Cover

Federal Agency and Organization Element to Which Report is Submitted:

National Science Foundation

Federal Grant or Other Identifying Number Assigned by Agency:

OCE-1138046

Project Title:

Expansion of metadata management, visualization and data processing functionality of OBIS-SEAMAP for passive acoustic monitoring data

PD/PI Name:

Dr. Patrick N. Halpin

Recipient Organization:

Duke University, Nicholas School of the Environment

Project/Grant Period:

2 years (July 2011 – June 2013)

Reporting Period:

July 2011 – June 2014

(2) Major Accomplishments:

What are the major goals of the project?

With increasing use of passive acoustic monitoring (PAM) data in marine monitoring programs, habitat modeling and marine spatial planning, this project focused on enhancing common standards and accessibility of PAM data. We did this through the development of novel tools for advanced spatio-temporal analyses and visualizations and the improvement of the interoperability of PAM data among institutions and data centers that host PAM data.

What was accomplished under these goals (you must provide information for at least one of the 4 categories below)?

1) Major activities

Our major activities in this project were summarized as follows:

1. Consultation with PAM researchers to improve the spatio-temporal analyses and visualizations of PAM data using the OBIS-SEAMAP information system and registration of their PAM detection records into the OBIS-SEAMAP database;
2. Development of a semi-automated data transfer mechanism from the Tethys Metadata Server to the OBIS-SEAMAP database;
3. Expansion of the OBIS-SEAMAP database to increase the interoperability of PAM data among institutions and data centers that host PAM data;
4. Development of mapping and visualization tools for PAM data on the OBIS-SEAMAP web site; and
5. Release of the improved OBIS-SEAMAP mapping and visualization tools.

The Tethys Metadata Server is a major product in a sister NOPP project "Acoustic Metadata Management and Transparent Access to Networked Oceanographic Data Sets" led by Dr. Marie Roch, San Diego State University. The project has established the Tethys metadata standards for PAM detections. We developed a productive collaboration with the researchers involved in the sister NOPP project, in particular, Dr. Marie Roch, San Diego State University and Dr. Sean Herbert, Scripps Institution of Oceanography, to incorporate PAM data archived in the Tethys Server into the OBIS-SEAMAP database.

The sister project has established metadata standards for PAM data and our data transfer mechanism adopts the standards. Thus, the transfer mechanism will be easily applied to additional subsets of the Tethys Server data at the San Diego State University as well as any other Tethys Server instances.

To register and disseminate other PAM data, we also developed a productive collaboration with researchers involved in the DECAF (Density Estimation for Cetaceans from passive Acoustic Fixed sensors) project including Dr. Len Thomas, Dr. Dave Morretti, Dr. Steve Martin, Dr. Jessica Ward, and Dr. Elizabeth Kusel. Dr. Melissa Soldevilla at NOAA Southeast Fisheries Science Center made a significant contribution as liaison to DECAF researchers. These activities include organizing DECAF data for incorporation in OBIS-SEAMAP as well as overseeing the improvement of mapping and visualization tools for the OBIS-SEAMAP web site. Other

researchers who contributed PAM data to OBIS-SEAMAP include Dr. Sophie Van Parijs, from the Northeast Fisheries Science Center, Dr. Kate Stafford, University of Washington and researchers at HDR Environmental, Operations and Construction, Inc. who conducted Navy-funded marine mammal surveys.

2) Specific objectives

As continued efforts from the previous OBIS-SEAMAP project (Award Number: OCE-07-39199) to integrate passive acoustic monitoring (PAM) data into the OBIS-SEAMAP system, this project was aimed at encouraging the PAM researchers to share their data through a publicly available data center and facilitating the use of the PAM data for assessments of species abundance and density as well as conservation-oriented research projects.

3) Significant results, including major findings, developments, or conclusions (both positive and negative)

Through the consultation with PAM researchers, we have developed advanced mapping and visualization tools on the OBIS-SEAMAP web site for better spatio-temporal analyses of PAM detection records. The highlights of the advancements include:

- Fixed sensor locations are mapped with indication of effort presence circling around the location;
- Spectrogram images and recorded sounds associated with the detection records can be visualized or linked to the external Internet services;
- Individual sensors are selectable for further investigation online;
- Interactive time-series graphs visualize click counts and detections per species with effort hours;
- Diel plots are available to depict the tendency of animal's daily behavior;
- 3D mapping capability using Google Earth is introduced to effectively visualize the dive profile of animals tagged with DTags.

Moreover, we made significant efforts to integrate PAM data with other data types such as traditional visual line-transect sightings and locations of tagged animals in a consistent, scientifically sound way of querying and visualizing various data types together. As a result, the OBIS-SEAMAP web site allows users to:

- set spatio-temporal criteria to extract and map PAM detection records along with other data types;
- distinguish PAM data from other types of data with different symbology on the map; and
- assess temporal graphs (e.g. the number of records over years or in seasons) with different data types stacked;
- assess more complete time series graphs with no gaps scattered around in the time series which lowers the possibility of a misrepresentation of species occurrence over time;
- search datasets based on any words using a full-text search against the metadata elements in the database.

The development of the data transfer mechanism between the Tethys Server and OBIS-SEAMAP has achieved increased interoperability of PAM data among institutions and data centers that host PAM data and the reliability and efficiency of the data transfer. The OBIS-SEAMAP database is extended to better archive PAM data and metadata that follow the Tethys metadata standards. The extended database is able to hold important attributes that are unique to PAM data such as call type, granularity, detection type (e.g. individual calls, binned detections or encounters) and description of algorithm used to detect the vocal activities. These attributes are essential to help researchers understand the PAM data and develop appropriate analytical methods. We successfully transferred 125 datasets containing more than 16,000 PAM detection records from the Tethys Server hosted at the San Diego State University with help of Dr. Marie Roch, San Diego State University and Dr. Sean Herbert, Scripps Institution of Oceanography. Thanks to the increased interoperability, the transfer mechanism will be easily applied to additional subsets of the Tethys Server data at the San Diego State University as well as other PAM data archived in any Tethys Server instances.

The major upgrades of the OBIS-SEAMAP web site including the incorporation of PAM data were released to the public in November 2013. These upgrades provide more comprehensive integration of multiple data types, more intensive exploration of PAM data and better reliability of PAM data in the OBIS-SEAMAP database.

Our efforts in this project have greatly increased attention in the field to share PAM data with researchers around the world and have helped make OBIS-SEAMAP one of the most productive venues for aggregating, disseminating and archiving PAM data. Since we adopted the Tethys metadata schema, OBIS-SEAMAP provides greater interoperability for the exchange of PAM data among research programs.

4) Key outcomes or other achievements. Include a discussion of stated goals not met.

In total, 138 datasets with 202,500 detection records have been registered in the OBIS-SEAMAP database covering the following 22 species:

- Balaena mysticetus (Bowhead)
- Balaenoptera acutorostrata (Minke Whale)
- Balaenoptera brydei (Bryde's whale)
- Berardius bairdii (Baird's Beaked Whale)
- Delphinapterus leucas (Beluga)
- Erignathus barbatus (Bearded Seal)
- Eschrichtius robustus (Gray Whale)
- Eubalaena glacialis (North Atlantic Right Whale)
- Grampus griseus (Risso's Dolphin)
- Hyperoodon ampullatus (North Atlantic bottle-nosed whale)
- Lagenorhynchus obliquidens (Pacific White-sided Dolphin)
- Megaptera novaeangliae (Humpback Whale)
- Mesoplodon densirostris (Blainville's Beaked Whale)
- Mesoplodon stejnegeri (Bering Sea beaked whale)
- Odobenus rosmarus (Walrus)

- Orcinus orca (Killer Whale)
- Phocoena phocoena (Harbor Porpoise)
- Physeter macrocephalus (Sperm Whale)
- Stenella coeruleoalba (Striped Dolphin)
- Stenella frontalis (Atlantic Spotted Dolphin)
- Tursiops truncates (Bottlenose Dolphin)
- Ziphius cavirostris (Cuvier's Beaked Whale)

Our development efforts and findings in the project have led to four peer-reviewed publications; three are published and one is in preparation for submission.

We see a need for the continuation of these efforts into the future. Without funded programs to assist research efforts to aggregate and archive these complex data types, sustained participation by individual researchers will be difficult. New efforts should be coordinated with emerging research development by the marine acoustic community in order to anticipate new trends in PAM research and development. For example, detection locations will need to be either localized or visualized with an estimated range of detections to increase the accuracy or avoid the misrepresentation of the data. The localization of detection data are still at an early stage of research and development. Methods for calculating species abundance are different between visual sighting data and PAM data and effort merging these methods for more robust estimations of species abundance is an important subject of current research. Finally, we initially planned to make direct links from detection records in the OBIS-SEAMAP database to external data sources or databases archiving recorded sounds and other resources. However, since the Tethys Server at the San Diego State University is not open to the public, we import and store these data directly at our facilities. We regard the need to develop direct links between public data archives as a need for future improvement and development.

What opportunities for training and professional development has the project provided?

Nothing to Report

How have the results been disseminated to communities of interest?

Three publications describing our efforts and scientific findings have been published in the scientific peer-reviewed literature. A fourth paper is in preparation. Two presentations were made in an international conference and a working group for the CetMap project. The integrated database and improved mapping and visualization tools are available to the public through the OBIS-SEAMAP web site.

What do you plan to do during the next reporting period to accomplish the goals?

Nothing to Report (this is the final reporting period).

(3) Products

Publications

- Fujioka, E., Halpin, P.N., 2014. Spatio-temporal Assessments of Biodiversity in the Open Ocean: an Introduction to Novel Online Tools in OBIS-SEAMAP, a global biogeographic database. Endangered Species Research, Vol. 24: 181-190.
- Fujioka, E, Soldevilla, M.S., Read, A.J., and Halpin, P.N., 2014. Integration of Passive Acoustic Monitoring Data into OBIS-SEAMAP, a Global Biogeographic Database, to Advance Spatially-explicit Ecological Assessments. Ecological Informatics, Vol. 21: 59-73.
- Fujioka, E., Kot, C.Y., Wallace, B.P., Best, B.D., Moxley, J., Cleary, J., Donnelly, B., Halpin, P.N., 2014. Data Integration for Conservation: Leveraging Multiple Data Types to Advance Ecological Assessments and Habitat Modeling for Marine Megavertebrates using OBIS-SEAMAP. Ecological Informatics, Vol. 20: 13-26.
- Roch, M.A., Baumann-Pickering, S., Batchelor, H., Berchok, C.L., Fujioka, E, et al. In preparation. Acoustic metadata management for bioacoustics.

Presentations

- Fujioka, E, P. N. Halpin, A. J. Read, M. Soldevilla, K. Urian, C. Y. Kot, A. DiMatteo, B. D. Best, J. A. Cleary and B. Donnelly. 2011. Archiving and disseminating non-traditional marine mammal data for growing data needs in marine mammal conservation. Poster presentation, 19th Biennial Conference on the Biology of Marine Mammals, Tampa, Florida, USA. November 27 – December 2, 2011.
- Halpin, P.N., J.A. Cleary, C. Curtice, E. LaBrecque, CetMap Working Group. 2012. Cetacean Density and Distribution Mapping Working Group: Products & Details. Mapping Cetaceans And Sound: Modern Tools For Ocean Management, Washington DC, May 23-24, 2012.

Technologies or techniques

As proposed in our original application, this project developed: (1) initial data schemas for the exchange and storage of PAM data; (2) initial metadata standards for the documentation of PAM data; (3) visualization methods for the viewing of different types of PAM data.

Inventions, patent applications, and/or licenses

Nothing to report

Websites

OBIS-SEAMAP, http://seamap.env.duke.edu

Other products, such as data or databases, physical collections, audio or video products, software or NetWare, models, educational aids or curricula, instruments, or equipment

Registration of 202,500 detection records from 138 datasets into the OBIS-SEAMAP database including the followings:

Datasets from the Density Estimation of Cetaceans from Passive Acoustic Fixed Sensors (DECAF) project:

- PMFR Minke Whales - Multiple Sensor - Boing Associations (Steve Martin, Space and Naval Warfare Systems Center; http://seamap.env.duke.edu/dataset/664)
- PMFR Minke Whales - Multiple Sensor - Manual Boing Detections (Steve Martin, Space and Naval Warfare Systems Center; http://seamap.env.duke.edu/dataset/666)
- PMFR Minke Whales - Multiple Sensor - Automated Boing Detections (Steve Martin, Space and Naval Warfare Systems Center; http://seamap.env.duke.edu/dataset/668)
- PMFR Minke Whales - Multiple Sensor - Boing Localizations (Steve Martin, Space and Naval Warfare Systems Center; http://seamap.env.duke.edu/dataset/675)
- AUTEC Beaked whales - Multiple Sensors - Click counts (Jessica Ward, Naval Undersea Warfare Center; http://seamap.env.duke.edu/dataset/677)
- AUTEC Sperm Whales - Multiple Sensors – Samples (Jessica Ward, Naval Undersea Warfare Center; http://seamap.env.duke.edu/dataset/680)
- AUTEC Sperm Whales - Multiple Sensors - Complete Dataset Samples (Jessica Ward, Naval Undersea Warfare Center; http://seamap.env.duke.edu/dataset/682)
- AUTEC Beaked Whales - Multiple Sensors - DTag Samples (Jessica Ward, Naval Undersea Warfare Center; http://seamap.env.duke.edu/dataset/685)
- AUTEC Beaked Whales - Single Sensor case study (Elizabeth Kusel, Oregon State University; http://seamap.env.duke.edu/dataset/720)
- AUTEC Beaked Whales - Multiple Sensors - DTag Seafloor array presence Samples (Jessica Ward, Naval Undersea Warfare Center; http://seamap.env.duke.edu/dataset/722)

Datasets from individual researchers:

- North Atlantic right whale up-calls in Stellwagen Bank National Marine Sanctuary 2006-2007 by Sofie Van Parijs, NOAA Northeast Fisheries Science Center (http://seamap.env.duke.edu/dataset/892)
- Acoustic detections of Arctic mammals in the western Beaufort Sea 2010-2011 by By Kate Stafford, University of Washington (http://seamap.env.duke.edu/dataset/914)
- Acoustic Detections for Airborne Mine Neutralization System Passive Acoustic Monitoring in the NSWC PCD Study Area from December 2011 by Jennifer Latusek-Nabholz, HDR Environmental, Operations and Construction, Inc. (funded by the Navy; http://seamap.env.duke.edu/dataset/950).

Datasets from the Tethys Server at San Diego State University:

- SOCAL Deployment 31 at Site H (http://seamap.env.duke.edu/dataset/200000001)
- SOCAL Deployment 31 at Site M (http://seamap.env.duke.edu/dataset/200000002)
- SOCAL Deployment 31 at Site M (http://seamap.env.duke.edu/dataset/200000003)

- SOCAL Deployment 31 at Site M (http://seamap.env.duke.edu/dataset/200000004)
- SOCAL Deployment 31 at Site N (http://seamap.env.duke.edu/dataset/200000005)
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Some datasets may not be publicly available at the time of the release of this final report being under review by data owners or pending with data updates.

(4) Participants

What individuals have worked on the project?

Name, Most Senior Project Role, Nearest Person Month Worked, Action

Patrick N. Halpin, PI, 3 month, Project management
Ei Fujioka, Research Scientist, 12 months, lead scientist
Ben Donnelly, System administrator, 3 month, systems development
Jesse Cleary, GIS specialist, 3 month, geospatial analysis

What other organizations have been involved as partners?

Melissa Soldevilla, NOAA Southeast Fisheries Science Center
Marie Roch, San Diego State University
Sean Herbert, Scripps Institution of Oceanography, University of California
Sofie Van Parijs, NOAA Northeast Fisheries Science Center
Kate Stafford, University of Washington
Jennifer Latusek-Nabholz, HDR Environmental, Operations and Construction, Inc.
Researchers involved in the Density Estimation for Cetaceans from passive Acoustic Fixed sensors (DECAF) project

(5) Impact

What is the impact of the project? How has it contributed?

What is the impact on the development of the principal discipline(s) of the project?

The successful development of an operational data center for passive acoustic monitoring data now encourages PAM data collectors to submit their data for aggregation, dissemination and archiving which in turn facilitates broader, more integrated analyses for marine species habitat modeling, species density estimates, human impacts on marine species and conservation assessments. The outcomes of our project broaden the active use of PAM data in a wider range of research and management activities. In particular, the development of the data transfer mechanism between the Tethys Server and the OBIS-SEAMAP database has increased interest in sharing PAM data through OBIS-SEAMAP among PAM researchers. For example, we have recently received several requests to share PAM data from researchers at universities around the world. In addition, collaborators Roch and Herbert plan to continue contributing additional sets of PAM data once the original data providers agree to share the most recent data.

Our activities were also directly contributing to the NOAA Cetacean Density and Distribution Mapping Working Group (CetMap) project. PAM data were key inputs to create a Cetacean Data Availability tool developed by the working group. Several new sources of PAM data in data-poor regions and seasons were identified within the working group and will be added to the OBIS-SEAMAP database. The results from the CetMap working group, and a parallel working group on underwater sound modeling, were presented in a 2 day symposium in Washington, DC attended by several hundred representatives from interested regulatory agencies, the cetacean and sound scientific communities, and ocean user groups. A key recommendation of the symposium group was better warehousing and access to PAM data through a data center such as the one we developed in this project.

Since the OBIS-SEAMAP team is also a leading developer for the international OBIS portal and OBIS-USA projects, our skills and knowledge acquired during this project have made significant contribution to the development of the biogeographic databases and online mapping applications for these projects. The OBIS-USA team is involved in extending the Darwin Core biological data standards to integrate visual sightings from line transect surveys and PAM detections. We are in ongoing discussions with the OBIS-USA team on methods to improve the extension of the Darwin Core data schema to incorporate PAM data into the OBIS-USA database.

What is the impact on other disciplines?

While this project focused on passive acoustic monitoring research on marine mammals, the enhanced mapping and visualization tools on the OBIS-SEAMAP web site are useful for communities and researchers using other data collections methods such as traditional visual line-transect surveys or satellite telemetry, or on other taxa including seabirds and sea turtles. For example, the integrated tools are applied to an online mapping application for the State of the World's Sea Turtles (SWOT). Similarly, an online decision support system previously developed

as a stand-alone system for the SERDP cetacean habitat modeling project supplemented by funding by NASA and NOAA is integrated into the main OBIS-SEAMAP web site and can combine habitat suitability estimates with species occurrence data in the OBIS-SEAMAP database.

A growing number of government agencies have expressed their interests to collaborate with the OBIS-SEAMAP team, especially, to include OBIS-SEAMAP data into their own applications. The NOAA Multipurpose Marine Cadastre (MMC; http://www.marinecadastre.gov/), for example, already incorporates predictive habitat modeling data produced for the Strategic Environmental Research and Development (SERDP) Program and hosted on the OBIS-SEAMAP web site. We will continue expanding this relationship with MMC to exchange a wider variety of data. We have also discussed the data transfer mechanism with the Navy who is planning to consume the OBIS-SEAMAP data into their internal system, Environmental Information Management System (EIMS).

What is the impact on the development of human resources?

Nothing to report

What is the impact on physical resources that form infrastructure?

Server hardware and digital storage media purchased in the development of this project will continue to support public dissemination of PAM data for the lifetime of the hardware.

What is the impact on institutional resources that form infrastructure?

Nothing to report

What is the impact on technology transfer?

We developed novel tools to explore and exchange PAM data in the context of a biogeographic information system. The general public, researchers or other institutions can access the data through the OBIS-SEAMAP web site and utilize these data for their projects, research or educational purposes.

What is the impact on society beyond science and technology?

Nothing to report

(6) Changes / Problems

Changes in approach and reasons for change

Nothing to report

Actual or Anticipated problems or delays and actions or plans to resolve them

Nothing to report

Changes that have significant impact on expenditures

Nothing to report

Significant changes in use or care of human subjects

Nothing to report

Significant changes in use or care of vertebrate animals

Nothing to report

Significant changes in use or care of biohazards

Nothing to report