A System for Broadband Acoustic Resonance Classification of Swimbladder-Bearing Fish

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LONG-TERM GOALS

To understand and exploit the resonance scattering by swimbladder-bearing fish (typically in the 1-10 kHz frequency region). Exploitation of the resonances can significantly reduce ambiguities in interpreting acoustic scattering in terms of meaningful biological parameters compared with traditional higher frequency approaches.

OBJECTIVES

To purchase new commercial broadband-acoustic technology that is optimized for use in the resonance scattering region of fish. This purchase will enable a new class of quantitative acoustic studies of scattering by swimbladder-bearing fish to be conducted.

APPROACH

Under this instrumentation grant, a commercial system that was originally designed for marine geological and gas/oil exploration was purchased. It is especially attractive for use in studying swimbladder-bearing fish because this seismic system was optimized for use in the frequency band in which swimbladders typically resonate. The off-the-shelf sensors on the system (in particular, the transmitters and receivers) were selected and configured in a manner best suited for the fish application.

WORK COMPLETED

Under ONR research grant #N00014-04-1-0440, the specifications for the system were finalized. Once the system was purchased from Edgetech using the funds from this DURIP grant (#N00014-04-1-0475), the system was tested and used through funds in the research grant.

The system specifications are summarized as follows: This is a towed broadband active acoustic system, towable to depths of 300 m (Fig. 1). The transducers span the frequency range 1-100 kHz with a gap in the 25-35 kHz range. This range is realized through the use of two seismic transmitters for the lower range (1-25 kHz) and one broadband transducer for the upper range (35-100 kHz). Two hydrophone arrays are used to receive the lower frequency signals: an inner array for the upper-lower

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14. ABSTRACT
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15. SUBJECT TERMS

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frequencies and the combination of the inner and outer array for the lower-lower frequencies. A 0.32-in.-diameter 1000-m-long coax tow cable is used to tow the system, as well as to provide electrical power to it and for two-way data telemetry. A shipboard computer is used for real-time display of matched filter processed broadband echoes in each of the three channels.

The system was tested and calibrated in a lake in Florida, a well in the WHOI pier, an inground test tank at the University of New Hampshire, and through use of the R/V Tioga.

The system was deployed for its first science cruise with the NOAA vessel FR/V Delaware II in the Georges Bank and Gulf of Maine regions. Fish schools were surveyed through use of this Edgetech system, the traditional high frequency narrowband system onboard the Delaware II, and through use of the pelagic trawls.

More details are given in the FY05 Annual Summary to ONR grant #N00014-04-1-0440 which funded these activities.

RESULTS

The system delivered to WHOI was determined, through funding by the research grant, to satisfactorily meet the specifications as given above. That is, this system produced broadband sound over a wide enough range and with enough sensitivity to be able to detect swimbladder fish and the resonance associated with it.

Although scientific use of the system was funded by ONR grant #N00014-04-1-0440 and reported in the FY05 Annual Summary to that grant, the results and impact/applications will be repeated below for completeness of this report:

Although processing of the data has just begun at the time of this writing, much was learned during our "quick look" of the 50 Gbytes of data collected at sea.

1) High resolution: This new system was selected for its bandwidth to measure echo spectra of the fish. A most visually impressive capability of the system is the improvement in resolution over conventional narrow band systems. This improvement is due to the matched filter processing performed on broadband echoes. With a range resolution inversely related to bandwidth, the resolution ranged from about 20 cm in the low frequencies (single digit kHz) down to about 2 cm at the higher frequencies (10's of kHz). The combination of this improved resolution and towing the system near the fish resulted in a dramatic improvement over the narrowband high-frequency (120 kHz) hull-mounted system (Figs. 2 and 3). Through this improvement, the structure and patchiness of the fish schools could be resolved to a much finer degree (Fig. 2). Also, in the case in which we towed the system through the school, the fish could be resolved on an individual basis (Fig. 3) from each other and from the seafloor. Certainly, such resolution could be achieved by towing a very high frequency system near the fish, but it would also be sensitive zooplankton which could blur the image. This new system, which operates in the low kHz region, is only sensitive to the fish because of the low frequencies.

2) Peak in fish spectral curve: We have observed a consistent peak in data dominated by swimbladder-bearing fish. The peak occurs at about 3.5 kHz, which is consistent with the swimbladder resonance of this size of fish (20-cm-long Atlantic Herring) at a 200 m depth.

3) Strong frequency dependence in zooplankton spectral curve: In data dominated by zooplankton, we have observed a steep rise in spectral curve followed by a leveling off at 60 kHz or higher. This pattern is consistent with the large shrimp caught in the nets in that area.

IMPACT/APPLICATIONS

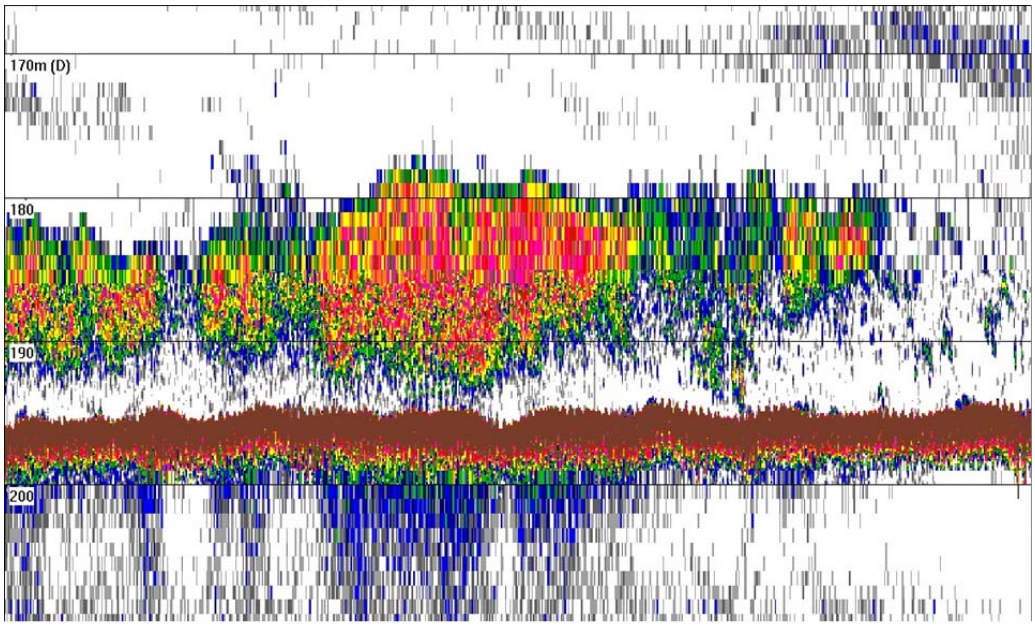
The results have potential for two-fold impact: 1) Because of the large bandwidth of this system and the fact that two of the channels of the system operate in the low kHz region, the system not only has very high resolution to resolve fish and fish schools, but it can also select only the fish (versus zooplankton). Because of this combination of resolution and sensitivity to only fish, this approach can significantly improve studying the behavior of fish through improved accuracy in directly counting them and quantifying the patchiness of the schools. 2) The spectral characteristics of the fish and zooplankton echoes can be used for an accurate means of sizing the organisms. Traditionally, narrowband acoustic systems have been used to assess distributions of organisms, resulting in ambiguities in the analysis. Through use of this broadband system which provides nearly continuous portions of the echo spectra, important characteristics of the spectra can be determined accurately. For example, the resonance of the fish echo is directly related to the size of the swimbladder and the depth of the fish. Through knowledge of the depth and through use of scattering modeling, the size of the fish can be determined with fewer ambiguities than with traditional high frequency narrowband signals.

Since the above results were obtained with an off-the-shelf commercial system, it is possible that such valuable results can be obtained routinely by any investigator.

RELATED PROJECTS

This project is related to the ONR grant #N00014-04-1-0440 which used the instrument to study resonance scattering by swimbladder-bearing fish at sea.

Figure 1. Edgetech towbody being deployed for use during the September 2005 cruise on the FR/V Delaware II. The system was towed near the surface, deep in the water over fish schools, and deep in the water through fish schools.



EK-500 120kHz, 2005.09.11, 1902-1926

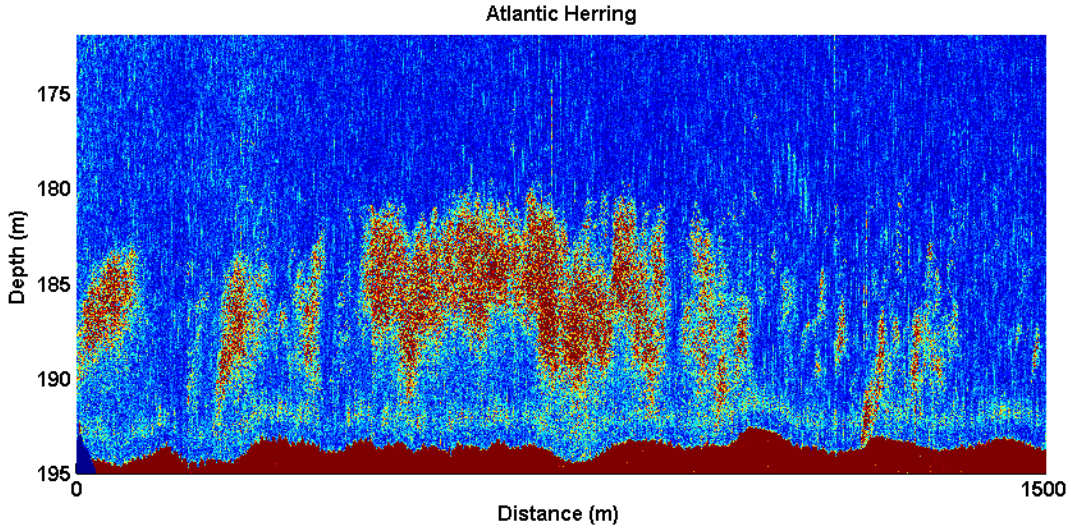


Figure 2. Top panel: Echogram of herring school from hull-mounted EK-500 120 kHz echosounder on September, 2005 cruise on FR/V Delaware II. Bottom panel: Echogram of same section of herring school using Edgetech system; 7-17 kHz band. Although the frequencies are much lower with the Edgetech system, the combination of matched filter processing (providing 10 cm range resolution) and towing deeply over the school, provides a significant improvement in resolution of the fish school over the traditional high frequency hull-mounted system.

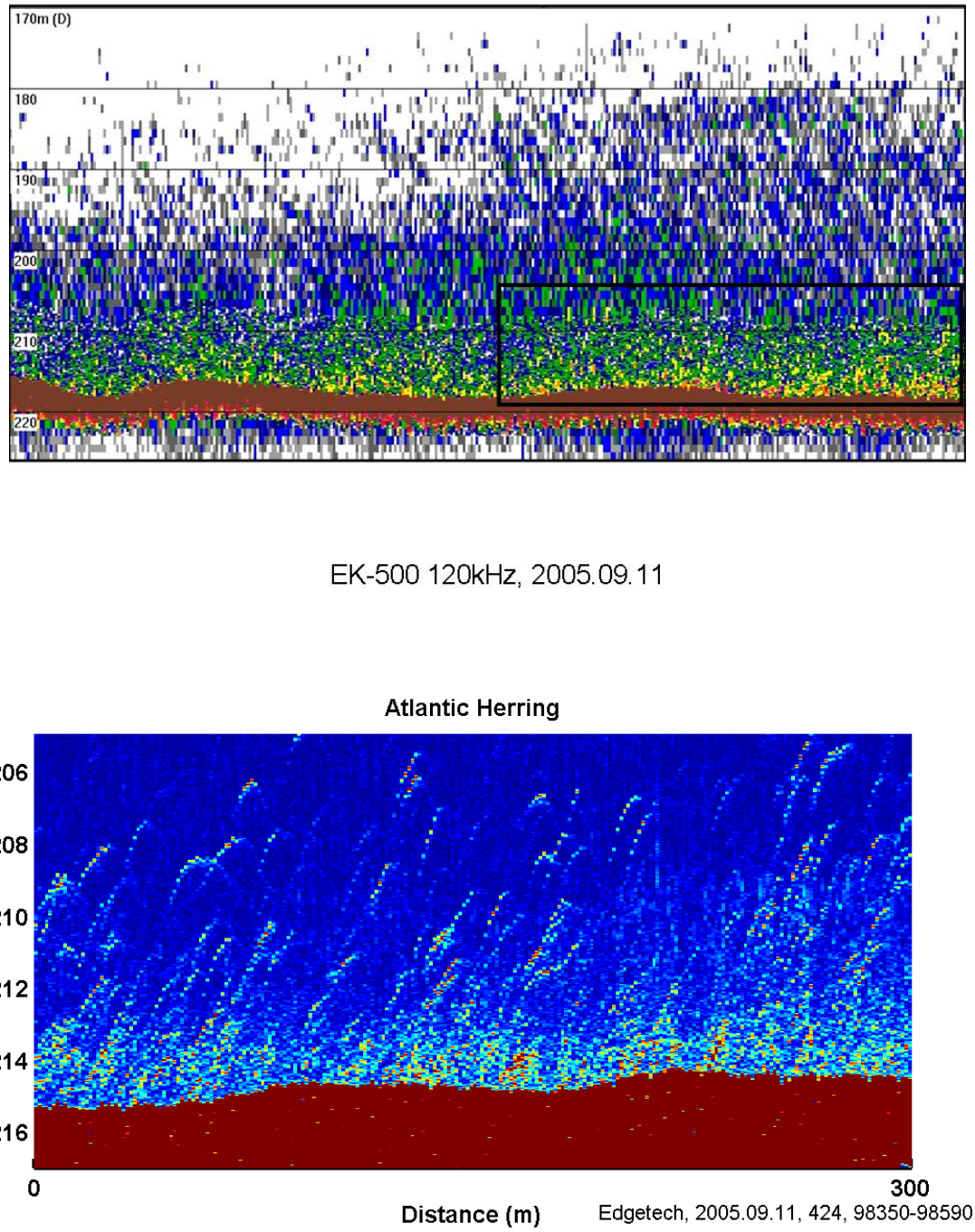


Figure 3. Top panel: Echogram of herring school from hull-mounted EK-500 120 kHz echosounder on September, 2005 cruise on FR/V Delaware II. Bottom panel: Echogram from <u>within box</u> in top panel using Edgetech system; 7-17 kHz band. In this case, the Edgetech towbody passed <u>through</u> the fish school, resulting in resolved echoes.