

Short communication

Depth of activation on a mixed sediment beach

Sherestha Saini^a, Nancy L. Jackson^{a,*}, Karl F. Nordstrom^b^a Department of Chemistry and Environmental Science, New Jersey Institute of Technology, Newark, NJ 07102, USA^b Institute of Marine and Coastal Sciences, Rutgers University, New Brunswick, NJ 08901, USA

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ABSTRACT

The relationship between wave height and depth of sediment activation is evaluated on an estuarine beach to determine whether activation depth is less in pebbles than sand. Rods with washers were used to monitor three excavated beach plots filled with (1) pebbles with mean grain size of 11.5 mm; (2) sand and granules; and (3) sand, granules and pebbles. Plots were monitored for 26 events over 27 days. Significant wave heights ranged from 0.18 to 0.40 m and activation depths from 0.02 to 0.12 m. Activation depths in the pebble plot were less than the other two plots when waves reworked sediment not activated during previous tidal cycles. Proportionality coefficients for activation depth to wave height, when net change was <0.02 m, were 0.24 in the pebble plot and 0.30–0.31 in the other plots when experimental fill sediments remained and 0.22 to 0.23 in all three plots over the entire monitoring period, which included activation of newly deposited native sediment. Results suggest that for similar wave heights, activation depths in pebbles is lower than in sand, granules and pebbles or sand and granules, but once waves have reworked the sediment there is little difference in activation depths.

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1. Introduction

Knowledge of sediment mixing and activation across the surf and swash zones is important for calculating rates of sediment transport (Kraus, 1985; Sherman et al., 1994) and understanding disturbance or dislodgement of fauna (Denny, 2006). The characteristics of waves, topography and sediments are important in predicting the thickness of the active layer over periods of minutes to hours (sediment mixing) or tidal cycles or storm events (sediment activation). Increases in sediment mixing and activation depth with increasing breaking wave heights are documented in field studies, revealing a general linear relationship with a proportionality coefficient ranging from 0.02 to 0.40 (King, 1951; Kraus, 1985; Jackson and Nordstrom, 1993; Sherman et al., 1994; Ciavola et al., 1997; Masselink et al., 2007). Investigations suggest these coefficients vary with morphodynamic state or location in the surf or swash zone.

Most field studies were conducted on beaches composed of sand, where the relationship between grain size and sediment mixing and activation can be weak (Ciavola et al., 1997). King (1951) found that activation depths were greater on a medium sand beach (0.40 mm) than on a fine sand beach (0.20–0.29 mm), which was attributed to greater turbulence associated with waves breaking directly on the steeper coarser-sand beach. The Sunamura and Kraus (1985) model indicates that mixing depth in the surf zone is a weakly increasing function of sediment size for breaking wave heights less than 1.5 m in

sand-sized sediment (0.20, 0.40 and 0.60 mm). They note that the model may underpredict mixing depth on beaches where turbulence associated with plunging breakers and swash/backwash interaction are more influential than wave-induced bed stress in a surf zone.

Results of these field and model studies suggest that mixing and activation depth in surf zones will increase with breaking wave height in fine to coarse sand, but this relationship has rarely been evaluated in mixed sand and gravel populations (Kraus, 1985; Masselink et al., 2007). Kraus (1985) measured sediment mixing on a steep beach with coarse sand and pebbles and found that mixing depths could be greater or less than predicted by breaking wave height. Interest in mixed sand and gravel beaches is increasing as more gravel is used for beach nourishment (Buscombe and Masselink, 2006). Our study was conducted to assess the effects of three types of sediment on depth of activation on an estuarine beach. Sediment types consisted of: only pebbles; sand and granules; and sand, granules and pebbles. Most previous investigations of depth of activation compared sites with contrasting hydrodynamic and morphologic characteristics. This study controls for the variability in wave height, wave period and foreshore slope by comparing activation depths in different sediment types on the same beach.

2. Study area

The field site, Slaughter Beach, is on the west side of Delaware Bay near the mouth of the estuary (Fig. 1). Tides are semi-diurnal with a mean range of 1.4 m and a spring range of 1.7 m (NOAA, 2006). Dominant waves are generated within the estuary by local winds. Plunging waves break on the foreshore and are converted directly into

* Corresponding author.

E-mail address: jacksonn@njit.edu (N.L. Jackson).

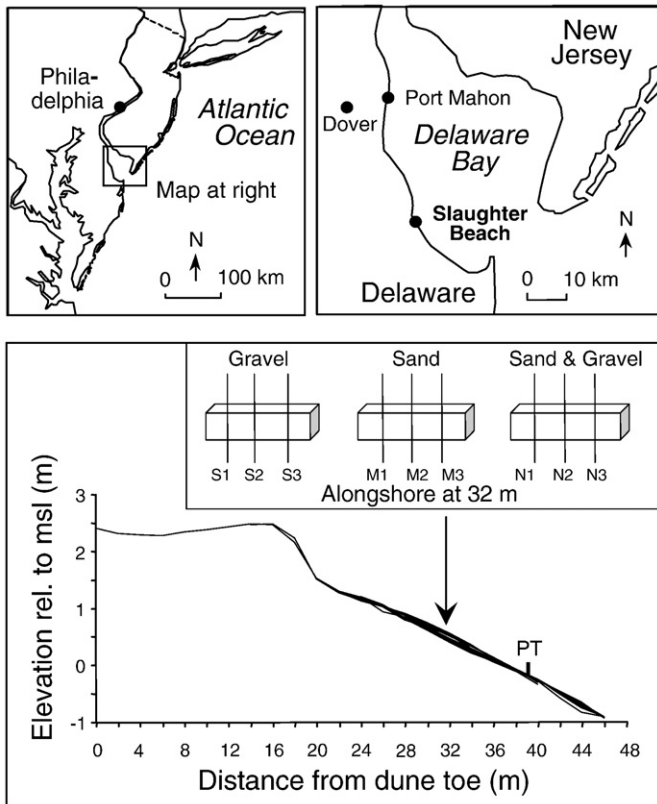


Fig. 1. Locations of study area, beach profiles, experimental plots and pressure transducer (PT).

swash without passing through a surf zone. In 2005, the state of Delaware modified this beach through artificial nourishment and dune construction. The planar foreshore is steep (9.0°) and approximately 20 m wide during spring tides. Sediments are predominantly quartz and feldspar sands. Like most sandy estuarine beaches, there is a conspicuous gravel fraction (Nordstrom and Jackson, 1993).

3. Methods

Field data were collected from 20 May to 16 June 2006 in three mid foreshore plots, excavated and refilled with sediment having different grain size distributions. The plots (Fig. 1) measured 0.75 m alongshore, 0.30 m across the shore and 0.15 m deep and were separated from each other by 0.17 m. Sediments used to fill plots were collected from the dry backshore and passed through a 4 mm sieve. The cutoff of 4 mm was used because the granule fraction (2–4 mm) is transported within the sand population on estuarine beaches rather than with the coarser sediments (Nordstrom and Jackson, 1993). Sediment retained on the sieve (all pebble-sized) was used in Plot 1. Sediment that passed through the sieve (sand and granules) was used in Plot 2. Unsieved backshore sediment (sand, granules and pebbles) was used in Plot 3. Sediments were physically compacted. Three steel rods of 10 mm diameter were emplaced alongshore within each of the three plots (Fig. 1). A loose fitting washer was placed over each rod, and net change (top of rod to beach surface) and depth of activation (top of rod to washer) were measured to the nearest mm during daylight low tide 20 May to 14 June (26 events). Washers were relocated to the surface after each measurement.

Wave heights were measured with a pressure transducer on the lower foreshore, 7 m bayward of the plots (Fig. 1). The data used here

represent times when water level was at the location of the plots at either the rise or fall of the tide, depending on when wave heights were greatest. Significant wave heights were used to allow comparisons with other field studies in estuarine environments (Jackson and Nordstrom, 1993; Sherman et al., 1994). The cross-shore edges of the plots were excavated at the end of monitoring to determine the depth of the boundary between the reworked and unworked plot fill. Bulk sediment samples of about 350 g were collected from the fill materials on the backshore when plots were established and to a depth of 0.10 m in the three plots after eight tidal cycles. This depth was below the maximum activation depth measured during the time interval. The samples were washed, dried, sieved at 0.5 ϕ intervals and analyzed according to Folk (1974).

Depths of activation are calculated using each pre-event surface. In most cases, activation measurements were made within one or two tidal cycles. One exception was recovery of the washers on 03 June after a storm occurred on 31 May. Cases where the average depth of activation was below the initial surface elevation of the plots at the beginning of monitoring, on 20 May, were analyzed using a one-way analysis of variance. A Tukey HSD test was run to determine significant differences between the three plots. The Anderson-Darling test of

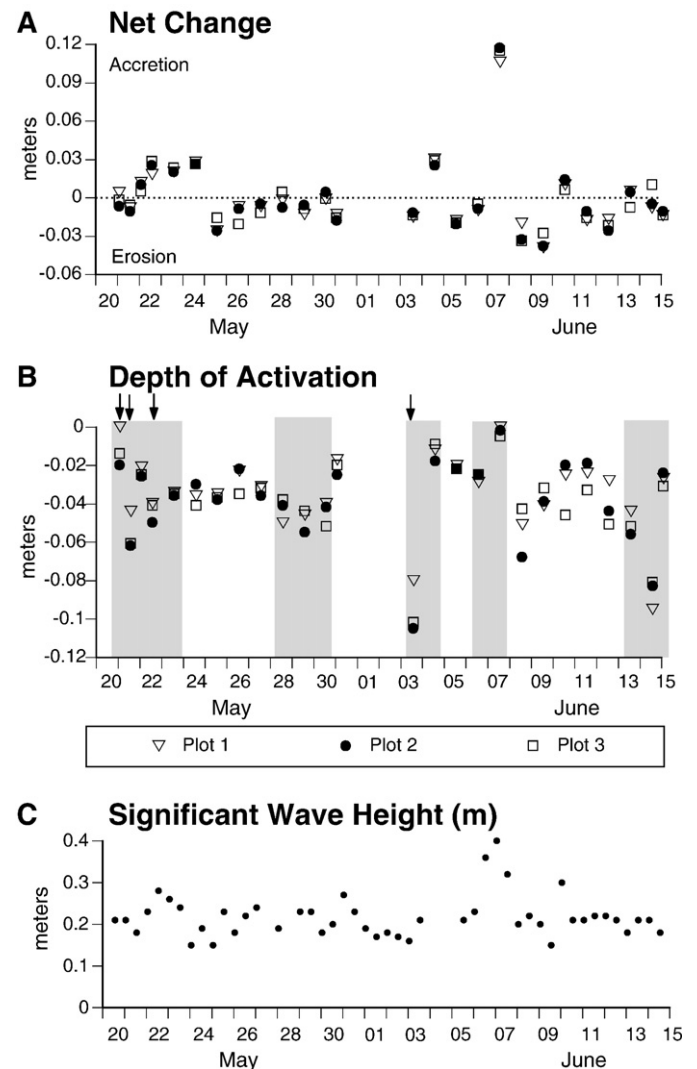


Fig. 2. Mean net surface elevation change (A), depth of activation (B) of the three rods in each plot and significant wave height monitored on the lower foreshore (C). Shaded areas indicate events when activation depths penetrated below the initial surface elevation of the plots measured on 20 May. Arrows identify events described in text.

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