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The assets archived in this study are all freely viewable and playable online at no charge.

13. SUPPLEMENTARY NOTES

14. ABSTRACT

This project funded the creation of the world's largest online reference collection of marine animal sounds at the Macaulay Library (Cornell Lab of Ornithology). Over a 6 year period, 5700 audio clips (1200 hours) of marine mammal and fish sound recordings were digitized, documented in an extensive metadata base, and made available for free online playback. Users can search the collection using a variety of criteria and either play back the clips directly, or alternatively play them back while watching customizable and real-time waveforms, spectrograms, and power spectra. Usage of the collection has grown 7-fold in the last two years and serves the needs of researchers, military staff, educators, K-12 and college students, conservation and wildlife programs, the arts, museums, zoos, and aquaria, publishers, nature outreach industries, and both public and commercial media. A suite of 30 standardized sound measures were developed during the project and are now being tested for robustness as features extractable from annotated clips in the collection. Extracted features will be used as additional search criteria, data for automatic species identification, and ecological comparisons of sound communication in diverse habitats.

15. SUBJECT TERMS

Marine mammals, sound recordings, animal behavior library, online archive

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A Comprehensive Web-based Library of Marine Biological Sounds
Final Report--7 July 2008

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LONG-TERM GOALS

The Macaulay Library is the world's largest archive of animal sounds and was selected by the Office of Naval Research in 2002 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. Our long-term goals have been to build as synoptic a collection a possible, log full documentation of all acoustic specimens, provide the online tools necessary for effective search, retrieval, and distribution, and promote usage of the collection by the worldwide marine bioacoustics community and all other users of rich media recordings of animal behavior.

OBJECTIVES

This project's goals were to: 1) assemble a system for processing aging analog sound recordings of marine animals into high resolution deep archive storage specimens and lower resolution files that could be distributed, studied, analyzed, and compared by online users; 2) prioritize archival to obtain first broad taxonomic coverage and then fill in missing behavioral, geographic, age, and cultural variants; 3) create and implement a relational database for the recordings that fulfills the metadata needs of diverse clients including researchers, educators, conservation biologists, the military, and the media; and 4) create software that: i) integrates the sound recording archival system for maximal efficiency; ii) allows for automatic extraction of sound parameters from recordings; iii) permits metadata annotation from remote locations; iv) enables users to search the database, preview archived

samples, perform sound analyses online, and download copies of the sounds in any of a variety of formats; v) provides resources for identification of unknown marine sounds; vi) supports large scale comparisons of sound structures; and vii) provides sounds for playback in research and wildlife management applications.

APPROACH

The first years of this project were devoted to assembling the relevant hardware, writing the core software, and hiring and training personnel. The software tools envisioned included an online playback engine that provided real time spectrographic and waveform visualization of the sounds being played. Once sufficient structure was in place, we made a major effort to advertise the marine archive at national and international meetings, and to work with a long list of known marine recordists to prepare their recordings for archival. Recent efforts have focused on refinement of the geographic and taxonomic tools available during archival and search, and creation of a set of 30 acoustic measures that can be extracted from annotated segments within recordings to compare with unknown sounds, with similar sounds by related species, or with sounds produced by the same animals in different habitats. This will allow for a more quantitative use of the collection and provide a reference collection for researchers designing automatic and batch detection tools. We also currently working on an online registry tool that will allow registered users to select and download segments of recordings as well as play them online.

WORK COMPLETED

The archival and server hardware has just been completely upgraded to the newest Sound Blade and Apple SAN systems and should be sufficient for input and output functions for the next 5+ years. A recent endowment ($5M) made to the Library provides a buffer for necessary repairs, upgrades, and expansions of the storage capacity of the system. The marine collection is not only operationally functional but it is also fiscally sustainable at current levels.

Major efforts were made to build a comprehensive marine animal sound collection from scratch. Most of the marine bioacoustics community were extremely supportive and the influx of old and new audio recordings has kept 3 audio archivists busy full time during the life of this award. The collection now includes most of the classic recordings that were critical to the field (e.g. Fish, Mowbray, Myrberg for fish and Perkins, Ljungblad, Steiner, Norris, Marshall, Poulter, Winn, Levenson, Thomas, Miller, Terhune, etc.), and that has in turn attracted continuing large numbers of contributions by more recent recordists. Regular reports on the progress of the marine collection and solicitations for new contributions were provided at meetings of ESME, ECOUS, and most recently, a meeting for OBIS-SeaMap at Duke in April 2008.

A complex Oracle relational data model was constructed and has been used during archival of all sounds in the marine collection. Online tools allow users to search using a wide variety of criteria, see locations of archived recordings using the well-known Google map format, invoke a taxonomy tool to resolve common and scientific names, and recover extensive data on each recording. Sound files could be played back for free using a REAL plugin to the user's browser. Because REAL has become increasingly unpopular with the advent of the ubiquitous FLASH (Adobe) player plugin, the Library converted all of its audio files from REAL formats to ones that can play in FLASH during spring of 2008. Nearly all browsers now come with the FLASH plugin, and this change makes audio playback on the Macaulay Library site extremely simple for most users. This same player will also play back videos archived in the Macaulay Library. A second playback option available on the website provides

visualization of played back audio. This tool provides real time waveform, spectrogram, and power spectrum views with settings that are customizable by the user. The original version of the visualization tool was relied on a combination of Apple QuickTime and FLASH technologies and was posted in 2006 where it won second prize in the annual NSF/AAAS Technology Challenge for Interactive Media. In late 2007, Apple unexpectedly blocked the transfer of data between QuickTime and FLASH due to security problems. This "broke" the existing visualizer. We worked hard throughout the winter of 2008 to fix the visualizing tool, and it is now up and running in a new form on the website. Users again have the choice of simple playback of audio files in the archive or playback with associated waveform and spectrogram visualization.

Thirty acoustic measures were derived in collaboration with Dr. David Mellinger that were deemed highly suitable for comparison of marine animal sounds, provision of data for automatic sound identifiers, and identification of unknown sounds. These were formulated at Matlab routines and posted on a website (http://mlsource.ornith.cornell.edu/ethodata/features/) to solicit trial and input by colleagues in the marine bioacoustics community. Unfortunately, implementation of feature extraction depended critically on use of the online visualization tool. When Apple broke the viewer, we were unable to continue development of the feature extraction tools, as well as tools for expert annotations of archived clips and registered user downloads of selected segments within clips. All of these parts of the project are thus behind schedule, but are now being pursued with funds from another source.

RESULTS

As of this report, the Macaulay Library has archived over 5700 acoustic recordings (over 1200 hours) of marine animals. We now have coverage of 67% of Pinniped species, 75% of Mysticetes, 46% of Odontocetes, and 2 of the 5 Sirenians. The fish sound collection has also flourished. The Macaulay Library currently has 527 sound clips sampled from 143 species of fish representing 93 genera and 45 families. Because 96% of the fish recordings are from the Western Atlantic and Caribbean, the Library is currently seeking funds to build a complementary collection of sounds of eastern Pacific species. Wherever possible, we have prioritized archival to provide examples of different classes of vocal behavior within a taxon. Online usage of the marine sound collection has increased dramatically from about 500 playbacks/month in early 2006 to over 3500 playbacks/ month currently. The upsurge in usage was concurrent both with implementation of the online/spectrogram player and concentrated efforts by Macaulay Library staff to promote the collection at national and international meetings.

IMPACT/APPLICATIONS

The new search/retrieval, playback, and visualization tools have greatly facilitated access to the marine collection. Urgent demands by television and radio programs for exemplars of a particular species' sounds can now be filled quickly and remotely. Public institutions such as zoos and museums can select online those sounds that they deem are appropriate for new exhibits. Similarly, the Macaulay Library has long been a source for reference sounds used in bioacoustic censusing by wildlife management programs worldwide. The new search and preview tools greatly simply the task of finding suitable recordings for these functions and allow these users to customize which materials they receive. The growing industry in popular usage of natural sounds frequently comes to the Macaulay Library for source materials. There is widespread interest in educational and conservation institutions for access to marine animal sounds. These are now available online and can be played for free in any venue.

In 2006, the Macaulay Library began a program (funded by the NSDL program within NSF) to use animal behavior as a springboard/entry point for teaching sciences other than biology. The first

application has been to help teach physics in the K-12 age groups. Marine sounds and marine animals are very appealing to school children, and by starting a physics course at this level with examples and discussions of marine animal vocal behavior, the students are more easily attracted to the topics. This approach has proved very successful in pilot programs that are being currently tested nationwide.

TRANSITIONS

Macaulay Library assets are widely used by commercial entities, museums, zoos, aquaria, science centers, education, and the media. While the original goal of the visualization, playback, and search/retrieval tools was to facilitate research, we are now finding that they have also increased access and usage of the archive by these many other users. A number of commercial products using Macaulay Library assets have been extremely popular including plush toys, books and calendars that include tiny sound players, and a recent PDA bird field guide.

RELATED PROJECTS

This project has been complemented by a concurrent grant from the NOPP program (N00014-04-1-0663), two NSF awards as part of the National Science Digital Library program (NSF DUE -0332872 and DUE-0532786), and third NSF award funding the development of a general data model for animal behavior (NSF IBN-0337507).

HONORS/AWARDS/PRIZES

The Macaulay Library's online sound and video player received second place for "Interactive Media" in the 2006 NSF/AAAS "Science and Engineering Visualization Challenge" contest. Details on this prize can be found online at:

http://www.sciencemag.org/sciext/vis2006/show/slide13.dtl