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Environmental Function Analysis: A decision support tool for integrated sandy beach planning

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ABSTRACT

Worldwide, sandy beach socio-ecological systems are under stress, yet there are few systematic approaches to guide conservation and development planning. Four sandy beaches in the Halifax Regional Municipality (HRM; Nova Scotia, Canada) were evaluated using a modified Environmental Function Analysis (EFA). Our goal was to reduce the severe data requirements of traditional EFA by using more proxy indicators as well as combining indicators into higher-level metrics. We also sought to incorporate landscape-scale evaluation by incorporating adjacent habitats. Twenty ecological and socio-economic indicators were scored according to their performance, normalized, and plotted in a conservation/use development matrix. Results show that beaches near large cities or towns, have already been extensively developed for their recreational use, and are subject to significant environmental degradation. Other beaches were conflicted between recreational, touristic, and/or exploitative opportunities, versus richer biodiversity, habitats, and species of conservation interest. Scenario analysis demonstrates that management strategies which focus on minimizing the invasive nature of park infrastructure and enhance biophysical restoration, can significantly increase beach conservation value, and shift sites into the conservation zone. Provincial government officials applied results to revised management of one of the study beaches. EFA not only provides general observations allowing beaches to be compared and contrasted, but it also gives useful insight on individual beaches, allowing for better-informed decision-making and tailored management. The simplified EFA methodology proposed is user-friendly, provides conclusive results, and offers a cost-effective approach to sandy beach environment evaluation.

1. Introduction

Coastal environments are increasingly being solicited for their ecosystem goods and services, especially sandy beaches. Today, more than 67% of the world's population lives within 60 km of the coast, a value expected to reach 75% by 2020 (Gray, 1997; Schlacher et al., 2008). Since 75% of ice-free coastal shorelines consist of beach ecosystems (Brown and McLachlan, 2002), economic development, resource extraction, and recreational demand triggered by population growth are placing unprecedented pressure on the world's beaches (Schlacher et al., 2008). Along with human-induced pressures on the landward side, sea level rise induced by climate change gradually constricts sandy beaches on the seaward side (Defeo et al., 2009; Schlacher et al., 2008).

The various anthropogenic and natural stressors imposed on sandy beaches have led to widespread erosion and degradation of these complex ecosystems with consequences for both social and ecological realms. Sandy beaches are valuable to coastal residents since they support a variety of ecological, social, cultural, and economic goods and services (Schlacher et al., 2008). These environments are not only prime recreational grounds supporting the tourism industry; they also provide important nursery grounds for many fish species, supporting stocks and sustaining local fisheries (Schlacher et al., 2007). Sandy beach ecosystems also offer important functions such as nutrient recycling, water filtration, coastal

Abbreviation: Halifax Regional Municipality, (HRM); Environmental Function Analysis, (EFA); Nova Scotia Department of Natural Resources, (NSDNR); Integrated Coastal Zone Management, (ICZM); Socio-Economic Status, (SES); Rainbow Haven Provincial Park, (RHV); Conrad Beach, (CRD); Lawrencetown Beach Provincial Park, (LTN); Martinique Beach Provincial Park, (MTQ); Nature Conservancy of Canada, (NCC); Nova Scotia Topographic Database, (NSTDB).

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protection, and nesting and foraging sites for vertebrate and invertebrate species including endangered fauna (Schlacher et al., 2007). Therefore, an integrated approach to beach management, with emphasis on minimizing the impacts of human activities and climate change while maximizing the sustainable use of sandy beach ecosystems, is critically needed (Schlacher et al., 2008).

The eastern Canadian province of Nova Scotia has an extensive coastline (7400 km) and its numerous beaches figure prominently in recreation, tourism, and nearshore habitat. Beach management and conservation have been driven mainly by the implementation of the provincial *Beaches Act*, which restricts use and promotes beach conservation, and the *Provincial Parks Act*, which aims at sustainable use of selected beaches for recreational purposes. However, the designation process for protected beaches using these Acts lacks a systematic approach to beach conservation, use, and development planning. Presently, the *Beaches Act* designation procedures policy, which is yet to be approved by the Minister, relies on formal requests from the Minister, Deputy Minister, or Nova Scotia Department of Natural Resources (NSDNR) to initiate an evaluation process and consider individual beaches to be protected or not under the Act. Historically, community organizations and concerned citizens have provided the political legitimacy for these formal requests. Unfortunately, the reactive nature of this approach has left coastal planners with little pragmatic support to fulfill their conservation mandate. In a time where the Government of Nova Scotia is contributing to the design of an Integrated Coastal Zone Management (ICZM) strategy and recognizes that sandy beaches and associated dune ecosystems are under “high risk” (Government of Nova Scotia 2009), the need for a more efficient approach to sandy beach planning has become a priority.

However, before the implementation of any management strategy, indicators and decision support tools need to be developed and applied to inform and guide sustainable development and conservation of beaches (Phillips et al., 2007). One relevant methodological framework is Environmental Function Analysis (EFA) proposed by Cendrero and Fischer (1997). Influenced by the concept of environmental functions (i.e. goods and services) suggested by de Groot (1992), the EFA method is based on assessment of ecological and socio-economic components to lead coastal planning. This framework evaluates and scores environmental quality and development indicators to assess multiple sites simultaneously. These values are then plotted in a conservation/development matrix allowing a comparison of sites with respect to environmental values and conflict levels. Despite the various modifications proposed by coastal planning experts (van der Weide et al. (1999), and sandy beach planning researchers (Micallef and Williams, 2003; Phillips et al., 2007), the EFA methodology still requires input of environmental data that is not readily available in many locations. Also, the number of required indicators is burdensome for local capabilities. Furthermore, many indicators proposed by Cendrero and Fischer (1997) do not apply to the Nova Scotia environment and must be adapted to local conditions.

In this context, the present study, based on previous work (Amyot, 2011) has the following objectives:

- Reduce the data/time burden associated with EFA by providing easily identifiable environmental quality indicators
- Create aggregate indices and proxies to make EFA more practical in data-poor environments
- Select and define environmental quality indicators for different environmental components (ecological and socio-economic), relevant to selected beach environments in Nova Scotia.
- Determine which management decisions (affecting a specific environmental indicator), can be most effective in the conservation/use development potential of beaches.
- Discuss the optimal management action for the selected sandy beaches.

2. Material and methods

2.1. Limitations and proposed modifications

Despite the previously successful application of the EFA framework to guide decision-making for sandy beach management, the absence of accurate local environmental data remains the biggest obstacle to scientifically objective analysis. Lacking indicator data (e.g. local coastal water contamination), researchers have relied on a combination of various qualitative (e.g. bad, moderate, good, best, etc.) and quantitative variables (e.g. %vegetation cover, beach width, etc.) to evaluate environmental quality on sandy beaches (Cendrero and Fischer, 1997; de Araujo and da Costa, 2008; Micallef and Williams, 2004).

In our study, a number of modifications to EFA were carried out. First, proxy indicators were selected and described to effectively compensate for the lack of available biological data. Also, equal numbers of ecological-based compared to socio-economic indicators were selected to prevent a bias of conservation over development which typically occurs (Micallef and Williams, 2003; Phillips et al., 2007; van der Weide et al., 1999). Furthermore, to simplify the field investigation and limit overlap, 20 indicators, which utilize easily accessible data were selected.

Data were obtained using Google Earth 2011 (6.1.0.5001), assessed visually, and validated with field observations. Although Google Earth data may have been derived from different years, they are all fairly recent. With Nova Scotia's small population and land mass, land use changes occurring since images were produced would be known to us. Images used were thus considered up to date. Socio-economic and population -related data were obtained from the Nova Scotia Community Counts, a program from the Economics and Statistics division of the Nova Scotia Department of Finance (Government of Nova Scotia 2011). Although the authors recognize that these data sets contain uncertainties, it is beyond the scope of this paper to discuss limitations of third party information sources. Finally, a Delphic approach was used to avoid personal biases, relying on expert opinions in assessing environmental and socio-economic components when hard data were unavailable (Phillips et al., 2007). By applying these modifications to the methodology, it is expected that results yield will provide more practical and wider application of EFA as a beach management tool.

2.2. Selection of environmental quality indicators

The basic categories of environmental components chosen (Tables 1 and 2) have previously been used in the literature (Cendrero and Fischer, 1997; Micallef and Williams, 2003; Phillips et al., 2007; van der Weide et al., 1999). However, new characteristics (e.g. landscape structure, coastal sensitivity) and merged proxy indicators were proposed in order to reduce the time/data burden associated with EFA. Indicators were then aggregated by their relevant environmental components. This was based on past EFA and by subject appropriateness. The descriptions of each new ecological indicator, along with associated assumptions are discussed below, whereas previously used indicators are described only within Table 1.

2.2.1. Ecological indicators

In the following text, we summarize 11 ecological indicators into 6 broad categories (ecological components) as summarized in Table 1. The broad intent of those indicators is also specified in the