

Effects of Benthopelagic Animals on Seabed Properties

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LONG-TERM GOALS

The long-term goals of this research are to improve the ability of benthic biologists and biological oceanographers to observe life on and in the seabed; to describe the interactions between the animals that live there, their neighbors and their food; to improve our understanding of the coupling between the benthic and the pelagic communities; and to assess biologically mediated changes in those physical properties of the seabed that affect scattering and penetration of sound into the bottom.

OBJECTIVES

Direct observation of animals that live on or in the seabed can be exceptionally difficult. This is especially true in areas with characteristically poor visibility or in water that is too deep to allow divers to spend much time near the bottom. Little attention has been given to developing instrumentation and sensors that would allow remote observation of benthic animals for long periods at high spatial and temporal resolution. Our short- and medium-term objectives involve developing high frequency acoustic sensors to fill this gap, thereby improving the information that benthic ecologists can access about benthic and benthopelagic animals and the seabed environment. In addition, the presence and

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behavior of benthopelagic animals and the presence of benthic micro-algae in and on the seabed modifies the reflectivity and frequency spectrum of sound as it is scattered from and propagates through the sediment. Understanding these interactions is a key to predicting basic acoustical properties of the seabed. Understanding the benthopelagic community and the behavior of organisms that use it as a food resource is necessary in order to understand how acoustical properties of the seabed vary in time and space.

APPROACH

Our approach to achieving a better understanding of how biology modifies the seabed involves a combination of direct observation with high frequency acoustics in various littoral environments and model-based inverse processing of the data acquired. This allows us to interpret the acoustical measurements in terms of observed distributions and behaviors of biological organisms in relation to cues such as light, food, predation and currents near the seabed. The reverse is also true, since as we gain a better understanding of behavior we are better able to predict the impact of biological organisms on the propagation and scattering of sound in the sea and at its boundaries.

WORK COMPLETED

We have been attempting to improve our ability to interpret acoustical observations of benthopelagic migrators. Some of these migrating organisms are known to modify the volume heterogeneity and surface microtopography of the seabed, both of which affect the scattering and propagation of sound at the ocean's floor. We employed a distorted wave Born approximation method (McGehee, O'Driscoll, and Martin-Traykovski, 1998; Martin-Traykovski, O'Driscoll, and McGehee, 1998) to calculate the azimuthal and frequency dependence of sound scattering from a mysid, *Neomysis* spp. In many coastal environments, this animal is known to move between the seabed and the water column. Our objective was to acoustically distinguish different shapes of migrating animals in the multi-frequency scattering signals observed at dawn and dusk, and sometimes throughout the night. This modeling, and the development of new computer code for making improved inverse calculations, allowed us to describe data collected at the sandy SAX-99 site (Thorsos *et al* 2001; Richardson *et al* 2001). It was also used to analyze data collected at several other sites where we observed organisms moving between the seabed and the water column.

We also examined the possibility that benthic micro-algae could produce small gas bubbles in sufficient quantities to modify the bulk sound speed properties of the upper few centimeters of the sediments. In laboratory cultures of benthic micro-algae collected from Mission Bay, San Diego, CA, we were able to observe diel changes in the frequency spectrum of echoes from a sandy surface. These observations were consistent with the production of visible gas bubbles by photosynthesis on the sandy substrate in a laboratory beaker during daylight hours. The results suggest a way to measure, *in situ*, the presence of microscopic and macroscopic bubbles that may result from high daytime productivity in shallow coastal waters. In locations where this occurs, one can expect measurable changes in the acoustic propagation and scattering in the seabed at low, as well as high acoustic frequencies.

Selected results and methods developed under this contract were used in preparation of five journal publications. Additional results have been presented at several scientific meetings. In addition to the published results, a final technical report for the project is available on request.

RESULTS

The seabed is a dynamic, rather than a static environment. Numerous physical and biological phenomena continuously modify bottom topography and sediment properties. One of these phenomena is the emergence and re-entry of organisms into the seabed. This activity modifies both the surface roughness and the volume heterogeneity of the sediments. Additionally, foraging by fish and other organisms at the bottom change both bottom topography and sediment properties. We used high-resolution acoustical technology to observe these behaviors in both nekton and members of the benthic-pelagic communities. Opportunities for testing behavioral hypotheses and for correlating spatio-temporal patterns with other environmental data were greatly enhanced by use of our acoustical sensors. Using acoustic information to choose times and places for “smart” or “directed” sampling is an efficient means to accelerate analysis of the complex migration patterns already known in shallow-water environments. Implications for bioturbation, benthic community structure and the seabed’s acoustical environment are substantial, just as they are for material exchanges between benthic, planktonic and nektonic components of nearshore ecosystems.

At very high acoustical frequencies, we determined that one of the keys to predicting the amount of sound backscattered from a sandy seabed is the grain size. Field measurements of bottom scattering strengths were made with a multi-frequency sonar above a sandy bottom off West Destin, Florida at five frequencies between 265-1850 kHz. Grazing angles ranged from 9-20° and at azimuths up to ±90° around a bottom-mounted tower. Scattering strengths increased with a $f^{1.4}$ dependence up to >400 kHz, peaked between 700 and 1100 kHz, and decreased at higher frequencies. The cause of this rolloff was surmised to include sandgrain size effects (C.F. Greenlaw, *et al* 2000). Subsequent laboratory measurements for common beach sand from San Diego, CA validated the assumption that sand grain size strongly affects the surface scattering strength of smooth bottoms at low grazing angles (20°) and at high frequencies (0.2-4 MHz). Comparison of the data with simple models (Faran 1951; Holliday 1987) and measurements (Hay 1991; Sheng 1991) produced reasonable agreement with the mean grain size of the sand (Figure 1). Linear inversions, however, failed to reproduce the actual distribution of grain sizes. Although grain size is clearly an essential parameter in a predictive scattering model at these acoustical frequencies, it is evident that today’s scattering models do not adequately describe scattering at very high acoustical frequencies.

In the laboratory, we have also shown that microphytobenthos can modify acoustic scattering by the photosynthetic production of bubbles in and on a sandy substrate, and in a mat of microphytobenthos overlying mud. This would suggest a strong link between the spatial and temporal distribution of microphytobenthos in shallow littoral environments, ambient light levels, and acoustical backscattering.

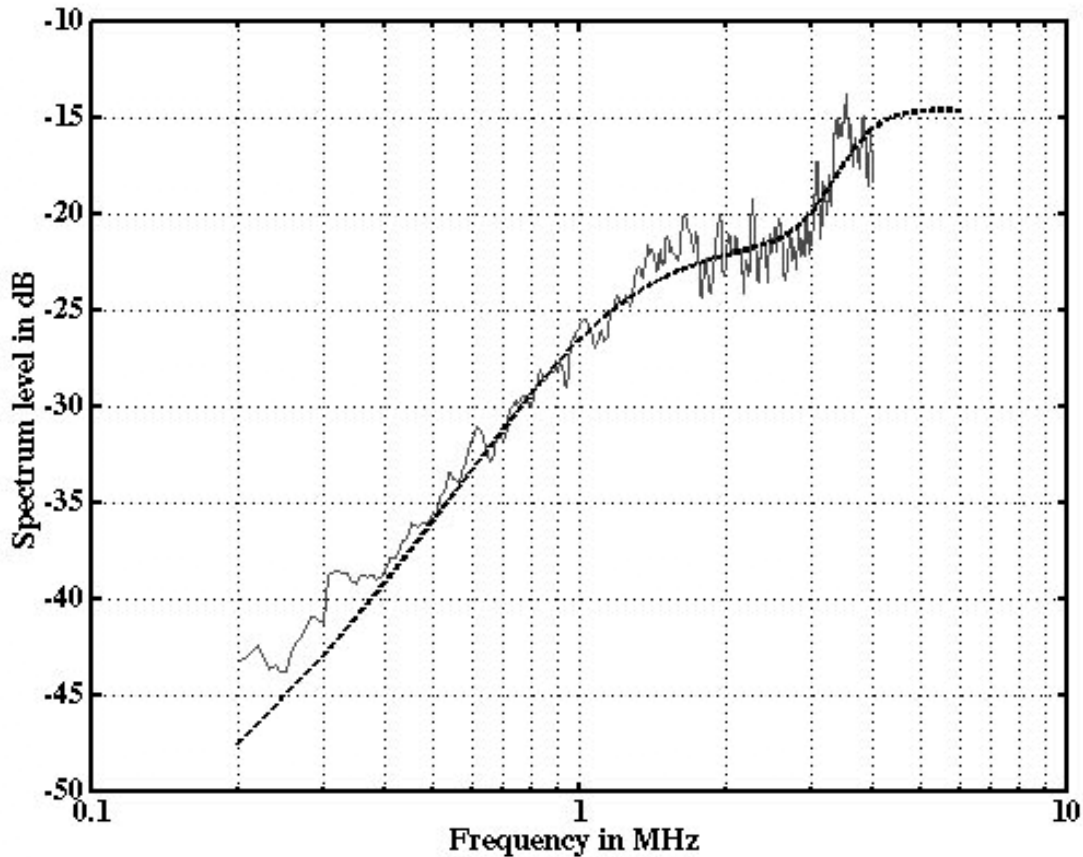


Figure 1: Composite backscattering spectrum from a sandy bottom at 20° grazing angle, illustrating similar dependencies on acoustical frequency. The raw spectra have been corrected for relative areal changes over frequency from the finite apertures of the transducers. Three transducers, covering different overlapping frequency bands were used in the scattering measurements and after correcting for system frequency responses and insonified areas; the data were averaged to produce a single composite spectral estimate. A scattering model (dashed curve, Sheng 1991), for a single sand grain of 0.25 mm diameter has been arbitrarily adjusted vertically to illustrate close similarities between the frequency dependence of the measured scattering spectrum and that predicted by Sheng's model.

IMPACT/APPLICATIONS

Biological activity by organisms from several trophic levels has been clearly shown to affect the scattering and propagation of sound from, and in, the seabed. A comprehensive model of acoustical scattering from the seabed must include both physical and biological effects if it is to be truly predictive and tactically significant.

The heterogeneity and temporal variations of acoustical scattering from the seabed may offer both challenges and opportunities in some tactical naval applications. The same changes may have positive implications for those interested in the mapping and characterization of benthic habitat. With an adequate description of how biological organisms modify the physical seabed and the character of its

acoustical scattering, one can conceive of ways to detect and monitor the spatial distribution and activities of those organisms.

TRANSITIONS

Some of the results from this project are being used in preparation of an ICES Cooperative Research Report on the acoustical characterization of benthic habitat. The report will be a product of the ICES Study Group on Acoustic Seabed Classification (SGASC). ICES is an acronym for the International Council for the Exploration of the Sea (<http://www.ices.dk>). The report is intended to serve as guidance for the 19 member nations of ICES regarding methods and standards for using acoustics in complying legislative mandates for conducting habitat assessments in their EEZ's.

RELATED PROJECTS

During this project, we worked with Peter Jumars, Keli Kringel, Liko Self, Jan Rines, and David Thistle, and many of the individuals who were associated with ONR's SAX-99 team. In some of our work on benthopelagic species, especially mysids, we used the 2-D DWBA modeling methods developed by McGehee and his co-PIs in previous ONR-sponsored projects (as cited below). We have been able to move ahead more quickly by using several results, including the DWBA computer codes, from that work and from a separately funded ONR-sponsored project with Mark Benfield.

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HONORS/AWARDS/PRIZES

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