Science of the Total Environment 649 (2019) 661–671

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

# Optimizing conservation benefits for threatened beach fauna following severe natural disturbances

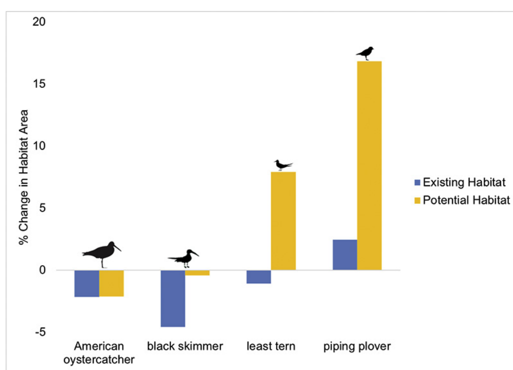
Brooke Maslo [a,b,*], Karen Leu [a], Todd Pover [c], Michael A. Weston [d], Ben L. Gilby [e,f], Thomas A. Schlacher [e,f]

[a] Ecology, Evolution, and Natural Resources, Rutgers, The State University of New Jersey, New Brunswick, NJ, USA
[b] Rutgers Cooperative Extension, New Jersey Agricultural Experiment Station, Rutgers, The State University of New Jersey, New Brunswick, NJ, USA
[c] Conserve Wildlife Foundation of New Jersey, Trenton, NJ, USA
[d] Deakin University, Geelong, Centre for Integrative Ecology, School of Life and Environmental Sciences, Burwood Campus, Victoria, Australia
[e] The AMIMAL Research Centre: health + ecology + conservation, University of the Sunshine Coast, Maroochydore, Australia
[f] School of Science and Engineering, University of the Sunshine Coast, Maroochydore, Australia

## HIGHLIGHTS

- Wildlife habitat on beaches is reduced by human land use; land acquisition is rare.
- Coastal storms can benefit species by creating new habitat.
- Hurricane Sandy created nesting habitat for 3 of 4 avian species examined.
- Gains did not benefit birds because habitat was created outside the existing network of conservation areas.
- Flexible spatial conservation investments are a key input in storm-recovery planning.

## GRAPHICAL ABSTRACT




## ARTICLE INFO

*Article history:*
Received 20 July 2018
Received in revised form 22 August 2018
Accepted 23 August 2018
Available online 25 August 2018

Editor: D. Barcelo

*Keywords:*
Beach-nesting birds
Climate change
Habitat conservation
Species distribution modeling
Wildlife management

## ABSTRACT

Wildlife on sandy beaches is often constrained by transformation of natural areas for human use, and opportunities for acquiring or restoring new habitat are rare. Storms can often force changes in land use naturally by reshaping coastal landforms, thereby creating high quality habitat; yet, wildlife requirements are seldom considered in post-storm recovery planning, and conservation practitioners lack suitable evidence to argue for the protection of habitats freshly formed by storms. Here we used a maximum-likelihood spatial modeling approach to quantify impacts of Hurricane Sandy (mid-Atlantic United States, October 2012) on nesting habitat of four bird species of conservation concern: American oystercatchers, black skimmers, least terns and piping plovers. We calculated the immediate storm-created changes (loss, persisting, gained) in nesting habitat under two levels of conservation protections: the current regulatory framework, and a scenario in which all potential habitats were under conservation protection. Hurricane Sandy resulted in apparent large gains for least terns (+181 ha) and piping plovers (+289 ha). However, actual gains were reduced to 16 ha for plovers and reversed for least terns (net loss of 6.4 ha) because newly formed habitat occurred outside existing reserve boundaries. Similarly, under the current management framework, black skimmer nesting habitat decreased by ~164 ha. We also tested whether birds benefited from newly created nesting habitat by identifying nest and colony locations for three years following Hurricane Sandy. All species overwhelmingly nested in habitat that existed prior the storm (76–98% of all nests/colonies); only a small percentage (≤17% for all species) occupied newly created

* Corresponding author at: Evolution and Natural Resources, Rutgers, The State University of New Jersey, 14 College Farm Road, New Brunswick, NJ 08901, USA.
*E-mail address:* brooke.maslo@rutgers.edu (B. Maslo).

https://doi.org/10.1016/j.scitotenv.2018.08.319

habitat. We conclude that static spatial conservation efforts fail to capitalize on potentially large gains resulting from storms for several species and recommend flexible spatial conservation investments as a key input in post-storm recovery planning.



## 1. Introduction

Sandy beaches and dunes on high-energy coastlines are highly dynamic landforms that are continually re-shaped by changes in sediment supply, wind, waves and tides (Davis and FitzGerald, 2009). Several species, including many of conservation significance, are reliant upon beaches or dunes throughout their lifecycle. Many have evolved a number of life history traits and behaviors in response to the physical attributes and dynamism of ocean beaches and dunes. For example, some exhibit physiological tolerance to environmental stresses (Gray, 1985), or modify their reproductive strategies to compensate for flood risk or sand burial (Maun, 1998; Thompson et al., 2001). Others change foraging behaviors to efficiently exploit pulses and spatial changes in food availability and shifts in habitat use as a response to significant habitat change (Erwin et al., 1981; Schlacher et al., 2014b).

Beaches are also important sites for human recreation, commerce and habitation, which can cause widespread and intensive human transformations of beach landscapes (Lockwood and Maslo, 2014). This development places significant and increasing pressures on the extent and quality of nesting and feeding habitats for beach-dependent species. In addition, birds attempting to breed, roost or feed in relatively undisturbed habitats are sometimes killed by human commensal predators (e.g., red foxes, cats, corvids; Ekanayake et al., 2015; Maslo et al., 2016b; Schlacher et al., 2015), or have restricted access to foraging resources (Greene, 2002; Heerhartz et al., 2014; Schlacher et al., 2016). Stark declines in populations of numerous coastal species of wildlife are regularly attributed to these threats. Alarmingly, maintaining remaining habitat patches of sufficient quality often fails to ensure a species' persistence (McClenachan et al., 2006).

Land use along existing coastlines is almost entirely designated, and changing existing regulation is difficult (Wescott, 2004). Continual human demand for coastal land to construct and renew housing and increase recreational opportunities results in limited opportunities for increasing habitat extent through land acquisition (McFadden, 2007; Tarlock, 2007). In addition, there is rarely any political will to increase conservation area extent because the ecological values and functions of dunes and beaches for wildlife are usually undervalued (Beatley, 2012; Jones et al., 2017). While significant natural events like storms can change the shape, size and configuration of coastal landscapes (Bergillos et al., 2017), land-use planning continues to operate on the premise that landscapes are static, thereby further limiting the flexibility of coastal habitat changes for conservation purposes.

Significant storms can lower dunes, scour vegetation and deposit large amounts of shell and wrack material (Masselink et al., 2016; Splinter et al., 2018). These processes reset the successional trajectory of the ecosystem and can create habitat features (i.e., overwash fans, ephemeral pools, and mottled substrates) known to be important for several beach-dependent species (Cohen et al., 2009; Rumbold et al., 2001; Wunderle et al., 2007). Extreme weather events can also cause significant damage to public infrastructure, housing and personal property (Hsiang et al., 2017). As a result, environmental regulations are often relaxed to facilitate human recovery efforts (e.g., waivers from U.S. Clean Air Act requirements after Hurrican Katrina, 2005; Gerrard, 2006; Ingram et al., 2006). Further, a common response to storm impacts is increased investments in coastal armoring (Rotimi et al., 2009). In most cases, no regulatory mechanisms or processes exist to identify whether and where suitable habitat has been created by storms for animals or how to legislate to maximize the potential conservation benefits of these changes. Despite widespread evidence that storms can actually enhance the size and quality of habitat for several threatened beach-dependent species on exposed shorelines (e.g., Cohen et al., 2010), arguments pertaining to wildlife conservation are rarely considered in storm recovery planning (Berke and Campanella, 2006; Mainka and McNeely, 2011). Therefore, empirical evidence generated through a consistent and systematic approach to identify newly created habitat worthy of future protection will make a more compelling case.

Here we used a maximum-likelihood spatial modeling approach to quantify the impacts of Hurricane Sandy, which made landfall on the mid-Atlantic United States in 2012, on existing nesting habitat of four beach-dependent bird species of conservation concern along the coast of New Jersey, USA. For each species, we calculated the net change in predicted nesting habitat across the study area and mapped where habitat was lost, persisted, or was created by the storm. Because availability of nesting sites is largely controlled by the intensity and type of recreational and maintenance activities (Maslo et al., in press), we compared the net change in habitat resulting from Hurricane Sandy under the current spatial configuration of conservation protection with a hypothetical scenario in which all of the coastline is protected. Using three years of post-storm nesting data, we examined whether target species capitalized on the newly created habitat areas. Through this work, we demonstrate the practicality and value of models to build evidence that conservation practitioners and land-use planners can use to secure protection of target species. Based on this new evidence, we provide guidance and recommendations on how to use flexible spatial conservation interventions following major storm impacts on sandy coastlines.

## 2. Materials and methods

### 2.1. Description of study area and existing conservation protections

This study was conducted within 5 km of the New Jersey, USA coastline (NJDEP, 2007), from Gateway National Recreational Area – Sandy Hook Unit, south to Cape May Point (~250 km; Fig. 1). We included all beaches, dunes, saltmarshes and tidal flats where the focal species could potentially nest. Fewer than half of the known birds nesting on New Jersey's beaches are in federally protected wildlife refuges (T. Pover, pers. comm; Heiser and Davis, 2017). Outside of protected areas, most beaches are used primarily for recreation, including sunbathing, action sports (surfing, kite-surfing, etc.), fishing, campfires, off-leash dogs, and off-road driving. In these locations, smaller nesting areas persist as part of negotiated beach management plans among site owners (i.e. municipalities, county parks), the United States Fish and Wildlife Service (USFWS) and New Jersey Endangered and Nongame Species Program (ENSP). Beach management plans are intended to provide long-term protection and recovery of protected species while balancing recreational use and storm protection. In areas under management for beach-nesting birds, pedestrian and vehicular access is restricted in nesting and foraging areas for all or part of the year (through closures and symbolic fencing), and there are restrictions on beach-raking, dogs, kite-flying, fireworks, and other active recreational activities.

### 2.2. Species habitat requirements

We studied four bird species of conservation concern in New Jersey: i) American oystercatcher (*Haemotopus palliatus*); ii) black skimmer