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Coastal impact ranking of small islands for conservation, restoration and tourism development: A case study of The Bahamas

Kathleen Sullivan Sealey [a,*], Vanessa Nero McDonough [a,b], Kathleen Semon Lunz [a,c]

[a] Coastal Ecology Laboratory, Department of Biology, University of Miami, P.O. Box 249118, Coral Gables, FL, USA
[b] Biscayne National Park, National Park Service, Homestead, FL, USA
[c] Fish and Wildlife Research Institute, Fish and Wildlife Commission, St. Petersburg, FL, USA

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ABSTRACT

An 11-year project to characterize, then assess, the health of coastal environments of The Bahamas ranked a total of 238 sites on ten different islands. Satellite images and aerial photography were used to characterize coastal types (e.g. substrate, geomorphology and wave energy to describe beaches, mangroves, or rocky shores), and then field assessments ranked four types of anthropogenic impacts that influence ecosystem function and coastal system services. The ranking of coastal health was based on physical alterations, destructive use of the coastal zone, coastal development and occurrence of Invasive Alien Species (IAS). The characterization and assessment methods were developed to serve as a rapid survey of coastal stability, biological diversity and quality of wildlife habitats. A system of coastal ranking is presented using numerical scores for four impact criteria along with terrestrial plant surveys to examine the intactness of the coastal environment. Some locations (Exuma and Great Guana Cay) were repeatedly monitored over time. Scores ranged from "0" for no human impacts or invasive coastal plants to "20" for highly altered with dredging, coastal development and loss of native vegetation. The mean impact rank for all sites across all islands was 5.7 ± 4.3, which indicates "Medium" ranks for at least two of the four human impact criteria. Only one uninhabited island (Cay Sal) had all coastal impacts scores of "None". Over 77% of all the sites surveyed had abundant occurrences of Invasive Alien Species (IAS) coastal plants. The Australian Pine (*Casuarina equisetifolia*) was the more pervasive and the most widespread IAS in the coastal environment, and its abundance increased in all sites that were re-surveyed over time. Degradation of coastal function can signal greater risks to coastal property, flooding events or loss of wildlife populations. The coastal impact ranking protocol presented here helps identify target areas for conservation as well as identify areas with the greatest feasibility for coastal restoration.

1. Introduction

Islands are, by their nature, only pieces of a larger whole. Ecologists have come to understand the nature of islands by their isolation, size, and susceptibility to large-scale disturbances. Islands are often studied as groups or archipelagos for biogeographic studies, but national boundaries usually limit studies of development impacts to local scales. The past two decades have produced important research on island ecology in the tropical Atlantic that illustrates the integration of ecological function across land-sea boundaries, and the connectivity between islands (Barbier et al., 2011; Kemp and Boynton, 2012). Coastal processes across the land-sea interface control sediment, nutrients and run-off characteristics, particularly in hot, dry climates with few surface water resources (Ray and McCormick-Ray, 2004). Physical alterations to the shoreline or changes in coastal land use will impact coastal processes, especially altering adjacent marine communities (Sealey, 2004). The loss of biological diversity, erosion of beaches and loss of mangrove areas can impact ecosystem function, particularly shoreline stabilization (see summary in Nagelkerken, 2009).

Humans receive valuable ecosystem services from coastal and estuarine ecosystems, including shoreline stabilization, protection of property, fisheries production and supporting biological diversity, but these services are lost with over-exploitation of coastal resources and loss of habitat (Jackson et al., 2001). Coastal ecologists are paying greater attention to both the role of native plants in maintaining coastal ecosystem stability (McGlathery et al., 2007), and to ecosystem service damage resulting from human

* Corresponding author. Tel.: +1 305 284 3013.
E-mail addresses: ksealey@miami.edu, ksealey56@gmail.com (K.S. Sealey).

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disturbance, particularly through the introduction of Invasive Alien Species (IAS) (Gedan et al., 2011). Threat of eutrophication may be especially insidious in oligotrophic tropical islands, where very small thresholds of nutrient enrichments may cause "phase shifts" or irreversible ecological changes to near shore reefs (See discussions by Aronson et al., 2003; Hughes, 1994; Fabricius, 2005; and Lapointe et al., 2004. Nowhere may these land-sea nutrient fluxes and ecosystem services be more important that in the extreme oligotrophic environments of the Bahamian archipelago (see Buchan, 2000, for ecosystem overview).

In The Bahamas, the characteristic turquoise, clear waters and oligotrophic conditions are maintained by intact coastal plant communities, the absence of surface water discharge, as well as the limited and episodic nutrient input to near shore marine communities (Sealey, 2006; Buchan, 2000). The structure of the carbonate limestone banks with small islands and cays aligns much of the reefal habitat in close proximity to islands. The relationship between biological production (ecosystem function) and diversity has become a central focus of ecosystem management (see review by Loreau et al., 2001).

Changes in coastal environments have not been systematically tracked and documented, and human alterations to the coast are rarely limited to a single activity. The coastal development impacts on near shore marine habitats only amplify the barriers to successful reproduction, recruitment and growth of coastal species, including corals, invertebrates and fishes. How can these changes in the landscape ecology of coastal environments, including species extirpation, habitat loss and fundamental shifts in nutrient dynamics with water quality change be tracked and characterized?

The aim of this study was to determine the comparative "intactness" or a proxy for community stability based on a ranking system of coastal environments over numerous islands ranging from very low to high population densities. The survey was motivated by two questions; first, what was happening to the coastal resources throughout the country outside of national parks and protected areas? Second, how do coastal developments and alterations affect coastal plant diversity? Patterns of coastal use and degradation were determined from a combination of coastal plant surveys and an impact ranking system designed to rapidly identify key areas appropriate for coastal protection, restoration, remediation, or continued monitoring for land-based sources of pollution.

2. Materials and methods

2.1. Bahamian islands study sites and Reference Conditions

In order to gain an overview of the state of the coastal environment and develop a protocol to uniformly assess human impacts, 238 sites at 11 islands of varying size and population density were visited between 2002 through 2012 (Table 1). LandSat images using coastal classification guidelines (Cowardin et al., 1979; CMECS, 2012) were employed to develop a stratified random sampling allocation scheme which incorporated all coastal types (beaches, mangroves and rocky shore) with road access. Topographic maps (produced by the Department of Lands and Surveys, Government of The Bahamas (DLS)) were used in the field; these sectional maps were based on United Kingdom Overseas Survey Department photography taken between 1967 and 1972. Historical aerial photographs were obtained from DLS and private collections from 1972 for selected areas of Andros and Great Guana Cay, Abaco, and 1942 aerial photographs were available for Great Exuma. Google Earth Pro was used to view historical imagery of islands from 1990 to present to verify that historical alterations to the coastal environs were dated as occurring after a known dated imagery. This survey also did not include the large ports in Nassau, New Providence and Freeport, Grand Bahama.

Because the historical use of coastal resources is often poorly known, a coastal impact ranking system was used to develop the criteria for determining "Reference Condition" as defined by wetland and stream ecologists (Stoddard et al., 2006). Surveys consisted of two parts: 1) Classification of the coastal environment, and 2.) Coastal ranking and assessment.

2.2. Classification of coastal environments

Classification of a coastal survey site included 1.) a description of coastal habitat classification, 2.) documentation of the visible coastal zonation from the waterline to upland vegetation, and 3.) a survey of coastal plants using a standard checklist along a transect of the coastal environment.

Coastal environments were described in terms of sediment type, and wave and wind energy using existing definitions and terminology (Table 2). The classification included a description of coastal vegetation using existing plant community and coastal wetland

Table 1
Overview of the islands surveyed in the Bahamian archipelago. 11 islands were surveyed, varying in area, history and population density.

Island	Area (square kilometers)	Population (2010)	Communities and history	Years surveyed in this study
North Andros	4700	6267	Many small communities, heavy reliance on fishing and farming; Several US Navy Military Installations along the coast	1
South Andros	1257	1119	Many small communities, heavy reliance on fishing	1
Cat Island	388	1503	Many communities and several small resorts. This island has lost population since 1960.	1
Eleuthera – South	518	2711	Nearby communities include Deep Creek, failed resort development, Rock Sound is nearest airport	1
Eleuthera – Windermere	8	320	Resort residential community near the community of Palmetto Point and Governor's Harbour	1
Abacos – Great Guana Cay	14	472	Great Guana Cay settlement and three large private home developments	5
Exuma	264	7314	George Town as first capital of the Bahamas, many settlements, resorts and private vacation homes	7
Inagua	1544	911	Site of largest modern solar salt production (Morton) and Mathew Town. Active settlement for 285 years	2
Long Island	448	3024	Resort, farming and formerly used for salt production. Includes Deadman's Cay and Clarence Town	1
New Providence	210	248 948	Most populous island, Capital city of Nassau, largest harbour. Population center of the country, with limited public access to coast	1
Cay Sal Cay	4	0	Un-inhabited	1