

## **TREX13: Mid-Frequency Measurements and Modeling of Scattering by Fish**

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### **LONG-TERM GOALS**

To quantify properties of mid-frequency acoustic reverberation in terms of the physical and biological properties of the environment. The results will improve the ability to predict sonar performance.

### **OBJECTIVES**

This component of the TREX13 program concerns characterizing the contributions of acoustic scattering by fish to the reverberation. The clutter characteristics of the fish will also be quantified.

### **APPROACH**

The research is based, in part, on a large multi-PI experiment that took place in April/May, 2013 off of Panama City, Florida. The program is led by APL:UW (Tang/Heffner) and details of the experiment are in their report. A key element of the fish component was the measurements of mid-frequency reverberation from a fixed source and receiver. The measurements were made nearly continuously, 24 hours per day. Another key element to the fish effort is the UW-led (Horne) high frequency surveys of fish in the area. The WHOI-led (Stanton) effort focusses on analyzing and modeling the mid-frequency reverberation data in terms of the fish that were presumed present. Modeling will be in terms of the fish patchiness, sonar parameters, and physical (waveguide) environment. Contributions to the reverberation and clutter by the fish will be characterized. Stanton oversees this fish component of the research and participates in all phases of the research. Jones conducts data analysis and modeling of the fish echoes. The analysis includes characterizing the echoes in terms of their spectral content and statistics. The modeling includes taking into account waveguide effects and other

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environmental properties that affect propagation and scattering of a long-range sonar signal. These efforts will be leveraged by those of other PIs in the TREX13 program through participation in regularly scheduled workshops.

## WORK COMPLETED

This year focussed on beginning the analysis of data collected in the 2013 experiment. This was part of a processing chain beginning at APL:UW where the data were initially beamformed, put into analyzable form, and made available to the community. Portions of relevant data were made available to WHOI. The WHOI-led component completed the following tasks:

1. **Displaying and inspecting beam-level echo data from selected days.** The goal of this task was to separate echoes from fixed sources of scattering (such as the seafloor) from echoes from moving sources (such as fish). This began with receiving and inspecting selected data from APL:UW which had candidate fish echoes in it. These data were from along the reverberation track. We turned the echoes from the beam-level series of pings into movies and inspected the data qualitatively for fixed and moving echoes.
2. **Identifying fish echoes in data.** From task#1, fish echoes were identified in many sets of data and are illustrated in Fig. 1. These echoes were coherent from ping-to-ping and moved slowly across the reverberation track. That quality, in addition to being patchy and varying in patch shape and dimension from ping-to-ping, is consistent with echoes from patches of fish. This is in contrast to echoes from other sources that remained relatively constant from ping to ping. These fish-like echoes were observed only at night. There were generally no fish-like echoes during the day, which is consistent with the diurnal migration of fish.

Also, at these mid-frequencies, the echoes are most likely from fish with gas-filled swimbladders. As illustrated in last year's report, the fish observed throughout the experiments on the seafloor-mounted camera were identified as being ones with swimbladders: 1) Round scad ("cigar minnow") (*Decapterus punctatus*), 2) Tomtate (a type of "grunt" fish) (*Haemulon aurolineatum*), and 3) Atlantic spadefish ("angelfish") (*Chaetodipterus faber*). Each of these fish has a swimbladder. Images of these species are given in last year's report. These fish appeared to be in the size range 6-12" long. At any given time, there were many fish in the view of the camera (10's to 100's). The presence of clouds of fish around the equipment was observed by divers.

3. **Investigating existing models of scattering by bubbles (swimbladder-bearing fish) near boundary.** A question in this research has arisen regarding the degree to which the fish contribute to the scattering when they are near the seafloor. There is an abundance of literature on acoustic scattering of bubbles near a water/pressure-release interface (sea surface) and insight was obtained through a literature search. Since swimbladder-bearing fish behave as monopole scatterers at mid-frequencies, calculations involving spherical bubbles apply.

In a paper by Ye and Feuillade (J. Acoust. Soc. Am., vol. 102, pp. 798-805, 1997), it was shown that when the bubbles approach the sea surface (i.e., a pressure release surface), the resonance frequency increases while the scattering amplitude at resonance decreases. Conversely, for a hard surface, it is expected that the resonance frequency would decrease and scattering amplitude at resonance to increase when the bubble approaches the hard surface (Feuillade,

personal communication, 2014). In the context of the current problem (fish approaching the seafloor), the latter results would be more applicable. If the fish are resonating at depths away from the bottom, then it is possible that the resonance frequency would decrease as they approach the bottom and the scattering amplitude (now above resonance) would decrease. However, if the fish are below resonance at depths away from the bottom, then it is possible that, once near the bottom, they become resonant and the scattering amplitude increases.

## **RESULTS**

The TREX13 measurements illustrate the spatial and temporal variability of mid-frequency echoes due to the presence of fish. They also illustrate the importance of accounting for fish echoes, as these echoes dominated echoes from other sources (seafloor and sea surface) in spite of the fact that this was a shallow waveguide with many echoes from both boundaries. The fish echoes occurred only at night, varied from night to night (and not being significant some nights), and varied within a night. Very importantly, the fish were shown to migrate horizontally at night. This observation, in combination with the fact that the scattering by fish near a boundary can change significantly (increase or decrease, depending on their resonance frequency), may help to explain why there are negligible fish echoes during the day. That is, during the day, the fish may have either moved out of the region or moved to the seafloor.

Also, on a related note, the diurnal pattern of noise observed in the mid-frequency band is also presumed to be related to the presence of fish, as they are not only scatterers of sound, but they are also producers of sound. It is probably a different type of fish that scattered sound vs produced the sound.

What makes all of these results special is the controlled nature of the reverberation experiments and associated characterization of the environment. Because of the control, the environmental properties can be accounted for in the modeling of the acoustic propagation and scattering and the fish-echo data can be studied with greater accuracy (fewer unknowns) than in other previous studies.

We are now positioned to conduct a more in-depth analysis of modeling propagation effects, apply an energy normalizer to the data (such as the one used in Navy sonar signal processors), and calculate echo statistics (including probably of false alarms).

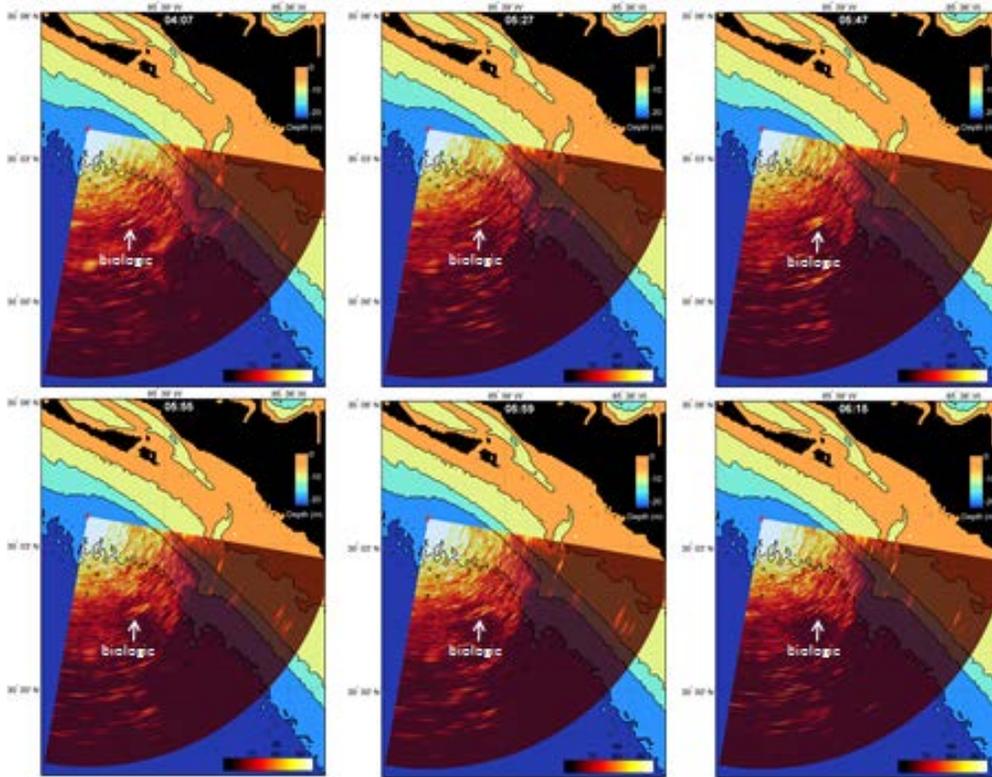
## **IMPACT/APPLICATIONS**

These results add to the growing body of evidence of the importance of fish in the performance of sonars—both active and passive sonars. The spatial and temporal variability of the fish will cause a correspondingly variable effect on the performance of sonars. Depending on the size and degree of heterogeneity of the fish distributions, the fish echoes will either be a source of “clutter” (i.e., target-like) or reverberation (i.e., background-like), each which affect the performance of ASW systems.

These data are consistent with the pattern of significant changes in reverberation and clutter as observed in Navy surface ship mid-frequency active systems.

## RELATED PROJECTS

This research builds on the methods that Stanton, Jones, and colleagues have developed in two other former ONR programs: 1) ONR MMB/NOPP project (N00014-1-10-0127) in which mid-frequency fish-echo data were collected in a complex propagation environment (Gulf of Maine) and 2) HiFAST FNC program in which fish echoes were simulated for used in Navy sonar trainers (SAST-NAVSEA and CASE-NAVAIR). In each program, simulation tools were developed to describe various aspects of fish echoes (spectral and statistical) as a result of long-range propagation of a mid-frequency acoustic signal in a complex ocean waveguide. The HiFAST program has resulted in two transitions completed so far (SAST ACB13 and CASE), with one more approved and in progress (SAST ACB15).



*Figure 1. A patch of fish moving across the reverberation track in TRES13.*