

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

Timothy K. Stanton
Applied Ocean Physics and Engineering Department
Woods Hole Oceanographic Institution
Bigelow 201, MS #11
Woods Hole, MA 02543
phone: (508) 289-2757 fax: (508) 457-2194 email: tstanton@whoi.edu

CDR Ben Jones
Ocean Acoustics Lab
Oceanography Department
Naval Postgraduate School
Monterey, CA 93943
Phone: 757-836-1163 email: bajones@nps.edu

Award Number: N00014-13-1-0315
<http://www.whoi.edu/people/tstanton>

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 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 participating in the experiment which was led by APL:UW. The WHOI-led component completed the following tasks:

1. **Design of fish-acoustics component of experiment.** This involved discussions with the Chief Scientists of the program, D.J. Tang and Todd Heffner, and the PI of the fish survey component, John Horne.
2. **Participating in the fish-acoustics component of the experiment.** This took place for one week in May, 2013 off of Panama City, Florida. Since the acoustic equipment was being run by APL:UW, Stanton's principal activity involved identifying fish in the video monitor mounted on the seafloor. Also, fish were viewed from the sea surface (near-surface fish only) and from a diver-held video camera. A secondary activity involved investigating a persistent source of narrowband noise near 5 kHz that was observed by John Preston and others to occur at night. Results are summarized as follows:
 - a. Mid-frequency reverberation data. The reverberation time series showed episodes of elevated levels (Figs. 1, 2). The degree to which the echoes were elevated varied in time both within an hour, within the day, and from day to day. Specifically, it only became elevated at night and not every night. Furthermore, within the periods of elevated levels, the signals varied from ping to ping. This pattern of echoes is consistent with the patchiness and diurnal migration of fish. And, at these mid-frequencies, the echoes are most likely from fish with gas-filled swimbladders.
 - b. Presence of fish at experimental site. There were three species of fish that dominated the numbers in the fixed camera system: 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, taken off the web, are given in Fig. 3. 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. There were also observations through a diver-held video and from the surface of schools of fish that were not directly associated with the tower. The schools were swimming freely, constantly changing direction, shape, and size. The schools are estimated to be 10- 40' in length. In several schools, the fish were identified to be round scad and tomtate (same as two of the types of fish near the tower).
 - c. Persistent narrowband noise at experimental site. This peak was observed by John Preston and others to begin near dusk, persist throughout the night, and end near dawn. Also, it had directional characteristics in that it was observed to be coming from two sectors. This peak is consistent with the recent several years of observations by Carrie Wall and others near this site. The purpose of their work was to identify sounds due to various species of fish. While other sources of sound (100's Hz) in this region were identified by them as being definitively due to fish, this particular sound could only be hypothesized by Wall as

being due to fish. It is strongly suspected to be of biological origin because of its diurnal nature. The sound was hypothesized by Wall as being due to the gas being released in association with the diurnal migration of the swimbladder-bearing Clupeid fish (e.g., herring) in the area.

RESULTS

These measurements illustrate the spatial and temporal variability of mid-frequency echoes and ambient noise due to the presence of fish. The echoes occurred only at night, varied from night to night (and not being significant some nights), and varied within a night. Also, the diurnal pattern of noise 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 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.

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.

RELATED PROJECTS

This research builds on the methods that Stanton, Jones, and colleagues have developed in two other 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.

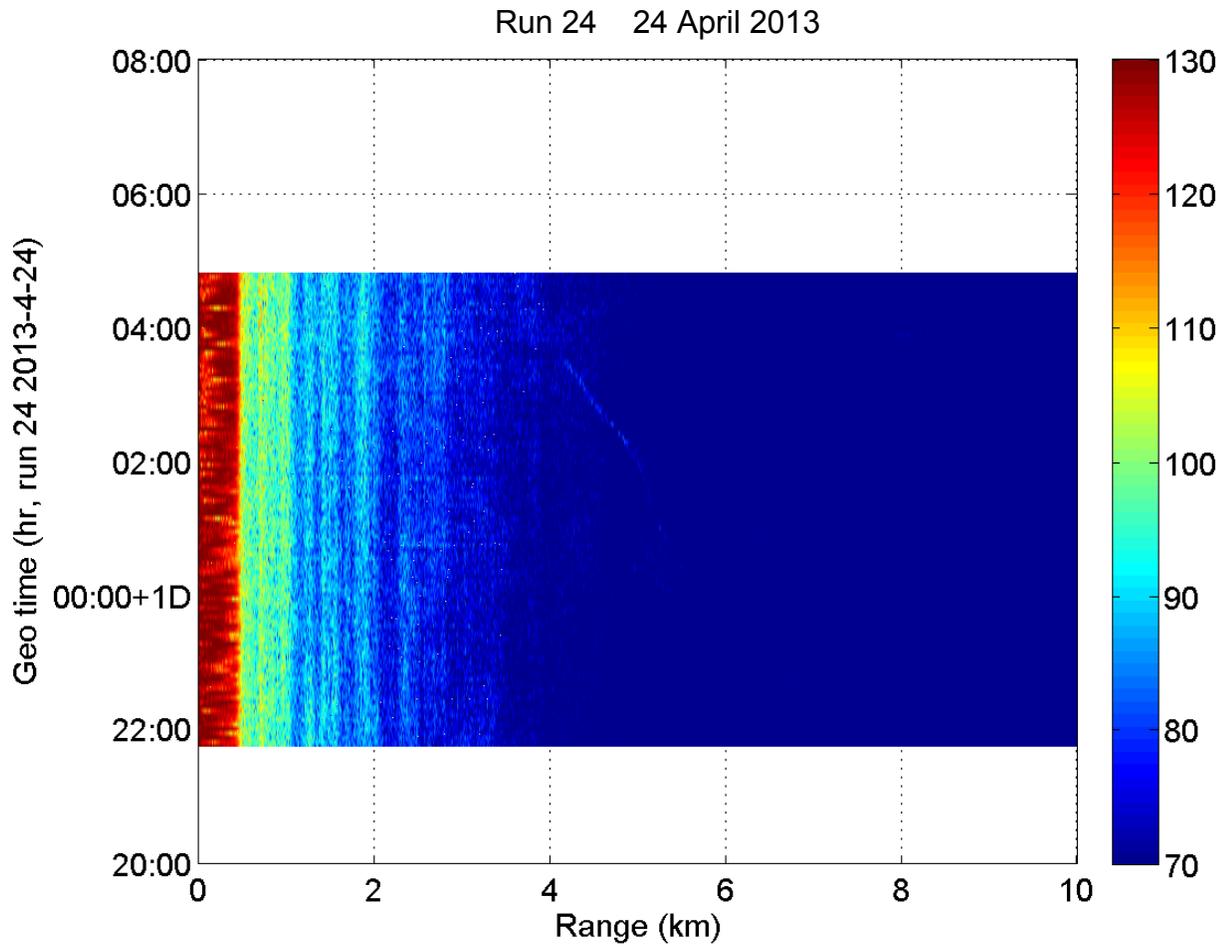


Figure 1. Night-time data from a single beam of mid-frequency reverberation system collected as part of TREX13 experiment. Times given on the vertical axis are local (Florida) time on a 24-hour clock. The data reveal negligible presence of fish.

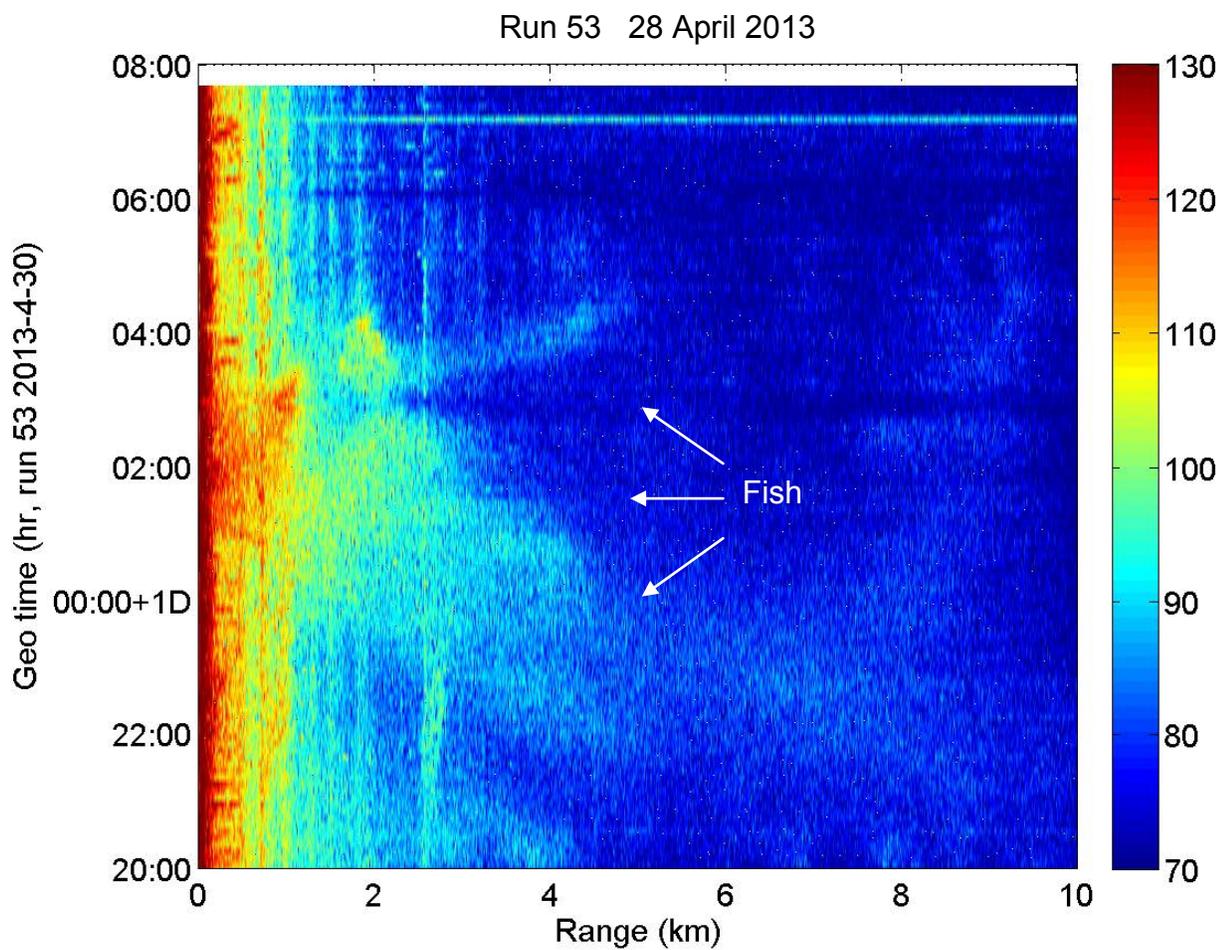


Figure 2. Same as Fig. 1, except that fish appeared in data during this night-time measurement.

Round scad (“cigar minnow”)



(a)

Tomtate (a type of “grunt” fish)



(b)

Atlantic spadefish (“angelfish”)



(c)

Figure 3. The dominant species of fish present at experimental site. All have swimbladders which can scatter sound at mid-frequencies. Photos taken off the web—various sources.