

Benthic Biota and High-Frequency Acoustic Propagation

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Award #: N00014-98-1-0888
<http://www.ume.maine.edu/~marine/jumars/acoustics.html>

LONG-TERM GOALS

Our long-term goals are to understand — to an extent that allows quantitative prediction — important interactions among acoustic propagation, marine organisms, particles (including sediments), solutes and moving fluids. The reason for this goal is to allow us to solve interesting forward and inverse problems in the marine environment.

OBJECTIVES

The objective of this work are to identify mechanisms whereby benthic biota influence propagation of sound into medium sands. The field site selected was at roughly 20 m water depth off Fort Walton Beach, FL. The mechanisms that we considered most likely were modifications of surface microtopography, volume heterogeneity and force transmission at grain-grain contacts.

APPROACH

We explored the region for large infauna capable of altering surface microtopography and volume heterogeneity. Sand dollars became the primary target for experimental manipulation. We enhanced their abundance in three 1-m² pens within the view of each of BAMS and XBAMS, and paired each treatment with a control for effects of the plastic-mesh pen.

We also targeted emergent fauna for manipulation, choosing elimination over enhancement as a more practical manipulation. Treatments consisted of smoothing 4-m² plots by hand and covering them with black plastic weighed down by rebar to smother the underlying fauna. Paired controls included smoothing and rebar, but no plastic. After about 3 d, the plastic was removed to monitor the effects of repopulation by emergent fauna re-entering from other sites. As background information for this manipulation, we also collected emergence-trap samples from the study site and five 0.1-m² grab samples from each of four stations near the corners of the study area.

Our most intensive effort was to sample and characterize bacteria with respect to grain-grain contacts. This work constitutes the Ph.D. research of Jill Schmidt (2001). The first task was to make predictions of bacterial location based on alternative processes controlling their abundance. Nutrient-supply effects of location relative to boundaries and relative to neighbors were predicted with the analog methods of Berg and Purcell (1977). Epoxy embedding of carefully taken diver cores was used. Both unmanipulated

Report Documentation Page				Form Approved OMB No. 0704-0188	
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1. REPORT DATE SEP 2001		2. REPORT TYPE		3. DATES COVERED 00-00-2001 to 00-00-2001	
4. TITLE AND SUBTITLE Benthic Biota and High-Frequency Acoustic Propagation				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) School of Oceanography, Campus Box 357940,, University of Washington, Seattle, WA, 98195				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT Same as Report (SAR)	18. NUMBER OF PAGES 5	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			

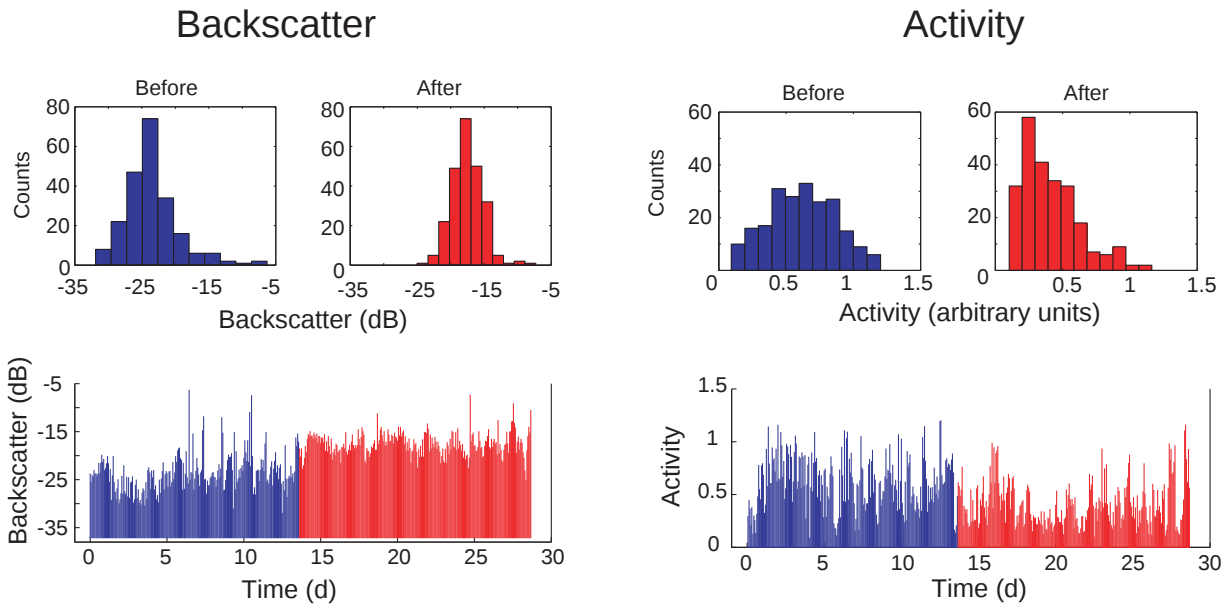


Figure 1. Effects of sand dollars on backscatter intensity and activity. [Activity is the arcsine transform of one minus the complex correlation coefficient. It is a measure of the rapidity of decorrelation of the acoustic backscatter signal. Shown are the actual data from treatment pixels of one replicate corral that enclosed approximately 100 sand dollars in 1 m². Adjacent control pixels inside a similar corral showed no such changes.]

WORK COMPLETED

BAMS and XBAMS records for sand dollar and smothering manipulations have been analyzed by the time-series technique of intervention analysis (Box *et al.* 1994). In this procedure, an ARIMA (AutoRegressive Integrated Moving Average) time-series model is fitted to the data before the manipulation, and the treatment effect is resolved as a departure from the forecasts of this model. All emergence-trap samples have been counted.

Predictions for bacterial location have been made, based largely on the analog modeling (Schmidt and Jumars, in press). Sections were prepared and stained, and bacterial locations have been mapped in a number of images and sub-images, based on anticipated statistical power needed.

RESULTS

The smothering experiments showed a treatment effect that lasted for only a single inter-scan interval. Intervention analysis showed a significant effect that would have been impossible to detect by eye. Conversely, despite the fact that there was little diver-observable surface evidence of the sand dollars, the sand-dollar treatments showed enhanced backscatter and decreased rate of change of backscatter. The effect is so obvious that intervention analysis is barely needed (Fig. 1).

Our analog modeling results for bacteria suggest that even a little distance from a solid boundary can make a large difference in flux of solutes to a cell. They also strongly implicate the effects of neighbors

in reducing flux of nutrients as a reason for the observed plateau of bacterial abundance at 10^9 cells ml⁻¹ of pore water (Schmidt *et al.* 1998).

Population regulation by competition for nutrients with neighbors suggests that bacteria should be most abundant in the “wide open volumes” of large pore spaces, whereas refuge from predators should favor higher bacterial abundances in smaller crevices. The data refute the latter hypothesis.

IMPACT/APPLICATION

The sand-dollar effects have potential importance because of the prevalence of high abundances of sand dollars just offshore of sandy beaches. Further experiments are needed, however, to test alternative hypotheses about the mechanisms responsible.

Our most important impact is probably the attention our work (Self *et al.* 2001) brings to intervention analysis (Box *et al.* 1994). We believe that it will become widely used in both basic marine ecology where time series are long and replication is sparse and also in detection of suspected seafloor events when the timing of those events can be anticipated or detected but the magnitude and precise location are less well known.

RELATED PROJECTS

This project is one of several that are integral parts of the ONR DRI on High-Frequency Sound Interaction in Ocean Sediments (coordinated by Eric Thorsos of the Applied Physics Laboratory of the University of Washington). Evolving details can be found at <<http://www.apl.washington.edu/hfsa-dri/Program/prog.html>>.

Chris Jones of APL (N00014-00-1-0034) and Pete Jumars of the University of Maine (N00014-00-1-0035) are developing a cluster of instruments that allow experimental testing in convenient field sites of the putative effects of organisms whose field abundances can be manipulated. The concept is of a portable acoustic laboratory (PAL) that can be deployed wherever there is a source of power and a data cable for download. In this way mechanisms can be investigated without waiting for an expensive experiment to be fielded. The system currently has 300- and 120-kHz transducers to ensonify the sediments in much the same geometry as XBAMS. The title of both grants is “Effects of Biota on Backscatter: Experiments with the Portable Acoustic Laboratory (PAL).”

Under separate funding, Pete Jumars at the University of Maine is also working with the related phenomenon of emergence by seabed fauna that may influence both surface microtopography and volume heterogeneity. This complementary grant is entitled “Shallow Scattering Layer (SSL): Emergence Behaviors of Coastal Macrofauna” (N00014-00-1-0662).

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