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Research article

Use of structured decision-making to explicitly incorporate environmental process understanding in management of coastal restoration projects: Case study on barrier islands of the northern Gulf of Mexico

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A B S T R A C T

Coastal ecosystem management typically relies on subjective interpretation of scientific understanding, with limited methods for explicitly incorporating process knowledge into decisions that must meet multiple, potentially competing stakeholder objectives. Conversely, the scientific community lacks methods for identifying which advancements in system understanding would have the highest value to decision-makers. A case in point is barrier island restoration, where decision-makers lack tools to objectively use system understanding to determine how to optimally use limited contingency funds when project construction in this dynamic environment does not proceed as expected. In this study, collaborative structured decision-making (SDM) was evaluated as an approach to incorporate process understanding into mid-construction decisions and to identify priority gaps in knowledge from a management perspective. The focus was a barrier island restoration project at Ship Island, Mississippi, where sand will be used to close an extensive breach that currently divides the island. SDM was used to estimate damage that may occur during construction, and guide repair decisions within the confines of limited availability of sand and funding to minimize adverse impacts to project objectives. Sand was identified as more limiting than funds, and unrepaired major breaching would negatively impact objectives. Repairing minor damage immediately was determined to be generally more cost effective (depending on the longshore extent) than risking more damage to a weakened project. Key gaps in process-understanding relative to project management were identified as the relationship of island width to breach formation; the amounts of sand lost during breaching, lowering, or narrowing of the berm; the potential for minor breaches to self-heal versus developing into a major breach; and the relationship between upstream nourishment and resiliency of the berm to storms. This application is a prototype for using structured decision-making in support of engineering projects in dynamic environments where mid-construction decisions may arise; highlights uncertainty about barrier island physical processes that limit the ability to make robust decisions; and demonstrates the potential for direct incorporation of process-based models in a formal adaptive management decision framework.

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1. Introduction

Barrier islands are narrow island chains that run parallel to the mainland and protect it from wave attack. They also provide critical habitat for species such as sea turtles and shorebirds (Feagin et al., 2010). The cross-shore profile of a barrier island typically consists of a seaward facing lower beach that is regularly inundated by waves and tides; a higher-elevation upper beach that is typically dry but may be inundated during modest storm events; a dune that rises a few meters and is only reached by water levels during more extreme storms; and a back-barrier that may consist of lower beach habitat or marsh (Komar, 1988). The lower beach changes daily as a result of wave and tidal action, while the upper beach and dune regions evolve slowly under most conditions (Sallenger, 2000). During storms, however, elevated water levels can result in rapid changes to the upper beach and dunes (Sallenger et al., 2007; Stockdon et al., 2007). The cumulative impact of storms may result in longshore or cross-shore migration of the island while the subaerial profile is maintained (Morton, 2008). However, insufficient sediment supply, local sea level rise, anthropogenic modifications, and climatic changes in storm patterns can increase the vulnerability of barrier islands and raise the risk the islands (and their benefits) will be lost (Stutz and Pilkey, 2011). Threatened barrier islands may be targeted for restoration in order to preserve their natural and anthropogenic benefits.

The Mississippi barrier islands (Fig. 1) are the first line of defense between the Gulf of Mexico and the Mississippi mainland, and are an important habitat for threatened Gulf Sturgeon, endangered and threatened sea turtles species, and threatened shorebirds (USFWS, 2015). The islands are experiencing changes in subaerial acreage and habitat due to frequent intense storms, relative rise in sea level, and changes in sediment supply (Byrnes et al., 2013), similar to other islands in the northern Gulf of Mexico (Penland and Boyd, 1981; Morton, 2008; Otvos and Carter, 2008). Long-term island loss threatens the productive Mississippi Sound estuarine ecosystem and exposes the mainland coast and its wetland habitats to increasing saltwater intrusion and damage from tropical storms.

In 2009, the Mississippi Coastal Improvements Program (MsCIP) was developed by the Mobile District, U.S. Army Corps of Engineers (USACE) in conjunction with other Federal and State agencies. The Mississippi barrier island system was examined with the goal of restoring the natural ability of the barrier island system to reduce hurricane impacts (Wamsley et al., 2013). One planned coastal engineering project is the restoration of Ship Island. As of 1848 Ship Island was a single, low-elevation landform with intermittent marsh and areas of higher dunes at each end (Foxworth et al., 1962). Historical maps document breaching of the island after the "Great Mobile" hurricane of 1852 (Byrnes et al., 2012), but littoral sediment transport from eastern Ship Island supplied enough sand to close early breaches and maintain a continuous island. A breach created in the hurricane of 1947 remained open for many years, but closed at some point prior to Hurricane Camille in 1967 (Knowles and Rosati, 1989; Byrnes et al., 1991; Morton, 2007, 2008). Since the creation of Camille Cut, Ship Island has not reformed into a single island, despite some narrowing of the cut in the mid-1990s prior to Hurricane Georges (Byrnes et al., 2012). Multiple storms in the years that followed (Hurricane Georges, 1998; Hurricane Ivan, 2004; and Hurricane Katrina, 2005) widened Camille Cut from ~2500 m to 5800 m (Morton, 2007, 2008; Wamsley et al., 2013). The island has undergone significant land loss, and between 1848 and 2008 lost more than 64% of its area with an average loss of between 8.5 and 22.4 ha/yr between 1986 and 2005 (Morton, 2007, 2008).

The restoration project will close Camille Cut and restore sand to East Ship Island. Sand placed at the eastern end is expected to increase island resiliency by supplying sediment to areas to the west through the net westward longshore transport. In addition to sheltering the mainland, the project will restore subaerial habitat for shorebirds and sea turtle nesting. Due to the dynamic nature of barrier islands and the threat of extreme storms, portions of the project may be damaged during construction, forcing the project managers and engineers to make decisions regarding repairs. Damage and repair choices can potentially impact the resiliency of

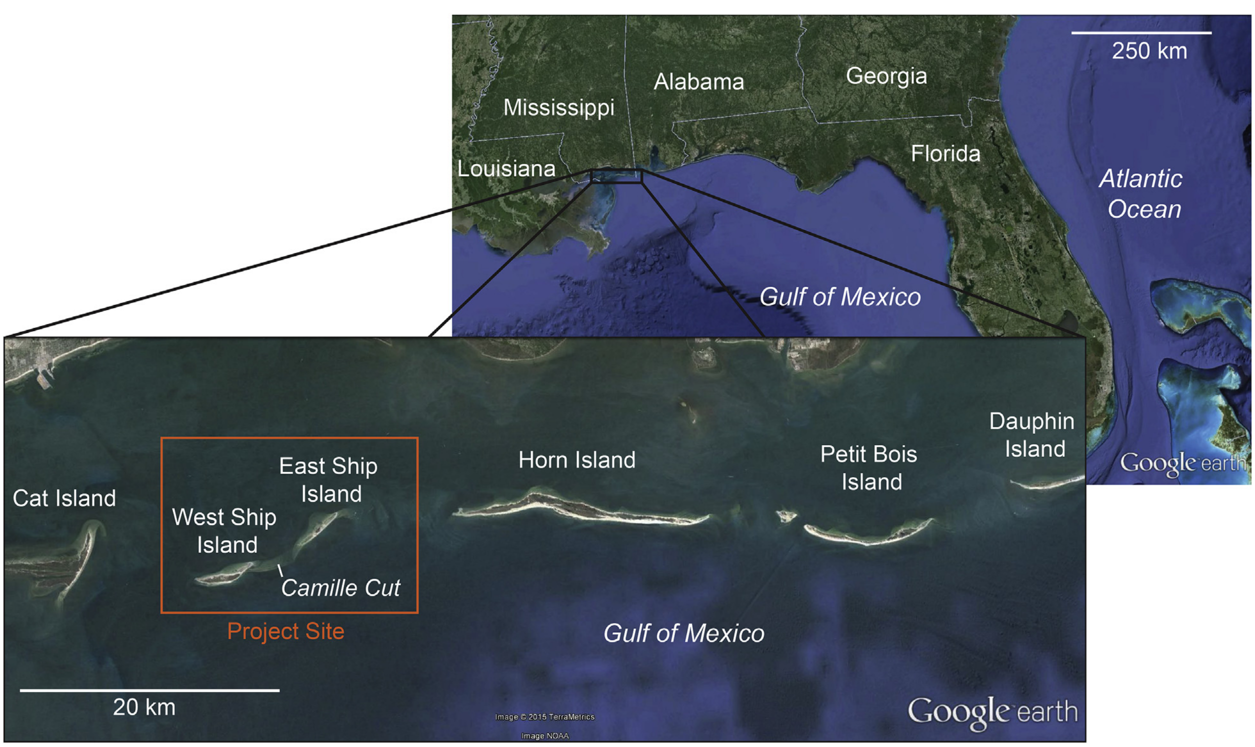

Fig. 1. Mississippi Barrier Island System. From west to east, the islands are Cat Island, West Ship Island, East Ship Island, Horn Island, Petit Bois Island, and Dauphin Island. Images from Google Earth©.