Fish Sounds and Noise Pollution: Engaging the Public in Bioacoustics

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Abstract

Science literacy is essential to ensure public awareness of research findings and foster meaningful engagement with scientific endeavors. However, a disconnect persists between scientific research and public understanding, as outreach is frequently overlooked in favor of data collection, analysis, and publication. Here, the authors describe their outreach initiative, FishSounds Educate, aimed at increasing the accessibility of ocean acoustics research, with a focus on fish sounds, noise pollution, and the broader effects of sounds on aquatic life. Bioacoustics provides an engaging entry point into topics such as fish and

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invertebrate biology, marine ecology, the physics of sound, and human impacts on aquatic environments. To cultivate public engagement, the authors developed and implemented interactive workshops, activity tables, seminars, and a coloring book, adaptable for all ages, from elementary to university-level students and lifelong learners. As of summer 2025, they have reached almost 4000 participants with more than 80 visits to schools, universities, aquariums, nature clubs, and public programs. Through FishSounds Educate, the authors have gained valuable insights into making bioacoustics research more accessible and are applying these lessons to ongoing work, including adapting a recent meta-analysis for young readers. Their experiences highlight the benefits of integrating outreach into research from the outset.

Keywords

Community engagement · K–12 education · Ocean literacy · Online resources · Public outreach · Science communication · Soundscape ecology

Introduction

Science and information literacy are essential to ensure public awareness of research findings and foster meaningful engagement with scientific endeavors (Brewer 2006; Liu 2009; Klucevsek 2017). Core components of science literacy encompass grasping basic scientific principles, understanding the nature of scientific inquiry, ethical considerations in science, and the relationships between science, society, and technology (Liu 2009). However, there remains a concerning divide between ongoing scientific activities and science literacy of the public (Brewer 2006; Liu 2009; Klucevsek 2017). This divide limits opportunities for better-informed political and economic decisions, critical assessment of environmental information, and effective application of scientific understanding to societal challenges (Brewer 2006; Liu 2009).

The disparity between scientific activities and science literacy is especially problematic given that most research is funded by the public, creating a responsibility to ensure that scientific findings are accessible and beneficial to taxpayers. Yet, access to research is often restricted by journal paywalls and obscured by technical language, leaving many students and other members of the public unable to engage with peer-reviewed literature (Shanley and López 2009; Klucevsek 2017). These barriers are particularly concerning in fields like marine ecology and conservation biology, where public awareness and participation are essential for tackling pressing environmental challenges (Brewer 2006).

Ocean literacy is an evolving concept that refers to an individual's understanding of the interconnected relationship between human activities and marine environments (Glithero 2020; Worm et al. 2021; McKinley et al. 2023). It reflects many of the broader challenges facing science literacy, such as the complexity of concepts and barriers to inclusive participation, while also facing obstacles like limited

coverage in formal education (Worm et al. 2021; McKinley et al. 2023; Pandeva et al. 2024). The 2021–2030 United Nations Decade of Ocean Science for Sustainable Development underscores the importance of ocean literacy initiatives in achieving its goals (McKinley et al. 2023), while national coalitions work to establish stronger frameworks for public involvement and ocean-related action (Glithero 2020).

Scientists must take a more active role to close the gap between research and public understanding (Brewer 2006; McKinley et al. 2023). Researchers not only carry a responsibility to share the progress and outcomes of scientific work, but also to develop meaningful collaborations that place community engagement at the forefront (Shanley and López 2009). Despite this need, outreach and accessible science communication are often treated as lower priorities than core academic tasks such as data collection, analysis, and publishing (Andrews et al. 2005; Brewer 2006; Shanley and López 2009), leading many scientists to devote minimal time to these efforts. Interactive, inquiry-based, and hands-on educational visits by experts have been identified as effective tools for bridging classroom and experiential learning, sparking curiosity, and strengthening science literacy (Liu 2009; Clark et al. 2016; Worm et al. 2021). These efforts are especially important for underrepresented topics in K–12 education, such as marine conservation and bioacoustics.

Bioacoustics and aquatic soundscapes offer an engaging entry point into subjects such as fish and invertebrate biology, marine ecology, the physics of sound, and human impacts on aquatic environments (Spriel et al. 2024). The audio component of bioacoustics research naturally lends itself to interactive learning, allowing participants to form immediate, sensory connections to scientific concepts. While much of the public is familiar with marine mammal vocalizations, learning that fishes and invertebrates also produce sounds often sparks surprise and curiosity (Spriel et al. 2024). Additionally, although all areas of science benefit from public engagement, aquatic soundscape research is relatively noncontroversial (unlike topics such as climate change or vaccines), which makes it especially well-suited for reaching diverse audiences and building trust in the scientific process.

Many excellent open-access tools already link marine science research to classrooms. Comprehensive platforms like Ocean School offer multimedia resources across a wide range of marine science topics (Worm et al. 2021), while the Canadian Network for Ocean Education maintains a diverse library of ocean education activities. The Thalassophile Project takes a different approach by emphasizing universal accessibility in marine science learning (Pandeva et al. 2024). Publicly available resources on bioacoustic topics include the “What Role Does Sound Play in the Ocean?” video from the Hakai Institute, the “Shouting Whales” activity from Ocean Networks Canada (ONC), and a fish sound quiz from FishBase.

Although several valuable tools exist to support ocean literacy and introduce aspects of bioacoustics, comprehensive resource packages focused specifically on underwater sound remain limited. The University of Rhode Island’s Discovery of Sound in the Sea (DOSITS) hosts the most extensive collection of freely available underwater acoustics content, offering accessible educator resources such as classroom activities, videos, and games, alongside more advanced topic pages for

specialized learning (dosits.org; Scowcroft 2021). Building on such resources, a recent initiative created interactive bioacoustics content adaptable to diverse educational and public settings, whether delivered by visiting scientists, through online platforms, or downloaded by teachers (Spriel et al. 2024).

Originally developed through a partnership of five universities and organizations to inventory fish sound production studies worldwide, the FishSounds initiative (FishSounds.net) has evolved into a comprehensive resource for both researchers and the public (Looby et al. 2025). This chapter provides an overview of *FishSounds Educate,* an outreach program designed to increase the accessibility of ocean acoustics research, with a focus on fish sounds, noise pollution, and the broader effects of sound on aquatic life. The authors describe how bioacoustics can serve as an engaging entry point into ocean science learning, outline the FishSounds Educate approach, and share lessons learned along with future directions.

Bioacoustics as a Gateway to Ocean Science

Although marine mammal vocalizations have become relatively well known through popular media and public fascination with charismatic species, the sounds produced by fishes and invertebrates remain largely unfamiliar. Public audiences, however, often express strong curiosity about underwater sounds, especially when they have personal connections to these animals through experiences such as fishing, visiting aquariums, or seafood consumption. With the FishSounds website now offering searchable sound production data for over 1000 fish species, as well as interactive visualization tools and project pages (e.g., Invertebrate Bioacoustics), its value extends well beyond the research community (Looby et al. 2025). The authors recognized its potential as an accessible platform for outreach and education (Spriel et al. 2024). In response, the FishSounds Educate program was created to provide foundational fish bioacoustics content and to encourage further exploration of underwater sound through the FishSounds platform.

While the program content centers on fish sound production, it also introduces related topics such as fish physiology, marine ecology, the physics of underwater sound, data analysis and visualization, and anthropogenic noise impacts. These themes offer engaging ways to present scientific concepts that are often underrepresented in public education but align with core curriculum goals. In British Columbia (BC), Canada, for instance, FishSounds Educate materials support high school learning outcomes in courses such as general science, Physics 11, Environmental Science 12, and Science for Citizens 11. The program content also incorporates key competencies like interpreting graphs and diagrams as well as exploring the social and environmental relevance of scientific topics.

Bioacoustics offers several unique advantages for science communication. Unlike more abstract scientific topics, underwater sound naturally lends itself to multisensory, experiential learning. Participants can listen to mystery sounds, discover what their favorite fishes sound like, “see sound” through spectrograms, and engage with physical materials such as otoliths and hydrophones. While the base workshop was

designed for middle and high school students, small adaptations allow the materials to engage learners across a wide age range, from early elementary students to adults. For lifelong learners, the program builds on existing knowledge of ocean soundscapes, such as public awareness of whale communication and ship noise, by introducing new and lesser-known aspects of aquatic soundscape ecology.

The FishSounds Educate Approach

Program Design

Engaging in outreach as a scientist can be a daunting task due to limited time and training in science communication. To support others interested in developing similar initiatives, this section outlines the framework used to create the FishSounds Educate program (Fig. 1), which may serve as a reference for bioacousticians or other researchers seeking to share their work beyond academic audiences.

Funding and Planning

The first step in developing the program involved securing funding specifically dedicated to public engagement. In this case, support was obtained through Fisheries and Oceans Canada's Oceans Management Contribution Program, which funds outreach, monitoring, and capacity-building initiatives aligned with Canada's marine conservation targets. Although this project benefited from an outreach-focused funding stream, the authors emphasize that most research grant proposals can also include dedicated sections for public engagement. While universities have

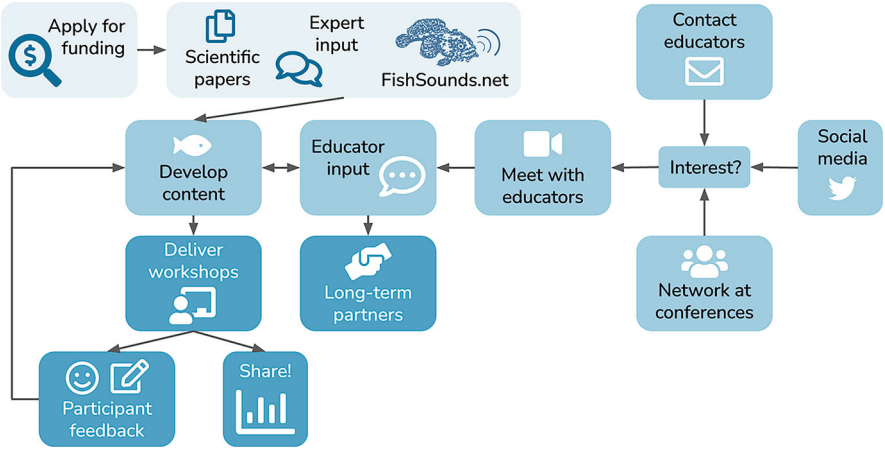

Fig. 1 The framework used to develop the FishSounds Educate outreach program. (Source: © 2025 FishSounds Educate)

historically placed limited value on science communication beyond peer-reviewed publications, funding agencies increasingly recognize the importance of outreach, either as a desirable addition or a formal requirement. Dedicated funding was seen as essential to allow time and resources for high-quality science communication, without placing an added burden on researchers.

With funding in place, the team drew on peer-reviewed literature, their bioacoustics expertise, and data from the FishSounds website to begin developing educational content. To avoid a one-way transfer of information from scientists to public audiences, they prioritized early consultation with educators. This involved sharing posts on FishSounds social media (i.e., Twitter/X), networking at conferences and events such as the Deep Bay Marine Field Station's teacher professional development workshop, and directly reaching out to teachers in their networks and communities. In total, over 80 emails were sent, and numerous online meetings were held with educators and outreach professionals to better understand public interest, knowledge levels, and content needs related to bioacoustics.

Collaborations and Content Development

Partnering with an established science outreach program played a key role in content development and broadening engagement. The authors collaborated with ONC's K–12 education team, a partnership that offered several mutual benefits. Through this collaboration, the FishSounds team received feedback from experienced science communicators, participated in existing ONC outreach events, and expanded their network of educators. In turn, ONC gained access to adaptable bioacoustics content that could either be codelivered or presented independently by their team.

Once the content was developed and aligned with community and educator needs, workshops were delivered across a range of settings. To ensure that the content was engaging for participants, the team collected informal feedback after the workshops and made iterative improvements. Given the time and logistical constraints of conducting formal surveys (e.g., human ethics approvals, parent/guardian consent), feedback was gathered anonymously through brief written prompts using a "two stars and a wish" format. This approach allowed participants to highlight what they enjoyed and suggest improvements without pressure or a considerable time commitment. For instance, one participant noted, "I really liked being passed the fish otoliths and seeing things up close! For example, the hydrophone!" while another suggested, "Longer presentation :)." Feedback was incorporated after each delivery to refine the materials for different audiences, settings, and time constraints.

Implementation Across Diverse Settings

From January 2023 to June 2025, the FishSounds Educate program reached 3931 participants through 84 outreach events across Canada and the United States, with a geographic focus on Vancouver Island, BC (Fig. 2a). The number of visits and

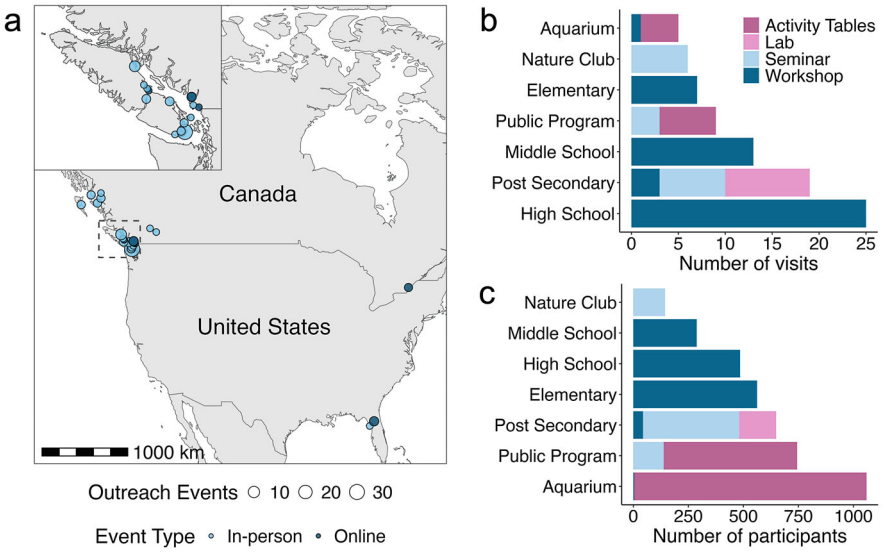

Fig. 2 (**a**) Map of North America showing the locations of the 84 FishSounds Educate outreach events from January 2023 to June 2025. The inset zooms in on Vancouver Island and the south coast of British Columbia, Canada, where the majority of outreach events took place. Points are scaled by number of events and colored by delivery format: in-person (light blue) and virtual (dark blue). Bar plots show the number of (**b**) outreach visits and (**c**) participants at each location type, colored by outreach format. (Source: © 2025 FishSounds Educate)

Table 1 Overview of FishSounds Educate content formats, with descriptions of typical audiences, delivery settings, and durations

Resource type	Description
Activity tables	Public programs and aquarium events (e.g., World Ocean Day) Full day events with hands-on activities for all ages
Labs	Postsecondary ichthyology course 3-hour lab sessions with a short presentation and student-directed activities
Seminars	Nature clubs, postsecondary classes, and nonprofit societies 1–2-hour tailored lectures
Workshops	K–12 classrooms, postsecondary courses, and aquarium after-school camps 60–90-min interactive presentations

participants far exceeded initial targets: more than 4.5 times the original goal of 18 visits and over 6.5 times the target of 600 participants. The program was delivered across a wide variety of settings, including school classrooms (elementary through postsecondary), public events, aquarium events and after-school programs, and nature clubs (Fig. 2b, c). To accommodate this range, the team created four distinct content formats (Table 1), each offering unique advantages depending on the audience and setting. In delivering the program, the authors also considered obstacles some groups face in accessing science. When possible, they prioritized visits to

remote communities, Indigenous schools, and alternative learning environments to help reduce systemic barriers to participation in Science, Technology, Engineering, and Mathematics (STEM) outreach opportunities.

Among these formats, interactive workshops, mainly in K–12 school settings, were the most frequently delivered ($n = 49$ visits; Fig. 2b). These sessions were prioritized because the time-frame and age groups allowed for the delivery of in-depth content, while fostering meaningful small-group interactions and class discussions on related topics such as ocean conservation and science careers. In contrast, activity tables at public events reached the highest number of participants overall ($n = 1661$ participants; Fig. 2c). Events like World Ocean Day at the Shaw Centre for the Salish Sea and Science Rendezvous at the University of Victoria allowed for all-day engagement with a wide public audience, although individual interactions were typically shorter and less in-depth (Fig. 3).

Seminars were delivered to groups with a specific interest in ocean science, including nature clubs and postsecondary classes. These provided a lecture-based format tailored to each group's interests. Finally, although labs were the least-used format, they provided valuable opportunities for extended engagement. The longer sessions enabled undergraduate students to explore bioacoustics content in greater depth through hands-on activities, independent tasks, and informal discussions with presenters about current research, graduate school, and careers in science.

Workshop Pedagogy, Accessibility, and Content

The authors worked closely with educators and science communicators to ensure the workshop content was interactive, engaging, and grounded in sound pedagogical principles. These included inquiry-based learning, a learner-centered (constructivist)

Fig. 3 Example activity table from Science Rendezvous at the University of Victoria, showing a station for examining fish otoliths under a microscope. Other activities included sound guessing games (e.g., "Fish or Fart?!"), viewing preserved soniferous fish specimens, coloring a giant marine soundscape mural or themed printouts, and experimenting with underwater sound using a hydrophone in a water bucket connected to an amplifier. (Source: With permissions from UVic Science. © 2025 University of Victoria)

approach, and the careful scaffolding of new scientific concepts. Principles of Universal Design for Learning were also incorporated, along with accessibility recommendations from the Common Accessibility Framework developed by The Thalassophile Project (Pandeva et al. 2024).

Specific accessibility features included visually engaging slides, integrated audio elements, highly readable formatting (e.g., large, high-contrast, left-aligned text), informative headings, embedded hyperlinks, alt text for all images, and slide components ordered for compatibility with screen readers. To support ease of use for educators, the workshop was also packaged with clearly outlined focus and summary statements, seven learning objectives, a keyword list, instructions, a required materials list, and a breakdown of the workshop into seven flexible segments with descriptions.

Below are selected features of the 60–90-min "*Biology of Sounds in the Ocean*" workshop (Fig. 4):

- A customizable territory acknowledgement slide to encourage place-based reflection at the start of the lesson
- Storytelling elements integrated at the beginning of the workshop to spark curiosity and engagement
- A preserved plainfin midshipman (*Porichthys notatus*) specimen for participants to view up close
- "Fish Files" featuring facts about the diet, size, bioacoustics, and geographic range of soniferous fish species
- Photos and facts about diverse fish species, linked to iNaturalist (iNaturalist.org), to encourage connection to nature and participation in citizen science

Fig. 4 Examples of slides from the FishSounds Educate "Biology of Sounds in the Ocean" interactive workshop. (Source: © 2025 FishSounds Educate)

- Aesthetic illustrations and animated GIFs to support visual engagement and accommodate different learning styles
- Thought-provoking brainstorm and discussion prompts, including a science-themed riddle
- High-quality photographs contributed by colleagues in the field
- Step-by-step screenshots demonstrating how to navigate and explore the FishSounds website
- A variety of real fish otoliths and hydrophone types available for hands-on exploration
- Interactive sound guessing games using real recordings and visualizations from the FishSounds database, including "Guess That Sound!", "Fish or Fart?!", and "Guess That Spectrogram"
- An optional short BBC Earth video that reinforces key workshop topics through visual storytelling

Program Longevity and Online Access

The authors have supported the longevity of the FishSounds Educate program in two primary ways. The first was by partnering with ONC, an established provider of K–12 marine science outreach, as members of the ONC team continue to deliver components of the interactive workshop during their outreach visits. The second was by making all FishSounds Educate resources freely available online through the FishSounds Educate webpage (FishSounds.net/educate), where any educator can download and implement them (Table 2). So far, the webpage has received 1898 views from 1036 visitors, resulting in 146 file downloads by 55 users.

The core workshop, "*Biology of Sounds in the Ocean*," is offered in both English and French and includes a variety of adaptable teaching materials. These include editable slide decks with embedded media, a printable teacher guide outlining learning objectives and curriculum links, printable slide notes with talking points, and a fill-in-the-blank worksheet designed for high school students. Younger participants can enjoy a double-sided coloring page or a 14-page illustrated coloring book ("*What Sound Does a Fish Make!?*") that introduces fish hearing, sound production, and anthropogenic impacts.

To complement the downloadable materials and engage more advanced learners, the FishSounds Educate webpage also features an eight-part YouTube seminar series titled "*All About Underwater Sounds and Their Study*." These recorded talks, hosted initially between November 2024 and March 2025, explore a variety of ocean sound topics, from snapping shrimp to passive acoustic monitoring. Approximately 200 Zoom attendees participated across the seminars in total, with over 1100 views on YouTube. Visitors can also find a recorded virtual lesson hosted in collaboration with *Exploring by the Seat of Your Pants*, along with a curated list of recommended bioacoustics and marine ecology resources. A feedback form is available to guide future updates, and materials will continue to be revised to ensure accessibility and accuracy.

Table 2 Freely available resources on the FishSounds Educate webpage (FishSounds.net/educate), including descriptions, download formats, and French translation availability

Resource name	Description	Format	French
Instructions for Teachers	Workshop overview including learning objectives, accessibility information, materials required, curriculum links, and segment summaries	PDF document	Yes
Biology of Sounds in the Ocean	Interactive 60–90-min workshop with embedded media	Google Slides/ PowerPoint	Yes
Slide Notes for Teachers	Printable talking points and fun facts accompanying each slide	PDF document	Yes
Worksheet for Students	Fill-in-the-blank activity with grading rubric, designed for high school students	PDF document	Yes
Coloring Page	Double-sided coloring sheet suitable for all ages, illustrating key workshop concepts	PDF document	Yes
What Sound Does a Fish Make!? A Coloring Book	14-Page illustrated book introducing fish hearing, sound production, and anthropogenic impacts	PDF/Print version	No
Online Seminar Series	Eight recorded seminars on ocean sound topics including marine mammals, fishes, soundscapes, and monitoring applications	YouTube recordings	No

Future Directions and Lessons Learned

Distilling bioacoustics and soundscape research into accessible formats for students and the public can be challenging. However, the wide reach of the FishSounds Educate program, reflected in its numerous events and participants, shows that it is a worthwhile endeavor. Moving forward, the authors plan to apply the skills developed through this initiative and continue exploring new methods for sharing their research with broader audiences.

Although no formal pre- and postprogram surveys were conducted, the authors interpret the strong participation levels and positive written feedback from students and educators as signs of success. Over the 2 years of program development and delivery, several important lessons emerged. Dedicated outreach funding proved essential, allowing researchers to focus on the initiative without added burden. Early collaboration with a diverse group of contributors was also crucial to build a program that was engaging, age-appropriate, and accurate, including working with K–12 educators, postsecondary instructors, science communication specialists, aquarium program staff, community event organizers, illustrators, and other researchers.

Another promising avenue for sharing research beyond academia is the Frontiers for Young Minds journal, which engages young reviewers in the editorial process to produce versions of scientific papers written for kids (e.g., Jasper et al. 2023). Science educators use these articles in their classrooms to teach students how to read and interpret research. Inspired by this approach, the authors have adapted a

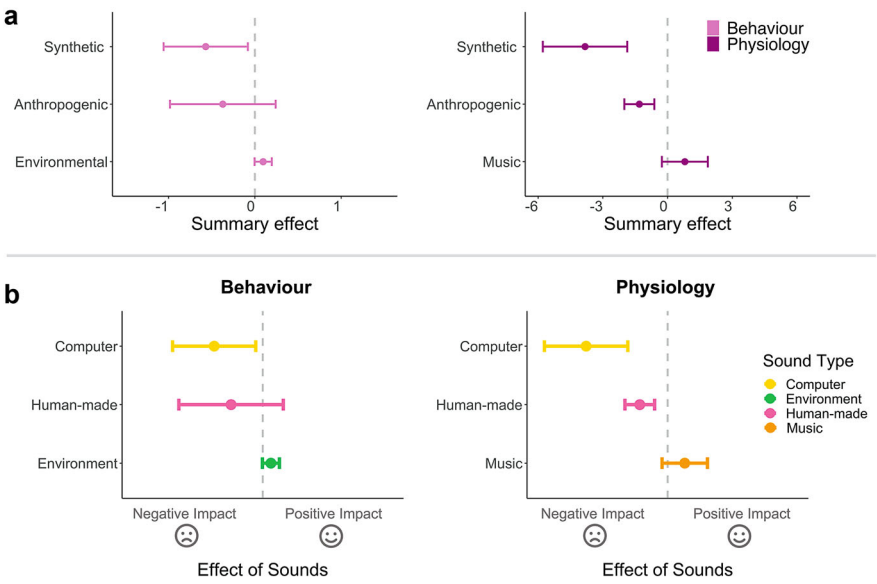

Fig. 5 Comparison of (**a**) the original published graphs (Davies et al. 2024, used under CC BY-NC-ND 4.0) and (**b**) the adapted versions for young readers, showing the effects of each sound source category on aquatic invertebrate behavior and physiology. (Davies et al. 2025, used under CC BY 4.0)

recent meta-analysis on the impacts of various sound sources on aquatic invertebrates (Davies et al. 2024) for submission to the journal. The adapted article includes a fun and engaging title, a simplified abstract, and scaffolded explanations of scientific concepts (Davies et al. 2025). It also features a glossary of key terms, high-quality images that highlight the diversity of aquatic invertebrates, and a colorful soundscape illustration to visualize the different sound source categories. To support science literacy skills, the article includes bullet-point takeaways and a modified graph with step-by-step instructions to guide more advanced learners in interpreting results (Fig. 5).

Finally, the authors emphasize that outreach should be understood as a two-way process. FishSounds Educate fostered reciprocal learning experiences that built trust between researchers and participants. For the authors, benefits included stronger science communication skills, increased confidence in public speaking, new perspectives on their research, and renewed excitement for their work. While they encourage others in the field to adapt components of this outreach model, they also highlight that many formats can be effective for making underwater soundscapes more accessible. These may include written summaries of published work, infographics, community presentations, or policy briefs. Looking ahead, the authors plan to grow the FishSounds platform with new projects, dismantle barriers to early STEM engagement, incorporate community feedback more formally, and encourage future leaders in ocean conservation.

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