# Analysis of High Spatial, Temporal, and Directional Resolution Recordings of Biological Sounds in the Southern California Bight

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## LONG-TERM GOALS & PROJECT OBJECTIVES

The long-term goals of this research effort were to detect, localize, and characterize the underwater biological sounds in the Southern California Bight for the benefit of Navy environmental compliance. The particular focus in this program was on the biological sounds at low to mid frequencies recorded during a large Navy experiment off the southern California coast in 1999. The data analysis efforts helped support the thesis research by two graduate students at the Scripps Institution of Oceanography (SIO), studying a) the potential impact of man-made sound on the calling behavior of baleen whales in the Southern California Bight, and b) the development of "smart" data acquisition systems for oceanographic research. In addition, two undergraduate students in the University of California, San Diego (UCSD) Environmental Engineering department participated in the project. One aspect of the data analysis conducted to date was an in-depth investigation of an unusual biological chorus off the Southern California coast, and the application of the physics of excitable media to numerical modeling of this and other biological choruses. The analysis results helped characterize the low frequency underwater sonic environment in an area of operational (training) interest to the Navy.

## APPROACH

In 1999, a large experiment was conducted off the Southern California coast. This experiment involved the deployment of 16 horizontal hydrophone line arrays on the ocean bottom. The outputs from these arrays were fiber-optic cabled to shore and recorded continuously for a period of a few months. The complete data set is archived at the Applied Research Labs, University of Texas at Austin (ARL/UT). While ARL/UT was in the process of transcribing their data archive onto newer recording media, they also provided us with a copy of the unclassified portion of this data set.

The approach used in this program was to convert the array data into a binary format that permitted the use of Matlab and custom software at the Marine Physical Laboratory, Scripps Institution of Oceanography (MPL/SIO) for signal/array processing. Spectrograms and wav-format files were created from the data from a single element of selected sub-arrays to allow rapid visual and auditory scanning with the MPL/SIO software. Time periods containing biological sounds were identified for more in-depth processing. The complete 1999 data set is too large to be thoroughly examined in a

project of this size, so the analyses were focused on selected arrays and selected periods of time, depending upon the biological phenomenon under study.

The work in this project was leveraged with other ongoing programs, listed in Related Projects below.

## WORK COMPLETED

Almost all of the data from the 2-mo. data recording period from the three nearest-to-shore arrays (no. 13, 14, and 44), and most of the data from the three arrays 15 km further offshore (nos. 12, 11, and 43) were quality-checked, converted into the in-house binary format files and into wav files, and spectrograms were created. In addition, samples of data from the 7 deeper-water arrays (nos. 21-22, 24, and 31-34) were converted and examined. (No data were provided by ARL/UT for the three remaining arrays 23, 41, and 42 because their data contained signatures from Navy platforms). Much more work remains to be done with the data from these farther offshore arrays. However, a variety of biological sounds, including baleen whale calls, primarily blue and fin whales, and fish sounds, were identified in the data converted to date.

A significant effort in the project was devoted to studying the spatial, temporal, and spatiotemporal properties of an unusual near-shore fish chorus that occurs only at night. Some of the results from the analysis were published in the conference proceedings for the spring, 2013 Acoustical Society of America meeting (D'Spain et al., 2013). A numerical model, based on the physics of excitable media, was further developed to predict the temporal and spatiotemporal patterns of this chorus. With changes in the input parameters, the model can predict the temporal characteristics of a wide variety of biological choruses. The two undergraduate environmental engineering students who participated in the project spent their efforts on the data processing and numerical modeling to support this investigation. A peer-reviewed publication with these, and subsequent results, is in preparation. The proposed work on relating the best-fit model parameters to properties of the environment and to the fishes themselves was only started – additional research still must be conducted.

One graduate student who worked with these data was investigating the overall topic of the potential impact of man-made sounds on the calling behavior of baleen in the Southern California Bight. As part of this research, the "GPL" detector based on a power-law processor was developed (Helble et al., 2012). A power-law processor, not an energy detector, is the optimal detector for transient signals when no *a prioi* knowledge of the arriving signal exists. This algorithm was used to scan the 1999 data set for biologically-created transient signals. Unfortunately, no humpback whale calls were found in the data set. However, a large number of finback and blue whales calls were detected.

A second graduate student who used the data set started in the Applied Ocean Science curricular group at SIO this past year. She initially was interested in the underwater sounds created by fish and invertebrates, with the goal of integrating passive ocean acoustic measurements with standard methods to improve habitat assessments and ecosystem monitoring. However, her interests became more engineering focused and she turned to the general area of "smart" (i.e., real-time adaptive) data acquisition systems for oceanographic research. Some initial work was completed in developing a smart, autonomous fish species identification (ID) system, using the 1999 data set to help tune the detection/classification algorithm. A fish ID system is an important first step in the use of passive underwater acoustic monitoring for habitat assessment because so few underwater biological sounds recorded off the west coast of the U.S. have been associated with specific fish and invertebrate species

(e.g., the species of fish creating the chorus discussed in D'Spain et al., 2013 has not yet been identified). Much of this student's time was spent taking the required set of first-year classes and studying for the Departmental exam, so much of the work in this fish ID system development effort remains to be done.

Ancillary and oceanographic data for the temporal and spatial attributes of the data set were gathered in the program and placed into a Geographic Information System (GIS) for use in habitat modeling and spatial analysis. The data are in a format compatible with Matlab, with ESRI ArcGIS, and with other data analysis software packages. The types of data assimilated include: bathymetry (from several sources), offshore landforms, marine protected area boundaries, species distribution for several of the fishes, temperature and salinity, and numerous types of satellite-based data, as well as locations of the arrays and HARP data recording packages.

## RESULTS

Some detailed results from this program have been listed in the program annual reports, and so will not be repeated here. The low frequency fish chorus with cycling amplitude, observed in data from the mid 1990s, also is ubiquitous in the recordings at night from the nearest-to-shore arrays in the 1999 data set, particularly arrays 14 and 13 located on the very shallow-water shelf just offshore Camp Pendleton. Some results from the analysis of this fish chorus in the 1999 data set are contained in the paper, D'Spain et al., 2013, accompanying this final report. All significant results from these data analyses and the matching numerical modeling results are being prepared for publication (D'Spain et al., 2014a; 2014b).

## IMPACT/APPLICATIONS

The scientific studies enabled by the large 1999 underwater acoustic array data set contribute to a greater understanding of the bioacoustics characteristics and overall ecosystem properties of the Southern California Bight, a region containing a high density of marine mammals, essential fish habitat, and a high level of U.S. Navy activity. The studies dealing with the potential impact of Navy activities, and human activities as a whole, on marine mammal and endangered species populations in the region is particularly relevant. A natural outgrowth of these studies was a characterization of the low frequency underwater sonic environment in and near the SOCAL and Camp Pendleton Navy Range Complexes off the Southern California coast. By supporting the research efforts of graduate students in the field of marine bioacoustics and ocean acoustics, and undergraduates in environmental engineering, this project has helped provide the Navy with the future generation of highly trained ocean acousticians, bioacousticians, and environmental engineers aware of both Navy needs and environmental issues.

## RELATED PROJECTS

The efforts in this project have been heavily leveraged with other programs. Foremost, the 1999 program that provided the high quality, high spatial, temporal, and directional resolution data set enabled this research effort to be undertaken. The data archival efforts by ARL/UT provided the opportunity to obtain a second copy of the data tapes. Both the Department of Defense SMART fellowship and other fellowship programs at SIO covered the graduate student costs. Participation, on a voluntary basis, by senior-class undergraduate students from the UCSD Environmental Engineering department was arranged by the UCSD Vice Chancellor of Academic Research. Algorithms from the

Glider-Based Passive Acoustic Monitoring Techniques in the Southern California Region, Code 322-MBB, were used to automatically scan the data for humpback whale and other biological sounds. Finally, the analyses also have used data from the CalCOFI program at the Scripps Institution of Oceanography, and from the environmental monitoring efforts at the San Onofre Nuclear Generating Station.

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