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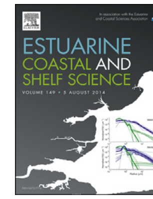

# Seabed texture and composition changes offshore of Port Royal Sound, South Carolina before and after the dredging for beach nourishment

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ABSTRACT

Beach nourishment has been a strategy widely used to slow down coastal erosion in many beaches around the world. The dredging of sand at the borrow site, however, can have complicated physical, geological and ecological impacts. Our current knowledge is insufficient to make accurate predictions of sediment infilling in many dredging pits due to lack of detailed sediment data. Two sites in the sandy shoal southeast of Port Royal Sound (PRS) of South Carolina, USA, were sampled 8 times from April 2010 to March 2013; one site (defined as 'borrow site') was 2 km offshore and used as the dredging site for beach nourishment of nearby Hilton Head Island in Beaufort County, South Carolina, and the other site (defined as 'reference site') was 10 km offshore and not directly impacted by the dredging. A total of 184 surficial sediment samples were collected randomly at two sites during 8 sampling periods. Most sediments were fine sand, with an average grain size of 2.3 phi and an organic matter content less than 2%. After the dredging in December 2011–January 2012, sediments at the borrow site became finer, changing from 1.0 phi to 2.3 phi, and carbonate content decreased from 10% to 4%; changes in mud content and organic matter were small. Compared with the reference site, the borrow site experienced larger variations in mud and carbonate content. An additional 228 sub-samples were gathered from small cores collected at 5 fixed stations in the borrow site and 1 fixed station at the reference site 0, 3, 6, 9, and 12 months after the dredging; these down-core sub-samples were divided into 1-cm slices and analyzed using a laser diffraction particle size analyzer. Most cores were uniform vertically and consisted of fine sand with well to moderately well sorting and nearly symmetrical averaged skewness. Based on the analysis of grain size populations, 2 phi- and 3 phi-sized sediments were the most dynamic sand fractions in PRS. Mud deposition on shoals offshore of PRS presumably happens when offshore mud transport is prevalent and there is a following rapid sand accumulation to bury the mud. However, in this borrow site there was very little accumulation of mud. This will allow the site to be used in future nourishment projects presuming no accumulation of mud occurs in the future.



## 1. Introduction

Beaches are common sandy sedimentary environments on many continental margins worldwide. The condition and stability of these beaches form an integral part of coastal economies, primarily by providing support for local tourism and infrastructure protection, particularly for the East and Gulf Coasts of the USA. Coastal erosion along developed shorelines, however, can have adverse effects on beaches and beach-related recreational and economic benefits. Like many tropical and subtropical areas around the world, the East and Gulf Coasts of the USA have a rich history of tropical storms and hurricanes. Depending on the pathways, timing, and intensities of storms, coastal erosion during these extreme meteorological and oceanographic conditions can be severe, resulting in a significant amount of sediment eroding from the

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beach to the offshore inner continental shelf, and/or onshore into the back-barrier system as overwash. In addition, relative sea-level rise during the past several decades has exacerbated the beach erosion problem in many areas around the world.

Besides hard structures like jetties, groins, breakwaters and sea walls, many coastal states in the USA have adopted beach nourishment as the predominant strategy for addressing adverse effects of coastal erosion. Although there are various definitions, beach nourishment in South Carolina is generally defined as '*the artificial establishment and periodic nourishment of a beach with sand that is compatible with the existing beach in a way so as to create a dry sand beach at all stages of the tide*' (DHEC, 2010). A typical nourishment project consists of dredging and transferring beach-compatible sand from offshore sites (often called 'borrow' areas) to the beach. An ideal borrow location should be close to the beach to minimize the transferal costs, and generally consists of high quality sediment, e.g., >90% of sand, well sorted, low shell content and low organic matter (Bergquist et al., 2009).

The dredging for beach nourishment, however, can have complicated physical and biological impacts on the borrow areas. For example, drastic bathymetric changes may cause localized scouring and hydrodynamic variation in the borrow pits; this needs to be considered in diving, fishing and navigation activities. The borrow pits may lead to collapse or mass failure of nearby seafloor, which is a potential geological hazard to manmade structures like gas pipelines and oil platforms; therefore, a setback buffer zone needs to be defined in many borrow areas to minimize the impact of borrow areas to nearby manmade structures (Nairn et al., 2005). In the southeastern US, dredging nearshore shoals often leads to the filling of the borrow sites with mud, thereby changing the physical and ecological characteristics of the sites (Bergquist et al., 2009). Benthic communities are generally totally removed by the dredging process, and it may take months to years for benthic communities to be reestablished to pre-dredge conditions, potentially impacting fishery resources that rely on those benthic fauna (Bergquist et al., 2009).

The focus of this study is South Carolina, which shares its similarity with many states in the Gulf and East Coasts of USA. South Carolina has a rich history of hurricanes and storms, with thirty severe storms making landfall in coastal areas of South Carolina between 1871 and 1999 (Gayes, 1990). Since 1985, at least 24 nourishment projects have occurred in South Carolina, with a total of over 21 million $m^3$ of sand added to beaches at a price of nearly \$225 million U.S. dollars. Hilton Head Island, Myrtle Beach, and Folly Beach of South Carolina have had the most sand applied, representing a combined 76% of the South Carolina's total (DHEC, 2010). However, coastal sand resources in South Carolina suitable for beach nourishment are limited; efficient and low-impact use of those resources is therefore important to the sustainability and management of future nourishment projects.

Previous monitoring efforts have shown that borrow areas near Hilton Head Island and Myrtle Beach can fail to refill in a timely manner, occasionally refill rapidly with sand, refill with high concentrations of mud, or refill with laminated mud and sand (e.g., Bergquist et al., 2009; McCoy et al., 2010). Refilling with mud and very slow refilling can prevent the sustainable reuse of the borrow area, forcing future projects to seek sand sources further offshore at greater cost, and impacting the ecology of additional areas of seafloor. Seabed texture and composition as well as the location and design of the borrow pits may influence the rate of infilling, source and type of sediments refilling the pit, and the recolonization of disturbed sediments by background fauna. Unfortunately few studies have monitored the seabed sediment texture and composition changes *repetitively* both before and after the dredging activities, and our current knowledge is insufficient to make accurate predictions of infilling processes after the dredging activities.

During the past several decades there have been many physical, geological, and biological studies at both nourished beaches and borrow areas in South Carolina (e.g., Kana, 1988; Bruun, 1988; Van Dolah et al., 1992; Van Dolah et al., 1998; Jutte et al., 2001; Byrd, 2004; Bergquist et al., 2009; McCoy et al., 2010; Obelcz et al., 2010). In addition, many scientists have been using modeling and observational (e.g., geophysical surveys, corings, moorings, and tripods) methods to study sediment transport processes in estuary, marsh, inlet, and shelf sedimentary environments (Ojeda et al., 2004; Gardner and Kjerfve, 2006; Murphy and Voulgaris, 2006; Wargo and Styles, 2007; Schwab et al., 2008; Haas and Warner, 2009; Wren et al., 2011; Kumar et al., 2011; Warner et al., 2012). Although many beach nourishment projects conducted in South Carolina have been monitored, most of the post-dredge monitoring has been limited to the first year of post-nourishment recovery (DHEC, 2010). In order to improve future beach nourishment monitoring in South Carolina, DHEC (2010) suggested '*pre- and post-monitoring for all beach nourishment projects, for both offshore (borrow area) and onshore (beach and surf zone) areas, including downdrift shoreline changes*'.

The overall objectives of this study are to: 1) collect sediment samples *inside* and *outside* of borrow areas repetitively *before* and *after* the dredging on multiple sites offshore of Port Royal Sound, South Carolina; 2) determine the changes of surficial sediment texture and composition (e.g., carbonate and organic matter) in response to dredging; 3) investigate down-core sediment texture variations to see if mud-sand laminations can be preserved; and 4) determine whether mud preservation occurred at the borrow site on the sandy shoal. We chose Port Royal Sound as our study site because: i) this area was used for beach nourishment of Hilton Head Island where multiple beach nourishments have been performed; ii) substantial data have been collected in the area over the past two decades; iii) South Carolina Department of Natural Resources (SCDNR) staff associated with this study had worked with the contractor responsible for the PRS borrow site design to configure it so that the potential accumulation of mud in the borrow site was minimized; and iv) ebb tidal deltas are often the targeted areas for beach nourishment and large volumes of sand can be exchanged among the ebb-tidal deltas, tidal channels, and adjacent beaches (Miner et al., 2009). Our findings from this study may shed some light on the studies in other borrow areas near the ebb tidal deltas around the world, and can help the design and permitting processes of future beach nourishment projects in South Carolina and elsewhere. In addition, our data can be used to validate or calibrate the morphological or sediment transport models for the predictions of borrow pit infilling process in the future.

## 2. Background

Hilton Head Island (HHI, Fig. 1), located in Beaufort County of southwestern South Carolina, USA, is a barrier island with ~20 km of sandy beach shoreline next to the Atlantic Ocean. The island supports a population of approximately 34,000 residents and a tourist industry worth nearly one billion dollars annually. Major sedimentary environments include sandy "drum-stick" barrier islands, tidal inlets, tidal creeks (mostly muddy sand and sandy mud) and muddy marshes as well as a sandy ebb tidal delta (half-circle shaped, over 15 km wide, Fig. 1). East of HHI is Port Royal Sound (PRS), which is a large well-mixed estuary in southwestern South Carolina. The PRS receives only a small freshwater input from the Coosawhatchie River and consequently has high salinity throughout (Crotwell and Moore, 2003). The PRS bottom is underlain by fine- and coarse-grained sand; the percentage of mud