Real-Time Measurements of Sediment Modification by Large Macrofauna

Roberta L. Marinelli
University of Maryland, Center for Environmental Science
Chesapeake Biological Laboratory
PO Box 38
Solomons, MD 20688
phone: (410) 326-7201 fax: (410) 326-7378 email: marinelli@cbl.umces.edu

Grant Number: N00014-0310353

Sarah A. Woodin
Department of Biological Sciences
University of South Carolina
Columbia, SC 29208
phone: (803) 777-5087 fax: (803)777-4002 email: woodin@biol.sc.edu

David S. Wethey
Department of Biological Sciences
University of South Carolina
Columbia, SC 29208
phone: (803) 777-3936 fax: (803) 777-4002 email: wethey@biol.sc.edu

Grant Number: N00014-0310352

LONG TERM GOALS

Marine sedimentary infauna alter acoustic properties of sediments by creating voids and air bubbles, manipulating grain and shell distributions, and creating surface roughness elements. To date there is little information on the rates of change of these sediment properties as a result of infaunal activities. Recent studies suggest that organisms move locally in response to transient ecological and geochemical events. Such movements will create significant change in sediment physical structure on short spatial and temporal scales. Our proposed research addresses a fundamental question in benthic biological oceanography that has strong relevance for naval operations: what causes large infauna to move and how do movements affect sediment acoustic properties? Our research has two thrusts: (1) the development of new technologies to measure, in real-time, organism movements and the effects of these movements on the pressures, voids and surface roughness elements of nearshore sediments; (2) the experimental determination of the ecological and geochemical factors, including organism density, resource availability, and the concentration of reduced metabolites in the porewater, that affect rates of organism movement. These results will allow us to link the behaviors and dynamics of macrofauna to the predictability of acoustic properties of operational importance to the Navy.

OBJECTIVES

We believe organism relocation to be a major source of biological, geochemical and physical heterogeneity and a significant contributor to the population structure and dynamics of sedimentary

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **30 SEP 2003**	2. REPORT TYPE	3. DATES COVERED **00-00-2003 to 00-00-2003**

4. TITLE AND SUBTITLE **Real-Time Measurements of Sediment Modification by Large Macrofauna**	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) **University of Maryland, Center for Environmental Science,,Chesapeake Biological Laboratory,,PO Box 38,,Solomons,,MD,20688**	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	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**6**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

infauna. Our objectives are to examine the processes that promote relocation and the subsequent effects on sediment physical and biological properties. As such, we are measuring rates of movement of large macrofauna in real-time via recently developed technologies and altering these rates of movement via a series of experiments designed to address the causes and consequences of such movements. This research ultimately will lead to fuller understanding and prediction of the processes that control the abundance and distribution of benthic organisms, and spatio-temporal dynamics of sediment physical structure and acoustic properties.

Our proposed research includes experimental field components and uses real organisms. It also advances two technologies for the tracking and measurement of biological and physical properties of shallow water sediments in real-time. Our research fulfills three important goals within ONR's Biological and Chemical Oceanography Program:

- To enable the prediction of the distribution and abundance of biota in shallow water sediments
- To understand how the biota affect the acoustical properties of operational importance to the Navy
- To explore new instruments to sample and observe biological processes and phenomena

APPROACH

In order to understand the mechanisms by which macrofauna control the dynamics of sediment modification, we are measuring in **real-time**: (1) the rate of movement by individual burrowers, (2) the mechanical forces with which they displace sediment, and (3) the rate of creation and destruction of voids and surface roughness elements. These measurements are combined with experiments designed to increase or decrease rates of movement of large macrofauna and thus change rates of sediment alteration. The experiments address fundamental ecological questions concerning immigration, emigration, and resource availability while also addressing the implications for sediment physical structure. Our research is concentrated initially on rates of movements and the physical implications of these movements.

The field and laboratory work is based at the Friday Harbor Laboratories and surrounding habitats. The sedimentary habitats contain high densities of large organisms, which are easy to collect and manipulate, and the investigators have substantial experience with them.

WORK COMPLETED

PIT tags have been used to follow the movements of both infaunal worms and clams in real-time in burrowing organisms in the field. (Woodin and Wethey)
Small pressure transducers have been implanted into intertidal sediments and used to record continuously the infrasounds of burrowing, tube building and irrigation of infauna for up to 1 month at 40 Hz. (Woodin and Wethey)
We have not yet succeeded in measuring voids with a portable ultrasound-imaging device since it was not delivered until after our field season.
We wrote the software necessary to overlay the digital maps of surface activities. (Wethey)
We built and tested our devices for manipulation of porewater concentrations in the field and conducted a preliminary manipulation experiment using these devices. (Marinelli, Woodin, and Wethey)

We have devised the necessary procedures for rapid analysis of a variety of porewater nutrients, and particle-associated properties having significant nutritional value for infauna, including chloropigments and amino acids, via HPLC. These protocols are necessary for the resource availability experiments planned for next summer. (Marinelli)

RESULTS

(1) *Real-time measurement of the rate of movement by individual burrowers:*
We labeled adult polychaetes (*Abarenicola pacifica)* and clams (*Macoma nasuta)* with PIT tags. Tags were injected into the coelom of the polychaetes and were glued on the shell of the clams. The adults were returned to the field and allowed to burrow into undisturbed but marked locations. In order to measure dynamics on long time scales, we established a grid coordinate system, delineated by wooden stakes placed at 0.5 m intervals, in which tagged individuals were implanted. Tags could be detected at depths of 20 cm within sediments. We tracked the movements of the polychaetes for 2-3 days, and the clams for 8 weeks. The polychaetes extruded their tags when they turned around in their tubes, so the worms could not be followed for longer than a few days. Clams moved up to 30 cm, and polychaetes moved up to 40 cm. (Woodin and Wethey)

(2) *Real-time measurement of the mechanical forces with which burrowers displace sediment:*
We recorded large amplitude, species-specific infrasound (0.002 Hz – 0.2 Hz) signals from infaunal organisms, both in the intertidal zone and the lab. Laboratory recordings of single individuals allowed us to identify characteristic infrasounds of Arenicolid and Nereidid polychaetes, and Tellinid bivalves (Fig. 1). In the bivalve *Macoma nasuta*, there were high amplitude infrasound signals associated with burrowing and with siphon movements. In the polychaetes *Neanthes brandti* and *Abarenicola pacifica*, there were high amplitude infrasound signals associated with burrowing and burrow ventilation. These signals were detectable at distances of at least 10 cm. (Wethey and Woodin)

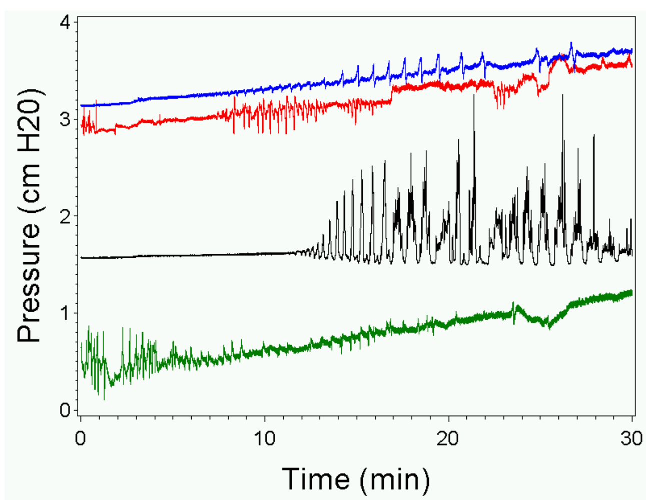

Figure 1. Laboratory recordings of infaunal infrasound. Arenicolid (blue trace) burrowing signal: 0.0125 Hz, maximum amplitude 3 mm H_20. Nereidid (red and green traces) burrowing signal 0.03 Hz, maximum amplitude 4 mm H_20. Tellinid (black trace) burrowing signal 0.02 Hz, maximum amplitude 17 mm H_20.

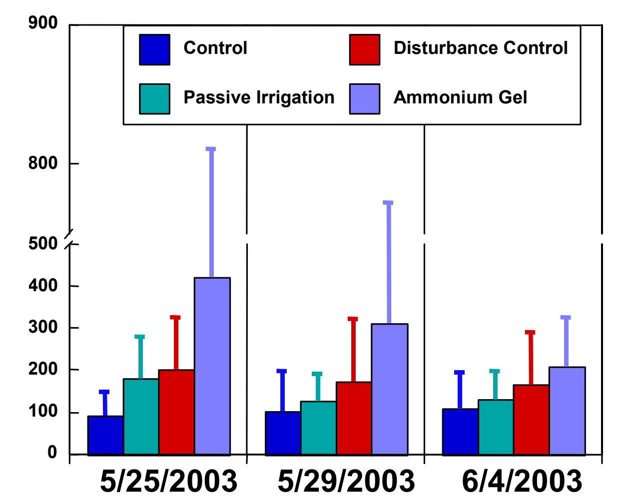

Figure 2. Porewater ammonium concentrations (µM) in field manipulations. Ammonium was lowest in unmanipulated controls, highest in ammonium gel diffuser treatments, and intermediate in disturbance controls and passive irrigation treatments.

(3) *Mapping of movements of large infauna in the field*
Using a modification of digital approaches used by one of us in the rocky intertidal (Wethey), we created the constructs necessary to overlay daily maps of organism locations to determine movements from digital images. Unfortunately the complexity of the sediment surface and the changing nature of the texture, so far has precluded our attempts at background subtraction so the locations of individuals on images must first be determined by hand. (Wethey and Woodin)

(4) *Alteration of concentrations of reduced compounds in the field and its consequences.*
A primary goal of our research is to determine the factors that cause infauna to move and create pressure waves, voids, and inhomogeneities in the sediment fabric. We hypothesized that changes in food availability and alteration of the local geochemical environment were likely to promote significant movements on centimeter scales. In this first year, we conducted an experiment to examine the significance of local geochemical processes to infaunal location and activity, in the absence of food concentration alteration. We attempted to both elevate and reduce the ammonium concentration in sediment porewater through implantation of ammonium-spiked acrylamide gel diffusers (elevated) and passively irrigated flow through tubes (reduced). Controls included unmanipulated sites and a manipulation control (a solid tube with no passive irrigation or acrylamide gel). Our experimental manipulation was partially successful (Fig. 2), with significantly higher ammonium concentrations occurring within the acrylamide gel diffuser treatment on three successive sampling dates (25 May, Ammonium gel > all other treatments, $p=0.0018$; 29 May, Ammonium gel > Passive Irrigation and Control, $p=0.0035$; 4 June, Ammonium gel > Passive Irrigation and Control, $p=0.0035$); however the passive irrigation technique was troublesome due to clogging of the tubes by sediment that was suspended with the incoming tide. We also discovered that the disturbance associated with manipulation caused porewater ammonium to increase, likely the result of adsorption-desorption reactions occurring during sediment disruption, and this increase persisted for at least one week. In spite of these complications, there was a sustained elevation of ammonium in sediments containing acrylamide gels, which significantly exceeded the manipulation artifact; so, we now have a reliable method of elevating solute concentrations in nearshore sediments.

We did not find a trend of higher densities of arenicolid polychaetes in ammonium-enriched sediments relative to unmanipulated sites. We did however observe a number of large arenicolids pressed against the ammonium source at takedown, suggesting a strong affinity for this substance. This finding is in accordance with recent results suggesting that juvenile arenicolids grow faster in high ammonium sediments experiencing light (i.e. shallow sediments in the photic zone), presumably due to greater productivity by benthic diatoms. It also suggests that some large burrowing infauna may locate food patches by following porewater plumes, which we can now test using a combination of acrylamide gels with fluorescein. (Marinelli, Woodin, and Wethey)

(5) *Determination of resource availability*
Prior to manipulating resources such as food, we needed to develop the instrumentation and methodologies necessary for the determination of concentrations of nutritionally significant compounds, including chloropigments and amino acids. We now have the instrumentation in hand and are experimenting with methodologies. (Marinelli)

IMPACT/APPLICATIONS

At the end of this project, we will be able to make quantitative predictions about the dynamics of sediment modification by large macrofauna, and the influence of population density, resource availability and geochemistry on these processes. These results will allow us to link the behaviors and dynamics of macrofauna to the predictability of acoustic properties of operational importance to the Navy.

RELATED PROJECTS

The project of Woodin and Wethey (Grant Number N00014-0310352 Univ. South Carolina) is a collaboration with Marinelli (Grant Number N00014-0310353 Univ. Maryland). As should be obvious from the descriptions of results and the names following each paragraph, these projects are completely intertwined and each requires the participation of the other. This will continue to be true for the duration of the two projects. Marinelli's responsibilities concentrate on determination of the resource base and porewater concentrations while Woodin and Wethey's responsibilities are centered on measurements of individual movements of the infauna and the technology to detect those movements without excavation. The experiments involve manipulations of the resource base in ways designed to ask how the infauna respond in terms of emigration and immigration, clearly the skills of all three investigators are necessary for success.

These projects are both also related to those of Bernard Boudreau (N00014-0210107), Peter Jumars (N00014-0210091, N00014-0210653, and N00014-0010035), and Larry Mayer (N00014-0210653—collaboration with Dr. Jumars). All three are interested in the movements of infauna and their bioturbation activities. Dr. Boudreau's lattice automata models actually require the information on infaunal movements and void creations that we are collecting. We have been discussing those models with him for the past year and clearly plan to continue to do so. Dr. Mayer and Dr. Jumars' interest in nutritional control of bioturbation is clearly linked to our planned experiments on whether infauna responds via movements to resource changes. Additionally Dr. Jumars has been involved for some time in analysis of acoustic signals both of sediments and near bottom events, which is obviously of interest to us. We have initiated conversations with all three investigators and spent time in Maine in March with Drs. Jumars and Mayer. We are planning to meet at least Drs. Boudreau and Jumars at the ASLO meeting in February 2004 to discuss progress and possible collaborations.