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Management of estuarine beaches on the Amazon coast though the application of recreational carrying capacity indices

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HIGHLIGHTS

- A specific approach based on the RCC model was adopted for estuarine beaches.
- Local human pressures have impacted both the quality of the beaches and their carrying capacity.
- The principal problems are a lack of infrastructure or a public sanitation system.
- Major investments in services are needed to guarantee the recreational experience.
- The specific methodology adopted in this study can be used for other Amazon beach.

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ABSTRACT

The purpose of this paper is to determine the Recreational Carrying Capacity of three estuarine beaches (Colares, Marudá and Murubira) on the Amazon coast of Brazil, based on the combined assessment of natural conditions and visitor facilities. In the final analysis, the carrying capacity of Colares beach was estimated to be 1089 visitors per day, and that of Murubira beach, 238 visitors per day. At Marudá beach, however, the inadequate quality of the water resulted in an RCC of zero, indicating that the beach should not be visited for recreational use. The results of this study may provide a valuable diagnostic tool for the development of future state and municipal coastal management programs. We believe that the procedures adopted in this study are applicable to other estuarine beaches on the Amazon coast, as well as in other estuarine beaches elsewhere with similar natural characteristics.

1. Introduction

The use of the term carrying capacity in tourism has its origins in the 1960s (Coccossis & Mexa, 2004), to refer to the limits on the numbers of visitors that a tourist attraction can support. Over the past three decades, the growing interest in areas of tourism, such as beaches, has led to the elaboration of the Recreational Capacity Carrying (RCC) conceptual approach to support the development of management plans. Many variables have been used to define the RCC, including the biophysical limits of the environment, its numerical capacity, and the quality of the visitor experience (Coccossis, Mexa, & Collovini, 2002; Saarinen, 2006; Saveriades, 2000). The most widely-used definition of the RCC is the maximum number of people that may visit a tourism destination at the same time without causing the degradation of the physical, economic and socio-cultural environment or any unacceptable decrease in the quality of the satisfaction of visitors (WTO, 1981).

The definition of the carrying capacity of recreational areas has become an essential tool for beach management, as it "enables the preservation of the high quality and quantity of coastal resources whilst meeting not only the current needs, but also securing long-term economic and ecological benefits for future generations" (UNEP/PAP, 1997), leading to an extensive literature in recent years,

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with a worldwide focus. As the RCC is used to evaluate problems related to overcrowding, these scientists have all been asking the same question – in scientific terms, how many visitors are "too many" for this beach?

In this context, carrying capacity assessment is a technique commonly used in beach management, being applied in different ways and in distinct socio-ecological settings and some recent examples of its application are provided below. De Ruyck, Alexandre and Mclachlan (1997) estimated the social carrying capacity from the opinion of users interviewed on King's Beach and Hobie Beach in South Africa. Silva (2002) combined physical and social carrying capacity assessments by using aerial photographs, video images and interviews with beachgoers in Sines (Portugal). Botero, García, Porto, Manjarrés, and Rocca (2008) developed a model to calculate carrying capacity based on environmental support, urban infrastructure and tourist services, which was used to assess five Caribbean beaches in Colombia. Jurado et al. (2012) developed an approach to evaluate the growth limits of tourist destinations using a mathematical formula based on integrated RCC indices, which were applied to two scenarios of sustainability, one weak and one strong on the eastern Costa del Sol, Spain.

Studies of the RCC of beaches, based on the fundamental principles of the concept, have been undertaken at a number of sites on the eastern and southern Brazilian coast (e.g., Cordeiro, Korossy, & Selva, 2012; Polette & Raucci, 2003; Silva, Leal, Araújo, Barbosa, & Costa, 2008), although only limited research has been conducted on Amazon beaches (Pessoa, Pereira, Sousa, Magalhães, & Costa, 2013; Silva et al., 2011a; Sousa, Pereira, Costa, & Jiménez, 2014, 2011), and these studies have focused on oceanic beaches, rather than estuarine ones. Located on the Brazilian Amazon coast, the littoral of Pará state encompasses major estuarine systems and one of the World's largest and best preserved mangrove forests (Souza-Filho, Martins, & Costa, 2006). The local landscapes are highly valuable in both ecological and esthetic terms, and both oceanic and estuarine beaches are important recreation areas (Pereira, Vila-Concejo, Costa, & Short, 2014; Sousa et al., 2014). Over the past few decades, the construction of access roads has resulted in the increasing use of the beaches for recreational activities, and tourism has become one of the principal sources of income for the local economy, especially during the vacation periods (Pereira, Guimarães, Costa, & Souza-Filho, 2007; Szlafsztein & Sterr, 2007; Szlafsztein, 2009).

Unfortunately, almost 30 years after the implementation of federal law number 7661, which established the National Coastal Management Plan, and with many state coastal management plans in force, few practical measures have been taken to minimize, prevent and/or solve the conflicts associated with the use of land along the coast of Pará. As the popularity of the state's beaches has grown exponentially in recent years, the need for coastal zoning and management plans – including the monitoring of RCC indicators – has become increasingly urgent.

An RCC approach is important here because, while these coastal environments are still relatively well-preserved, its beaches already lack sufficient infrastructure and services to satisfy current levels of demand (Pereira et al., 2014). Unplanned and uncontrolled development has resulted in social and economic conflicts, as well as the deterioration of local coastal resources (Oliveira et al., 2011; Pinto et al., 2011; Silva et al., 2011b; Sousa, Pereira, & Costa, 2013).

In this context, the principal aim of this study was to contribute to the improved management of the beaches in this estuarine environment using the Recreational Carrying Capacity (RCC) concept. To this end, we adapted the standard RCC model to provide a combined assessment of natural and anthropogenic factors considering the unique characteristics of this type of beach. In general terms, it is extremely difficult to determine the "magic number" of tourists because the threshold established by tourists tends to differ from the ecological limits (Jurado et al., 2012), but we adopted a specific approach for these estuarine beaches that can also be used at other Amazon beaches.

2. Amazon estuarine beaches

Estuarine beaches typically have a relatively long shoreline in comparison with those on open coasts, and are affected primarily by tidal currents, with negligible wave action (e.g., Nordstrom, 1992; Vila-Concejo, Hughes, Short, & Ranasinghe, 2010), and are thus considered low energy environments. However, the beaches of the estuaries of the Amazon coast have distinct characteristics, and do not necessarily conform to the classification system adopted by Jackson, Nordstrom, Eliot, and Masselink (2002).[1]

Amazon estuarine beaches are located within a mangrove-dominated fluvial-marine ecosystem controlled by meso- and macrotides, waves of moderate energy and strong tidal currents. The climate of the study region is humid equatorial with a mean annual temperature of 26–27 °C and annual precipitation generally between 2000 and 3000 mm, with 75–85% of this precipitation falling during the rainy season, between January and May, and a dry season during the second half of the year (INMET, 2015).

The enormous fluvial discharge observed in this area is the result of the region rainfall pattern, which generates a massive input of suspended particulate matter (such as suspended sediments, detritus and organisms) and stained dissolved organic matter (humic substances) from the extensive areas of mangrove. Tide-dominated conditions and strong local tidal currents are responsible for the resuspension of the fine particulate matter contributing to much higher turbidity levels (>100 NTU) in the coastal waters, including the estuarine beaches. The enormous fluvial discharge from the Amazon River and adjoining estuaries, which represents 20% of the planet's freshwater, results in the typically reduced salinity (near zero) of the region's estuarine beaches, especially during rainy season.

The tidal range reaches a maximum of 11 m at Igarapé do Inferno (Amapá), decreasing northwards along the Amapá coast to 7 m and then 4 m, and 5–6 m to the south on the Pará coast, 3–4 m in Marajó Bay and at Belém, rising eastwards to 7 m in the Gulf of Maranhão, and then declining again to 3 m at the Parnaíba delta (DHN, 2015). Local values of tidal elevation together with estuarine geomorphology determine local tidal current patterns. Strong tidal currents affect the estuarine beaches and can reach velocities of more than 2.0 m s^{-1} (Beardsley et al., 1995). Offshore significant wave heights can reach more than 1.5 m, but the influence of the tides normally prevails over wave action, especially at low tide, when the estuarine waters are sheltered by sandbanks, which reinforce the tidal modulation.

In contrast with other parts of Brazil, the principal recreational period on the Amazon coast coincides with the July school vacation and bank holidays during the second half of the year, given that the January school vacation – the peak period in most other Brazilian regions – coincides with the beginning of the Amazon's long and intense rainy season. Other factors, such as the relative isolation of the beaches due to extensive area of mangrove forest, the difficult access due to presence of countless estuaries, creeks and rivers, and

[1] Jackson et al. (2002) proposed four criteria to define low-energy beaches: (i) negligible significant wave heights (H_s < 0.25 m) during non-storm conditions, (ii) low significant wave heights (H_s < 0.50 m) during strong onshore winds, (iii) narrow beach face width (<20 m in microtidal environments) and (iv) morphological features that may include those inherited from higher energy events.