Animal-Sediment Interactions Relevant to Shallow-Water Boundary-Layer Flows and Sediment Transport

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LONG-TERM GOALS

The long-term goals of this research are to identify conditions where existing abiotic, sediment-transport models would make reasonably accurate predictions, and to identify the key, biologically relevant parameters that would improve sediment-transport models to account for biological effects. Ultimately, this research would contribute to a new generation of models that could provide meaningful sediment-transport predictions which are meaningful for both biotic and abiotic conditions.

OBJECTIVES

The objectives of this study are to obtain estimates of the seafloor area covered by dense assemblages of organisms that are likely to affect sediment transport in high-energy, very shallow water (<15 m), sandy environments and to quantify the effects of these organisms on near-bed flows and sediment transport in a laboratory flume. The project consists of three components: technology development (FY96), field observations and sampling (FY97), and laboratory flume studies (FY98). The specific objective of the research conducted during FY98 was to determine how dense assemblages of sand dollars (*Echinarachnius parma)* affect the transport of sands, and how the flow and sediment-transport environment may shape the distribution of this species.

APPROACH

Faunal surveys conducted during FY97 off the south shore of Martha's Vineyard Island, MA, mapped relatively dense (up to 55 per m^2) populations of the sand dollar *Echinarachnius parma.* This organism was the most abundant surface-visible macrofaunal species occurring in these sandy (250 µm) sediments, whereas a spionid polychaete (*Spiophanes bombyx*) dominated the shore-perpendicular, ~100 m wide "mud belts" in this region. Sand dollar aggregations are a pervasive feature of sandy nearshore sediments, sometimes occurring in startling abundances (e.g., several hundred per square meter). Yet virtually nothing is known about the effects of these organisms on the flow and sediment-transport environment. Thus, flume studies during FY98 were designed to determine if *E. parma* populations have significant effects on sand transport. Because knowledge of the factors that control sand dollar distributions is required in order to predict locations likely to contain dense aggregations, flume studies are also being conducted on the effects of the flow and sediment-transport regime on sand dollar ecology.

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WORK COMPLETED

Sand dollar (*E. parma*) populations of 45 and 150 per m^2 were placed in the test section of a 17-m long flume (test section locatied 12.5 m from channel entrance). The entire flume bed upstream of the test section was covered with sand (250 µm). Earlier flume runs in the absence of biota established the critical erosion velocity of this sand, and characteristics of the bed when sand was transporting as bedload. Flume runs with sand dollars were conducted in subcritical flow (i.e., below the threshold for sand transport under abiotic conditions).

RESULTS

Sand dollars added to the flume burrowed immediately. Most of the animals were very mobile, moving just below the sand surface, plowing a furrow they go. A few individuals crawled along on top of the sediment bed. Most individuals moved laterally or downstream, but a few individuals moved considerable distances upstream. This species is reported to deposit feed by entraining particles (primarily diatoms, we think) from their aboral surface. These particles then are transferred around the ambitus (the periphery) to the oral surface and then to the oral food grooves. Presumably the plowing behavior enhances contact with diatom-laden sand.

At the highest sand-dollar density (150 per m^2), ripples quickly (within 30 min) formed within and downstream of the sand dollar bed. The ripples became more well-developed with time and eventually migrated downstream of the sand dollar bed. No ripples formed upstream of the bed. At the lowest sand-dollar density (45 per m^2), disturbances to the sediment bed developed immediately downstream of the more exposed sand dollars, but these disturbances did not coalesce into a ripple field. These observations are similar to those obtained in our earlier study of the effects on sand transport of fecal mounds produced the head-down, deposit-feeding polychaete *Cistenides gouldii* (Fries et al., in press). In this study, migrating ripple beds were also produced in dense mound arrays at subcritical flow.

The mobility and plowing behavior of the sand dollars was intriguing because it is, no doubt, energetically costly to be in near-constant motion foraging for “fresh” (diatom-laden) sand. Thus, we are conducting experiments to determine if, under simulated field conditions, sand transport in a migrating ripple field would bring relatively fresh sand to the animals, thus decreasing their need to forage actively. That is, during bedload transport, the sand dollars may simply sit and wait for sand to pass overhead, whereas in more benign flows they would need to plow through the sand in search of fresh material. These experiments test this hypothesis by quantifying sand dollar mobility under flat bed and migrating ripple conditions. The prediction is that there will be substantially decreased sand dollar mobility when sand is transporting. Such experiments are underway.

IMPACT/APPLICATION

Sedimentologists have long regarded sandy nearshore sediments as biological deserts with negligible impact on nearbed flows and sediment transport. In contrast, some sedimentologists now concede that benthic biology in offshore muddy sediments can sometimes have a significant effect on sediment transport. Two goals of this study were to determine (1) if the assumption is valid that nearshore sands are biologically impoverished, and (2) if a dense assemblage of sand-dwelling organisms can significantly affect sand transport. Most biological surveys have focussed on intertidal beaches or subtidal areas that are not affected by the substantial wave action experienced on south-facing beaches such as our Martha’s Vineyard study site. In fact, the exposed high-energy “inner shelf” — the region from a few meters depth to a few 10's of kilometers offshore — is probably the most biologically and physically undersampled coastal environment.

This study demonstrates that two species (the sand dollar *Echinarachnius parma* and the polychaete worm *Spiophanes bombyx*) of relatively large, surface-visible benthic organisms live in sufficiently high abundances on the inner shelf to potentially affect sediment transport. Moreover, field surveys with a spatial resolution of 10's of meters clearly were necessary to document the boundaries of the mud belt and the association of the tube worms with it. The flume studies indicate that dense populations of sand dollars sufficiently enhance the bed stress such that sand transports in subcritical flow. Thus, an abiotic critical flow criterion does not apply in such regions, a limitation that should be of particular interest to those researchers using visual observations of ripple fields to infer flow conditions.

This information should be of great interest to nearshore sedimentologists or oceanographers who have been assuming that (1) high-energy nearshore areas consist of sands only (i.e., that mud patches could not persist in such physically reworked regions), and (2) there is negligible biology in sands and thus abiotic sediment transport models apply.

TRANSITIONS

The recent shift in focus of Naval operations from deep water to nearshore coastal regions has resulted in enhanced development of research programs on various aspects of mine countermeasures — the detection, identification and neutralization of mines — in depths from the beachface to “very shallow water” (10-40 m). Predicting the distribution of mines in such regions requires models that incorporate all relevant transport parameters. Thus, transitioning the results of this biological study to nearshore physical oceanographers and sedimentologists who use models to predict sand transport should enhance the accuracy of their model predictions, predictions that could be an invaluable for a variety of mine countermeasures activities.

RELATED PROJECTS

The results of this study should facilitate interpretation of the generality of point measurements used to predict sediment transport in nearshore regions, such as those made during ONR’s SandyDuck Program.

REFERENCES

Fries, J.S., Butman, C.A. and Wheatcroft, R.A. in press: Subcritical ripple formation induced by biogenic mounds, Mar. Geol.

PUBLICATIONS

Sisson, J.D., Shimeta, J. and Butman, C.A. submitted: A method for mapping surficial benthic assemblages with meter-scale resolution over kilometer-scale areas of the shallow subtidal, Mar. Ecol. Prog. Ser.