Biological Conservation 144 (2011) 393–401

Contents lists available at ScienceDirect

Biological Conservation

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

Effect of sea-level rise on piping plover (*Charadrius melodus*) breeding habitat

Jennifer R. Seavey [a,*], Ben Gilmer [b], Kevin M. McGarigal [c]

[a] *Department of Wildlife Ecology and Conservation, University of Florida, Gainesville, FL 32601, United States*
[b] *Global Marine Initiative, The Nature Conservancy, Seattle, WA 98101, United States*
[c] *Department of Natural Resources Conservation, University of Massachusetts, Amherst, MA 01003, United States*

ARTICLE INFO

Article history:
Received 3 January 2010
Received in revised form 10 September 2010
Accepted 13 September 2010
Available online 20 October 2010

Keywords:
Barrier islands
Climate change
Shorebirds

ABSTRACT

Climate change is raising sea levels, threatening many low-lying coastal areas and associated wildlife. We assessed the threat of sea-level rise (SLR) to the breeding habitat of the federally threatened piping plover on the barrier islands of Suffolk County, New York. We determined the extent of habitat change over the next 100 years under several SLR estimates, as well as the interactive effects of coastal development and storm surge. We found that if plover habitat cannot migrate, SLR is likely to reduce breeding areas. However, if habitat is able to migrate upslope and inland, breeding areas could actually increase with SLR. Unfortunately, this potential habitat gain is stymied by human development, which we found to reduce migrating habitat by 5–12%, depending on SLR estimates. We also found that the spatial configuration of developed areas mattered more than intensity of development in blocking the migration of potential habitat area. Our results raise concern over the likelihood of increased conflict between plover habitat protection and human recreation as habitat is likely to become a larger proportion of the barrier islands in the future. Finally, our results highlight risk from the synergism between SLR and coastal storms, as we estimate that a large hurricane could flood up to 95% of plover habitat. To assure the future of plover habitat on these barrier islands, management needs to promote natural overwash and habitat migration, while minimizing development adjacent to future breeding habitat.

1. Introduction

Habitat loss, a leading threat to wildlife, is expected to escalate under global climate change resulting in the extinction of many species (Jetz et al., 2007; Mac Nally et al., 2009; Sekercioglu et al., 2008; Thomas et al., 2004; Wilcove et al., 2000). Habitat loss is predicted to be particularly high among low-lying coastal systems because of their vulnerability to sea-level rise (Farbotko, 2010; Nicholls et al., 2007). Coastal land loss will escalate extinction risk for associated wildlife species, especially those imperiled under current climate conditions (Baker et al., 2006; Daniels et al., 1993; Fish et al., 2008; LaFever et al., 2007; Markham, 1996).

Melting ice and thermal expansion are expected to increase sea levels between 0.18 m and 2 m over the next 100 years (Rahmstorf, 2010; Grinsted et al., 2009; Richardson et al., 2009; IPCC, 2007). The consequences of these rising sea levels on coastal systems include inundation of low-lying areas, as well as increased erosion and storm flooding (IPCC, 2007; Klein and Nicholls, 1999; Titus and Richman, 2001). For example, inundation from a 1.5 m rise is expected to result in the loss of 6 million hectares of coastal land along the eastern shores of the United States (Titus and Richman, 2001). The mid-Atlantic shoreline, from New York to North Carolina, is especially vulnerable due to higher than the global average rates of sea-level rise (Titus et al., 2009). In addition, the northeast coast of the United States is expected to experience changes to the Atlantic meridional overturning circulation as a result of global climate change, which will also lead to increased sea-level rise in this region (Yin et al., 2009).

Negative impacts from sea-level rise (SLR) are expected to be especially acute on barrier islands because of their abundance of low elevations in combination with the process of island migration (Davis and Fitzgerald, 2004; FitzGerald et al., 2008; Hayes, 2005). Island migration is the mechanism by which barrier islands have historically absorbed SLR (Titus et al., 2009). This absorption process is driven by waves and storm surges that push ocean water over islands, carrying sediment from the ocean side to the leeside. This movement of sediment causes a shift of the landform, which ultimately maintains the island system. The concern among many scientists is that the rate of SLR under climate change will outpace the migration process (Titus et al., 2009; FitzGerald et al., 2008; Hayes, 2005; Zhang et al., 2004). If the migration process is overwhelmed by rising waters, erosion and flooding are expected and will lead to the inundation and loss of many barrier islands (Titus et al., 2009; Zhang et al., 2004).

Aggravating this threat to migration dynamics is the prevalence of coastal development. Human development alters barrier island

* Corresponding author. Tel.: +1 413 237 7733.
E-mail address: jseavey@ufl.edu (J.R. Seavey).

0006-3207/$ - see front matter © 2010 Elsevier Ltd. All rights reserved.
doi:10.1016/j.biocon.2010.09.017

migration by blocking and altering the movement of wind, sand, and water (Feagin et al., 2005; FitzGerald et al., 2008; Hartig et al., 2002; IPCC, 2007; Titus, 1989; Zhang et al., 2004). Further, coastal development can squeeze barrier island habitats between the ocean and hardened surfaces such as walls, jetties, roads, and buildings (French, 2001), causing a rearrangement of landscape patterns and change in habitat connectivity (Feagin et al., 2005; Galbraith et al., 2002).

Habitat loss associated with SLR threatens all barrier island organisms, including shorebirds. Worldwide, scientists estimate that many shorebirds are currently in decline and will suffer further reduction from habitat loss brought about by climate change (Galbraith et al., 2002; Le V. dit Durell et al., 2006; Warnock et al., 2002). The decline of the piping plover (*Charadrius melodus*), federally listed in 1986, is blamed primarily on habitat loss and degradation resulting from human development (USFWS, 1996). Habitat degradation is expressed as increased disturbance and predation on plover populations (USFWS, 1996). Though conservation management over the past 20 years has led to a steady increase in the plover population, recovery goals have not been met and concern is increasing over climate change impacts, especially from rising sea levels (USFWS, 2009).

In addition to direct habitat loss, SLR is expected to act synergistically with global changes in storms to increase coastal flooding that will likely increase the risk of negative impacts on plover nesting habitat. Higher sea-surface temperatures in the tropics that are expected from global climate change are predicted to increase the frequency and intensity of storm events in the future (Bender et al., 2010; Frumhoff et al., 2007). These storms are expected to have increased wind speeds, heavier precipitation, larger and more frequent tidal surges, and wind-driven waves, all of which will increase flooding along the Atlantic Coast during the breeding season (Frumhoff et al., 2007). Increased flooding of plover nesting habitat is expected to amplify nest abandonment and bird (especially eggs and chick) mortality (USFWS, 2009).

New York's piping plover population, second only to Massachusetts in terms of both population size and recovery (USFWS, 2009), is reliant on low-lying barrier island habitat as it provides the majority of the state's breeding habitat (Seavey, 2009). These islands provide plover habitat primarily through the process of barrier island migration (Cohen, 2005; Cohen et al., 2009; Elias-Gerken, 1994; Seavey, 2009). However, if migration is overwhelmed by SLR, island land area (Hayes, 2005; Zhang et al., 2004) and plover habitat could be lost. The assessment of risk from rising sea levels to the piping plovers of New York's barrier islands is critical to plover recovery planning. In this study, we examined potential changes to piping plover breeding habitat from rising sea levels under several SLR estimates over the next 100 years. In addition, since the methodology for modeling SLR is currently debated and rapidly changing (FitzGerald et al., 2008; Thieler and Hammar-Klose, 2000), we explored different models to examine uncertainty in our predictions. Further, we investigated the influence of human development in altering SLR impacts and flooding risk from storms. With these analyses, our aim was to quantify potential SLR impacts to piping plover habitat in an important region of the current breeding range and highlight management concerns.

2. Material and methods

2.1. Study Site

Our study area encompassed the barrier island system of Suffolk County, which spans 93 km of barrier island and peninsula shoreline along the southern coast of Long Island, New York, USA (Fig. 1). Multiple inlets break this barrier system into four segments (from west to east): Jones Beach Island, Fire Island, Westhampton Island, and Southampton Beach. The current dimensions of the islands are approximately 6 km by 0.1 km for the smallest and 50 km by 2.6 km for the largest. These dimensions are not stable, as island profiles are shifting and dynamic (McCormick et al., 1984). The elevation of these islands is almost entirely below 3.5 m, especially along Westhampton Island, where most of the island is below 1.5 m (Titus and Richman, 2001). This barrier island system is considered sand limited and has historically been subject to frequent storm erosion due to its low topography and sandy soils (Schwab et al., 2000). Human development within the system is highly variable, ranging from large, day-use public recreation facilities along Jones Beach and Fire Island to low-density (195.3 units per km^2) summer homes along Westhampton Island and Southampton Beach (USCB, 2003).

2.2. Habitat and landform response models

We modeled two possible responses of plover habitat to SLR: static and dynamic. In the static habitat response, we assumed that SLR would occur at a rate that outpaces the migration of habitat and the islands themselves. In this model, the spatial distribution of habitat was fixed and the rising sea level simply submerged land and existing habitat, resulting in a new spatial configuration of remaining habitat. A static habitat response is expected if the rate of SLR outpaces the ability of flora and fauna to migrate upslope and/or if development blocks movement of the landform (Bush et al., 2004; Feagin et al., 2005). There are two reasons this habitat response model is plausible in our study area. First, human development in our study system has been shown to restrict land movement (McCormick et al., 1984). Second, the likelihood of a static response is also deemed higher in a sand-limited system such as ours where a lack of substrate limits island movement (Fallon and Mushsacke, 1996; Hartig et al., 2002; Schwab et al., 2000; Zhang et al., 2004). This static response represents the most liberal habitat loss scenario that we considered and has been widely adapted for modeling sea-level rise impacts (Bush et al., 2004; Cooper and McKenna, 2008; Demirkesen et al., 2008; Feagin et al., 2005; LaFever et al., 2007; Titus and Richman, 2001; Weiss and Overpeck, 2006).

The second response model allowed for a dynamic habitat response wherein habitat could shift upslope and inland, redistributing itself based on the underlying landform. Our initial run of this model was conducted without the restriction of habitat movement by development (see below for a description of our development modeling). Documented movement of flora both inland and upslope with historic SLR in many coastal systems validates this as a plausible response model (Clark and Patterson, 1985; French, 2001; Gilman et al., 2006; Michener et al., 1997; Moorhead and Brinson, 1995).

We purposefully did not incorporate a dynamic landform response. This response, which would include the movement of both habitat and island landforms, is based on historic observation of barrier island dynamics (Leatherman, 1979, 1985; Zhang et al., 2004). A dynamic landform response is more likely in areas with minimum development and abundant sediment (Zhang et al., 2004). Because of the widespread extent of beach stabilization structures (Hecht and Melvin, 2009), and lack of sediment (Hartig et al., 2002) in our study area, we expect that landform dynamics are severely constrained and unrealistic, and thus we did not considered it in our analysis.

2.3. Habitat modeling

We modeled habitat response to SLR based on a plover breeding habitat map created during May through July of the 2005 breeding