



Informing conservation planning using future sea-level rise and storm surge modeling impact scenarios in the Northern Gulf of Mexico



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ABSTRACT

Coastal communities across the Gulf of Mexico are increasingly vulnerable to coastal hazards, including sea level rise. The Gulf of Mexico contains 20 000 km² of land below 1.5 m in elevation and is one of the most vulnerable regions to sea level rise in the continental U.S. Wetlands are among the Gulf of Mexico's most economically and ecologically important habitats that comprise thirty-one percent (28 372 mi²) of land within the U.S. Gulf coastal watershed. These increasing hazards threaten not only the human-built infrastructure and coastal communities, but also natural habitats and ecosystems. Through a participatory stakeholder process the project team and regional stakeholders identified ongoing and future conservation planning efforts that were best suited to be informed by sea-level rise and storm surge projections, socioeconomic indicators, and marsh migration scenarios. This study estimates the potential impacts of SLR and storm surge to human communities and natural habitats, with emphasis on coastal marshlands, in both the Galveston Bay region of Texas and the Choctawhatchee and Saint Andrew Bay region of Florida. Project results include A) marsh change and viability analysis, B) community risk analysis, C) community resilience analysis; and D) long-term marsh management analysis. Our study suggests that sea-level rise impacts should be incorporated into ongoing conservation planning and management activities in order to allow decision makers to more easily develop adaptation strategies that foster coastal resilience in the face of a changing climate.

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1. Introduction

With millions of people living in vulnerable regions along the United States coastline, the potential impacts of rising sea levels on low-lying coastal communities and infrastructure is increasingly becoming a recognized hazard (IPCC, 2007; Karl et al., 2009; Weiss et al., 2011; Parris et al., 2012). The Gulf of Mexico contains 20 000 km² of land below 1.5 m in elevation (Titus and Richman, 2001) and is one of the regions in the continental U.S. that is most vulnerable to coastal hazards, including sea-level rise (SLR) and storm surge (Tebaldi et al., 2012; Weiss et al., 2011; Thieler and Hammar-Klose, 2000). The potential effects of rising sea levels and storm surge on coastal communities and habitats can vary greatly, both spatially and temporally, with the greatest impacts of inundation occurring in low-elevation areas with little or no topographic relief (Nicholls et al., 2011; Weiss et al., 2011); areas which

typically include coastal communities and habitats like salt marshes, coastal plains, river deltas and barrier islands. The population in these vulnerable areas, especially in Texas and Florida, is expected to increase significantly in the future. By 2050 the Texas General Land Office predicts that the population of the 18 coastal counties in Texas will approach 9.3 million people, an increase from 2010 of about 3.2 million new residents (GLO, 2013). As the population continues to grow, the pressure being exerted on the fragile wetland habitats of the gulf coast will also increase; but so too will the demand for the services and benefits that they provide. Local planners and property owners have generally not decided how they will manage their response to SLR (Titus et al., 2009) nor have they developed future habitat or shoreline management strategies to mitigate these vulnerabilities that take rising sea-levels into account (CCSP, 2009).

These increasing hazards threaten not only the human-built infrastructure and coastal communities, but also natural habitats and ecosystems. Gulf of Mexico's wetlands have experienced significant declines in recent decades (National Ocean Service NOAA, 2011) and accelerated SLR projections are expected to further increase the rate and magnitude of wetland loss (Nicholls, 2004;

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Parris et al., 2012). Wetlands are among the Gulf of Mexico's most economically and ecologically important habitats and comprise thirty-one percent (73 483 km²) of land within the U.S. Gulf of Mexico coastal watershed (NOAA, 2006). These wetland habitats provide many benefits for human and natural communities including vital nursery habitat for commercial and recreational fish species, storm surge protection, erosion prevention, pollutant removal and are an important habitat for a wide diversity of plants and animals (National Ocean Service NOAA, 2011). Harm to these habitats, which degrade their ability to provide these benefits, can increase the cost of storm recovery efforts and damage already stressed natural communities.

According to the Climate Change Science Program, populations living in low lying coastal communities face two broad options when responding to future SLR: 1) shoreline protection; and/or 2) retreat (CCSP, 2009). How individual communities respond has a lot to do with their environmental and socioeconomic conditions, both of which influence their vulnerability to coastal hazards and their resiliency in the face of future impacts. Recent research efforts found that many socially vulnerable communities located on the US coast are at risk to SLR, with more than half of them occurring in the Gulf Coast region and that the socially disadvantaged living in these communities may be disproportionately affected (Martinich et al., 2013). Throughout the five Gulf States it is estimated that 14% of the population that lives within the Gulf Coast Special Flood Hazard area are below the poverty level (National Ocean Service NOAA, 2011). Planning and responding to a global threat such as SLR ultimately falls to regional and local administrators who need critical information on the potential impacts of SLR and storm surge necessary to support informed decision making and increase community resiliency (Najjar et al., 2000; Nicholls et al., 2007, 2008; CCSP, 2009; National Research Council, 2009). Most state and local coastal hazard risk assessments in the U.S. are focused on current hazard risk, and do not incorporate potential future risks due to climate change impacts such as SLR (Frazier et al., 2010; Shepard et al., 2011a; National Research Council, 2011). To ensure that coastal planners consider flexible and cost-effective measures for conserving coastal habitats and protecting communities it is essential they have access to data on a range of projected SLR scenarios that are based on scientific, engineering and economic principles (Williams, 2013).

Resource managers and policy makers need access to information on the potential impacts of SLR on coastal habitats and communities in order to make the best informed conservation and coastal resiliency decisions. Coastal resiliency involves incorporating natural habitats and their ability to mitigate damages from SLR and storm surge into development, climate adaptations and risk reduction strategies in order to reduce the impacts of natural disasters and improve recovery efforts. We addressed this challenge by designing a conservation and resiliency analysis methodology that provides coastal planners, administrators and resource managers with a series of indices and spatial tools that can be used to inform the planning process, help protect vulnerable communities, improve coastal resiliency, and help inform coastal habitat conservation efforts. The methodology focuses on coastal habitats, such as regularly and irregularly flooded salt marshes, that could provide protection and mitigation from SLR and storm surge impacts. As part of the scoping process, the project team, which consisted of scientists from The Nature Conservancy and representatives from the Gulf of Mexico Alliance, and regional stakeholders identified ongoing and future conservation planning efforts that were best suited to be informed by SLR and storm surge projections, socioeconomic indicators, and marsh migration scenarios. Through this scoping process the team identified four relevant questions (shown below) that formed the basis for the

development of the conservation and resiliency framework described in this publication:

1. What are the potential impacts of a 1 m sea level rise to irregularly- and regularly-flooded marshes in the study area?
2. Which communities are potentially most at risk to hurricane storm surge, and how might sea-level rise increase present-day risk to storm surge?
3. Which communities might be most or least resilient to future changes based on socioeconomic indicators, inundation exposure, and marsh viability?
4. How might SLR impacts and future marsh habitat distribution inform land acquisition and habitat conservation planning?

Once we identified which indices were the most relevant to answer these questions and inform these communities, spatially-explicit computer simulation models were used to explore the potential impacts and risks of inundation using several different SLR and storm surge scenarios. These models included the Sea-Level Affecting Marsh Migration (SLAMM) model and Advanced Circulation model (ADCIRC), which were employed on two coastal bay environments, one in Texas and the other in the panhandle region of Florida.

Viable and healthy salt marshes, which are allowed to migrate naturally with rising sea levels, can provide non-structure flood control for coastal and human protection, reduce coastal erosion and provide the ecological structure needed to maintain additional coastal habitats, including seagrass beds, fresh water marshlands and even coastal prairie grasslands. They also provide vital nursery and spawning grounds for crab, shrimp, oyster and numerous fish species. All of which are important factors that influence coastal resiliency. By focusing primarily on the potential impacts of SLR on marsh migration processes and how changes in habitat (lost or gained) might impact future storm events, our research makes the connection between our changing coastal environment and its ability provide benefits (i.e. – storm protection) to surrounding communities. Using our modeled results of marsh migration and storm surge under a projected 1 m by 2100 SLR scenario we assess how these scenarios might impact coastal communities, including those most socially vulnerable. Indices for future marsh viability, community risk, community resiliency and marsh management were then calculated based on our model outputs in order to score the potential impacts of SLR on coastal communities. These indices were developed to provide relevant spatial data on the potential impacts of future SLR in order to inform coastal conservation and management efforts and to be used as a direct tool for planning and conservation strategies in the Gulf of Mexico. The outputs of this conservation and resiliency analysis which include GIS data, maps and reports are hosted on a newly developed web interface located at <http://slrportal.org> and are available for download.

2. Methods

2.1. Conservation analysis

The methodological approach used in this study follows an overarching project framework for informing ongoing and future coastal conservation planning efforts through SLR and storm surge models, marsh migration scenarios, and their implications for habitat and human community resilience (Fig. 1). The methods described herein detail our approach for assessing socioeconomic and ecological risk to SLR and storm surge, coastal habitats and their relation to vulnerable human communities, and future management options needed to support conservation planning for climate-enhanced coastal change.

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