Acoustic Scattering Classification of Zooplankton and Microstructure

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LONG-TERM GOALS

To understand the acoustic reverberation properties of zooplankton and microstructure. The results will lead to improved capability in 1) predicting sonar performance and 2) use of sonars in the mapping of the zooplankton and microstructure.

OBJECTIVES

To understand the physics of the scattering by naturally occurring (complex) bodies or processes so that realistic acoustic scattering models of zooplankton and microstructure can be developed and applied to high-frequency acoustic surveys.

APPROACH

The research program has been a combination of theoretical analysis, numerical simulations, and experimentation in the laboratory and local waters at WHOI. The acoustic scattering theories are approximate and have included various ray, volume integration, and modal-series-based solutions. An acoustic pulse-echo laboratory is used to collect backscatter data with animals and microstructure over a wide range of acoustic frequencies (24 kHz - 1 MHz) and all angles of orientation (0 to 360 degrees in 1-degree steps). A high performance towed platform (BIOMAPER-II) is used to simultaneously collect acoustic backscatter data (transducers at five frequencies (43 kHz to 1 MHz) looking up and down), video data, and environmental data (temperature, etc.). Tim Stanton has led the laboratory measurements and development and application of scattering modeling while Peter Wiebe leads the field surveys and interpretation. Dezhang Chu has also played a key role in the laboratory and modeling work while Joe Warren has played a key role in the surveys and classification.

WORK COMPLETED

A number of major tasks were completed this year involving various parallel efforts focused principally on a scattering-model-based classification of our high-frequency acoustics survey data.

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1) PUBLICATIONS. In FY99, one book appeared in print of which we were co-editor as well as co-authors of three of its chapters; two peer-reviewed papers appeared in a scientific journal; three manuscripts were submitted to peer-reviewed journals; and one review article of our work was submitted and published in Chinese. We also continued to make significant progress toward putting into final form the book that was accepted the previous year.

2) SURVEYS OF A SHALLOW-WATER COASTAL REGION USING BIOMAPER-II. Cruises #4 and #5 of a five-cruise series were completed this year using the newly developed BIOMAPER-II tow vehicle and handling system. This system, which contains five acoustic frequencies (43 kHz to 1 MHz), a video plankton recorder, and various environmental sensors, was used to map the spatial and temporal variability of zooplankton and internal waves in the Gulf of Maine and over Georges Bank, a shallow water coastal region off New England.

3) CONTINUED ANALYSIS of BIOMAPER-II cruises #1 - #3 and preliminary analysis of BIOMAPER-II cruises #4 and #5 (analysis in each case of ONR-sponsored component of the cruises). This has been a significant effort of integrating acoustic scattering data with the samples of organisms (from MOCNESS tows and the video plankton recorder) and environmental data (from cast and towed CTD's). The integration has involved statistical comparison of the different types of data (through correlations) and a scattering-model based analysis. This analysis has provided estimates of the proportions with which the scattering is due to each of the various anatomical groups of animals and microstructure. Inferences are being made from the acoustic data to parameterize the animals and microstructure field.

RESULTS

The analysis of the high-frequency acoustic surveys has yielded information on the dominant sources of acoustic scattering. In some sections of the water column, the marine life appears to dominate the scattering, whereas in other sections, the microstructure appears to dominate. This information is allowing us to describe the various biological entities or physical processes in the water column. These results are significant because we are, for the first time, able to discriminate between the different sources of acoustic scattering and convert the acoustic data into meaningful biological and physical parameters. These parameters provide information on the spatial and temporal variability of the biological and physical processes.

IMPACT/APPLICATIONS

The impact and applications of these results are significant: Traditionally, and with few exceptions, high frequency acoustic scattering from the water column has been attributed entirely to the presence of marine life. Thus, when measurements of acoustic scattering are made, the results were automatically converted into some measure of biomass of animals. Since our results show that there are conditions under which the source of scattering could be a physical process, those types of analyses could grossly overestimate the presence of marine life. Another outcome of our results is the ability to infer the parameters describing the microstructure. Microstructure is very difficult to measure through direct means and the acoustic approach may provide a means for synoptic studies of the fields.

TRANSITIONS

1) NUWC/Newport has recently expressed an interest in our physics-based approach toward classification of broadband sonar signals. We currently have plans directed toward combining our physics-based approach with their statistics-based method in order to classify sonar data from various Navy systems as well as from scientific systems.

2) The Prince Williams Sound Science Center has been using several of our models in their acoustic surveys of various zooplankton in Prince Williams Sound.

3) The British Antarctic Survey has been using one of our models in their interpretation of acoustic surveys of Antarctic krill.

4) The Southampton Oceanography Centre has been using several of our models in their interpretation of acoustic surveys in the N.W. Indian Ocean.

5) Some of our acoustic scattering models have already been used by NUWC/Newport in sonar performance predictions in their development of the standoff system, which is now operational.

6) We have used the results of our models to provide plausible explanation for false target echoes in Mk48 ADCAP torpedo reverberation collected by NUWC/Newport.

RELATED PROJECTS

1) We have applied experimental methods and scattering models developed as well as equipment purchased under this grant toward at-sea laboratory experiments funded by NSF grant OCE-9201264.

2) We have applied some of the scattering models developed under this grant to help in interpreting acoustic survey data collected over the Georges Bank (a shallow water coastal region). The data were collected through both ONR and NOAA funding (grant NA16RC0515, US GLOBEC).

PUBLICATIONS

Books:

Harris, R., P. Wiebe, J. Lent, H. Skjoldal and Huntley (eds), 2000. ICES Zooplankton Methodology Manual. Academic Press.

Foote, K.G. and T.K. Stanton, Observing Aquatic Organisms by Sound and Light, accepted by Springer-Verlag.

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Skjoldal, H.R., P.H. Wiebe, and K.G. Foote, 2000. “Sampling and experimental design,” ICES Zooplankton Methodology Manual. Chapter 2. Academic Press. 33-54.

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Stanton, T.K., 2000. "Acoustic remote sensing of marine organisms," Physics Bimonthly and Proceedings of the National Science Council; Part A. Physical Science and Engineering (Taiwan). (Translated into Chinese).

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Stanton, T.K. and D. Chu, In press. "Review and recommendations for modeling of acoustic scattering by fluid-like elongated zooplankton: Euphausiids and copepods," *ICES J. Mar. Sci*.

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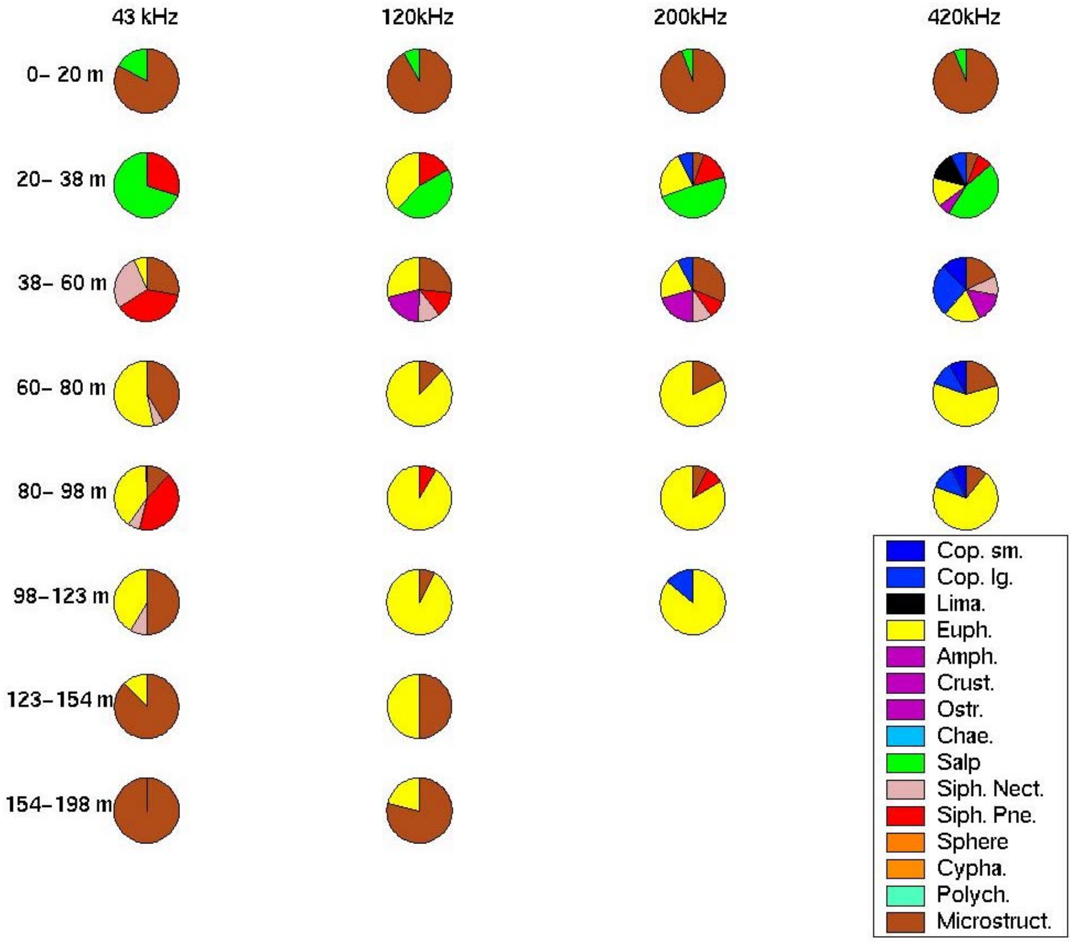

BIOMAPER-II survey data from internal wave. The pie charts illustrate the proportion of acoustic scattering due to different sources of scattering at different acoustic frequencies. The top row illustrates that the acoustic scattering is dominated by microstructure (brown color) in the upper water column at all frequencies. Below that layer, the scattering is shown to be dominated by salps (green) and euphausiids (yellow).