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Research Paper

Spatial conservation prioritization to conserve biodiversity in response to sea level rise and land use change in the Matanzas River Basin, Northeast Florida

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HIGHLIGHTS

- We develop an integrated modeling process to identify conservation priorities.
- We show how current reserves could be expanded for adaptation to sea level rise.
- Existing conservation layers are good foundations for adaption to sea level rise.
- We demonstrate how development scenarios could be integrated in the planning process.

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ABSTRACT

Sea level rise and land use change are likely to be some of the most fundamental and important challenges for biodiversity conservation in low-lying coastal areas in the 21st century. To protect biodiversity in coastal areas, there is an urgent need to identify conservation priorities in response to sea level rise and land use change. In this study, an integrated modeling process using a geomorphological model, species habitat models, and conservation prioritization is developed to identify conservation priorities in the face of sea level rise and land use change. We present a case study in the Matanzas River Basin of Northeast Florida that utilizes this integrated modeling approach with data for 38 focal species. We incorporate species-specific connectivity requirements in the analysis and compare the conservation priorities with existing conservation datasets including current conservation areas and the Florida Ecological Greenways Network (FEGN). Results show that current reserves are not adequate to protect some of the most important conservation priorities in response to sea level rise but the updated FEGN does serve as a good foundation to inform future conservation decisions relevant to sea level rise. To protect the top 10% conservation priorities, approximately 11,700, 10,900 and 15,200 acres of additional land will need to be acquired for the 0.5, 1.0, and 2.5 m sea level rise scenarios respectively.

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1. Introduction

Among the effects of climate change, sea level rise is considered as the most certain, immediate, widespread and visible result of climate change (Noss, 2011; Pilkey & Young, 2009). Sea level rise affects habitats, species and ecosystems (Geselbracht, Freeman, Kelly, Gordon, & Putz, 2011), and it is accepted that sea level rise is likely to cause species extinction and ecosystem disruption in the near future (Noss, 2011). Most tidal wetlands in areas with low freshwater and sediment supplies will "drown" in locations where sea level rise outpaces their ability to accrete vertically (Nyman, DeLaune, Roberts, & Patrick, 1993). Salt marshes are expected to move upslope with sea level rise (Brinson, Christian, & Blum, 1995), but human development is likely to limit their ability to retreat and migration (Desantis, Bhotika, Williams, & Putz, 2007; Donnelly & Bertness, 2001; Feagin, Sherman, & Grant, 2005). The most severe losses for intertidal habitat are likely to occur at sites where the

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coastline is unable to move inland because of steep topography or seawalls (Galbraith et al., 2002).

Coupled with land use change caused by rapid population growth, sea level rise is likely to constitute one of the most fundamental and important challenges for biodiversity conservation in low-lying coastal areas of the world (Reece, Noss, Oetting, Hoctor, & Volk, 2013). It is estimated that habitats, species, and entire coastal ecosystems will likely be lost to sea level rise if without adaptation strategies (Cameron et al., 2012; Noss, 2011). In response to sea level rise and land use change, it is critical to identify current and future conservation priorities, and to make proactive land use decisions that protect these areas and help them to remain resilient in the face of climate change. Identification of conservation priorities in response to sea level rise has been recommended by conservation biologists as one of the most urgent research needs necessary to maintain biodiversity and resilient ecosystems as sea levels rise (Noss, 2011).

The use of Geographical Information Systems (GIS) based models are one method for identifying conservation priorities and form a critical quantitative and science-based foundation for conservation and land use decision making (Gordon, Simondson, White, Moilanen, & Bekessy, 2009). Along with the application of the Sea Level Affecting Marshes Model (SLAMM; Warren Pinnacle Consulting, Inc.), which predicts changes in wetland habitats and shorelines due to long-term sea level rise, conservation priorities in response to sea level rise can be identified based on SLAMM results and spatial conservation prioritization modeling (Runting, Wilson, & Rhodes, 2013; Veloz et al., 2013). Spatial conservation prioritization techniques have been used to identify sea level rise adaptive conservation priorities, however they have generally been conducted at the natural community level that conservation priorities at the species level were not identified.

This paper focuses on species-specific conservation prioritization, and how these priorities can be used to expand current reserves or create new reserves to facilitate biodiversity adaptation to sea level rise. We present the results of a sea level rise adaptation planning case study using an integrated modeling process that incorporates a coastal impact model (SLAMM), species habitat models and spatial conservation prioritization software to identify species-specific conservation priorities in the Matanzas River Basin of Northeast Florida. We demonstrate how these tools can be used to help identify locations where existing conservation areas should be enlarged, where corridors should be established and where new conservation areas should be created to facilitate biodiversity adaptation to sea level rise and land use change. The conservation priorities identified in this research are used to assess the utility of existing conservation layers in Florida including current designated conservation lands and the Florida Ecological Greenways Network (FEGN; Hoctor, Volk, & Spontak, 2013) for mitigating and adapting to the impacts of sea level rise. In addition, the conservation priorities identified in this research are used to assess future development scenario that are likely to conflict with future sea level rise adaptive conservation priorities.

2. Methods

2.1. Study area

Florida is an instructive case study for seal level rise adaptation, and how Florida responds to sea level rise will offer lessons to other coastal regions in the world (Hoctor, Oetting, Noss, Volk, & Reece, 2014; Noss, 2011; Zhu, Xi, Hoctor, & Volk, 2015). The ecological and socio-economic features of the Matanzas River Basin provide a salient case study for developing adaptive conservation designs and priorities in response to sea level rise and land-use change. For this research, we extended the study area to include a 5 km buffer beyond the Matanzas River Basin in order to incorporate regional land-use and ecological considerations (e.g., the FEGN).

The Matanzas River Basin is the watershed for the Matanzas River, which is a coastal estuarine water body that extends from the St. Augustine Inlet southward into the Intracoastal Waterway along the east coast of Florida. The basin covers approximately 100,000 acres between the cities of St. Augustine and Palm Coast and rural lands to the west. The basin contains the southern portion of the Guana Tolomato Matanzas National Estuary Research Reserve (GTMNERR) and the Fort Matanzas National Monument (Fig. 1). The coastal ecosystems contained within the basin and the GTMNERR are home to considerable biodiversity. At present, 44 mammals, 358 birds, 41 reptiles, 21 amphibians, 303 fish, and 580 plant species have been documented in the reserve.

Located within one of the fastest growing regions in Florida, the Matanzas River Basin is under great pressure from future development. The population of St. Johns and Flagler Counties, where the Matanzas River Basin is located, has grown approximately 40% since 1990 (Florida Department of Environmental Protection, 2012). More than 1.5 million people are living within 50 miles of the basin including the cities of Jacksonville, St. Augustine, and Daytona Beach. Based on Florida 2060 report (Zwick & Carr, 2006), it is estimated that developed land uses in this region could increase significantly if current population growth rates continue in the coming decades.

Under the combined impacts of sea level rise and land use change, there is an urgent need to develop adaptive conservation strategies for biodiversity conservation in the Matanzas study area. To plan for sea level rise adaptation, this research uses a reserve design algorithm to identify conservation priorities in the face of landscape dynamics due to sea level rise and land use change. Methodologies developed in this research should be transferable to other low-lying coastal areas around the world to plan for sea level rise adaptation.

2.2. Sea level rise scenarios

Predictions about sea level rise are constantly improving with increased model sophistication and data accuracy, and current sea level rise estimates are between 0.7 and 2.0 m by 2100 (Cameron et al., 2012; Grinsted, Moore, & Jevrejeva, 2010; Rahmstorf et al., 2007), though there is also the potential for sea level rise above 2.0 m (Hansen, 2007; Nicholls et al., 2011). The IPCC 5th Assessment report predicted sea level could likely rise of 40–60 cm and a worst case of 1.0 m by the end of this century (Church et al., 2013). However, the report' authors also concluded that sea levels could rise much higher than the “likely” range in the 21st century if the Antarctic ice sheet collapses (Church et al., 2013).

Sea level rise scenarios are fundamental to vulnerability assessments and all other following parts of the adaptation planning process in coastal areas. For this research, we chose scenarios of 0.5, 1.0, and 2.5 m sea level rise by 2100 for the adaptive conservation design analyses. The 0.5 m sea level rise projection is the lowest case scenario and it falls in the “likely” sea level rise range projected by AR5. The 1.0 m sea level rise projection is the intermediate case scenario and it is the worst case “likely” sea level rise projection according to AR5. We chose 2.5 m as the highest sea level rise scenario because this was the highest sea level rise projection included in the SLAMM models used for this project, and this extreme case is possible based on estimates from AR5. Additionally, it provides a point of comparison with less extreme scenarios, showing which conservation priorities identified for 0.5 or 1.0 m sea level rise are still relevant under a higher scenario.

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