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Constraints on aeolian sediment transport to foredunes within an undeveloped backshore enclave on a developed coast

Kayla L. Kaplan [a], Karl F. Nordstrom [b], Nancy L. Jackson [a,*]

[a] Department of Chemistry and Environmental Science, New Jersey, Institute of Technology, Newark, NJ 07012, United States
[b] Department of Marine and Coastal Sciences, Rutgers University, New Brunswick, NJ 08901, United States

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ABSTRACT

Landforms present in undeveloped beach enclaves located between properties developed with houses and infrastructure are often left to evolve naturally but are influenced by the human structures near them. This field study evaluates how buildings and sand-trapping fences change the direction of wind approach, reduce wind speed, and restrict fetch distances for sediment entrainment, thereby reducing the potential for aeolian transport and development of dunes in enclaves.

Field data were gathered in an 80 m long, 44 m deep beach enclave on the ocean shoreline of New Jersey, USA. Comparison of wind characteristics in the enclave with a site unaffected by buildings revealed that offshore winds in the enclave are reduced in strength and altered in direction by landward houses, increasing the relative importance of longshore winds. Vertical arrays of anemometers on the foredune crest, foredune toe and berm crest in the enclave revealed increasing wind speed with distance offshore, with strongest winds on the berm crest. Vertical cylindrical traps on the foredune crest, foredune toe, mid-backshore, berm crest and upper foreshore revealed the greatest rate of sediment transport on the berm crest. Sediment samples from the beach and from traps revealed limited potential for aeolian transport because of coarse grain sizes.

Strong oblique onshore winds are common in this region and are normally important for transporting sand to dunes. The length of an enclave and the setback distance on its landward side determine the degree to which sediment delivered by oblique winds contributes to dune growth. The landward edge of the enclave (defined by a sand fence near the dune toe) is sheltered along its entire length from winds blowing at an angle to the shoreline of 25° or less. A foredune set back this distance in an enclave the length of an individual lot (about 20 m) would be sheltered at an angle of 57° or less, reducing the opportunity for dune building by onshore winds. Reduced potential for aeolian transport in enclaves implies that human actions may be required to build dunes artificially to protect buildings and roads from storm overwash.

1. Introduction

Human development of the coast is expanding, resulting in ever-increasing modifications or losses of natural shoreline landforms and habitats (Defeo et al., 2009, Hernandez-Calvento et al., 2014). The losses may be direct, caused by replacement of beaches and dunes by buildings, roads and parking lots, grading of beaches and dunes to facilitate recreational use, or raking and driving on the beach (Kelly, 2014). Losses also may be indirect, caused by stabilizing shoreline position with shore-parallel protection structures (i.e. seawalls and bulkheads), which truncate the beach in areas of persistent erosion (Hall and Pilkey, 1991; Dugan et al., 2008). The ever-increasing costs of preventing damage to coastal properties or compensating property owners for erosion-related damages have resulted in calls to implement land-use controls to mitigate hazard risks or reduce the number of structures subject to damage (National Research Council, 2014). Managed retreat and coastal construction setbacks provide the opportunity to retain or establish backshore and dune environments and are appropriate in locations where infrastructure is sparsely developed or is expendable and can be removed (Berry et al., 2014).

Removal of buildings near the beach can create undeveloped enclaves of wide sandy backshores bounded alongshore by developed segments of shoreline. Surveys following major storms reveal many locations where damaged houses could be removed to allow shorelines to evolve naturally in these kinds of enclaves (Platt et al., 2002). The number of damaged houses is likely to increase in the future as erosion continues and sea level-rises. Google Earth images for 2013 after Hurricane Sandy, occurring in October 2012, revealed 72 enclaves in a 16-km-long shoreline segment north and south of Bay Head, New Jersey (Fig. 1A) — the region where the storm made landfall. These enclaves, which can be single or multiple lots, have an average length of 38 m and width of 25 m. The enclaves are bounded by buildings on the

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

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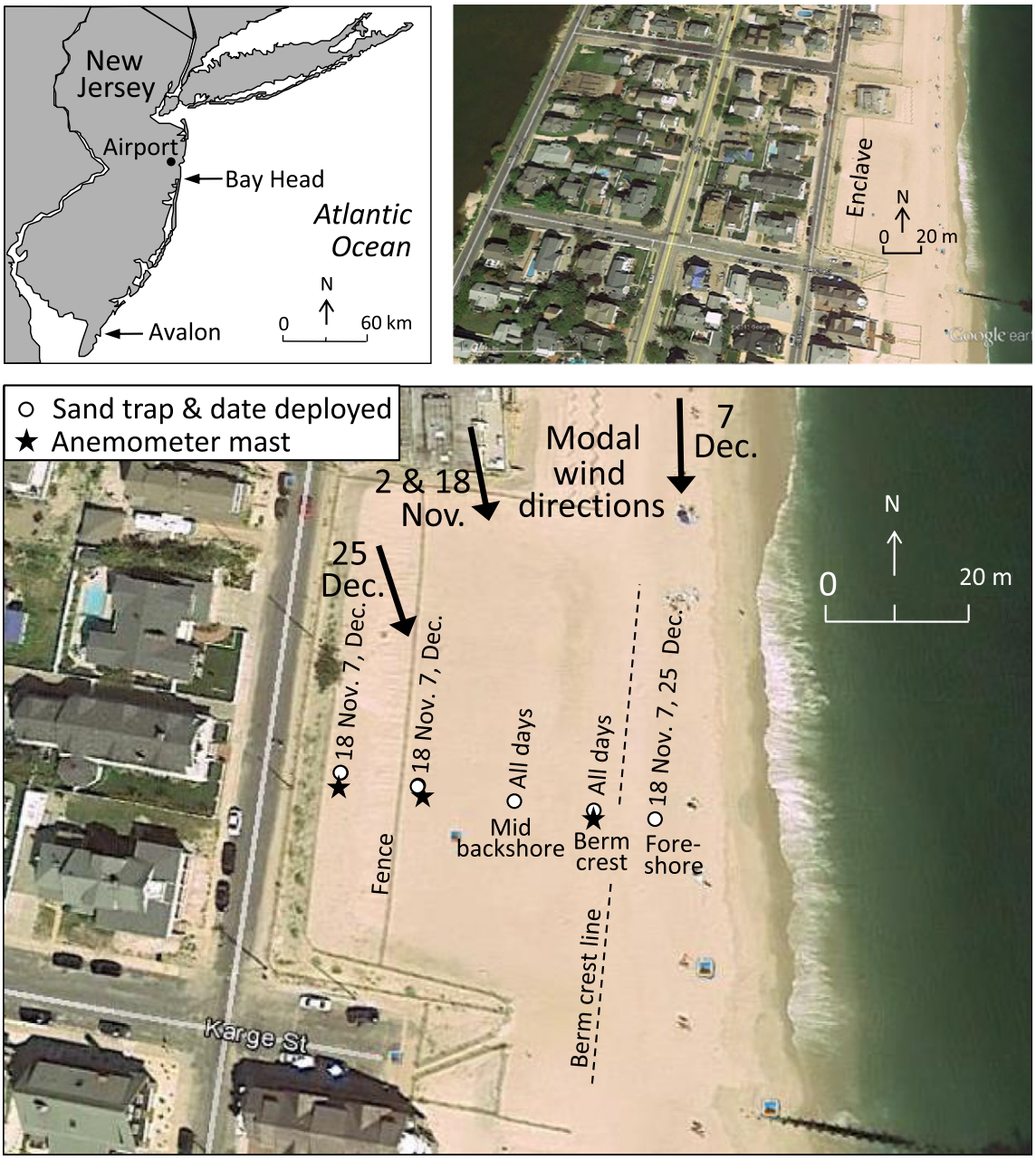

Fig. 1. Study site, showing location of Bay Head relative to the airport (A), relationship of buildings and infrastructure to the beach (B) and location of instruments and traps relative to the wind directions monitored (C).

north and south sides, with the majority located between two residential houses (Fig. 1B).

Maintaining undeveloped sandy beach enclaves within lengths of shoreline developed with houses offers environmental opportunities not otherwise available (Kelly, 2014). Enclaves add to shoreline complexity alongshore and across the shore (Jackson et al., 2015). Processes and landforms within these local enclaves may not mimic conditions in adjacent developed areas or in larger, unconfined natural areas that are managed as parks or preserves.

Under natural conditions, the position of the beach/dune contact is determined by the balance between accretion of wind-blown sand at seaward-growing vegetation or wrack lines, juxtaposed against erosion of that accretion by storm wave run-up (Hesp, 1989; Kuriyama et al., 2005; Nordstrom et al., 2007). Dunes fronting buildings are often found seaward of the cross-shore position where natural dunes would be because houses, roads and parking lots are often built where the foredune would be (Morton et al., 1994; Nordstrom, 2000), and attempts are made to build and maintain a dune seaward to protect infrastructure. Dunes in developed areas are valued primarily for shore protection and can be created by a variety of natural and human processes, including bulldozing, aeolian accretion at sand fences or artificial vegetation plantings that help maintain the dunes farther seaward than their natural equilibrium position.

The evolution of dunes within enclaves that are left to evolve naturally will depend, in part, on the type and location of human alterations adjacent to them and within them. Sediment transport into and within enclaves will be influenced by wind modification in the lee of buildings surrounding the enclave as well as by fetch constraints (limitations on width of unconstrained sand sources) imposed by buildings and sand fences on the backshore. Wind speeds decrease in the lee of these structures as a result of their height, width, configuration, and density (Nordstrom and McCluskey, 1985; Hotta et al., 1987;