The Influence of Oceanographic and Biological Processes on the Distribution of Cetaceans on the West Florida Shelf: A Synoptic Study Based on Underwater and Space-Based Remote Sensing

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LONG-TERM GOALS

Studies employing visual surveys for cetaceans typically suffer from high levels of spatial and temporal aliasing due to limitations in the survey effort. To overcome some of these limitations we will use autonomous acoustic data recorders to monitor cetaceans over large spatial and temporal scales in addition to visual surveys conducted during and within the deployment area. With *in situ* and satellite remote sensing oceanographic data, relationships between the distribution of cetaceans and sea surface temperature, chlorophyll levels and background noise levels will be investigated on appropriate temporal and spatial scales. Results from existing numerical circulation models of the Gulf of Mexico will help us to understand underlying oceanographic processes.

OBJECTIVES

1. Determine the spatial and temporal distribution of cetaceans and noise on the central West Florida Shelf (WFS) through autonomous passive acoustic monitoring
2. Determine source levels of common cetacean species on West Florida Shelf and model sound propagation
3. Detect and quantify biological and physical oceanographic features present on the central WFS with satellite imagery, *in situ* measurements, and modeling
4. Develop a library of sounds produced by common cetaceans from the Gulf of Mexico
5. Characterize the relationships between cetacean distribution, oceanographic variables and ambient noise levels

APPROACH AND WORK PLAN

Key individuals and their roles:
Dr. David Mann is PI overseeing the project and is responsible for acoustic recorder development.
Peter Simard and Carrie Wall are Ph.D. students with Dr. Mann responsible for managing field deployments and analysis of acoustic, physical and satellite data.
Dr. Adam Frankel of Marine Acoustics, Inc. is responsible for towed array recordings to determine dolphin whistle source levels and modeling acoustic propagation.
Dr. Robert Weisberg is responsible for the COMPS buoy system and 3-D physical oceanographic modeling data for the sound propagation model analyses of dolphin distribution to physical events.
Dr. Frank Muller-Karger is responsible for satellite oceanography operations with Dr. Chuanmin Hu.

In the upcoming year we will:

1. Begin recorder retrieval, and deploy a near-shore array for one year.
2. Continue deployment of the BSOP's and gliders with onboard DSG recorders to add to the acoustic and physical oceanographic data from the full array.
3. Complete analysis of the acoustic data from the initial three month deployment, and analyze data from the large array as it is collected.
4. Analyze cetacean distribution data with satellite oceanography data.
5. Release DSGlab for automated analyses of passive acoustic recordings.

WORK COMPLETED

This project began in August 2007. The main achievements in the first year were the development and successful deployment of the DSG recorder, measurements of cetacean whistles with a towed hydrophone array, analysis of dolphin echolocation in relation to water depth, analysis of archived satellite data for probability of oceanographic front presence, incorporation of the DSG recorder into the Bottom-Stationed Ocean Profiler (BSOP), and development of a data analysis suite based in MATLAB (DSGLab). In the second year we redesigned the DSG housing, incorporated the DSG recorder into several autonomous underwater vehicles, namely Slocum gliders (gliders), and deployed 92 DSG recorders on the West Florida Shelf. We began development of an open-source MATLAB-based signal processing platform named OOMA for database storage, rapid signal processing development, testing, and implementation of automatic detection algorithms. Finally, we conducted additional towed array measurements for source level estimation of dolphins on the West Florida Shelf.

SUMMARY OF MAJOR DEVELOPMENTS AND FINDINGS

- Towed array recordings showed that the mean whistle source levels for bottlenose dolphins were approximately 151 dB re 1 μPa compared to 147 dB re 1 μPa for Atlantic spotted dolphins (Figure 1). The whistle detection range based on these source level estimates and acoustic propagation modeling is about 2-3 km, depending on background noise levels.

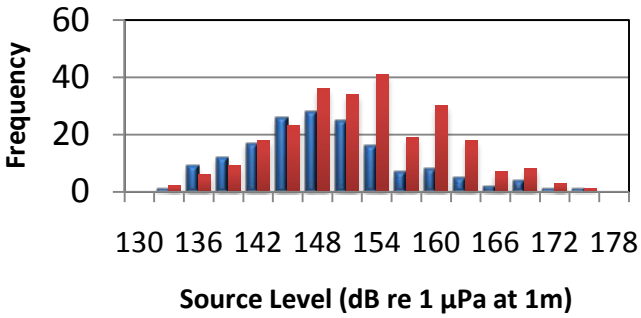

Figure 1. Histogram of source level estimates for spotted (blue) and bottlenose dolphins (red) from the towed array recordings. Source levels reach 174 dB re 1µPa.

The DSG acoustic recorder was developed and successfully tested in preliminary deployments in June and July 2008. This recorder was also integrated into the BSOP and glider. Analysis of the (uncompressed) sound files from the June 2008 deployment and most of the July 2008 deployment is complete. Spatial and temporal patterns in dolphin vocalizations are being found (Figures 2, 3).

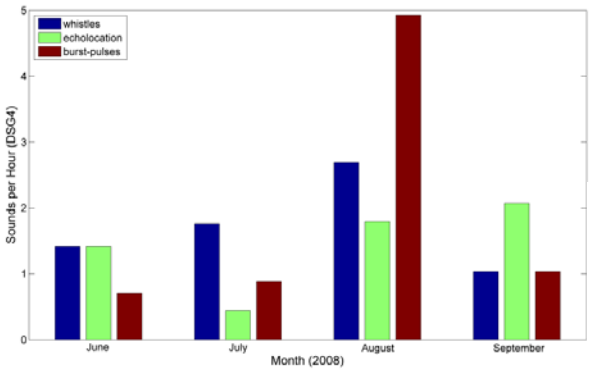

Figure 2. Dolphin sound production increased in August compared to June and July.

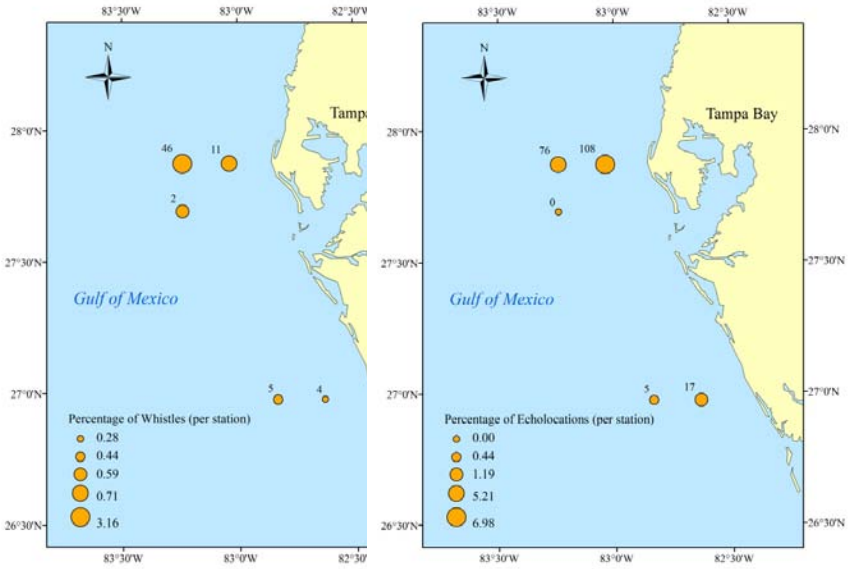

Figure 3. Percentage of echolocation (left) and whistles (right) detected for five recorders manually analyzed (July 2008 deployment). The values indicate the total number of sounds identified for that station. More sounds were detected at the northern stations compared to the southern stations

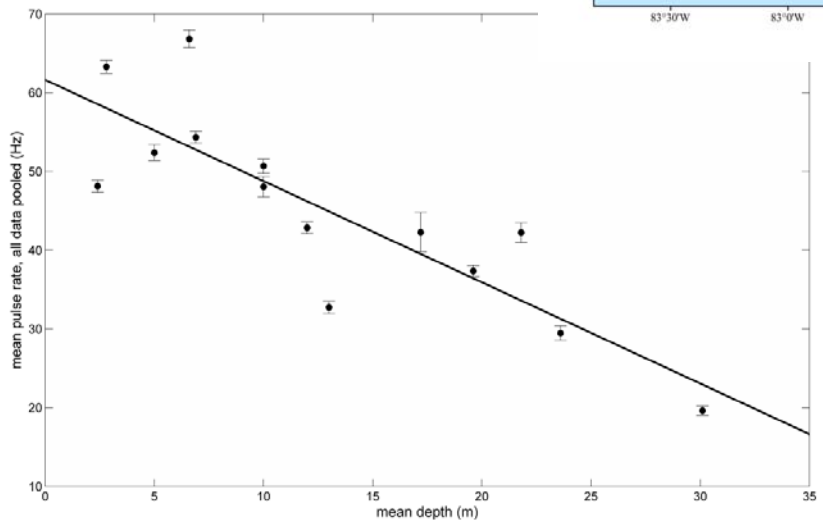

Figure 4. Analysis of offshore bottlenose dolphin versus inshore bottlenose dolphin echolocation click trains showed that on average dolphins living in shallower water tended to click at higher rates than dolphins living in deeper water.

- Several unidentified sounds, likely produced by fishes, have been detected in the Gulf of Mexico (Figure 5) and ambient noise levels are being quantified (Figure 6).

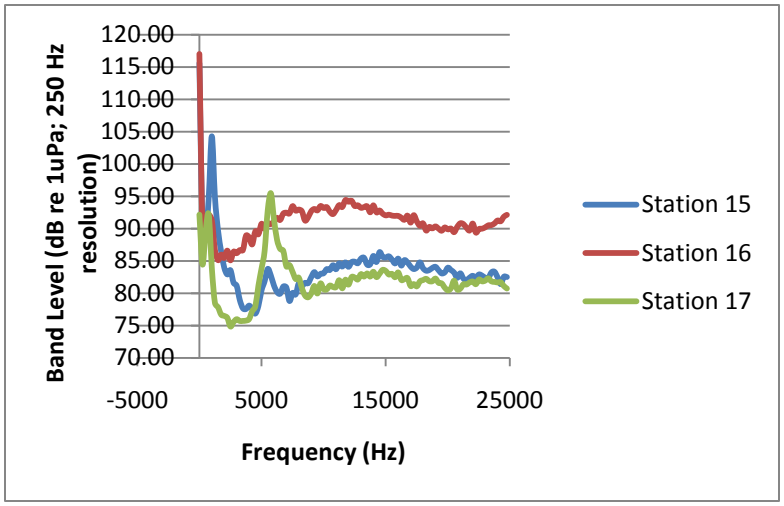

Figure 5. Band sound pressure levels (250 Hz resolution) at three stations (station 15 near shore, station 16 mid shore, and station 17 offshore; July 2008 deployment) for September 27, 2008 at 1900 hours. Peak near 6 kHz is from an unknown source.

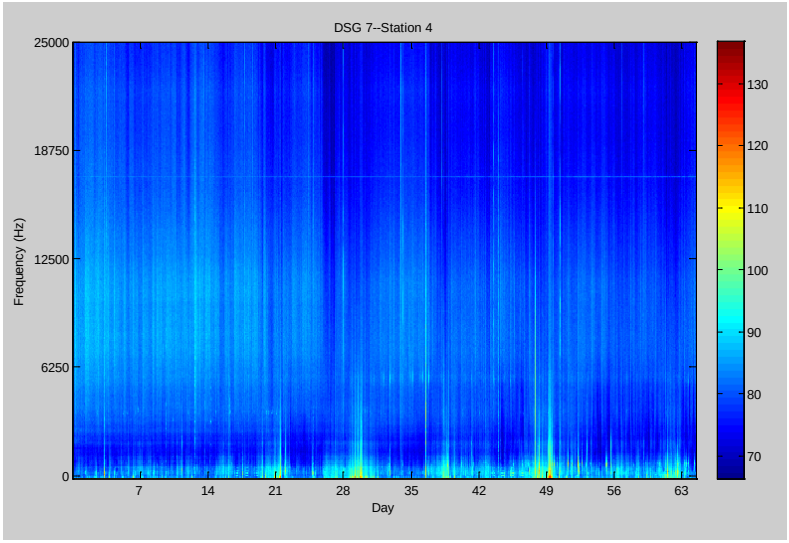

Figure 6. Composite spectrogram showing spectrum level sound over a two month period at Station 4 (July 2008 deployment). Sound pressures are band levels with 76 Hz frequency resolution.

Figure 7. 92 DSG recorders with hydrophones prior to deployment at 63 stations on the West Florida Shelf from the R/V Weatherbird II. The PVC mooring (maroon) had one or two DSG recorders mounted to the center post (right).

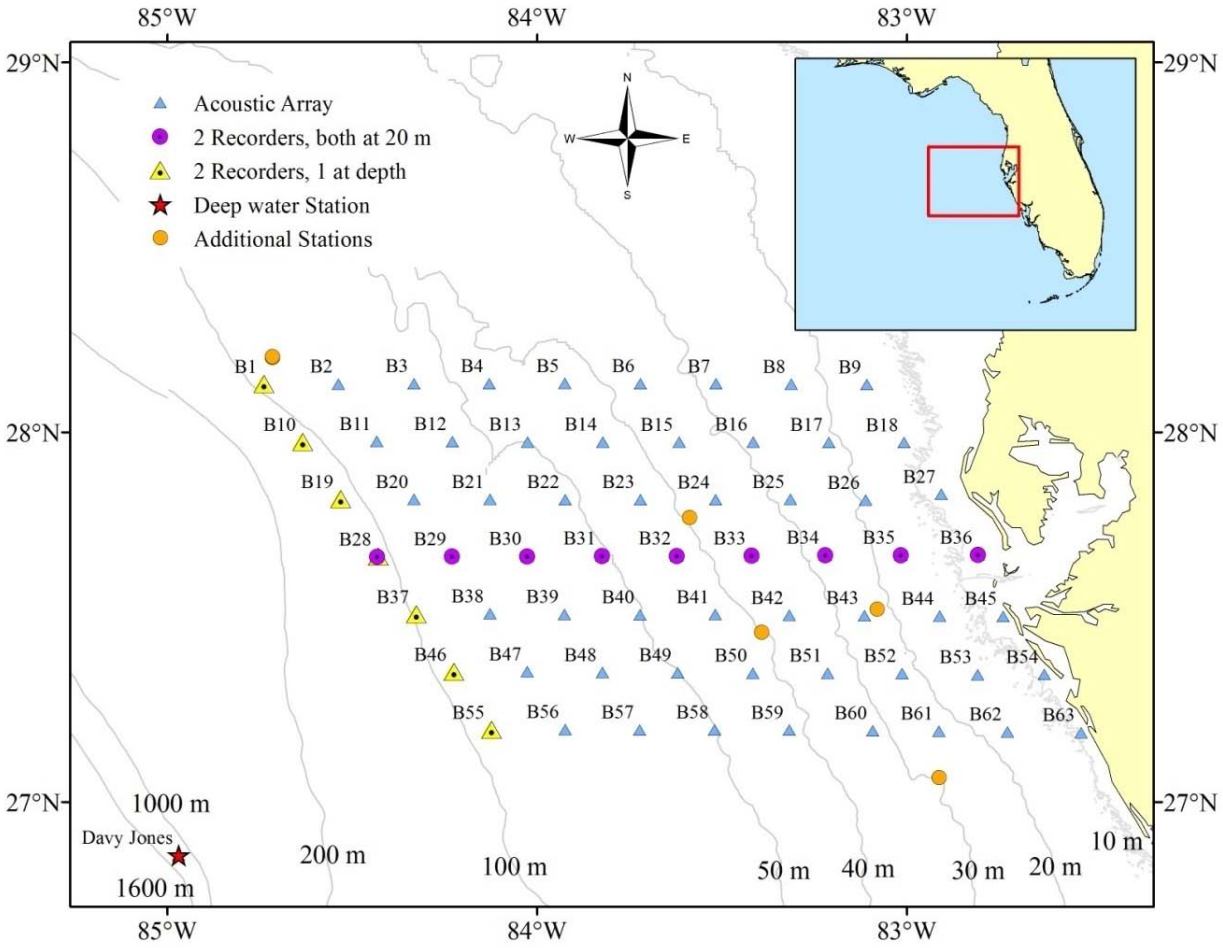

Figure 8. June 2009 acoustic recording array in the Gulf of Mexico.

OOMA—OCEAN OBSERVING METADATA ARCHIVE

We are developing an open-source MATLAB-based data management and analysis system to manage and process the data from this and other projects (Figure 9). The system is composed of three parts:

1. **MySQL database**: The backbone of the system is a set of MySQL databases to store the acoustic and any associated physical oceanographic data (e.g. temperature, salinity, Chl) from the temperature loggers, BSOP, and gliders. The key feature of the database is all data can be queried based on latitude, longitude, depth, date and time (as well as specific data values).

2. **SigChain**: SigChain is a signal processing system built in MATLAB that packages standard signal processing functions into clickable buttons. It is designed to process data in specific directories or data resulting from MySQL database queries. SigChain is extensible allowing custom signal processing routines to be added and shared by any user.

3. **DSGlab:** DSGlab is the main user interface to catalog data in the database and to explore data processed by SigChain.

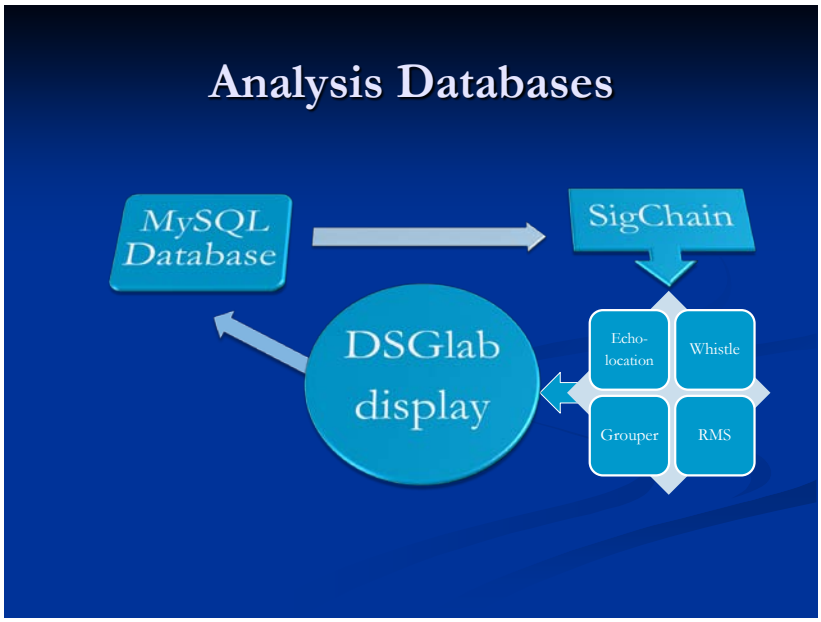

Figure 9. Conceptual overview of OOMA system.

IMPACT AND APPLICATIONS

National Security

The acoustic array deployed on the West Florida Shelf, and integrated into the autonomous underwater vehicles has the ability to record the movement of boats and could serve as the basis of a boat detection system.

Economic Development

The development and release of the open-source Matlab-based signal processing platform will allow other researchers to test and analyze large datasets rapidly and with increased efficiency.

Quality of Life

We expect this technology to become an integral part of coastal observing systems for monitoring marine ecosystems. Our results will allow us to determine patterns of cetacean distributions in relation to physical and biological oceanographic features. This will establish baseline data for understanding future potential impacts, such as the effect of seismic air-gun exposures on the behavior and distribution of whales and dolphins. This is important information for the oil and gas industry.

Science Education and Communication

This study will result in tools that integrate many disciplines, including physics and biology, for science education. Because the project involves distributions of dolphins and whales, it is of inherent interest to the general public and thus readily communicated.

TRANSITIONS

Economic Development

The DSG recorders have been made available to other researchers and are being used internationally in cetacean research projects including studies in the Bahamas and Denmark.

PUBLICATIONS

Simard, P., Hibbard, A.L., McCallister, K.A., Frankel, A.S., Zeddies, D.G., Sisson, G.M., Gowans, S., Forys, E.A., and **Mann, D.A.** in press. Depth dependent variation of echolocation pulse rate of the bottlenose dolphins (*Tursiops truncatus*) J. Acoust. Soc. Am.