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Designing Cyberinfrastructure for Knowledge Sharing: A Bioacoustics Case Study

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Abstract

FishSounds (https://fishsounds.net) is an online portal that provides open and user-friendly access to academic scholarship regarding the sounds made by fish species. It is the result of an international collaboration between students, scientists, and information professionals, and has become a resource used around the globe for research, education, journalism, and general interest. This website is just the first instance of a new approach to sharing knowledge and an emerging cyberinfrastructure for open scholarship. The codebase behind FishSounds was designed to be reusable with other datasets, and in the coming years additional portals will connect users to knowledge from varied subject areas across academic disciplines. This discussion examines the development and reception of FishSounds as a case study for the creation of these websites, called Searchable Online Catalogues of Knowledge, or SOCKs. An examination of the lessons learned from different audiences accessing FishSounds will be used to guide the development of the SOCK platform as it is publicly released.

Keywords: open scholarship, citizen science, platform development, reusability principle

Introduction

Over the past five years, an international team of students, scientists, and information professionals have collaborated to transform the subdiscipline of fish bioacoustics from one considered understudied and poorly catalogued to a leader in ecological science that other efforts may look to as a model (Looby, Vela, et al., 2023; Parsons et al., 2022; Rountree et al., 2006, 2019). The core of this change were systematized reviews of scholarship in the field (Looby et al., 2022; Looby, Bravo, et al., 2023; Looby, Cox, et al., 2023) and the development of a new website, FishSounds, that presents the collected data in an easy-to-find and intellectually accessible way (Looby, Vela, et al., 2023; Looby et al., 2024). The methodology and technology behind FishSounds were designed to be reusable for other subject areas, and an upcoming project will further develop the codebase into a robust cyberinfrastructure that will be used to create additional websites from a variety of academic disciplines. These websites, known as Searchable Online Catalogues of Knowledge (SOCKs), have the potential to revolutionize open scholarship by making the key information freely available and by expanding the scope of who can contribute to academic inquiry. This discussion summarizes the project to-date and reflects on the lessons learned from the reception of FishSounds as we prepare for the wider release of the SOCK platform.

Background

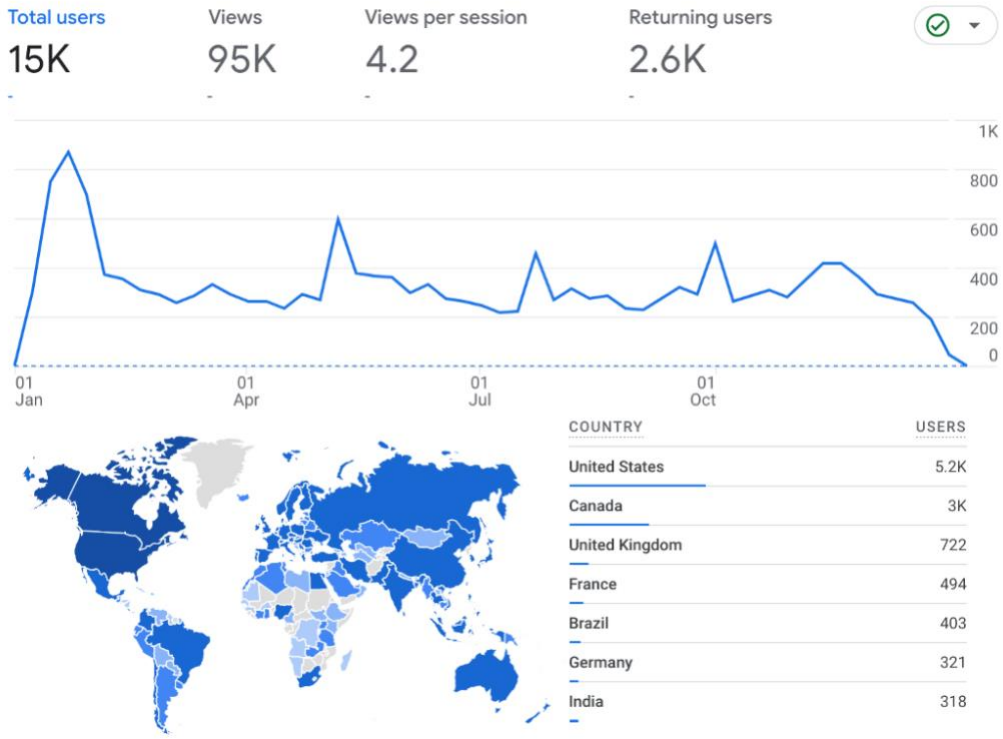
Fish bioacoustics—the study of the sounds produced by or affecting fishes—is a field with ancient origins that became a formalized science in the late 19th century (Looby, Cox, et al., 2023). Despite this extensive history, research into fish sound production has faced limitations due to the sheer diversity of fish species (~35,000 species) and their acoustic behaviors as well as technological constraints, among other factors (Looby, Cox, et al., 2023; Parsons et al., 2022). This has led the subdiscipline to lag behind comparable taxa, such as marine mammals, when it comes to assembling recording libraries or standardizing sound naming conventions (Looby, Cox, et al., 2023).

To address these challenges and facilitate future research, Dr. Audrey Looby undertook a systematized review of academic literature related to sound production by fishes as part of her graduate research in 2018 (Looby et al., 2022). In partnership with the research group MERIDIAN, the resulting dataset was then used as the basis for FishSounds, which launched in October 2021 (Looby, Vela, et al., 2024). The initial website allowed users to search through a comprehensive corpus of scholarship via three search forms that accessed the collection from one of three points of view: fish-centric, research-centric, or recording-centric (Looby, Vela, et al., 2023). A version 1.1 release expanded the materials included and provided additional resources (Cox et al., 2023), while updates under version 2 added data visualizations and numerous features and revisions in response to user feedback (Looby et al., 2024). FishSounds is now the largest public repository of fish sound production information and recordings, with information on over 1,000 species and over 1,200 representative recordings (Looby et al., 2024).

Reception of the website has been positive, and it has a steadily growing userbase from various backgrounds (Google Analytics, 2023). Academic researchers who study fish and/or bioacoustics contribute to a baseline usership of approximately 350 visitors per week as of Spring 2024. There are also frequent peaks in traffic when the site is referenced in media

reports or shared on social media, resulting in a total of over 15,000 users and almost 100,000 pageviews in 2023, with a true global spread (see Figure 1). The project FishSounds Educate, funded by Fisheries and Oceans Canada, used the website to bring the science of underwater sound into classrooms across Canada and the United States (Spriel et al., 2024), while the upcoming FishSounds Fisheries expansion will increase engagement with government and industry stakeholders. All in all, FishSounds has taken scholarship regarding fish bioacoustics from an inaccessible and underappreciated niche to a freely available and widely referenced topic.

Figure 1
Google Analytics for FishSounds



This singular website is only the beginning, however, as the codebase behind FishSounds was developed with re-use in mind and is intended to be the foundation of a new cyberinfrastructure for open scholarship across disciplines. Development of the websites, termed Searchable Online Catalogues of Knowledge (SOCKs), follows two key principles: 1) they use a data-first approach where a representative sample of real information is gathered and assessed by domain experts for significance and quality, and this assessment determines how the site will be designed; and 2) the code follows the Reusability Principle (Anguswamy & Frakes, 2012), such that the built-in functions will work with any well-structured dataset to perform search tasks, while allowing room for custom functions to be added where needed. FishSounds itself already re-uses the code in its three views (fish, reference, and recording), with different data schemas and search form settings in each. The pilot version of the codebase is available now under the MIT license (MIT Technology Licensing Office, n.d.), and updates, including a graphical interface for implementing a SOCK, will be made as stable releases are developed.

As we prepare to launch the next phase of our research and move from a single pilot website to a suite of SOCKs, the lessons learned from the original effort will be key to success.

Lessons Learned

The initial audiences for FishSounds were scientists and researchers studying fish bioacoustics, groups who quickly recognized the potential of the application. The version 1 launch was promoted primarily to the professional and social networks of bioacousticians involved in the project as we sought early feedback. The response from the research community was overwhelmingly positive, with scientists eager to contribute recordings from their own research and provide citations for materials missed in the initial review. It also caught the attention of an international working group of bioacousticians attempting to develop standards for acoustic data and envision cyberinfrastructure to facilitate their use (Parsons et al., 2022). In our conversations with members of the Global Library of Underwater Biological Sounds (GLUBS) working group, one risk for SOCKs that became clear was the potential for over-proliferation of the sites if separate instances are established for very similar topics. Having more information collected in one place makes it more accessible for users, but academic funding and advancement models tend to incentivize the creation of many smaller products each controlled by a different Principal Investigator. We intend to address this risk by demonstrating the advantages of contributing to an existing SOCK rather than starting a new one, supporting attribution of data contributors to the sites, and adding functionality that will allow a single database to provide the backend for multiple SOCKs so that both larger general sites and smaller more specific ones can exist simultaneously.

Beginning in January 2023, FishSounds Educate brought the website into classrooms of all sorts, including K-12 public schools, post-secondary institutions, virtual spaces, and nature clubs (Spriel et al., 2024). The commentary we received from student and teacher audiences on the site was invaluable in revising the interface and functionality in the version 2 releases. Search forms were modified so users can search by fish species on all pages, and the common name field, which is more familiar to a public audience, was highlighted over taxonomic names. The need for interactivity was also a key takeaway, as games and activities proved to be an effective pedagogical tool for helping students understand the science of sound. To date, three interactive visualizations have been added to the website: a map demonstrating geographical spread of data, a dendrogram or tree chart showing a taxonomical breakdown of data, and a list view presenting an alphabetized inventory of data. While the inclusion of such visualizations in future SOCKs will require custom coding, a growing library of supported plug-ins will make additions relatively simple.

A third source of traffic and feedback on the site has been the result of exposure to the public via journalistic media and social media venues (Looby, Vela, et al., 2023). While the project has been included in a few formal press releases, increasingly, journalists will cite the website as an authority in articles reporting on fishes in various capacities (e.g., Adkins, 2024). Users visiting from these reports are visible in the Google Analytics referral tracking, as are links from AI products such as ChatGPT (OpenAI, 2024) that have included FishSounds' data as part of their training material. Our experience with this audience has introduced two main challenges to be addressed. First, while researchers are accustomed to, and indeed often prefer, the idea of "grey" truth in information—where what is true can be nuanced or contested and may change over time—the public has been conditioned to expect a simple binary answer to most questions,

like what search engines can display in a result snippet or an AI tool can provide in a response. Second, though members of the public are enthusiastic about sharing knowledge and want to contribute as citizen scientists, academic scholars remain protective of their expertise and are reluctant to treat data collected by citizen scientists as equivalently reliable. We have attempted to address the former by frequently engaging with the media ourselves directly, while we are addressing the latter through a collaborative open call for freshwater sound recordings, which will first be validated through a peer-reviewed data publication before being added to the website. Additional solutions to these issues, however, may require further investigation.

Next Steps

Development of FishSounds as a pilot SOCK will continue over the coming years. An Administrative Portal is entering alpha testing and will enable more frequent data updates, starting with recent publications and a backlog of donated recordings. The collection will also be significantly expanded by adding the results of a new systemized review of underwater invertebrate sound production, as the test case for having multiple SOCK search interfaces connected to the same database. Several of the most effective activities developed for FishSounds Educate will also be reproduced digitally, to create an interactive lab for student visitors. Finally, the FishSounds Fisheries project will allow us to work with new audiences from industry and government perspectives and determine what data and functionality are required to support their information needs.

Meanwhile, the SOCK cyberinfrastructure project is currently seeking partners as we prepare a funding application to support the creation of additional websites. We hope to include use cases from varied disciplines to test how well the system can adapt to data from various domains such as Science, Social Science, Humanities, Medical, and Legal. Each SOCK instance will be overseen by a team consisting of a subject matter expert in the field, a librarian or information professional to help define the scope of the topic area, and a research assistant who will perform the required systemized review. Development staff on the project will then work with these teams to convert each dataset into a new SOCK. The feedback from this development will inform the public release of a cyberinfrastructure software package.

In conclusion, FishSounds has been a successful pilot project in the development of a new cyberinfrastructure for SOCKs. The reusability of the system will be thoroughly tested and improved in an upcoming expansion project, and the resulting codebase has the potential to advance open scholarship by making important information more available and incorporating more viewpoints into our understanding of the world. Many of the challenges we face in this regard are not technological but sociocultural, as academia continues to struggle with altering conventional notions of authority and trustworthiness. However, we believe that SOCKs are well-placed to demonstrate to researchers that there are more benefits than threats to involving the public in knowledge creation and sharing, and that establishing this value will be key to initiating meaningful change.

Author's Contributions

SV was the data manager and developer for FishSounds and the SOCK codebase and was the primary author of this paper.

AL completed the original systemized review to collect data for the FishSounds website and was an editing author of this paper.

BS was the Project Coordinator of FishSounds Educate and was an editing author of this paper.

HLD was the Lead Researcher and Coordinator of FishSounds Educate and was an editing author of this paper.

KC provided subject matter expertise in the design of FishSounds and was an editing author of this paper.

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Ethics Statement

Ethics review was not applicable because this paper reports on a practice innovation and no research on human or animal subjects were undertaken.

Conflict of Interest

The authors do not declare any conflict of interest.

Data Availability Statement

All data associated with the website are openly available both on the FishSounds website itself at FishSounds.net (Looby, Vela, et al., 2024) as well as in a Borealis permanent data repository at https://doi.org/10.5683/SP2/TACOUX (Looby et al., 2021).

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