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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.

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.

Table 1
Relevance levels and its correlation with nest density classes on northern Bahia.

Relevance level	Significance	Nest density classes	Number of nests[a]		Number of kilometers	
			n	%	n	%
1	Low	1 to 20	1,020	15	95	44
2	Medium	21 to 60	2,924	42	90	42
3	High	Up to 60	2,969	43	29	14

[a] Based on the average of the last five nesting seasons (2007/2008 to 2011/2012) (TAMAR, database).

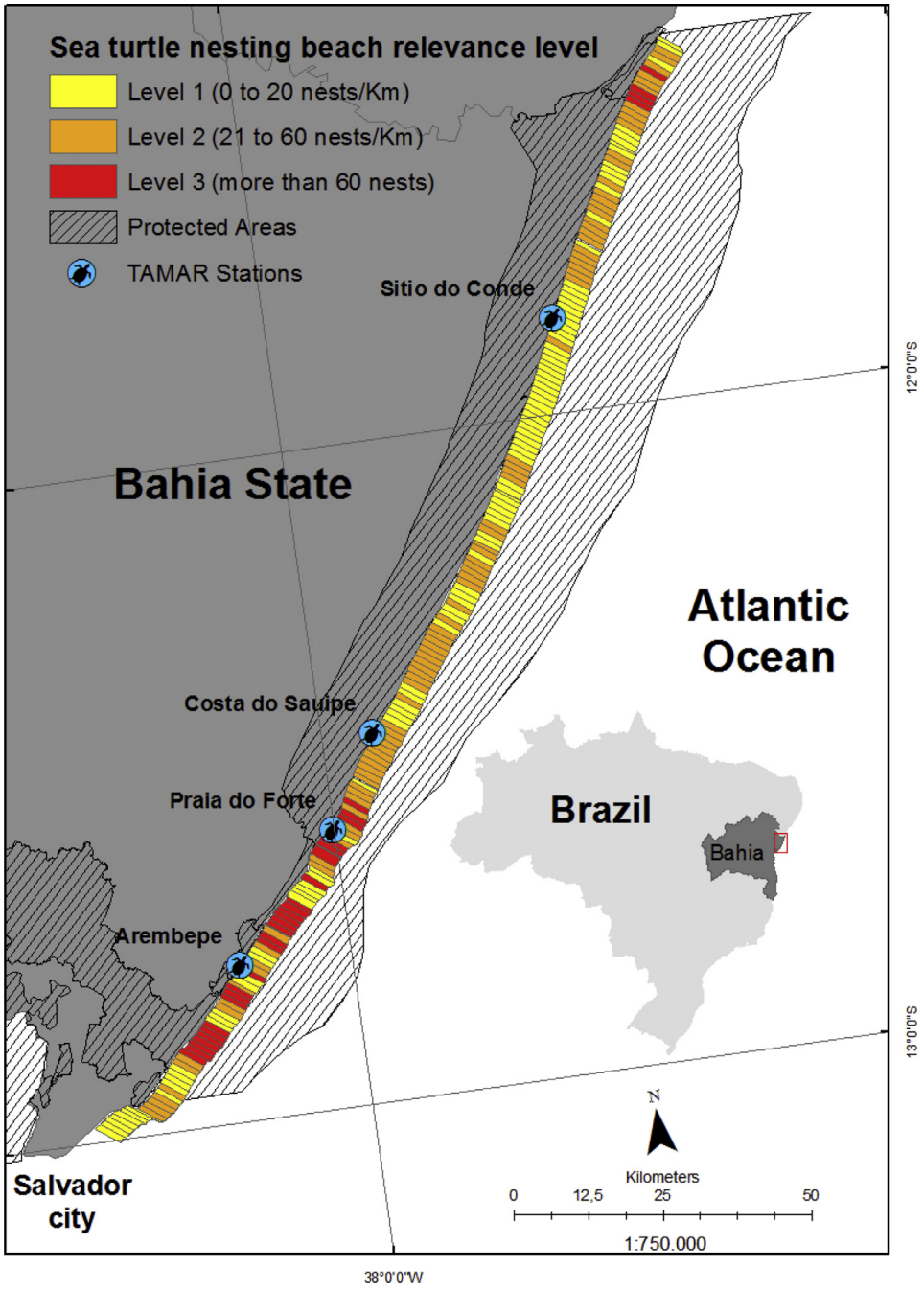

Fig. 1. A GIS map of Bahia, Brazil, with areas of coastline graded by colors, representing the amount of sea turtle nests per kilometer (levels of relevance). Land use strategies that correspond to each level were developed to help protect sea turtles in the area.

Additionally, building features (e.g. number of floors and occupancy limit) are determined by specific regulations, such as the environmental licensing legislation or coastal zone management tools (e.g. ecological-economic zoning). By regulating building features, it is possible to minimize disturbances on nesting beaches.

Due to the intense development of the mass tourism industry

Table 2
Recommendations for safeguarding sea turtle nesting beaches, taking into account their level of relevance.

Features	Relevance levels		
	Low (level 1)	Medium (level 2)	High (level 3)
Construction setbacks	60 m	120 m	180 m
Floors or levels of buildings	–	Front buildings with a single floor	All buildings with a single floor
Occupancy density	High	Medium	Low
Beachfront lighting	Low and indirect lighting behind the nesting beach	Indirect lighting and control of light scattering	Fully shielded indirect lighting
Beach access	–	Restricted access	Very restricted access or no access at all
Beach use	No habitat changes	No habitat changes	No habitat changes
Beach furniture and recreational equipment	Place beach furniture and recreational equipment at a minimum distance from the sea turtle nests	Avoid non-permanent structures (e.g. beach umbrella) on nesting beaches and remove at night	Restrict non-permanent structures (e.g. beach umbrella) on nesting beaches and remove furniture and recreational equipment at night
Beach use at night	–	Avoid walking on the beach at night during sea turtle nesting season	Do not walk on the beach at night during sea turtle nesting season

along the northern coast of Bahia in recent decades, hundreds of thousands of visitors are attracted to the beach for recreational use. Major tourist destinations in the area include the beaches adjacent to Salvador and some urban-villages along the coastline, as well as sandy beaches in front of large tourist developments. Unfortunately, this results in the common removal of beach vegetation for leisure purposes, which disrupts nest site selection by sea turtle females and subsequent egg incubation (Serafini et al., 2009). Intensive beach use could also potentially reduce hatchling success from trampling, due to the effect of sand hardness (Kudo et al., 2003). The introduction of beach furniture (e.g. beach chairs and umbrellas) and recreational equipment (e.g. sailboats), especially if they remain on the beach at night, may harm, disturb and entrap nesting sea turtles and hatchlings, as well as compact the surface of the sand, killing the eggs within the nests.

Controlling human access to nesting areas and recreational beach use becomes crucial, especially in areas of high relevance. With the exception of specific legislation prohibiting vehicle traffic on beaches, many of the coastal recreational activities are not regulated by any laws or management tools, requiring cooperation among users and other stakeholders to minimize the impacts on sea turtles and their nesting beaches.

3.1. Using the guide to promote conservation of Bahia's sea turtle nesting beaches

One of the immediate applications of the Guide has been the environmental licensing process of major tourism projects. In Brazil, large developments located in areas of high environmental significance, require the preparation of an Environmental Impact Assessment (EIA). When these developments are also located on sea turtle nesting beaches, Brazilian law stipulates that the licensing process can only become effective after evaluation and recommendation of the Brazilian Institute for the Environment and Natural Resources (IBAMA) and after hearing the Brazilian National Sea Turtle Conservation Program – Centro TAMAR (National Environmental Council – CONAMA Resolution n° 10 from October 24, 1996) recommendations. The EIA is required to provide detailed information about the proposal, the potential environmental impacts (taking into account the presence of endangered species, such as sea turtles) and the practical measures to mitigate negative impacts.

The Guide has been used to provide a basis for entrepreneurs when preparing their projects and what measures are needed to mitigate the potential impacts on beaches and sea turtles. For example, between 2007 and 2009 on Guarajuba beach, a medium-sized beach front hotel (about 1000 guests) was established in a sea turtle nesting area of high relevance (Fig. 2). During the environmental licensing process, the project was designed to allow for the operation of the hotel in accordance with the recommendations to protect sea turtle nesting areas. As a result, the beach in front of the hotel provides suitable conditions for the maintenance of nests *in situ*, especially with regard to the incidence of light on the beach. All light sources have been designed so that the effect of direct and indirect lighting of the project was minimized (Fig. 3).

The Guide has also been used to conduct efforts of TAMAR to deal with threatens. For example, beaches shown in Fig. 2, were mainly pristine in the until the 1990's. Limited beach use by tourists and local residents permitted the preservation of sea turtle nests *in situ*. However, by the early 2000s, the occupancy of the entire length of the coast (16 km) by second residence condominiums and hotels increased, resulting in significant light-pollution and heavy beach use. This forced TAMAR to relocate clutches to a beach hatchery or more suitable nest sites. For instance, on Itacimirim beach all clutches were transferred to the Praia do Forte's beach hatchery up until the 2009/2010 nesting season (n=105, 100%). However, after implementing appropriate management practices based on the recommendations of the Guide, during subsequent nesting seasons (2010/2011 and 2011/2012), half of the clutches (n = 146, 62% and n = 76, 51%, respectively) were able to be left *in situ* due to improved habitat conditions (TAMAR, database).

This example illustrate that by implementing the recommendations of the Guide with beach front developments, it is possible to encourage habitat recovery enough so that turtle nests can remain *in situ*. Priority recommendations were based on reducing the amount of light that reaches the nesting beaches. Night-time inspections were conducted in order to identify light sources observable from the beach. Hotel, condominium and resort projects were encouraged to incorporate “sea turtle friendly lighting” into their buildings (Fig. 4). Environmental education campaigns were also carried out in order to raise public awareness of the impact of light pollution on sea turtles.

In addition to the immediate application of the environmental licensing processes in the improvement of existing urban infrastructure, the Guide was initially used as a tool for coastal management and conservation policies. One of the current uses is to establish priority zones for environment conservation in the state of Bahia. This is part of the Brazilian effort to achieve international conservation goals defined by The Convention on Biological Diversity. This initiative has been coordinated by the World Wide Fund for Nature (WWF), in order to plan a map of priority zones in Bahia. The areas mapped in the Guide were integrated in the methodology (based on the Software MARXAN for spatial conservation prioritization – Ball et al., 2009) to create a map of priority

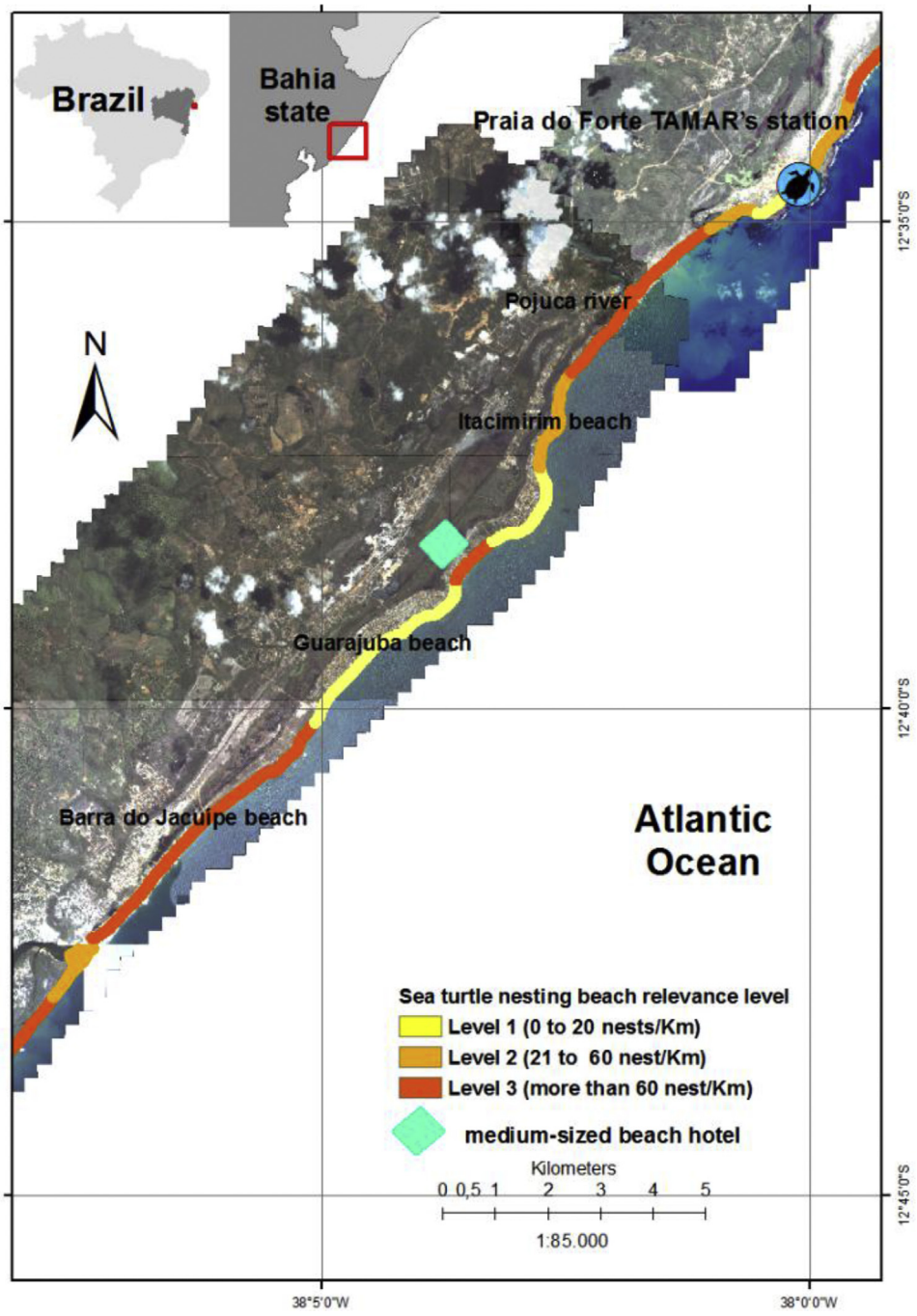

Fig. 2. The map shows a coastline segment of northern Bahia, northeastern Brazil, which is one of the largest nesting areas in Brazil, but also is considered a popular destination for tourists.

zones for biodiversity conservation. The areas mapped in the Guide and identified as a high level of relevance for sea turtle nesting were designated as targets for conservation efforts.

Other current uses has been to support the management of a Protected Area in the Bahia northern coast. In the late 1990s and early 2000s the government of Bahia created six Protected Areas for sustainable use called Environmental Protected Areas (*APA – Área de Proteção Ambiental*) (Fig. 1) (Oliveira, 2002). The APA Litoral Norte is the largest (142,000 ha), and since 2014, Bahia's government is revising its ten year old Management Plan. The levels of relevance mapped in the Guide serves as a base to determine potential uses of the coast, in order to ensure the protection of sea turtle relevant nesting areas inside the APA area.

4. Conclusions

The Sensitivity Map Guide presented here for sea turtle nesting ground conservation could potentially improve: (i) the quality of the development projects implemented in Bahia northern coast regarding sea turtle nesting protection, especially in the EIA process; (ii) guide entrepreneurs in the selection of areas for tourism projects, avoiding areas of high relevance for sea turtle nesting; (ii) guide the effort of TAMAR's conservation activities in the areas of high level of relevance for sea turtle nesting; and (iii) create a tool

Fig. 3. Development of a light-pollution mitigation strategy in a medium scale hotel on northern Bahia.

Fig. 4. Public sidewalk along a sea turtle nesting beach on northern Bahia, before (left) and after (right) lighting inspections and corrective measures.

to support decision-making on coastal planning and conservation, as management plans of Protected Areas, and efforts to establishing proprietary zones for biodiversity conservation.

The potential use of the Guide for coastal management on the northern coast of Bahia depends on political efforts in order to encourage proper use by local stakeholders through the support of public policies for integrated coastal management. Nevertheless, this initiative represents an important effort for sea turtle and coastal conservation in Brazil, and could be used as a tool in other tropical coastal zones under high coastal development pressures. Its integration with public policies for coastal management could improve not just sea turtle conservation, but also the coastal stewardship through the definition of sensitive areas for coastal conservation.

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