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Coastal development at sea turtles nesting ground: Efforts to establish a tool for supporting conservation and coastal management in northeastern Brazil

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ABSTRACT

While tropical and subtropical coastal areas are considered prime areas for a wide range of tourism projects, they also host important sea turtle nesting grounds. Preserving these nesting areas is critical to ensure reproductive success and maintain viable sea turtle populations. The northern coast of the State of Bahia, in northeastern Brazil, is an important sea turtle nesting ground. Sea turtle conservation activities in Brazil began in 1980, focusing initially on reducing harvesting of nesting females and egg collection. Recently, new threats resulting from unplanned coastal development have emerged. In this paper, a geospatial tool, as an initiative of the Brazilian National Sea Turtle Conservation Program (TAMAR) to identify key areas for sea turtle nesting along the coast northern coast of Bahia, is presented. A Sensitivity Map was created, using a detailed GIS map graded by colors representing relevance levels of the coast for sea turtle nesting. From this map, recommendations of management practices that correspond to each sensitivity category can be made. This methodology allows for the identification of critical sea turtle habitats and the subsequent implementation of mitigation measures at nesting beaches, as well support coastal management policies.

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1. Introduction

Coastal development has been taking over tropical coastal and adjacent sea turtle nesting beaches. If poorly managed such development can damage the natural environment, especially without environmental planning legislation and adequate implementation (Hall, 2001; Orams, 2003; Lee, 2010; El Mrini et al., 2012). In Brazil, the northern coast of Bahia is an important nesting ground, primarily for loggerheads (*Caretta caretta*), olive ridleys (*Lepidochelys olivacea*) and hawksbills (*Eretmochelys imbricata*), and to a lesser extent for green turtles (*Chelonia mydas*). Sea turtle conservation initiatives in Brazil began in 1980, with the creation of Projeto TAMAR (Brazilian National Sea Turtle Conservation Program) (Marcovaldi and Marcovaldi, 1999).

Until 1950, the northern coast of Bahia was considered a poorly developed and sparsely populated agricultural region. In the early 1970s, a phase of Petrochemical industrial development took place in the municipalities neighboring Salvador. In the 1990s a state highway was completed connecting Salvador to the northern area through the coastline, allowing for the expansion of tourism and urban development. At this time, the Brazilian Government launched a tourism development program in Northeast Brazil named PRODETUR/NE (*Programa de Desenvolvimento do Turismo no Nordeste*), in order to boost the tourism industry in this region. Since then, large public and private investments have been made, mainly for the provision of basic infrastructure and support for tourism development (Lyrio, 2003; Silva et al., 2008). Currently, the coastline is characterized by a highly consolidated urban area in Salvador that decreases toward north.

At the start of TAMAR's activities in the 1980s, the main threats for the sea turtles were the direct harvesting of eggs and nesting females on the beach. Egg poaching was widespread all along the

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coast, often approaching 100% of all eggs laid. However, poaching was primarily for local subsistence as no formal markets for turtle products existed (Marcovaldi and Marcovaldi, 1999). After decades of conservation efforts, which included the involvement and participation of local communities as well as other stakeholders, the number of eggs laid by loggerhead (Marcovaldi and Chaloupka, 2007), hawksbill (Marcovaldi et al., 2007), olive ridley (Silva et al., 2007), and leatherback turtles (Thomé et al., 2007) gradually increased.

Unfortunately, while the threat of egg poaching and harvesting of nesting females was being reduced, over the last two decades new threats have become increasingly evident. Intensive development in the coastal zones not only places sea turtle populations at risk (i.e. artificial lighting, shoreline armoring, beach driving) but also degrades the ecosystems (i.e. pollution, erosion, overfishing). In the northern coast of Bahia, most of the environmental degradation and habitat loss are due to urban development, where several resort projects and super-sized condominiums are implemented every year (Lyrio, 2003; Silva et al., 2008). An evaluation on the recreational quality and the carrying capacity of beaches on northern Bahia revealed that many beaches currently undergoing development have problems of carrying capacity as well as important environmental constraints (Silva et al., 2012).

This new regional development poses challenges to sea turtle conservation, requiring the creation of an appropriate institutional framework for coastal management to mitigate the potential negative impacts to these animals. The aim of this study is to present a Sensitivity Map Guide and some preliminary results of its application, as an initiative to create a supportive tool for coastal management and conservation in Bahia northern coast, focusing on sea turtle nest protection. It includes a detailed GIS map graded by colors representing relevance levels of the coast for sea turtle nesting, and recommendations of management practices that correspond to each sensitivity category. It has the potential to be applicable to other sea turtle nesting areas under intense development pressure.

2. The methodological approach of the Sensitivity Map Guide for sea turtle nesting ground conservation

The Sensitivity Map Guide and best practical measures for safeguarding sea turtle nesting grounds in Bahia were developed according to the TAMAR's standard sea turtle conservation practices. This includes daily and night beach patrols to locate nests, *in situ* nest monitoring, and relocation of at risk nests to other beaches and/or open-air hatcheries, as well as community outreach and education within the coastal villages (Marcovaldi and Marcovaldi, 1999). The Guide was based on Environmental Sensitivity Index (ESI) mapping for oil spill contingency planning and response (e.g. Jensen et al., 1998). We used Geographic Information System – GIS tools to rate sea turtle nesting beaches with different levels of relevance.

The northern Bahia coastline was divided into 214 km (covering 34 beaches). According to TAMAR's fieldwork routines (for details see Marcovaldi and Marcovaldi, 1999) the kilometer of each sea turtle nesting activity, and its biological information, is registered in a database. Three relevance levels were created, based on the number of nests per kilometer (nest density), using the data from the last five nesting seasons (from 2007/2008 to 2011/2012), as follows: level one (low relevance = 0–20 nests/km); level two (medium relevance = 21–60 nests/km) and level three (high relevance $\geq$ 60 nests/km). The criterion used for determining the number of classes and the nest densities for each one of them was based on TAMAR's expertise and the relative abundance of sea turtle nests on the northern coast of Bahia.

Along with the Guide, recommendations for sea turtle conservation were made according to each level, so that sections with higher relevance levels would require the greater protection measurements.

3. Results and discussion

High relevance areas comprise nearly 43% of the nests laid on the northern coast of Bahia, and represent only 14% of the coastline length (Table 1). It was possible to protect areas of high nest densities without necessarily classifying the entire coast as a high relevance area. The use of GIS mapping provides visual display of data that can be easily accessed to identify the relevance level of a specific location along the coast, thus, facilitating its use by coastal management stakeholders (Fig. 1).

This methodology is an especially useful tool given that sea turtles exhibit nesting site fidelity resulting in consistent nest density from season to season (Marcovaldi et al., 2010; Matos et al., 2012). However, an ongoing review of each subsequent nesting season is critical to eventually adjust the level of importance of each costal segment.

For each level of relevance, recommendations for sea turtle nesting ground conservation were established. All the recommendations were based on internationally recognized best practices for safeguarding sea turtle nesting grounds (e.g. Eckert et al., 1999; Witherington and Martin, 2000). They include standard guidelines for coastal lighting, beach use, building setbacks, and others, some of them supported by sea turtles specific protection regulation (Table 2). The recommendations presented here focus mainly on the negative effects of light-pollution and increased human use of nesting beaches, since coastal development did not aggravate the old threats (e.g. egg poaching), but it has triggered new problems.

Light pollution, which can be defined as the introduction of artificially produced light into pristine areas, is considered one of the greatest threats to nesting females and to hatchling survival. Hatchlings typically emerge from the nests at night and use visual cues to find the ocean. As such, artificial lights can disrupt hatchling sea-finding behavior, making them more susceptible to mortality associated with exhaustion, dehydration, predation, among others, and can also disorient nesting females (Witherington and Martin, 2000).

Along the northern Bahia coast, disruption of hatchling orientation due to artificial lighting is becoming much more frequent, especially in more densely populated areas (Serafini et al., 2010). Since the 1990s, federal and state laws prohibit any artificial lighting on sea turtle nesting beaches on northern Bahia. Recommendations to prevent light-pollution seek to ensure compliance with legislation, and also to use global best practices to minimize the light-pollution impacts on sea turtle nesting grounds.

The building's distance, height and occupancy level near nesting beaches, as well as the quantity of users and the nature of beach activities has a direct impact on the sea turtle nesting grounds. For these reasons, measures such as construction setbacks, “turtle friendly” lighting and construction regulations (e.g. building size and occupancy limit) can help reduce the threats generated by coastal development. Setback regulations must be implemented not only to address light pollution and habitat alteration, but also to prevent expected impacts as a result of rising sea levels (Fish et al., 2008; Mazaris et al., 2009).

The federal and state environmental legislation in Bahia provides setback regulations (50 m from the beach) that may be appropriate for most sea turtle nesting areas (low relevance). However, in areas of greatest relevance (medium and high relevance) the setback regulation may be more restrictive, considering the importance of these areas as sea turtle nesting grounds.

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