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Beach nourishment is not a sustainable strategy to mitigate climate change

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ABSTRACT

Some studies published over the past several decades have concluded nourishment of oceanic beaches is a viable strategy to mitigate climate change. However, these were generally too limited in scope to accurately evaluate beach nourishment because each omit one or more of the following: (1) a realistic assessment of potential borrow area sand volume, (2) native beach compatibility, (3) construction costs, (4) all vulnerable geomorphic elements of the coastal zone, and (5) environmental impacts. When all of these parameters are considered, the results are markedly different. To demonstrate our point, we evaluated the recommendations of Houston (2017) using all five parameters. Contrary to Houston, we provide multiple lines of evidence that beach fill projects are not a sustainable strategy to protect or defend oceanic beaches of the Florida panhandle (USA), nor likely most of the world's developed coastlines at risk to the effects of climate change. The nourishment of oceanic beaches as historically constructed will surely continue over the next several decades. But, it must be done as an interim strategy during the formulation and implementation of a robust, long-term adaptive management strategy that incorporates managed withdrawal from the coastline.

1. Introduction

The rate of global eustatic sea level has accelerated as a consequence of human-caused climate change, averaging about 2 mm yr^{-1} since 1900 and over 3 mm yr^{-1} since 1993 (Church and White, 2011). Relative to the year 2000, sea level is very likely to rise 30–130 cm by 2100 (Sweet et al., 2017). An increase in the number of intense tropical cyclones is also predicted as the climate warms (USGCRP, 2017). Both of these phenomena are already impacting the coastal zone, as evidenced by expanded nuisance flooding, submergence of low lying areas, increased erosion, wetland loss, and salt water intrusion into aquifers and rivers. Future climate change will exacerbate the frequency, duration, and extent of these phenomena (Bird, 1985; National Research Council, 1987; Nicholls et al., 2007; Nicholls and Cazenave, 2010).

Historically, a wide range of shore protection installations have been constructed to mitigate coastal erosion and flooding (climate change), including ‘hard’ (i.e., seawalls, groins, breakwaters, revetments) and ‘soft’ (i.e., dune construction, beach nourishment) structures (c.f. National Research Council, 1987). The currently preferred approach is beach filling (Peterson et al., 2006) or hereafter nourishment because hard structural solutions have been shown to have detrimental effects on adjacent beaches and coastal ecology (c.f. Cooke et al., 2012; Hamm et al., 2002). Also, the construction and maintenance costs of hard structures are much higher than nourishment (Hoffman, 2016; Leatherman, 1996).

A number of studies have been conducted to assess the viability of beach nourishment as a cost-effective, long-term management strategy to mitigate climate change. These typically include an assessment of potential offshore sand reserve volume (Leatherman, 1996; Titus et al., 1991) and an economic analysis to determine the extent and/or cost of requisite nourishment (Hinkel et al., 2013; Langedijk, 2008; National Research Council, 1995; Yoshida et al., 2014). While these studies should be considered an important first step, there exist several significant limitations to the scope of each. First, volume estimates of potential marine sand reserves are generally based upon limited (i.e., reconnaissance-level surveys) data, making it highly likely the volume of recoverable sand will be much less than initially calculated. Second, cost estimates are often based upon existing market conditions. Third, in no case was native beach compatibility considered, nor the full extent of associated environmental impacts.

This investigation was precipitated by the recent publication of Houston (2017), in which he states annual beach nourishment along more than three-hundred kilometers of Florida panhandle shoreline (Fig. 1) can offset the effects of a sea level rise of between 0.38 m and 0.68 m (Church et al., 2013) by the year 2100. However, like the global (Hinkel et al., 2013), hemispheric (Hamm et al., 2002), national (Leatherman, 1989; National Research Council, 1987; Yoshida et al., 2014), and regional (Langedijk, 2008) assessments that preceded Houston (2017), the analysis was too limited in scope to accurately evaluate beach nourishment as a viable mitigation strategy. A more realistic assessment should consider: (1) potential marine sand reserve volume, (2) native beach compatibility, (3) construction costs, (4) all vulnerable geomorphic elements of the coastal zone, and (5)

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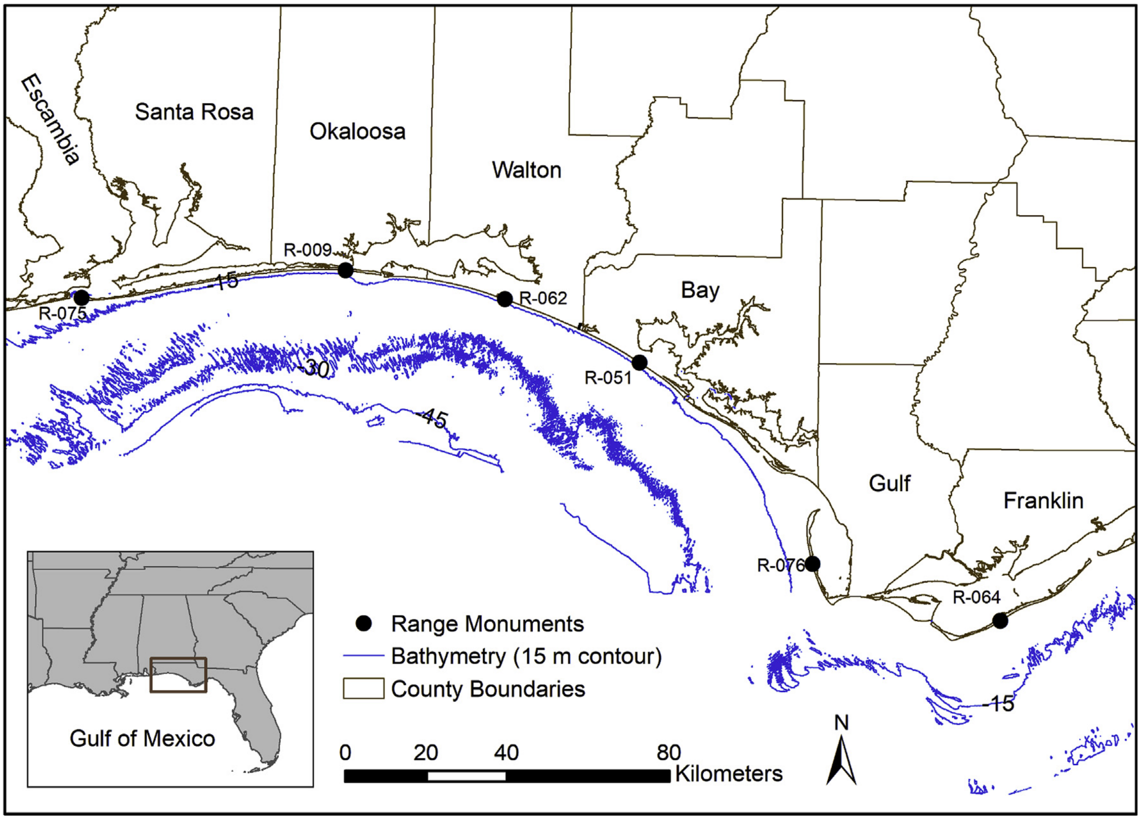

Fig. 1. Location of seven coastal counties of the Florida panhandle. Also shown are locations of six LIDAR-based topographic surveys shown in Fig. 5.

environmental impacts. When all of these parameters are considered, the results are markedly different. To demonstrate this point, the Florida panhandle study was evaluated using all of these parameters and the results clearly indicate beach nourishment is not a sustainable strategy to mitigate the effects of climate change along the Florida panhandle. Nor is beach nourishment likely a sustainable strategy to protect and defend most of the world's developed coastlines at risk to the effects of climate change.

2. Background

The coastal zone of the Florida panhandle is at high risk to climate change given its low elevation, erodible substrates, present and past evidence of shoreline retreat, and high probabilities of tropical storm and hurricane landfall (storms) (Gornitz et al., 1994). Based upon an analysis of coastal data collected since the 1800s, the annual placement of roughly 1.57 m^3 to 2.42 million m^3 (Table 1) of sand on 334 km of Gulf Coast oceanic shoreline is required to mitigate future impacts of sea level rise (Houston, 2017). Consideration of beach nourishment as a viable strategy to combat sea level rise is not new (c.f., Langedijk, 2008; Leatherman, 1989; Yoshida et al., 2014). In reality however, it is unlikely the requisite scale of construction could be sustained given what is known about compatible marine sand reserves and ballooning costs.

3. Marine sand reserve volume

Permitted borrow areas along the Florida panhandle are located proximal to the coastline (< 5 km), in relatively shallow water (< 15 m), are of limited horizontal scale (< 1 km), and typically contain less than 2 million cubic yards of sand (Fig. 2, Supplemental Table 2). Most of these have already been utilized or will be dredged in the next decade. Remaining permitted borrow areas are scant and will not meet the long-term volume requirements to sustain a nourishment campaign along the Florida panhandle to the end of this century.

By contrast, most *potential* sand reserves along the Florida panhandle are located more than 10 km offshore and in water depths

Table 1
Annual beach nourishment sand requirements proposed by Houston (2017) to maintain the Florida panhandle's 2016 shoreline position under four IPCC (Church et al., 2013) sea level rise scenarios until the end of this century. Also shown are estimated annual construction costs, held constant at \$30 m^{-3} and average annual State cost sharing to design and construct non-Federal planned beach nourishment projects. Appropriation data from Supplemental Table 1.

County	Average annual sand volume requirements (m^3x10^6)				Average annual cost ($\$x10^6$)				Average annual State appropriation FY 2013–2017 ($\$x10^6$)	
	RCP2.6	RCP4.5	RPC6.0	RCP8.5	RCP2.6	RCP4.5	RPC6.0	RCP8.5	Requested	Received
Escambia	0.21	0.26	0.27	0.37	6.3	7.8	8.1	11.1	6.5	1.8
Santa Rosa										
Okaloosa	0.08	0.10	0.10	0.14	2.4	3.0	3.0	4.2	0.0	0.0
Walton	0.80	0.90	0.90	1.20	24.0	27.0	27.0	36.0	0.0	0.0
Bay	0.13	0.15	0.16	0.19	3.9	4.5	4.8	5.7	0.9	0.9
Gulf	0.25	0.27	0.28	0.33	7.5	8.1	8.4	9.9	2.3	1.0
Franklin	0.10	0.13	0.13	0.19	3.0	3.9	3.9	5.7	0.0	0.0
Total	1.57	1.81	1.84	2.42	47.1	54.3	55.2	72.6	9.7	3.8