Advanced Multi-frequency Inversion Methods for Classifying Acoustic Scatterers

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LONG-TERM GOALS

This is a collaborative study between LSU and BAE Systems, San Diego, which began on January 1, 2001. The goals of this study are to develop species- and life-stage-specific acoustic scattering models based on morphologically-accurate digitizations of preserved or live-imaged zooplankton from coastal waters off New England and the northern Gulf of Mexico. These models will estimate scattering strength as a function of acoustical frequency, animal size, taxon, and orientation relative to the incident angle. These predictions will improve our ability to estimate animal abundances by taxon/morphological class via inversion.

OBJECTIVES

1) Develop lists of commonly occurring zooplankton species and life-stages as functions of the time of year for the Georges Bank/Gulf of Maine and the northern Gulf of Mexico;

2) Obtain representative images of taxa from the species lists using data from the Video Plankton Recorder (VPR), other video sources, photos of living and dead specimens, and scientific illustrations; and

3) Digitize images to develop acoustic scattering models.

APPROACH

Acoustical scattering models of zooplankton have generally been developed by modeling target taxa as relatively simple geometric shapes. As our understanding of scattering models has improved, there has been a progression towards the use of higher resolution, more anatomically correct scattering models (e.g. Stanton and Chu, 2000). Our approach follows this direction and we are attempting to develop models of scattering derived from digitizations of actual zooplankton shapes. These shapes will be derived from both in situ video images and preserved samples. One of the advantages of this approach is that orientation data can frequently be derived from in situ images of plankton (e.g. Benfield et al. 2000). Knowledge of the orientations of zooplankton may be critical in predicting scattering because the target strength can vary substantially depending upon the angle of incidence of the acoustic wave relative to the orientation of the animal.

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This is a collaborative project between LSU and BAE Systems. LSU is collecting the various images of zooplankton and developing lists of dominant taxa by season for our study areas while BAE Systems is digitizing the images and developing the scattering models.

At the inception of this project we planned to use VPR data from the Gulf of Maine/Georges Bank region collected during cruises undertaken during October 1997; October and December 1998; and October and December 1999. We selected these data because these cruises contained concurrent, VPR and multi-frequency acoustic data collected by the BIOMAPER II vehicle, punctuated by MOCNESS samples. Data from the Gulf of Mexico included 1m^2 net samples collected in the summer of 2000 approximately 50 km SW of the Mississippi River along with SEAMAP zooplankton records. The latter were to be used to estimate seasonal periodicity.

WORK COMPLETED

We have assembled large numbers of potentially suitable VPR images of a variety of zooplankton taxa (Fig. 1). The majority of these were digitized directly from the VPR tape recorded during cruise EN331 during December 1999. These images were evaluated by Duncan McGehee at BAE Systems who concluded that the images lacked sufficient detail to use as a basis for digitization of morphologically accurate silhouettes.

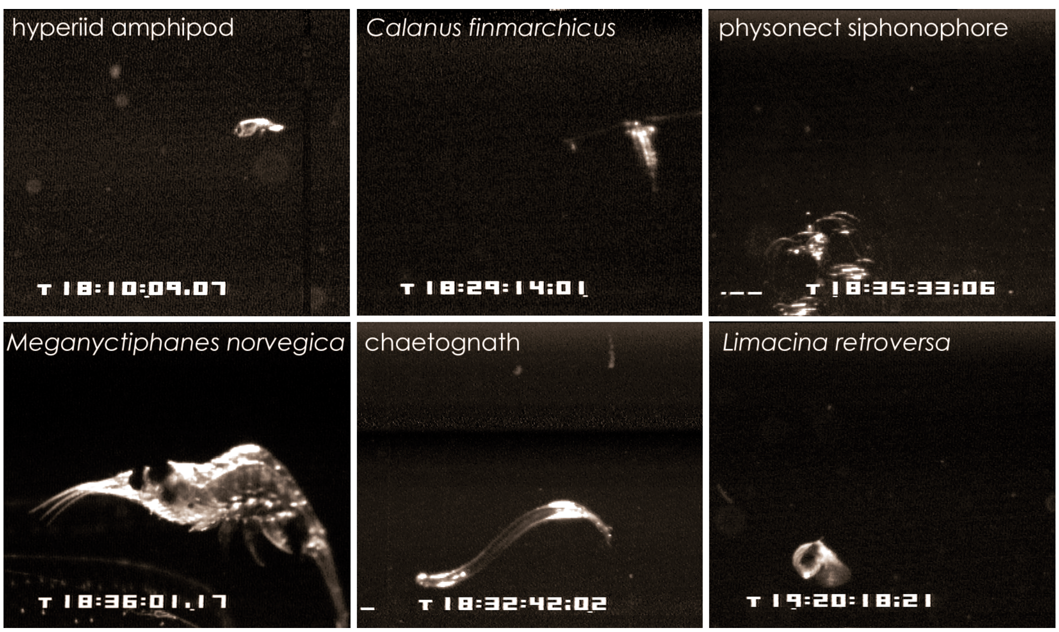

Figure 1. Examples of live zooplankton imaged by the VPR and digitized from videotape.

While the VPR dataset will provide essential data on in vivo orientation, we turned to preserved samples of zooplankton collected with the 1m^2 MOCNESS for higher resolution morphological data. Dr. Peter Wiebe at Woods Hole Oceanographic Institution has begun digitizing silhouette photographs (Ortner et al. 1979) of zooplankton collected in our study area. These high-resolution (1200 dpi) images appear well suited for development of morphological silhouettes (Fig. 2). Even small copepods contain sufficient detail to resolve their shapes. We are in the process of extracting sample images from these silhouettes for use by our colleagues at BAE Systems. Our laboratory already has a very high resolution, large format scanner system and this is being adapted to scan samples of zooplankton collected in the Gulf of Mexico so that they can be digitized in the same manner as the Gulf of Maine samples.

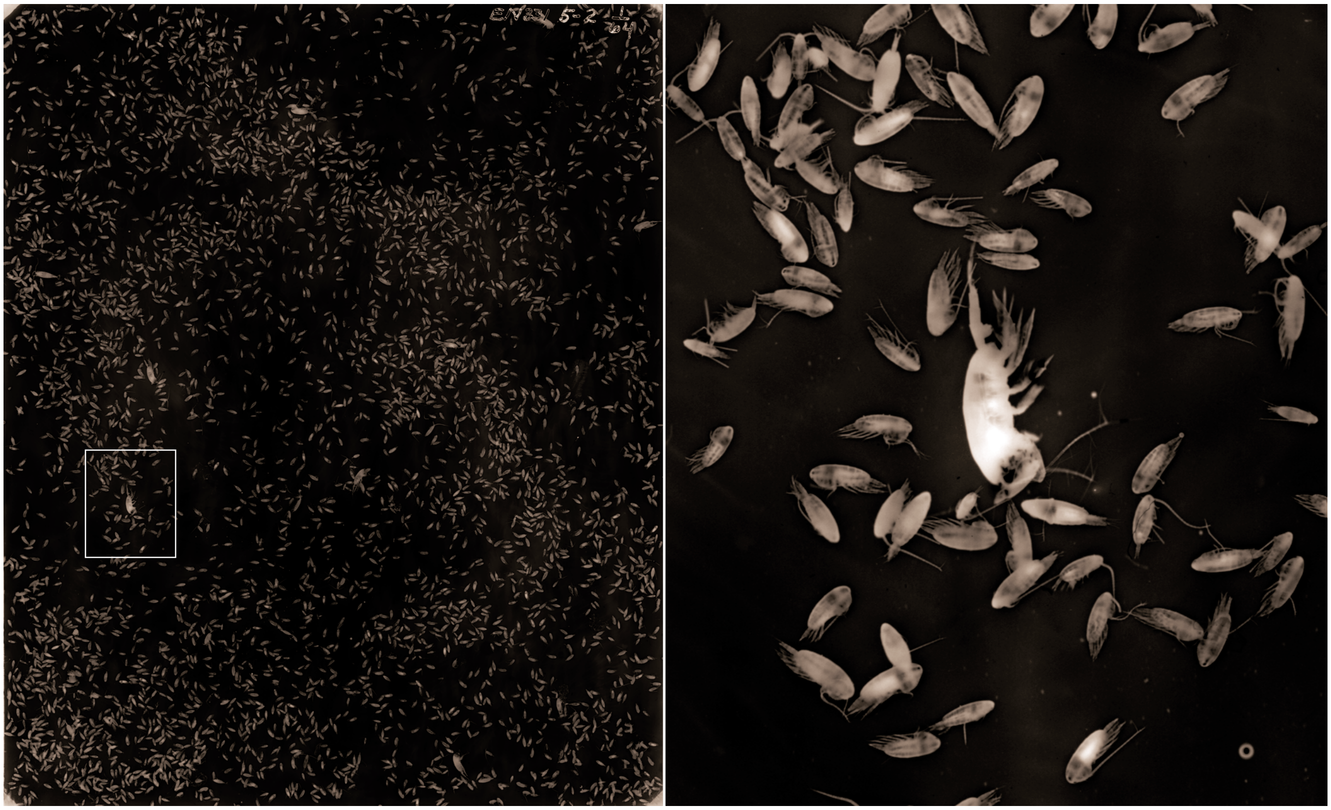

Figure 2. [Left] 7” x 9” silhouette photograph of a MOCNESS zooplankton sample that has been digitized at 1200 dpi. [Right] Close up of the highlighted region in the large silhouette containing a single medium-sized copepod surrounded by small copepods.

RESULTS

Images of zooplankton derived from VPR surveys lack sufficient detail to provide useful digitizations of zooplankton from which to derive scattering models. The reason appears to be the relatively low resolution of the VPR images (72 dpi). Nevertheless, these images have value because they provide essential information on typical orientations and postures of live zooplankton. High resolution scans of preserved zooplankton will be used to obtain morphological information.

An atlas of marine and estuarine zooplankton from the Gulf of Maine (Gerber, 2001) has just been published. This publication contains detailed line drawings of many of the taxa of interest in this study and will be used to supplement the silhouette photographs collected by the MOCNESS.

IMPACT/APPLICATIONS

ONR has allocated significant resources to the development of both sophisticated acoustic scattering models and multiple-frequency systems such as TAPS and BIOMAPER II. This research is a logical extension in merging those two lines of research. The long-range goal of this research is to develop a method that can be tailored to any multi-frequency or broadband acoustic system to provide real-time classification of scatterers.

The goal of biological oceanographers is to be able to determine: (1) what organisms are present in a given ecosystem; (2) at what abundance levels the organisms are present; (3) how they are distributed; and (4) what the factors are that control their abundances. This means we must be able to detect, count, and classify the organisms. There are currently three general ways of going about these tasks: nets and pumps, optics, and acoustics. Each of these has certain advantages and disadvantages. The present work seeks to integrate the data from these different sampling systems to provide a better view of the distributions of animals in the oceans.

The presence, abundance and dynamics of life in the sea at all trophic levels have both direct and indirect impacts on the ability of MCM, ASW, undersea warfare, expeditionary warfare, and special operations forces to perform their missions. Zooplankton and micronekton in the water column can control the optical properties of interest through grazing on phytoplankton. They may also interfere with operational and planned Navy acoustic systems. Many zooplankton are bioluminescent or influence the distribution and abundances of bioluminescent organisms at higher trophic levels. It has become increasingly important for the Navy to be able to know in real time what organisms are present in the water column and in what quantities. This study is aimed at directly assessing that need.

TRANSITIONS

We are in the process of attempting to integrate multi-frequency acoustic and optical data collected by the BIOMAPER II vehicle in the Gulf of Maine during 1997-1999. Comparisons of the datasets indicate relationships between acoustical scattering layers and the presence of individual zooplankton taxa. For example, physonect siphonophore larvae with small gas-filled pneumatophores (~0.20 mm) detected by the VPR appear to be associated with layers of strong scattering at multiple frequencies (Fig. 3). In collaboration with colleagues at the Woods Hole Oceanographic Institution (Andone Lavery, Peter Wiebe, Timothy Stanton, Nancy Copley) and Cornell University (Charles Greene), we are working to scale measured acoustic scattering into biomass distributions using existing scattering models and predicted abundances from the VPR (Benfield et al. In Prep). The techniques developed in this project will provide an alternative methodology for combining the information content of both sensor systems to estimate taxon-specific distributions of zooplankton biomass in the water column.

RELATED PROJECTS

Project N00014-98-1-0563 "Development of a Vertically Profiling, High-Resolution, Digital Still Camera System" has produced an in situ optical profiling system called ZOOVIS. This camera system will be deployed in Knight Inlet, BC during November 2001 as part of an ONR-funded project to examine aggregation of zooplankton near sills. ZOOVIS has higher resolution than the VPR and will likely generate images with sufficient detail as well as orientation information for incorporation into the present study.

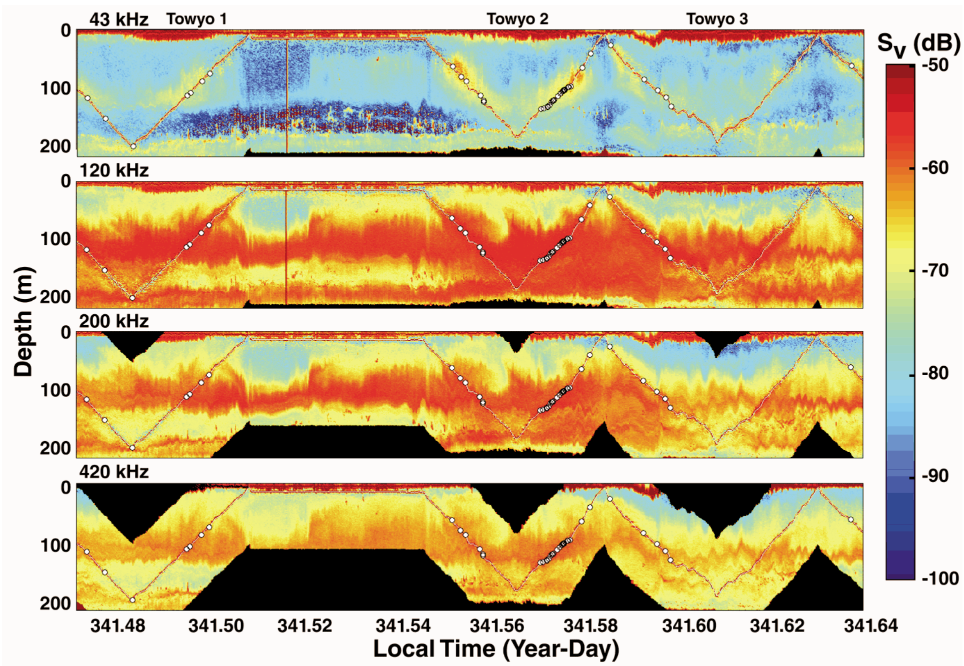

Figure 3. Acoustic scattering at 43, 120, 200, and 420 kHz measured by BIOMAPER II in Jordan Basin, Gulf of Maine over an approximately 2h period. The white circles indicate the presence of physonect siphonophore larvae detected by the VPR. Note the coincidence of the distributions of these organisms and layers of elevated scattering. The high scattering in the vicinity of siphonophore larvae at 43 kHz is believed to be an artifact of scattering by turbulence. From Benfield et al. In Prep., Fig. 8.

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