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Removing shore protection structures to facilitate migration of landforms and habitats on the bayside of a barrier spit

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ABSTRACT

Coastal landforms and habitats require space to reform in response to storm damage to increase the likelihood of long-term sustainability. The purpose of this study is to evaluate the potential for removing shore protection structures to allow natural shoreline processes to prevail as part of a strategy to adapt to sea level rise associated with climate change. The location of the study was Sandy Hook Spit, New Jersey, a site managed by the U.S. National Park Service (NPS). A field investigation was conducted to identify the structures that impede migration of landforms and habitats, the function of each structure in protecting resources, and the opportunities to facilitate landform migration by removing the structures or allowing them to deteriorate.

Nineteen shore-parallel walls are present along the ocean and bay shore of a 10 km long portion of the spit. Most of the shore protection structures were built when the spit was formerly used by the US Army, and many bulkheads on the bay shore have deteriorated. Sediment will become available to the longshore transport system where protection structures are removed, contributing to spit growth at the ends of drift cells, possibly mimicking the spits that were more conspicuous on the bay shore prior to human alterations. Observations indicate that new habitat can be created by loss and re-creation in a different location by longshore extension, not just by landward migration. Allowing shore protection structures to deteriorate will leave human infrastructure in the landscape. Removing these structures is more costly but can result in a more rapid reversion to a natural system. The time horizon is critical in determining the social, political and economic feasibility of removing structures and the expectations for geomorphic and habitat change. The feasibility of protecting threatened buildings and roads will decrease in the future as sea level rises and the existing protection structures degrade or fall below new design standards. We suggest that functional buildings with less historic value remain in use until threatened by erosion, but little reason exists to build new structures to protect them. A case is made for allowing developed sites to revert to natural processes to establish a precedent and provide good demonstration areas for promoting stakeholder acceptance of retreat strategies.

1. Introduction

Natural barrier island ecosystems and associated habitats, including beaches, dunes and maritime forests, retreat with sea-level rise and storms, often retaining or reinstating the basic form and function while moving landward (Leatherman, 1979; FitzGerald et al., 2008). Salt marshes are also dynamic environments, increasing in elevation or migrating inland as sea level rises (Redfield, 1965; Donnelly and Bertness, 2001). Under conditions of sea level rise, coastal landforms and habitats change morphology and location based on local conditions such as wave energy, sediment supply, and surface elevation. Under conditions of transgression, landforms and habitats require space to migrate to enhance ability to reform in response to storm damage and increase the likelihood of long-term sustainability. Without this ability to migrate, coastal landforms will be eroded in place or inundated. Shore protection structures (including bulkheads, seawalls, groins and jetties) can impede natural sediment transport processes, change morphology and serve as barriers to landform migration (Pilkey and Wright, 1988; Hall and Pilkey, 1991). These structures degrade through time, and eventually, a decision must be made to alter them to meet new management requirements.

Alternatives for altering existing shore protection structures include rebuilding them, repairing them, protecting them from scour by waves and currents, rebuilding new ones farther landward, removing them, or allowing them to degrade. Some of these options can enhance sediment transfers that are the basis for creating new landforms and habitats. Structures may be rebuilt to decrease the hazard potential and increase the stability of the land behind them. This is often done by replacing temporary, under-sized, or degraded structures with more substantial ones (Bocamazo, 1991; Jackson and Nordstrom, 1994). This option does not promote natural sediment transport but is vital to reducing flood incidence in densely populated areas (Gornitz et al., 2002). In contrast, structures may be rebuilt to decrease size or permeability to

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facilitate sediment transfers or increase natural dynamism. Examples of this include notching groins to enhance bypass (Rankin et al., 2004), lowering breakwater crests or widening gaps between them to restore more natural circulation (Aminti et al., 2003; Cammelli et al., 2006), or cutting breaches in dikes to allow buildup of marshes landward of them (Weinstein and Weishar, 2002). Habitat complexity can be increased on structures by adding cavities, pots and textured slabs to the surface to attract desirable species (Chapman, 2007; Borsje et al., 2011; Browne and Chapman, 2011). Structures that have begun to degrade or are under threat from undermining because of loss of beach fronting them may be protected from wave attack by nourishing beaches fronting them (Bocamazo, 1991; Jackson and Nordstrom, 1994), which has the added benefit of providing the potential for new sandy beach habitat. Structures may be removed and replaced in function by new structures built landward of them to decrease the size of the zone requiring protection or to reestablish natural processes at the removal location. Numerous examples of this kind of action are provided in studies of managed realignment in estuaries (French, 2006; Garbutt et al., 2006; Rupp-Armstrong and Nicholls, 2007), where the focus has been marshes. Structures can be removed without rebuilding new ones landward to reestablish natural processes or provide a recreational amenity, e.g. creation of urban green space (Zelo et al., 2000; Toft et al., 2010). Alternatively, structures can be left in place and allowed to degrade to eliminate the cost of repair. Examples include allowing groins to deteriorate or allowing storms to create breaches in dikes (Nordstrom et al., 2007).

Stability of coastal landforms still is often the major goal in shoreline management programs, and it is likely that degraded structures will be repaired and new structures will be built, especially in urban areas. At the same time, many scientists and managers of natural environments are advocating greater dynamism to allow for nature to undergo exchanges of sediment, nutrients and biota, follow cycles of accretion, erosion, growth, and decay, and retain diversity and complexity that can result in greater resilience (García-Mora et al., 2000; Doody, 2001). Studies exist to document that formerly stabilized coasts can be converted to more dynamic ones by removing vegetation cover in dunes (van Boxel et al., 1997; Arens et al., 2004; Hilton, 2006) or by implementing managed realignment programs. Managed realignment should also be considered a viable option for restoring geomorphically sustainable (self-regulating) coastal systems and ecosystem services on developed coasts (Cooper and Pethick, 2005; Luisetti et al., 2011). A global warming trend is predicted, accompanied by accelerated rates of sea level rise (Meehl et al., 2007). The need to re-evaluate the value of coastal structures increases with the likelihood of increased sea levels, which will make existing structures ineffective. Many projects implemented to reduce the impact of shore protection structures have been small scale or conducted in sparsely developed areas, but the technical feasibility has been demonstrated.

Human structures (i.e. buildings, roads, utility lines) are prevalent within the developed northeastern US coastal zone and are under threat from future sea level rise (Wu et al., 2009; Neumann et al., 2010). Shore protection structures were commonly emplaced to protect these developed areas, even in national parks. Almost the entire 47 km of shoreline in Jamaica Bay estuary (New York City) in Gateway National Recreation Area (Fig. 1) has been stabilized or altered. At Fire Island National Seashore in New York State, 18% of the bay shore is fronted by bulkheads, docks, or breakwaters (Nordstrom et al., 2009). Many of these structures were implemented before these areas were designated as National Park Service (NPS) sites.

This study is a feasibility assessment of the potential for removing shore protection structures or allowing them to deteriorate to allow natural shoreline processes to prevail as part of an accommodation strategy to anticipate the rise of sea level. Sandy Hook, a barrier spit at the northern end of the ocean shoreline of New Jersey (Fig. 1), was selected as a case study area. The site was selected because many shore protection structures have been used on the ocean and bay sides of the spit, allowing for evaluation of removal of structures on high and low energy shores with a variety of landforms and habitats. Elements of the study include (1) identifying structures that represent human-caused barriers to landform and habitat migration; (2) identifying the current function of each structure in protecting a cultural or natural resource; (3) identifying opportunities to facilitate landform and habitat formation and migration by removing or mitigating the structures; (4) prioritizing structures that can be removed cost-effectively or abandoned without adverse effects on valuable infrastructure; and (5) determining the effects of removal on landforms and habitats of the shoreline segment where removal should have highest priority. We assume that initial efforts to accommodate greater dynamism will be cautious, so we are evaluating actions to accommodate changes over relatively small scales (tens to hundreds of meters) over a period of 1–2 decades.

A major difference between this study and previous studies of removal of shore protection structures is that most previous projects have replaced the protective functions of hard structures with alternative means of shore protection, such as beach fill (e.g. Zelo et al., 2000) or construction of new, more flood-proof, but often shorter structures farther landward (Nordstrom et al., 2007; Rupp-Armstrong and Nicholls, 2007). This study identifies the consequences of removing structures and allowing formations landward to evolve naturally, without added protection.

2. Study site

Sandy Hook is a compound, complex recurved barrier spit that has been subject to considerable human modification since the mid-1900s, such as (1) construction of buildings, piers, roads, railroads, and military structures, including bunkers and ammunition storage buildings (all collectively termed infrastructure); (2) construction of shore parallel bulkheads and seawalls, shore perpendicular groins, and training walls (all collectively termed shore protection structures); and (3) implementation of land reclamation projects and beach nourishment projects (all termed fills). Prevailing winds at Sandy Hook are from the westerly quadrants. Wind speed, duration and fetch favor wave generation from the northwest in Raritan Bay (Fig. 1). Wave refraction causes the shallow water waves on the ocean-facing beaches to approach from the east–south–east (Fairchild, 1966). Mean observed significant breaker height on the ocean side of the southern portion of the spit is 0.82 m, with a period of 9.8 s; breaker height on the bay side near mid-spit position is 0.18 m, with a period of 3.6 s (Nordstrom, 1980). The net direction of longshore transport is south to north on the ocean side and north to south on the bay side (Nordstrom, 1980). Tides are semi-diurnal with a mean range of 1.4 m and a spring range of 1.7 m. The highest flood levels on the ocean and bay sides of the spit are associated with storm surges during easterly winds. For example, storm surge elevation recorded at the Sandy Hook tide station in Raritan Bay was 1.27 m during the 11 December 1992 storm with winds from the east–northeast at 8–17 m s^{-1} (Dobosiewicz, 1997). Water levels are lower during strong northwesterly winds. Satellite data and tide gauge data indicate a relative rate of sea level rise in the region of ~3.3 mm/yr from 1993 to 1997 (Miller et al., 2009). Foreshore sediments on both sides of the spit are well sorted sands in the medium size range (Nordstrom, 1977).

In the past, Sandy Hook has been an island; it has been attached to the mainland at the town of Highlands (Fig. 1); and it has been attached to the barrier to the south, as it presently is (Moss, 1967). All of these scenarios have occurred since 1832, but construction of a seawall in the southern portion of the spit beginning in 1898 has prevented breaching and kept the spit attached to the barrier to the south (Nordstrom et al., 1982). Longshore transport has caused northerly spit growth, with tidal currents and wave refraction contributing to the development of a series of northwest–southeast trending dunes and beach ridges at former spit termini (Fig. 2). Some of these landforms were eroded by bay waves to form beaches and small southerly-trending spits on the bay side. The shoreline of Sandy Hook now consists of several distinct