SPOTLIGHT

Underwater Acoustics for All: Expanding Capacity with Education and Low-Cost Sensors

By Kathleen J. Vigness-Raposa, Lora J. Van Uffelen, Mumin O. Oladipo, Eunice K. Asamoah, Abdulwakil O. Saba, Ngozi M. Oguguah, Aderonke O. Lawal-Are, and Kyle M. Becker

INTRODUCTION

Sound is a persistent yet dynamic component of the marine environment, reflecting both physical and biological properties. Whereas light can only travel tens of meters in the ocean, sound is able to travel tens to thousands of kilometers under certain conditions, revealing information at specific times and places. In addition, underwater sound provides opportunities for sustainable development and blue economy growth that aren't readily available with other technologies. For example, the melting rate of Arctic ice and the health of coral reefs can be estimated from acoustic measurements (Becker et al., 2023). However, underwater acoustics is a complex topic, requiring specialized education and equipment. To expand the capacity of underwater acousticians requires dedicated educational opportunities and low-cost equipment and analysis resources.

The Discovery of Sound in the Sea Project (DOSITS) has spent over 20 years expanding capacity through education and outreach initiatives focused on underwater sound. The project offers foundational educational content in various formats, along with advanced content based on peer-reviewed literature. Most recently, DOSITS has supported the United Nations Decade of Ocean Science for Sustainable Development (2021–2030) through the Ocean Decade Research Programme on the Maritime Acoustic Environment (OD-MAE; Spence et al., 2022; https://mae.dosits.org/) and the Coastal Ocean Environment Summer School In Nigeria and Ghana (COESSING; https://coessing.org). OD-MAE aims to develop a comprehensive science-based program to measure and objectively characterize underwater acoustic environments at regional and global scales. To reach that objective, there is a need to develop low-cost sensors that can be used effectively in countries such as Nigeria and Ghana. COESSING is an international collaboration aimed at advancing ocean science in West Africa and furthering ties between scientists in West Africa and around the globe through one-week summer schools (Arbic et al., 2025, in this issue). DOSITS and the University of Rhode Island (URI) participated in COESSING virtually (in 2022) and in person (in Ghana, 2023). Through these initiatives, the need for low-cost equipment has been accentuated, and multinational collaborations have developed to speed equipment development.

FIGURE 1. A screenshot depicts the stoplight parrotfish page in the DOSITS Audio Gallery that showcases sounds, animated spectrograms, and source descriptions (https://dosits.org/galleries/audio-gallery/fishes/stoplight-parrotfish/).

EDUCATIONAL OPPORTUNITIES

DOSITS primarily delivers educational content through its website (https://dosits.org) and focused professional development initiatives, including webinars and trainings (Vigness-Raposa et al., 2021). Traffic on the DOSITS website has grown from over 100,000 views in its first year to over 1,000,000 page views in 2023, and the number of site users continues to grow by at least 10% each year. The website includes more than 450 pages of content, which is divided into three main sections: Science of Sound, People and Sound, and Animals and Sound. The difficulty level begins with basic content describing sound and its properties, and how and why people and animals make and use sound. Content progresses through levels of difficulty, reaching university level in some advanced topics where physics and mathematics are introduced. Galleries provide information inviting to all ages, with audio files of underwater sound sources (Audio Gallery; **Figure 1**), equipment descriptions (Technology Gallery), representative scientists (Scientist Gallery), and careers that use acoustic skills (Career Gallery).

Professional development initiatives have included webinars and trainings. Webinars have been ongoing since 2015, offering opportunities for participants to connect virtually with acoustic professionals. There were more than 3,134 registrations and 1,385 individual live connections from over 79 countries for the 2023 webinar series (several people can participate in the DOSITS webinars as a group). As of fall 2024, 38 webinars have been offered; they are recorded and openly available for non-concurrent viewing (https://dosits.org/decision-makers/webinar-series/). Each webinar includes keynote speakers followed by a question-and-answer session. Supporting documents include an outline of the talk with links to foundational content on the DOSITS website, the presentation as a PDF file, and a transcript of the questions and answers.

Trainings have included structured independent studies and virtual and in-person teachings. Independent studies have included professional development (PD) opportunities through each year's webinars, and a more targeted program for formal and informal educators. The webinar PD program, which began in 2021, issues a certificate to individuals who complete all four webinars in the annual series along with

other required activities. Over 100 certificates were issued during the 2021 DOSITS webinar series, 132 for the 2022 program, and 170 for the 2023 program. During the educator PD program, participants complete online assignments that develop acoustic knowledge and participate in three virtual meetings with the DOSITS team to reflect on their assignments. The first cohort of 20 educators completed the program in summer 2024.

Virtual and in-person education has been offered at professional scientific meetings with paper and poster presentations and half- and full-day workshops. In addition, authors Vigness-Raposa and Van Uffelen participated in COESSING, introducing underwater acoustics and its uses for sustainable development to the other coauthors as part of the Fisheries and Marine Conservation Track. These connections have initiated ongoing capacity sharing to develop low-cost sensors and data processing software code with local West African scientists.

LOW-COST SENSORS

The development of a quality, low-cost, and user-friendly sensor began in a capstone project with senior undergraduate ocean engineering students at URI. The students began with do-it-yourself hydrophone building instructions and worked through each element of the design to maximize performance while reducing costs. The students created an accompanying Python package of data processing and visualization code, including a user manual, available through GitHub. With an assembly time between five and six hours, the final sensor design costs approximately $314 USD to build, compared to a commercially available SoundTrap ST300 that costs $3,100 USD. Future plans include publishing the build instructions, user manual, Python package, and a suggested mooring design to the DOSITS website to promote accessibility.

COESSING provided an opportunity for in-country training and field experience with African colleagues as Vigness-Raposa and Van Uffelen led a team that made acoustic recordings in a local inlet in Ghana (**Figure 2**). These recordings, along with some DOSITS Audio Gallery files, were used to teach COESSING students about sound characteristics and basic signal processing, as well as data import, digital sampling, and analyses using Python code. Capacity sharing with African researchers highlighted technological limitations, such as inconsistent power and unreliable internet, and limited funding resources for job training, advancement, and equipment.

LESSONS LEARNED

Long-term issues with expanding capacity include developing career paths and demonstrating the advantages of incorporating acoustics into existing programs. While scientists can currently acquire acoustics knowledge and low-cost sensors, future efforts need to focus on creating case studies that demonstrate opportunities for advancing sustainable development and growing the blue economy through the use of underwater sound.

There is a similar need to facilitate the integration of acoustics into academic environments, especially exposing students early in their educational journey and developing their interest in underwater acoustics. In formal education settings, there are curricula that must be covered within a school year. Dedicated acoustics courses are often highly specialized, only being offered at university, if at all. Initiatives need to be funded that map acoustic topics to curricula and develop easy-to-implement, hands-on classroom activities in order to encourage educators to include acoustics. Without this foundational support, it is highly unlikely that an educator will have the energy or aptitude to integrate acoustics and expose students to the field.

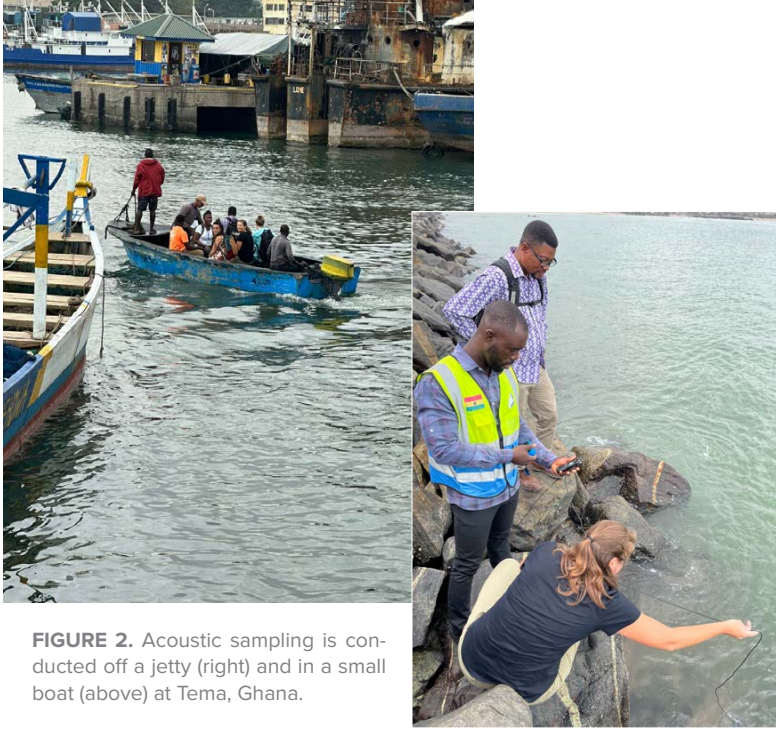

FIGURE 2. Acoustic sampling is conducted off a jetty (right) and in a small boat (above) at Tema, Ghana.

For those already in scientific or management fields or for the lay audience, providing a diversity of resources in formats most suitable and accessible for their needs has been crucial. In-person training allows for intimate discussions and personal connections; however, they can be expensive and limited in the number of participants. Online educational tools have grown in popularity and implementation after the COVID pandemic and can provide widespread, low-cost opportunities to engage audiences (Vigness-Raposa et al., 2021). Through capacity sharing initiatives, these resources can be developed and targeted to increase their success.

REFERENCES

Arbic, B., J. Adjetey, A. Agyekumhene, M.F. Akinwunmi, L.G. Akita, L. Anderson, J.K. Ansong, K.A. Addo, E.K. Asamoah, O.O. Awe, and others. 2025. The Coastal Ocean Environment Summer School in Nigeria and Ghana (COESSING): The value of long-term sustained capacity sharing. *Oceanography*.

Becker, K.M., T.C. Weber, H. Spence, and G.C. Smarsh. 2023. Putting ocean acoustics on the stage to address climate change. Lay Language Paper presentation at the 184th Meeting of the Acoustical Society of America, May 8–12, 2023, Chicago, IL, https://acoustics.org/putting-ocean-acoustics-on-the-stage-to-address-climate-change/.

Spence, H.R., K.M. Becker, and E.C.M. Parsons. 2022. The Ocean Decade Research Program on the Maritime Acoustic Environment (OD-MADE). *Marine Technology Society Journal* 56(3):39–43, https://doi.org/10.4031/MTSJ.56.3.9.

Vigness-Raposa, K.J., H. Morin, C. Knowlton, and G. Scowcroft. 2021. Online education tools: Effective practices from DOSITS. *Acoustics Today* 18(3):76–79, https://doi.org/10.1121/AT.2022.18.3.76.

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AUTHORS

Kathleen J. Vigness-Raposa (kathy@inspireenvironmental.com), INSPIRE Environmental, Newport, RI, USA. **Lora J. Van Uffelen**, University of Rhode Island, Narragansett, RI, USA. **Mumin O. Oladipo**, KolaDaisi University, Oyo, Nigeria. **Eunice K. Asamoah**, University of Ghana, Accra, Ghana. **Abdulwakil O. Saba**, Lagos State University, Lagos, Nigeria. **Ngozi M. Oguguah**, Nigerian Institute for Oceanography and Marine Research, Lagos, Nigeria. **Aderonke O. Lawal-Are**, University of Lagos, Lagos, Nigeria. **Kyle M. Becker**, Office of Naval Research, Arlington, VA, USA.

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