Educational strategies for teaching bioacoustic communication in marine and terrestrial species

Zilola Sattorova[1*]; Bashorat Sobirova[2]; Makhliyo Yuldasheva[3]; Ziyoda Alimova[4]; Ilyos Nuraliyev[5]

Received: 01 September 2025; Revised: 26 October 2025; Accepted: 22 November 2025; Published: 20 December 2025

Abstract

Bioacoustic communication encompasses a variety of vocalizations used for mating, territory defense, and navigation in both marine and terrestrial organisms. There are challenges in teaching communication bioacoustics due to the complex differences among organisms, their environments, and the sounds they produce. This paper aims to examine and propose possible methods for teaching bioacoustic communication. Marine and terrestrial systems will be integrated to demonstrate techniques, including the use of acoustic technology tools, field-based education, and interactive and multimedia workshops, that highlight the principles of sound production, transmission, and reception and their use in various organisms. The use of biological and acoustic tools, in combination with environmental science communication, is introduced into bioacoustic communication teaching methods. The paper emphasizes the need for students to apply hypotheses to the ecological and evolutionary aspects of bioacoustics. The educational techniques designed to fit diverse teaching situations, i.e., classrooms and the field, are expected to ease students' transition from theory to practice.

Keywords: Bioacoustic communication, Marine species, Terrestrial species, Educational strategies, Sound production, Acoustics, Field-based learning, Interdisciplinary education, Ecological implications, Sound analysis, Species behavior

1*- Tashkent State University of Oriental Studies, Uzbekistan. Email: zilola2022@list.ru, ORCID: https://orcid.org/0009-0008-8943-7677
2-Senior Lecturer, Gulistan State University, Uzbekistan. Email: sbashorat97@gmail.com, ORCID: https://orcid.org/0009-0009-5849-211X
3-Associate Professor, Fergana State University, Fergana, Uzbekistan.
Email: myuldasheva229@gmail.com, ORCID: https://orcid.org/0000-0002-4624-7039
4-Tashkent State Transport University, Tashkent, Uzbekistan. Email: ziyoda.alimova@icloud.com, ORCID: https://orcid.org/0009-0001-0299-5318
5-Denau Institute of Entrepreneurship and Pedagogy, Surkhandarya, Uzbekistan.
Email: i.nuraliyev@dtpi.uz, ORCID: https://orcid.org/0009-0001-4130-2385
*Corresponding author
DOI: 10.70102/IJARES/V5I2/5-2-81

Introduction

Communication through sound among animals is a behavioral characteristic that is equally present in the ocean and on land. Marine and terrestrial creatures use their vocal capabilities for numerous functions, such as socializing, navigating, warning fellow organisms of a predatory threat, calling mates, and inter-specific communication. (Spriel *et al*., 2024). While in the ocean, sound-producing animals like whales, dolphins, and fish communicate using sound waves that carry over long distances and throughout the volume of the sound-transmitting marine medium (Ladich and Winkler, 2017). Primarily on land, animals, including various bird species, and elephants, as well as dolphins that have adapted to terrestrial life, communicate through sound to relay important messages to others of their species or to members of other species. Quaintance with bioacoustics extends the frontiers of science through new findings in animal behavioral studies and, further, to conservation practices that support biosystem sustainability for protected animals (Khyade, Gaikwad and Vare, 2018). Habitat protection, species identification and monitoring, and population estimates of various organisms using bioacoustics systems could be immensely beneficial for all conservation systems. Interdisciplinary challenges in bioacoustics are multidirectional across biology, acoustics, and environmental science (Teixeira, Maron and van Rensburg, 2019).

Lectures and textbook approaches do not teach bioacoustic communication effectively and do not engage with the complexities of animals' sound-producing, transmitting, and receiving behaviors. Understanding and adequate skill development can be achieved, though, by incorporating new educational technologies, such as sound recording and analysis, which allow students to work in the field and engage with real-world natural acoustic environments (Hupper, Monte and Scheifele, 2000).

This, then, is the problem when developing educational strategies for bioacoustic communication. Knowledge and skills can be acquired through hands-on, interdisciplinary, and usable educational frameworks (Bharathi and Senbagam, 2025). Scientific and ecological understanding of bioacoustic communication can be comprehended and acquired through multimedia, interactive, and field-based educational pedagogies. Education strategies such as those described will not only advance education in this specialized field but also elevate knowledge concerning the sound communication of animals. Educational efforts such as these will enable students to preserve the acoustic environments fundamental to the existence and well-being of countless communicating animals (Villano, 2007).

Key Contribution

- This method enhances students' understanding by showing how biological, ecological, and physical factors shape bioacoustic communication. By integrating knowledge from different fields, students develop a comprehensive view of how animals produce,

transmit, and interpret sounds in various environmental contexts.

- Integrating modern technology like sound recording devices, acoustic analysis software, and visualizations of acoustic data is essential in teaching bioacoustic communication. These tools enable students to work with real-world data, analyze sound patterns, and understand the subtle details of animal calls vocalizations.
- Fieldwork allows students to interact directly with wildlife, experience the difficulties of sound recording outdoors, and learn to interpret bioacoustic signals within natural settings and ecosystems.
- These resources can effectively demonstrate complex ideas, like sound wave propagation or the variety of animal vocalizations, in an engaging and easy-to-understand way manner.
- This dual approach equips students with the tools needed to participate effectively in bioacoustic research or conservation efforts.

Literature Review

The application of sound to communicate with animals is known as bioacoustic communication, and is a vital process utilized by marine and terrestrial species in which animals utilize vocalizations to communicate mating, territory marking, navigation and social organization. With growing recognition of the importance of animal sounds in ecology, there is a growing effort to incorporate bioacoustics into the school curriculum (Cole, 2005). Nevertheless, bioacoustic communication is a challenging subject to teach, and its interdisciplinary nature is the main reason: it combines biology, acoustics, and environmental science. This complex subject matter can only be made accessible and engaging for students through effective educational strategies (Rajan and Fernandes, 2025). The use of high-quality recording devices, such as microphones and hydrophones, is one of the most noticeable teaching tools in bioacoustic communication, as students can gather acoustic information from animals on land and at sea. This sound analysis is then performed using sound analysis software like Raven or Audacity and this assists the students in acquiring the skill required to analyze the animal vocalizations and learn how they relate to the ecological processes. In addition to this, multimedia files (videos, podcasts, soundscape libraries etc.) can show the students real-life examples of species-specific calls and the variety of acoustic signals employed in the natural environment (Steele, Brink and Scott, 2019). In order to further the learning process, the digital simulations or acoustic models can be used to enable students to imagine the way the sound spreads in a particular environment and how various other factors, such as the structures of the habitat and the medium of the environment, influence the spread of sound. The addition of bioacoustic education to the curriculum has proven immensely advantageous, particularly through increased acoustic awareness, practical skills in recording and analyzing data, and an understanding of the interconnectedness of animal behavior, sound communication, and ecosystem health (Pietra, 1995). As a result of interdisciplinary, mostly hands-on learning exercises, students will learn

more about the ecological and evolutionary functions of sound in animals, as well as the consequences of anthropogenic noise and habitat change for animal communication systems. Nevertheless, several difficulties persist, including the lack of high-quality recording devices, the technical nature of sound analysis, and the inability to incorporate bioacoustics into the conventional curriculum (Bruno and Muraleedaran, 2025). Also, the absence of accessible field sites with acoustically diverse biodiversity or support for practical marine-based fieldwork may be a barrier to teaching bioacoustic communication. The future of bioacoustic education is likely to involve the establishment of well-scaffolded curricula in which simpler concepts are introduced first and more complex topics are introduced as the curriculum progresses (Carlton and Hodder, 2003). Bioacoustic learning can be expanded through the incorporation of digital and distance education, such as virtual field trips and citizen science portals, particularly in resource-intensive institutions (Doyle *et al*., 2011). Moreover, increased attention to conservation problems, such as the impact of noise pollution, will help students feel the urgency and practicality of their learning. Comparative study between terrestrial and marine ecosystems will enable students to examine the differences in the sound production and propagation in various environments which will lead to a more comprehensive view of bioacoustics. Finally, there is an increasing trend toward the development of educational methods for teaching bioacoustic communication in marine and terrestrial species that incorporate an interdisciplinary approach based on modern technology, field-based education, and activities. These strategies are expected to not only benefit students, in terms of improving their scientific understanding but also make them more conscious of the environment at large, which would contribute to the conservation and understanding of the natural world (Khyade, Pawar and Khilare, 2018).

Materials And Methods

Table1: Various methods and materials used for bioacoustics communication.

Material/Method	Description	Purpose/Outcome
Acoustic Recording Devices	High-quality microphones, hydrophones, and field recorders (such as Song Meter and TASCAM DR series)	To capture bioacoustic signals from animals across terrestrial and marine habitats.
Sound Analysis Software	Software such as Raven, Audacity, or MATLAB used for sound analysis and visualizing acoustic data.	Analyze recorded sounds, detect species-specific calls, and visualize acoustic patterns.
Interactive Acoustic Models	Digital simulations or applications that demonstrate how sound travels in various environments, such as land and water.	To assist students in understanding sound transmission and the impact of environmental factors on acoustic communication.
Field Work Equipment	GPS units, field notebooks, binoculars, and camera traps used for data collection in natural habitats.	To collect field data, observe animal behavior, and monitor acoustic activity in their natural environment.
Multimedia Resources	Videos, podcasts, documentaries, and online platforms like YouTube and iNaturalist that showcase animal vocalizations.	To give students real-world examples and case studies of bioacoustic communication among different species.
Workshops and Lab Sessions	Practical training sessions in bioacoustics labs, covering equipment operation and sound analysis.	To equip students with hands-on skills in gathering and analyzing bioacoustic data.

Table 1 describes some instruments and techniques used in bioacoustic communication. Acoustic recording devices (microphones and hydrophones) capture animal sounds at different locations, and sound analysis software (e.g., Raven and Audacity) helps analyze and/or visualize them. Interactive acoustic models demonstrate how sound can be modified across different environments and facilitate understanding of sound transmission. Fieldwork equipment (e.g. GPS and binoculars) is used to collect data and observe animals in their native habitats. Multimedia documents illustrate the animal sounds produced, and workshops enable participants to gain hands-on experience in the use of equipment and sound analysis. These techniques enhance the practice of bioacoustic communication in different animal species.

Educational Strategies for Teaching Bioacoustic Communication Marine and Terrestrial Species

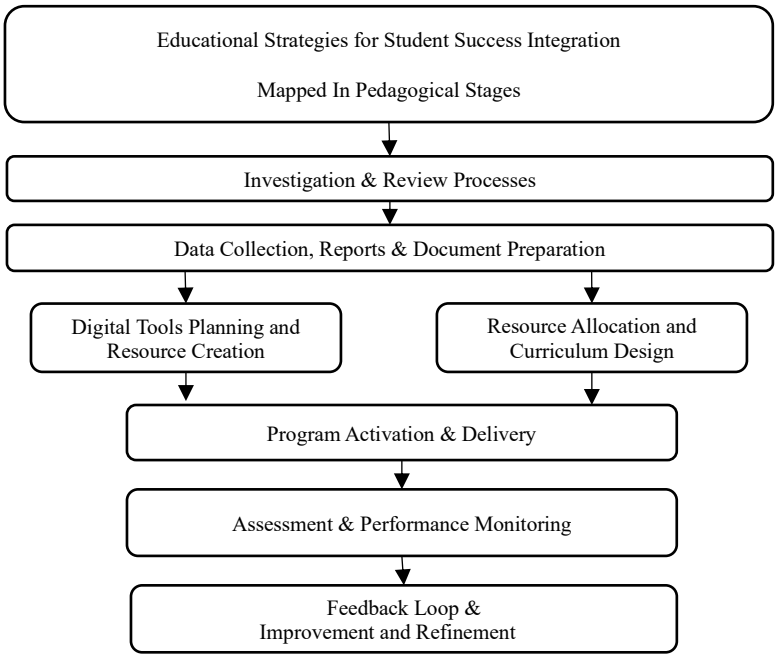

Figure 1: Conceptual framework for teaching bioacoustics communication marine and terrestrial species.

The diagram (figure. 1) shows the learning plans that will help enhance student success integration through a sequence of pedagogical steps. It starts with the Investigation and Review Processes, where research and analysis are conducted at the beginning. Data Collection Reports and Document Preparation follow this, and this is done to ensure that all necessary information is organized and recorded in a manner that will be used later. The following steps concern Digital Learning Tools and Resource Allocation, in which educational technologies and resources are integrated into the curriculum design. Activate Dara Activation & Delivery underscores the importance of activating these assets to achieve efficient lesson delivery. The diagram then shifts to Assessment and Performance Evaluation, which is essential in order to measure

student success and give feedback to keep track of progress. The cycle ends in the Feedback Loop where both the instructors and the students practice reflections to ensure endless improvement and development of students. Such a dynamic system of inquiry, resource distribution, activation, evaluation, and feedback determines the comprehensive educational process, which leads to lasting student achievement. In the case of Educational Strategies to Teach Bioacoustic Communication in Marine and Terrestrial Species, we shall be able to model the equation and see how various learning factors e.g. resources, fieldwork, analysis and feedback contribute towards student learning and understanding of bioacoustics. The equation might consider a number of factors which control the student success of learning bioacoustic communication.

Equation for Educational Success in Bioacoustic Communication:

$$S = f(I, D, R, A, P, F) \quad (1)$$

From the above Eqn (1) describes about the S as Student Success, I as Investigation and Review, D as Data collection and document preparation, R as Resources and curriculum design, A as activation delivery, P as performance assessment and F as Feedback Loop. The Function as F represents as the interaction among the three phases. In an ideal scenario, all stages positively influence each other, creating a feedback loop where each stage informs and enhances the next. This iterative cycle, with feedback at its core, ensures the ongoing development of student success.

Results And Discussion

5.1 Dataset Description

The Educational Strategies for Teaching Bioacoustic Communication in Marine and Terrestrial Species dataset includes a wide array of variables that are effective in determining students' knowledge of and interest in bioacoustics. It comprises information on teaching practices (lectures, fieldwork, workshops, multimedia resources), technology applications (acoustic recording devices, analysis software), and student-related information (pre- and post-assessment scores, participation, and feedback). Other learning outcomes considered in the dataset are knowledge acquisition, fieldwork competence and application of bioacoustic concepts in real-life contexts. The dataset also includes environmental factors, such as the emphasis on marine or terrestrial species and field conditions, including the amount of noise pollution, which might influence learning success. It gives an in-depth perspective of the influence of these teaching methods and factors on the success of students to gain insight on bioacoustic communication. Educators and researchers planning to assess and enhance bioacoustic education can find this helpful information, as this paper can give information about the most viable teaching methods, as well as the effect of various environmental factors on learning.

5.2 Performance Comparison of Impact of Teaching Strategies on Student Learning Outcomes in Bioacoustics Communication

Table 2: Performance comparison of impact of teaching strategies on student learning outcomes in bioacoustics communication.

Strategy	Effectiveness on student Learning Outcomes (%)
Field Data Collection	90%
Multimedia Resources	80%
Interactive Workshops	75%
Fieldwork Based Learning	85%
Lecture Based Learning	65%

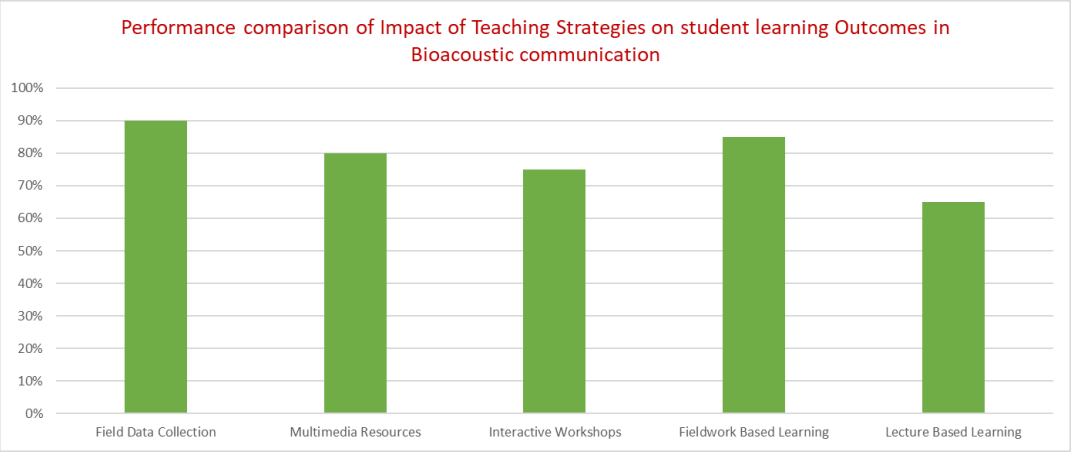

Figure 2: Performance comparison of impact of teaching strategies on student learning outcomes in bioacoustics communication.

The result analysis of the effects of teaching methods on student learning performance in bioacoustics communication (personal performance) (table 2 and Figure 2) indicates a considerable difference in the performance of the different methods. Field Data Collection was the most effective as it received a score of high effectiveness of 90, which implies that practical fieldwork where the students gather bioacoustics data plays a significant role in their learning and involvement. Fieldwork-Based Learning was also characterized by a high level of success with 85% effectiveness, showing the importance of the immersion and practical experience in the real-life setting that reinforced the knowledge of bioacoustics in both the marine and the inland environment in the students. The next one, Multimedia Resources, is at 80 percent, which indicates the usefulness of digital devices, including sound libraries, and videos, as well as interactive materials, in aiding learning by offering easy and interactive means of learning about bioacoustics communication. The Interactive Workshops received 75% as it has a positive yet comparatively lower impact than the other strategies. Workshops allow the active participation but may not be as effective as field-based or multimedia-based methods. Lastly, Lecture-Based Learning was the lowest scored with 65% indicating that classroom lectures (in isolation) though important in terms of theoretical knowledge, are less effective in deep engagement and practice of bioacoustics principles than more practical, technology amplified, or interactive approaches. Overall, this data indicates that fieldwork and multimedia resources are currently important to integrate into the curriculum and to improve student learning outcomes in bioacoustics, whereas more traditional lecture-based

approaches are still useful but not as effective on their own.

5.3 Discussion

Bioacoustic communication should be taught in a multi-dimensional way including theoretical background and practical and practical experiences, involving teaching in both sea and land species. This method is essential in explaining the concept of sound in the behavior of animals, ecological relationship and conservation. It is important to integrate biology, acoustics, and environmental science because bioacoustics cut across all those disciplines and help students be exposed to the production, transmission, and reception of animal sounds. To improve the knowledge of bioacoustics in students, the general educational approaches are field-based learning, technological applications, interactive workshops, and multimedia learning elements. Field based learning is especially useful in bioacoustic education through which students can directly interact with the environment. When they record sounds of animals in natural environments, e.g., in the sea or on land ecosystem, students will be able to use the theoretical knowledge and learn to use technical devices such as hydrophones and microphones. Fieldwork gives the student critical observational skills, which lead to a better appreciation of bioacoustic phenomena. The usefulness of the field data collection that scored 90 percent in the effectiveness survey highlights the importance of practical experience in bioacoustic learning. Bioacoustic education also involves the use of technological tools. Visual tools like Raven and Audacity are acoustic recording machines and sound analysis software, which enable the students to record, analyze and interpret the vocalizations of animals. These technologies are used to make students know the acoustical features of the communication of species, including the frequency, pitch, and call patterns. Multimedia materials such as sound libraries, video, and simulation can also be used in involving the students and increasing their comprehension of bioacoustic communication. These materials offer interactive, easily accessible information, and assist students in visualizing difficult bioacoustic ideas. Multimedia resources have a high level of effectiveness, 80, which makes them important in facilitating the learning process. Interactive workshops can be used to strengthen ideas studied during the lectures and in the field. These workshops can stimulate students to collaborate, analyze bioacoustic data and resolve problems in a positive, practice-based atmosphere. Workshops of this nature should encourage critical thinking and creativity enabling students to learn more about the concepts of bioacoustics. Although important, interactive workshops received a score of 75 percent in regard to effectiveness, implying that the interactive workshops might require additional field-based or technological approach so as to achieve the best learning outcomes. Although the traditional lecture-based learning is a fundamental aspect of bio acoustic education, it alone is not very effective at only 65 points. Theoretical information provided in the form of lectures is valuable in gaining idea of the basic

principles of bioacoustics, however, it should be supported by real-life interactive experiences that would trigger deep involvement and implementation of information. This shows that a blended learning solution should be provided which involves the integration of lectures and fieldwork, technology and interactive workshops. Besides technical and academic knowledge, the conservation-based education is also an imperative part of the instruction of bioacoustics communication. It is essential to comprehend the effect of human activities on the animal communication systems and thus conservation initiatives can be made to ensure animals are not affected by noise pollution. With the integration of conservation themes into the bioacoustic education, the students will be in a better position to see the bigger picture on how bioacoustics is applicable in protecting the endangered species and conserving the ecosystems. Such a method is helpful not only to increase the knowledge of bioacoustics among students, but it also makes them think critically about the environmental problems of wildlife that the wildlife has to face nowadays. To sum up, it is possible to identify a combination of field-based education, technological devices, multimedia resources, and interactive workshops as the most effective strategies of bioacoustic communication teaching. These approaches come up with a balanced education whereby theory is combined with practical applications among students. Although learning can only be supported by lecture learning, it should be supported with practical experiences to ensure that students are well involved and understand the concepts of bioacoustic communication well. The fact that conservation issues are included in the curriculum also enriches it and students are encouraged to use bioacoustic concepts in solving world environmental problems. These broad-based educational plans make students more ready to work in research, conservation, and environmental science.

Conclusion

This study highlights the importance of using various and interactive educational approaches in order to successfully educate bioacoustic communication in biospheres, both in the sea and on land. Besides combining the theoretical information with the practical experience, the research sheds light on the significance of the field-based learning, use of technology and multimedia resources, and interactive workshops in boosting student engagement and comprehension. Although conventional lecture-based education is very important in offering the basic background knowledge, it should be supported with practical experiences as well as incorporation of technology to enhance the learning process. Another important point of the research is the importance of inclusion of conservation-oriented education in which students are motivated to implement bioacoustic concepts in practical scenarios such as the protection of species and conservation of habitat. In the end, the results indicate that an interdisciplinary approach, which is a combination of theory, practice, and conservation, is the key to equip students with the skills and know-how required in bioacoustic research, wildlife conservation, as well as environmental

science, and the ability to solve vital ecological challenges.

References

Bharathi, S. and Senbagam, B., 2025. Elephant conservation on Indian railways using deep learning techniques, *Journal of Internet Services and Information Security*, *15*(2), pp. 146–159. https://doi.org/10.58346/JISIS.2025.I2.011

Bruno, M.A. & Muraleedaran, S., 2025. Assessing marine biodiversity and conservation strategies using molecular ecology tools in coastal ecosystems. *Natural and Engineering Sciences*, *10*(2), pp.130–138. https://doi.org/10.28978/nesciences.1714408

Carlton, J.T. and Hodder, J., 2003. Maritime mammals: terrestrial mammals as consumers in marine intertidal communities. *Marine Ecology Progress Series*, *256*, pp.271-286. https://doi.org/10.3354/meps256271

Cole, J.J., 2005. Communication between terrestrial and marine ecologists: loud, sometimes abrasive. but healthy and occasionally useful. *Marine Ecology-Progress Series*, *304*, p.272.

Doyle, L.R., McCowan, B., Johnston, S. and Hanser, S.F., 2011. Information theory, animal communication, and the search for extraterrestrial intelligence. *Acta Astronautica*, *68*(3-4), pp.406-417. https://doi.org/10.1016/j.actaastro.2009.11.018

Hupper, M.L., Monte, D. and Scheifele, P., 2000. Classroom of the Sea. *Science Teacher*, *67*(3), pp.44-47.

Khyade, V.B., Gaikwad, P.M. and Vare, P.R., 2018. Explanation of Nymphalidae Butterflies, *International Academic Journal of Science and Engineering*, *5*(2), pp. 87–110. https://doi.org/10.9756/IAJSE/V5I1/1810029

Khyade, V.B., Pawar, R.S. & Khilare, A.D., 2018. Description of Lycaenidae butterflies. *International Academic Journal of Innovative Research*, *5*(2), pp.9–25. https://doi.org/10.9756/IAJIR/V5I1/1810012

Ladich, F. and Winkler, H., 2017. Acoustic communication in terrestrial and aquatic vertebrates. *Journal of Experimental Biology*, *220*(13), pp.2306-2317. https://doi.org/10.1242/jeb.132944

Pietra, F., 1995. Structurally similar natural products in phylogenetically distant marine organisms, and a comparison with terrestrial species. *Chemical Society Reviews*, *24*(1), pp.65-71. https://doi.org/10.1039/CS9952400065

Rajan, S.S. and Fernandes, R.B., 2025. Designing Community Information Systems for Coastal Disaster Response and Maritime Livelihood Support', *Indian Journal of Information Sources and Services*, *15*(3), pp. 108–112. https://doi.org/10.51983/ijiss-2025.IJISS.15.3.12

Spriel, B., Davies, H.L., Looby, A., Shafer, H., Vela, S., Juanes, F. and Cox, K.D., 2024. Fish sounds as an effective tool in marine science communication. *Fisheries*, *49*(1), pp.28-34. https://doi.org/10.1002/fsh.11022

Steele, J.H., Brink, K.H. and Scott, B.E., 2019. Comparison of marine and terrestrial ecosystems: suggestions of an evolutionary perspective influenced by environmental variation. *ICES Journal of Marine Science*, *76*(1), pp.50-59. https://doi.org/10.1093/icesjms/fsy149

Teixeira, D., Maron, M. and van Rensburg, B.J., 2019. Bioacoustic monitoring of animal vocal behavior for conservation. *Conservation Science and Practice*, *1*(8), p.e72. https://doi.org/10.1111/csp2.72

Villano, M., 2007. Eavesdropping on whales' mealtime conversation. *Oceanus*, *45*(3), p.20.