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Topography, vegetation cover and below ground biomass of spatially constrained and unconstrained foredunes in New Jersey, USA

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ABSTRACT

Space for dunes is often limited in developed areas, placing increased importance on human efforts to aid dune-building. This study assesses how different management strategies influence dune topography, surface cover and below ground biomass of vegetation on four dune segments in New Jersey in two successive years. Two segments are evolving without human actions, one with a cover of native vegetation (*Ammophila breviligulata*) and one with an invasive exotic (*Carex kobomugi*). Two segments are in developed areas and are maintained using sand fences, vegetation plantings and bulldozers; one of these segments uses bulldozers to bury a seawall.

The foredunes evolving naturally are wider than foredunes in the developed segments and have more topographic variability alongshore. Foredunes in the developed segments are narrower because sand blown or washed landward is recycled. The naturally evolving *A. breviligulata* dune segment had the sparsest vegetation cover; the segment maintained mainly by sand fences and vegetation plantings had the densest cover. The crest of developed dunes can be higher than the crest of natural dunes with the same vegetation type and similar beach widths, but sediment volume may be restricted if the dune cannot migrate inland. Planting programs hasten dune accretion and are especially valuable on the dune ramp following wave erosion. Species dependent on mobile dunes can be favored where landward infrastructure is not threatened; species dependent on stable dunes can be favored in developed areas. Dune veneers placed over seawalls are temporary, but seawalls can favor evolution of stable-dune species landward of them.

1. Introduction

The coastlines of many countries are developed with buildings and infrastructure that are placed in locations susceptible to flooding and wave erosion. Development continues, even as the physical drivers of coastal change (sea level rise and storm frequency and magnitude) are projected to increase the likelihood of inundation and erosion (Webster et al., 2005; Bindoff et al., 2007; NRC, 2014). Beaches and dunes provide a natural buffer to protect human structures from these hazards. The protection provided by dunes is a function of their size and ability to survive erosion by waves and deflation by wind. The beach provides a buffer against wave attack, a source of sediment to the foredune, and a space for dunes to grow. Dunes play a key role in providing elevation to protect against flooding, but the limited space available for these landforms to build by natural processes in developed areas often restricts their size and longevity, placing increased importance on active management (Jackson and Nordstrom, 2011).

The location, size and stability of dunes can be enhanced using sand-trapping fences and vegetation plantings. These adjustments have a centuries-long history of use and have been subject to many investigations (e.g. Woodhouse, 1967; Schwendiman, 1977; Hotta et al., 1987, 1991; Skarregaard, 1989; Avis, 1995; Mendelssohn et al., 1991; Miller et al., 2001). The increasing need to overcome temporal and spatial constraints to natural dune building has placed emphasis on use of bulldozers to speed dune formation (Wells and McNinch, 1991; McNinch and Wells, 1992) and using hard cores within dunes that are not expected to survive for long (Nordstrom, 2014). These artificially constructed or maintained dunes are subject to reworking by natural processes (Conaway and Wells, 2005; Smyth and Hesp, 2015), leading to interesting nature-human hybrids. Recent emphasis on restoring native species in

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dunes previously stabilized by exotic species has complicated management decisions by suggesting restoration projects that create more mobile dune landscapes with greater ecological value but less value for protecting human structures (Hilton et al., 2005; Wootton et al., 2005; Walker et al., 2013; Pye et al., 2014; Konlechner et al., 2015).

Our study assesses the way alternative dune-building strategies influence dune morphology and vegetation characteristics by conducting topographic surveys and measuring surface cover, below ground biomass of vegetation, and sediment grain size. Data on these characteristics were gathered on four different dune segments in three jurisdictions on the developed shoreline of the State of New Jersey, USA (Fig. 1) in successive years in the autumn of 2015 and 2016. New Jersey was selected for study because foredunes are an important component of efforts to mitigate wave overwash and flooding there, and bulldozing, fencing and vegetation plantings are all used to maintain the dunes in developed areas. Dunes where sediment delivery is solely by aeolian sediment transport are found in parks and conservation areas.

Storms of different intensity and magnitude can have different levels of impact on beaches and dunes. Runup may be confined to the foreshore; runup may reach the dune and erode (scarp) the seaward portion; runup may overtop the dune (overwash) resulting in landward sediment transport; and storm surge may submerge the beach and dune (Sallenger, 2000). Post-storm management efforts may require totally rebuilding dunes (following the overwash scenario) or aiding recovery of a portion of the dune (such as following dune scarping). In some cases, elimination of the beach may reduce the potential for dune building to the point where the protection must be provided by shore-parallel walls.

The dunes evaluated here are in four shoreline segments that are managed at different levels of intensity. Two segments (both at Island Beach State Park) are evolving with little human action; one of these segments has a cover of native vegetation and one has an invasive exotic. Two dune segments are managed more intensively. Dune growth and stabilization in one of these segments (Seaside Park) are aided by sand fences and vegetation plantings. Dune growth and stabilization in the other segment (Bay Head) are aided by bulldozing, sand fences and vegetation plantings. A seawall was built in Bay Head to provide additional protection. Dunes in all locations are fronted by sand beaches with a mean size in the range of medium to coarse sand. Previous studies in this region quantified amounts of aeolian transport and topographic changes (Gares, 1990, 1992; Gares and Nordstrom, 1995; Kaplan et al., 2016), and evaluated the vegetation types used for stabilization, with a special emphasis on the invasive species *Carex kobomugi* (Wootton et al., 2005; Charbonneau et al., 2016).

Management of beaches and dunes is governed by state law (N.J.A.C. 7:7E Coastal Zone Management Rules). Coastal management rules apply to natural dunes with no active management, dunes modified to provide a protective barrier or enhance ecosystem function, and dunes engineered according to a federal or state design template. The state Coastal Zone Management Rules encourage communities to manage foredunes as barriers to storm waves and flood inundation. New Jersey law adopted provisions by the US Federal Emergency Management Agency under the National Flood Insurance Program (NFIP) for creation of dunes for shore protection. According to NFIP Regulations, primary frontal dunes are not considered effective barriers to base flood storm surges and associated wave action if the cross-sectional area of the dune perpendicular to the shoreline above the 100-year still-water flood elevation and seaward of the dune crest, is less than 1100 ft^2 (102 m^2).

Local communities receive a permit from the state to conduct beach and dune maintenance activities. Permitted activities that enhance the protective function of the dune include bulldozing sediment from the lower to the upper beach as part of an emergency post-storm restoration plan, placement and/or repair of sand fencing and planting and fertilizing dune vegetation. The Public Works Department of each municipality generally assumes responsibility for post-storm transfers of sediment to enhance dune recovery and placement of sand trapping fences to increase dune height and width. The Environmental Commission in each municipality is generally responsible for oversight of planting dune vegetation, based on a landscape plan submitted to the state. Vegetation planting should be diverse and limited to species native to the state. Use of American beachgrass (*Ammophila breviligulata*) is recommended for stabilization of foredunes.

2. Study area

Many of the former foredunes in this part of New Jersey were severely eroded by storm waves during Hurricane Sandy in October

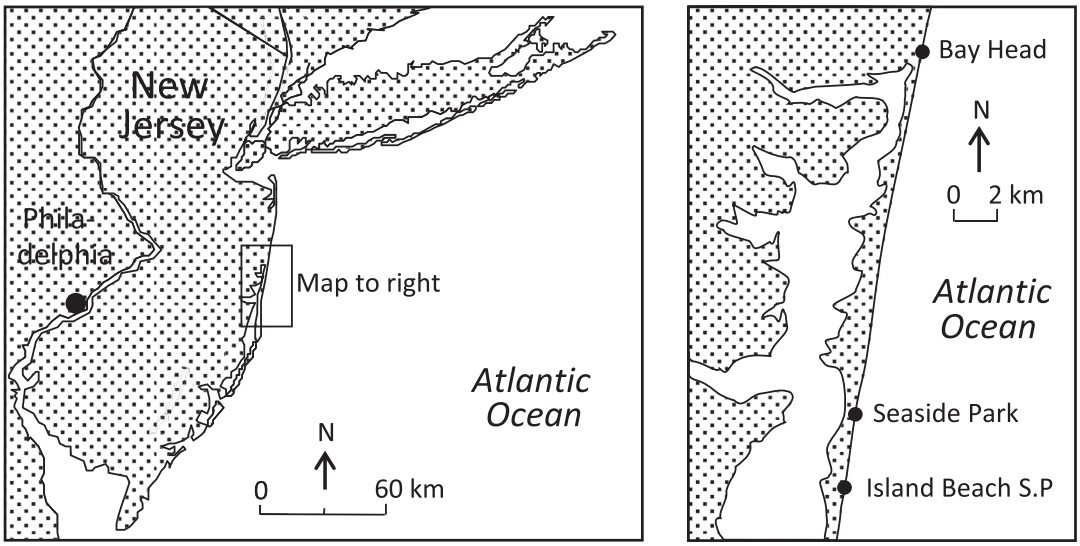

Fig. 1. Location of study sites.

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