

## **An Annotated and Federated Digital Library of Marine Animal Sounds**

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### **LONG-TERM GOALS**

The Macaulay Library is the world's largest archive of animal sounds and has been selected by the Office of Naval Research as a major repository for the deposition, digital archival, review, and retrieval of the many recordings of marine animals made over the last half-century. Archived marine recordings pose challenging retrieval problems given the typically long intervals of silence between animal sounds and the multiplicity of species detectable in any given recording. Our long-term goal is to design tools and interactive interfaces that streamline and enhance the search and retrieval functions of the marine archive, yet provide maximal access to the associated metadata.

### **OBJECTIVES**

One specific objective of this project is to design software that will permit remote experts to annotate the content of long recordings archived at the Macaulay Library through their web browsers. Annotations will permit subsequent searches of the archive database to retrieve not only suitable recordings, but also those parts of a recording meeting the search criteria. A second main objective is to define and extract a set of acoustic features from all archived marine recordings that can be used in subsequent search and retrieval tasks. A third task is to refine the geographical location data for each recording in preparation for collaborative linking with OBIS-SEAMAP. The combined capabilities will be unique to this sound collection, and will greatly enhance the accessibility and the utility of the archive to scientists, students, educators, military personnel, the media, and the general public.

## APPROACH AND WORKPLAN

Specific tasks to meet the first of our three objectives included creating a) browser-based software for visualizing and playing back digitized sounds stored in the archive; b) mouse-driven tools for identifying specific segments within the visual image of the sound; c) pull down menus that allow the annotator to assign standardized metadata terms for annotation d) suitable metadata structures for storage of the annotations and the relevant segment delimitation points and linkages to other relevant metadata fields; e) search engines that support the invocation of annotation terms during searches along with other standard criteria; and f) retrieval tools that identify relevant parts within archived recordings. The software was designed and implemented by the Macaulay Library Information Technology team in collaboration with Totally Hip Technologies. The data model was overseen by Mr. Tim Levatich of the Cornell Lab of Ornithology Information Services unit with extensive design ideas and testing by the Macaulay Library archival and distribution units.

To achieve the second objective, we sought to: a) consult with the marine community on desired measures; b) create algorithms for these measures; c) implement these algorithms so that they can be applied directly to annotated segments in the archive; d) provide suitable metadata structures to store the extracted feature data and link them to the other fields pertinent to any recording; and d) test and refine the measures with input from the marine community. This work was undertaken by Dr. David Mellinger of Oregon State University and Macaulay Library director Dr. Jack Bradbury in consultation with Dr. Kurt Fristrup (formerly of the Cornell Lab of Ornithology), and Dr. Chris Clark and his staff of the Bioacoustics Research Program (Cornell Lab of Ornithology).

The third objective required that we: a) define and classify the types of location information currently provided; b) assemble gazetteers and data sources for replacing names and descriptions with lat/long data; c) provide tools for interpolation and error circle definition; d) generate a database of known locations and their coordinates to accelerate translations; e) design data model for easy access and federation with OBIS-SEAMAP. This work was overseen by Audio Curator Greg Budney at the Macaulay Library, undertaken by the Macaulay Library IT staff, and tested extensively by the Macaulay Library archival and distribution teams.

## WORK COMPLETED

To date, the project has completed; a) adaptation of the metadata model for the Macaulay Library that would support annotation and retrieval of metadata assigned to specific segments within an archived recording; b) design and implementation of the online player and visualization tool required for demarcation of segments within recordings by annotators; c) selection of 30 candidate acoustic features, their implementation in Matlab, and their posting, along with documentation, on a forum website to promote testing and input from the marine bioacoustics community; d) the design and testing of new geographical tools for conversion of location data into coordinates; and e) design of data exchange and federation tools that will facilitate linkage of the marine archive to other databases.

## RESULTS

a) **Data model design and consequences:** Annotator assignment of metadata to segments within recordings requires a clearly defined data model that works at all levels. Some fields assigned to a recording can be inherited directly by “daughter” segments, but other fields are either not assignable to whole recording or existing assignments refer to general trends and not to all specific segments.

Designing the software that could make these assignments intelligently has taken a very large amount of thought and discussion. There are also subtle and tricky database structure issues that needed to be resolved (e.g. should daughter segments be treated as separate assets or not?). In addition, an entirely new ontology for behavior was designed and evaluated by the international animal behavior community. The initial behavior model has recently been enhanced with a simplified version that will allow easier data entry by non-expert internal staff and more meaningful search results by standard users. By adopting this dual strategy, we preserve the original specifications and data, while providing an easier searching experience to all users. We also recently added better tools to manage some of the more complex data, such as taxonomy. These tools provide the means for archivists to correct and otherwise modify taxonomy and naming in a logical, intuitive fashion; derivations of these advances will prove very beneficial to the public users as well. An online graphic user interface was designed for metadata entry by Macaulay archivists that limits entries to allowed fields and field values. This same interface is used to channel annotator input within boundaries set by the Macaulay data model. Considerable time was spent working with the archivists on their input tools before we could begin working on an online annotator version. The output (search) side was equally tricky, although sufficient forethought while designing the input side has avoided a number of potential pitfalls and problems. A new summary results page was recently implemented that accesses located assets more efficiently and simply.

**b) Design and implementation of annotations player:** The online player and visualization tool was made available online for beta testing mode in April 2005. Input from users was very positive and resulted in numerous refinements and improvements. Among these was the addition of a power spectrum view, (complementing the waveform and spectrogram views already implemented), saveable and customizable settings, the ability to open multiple windows to compare an archived specimen to one on the user's desktop, and faster loading and display procedures. We also resolved several bugs present in specific platforms. In the last year, the player was adapted to accept segment demarcation by an expert annotator, assign non-inherited metadata within the overall Macaulay Library model using an interface similar to that used by Macaulay archivists, and indicate locations of annotated segments in recordings retrieved in a search. The visualization player was awarded second prize for "Interactive Multimedia" in the Fall 2006 NSF/AAAS "Science and Engineering Visualization Challenge" contest. Details on this prize are posted at:

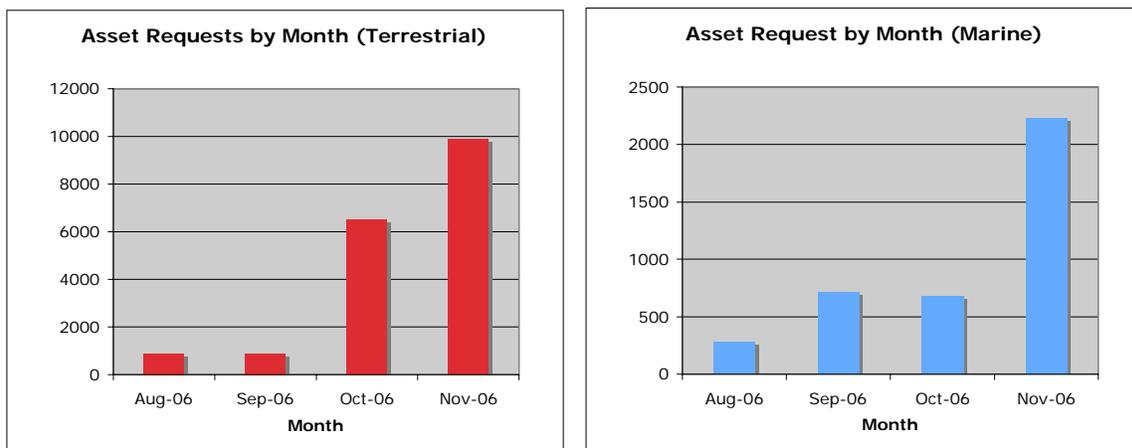
<http://www.eotopic.org/modules.php?op=modload&name=News&file=article&sid=682>.

**c) Feature extraction tools:** Based on prior published research by the marine community, a workshop held at the Cornell Lab of Ornithology, and detailed input from NOPP partners, 30 candidate acoustic features for future search and retrieval within the archive were identified and implemented as Matlab routines. These are currently posted on a website (<http://mlsource.ornith.cornell.edu/ethodata/features/>) where they can be retrieved for testing and feedback provided through an online forum. The relevant software for extraction of these features from annotated segments is largely complete but will not be implemented until sufficient time has been provided for possible substitutions and refinements provided by the marine bioacoustics community.

**c) Annotator registration and security:** At least at this stage, the Macaulay Library only intends to allow authorized and registered experts to annotate segments of archived recordings. This requires an online system for registering approved annotators and providing them with password access to the annotation tools. Registration is a general task that is required for several other classes of Macaulay Library users. At the moment, anyone wishing to download archived sounds must pay a fee. Fees are graduated with commercial users paying the most and academic or nonprofit institutions less. Once a

fee is paid, the client will be allowed registered access for the selected downloads. In addition, we intend to allow registered researchers and their staff free registration for a limited number of downloads per month. We are thus working on a general protocol for handling registrations, checking authenticities, and monitoring downloading that can handle each class of registered users. Until this protocol is complete, we cannot deploy the otherwise completed annotation tools. It is hoped to complete this process in the next 6-8 months. We are also holding deployment of the annotation tools while we discuss possible collaborations with producers of commercial sound analysis and annotation software. Researchers wish to download annotated sound files from the Macaulay archive directly into their analysis software with annotations intact. Similarly, sound files annotated in commercial software packages greatly increases the rate at which annotated files can be acquired by the archive. Some form of collaborative effort between the Macaulay Library and these software developers appears to be in everyone's interest and is currently under discussion.

d) **Usage:** Since the newer versions of the online tools became available this summer, usage of the Macaulay Library website has increased exponentially. This applies both to the existing terrestrial collection and the marine collection. Graphs of user demands for recordings are displayed below:



**Figure 1.** Rapid increase in usage of terrestrial (left) and marine (right) recordings since July 2006

## IMPACT AND IMPLICATIONS

### Economic Development

The new annotation, visualization, and search/retrieval tools should significantly facilitate remote access to the world's largest archive of animal sounds. Urgent demands by television and radio programs for exemplars of a particular species' sounds can now be filled quickly and even remotely by the programming staff. Similarly, public institutions such as zoos or museums that would like to compile a set of sounds demonstrating specific principles can now browse the collection remotely and select the material they need. There is an increasingly large industry creating nature-oriented products and many of these companies come to the Macaulay Library for authenticated rich media resources. The tools provide them with a way to both ensure accuracy and find sounds in the archive that they feel best meet their criteria.

### Quality of Life

The Macaulay Library has a long tradition of supplying reference sounds to wildlife management programs worldwide. Acoustic censusing has become a primary means for assessing biological community health in both forested and marine environments. Access to reference sounds is key to such programs. Our new tools will greatly facilitate remote selection of material by these agencies.

### **Science Education and Communication**

Animal behavior and in particular, marine animal behavior, is a topic of natural interest to children. It is one that can easily be used as a springboard into biology and other STEM topics including physiology, economics, mathematics, chemistry, and physics. The extensive rich media archives of the Macaulay Library can be used to create those springboards and enhance STEM teaching at all levels. Because the archives are so large, it can be daunting to teachers and curriculum writers to attempt to find optimal materials for a given task. The new preview, annotation, and search tools will greatly facilitate access by the education community, and the Macaulay Library recently hired a new “information broker” to serve as a guide to this community on use of the archives.

### **TRANSITIONS**

#### **Economic Development**

The Macaulay Library resources are widely used by commercial entities, museums, zoos, aquaria, science centers, education, and the media. While the original focus of the visualization, annotation, search and retrieval tools was largely to facilitate research, we are finding that they have greatly increased access and utility of the archive to these many other users. A number of commercial products using Macaulay Library sounds are currently quite popular and indirectly promote public awareness of nature and conservation. One book containing our bird sounds is among the top 10 products being purchased this holiday season.

#### **Quality of Life**

The new software tools have greatly enhanced the ability of conservation programs, marine refuge managers, and wildlife biologists to obtain reference sounds that they need for their projects and their interfacing with the public. Macaulay Library staff have participated in numerous national meetings on marine animal conservation (ECOUS, NOAA), and are active collaborators in several ongoing marine conservation projects.

### **Science Education and Communication**

As a twice-funded member of the National Science and Mathematics Digital Library (NSDL) program, the Macaulay Library and the Education Unit at the Cornell Lab of Ornithology are very actively involved in the development of science curricula including topics involving marine animal behavior and ecology. We collaborate with a number of marine parks and research programs to share educational materials. Perhaps as important, the general public now has free access to hearing and using the new visualization tools for any sound in the Macaulay Library archive.

### **RELATED PROJECTS**

This NOPP project has been complemented by concurrent grants from the Office of Naval Research that funded the acquisition and archival of marine animal sounds (N00014-02-1-0467). The educational outreach has been funded by two NSF-NSDL awards (DUE-0332872 and DUE-0532786). An earlier NSF award (IBN-0337507) funded the design of the data model relating to behavior.