigness-Raposa et al., 2008, 2012, 2014; Figure 2). The DOSITS website covers the foundational physical science of underwater sound and how sound is used by people and marine animals for

a wide range of tasks and behaviors, from exploration to communication and survival. Three main science sections organize the content around key concepts. The site also has four galleries, which focus on underwater sounds (Audio Gallery), scientific equipment (Technology Gallery), acoustics related research (Scientist Gallery), and related careers (Career Gallery). A brief introduction to the foundational science and galleries included on the DOSITS website follows, as well as a more detailed discussion of the newly developed Career Gallery.

Figure 1. *Humpback whale feeding at the ocean surface on fish. The upper jaw is displaying baleen plates that are used to sieve fish from the water, while the lower jaw is displaying distended throat grooves that allow for large gulps of water to be processed. Photo credit David Csepp, NOAA/NMFS/AKFSC/ABL, National Oceanic and Atmospheric Administration/Department of Commerce.*

DOSITS has also developed specialized resources that target a wide variety of audiences. There is much interest in underwater sound in the general public, particularly as it relates to potential effects of anthropogenic noise activities on marine animals (Nowacek et al., 2007; Southall et al., 2007; Popper & Hastings, 2009; Ellison et al., 2012; Moore et al., 2012; Popper & Hawkins, 2012). The media widely covers marine mammal stranding events due to the public's interest and fascination with marine mammals. The pictures of dead animals on beaches can result in an understandable desire to know the cause of such losses and how they could be prevented. Misinformation in the media may mislead the public into thinking that scientists may know the cause(s) behind specific stranding events. The resources that are available for the media to appropriately report on the issues of underwater sound and how people's use of sound may coincidentally occur with the strandings of marine mammals have been limited. The media, including print, radio, Internet, and television reporters, need easy access to short, succinct recaps of the most up-to-date scientific research results on underwater sound and its effects on marine life to complement the latest news event that they are investigating.

As mentioned above, educators in both formal and informal settings address the science of sound. It is important that when they search for related materials that they are able to find proven, research-based information, founded on published, peer-reviewed literature. DOSITS provides this content, as well as educational resources that identify national science education standards. It is relatively straightforward for an educator to incorporate these resources into their learning environment once they have access to them.

Finally, natural resource managers and regulators are required to make decisions based on the best available science. However, they have limited time in which to find and/or follow the plethora of published scientific manuscripts. In addition, they may not have the backgrounds in science, much less acoustics, on which to understand the literature or to review the published scientific research and synthesize it, thereby integrating it into their decision-making.

This article will focus on the resources available on the DOSITS website for each of these user groups: media, educators/students, and regulators.

Foundational Science

DOSITS has three science sections that are the foundation upon which the remainder of the site is built: science of sound, people and sound, and animals and sound. These three major sections include approximately 400 pages of content, which provide a thorough introduction to underwater acoustics, its many uses, and the appropriate level of concern regarding potential effects on the environment and marine life with both basic level information as well as in-depth content. More advanced scientific discussions of key topics are also included.

Content on the DOSITS website comes exclusively from published, peer-reviewed literature. On many pages, there are inline citations that acknowledge the science on which the content is based and provide the visitor with an opportunity to read the primary literature. In addition to a list of references, each page also contains links to additional resources for the enthusiastic user to delve deeper into a particular topic.

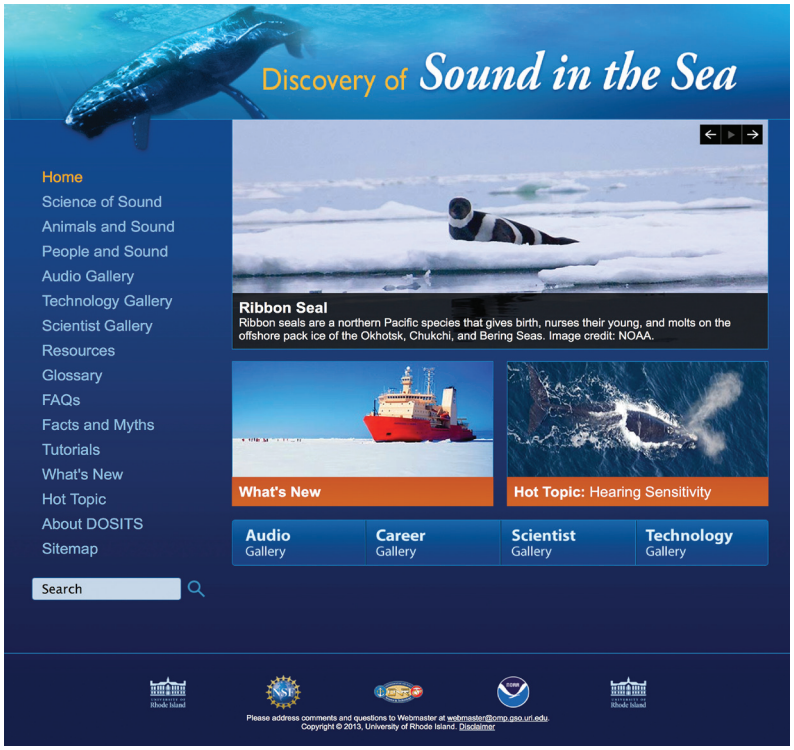

Figure 2. *Screen shot of the newly redesigned front page of the DOSITS website (www.dosits.org).*

Beyond being based on peer-reviewed literature, the process used to develop DOSITS content includes an additional level of peer review. Twice a year, the DOSITS scientific advisory panel is convened to review new material and update existing content, as new literature is published. The DOSITS core team of scientific advisors is joined by additional subject matter experts who review and edit every word before it appears on the site. With such intense scrutiny, the DOSITS site offers a fair and balanced view of the best available science on topics related to underwater sound.

The Science of Sound section (www.dosits.org/science/sciencesummary/) provides a comprehensive overview of the science of underwater sound. It begins with very basic pages that describe what sound is; how it is characterized by intensity, frequency, and wavelength; and how sound is produced. There are extensive sections on sound movement and measurement. Several of the science pages include associated advanced topics that extend the knowledge from the basic level presented on initial pages to a level that is targeted for upper high school, undergraduate, and early graduate level students (Vigness-Raposa et al., 2014).

The People and Sound section (www.dosits.org/people/peoplesummary/) includes information on the many important everyday activities in which people engage and on the ocean that depend on sound for success. Navigation, fishing, communication, and research and exploration are just a few examples of the tasks that require the use of underwater sound. Throughout the People and Sound section, there are extensive links to the Technology Gallery, which is described in more detail below, to provide insight into the tools and equipment that people use to accomplish these tasks.

Animals and Sound in the Sea (www.dosits.org/animals/animalsandsoundsummary/) includes information on how marine animals produce and receive sound, and use sound to sense their surroundings, communicate, locate food, and protect themselves underwater (Figure 3). Sounds may be intentionally produced as signals to predators or competitors, to attract mates, to maintain group cohesion, or as a fright response, for example. Sounds are also produced unintentionally including those made as a by-product of feeding or swimming. The animals may intentionally slap their bodies on the water or slap body parts together to make distinct sounds, like the sounds produced by a humpback whale breaching (Figure 4). The Animals and Sound section also includes an in-depth discussion on the current state of knowledge of the effects of underwater sound on marine mammals, fishes, and invertebrates.

Eye (and Ear!) Catching Galleries

Four galleries have been developed to highlight fascinating aspects of underwater sound and capture the imagination of all audiences, particularly those without an extensive science background. The four galleries focus on underwater sounds (Audio Gallery), scientific equipment (Technology Gallery), acoustics related research (Scientist Gallery), and related careers (Career Gallery).

The Audio Gallery (www.dosits.org/audio/interactive) is one of the most popular places on the site, as it includes sounds, videos, and images of over seventy-five sound sources. Even

Figure 3. *French grunts produce underwater sounds. Photo credit Julie Bedford, NOAA Public and Constituent Affairs, National Oceanic and Atmospheric Administration/Department of Commerce.*

Figure 4. *Time series of a humpback whale breaching. Photo credit Holly Morin, University of Rhode Island Graduate School of Oceanography.*

the youngest DOSITS user can spend hours listening and watching the variety of sound sources included in the Audio Gallery. Short descriptions of the sound sources support the media content, provided by over 150 generous acoustic researchers. Categories of sound sources include marine mammals, such as the humpback whale, Weddell seal, and killer whale; marine invertebrates, such as snapping shrimp and spiny lobster; natural sounds, such as lightning, rainfall, and waves; and anthropogenic sources, such as a torpedo firing, a transiting vessel, and Navy sonar. The Audio Gallery is continually being expanded to include new sources and new media files. Please review our current collection and if you are able to provide sound or video files of additional sources, we would love to talk with you!

The Technology Gallery (www.dosits.org/technology/techsummary/) highlights the tools and equipment that are used in underwater acoustics. Because light travels very short distances under water, sound is used for many tasks for which light would be used in air. To accomplish these tasks, unique equipment has been designed and engineered. The Technology Gallery highlights many of these, from broadly used gear such as hydrophones and projectors (sound sources) to very specialized technology such as Acoustic Doppler Current Profilers (ADCPs), archival marine acoustic recording units, acoustic fish tags, and multibeam echosounders. For example, the Automated Benthic Explorer (ABE) is an autonomous underwater vehicle (AUV) designed to collect data and samples, which uses multibeam echosounders for advanced seafloor mapping (Figure 5).

The Scientist Gallery (www.dosits.org/scientist/scsummary/) is designed to capture and motivate the next generation of science, technology, engineering, and mathematics (STEM) scientists. Young students and the general public are curious about the paths scientists took to get to where they are and what their daily activities involve. The Scientist Gallery includes interviews with five leading scientists, who describe their research relating to underwater acoustics. It also includes the video transcripts of the scientist interviews along with questions focused on what brought them into science, and acoustics in particular, and what they would recommend for the next generation of science leaders. These very detailed interviews are a wonderful complement to the extensive, broad Career Gallery that will be launched in spring 2014.

Newest DOSITS Gallery: Careers

There is a need to draw students into science careers. Students are enticed by adventure and action, and a career in ocean sciences offers both. Sixty-five percent of U.S. naval scientists are 40 years old or older and will need to be replaced by well-educated, future scientists that are U.S. citizens. The Career Gallery provides a glimpse into the variety of careers related

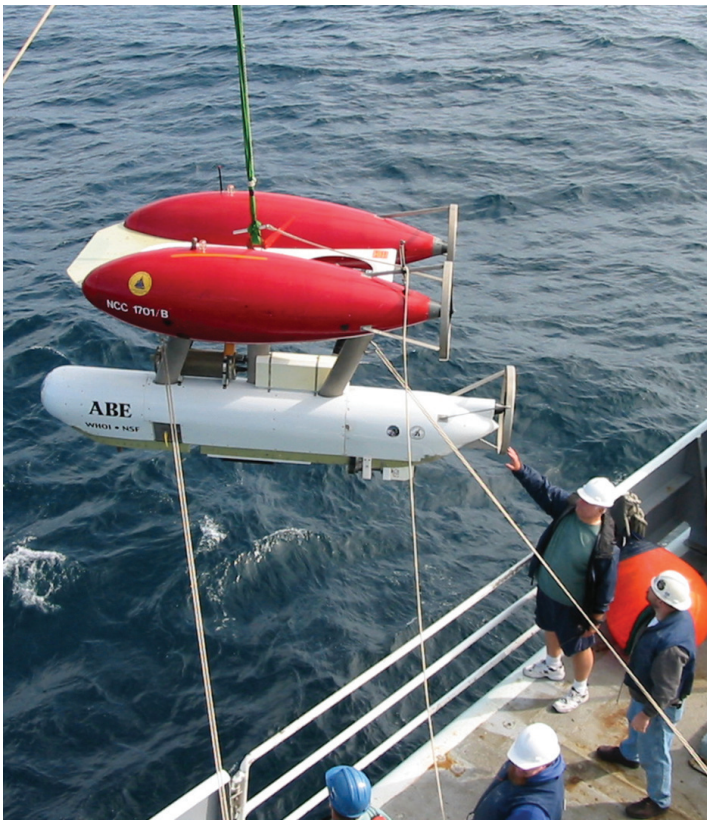

Figure 5. *The Automated Benthic Explorer (ABE) being launched for another night of data collection. Photo credit Submarine Ring of Fire 2002 Expedition, NOAA/OER, National Oceanic and Atmospheric Administration/Department of Commerce.*

to underwater sound. It is designed to help students gainan understanding of the diversity of career options, ranging from physical oceanographers, who map ocean currents, to ship operators and defense contractors.

DOSITS has developed material to encourage workforce development in STEM fields. The searchable career gallery describes over twenty ocean careers. Each career description includes details such as educational requirements, suggested knowledge and skills, possible duties and responsibilities, and estimated salary range taken from the U.S. Bureau of Labor Statistics (www.bls.gov). An example of a current person in each career is also included to provide real-world context to the reader. Links to the DOSITS Technology Gallery and other content pages are listed for each career description.

Resources for the Media

As mentioned above, reporters need straightforward resources that they can easily access (www.dosits.org/resources/). The media must often rapidly respond to events and quickly produce news content. DOSITS provides a Facts and Myths section to highlight the main questions that are continually posed by the general public on the science of underwater sound and to which media professionals are often responding. In a needs assessment with media and public affairs officers, an additional component to each quiz response was identified. Not only is it important to state the science facts, but the general public also wants a short explanation of how scientists know the given information. This explanation highlights the scientific process for understanding these critical questions. It also helps to educate the media and public affairs professionals, who will then transmit that knowledge to the general public.

In addition to the DOSITS Facts and Myths, there are several resources specifically designed for the media. There are two printed publications, a sixteen-page educational booklet and a trifold pamphlet. The educational booklet (www.dosits.org/resources/all/downloads/publications/booklet/) is designed for readers who may never get to the website. It includes summaries of the foundational science that is imperative for everyone to understand. It includes background information on the science of sound, sound production and reception by people and animals, recent scientific research highlights, and our current state of knowledge on the impacts of sound in the sea on marine animals.

The trifold pamphlet (www.dosits.org/resources/all/downloads/publications/brochure/) is designed as a teaser to the website content and is meant to pique the interest of the reader to explore the website for more details. It includes engaging pictures and brief statements focusing on critical points of underwater sound, but does not contain the rich knowledge found on the website or summarized in the educational booklet.

Most importantly, these printed publications have recently been translated into languages other than English, including French and Spanish. Work is ongoing to translate them into German and Italian. These printed materials have been distributed to members of Congress, public affairs officers, and other media outlets, as well as at scientific and educational conferences. All versions of the printed publications are available as PDF documents for download on the DOSITS website (www.dosits.org/resources/all/downloads).

An additional resource for the media is an FAQ (Frequently Asked Questions). This was created to focus on the most critical pieces of information about underwater sound, as well as those that are most difficult to understand and often misreported in media products. Eleven questions consolidate

information on the site into succinct answers, with links to other DOSITS web pages for more detailed discussions. The topics range from "What are common underwater sounds?" which lists sound sources and their source levels for comparison purposes, to "How does sound in water differ from sound in air?" and "What do we currently know about the effects of sound on marine animals?". These are fundamental concepts that the media needs to understand to accurately report on underwater sound.

The final resource for the media is a backgrounder on the topic of how animals hear underwater. The backgrounder is written as a stand-alone document that summarizes the current state of knowledge on animal hearing, but with links back to specific DOSITS pages for a more in-depth treatment of topics. It begins with the basic question of why sound is important to marine animals, then summarizes how marine mammals, fishes, and marine invertebrates hear. There is a final section that asks "Why is this important?". As the introduction to this page states, without a fundamental understanding of how marine animals hear, researchers cannot address the larger and more pressing issue of potential effects of underwater sound on marine life. There is a short discussion of how potential effects are quantified and a federal research plan that outlines the steps that need to be taken to better understand the problem.

Resources for Educators and Students

Educators and students need specialized resources to meet their instructional needs (www.dosits.org/resources/teachers/). As part of the original development of the DOSITS website, a cohort of teachers participated in a summer institute in which they received comprehensive instruction in the science of underwater sound. Their capstone project was to write a short description of a chosen "feature sound" and to develop an educational activity focused on underwater sound that addressed national science education standards. The content and related educational activities include highly quantitative exercises such as "Thinking Inside the Box," which is a hands-on inquiry activity that allows students to discover how scientists and researchers use sonar to explore the seafloor. They also include "Humpback Whales: The Great Communicator of the Sea," which includes two activities that engage students in a creative understanding of how humpback whales communicate using sound by choreographing and performing message movement phrases and composing and performing songs.

Oceanographers, submariners, whales, dolphins, fishes, in short, all working or living in the ocean, use sound to sense their surroundings, to communicate, and to navigate underwater.

Other helpful resources for teachers include a series of structured tutorials. Since educational instruction occurs with a linear progression of content, intended on developing more and more complex knowledge, the "web" format of an educational website can be intimidating for someone with limited background on the topic. In a needs assessment of educators, teachers expressed that they thoroughly enjoy the DOSITS website, but with its 400+ pages of content, they often didn't know where to begin. To facilitate their use of the site and its content, structured tutorials were created on key topics of the science of underwater sound, the technology of underwater sound, and the effects of underwater sound on marine life. The topics begin with foundational knowledge, then build in complexity, providing the linear structure that educators need for classroom instruction.

Presentations have also been created for educators to easily integrate DOSITS content into their classrooms. The content of the site has been transferred into Power Point files, including embedding image, sound, and video files for multimedia presentations on subject topics. The Power Point files are updated to maintain consistency with updates to the DOSITS site after each advisory panel meeting.

In addition to content presentations, two games have been developed. The "Name that Sound" Power Point is a wonderfully engaging activity for all ages to pique their interest in underwater sounds. A sound file is played and participants are then given four choices for the source of the sound. The answer slide plays the sound again, identifies the correct sound source, and provides background information on the sound source. The other game is Jeopardy!, based on the popular American television game show, with three levels of difficulty. The game is played just as the Jeopardy game show is played on television, with appropriate sound-related categories and increasingly difficult answers to which participants must provide the correct question. This game is a great introductory activity to assess students' current understanding of the science of underwater sound before exploring the DOSITS site or beginning a sound module. It can also be

used as an end-of-lesson assessment tool to determine the knowledge students have gained and retained during their sound studies.

As DOSITS has developed, there have also been requests from upper level high school and early level graduate instructors for materials that are more complex. While most pages on the DOSITS website do not contain equations or advanced mathematical functions, advanced topics have been written in each of the science sections to address more complex topics that are appropriate for advanced users. Recent topics that have been added to the advanced topic section include a discussion of explosive sound sources, statistical uncertainty, and detection threshold for sonar (as part of the sonar equation).

For those users who are not ready for advanced topics but would like to have a more comprehensive understanding of a given topic, each page on the website includes extension resources for expanded information. While the DOSITS site covers a broad range of topics, with over 400 pages of educational content, it is impossible to address each topic at the level of detail that every reader may desire. By providing extension resources, the enthusiastic user can use DOSITS as a jumping off point for their personal exploration of a topic in greater detail.

Resources for Regulators

It is clear that the regulator community needs easy to understand and rapidly accessible resources that are consistently available for reference. A web-based format is a logical go-to source for these stakeholders. The DOSITS team has had increasing inquiries for resources from the regulator community. Initial discussions with these stakeholders have identified several key resources that will aid regulators in making decisions related to underwater noise. Over the next two years, the DOSITS team will respond to this international need by developing two new resources: structured tutorials for regulators and an interactive iBook.

Similar to the problem that educators experience when first accessing the DOSITS website, the large abundance of scientific content in a web-based format, without consecutive structure, can be intimidating. For a non-science user of the site, the amount of information available may be overwhelming. In addition, regulators have specific informational needs compounded with impending deadlines that require a comprehensive, consistent, and easily accessible resource.

The planned structured tutorials on key topics will include a progression of sequential knowledge using existing DOSITS content. These topics will be identified through a needs assessment of the regulator community, to be conducted in spring 2014. The structured tutorials will be supported by additional existing pages within the DOSITS "Animals and Sound in the Sea" sections that maintain an up-to-date discussion of the most recently published peer-reviewed literature on the known effects on marine life from underwater sound exposures.

One tutorial topic that has already been identified is related to the process for determining the risk of marine animal exposure to noise. The basic question that regulators attempt to answer on a daily basis is "How do you determine if a sound source affects a marine animal?" The DOSITS site currently includes a single page that walks the reader through the basic steps of this risk assessment process. However, this does not adequately address the needs of the regulatory community. The corresponding tutorial will discuss underwater sound propagation; then progress to the coupling of the sound field to the potential field of marine life, including diving and movement behaviors, to predict exposure levels; and conclude with the range of potential effects that might occur based on those predicted exposure levels.

In addition to the structured tutorial, an interactive iBook is in development. The interactive Internet is widely recognized as the greatest learning tool in human history, with its impact broader than the printing press in knowledge dissemination and more rapid in its diffusions (Lewis et al., 2010). Web 2.0 features have enabled the developments of new digital media technologies that are not just the technical implementations themselves, but the frameworks that allow for direct participation and sharing of content (Jenkins, 2009). Digital media, particularly that used in hand-held devices such as smart phones, iPods, and iPads, are dramatically changing the science landscape, providing unprecedented opportunities for learning science content. The DOSITS interactive iBook will serve as a tool to make the science of underwater sound available to a wide audience of stakeholders, as well as people without Internet connectivity, via their hand-held and tablet devices. The iBook will utilize existing and updated content to provide a condensed electronic resource that will focus on how animals use, produce, and receive sound as well as an overview of the effects of sound on marine life.

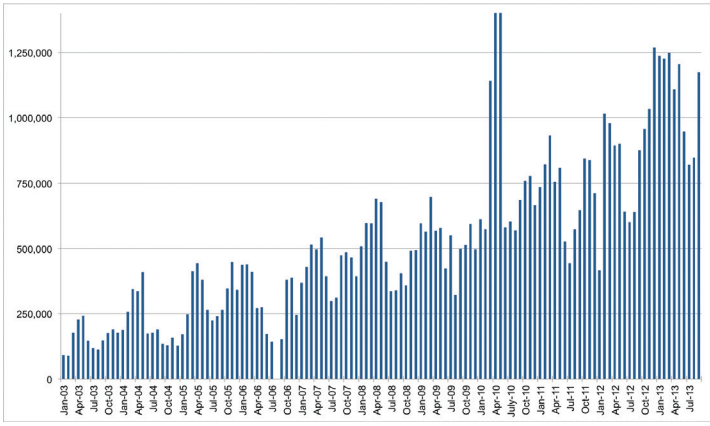

Figure 6. *DOSITS web traffic measured in number of hits per month from January 2003 to September 2013.*

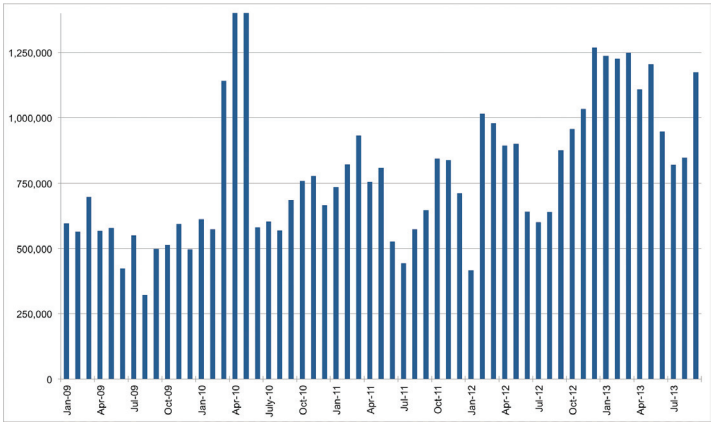

Figure 7. *DOSITS web traffic measured in number of hits per month from January 2009 to September 2013.*

DOSITS Traffic Summary

DOSITS was launched in November 2002. The site has experienced continued growth of visitor traffic each year, measured both in number of hits (Figure 6) and in amount of data served. Site traffic in the first few years exhibited a strong pattern that reflected the northern hemisphere school-year calendar, with the highest amount of traffic in the spring and the lowest amount in the summer and early fall. However, with additional international exposure and increasing use by media and regulator communities, the cyclical nature of visitor traffic has decreased.

In March 2010, DOSITS launched a thoroughly revised version of the website to take advantage of the advances in Internet capabilities since the original launch in 2002. The new version included an interactive front page, Audio Gallery, and Scientist Gallery, as well as adding video files to Audio Gallery pages and developing complex animations to the foundational science pages. In association with this launch, there was a huge media push that brought a large spike in traffic to the site.

Through September 2013, DOSITS has had over 68 million hits and over 5.9 million page views. In 2012, the DOSITS website saw a 20% growth in traffic to the site compared to 2011 and, through the first nine months of 2013, DOSITS saw approximately a 30% growth in traffic compared to the first nine months of 2012, measured in number of hits (Figure 7).

Visitors to the DOSITS website come from across the globe. Half the visitors during 2013 were from North America and close to a quarter of the visitors were from Europe (Figure 8).

One of the biggest changes to the traffic to the DOSITS site is due to the rise in use of mobile devices. Two years ago mobile devices represented only approximately 5% of the total traffic to the site. In the first nine months of 2013, mobile devices made up more than 27% of the site traffic (Table 1).

Since mobile devices are an increasing platform used by the DOSITS audience, the DOSITS team is making the site more mobile device friendly. Mobile devices, such as those running iOS platforms, cannot run Flash-based website material. To accommodate these devices, the DOSITS front page was recently redesigned to be Flash free and forward looking, enabling access for all devices (Figure 2). Other Flash heavy parts of the site (such as the current Audio Gallery) redirect mobile devices to non-flash equivalents.

Conclusions

All DOSITS information is based solely on published, peer-reviewed scientific research. Related research literature is continuously monitored for new information that is regularly incorporated into the website content and resources, ensuring that the most up-to-date research results can be found on the site. A new feature is the "hot topics" section, included on the front page. This feature is designed to highlight interesting and new developments provided by the research community that may occur between advisory panel meetings. Rather than waiting for new content to be written and reviewed by the advisory panel, which may delay its incorporation into the website for six months, if new peer-reviewed scientific papers are published in between advisory panel meetings that represent important, cutting-edge discoveries, a short summary of their results can be highlighted on the

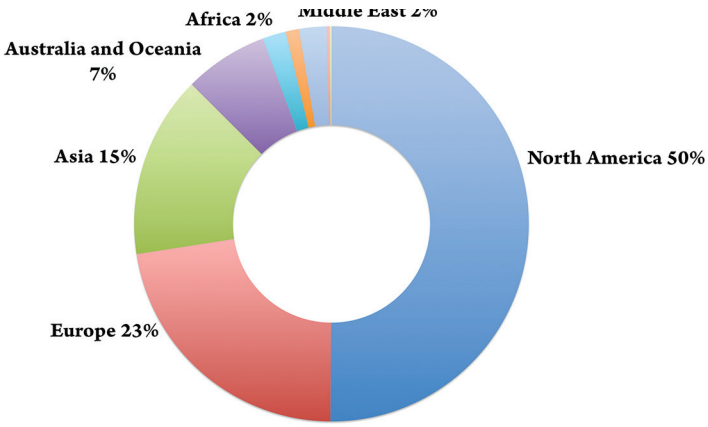

Figure 8. *DOSITS web traffic by region, measured as a percentage of total traffic for 2013.*

front page. More extensive content will then be reviewed by the advisory panel and incorporated into appropriate DOSITS sections following the regular procedure for content development.

In addition to DOSITS content being based on peer-reviewed scientific literature, the website itself regularly undergoes a thorough review by the DOSITS scientific advisory panel. Expertise in each of the major topic fields ensures the highest scientific accuracy and integrity possible for website content. Special thanks go to the Scientific Advisory Panel members: Dr. Peter Worcester of Scripps Institution of Oceanography, Dr. James H. Miller of the University of Rhode Island (current president of the Acoustical Society of America), Dr. Darlene Ketten of Curtin University, Dr. Arthur N. Popper of the University of Maryland (editor of Acoustics Today), Dr. Danielle Cholewiak of NOAA Fisheries Northeast Fisheries Science Center, and Dr. Peter Scheifele from the University of Cincinnati.

The model that DOSITS has developed to provide extensive science information, kept current and up to date with cutting edge, peer reviewed science, is unique among educational websites on the Internet. As the public turns to the Internet to explore any topic in which they have an interest, sites such as DOSITS need to be created and maintained to provide foundational science concepts and up to date information, which support educated decision-making about current events that may be occurring in the world around us.

The DOSITS project is currently in its 12th year. This longevity is possible only due to continued dedication we have received from funding agencies. The Office of Naval Research (ONR) has provided consistent support. This has been supplemented by the National Science Foundation (NSF) and the National Oceanic and Atmospheric Administration (NOAA) for the development of specific and/or timely content. Similarly, the DOSITS team offers the opportunity to other organizations to build on the project's foundation and the DOSITS well-established professional network as needs for expanded content on underwater sound develop.

In addition to monetary support, DOSITS would not be possible without the good will and expertise of the acoustics community of scientists, over 120 of whom have donated content, images, and audio files. Substantial contributions have also been made by Jill Johnen, Peter Cook, and Rebecca Briggs when employees of the University of Rhode Island. The site has been enhanced by the work and generous contributions from many individuals and organizations, as well as ten Rhode Island school teachers and over 40 independent scientific reviewers (www.dosits.org/about/). The DOSITS project continues to be a highly successful initiative that brings together scientists and education professionals to build and maintain a high quality resource for diverse audiences and stakeholders, ensuring that underwater acoustics is for everyone!

Mobile Operating System (OS)	Percentage of Total Traffic to DOSITS
iPhone	9.8
IPad	9.1
Android	6.2
Blackberry	0.4
Windows Phone	0.3
All Other Mobile OS	1.7
TOTAL iOS	**19.8**
TOTAL Mobile	**27.5**

Table 1. *Breakdown of mobile traffic to the DOSITS website in 2013*

Biosketches

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Holly Morin is a Marine Research Associate and Education Specialist with the Inner Space Center (ISC) at the University of Rhode Island's Graduate School of Oceanography (URI/GSO). Her work focuses on the development, coordination, and promotion of a variety of ocean science education programs, including the Discovery of Sound in the Sea (DOSITS) website (www.dosits.org). Before coming to URI/GSO, Holly worked at the Northeast Regional Office of NOAA's National Marine Fisheries Service, assisting with large whale management and fisheries interactions. Holly graduated from the University of New Hampshire with a Bachelor of Science (marine biology focus) in 2000. She then went on to receive her Master's Degree in Wildlife and Fisheries Science from Texas A&M University in 2005. Her graduate work focused on the diving behavior and movement patterns of young Steller sea lions in Prince William Sound, Alaska.

Christopher Knowlton is the Assistant Director of the Inner Space Center at the University of Rhode Island Graduate School of Oceanography. He received his B.A. in Geology from Colgate University and an M.S. in Oceanography from the University of Rhode Island.

Chris is interested in past climate on glacial-interglacial timescales but spends most of his time communicating science through modern devices and media to convey the science of the deep ocean, hurricanes, and underwater acoustics.

(left to right) *Christopher Knowlton, Gail Scowcroft, Kathleen J. Vigness-Raposa and Holly Morin*

References

Ellison, W. T., Southall, B. L., Clark, C. W., and Frankel, A. S. (2012) "A new context-based approach to assess marine mammal behavioral responses to anthropogenic sounds," Conservation Biology 26, 21-28.

Jenkins, H. (2009) Confronting the Challenges of Participatory Culture: Media Education for the 21st Century (MIT Press, Cambridge), 129 pp.

Johnson, M., and Tyack, P. L. (2003) "A digital acoustic recording tag for measuring the response of wild marine mammals to sound," IEEE Journal of Oceanic Engineering 28, 3-12.

Lewis, S., Pea, R., and Rosen, J. (2010) "Beyond participation to co-creation of meaning: Mobile social media in generative learning communities," Social Science Information 49(3), 1-19.

Moore, S. E., Reeves, R. R., Southall, B. L., Ragen, T. J., Suydam, R. S., and Clark, C. W. (2012) "A new framework for assessing the effects of anthropogenic sound on marine mammals in a rapidly changing Arctic," BioScience 62, 289-295.

Nowacek, D. P., Thorne, L. H., Johnston, D. W., and Tyack, P. L. (2007) "Responses of cetaceans to anthropogenic noise," Mammal Review 37, 81-115.

Popper, A. N., and Hastings, M. C. (2009) "The effects of anthropogenic sources of sound on fishes," Journal of Fish Biology 75, 455-489.

Popper, A. N., and Hawkins, A. eds (2012) The Effects of Noise on Aquatic Life. Springer Science+Business Media, LLC, New York.

Southall, B. L., Bowles, A. E., Ellison, W. T., Finneran, J. J., Gentry, R. L., Greene, C. R., Jr., Kastak, D., Ketten, D. R., Miller, J. H., Nachtigall, P. E., Richardson, W. J., Thomas, J. A., and Tyack, P. L. (2007) "Marine mammal noise exposure criteria: Initial scientific recommendations," Aquatic Mammals 33, 411-522.

Vigness-Raposa, K. J., Scowcroft, G., Knowlton, C., and Worcester, P. F. (2008) "Discovery of Sound in the Sea website: An educational resource," Bioacoustics 17, 348-350.

Vigness-Raposa, K. J., Scowcroft, G., Miller, J. H., and Ketten, D. R. (2012) "Discovery of Sound in the Sea: An online resource," Pages 135-138 in A. N. Popper and A. D. Hawkins, editors. The Effects of Noise on Aquatic Life. Springer Science+Business Media, LLC, New York.

Vigness-Raposa, K. J., Scowcroft, G., Miller, J. H., and Ketten, D. R., and Popper, A.N. (2014) Discovery of Sound in the Sea: Resources for educators, students, the public, and policymakers. In A. N. Popper and A. D. Hawkins, editors, The Effects of Noise on Aquatic Life II. Springer Science+Business Media, LLC, New York. In press

Wiley, D., Friedlaender, A., Weinrich, M., Bocconcelli, A., Cholewiak, D., Thompson, M., and Ware, C. (2011) "Underwater components of humpback whale bubble-net feeding behavior," Behaviour 148, 575-602.