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Estimating the response of wildlife communities to coastal dune construction

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ABSTRACT

Coastal ecosystems worldwide are being impacted by sea-level rise caused by climate change. As mitigation efforts increase to protect these threatened ecosystems, a deeper understanding of how wildlife adapt to coastal management techniques is needed. We monitored three constructed sand dunes (built in 2010 and 2014) and two natural dunes in central Florida from June 2015 through June 2016 to assess the impact of dune construction as a management technique on terrestrial vertebrates. Specifically, we tested if constructed dunes accumulated and maintained similar community composition and species richness to natural dunes. We used AHDriFT, a game camera-based trapping technique, to monitor terrestrial wildlife communities in both the natural and human-modified landscapes. After 4502 camera nights, we documented 2537 unique photo-capture events, comprised of 33 different species. Species communities were compared by constructing species accumulation curves for each dune type, and by modeling community similarity through multivariate hierarchical clustering. Species accumulation curves overlapped among all dune types, and the cluster analysis showed no pattern separating natural and constructed dunes. However, PERMANOVA found a difference between constructed and natural dunes, which was verified by a NMDS ordination that separated out constructed and natural dunes. Differences between dunes was likely driven by rare species, as commonly observed species overlapped across all dunes, including one protected species. Given the similarity between overall species richness, and that differences in community composition may be due to microhabitat variation and species rarity, we conclude that constructing dunes to increase coastal resilience does not negatively impact endemic wildlife in coastal zones and may provide suitable habitat for many wildlife species.

1. Introduction

Coastal ecosystems are ranked among the most threatened ecosystems worldwide due to a multitude of threats (Harris et al., 2015; Spalding et al., 2014). In addition to shifting temperatures, coastlines face rising sea levels and an increased severity in annual storms due to climate change (Scavia et al., 2002; Overpeck and Weiss, 2009; Zhang et al., 2013). Conversely, most research on climate change and its effects on wildlife species focuses on the impacts of increasing temperature and shifting weather patterns, while ignoring the immediate impacts of rising sea level (but see Schlacher et al., 2007 and Spalding et al., 2014; Noss, 2011; Reece et al., 2013). Mitigation for sea-level rise often emphasizes protecting human structures or impacts on marine wildlife, while neglecting terrestrial vertebrates (Noss, 2011). Due to these shortcomings, as sea levels increase, many plants and terrestrial animals are likely to be trapped without mitigation and management plans (Schlacher et al., 2007; Noss, 2011; Reece et al., 2013). Given that coastal ecosystems tend to have high endemic biodiversity, understanding how wildlife species respond to different management scenarios in coastal ecosystems will be critical as the impacts of climate change worsen (Schlacher et al., 2007; Harris et al., 2015; Jones et al., 2017).

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Coastal management efforts fall into two broad categories: 'hard' engineering or 'soft' engineering methods. 'Hard' engineering methods (e.g. sea walls) focus on using permanent structures to halt erosion, but often increase the overall loss of natural beach areas (Bernatchez and Fraser, 2011; Jones et al., 2017). 'Soft' engineering methods include sediment supplementation and dune construction, both of which aim to replace lost beach area to minimize overwash erosion during storms, increasing the resilience of sandy coastlines (Schlacher et al., 2007; Harris et al., 2015). For wildlife, dune construction is considered a minor disturbance and may be part of larger management plans to protect biodiversity in coastal areas, but more research on the response of terrestrial wildlife is sorely needed (Spalding et al., 2014; Harris et al., 2015; Martin et al., 2017a).

To assess the response of wildlife communities to dune construction, we compared vertebrate communities between three constructed and two natural dunes in coastal Florida. Florida is a major biological hotspot in the United States, and because no part of the state is greater than 150 km from a shoreline, climate-change induced sea-level rise is a growing threat to wildlife throughout the state (Reece et al., 2013; Noss et al., 2015). We aimed to estimate community composition on constructed and natural dunes, focusing on small mammals and reptiles, to determine whether constructed dunes accumulate and maintain species diversity equal to nearby natural dunes. We hypothesized that wildlife use constructed dunes as habitat similar to natural dunes; therefore, we expect to find community composition and species richness to have no differences between constructed dunes and natural dunes. Such results would indicate dune construction may function to protect coastal ecosystems and endemic wildlife as sea-level rise worsens.

2. Methods

2.1. Study site and monitoring design

We monitored two natural dunes and three constructed dunes at the John F. Kennedy Space Center/Merritt Island National Wildlife Refuge (MINWR) along the eastern shore of Florida from June 2015 through June 2016. Merritt Island is a barrier island that comprises one of the largest protected areas along the eastern U.S. coast, covering over 570 km^2, with many endemic species (Breininger et al., 1994). A combination of temperate Carolinian and tropical Caribbean species form the native flora and fauna assemblages, including several state and federally listed species, such as the southeastern beach mouse (*Peromyscus polionotus niveiventris*), eastern indigo snake (*Drymarchon couperi*), and gopher tortoise (*Gopherus polyphemus*) (Breininger et al., 1994).

Sea-level rise is a serious threat to MINWR, with recent storms eroding areas 25–60 m wide along the coastline (Rosenzweig et al., 2014; Foster et al., 2017). In 2010, NASA proposed the construction of new dunes to reduce further overwash erosion and to protect critical structures in the wake of Hurricane Sandy (Rosenzweig et al., 2014). A 214 m long dune was completed in 2010, with a larger dune extending 445 m long to the north and 1,088 m long to the south of the 2010 dune being completed in 2014. Post-construction, all constructed dunes were hand-planted with native herbaceous flora to promote stability (sea oats [*Uniola paniculata*] was the dominate species on the newly made dunes). In total, the constructed dunes were 1.77 km long, an average of 24.4 m wide, with a peak height of 18.3 m and covered over 4.3ha. In comparison, nearby natural dunes varied in both height and width, with the asymmetric northern dune having an average height of 16 m and width varying from 5 to 50 m. The southern natural dune height ranged from 1 to 9 m and was roughly symmetrical with a width of 30 m. Both natural dunes were dominated by a mixture of sea grapes (*Coccoloba uvifera*) and sea oats, with localized patches of the invasive Brazilian pepper-tree (*Schinus terebinthifolius*). The surrounding landcover of all dunes was a mixture of coastal strand and scrub, salt marsh, infrastructure and associated ruderal areas, and open beach/ocean.

To assess coastal wildlife communities, we used a series of game cameras deployed with the Adapted-Hunt Drift Fence Technique (AHDriFT) arranged throughout the constructed and natural dunes (Martin et al., 2017b). We deployed 18 NatureView® (Bushnell Corp., Overland Park, KS, USA) cameras in pairs at opposite ends of nine 7 m × 0.6 m x 0.63 m drift fences constructed of wooden, oriented strand boards supported by 1 m gardening stakes from June 2015 through June 2016 (Martin et al., 2017b). However, two cameras malfunctioned shortly after placement in the field and were removed from later analysis. Each camera was contained in a secondary housing structure following recommendations given by Martin et al. (2017b) and set to standardized motion-sensitive setting of three burst photos per trigger. Each drift fence (pair of cameras) was considered an independent camera station. Two camera stations were placed on four of the five dunes, while the northern 445 m 2014 constructed dune contained a single camera station. Camera stations were separated by 0.1–1.5 km.

2.2. Data management and analysis

Each camera station was treated as an independent survey unit. We removed duplicate captures by retaining captures separated by a minimum of 60 min using the package 'camtrapR' in R (version 3.3.4; Niedballa et al., 2016; Martin et al., 2017b). Due to unequal sampling (number of trap nights), we used sampled-based rarefaction, and extrapolated our curves out to 2000 trap nights (Colwell et al., 2012). Rarefaction and calculation of 95% confidence intervals for the species richness curves were done using the 'iNext' package in R (version 2.0.12; Hsieh et al., 2016). To assess similarities in species diversity between dune types, we ran a hierarchical cluster analysis using the package 'vegan' in R (version 2.4–6; Oksanen et al., 2008). First, dissimilarity is calculated between pairs of sites to generate a distance matrix. Then, hierarchical clustering iteratively pairs groups of sites by minimizing dissimilarity between them. Finally, groups the resulting pairs of sister sites are grouped based on the same criterion. We then estimated the goodness of fit between the mapped clusters and our original data by calculating the correlation between the cophenetic distances for the clusters (i.e. intergroup dissimilarity) and the distance (dissimilarity) matrix of our original data.

We used a permutational multivariate analysis of variance (PERMANOVA) implemented in vegan through the 'adonis' function to test for differences between constructed and natural dune communities using distance matrices based on the untransformed count data, and did not remove any species from the dataset (version 2.4–6; Anderson, 2001; Cao et al., 2001; Oksanen et al., 2008; O'Hara and Kotze, 2010; Poos and Jackson, 2012). Ordinations were then plotted using nonmetric multidimensional scaling (NMDS) in two dimensions with vegan's 'metaMDS' function using the Bray-Curtis distance and the default settings (Kruskal, 1964; Oksanen et al., 2008). Stress values for the NMDS plot were assessed to ensure good fit in a two-dimensional space, with a value less than 0.2 considered acceptable.

3. Results

During one year of surveying, 16 cameras photographed wildlife without errors over 4502 trap-nights (N = 927 for 2010 constructed dune, N = 1681 for 2014 constructed dunes, and N = 1894 for natural dunes) resulting in 2537 distinct capture events (N = 407 for 2010 constructed dune, N = 695 for 2014 constructed dunes, and N = 1435 for natural dunes). Each camera station documented an average of 17 species (± 2 SE, N = 16; Supplementary Table 1). Two cameras were removed from the final dataset due to malfunctions in recording date; one from the 2010 constructed dune, and one from the southern natural dune. Based on our analyses, there was no difference between the average number of species observed along each dune (Table 1). Additionally, confidence intervals for the species accumulation curves