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Ecosystem indicators for Southeast Florida beaches

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ABSTRACT

Beaches are landscapes valued greatly by society that, when left intact, support both ecological processes and sustainable use. In Southeast Florida, alteration of beaches for human activities has resulted in substantial loss of naturally functioning beach habitat and reduced biological diversity. Of particular importance is the impact on beach ecosystems by the nearby urban environment. Beaches are dynamic ecosystems that require space to respond to natural or anthropogenic drivers and pressures. In Southeast Florida urban development has restricted or eliminated the ability of most beaches to react in a manner that conserves the natural beach ecosystem. The frequent result has been oceanfront areas with little or no intact habitat and limited opportunities for restoration, though disturbed beaches may still provide opportunities for ocean access, recreation, and other socioeconomic benefits in highly urbanized areas. In this study we present a framework for selecting relevant ecosystem and human dimension indicators for the beaches of Southeast Florida based on a conceptual ecosystem model. To capture the level of beach disturbance relatively pristine beaches and heavily altered beaches are endpoints in a continuum of beach development. Across this continuum nine indicators were developed to quantify beach condition. For ecosystem and human dimension assessment purposes, beaches were placed in one of two overarching categories: undeveloped to relatively undeveloped, or developed to highly developed. Nine selected indicators are then assessed as good (3), fair (2), or poor (1). The indicator scores are then summed to produce a total condition score for a particular beach. This simple 'stop-light' method is applicable even when there are limited data and provides a useful relative determination of ecosystem condition. Case studies employing this methodology are presented for three Southeast Florida beaches ranging from mostly natural to highly developed condition.

The indicators directly address both ecosystem and human dimension goals to maintain healthy, sustainable, and useable beaches and shorelines in Southeast Florida. They balance the ecological benefit of remaining natural beaches with the societal benefit of recreational opportunities and access for a beach that can no longer sustain a suitable ecosystem. Each indicator is interpreted in the context of the trade-offs among multiple ecosystem and human dimension services provided by most beaches in Southeast Florida.

1. Introduction

Beaches are dynamic landscapes valued by humans because they provide critical habitat for plants and animals, opportunities for active and passive recreation, storm protection, and beach-related employment, particularly tourism (Johns et al., 2001). Beaches and beach-related tourism activities create over 400,000 jobs and contribute more than $15 billion dollars to Florida's economy annually (Stronge, 2000; Murley et al., 2003). In Broward County in southeast Florida beaches are estimated to add $1.4 billion to local property values, increase local economic production by more than $500 million, and generate almost $30 million in revenue for the local government (Stronge, 1998a,b). Within this region the beach is a widely used coastal environment by residents and tourists because of proximity to urban areas, easy vehicular access, and the social and cultural desirability of "hanging out" by the ocean. Approximately 44% of tourists visiting a Florida beach do so in Southeast Florida (CUES, 2005).

The drivers and pressures that cause change on Southeast Florida beaches range widely over spatial scales from localized overuse to global-scale sea level rise (Schlacher et al., 2007; Defeo et al., 2009). The primary threats to the world's beach ecosystems

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include erosion, artificial sand placement, shoreline hardening, off-road vehicles, beach cleaning, pollution, fisheries, sand removal (mining), climate-change, and introduced species; all of these, except off-road vehicles, apply to Southeast Florida beaches (Jones et al., 2009).

There are numerous beachfront parks in Southeast Florida managed by governmental and nongovernmental organizations. Most of these areas were designed to protect coastal flora and fauna, provide public beach access, facilitate beach nourishment, or a combination thereof. The majority of beachfront parks in the region include parking, beach access, and support facilities (restrooms, picnic areas, etc.). When left intact coastal beach ecosystems support both ecological processes and sustainable use by humans (Schlacher et al., 2008). However, in Southeast Florida, alteration of beaches for urban development, recreation, and other human activities has resulted in a loss of naturally functioning beach habitat and biological diversity. Only about 10% of natural vegetation remains at Broward and Dade County beaches; some natural areas remain in Palm Beach and Martin Counties (Bush et al., 2004). Unfortunately, as native beach vegetation is lost or removed in Southeast Florida, exotic vegetation, such as *Casaurina equisetifolia* (Australian pine) and *Scaevola taccada* (beach scaevola), frequently invades at the expense of native vegetation.

This spectrum of beach alteration has been taken into account in this study when creating indicators to quantify beach condition. Relatively pristine beaches and heavily altered beaches were used as endpoints in a scale of beach development and the Marine and Estuarine Goal Setting for South Florida (MARES) project provided a framework for developing indicators for the Southeast Florida coastal beach ecosystem. Here we present a methodology for selecting relevant ecosystem and human indicators and the information needed to assess the condition of beach ecosystems. The link between the beach ecosystem and the nearshore marine ecosystem is an important component of the indicators. Case studies provide applications of this methodology for Southeast Florida beaches ranging across the development gradient.

2. Methods

2.1. Characterization of Southeast Florida beaches

The study region is comprised of the ocean beach and immediately adjacent near-shore area in Southeast Florida, from St. Lucie Inlet to Cape Florida (Fig. 1). This coast includes several beach types including barrier islands and spits/peninsulas as well as ocean-front areas where the Atlantic Coastal Ridge fronts directly on the Atlantic Ocean. The latitude of South Florida means beaches are seasonally influenced by temperate and tropical oceanic environments. The Gulf Stream, locally comprised of the Florida Current, is a powerful oceanic current passing between the Bahamas and Florida that moderates the coastal water temperatures within the study area and affects regional climate.

Southeast Florida is frequently impacted by strong storm systems (e.g. hurricanes, 'nor'easters') as well as large swells that originate from storm systems farther offshore. Hurricanes and tropical storms can significantly alter beach habitat, morphology, and dune vegetation causing erosion and accretion through sand transport. Where the energy-absorbing dune system has been replaced by coastal structures such as seawalls, even relatively minor storms may negatively impact habitat and recreational uses of the beach.

Geologically, Southeast Florida beaches are comprised of unconsolidated material affected by waves, wind, and ocean currents. The sand composition of a natural beach in Southeast Florida is a combination of quartz and calcium carbonate, with the carbonate fraction increasing toward the south (Mayhew and Parkinson, 2007). Nearshore hardbottom areas are the remains of sabellariid polychaete worms, coquina (Anastasia Formation), and carbonate grainstones (Banks et al., 2008).

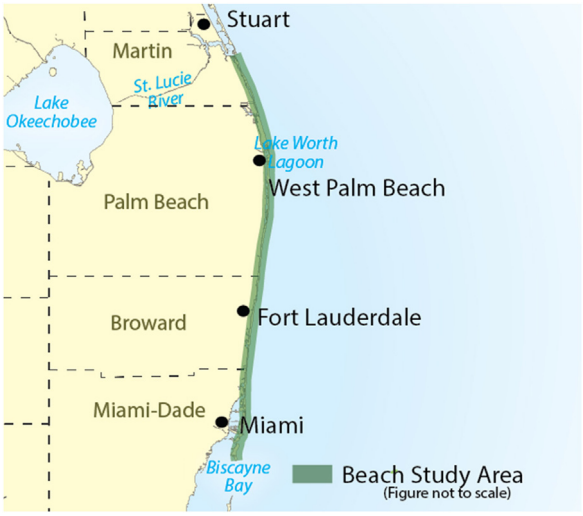

Fig. 1. The MARES Southeast Florida Region including the beaches of Martin, Palm Beach, Broward, and northern Miami-Dade counties.

Most beaches in southeast Florida are in close proximity to urban development. Often the natural sand transport mechanisms are frequently altered, resulting in chronic beach erosion. Sand nourishment and armoring have been the primary management responses to erosion. All counties in the study area, with the exception of Martin County, have nourished and/or armored large portions of the shoreline.

The existing natural beaches are characterized by similar vegetation, though tropical species comprise a larger proportion of the native vegetation in the south while subtropical beach vegetation predominates in the north (Johnson and Barbour, 1990). Beach vegetation within the study area typically occurs in the fore and back dune areas with hammock and scrub vegetation further landward. The transition from temperate to tropical trees occurs in the northern reach of the study area. Because of the large urban footprint, the remaining natural beach habitat is limited to isolated areas, primarily in protected parks.

As an example of the linkages between the open ocean and the beach ecosystem, marine vegetation (primarily *Sargassum* spp. and *Thalassia testudinum*) and marine debris – called wrack – frequently wash onto the beaches of Southeast Florida. While drifting in the surf zone, the presence of macrophyte detritus leads to greater abundance and diversity of surf-zone fishes (Robertson and Lenanton, 1984). Once washed upon the beach, many coastal communities in Southeast Florida mechanically remove seaweed wrack. However, wrack is an important energy source that assimilates into higher trophic levels via two pathways: grazing and decomposition (Ince et al., 2007). The primary pathway is incorporation by grazing herbivorous invertebrates inhabiting the wrack, such as amphipods and dipterans. Subsequent predation on these grazers transfers nutrients and energy to higher trophic levels (Ince et al., 2007; Duong, 2008). As wrack decomposes it remineralizes nutrients necessary for the growth of colonial dune vegetation which indirectly contributes to storm protection, an important ecosystem service.

The interstitial spaces of the sand on a beach support a relatively diverse infauna that experiences cyclic changes of water due to diurnal tidal cycles and seasonal variation. Infauna are represented by microalgae, bacteria, protozoans, and metazoan meiofauna (McLachlan, 1983; Schlacher et al., 2008; Defeo et al.,