Vibrational Sensing in Benthic Invertebrates

Peter A. Jumars
School of Oceanography
University of Washington Box 357940
Seattle, WA 98195-7940
phone: (206) 543-7615 fax:(206) 543-6073 email: jumars@ocean.washington.edu
Award # N00014-94-I-0656 & N00014-97-1-0643 (AASERT)
http://www.ocean.washington.edu/people/faculty/jumars/jumars.html

LONG-TERM GOAL

My long-term goal is to understand important interactions among organisms, non-living particles (including sediments), solutes and moving fluids. The reason for this goal is to be able to solve interesting forward and inverse problems dealing with marine biota.

OBJECTIVES

My current objectives under this grant are to determine what biological information can be obtained from acoustic backscatter arising at and on both sides of the sediment-water interface. Previous efforts under this grant also included assessments of effects of flow on motion of planktonic diatoms and the abilities of benthic animals to sense vibrations — explaining the grant title, which is now outdated and the current list of publications.

APPROACH

My approach to date has been to work with acoustical oceanographers, specifically with Darrell Jackson and Kevin Williams of the Applied Physics Laboratory and with existing, circularly scanning, bottom-landing sonars, namely BAMS (Benthic Acoustic Monitoring System) and XBAMS. BAMS operates at 40 and 300 kHz, whereas XBAMS operates at only 300 kHz but has higher scan speed and more storage capacity. My approach has been extended more recently to work also with Van Holiday of Tracor Applied Sciences in looking at backscatter caused by animals that migrate out of the seabed after dark and return before sunrise. This phenomenon is better known from tropical reef habitats and fresh water, where it is known as "emergence." TAPS operates at multiple frequencies, but the frequency that shows the phenomenon most clearly in our case is 265 kHz. Both devices were used in the ORCAS experiment conducted in summer of 1995. As part of the ORCAS experiment, we manipulated abundances of several benthic species within the scan region of BAMS. We deployed both BAMS and XBAMS in summer of 1996 within the Strataform program. Our purpose was to benefit from the many covariables measured at the 60-m depth of the deployments and to provide information to Strataform on spatial coherence of biological activities. Our deployment strategy was to have two series of scans at the maximal rate possible for each instrument, separated 10 (40 kHz) or 20 (300 kHz) days with only a few scans. Having two series provided replication in time, and the separation changed phasing of tides and daylight, primary drivers of biological activity cycles. Previous deployments of BAMS and XBAMS did not scan frequently enough to resolve individual bioturbation events, and we hoped to do so. In addition, rapid sonar scanning might allow us to trace individual large animals from pixel to pixel.

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Work completed and in progress has raised many questions that require experimental capability to obtain answers. Acoustic laboratory experiments can be fraught with artifacts due to bubbles and wall echoes, so we have opted to build a shallow-water sonar facility off the end of the Friday Harbor Laboratory pier on San Juan Island, Washington.

WORK COMPLETED

We have completed our analysis of ORCAS data and are collaborating with Mike Richardson of NRL Stennis to combine our data with his for publication. He is planning to provide this second input (the first being a review of our original draft) in early November 1998. We plan to submit the Orcas manuscript (A'Hearn et al.), focused on the results of biological manipulations of the seabed, to Limnology and Oceanography near the end of 1999.

In parallel, we are completing the TAPS data analysis, which is the M.S. project of Ms. Keli Kringel, who is scheduled to defend the work in December 1998. We plan to submit to *Limnology and Oceanography* on about the same time scale.

We have done some analysis of the Strataform data for spatial coherence of change in backscatter and for temporal pattern, along the lines of our published approach (Jumars et al. 1996).

We have acquired the components of a 300 kHz sonar system like that on BAMS and XBAMS but without the circular scan capability and have begun wiring it to the computer network at Friday Harbor Laboratories so that we can obtain data in real time for analysis, obviating the storage limits on BAMS and XBAMS and allowing us to share data with investigators elsewhere via the web.

RESULTS

The ORCAS data revealed some significant treatment effects in the 300 kHz data, but none were found with the 40 kHz. The strongest effects with the 300 kHz data were seen after adding small clams (*Acilla* of mean shell length = 1 cm) and deploying bait to attract near-bed scavengers.

Mysid shrimp dominated the diurnal migrations seen with TAPS. They emerged and returned to the seabed within a few minutes of the same time of day over the entire six-day record and showed characteristic group velocities despite the fact that we were not looking at the same group of shrimp from night to night (as they are advected out of the field of view each night and replaced by another group).

At the Strataform site we encountered extremely high rates of change of total backscatter, much of which seems to be due to demersal plankton rather than to events on and in the seabed. We draw this tentative conclusion because the activity (change in backscatter between successive scans) is correlated strongly with the signal from the upward-looking, 300-kHz ADCP.

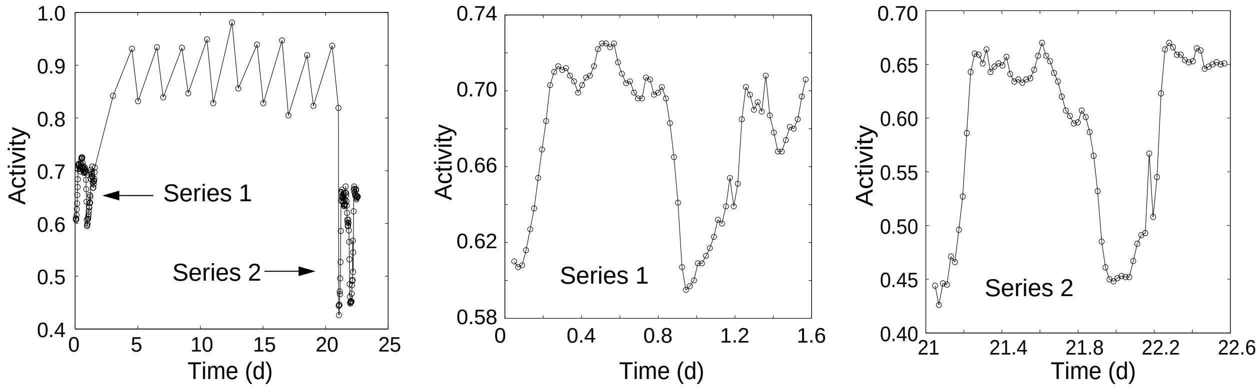

Fig. 1. Activity (1 - arcsine transform of the complex correlation coefficient) seen by XBAMS from 1 - 23 July 1996 at the 60-m long-term monitoring station in Strataform. Scans were taken every 0.5 h in each series and twice daily in between. The diurnal periodicity, with more change in backscatter at night, is striking in both the regularity of the sawtooth (left panel) and the structures of the rapid scan series (right two panels).

IMPACT/APPLICATION

Our work shows suprisingly strong modulation of benthic activity and demersal plankton activity by solar irradiance. Although such phenomena are known for the intertidal and for clear, shallow waters, the pervasiveness and strength of diurnal activity patterns in both benthos and demersal plankton had not been appreciated before this work. The temporal and spatial patterns of biological activity resolved with TAPS, BAMS and XBAMS are unique in marine benthic biology of soft sediments.

TRANSITIONS

The results are being used to help in planning of the ONR DRI on High-Frequency Sound Interaction in Ocean Sediments. Some of the backscatter effects are strong enough that they might limit effective range of acoustic search for mines, especially at a particular times of day.

RELATED PROJECTS

As noted above, our analyses are feeding directly into planning for the ONR DRI on High-Frequency Sound Interaction in Ocean Sediments.

REFERENCES

Jumars, P.A., D.R. Jackson, T.F. Gross and C. Sherwood. 1996. Acoustic remote sensing of benthic activity: A statistical approach. *Limnol. Oceanogr.* **41:** 1220-1241.

PUBLICATIONS (based on past work under this grant)

Jumars, P.A., J.E. Eckman and E. Koch. Animals and plants in benthic flows. pp. in B. Boudreau and B.B. Jørgensen, Eds. *The Benthic Boundary Layer: Transport Processes and Biogeochemistry*. Oxford Univ. Press, NY. (in press)

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