FishSounds Version 1.1: Data Archive, User Experience, and Online Resources

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A. N. Popper et al. (eds.), *The Effects of Noise on Aquatic Life*,
https://doi.org/10.1007/978-3-031-10417-6_35-1

Abstract

Fish sound production is taxonomically and geographically widespread. Produced actively or passively, acoustic contributions of fishes to aquatic soundscapes support a myriad of con- and hetero-specific interactions. Despite the ecological importance of fish sounds, the field of bioacoustics historically lacked a global inventory of fish species known to produce sound. FishSounds launched in 2021, cataloging examinations of active and passive sound production by 1185 fish species from 837 references, as well as 239 exemplary audio recordings. In April 2022, FishSounds released Version 1.1 to expand the website's data and improve its functionality. This new version updated the core dataset to include work published up until the end of the year 2021, adding 30 species, 25 recordings, and 85 references. It also added text to note the original species names used by the authors, updated all taxonomy data to FishBase version 02/2022, and included a webpage highlighting other resources that might be of interest to users. Additionally, FishSounds Educate launched a series of interactive lectures, classroom workshops, and field labs for primary, secondary, and university students. Future FishSounds versions will prioritize streamlining the data submission process, improving the user experience, and using bioacoustics to increase ocean literacy.

Keywords

Data portal · Bioacoustics · Soundscape ecology · Fish biology · Ocean literacy · Data archive · Passive acoustics · Education

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Introduction

Sound is widely used for information dissemination and acquisition by aquatic taxa (Ladich 2000; Duarte et al. 2021). Acoustic signals travel faster and farther in aquatic environments than in air, often reaching greater distances than other sensory cues (Staaterman and Paris 2014; Ladich and Winkler 2017). Because of the unique benefits of sound as a sensory cue in underwater ecosystems, many fish lineages have undergone convergent evolution to increase their physiological capacity to perceive and produce sounds for communication and the assessment of habitats, resources, and threats (Ladich 2000; Kasumyan 2009). Consequently, fish sounds can be recorded passively for the purposes of ecological monitoring and fisheries management (Lindseth and Lobel 2018). Passive acoustic recording allows fish populations to be studied remotely, thereby reducing reliance on invasive sampling methods, increasing the potential spatial and temporal coverage of research efforts, and documenting novel contributions to aquatic soundscapes (Rountree et al. 2006; Rountree and Juanes 2017).

The prevalence of sound production among fish remains indeterminate despite considerable advancements in bioacoustics and global interest in how noise pollution impacts fishes (Cox et al. 2018; Duarte et al. 2021). Although there have been numerous efforts to catalogue soniferous fish species, these endeavors have been constrained spatially (Fish and Mowbray 1970; Rountree et al. 2019) or taxonomically (Colleye et al. 2011). Furthermore, currently published reviews synthesizing information on sound production in fishes lack explicit data collection methodology and reporting (Kaatz et al. 2017) or have primarily qualitative descriptions (Kasumyan 2009). Consequently, bioacousticians have identified the need to determine the prevalence of soniferous fishes and develop a comprehensive and updateable list of fish species that have been examined for sound production (Gannon 2008; Linke et al. 2018; Lindseth and Lobel 2018; Rountree et al. 2019).

To rectify this widely recognized constraint, the FishSounds project was launched (Looby et al. 2021, 2022b, 2023). To do so, it established an international collaboration between researchers and website developers from six organizations – the University of Victoria, the University of Florida, Dalhousie University, Simon Fraser University, Universidade de São Paulo, and the Marine Environmental Research Infrastructure for Data Integration and Application Network (MERIDIAN). This collaboration applied a cross-disciplinary approach, combining expertise in fish ecology, bioacoustics, and data management to the consolidation, management, and application of fish acoustics. The FishSounds project focuses on three primary objectives: (1) conduct a global, systematized review to catalogue the fish species that have been examined for sound production, (2) construct a comprehensive web portal amalgamating acoustic recordings and published information on fish sound production, which allows researchers to contribute observations and search archived examinations by taxa, sound characteristics, or reference, and (3) disseminate this information to acousticians, conservation managers, and the general public. This conference proceeding outlines the progress on these objectives, focusing on the release of FishSounds Version 1.1 as part of ongoing efforts to expand the website's

data and improve its functionality and launching FishSounds Educate as an avenue for increasing ocean literacy.

FishSounds Version 1.1

The release of FishSounds Version 1.1 on 28 April 2022 included several extensive data and recording updates, improvements to the user experience, and additions to the web portal (Fig. 1). These updates are summarized below. Additional information on each development can also be found on the FishSounds.net website, as well as highlighted in tweets from the Twitter account (@FishSoundsWeb). When applicable, any changes made to the website are reflected in the Borealis data repository, which is versioned and archived (Looby et al. 2021).

Data and Recording Updates

The most significant change to the website featured an update of the core dataset on literature documenting known soniferous fish species. Following the methods in Looby et al. (2022a), the updated FishSounds dataset includes any references published by the end of December 2021. This update surveyed 625 new references for potential relevance. From these references, 85 examined a fish species for sound

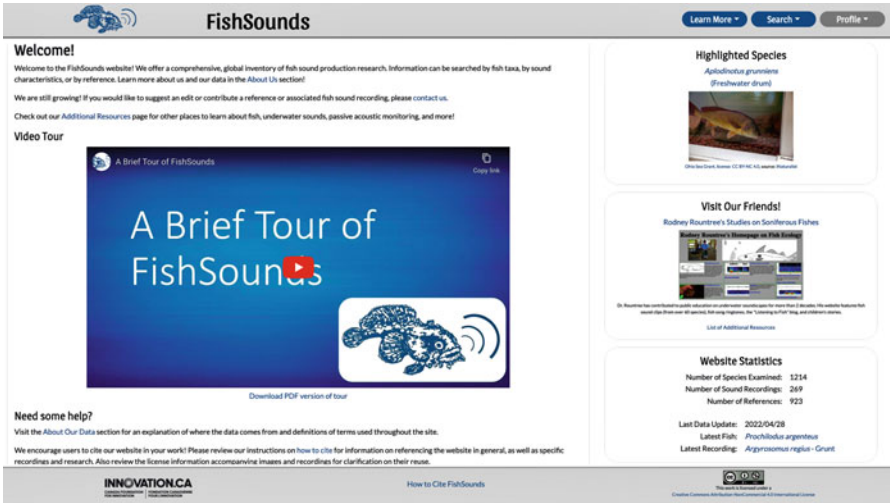

Fig. 1 FishSounds Version 1.1 home page. The latest version of FishSounds includes the addition of 30 species, 25 recordings and 85 references, updated taxonomic information, and a web page highlighting other resources that might be of interest to users. As a result of this update, FishSounds now catalogues records for 1214 species examined across 923 references and allows users to search archived examinations by taxa, sound characteristics, or reference

production, 30 of which were new species not yet included on the website. Several of the new literature additions included work that had been published in the year since the initial Looby et al. (2021) review was completed (e.g., Parmentier et al. 2022) as well as studies that the original review had missed (e.g., Lowe and Skelton 2008). With the inclusion of these additional examinations, the website now catalogues records for 1214 species examined across 923 references, which were identified by a literature review that now spans over 3000 references.

In addition to updating the soniferous fish diversity data, 25 new recordings were added to Version 1.1 of the FishSounds website. These included several additional recordings linked to the SOUNDS table on FishBase (Kaschner 2012; Froese and Pauly 2022). Contributors generously donated new recordings, such as clips of grunt and pulse sounds produced by the meagre (*Argyrosomus regius*) that were recorded as part of Viera et al. (2019) (Fig. 2). FishSounds now provides a total of 269 recordings, making it one of the largest global repositories for fish sounds that currently exists.

The fish species information listed on FishSounds was updated as part of Version 1.1. FishSounds provides general information on fish species, such as taxonomy or distribution, taken from FishBase using the R package rfishbase (Boettiger et al. 2012; Froese and Pauly 2022). The latest update included data from the FishBase data version released in February 2022, which incorporated information from Nelson et al. (2016), among other taxonomic authorities. Changes to the FishBase data also included recognizing eight taxonomic classes instead of six, 600 families instead of 590, and well-defined suborders of Perciformes at uplifted rank orders (Bailly 2021). Numerous alterations to groupings, species, and scientific names were also included

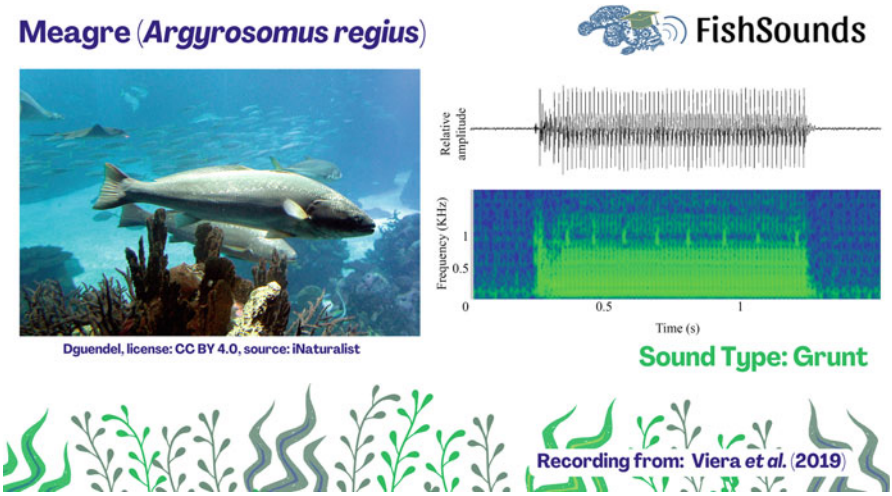

Fig. 2 An image of the meagre (*Argyrosomus regius*) alongside a waveform and spectrogram of a representative example of its grunt sound as displayed on FishSounds (Looby et al. 2022b). Waveform and spectrogram created with permission from Viera et al. (2019). (Fish image used with permission from Dguendel (2022), license: CC BY 4.0, source iNaturalist)

in this FishBase update (Bailly 2021). Since the release of FishSounds Version 1.1, FishBase has changed to a June 2022 version, which will be integrated into FishSounds in its next data update. Incorporating the latest versions of FishBase data will ensure that FishSounds more accurately reflects contemporary thinking on fish nomenclature and taxonomy.

Improvements to User Experience

FishSounds Version 1.1 added information to improve the user experience and website functionality. The most substantial addition included in this update was the provision of the species names originally used by the authors for the sound production examinations on the website. This will help users locate information within references for species names that have changed since their publication. For example, the scrawled cowfish was listed with the scientific name *Lactophrys quadricornis* in Fish and Mowbray (1970) but is currently listed on FishSounds as *Acanthostracion quadricornis* based on the latest FishBase classification (Froese and Pauly 2022); users may have previously had a hard time locating information on the species from its original reference because of the change. With the FishSounds Version 1.1, nomenclature previously used and currently accepted is now listed on the associated Reference Details page. The inclusion of changes in taxonomic classification will also improve the long-term sustainability of the FishSounds data, allowing it to adapt to ever-evolving fish nomenclature and making users aware of any reclassifications.

Editor's notes have also been added to the FishSounds website. Each note is indicated with a blue "" symbol and can be used by the FishSounds editors to denote potential contradictions in the literature or other notes of potential interest. For example, there is a so-called "chatter" sound that was misattributed in Fish and Mowbray (1970) to be produced by *Cynoscion regalis* (Sprague and Luczkovich 2001). Therefore, next to the Fish and Mowbray (1970) reference on the *C. regalis* species page, there is an editorial note that reads: "The chatter sound reported to be produced by this species was later shown to be produced by *Ophidion marginatum*." These editor notes will detail contradictions or corrections from the literature with more nuance than was possible during the Looby et al. (2022b) data collection.

FishSounds Version 1.1 also includes several additional features to increase users' awareness and use of external resources, web pages, and other bioacoustics repositories. All DOI numbers listed on the website, including those associated with each reference, are now hyperlinked to the source (e.g., published article). The inclusion of hyperlinks will more effectively encourage users to navigate from FishSounds to the original data sources. An "Additional Resources" page was also added to help users explore other related websites that may be of interest, such as the Ocean Networks SoundCloud or the Macaulay Library at the Cornell Lab of Ornithology, which also host impressive repositories of fish sounds and other recordings. A panel was added to the FishSounds homepage to further highlight websites from the Additional Resources page (Fig. 1). These improvements will

foster a sense of community among similar acoustics and fish websites while encouraging users to explore original research and related projects.

Additional Changes

The FishSounds Version 1.1. update implemented other website alterations to ensure cohesion across the associated FishSounds datasets and increase data transparency. Several of the terms used to describe aspects of the references were altered during this process. For example, the term "physiological examination" was switched to "morphophysiological examination" to more accurately describe studies examining the morphological (i.e., relating to structures) and/or the physiological (i.e., relating to functions) aspects of fish sound production. Distinguishing morphophysiological examinations is also consistent with Looby et al. (2022b), which is the foundation of the FishSounds website. Other terms had their definitions clarified in the Website Definitions provided on the About page, such as the "*** frequency" term used in the acoustic measurements tables to describe the frequency that divides the spectral content above and below the percentage or quartile reported in the measurement, represented by the three asterisks. All data definitions are listed in a searchable table that allows users to easily navigate the myriad of definitions used in bioacoustics and on the website. Future FishSounds versions will continue to revise terminology based on user feedback. Other changes were made throughout the website as needed. These included listing additional citations for recording credits, adding new fish images that had been donated, and updating the website acknowledgments to include new recording contributors and research assistants, whose support is greatly appreciated. There is also an updated list of presentations and publications that have occurred since the initial website launch (e.g., Parsons et al. 2022; Looby et al. 2022a, 2023). Finally, the citation to be used when crediting FishSounds has been updated to 2022 instead of 2021 and Version 1.1 instead of 1.0.

User Engagement with FishSounds

FishSounds has had success in garnering users and engagement. On 28 October 2022, FishSounds celebrated its 1-year anniversary (Fig. 3). Since launching, FishSounds has had over 13,000 users and 64,000 page views, with its highest user counts from the USA, Canada, and then Europe (Google Analytics 2022). The most viewed fish species on the website were the Bocon toadfish (*Amphichthys cryptocentrus*) and haddock (*Melanogrammus aeglefinus*) – fitting as the FishSounds logo is a toadfish. The FishSounds Twitter account (@FishSoundsWeb), which regularly highlights species and references from the website and shares other relevant news and papers (e.g., Fig. 4), achieved 690 followers and over 100,000 tweet impressions by December 2022 (Fig. 3).

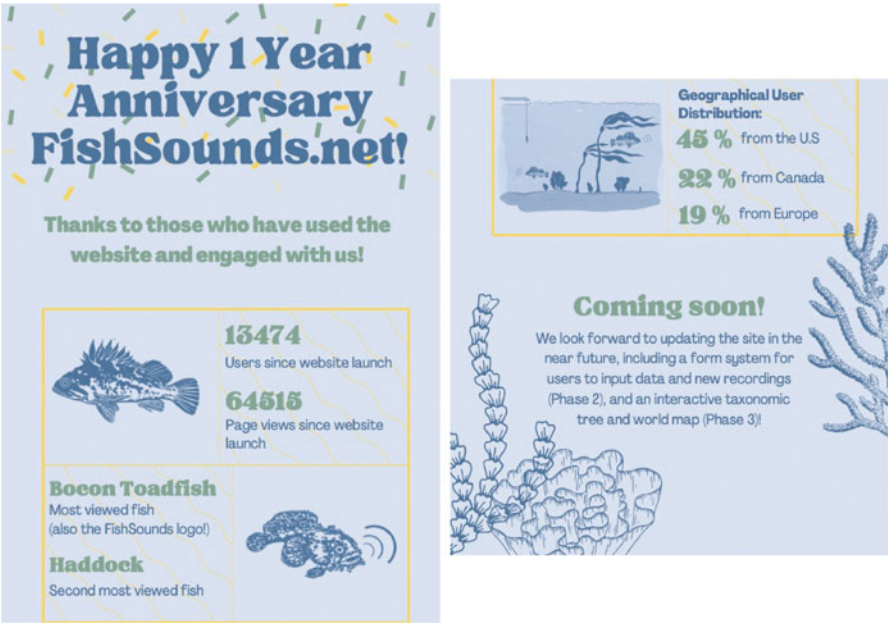

Fig. 3 Image shared in celebration of the 1-year anniversary of FishSounds on the FishSounds Twitter account (@FishSoundsWeb) highlighting some of the website engagement metrics and future plans

Upcoming Website Versions

Future versions of the FishSounds web portal have been scheduled for 2023. Led by Sarah Vela, these updates will continue to expand the functionality of the web portal and improve the user experience. Planned additions to FishSounds include the development of a form system for users to help contribute to FishSounds directly, an interactive map of fish passive and active sound production, and additional data visualizations. Future updates will also increase the number of species, recordings, and references in the core dataset to include work published in 2022. These data updates will follow the methods developed by Looby et al. (2022a). Version updates scheduled for the latter portion of 2023 and early 2024 will improve the extent to which users can search and download the FishSounds data and integrate a taxonomic tree illustrating passive and active sound production by fish. Future updates are the direct result of community input and aim to address the ever-expanding needs of bioacousticians, marine ecologists, and members of the public interested in fish sounds. Therefore, FishSounds is keen for feedback from the users of the web portal on how future updates can better meet the needs of the community that makes this work possible.

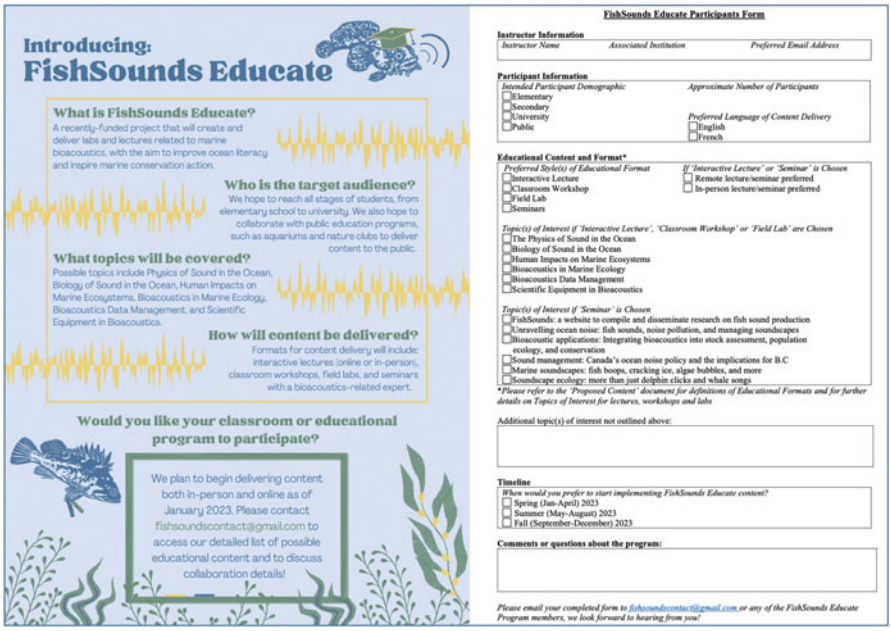

Fig. 4 FishSounds Educate launch announcement and participation form. To increase ocean literacy in Canada, FishSounds Educate is developing and implementing interactive lectures, classroom workrooms, and field labs for primary, secondary, and university students, as well as seminars for members of the public. Instructors or institutions interested in integrating bioacoustics into their lesson plans should contact the FishSounds team

FishSounds Educate

FishSounds Educate launched in September 2022 with the aim of increasing awareness of one of the most vital but understudied attributes of marine ecosystems – sound. This ambitious aim will be achieved through four primary objectives: establish educational partnerships, implement FishSounds Educate lectures and labs, disseminate resources equitably, and further develop FishSounds Educate online. The funding for FishSounds Educate was provided by Fisheries and Oceans Canada's Oceans Management Contribution Program, which supports outreach, monitoring, stewardship, and capacity-building initiatives to achieve Canada's commitment to marine conservation targets. The FishSounds team is currently establishing educational partnerships with instructors and institutions from across Canada to ensure that the materials reach a broad audience. Establishing partnerships involves connecting with instructors and institutions that have marine-focused programs (e.g., Bamfield Marine Science Centre), as well as those who have yet to integrate ocean sciences into their lesson plans. FishSounds Educate will implement four types of lesson materials: interactive lectures, classroom workrooms, field labs, and seminars. Each of these will be developed for primary, secondary, and university

students and then will be tailored according to classroom, institution or instructor's objectives, logistical constraints, and format. All FishSounds Educate materials will be available in English and French. FishSounds Educate will provide the training and equipment required for each type of lesson to be conducted, ensuring that participation in the program occurs at no direct cost to the instructor or institution, reducing any potential participation barriers. This will include providing access to software, hydrophones, and other acoustic recorders. FishSounds Educate will continue to support the instructors as they deliver the material or join the instructor either in person or remotely as guest presenters.

FishSounds Educate will be made freely available to the public by developing an education portal on the FishSounds website. This will include all lesson materials, instructional videos, and the information needed to become a FishSounds Educate partner. FishSounds Educate will be continually developed for the project's duration, including forming partnerships with public venues (e.g., aquariums) and non-governmental organizations. Finally, FishSounds Educate will develop the interactive lectures into a monthly seminar series on the importance of ocean noise as a tool for conservation, with the team and the broader research community presenting to academics, educators, and the public.

Conclusions

FishSounds is one of the first publicly available and interactive web portals consolidating existing information on active and passive sound production by fishes, allowing users to search by taxa, geographical distribution (e.g., region or water body), sound type, or reference. Consequently, the FishSounds web portal provides researchers globally with a comprehensive species-level description of sound production in fish and continually updates these descriptions as the field progresses. This momentous feat was made possible due to the decades of dedicated and innovative research conducted by bioacousticians, whose examinations form the foundation of FishSounds. This web portal addresses multiple barriers restricting the progression of investigations into the ecological importance of aquatic soundscapes and extends FishSounds' utility beyond that of an archive, generating a platform for connecting researchers, facilitating collaborations, and promoting emerging research. FishSounds Version 1.1 represents an important step toward this objective. Expansions of the FishSounds data and recording archive, improvements to the user experience, and increases in the functionality of the web portal are the primary products of this update. These accompaniments coincide with the launch of the ocean literacy project – FishSounds Educate. Future updates will further prioritize increasing researchers' ability to explore and engage with the FishSounds data and foster public outreach opportunities. Despite still being in its infancy, FishSounds has the potential to bolster the field of bioacoustics' ongoing efforts to advance research into soniferous fish diversity, passive acoustic monitoring, and human impacts on underwater soundscapes, as well as serve as a public resource for those interested in learning more about fish sounds and underwater soundscapes.

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