

Is there temporal variation on solid waste stranding in mangroves? A case study in Ratoes mangrove, Florianopolis, Brazil

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Resumo

Há variação temporal no encalhe de resíduos sólidos urbanos em manguezais? Um estudo de caso no manguezal de Ratoes, Florianópolis, Brasil. Áreas de manguezais estão diminuindo em todo o mundo devido às fortes pressões antrópicas geradas pelo crescimento populacional. Entre as atividades mais danosas, estão aterramentos, carcinicultura e o despejo de resíduos. Quanto aos resíduos sólidos, os estudos de padrões espaciais e temporais de encalhe são necessários para entender sua dinâmica, identificar possíveis fontes de despejo e entender seu papel na dispersão de organismos nas áreas naturais. Neste estudo, foi analisada a variação temporal de encalhe de resíduos sólidos no manguezal de Ratoes, noroeste da ilha de Santa Catarina (Brasil), durante um ano. Os resíduos encalhados em oito parcelas de 50 m² alocadas aleatoriamente foram coletados, quantificados e qualificados *in situ* mensalmente. Itens de plástico e nylon (ambos derivados de petróleo) representam 80% dos resíduos encalhados. Houve diferença significativa no encalhe temporal para o plástico, contudo não para o nylon. Os resíduos foram encontrados em todas as amostras e durante todo o ano, sendo algumas áreas mais afetadas. Áreas com densa borda de *Spartina alterniflora* Loisel (Poaceae) parecem ter menos resíduos no interior do bosque, talvez devido ao efeito de malha destas formações de gramíneas atuando como uma barreira. Os resultados encontrados refletem aspectos preocupantes para conservação, pois este manguezal é constantemente impactado pelo encalhe de resíduos sólidos urbanos, com maior concentração em áreas importantes como berçário.

Palavras-chave: Área Costeira; Contaminação; Ilha de Santa Catarina; Lixo

Abstract

Mangrove areas are decreasing around the world due to population increase. The most damaging activities include embankments, shrimp farming, and dumping of wastes. The temporal and spatial stranding patterns of

solid waste are important to establish probable sources and understand their role in the dispersion of organisms through natural areas. In this study, we analyze temporal variation of solid waste stranding in Ratones mangrove, northwestern of Santa Catarina Island (Brazil). Samplings were carried out monthly during one year in four different areas. In each area, two 50 m² random plots were sampled per month. All solid waste strands on the plots were removed, quantified, and qualified. Plastic and nylon items (both made of petroleum) represented 80% of waste stranding. There were significant differences in temporal stranding with regard to plastic, but not to nylon. Wastes were found in all samples throughout the year, and some areas are more affected than others. Places with dense edges of *Spartina alterniflora* Loisel (Poaceae) seem to have less solid waste inside mangrove forest, perhaps due to the effect of grass acting as a mesh barrier. The results reflected concerns with conservation, considering that these coastal ecosystems are impacted by waste dumping throughout the year, with highest concentration within important nursery points.

Key words: Coastal Zone; Contamination; Island of Santa Catarina; Litter

Introduction

Mangrove forests are very complex, dynamic, highly resilient, and resistant. They are characterized to occur in tropical zones and some subtropical regions all over the world (LUGO; SNEDAKER, 1974; CHAPMAN, 1977; SCHAEFFER-NOVELLI; CINTRÓN, 1986; SPALDING et al., 1997; LAL, 2003; NAGELKERKEN et al., 2008). Mangrove plant community consists of typical species, which are adapted to high saline substrate and periodical tide flooding (CHAPMAN, 1977; SCHAEFFER-NOVELLI; CINTRÓN, 1986; TOMLINSON, 1988; SPALDING et al., 1997; PARIDA; JHA, 2010). This ecosystem provides breeding, nesting, protection, and feeding to several species (CHAPMAN, 1977; SCHAEFFER-NOVELLI; CINTRÓN, 1986; TOMLINSON, 1988; NAGELKERKEN et al., 2008). Due to its ecological and socioeconomic significance, the Brazilian legislation establishes specific standards to ensure mangroves as permanent preservation areas. However, lack of knowledge about the law among people living nearby mangroves, shortage of resources and staff for environmental inspection agencies, as well as political and economic conflicts constitute strong factors to protection ineffectiveness.

Decrease in mangrove areas around the world is directly related to pressures generated by industrial and urban growth (POLIDORO et al., 2010). Pipeline work, changes in river flows, embankment, shrimp farming, salt extraction, and dumping of wastes are among the most damaging human activities (HAMILTON; SNEDAKER, 1984). The negative impacts of wastes on

local fauna includes ingestion (VLIETSTRA; PARGA, 2002; PROVENCHER et al., 2010; TOURINHO et al., 2010; POSSATTO et al., 2011) and entanglement (DERRAIK, 2002), besides dispersion of exotic and invader species (BARNES, 2002; BARNES; MILNER, 2005). Floating anthropogenic objects might facilitate long distance transport of species (THIEL et al., 2011) and result in native diversity loss at new locations (BARNES; MILNER, 2005).

Temporal differences in waste accumulation can be related to many variations, such as periodicity of beach use and rainfall (IVAR DO SUL; COSTA, 2007; PORTZ et al., 2011; TOURINHO; FILMANN, 2011; MACHADO; FILMANN, 2010; WIDMER; HENNEMANN, 2010; NETO; FONSECA, 2011; VIEIRA et al., 2011). Spatial and temporal patterns of solid waste stranding are significant to establish probable sources and understand their role in dispersion of organisms through natural areas (BARNES; MILNER, 2005; HINOJOSA et al., 2010).

Florianopolis is famous as a tourist city because of its beaches. According to IBGE (2010), this city has 404,224 inhabitants, but it is estimated to increase to almost 1 million during the tourist period. Each month, 766.6 tons of solid wastes are collected with rises to 825.5 tons on summer (COMCAP, 2011). Population explosion on summer without proper infrastructure has tragic consequences for coastal ecosystems.

Although studies about litter on Latin America beaches and the influence of tourism are already well established, they still have to be developed in other marine

ecosystems (IVAR DO SUL; COSTA, 2007). Researches about urban solid waste in mangroves are very recent and scarce (eg. GREEN; WEBBER, 1996; SOUZA et al., 2008; CORDEIRO; COSTA, 2010; VIEIRA et al., 2011), perhaps because these environments do not have the same aesthetic and economic appeal of beaches (ARAÚJO; COSTA, 2007; IVAR DO SUL; COSTA, 2007; NETO; FONSECA, 2011).

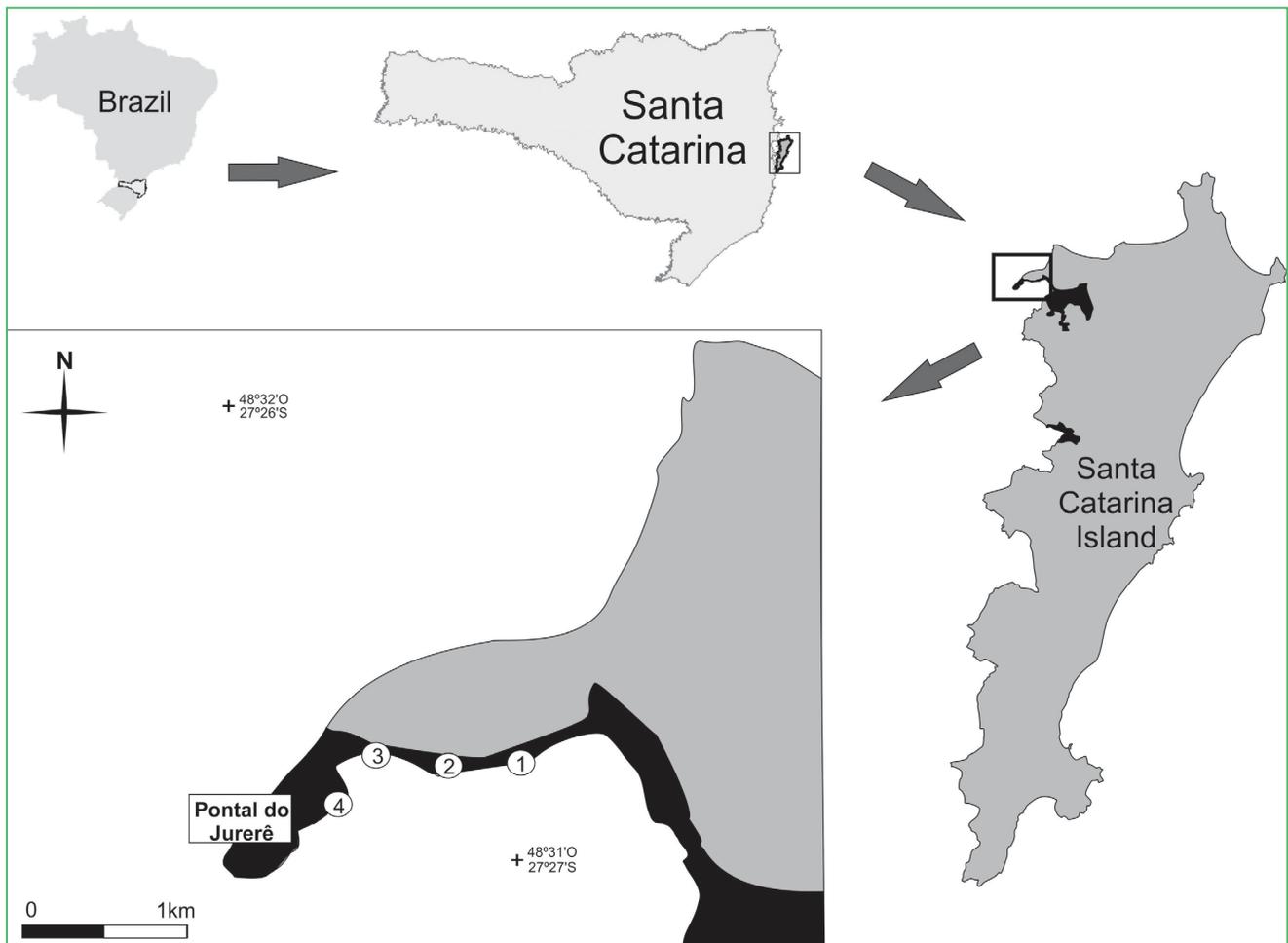
Vieira et al. (2011) discuss about solid waste quantities and homogeneity of stranding in Ratoles mangrove and show that there were spatial differences on solid waste stranding. Taking into account the expected population variation due to tourism and the proximity of mangrove to crowded beaches, temporal differences are also expected, with more wastes on spring and summer. Therefore, this study aims to analyze temporal

variation of solid waste stranding in a mangrove region of Florianópolis city, Brazil.

Material and Methods

Florianópolis is located at Santa Catarina Island (Brazil), nearing the southern boundary of mangrove distribution in South America (CHAPMAN, 1977; SCHAEFFER-NOVELLI; CINTRÓN, 1986; SPALDING et al., 1997). Mangrove forests spread in certain areas both along north and south bays, as well as in island and continent. Some of these mangroves are protected areas, such as the Carijós Ecological Station (Figure 1), which aims to protect Ratoles and Saco Grande mangroves.

FIGURE 1: Location of sampling areas at Pontal de Jurerê (or Pontal da Daniela), Carijós Ecological Station (black), Santa Catarina Island, Brazil.



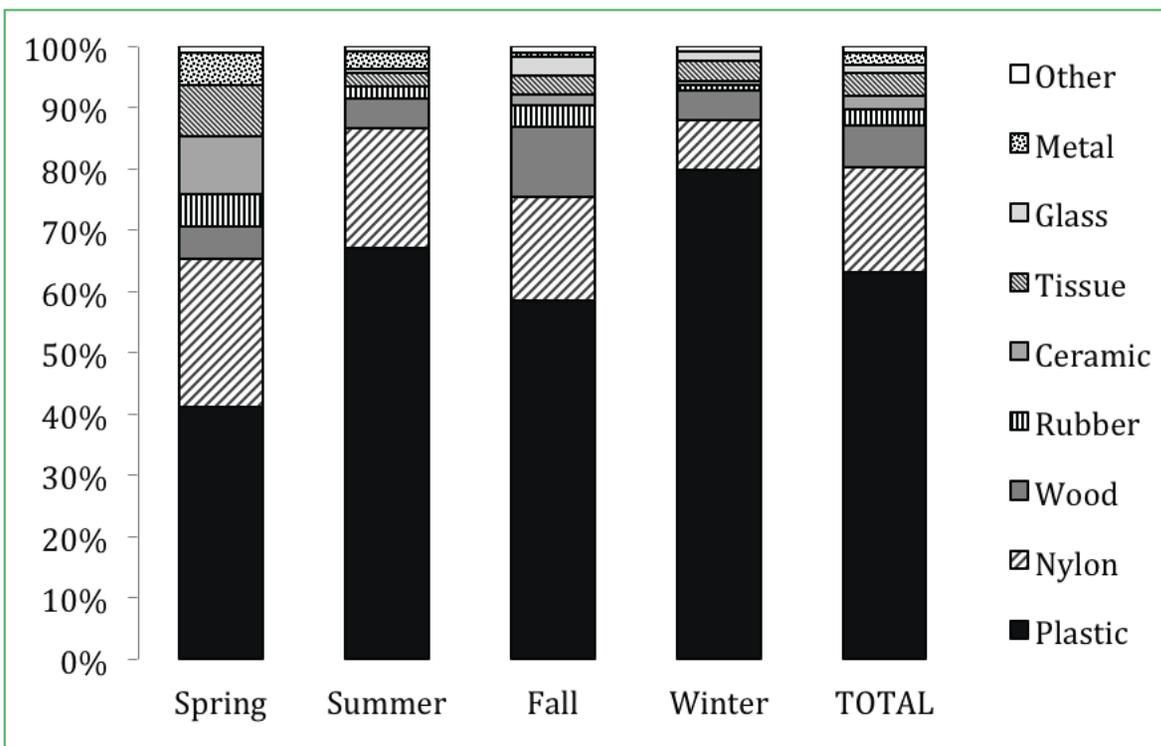
The Ratonés mangrove northern limit (27°27'S and 48°32'W) is located at the Pontal de Jurerê border (Figure 1), also known as Pontal da Daniela. This formation is a unique transition between mangrove and sandy beach. The mangrove forest is dominated by *Laguncularia racemosa* (L.) C. F. Gaertn (Combretaceae), *Avicennia schaueriana* Stapf & Leechm. ex Moldenke (Acanthaceae) and *Spartina alterniflora* Loisel (Poaceae), with few individuals of *Rhizophora mangle* L. (Rhizophoraceae).

At this region, four 650 m² areas (Figure 1) were chosen (described by VIEIRA et al., 2011) and totally cleaned before the research started, in order to avoid the influence of antecedent debris. Thereafter, two random 50 m² plots were monthly sampled in each area. This study is limited with regard to seasonal analysis, because using months as sampling periods can lead to a seasonal pseudoreplication (HULBERT, 1984) when only one year is taken into account. Nevertheless, temporal variations were focused throughout one year, with samplings between October 2008 and October

2009 during the lowest tide of each month. All solid waste items were analyzed, regardless of being whole or fragmented. These items were removed from samples and given to the company responsible by solid waste management (*Companhia de Melhoramentos da Capital – COMCAP*) aiming at a correct destination and to avoid interference by double-counting. Quantifying and qualifying processes happened *in situ*. Debris were not weighted due to their different nature.

Solid waste was categorized as: plastic, nylon, rubber, metal, wood, glass, tissue, ceramic, and other. Data was transformed to log₂ and tested for normal distribution with Shapiro-Wilk test. To test for variance homoscedasticity, Levene's test was used. The temporal variation of solid waste stranding was compared through two-way ANOVA test ($\alpha = 0.05$) using the software *Statistica 7.0* (STATSOFT, 2004) and grouping months into seasons (summer: December to February; autumn: March to May; winter: June to August; and spring: September to November). For significant differences, Tukey test *post hoc* was applied (ZAR, 1999).

FIGURE 2: Percentage of solid waste during seasons between 2008 and 2009 at the Ratonés mangrove, Brazil.



Results

Out of all components collected ($n = 602$) during 12 months, plastic represented the highest percentage of standing (63%), followed by nylon (17%), wood (7%), tissue (4%), rubber (3%), ceramic (2%), metal (2%), glass (1%), and other (1%), as shown in Figure 2. “Other” items included candles, cigarettes, and foam. Solid waste was found in all samples throughout the year, with some areas being more affected than others.

When considering the two main types of solid waste (plastic and nylon), the one-way ANOVA test showed a temporal variation for plastic components ($F = 3.02$; $p = 0.03$), with higher concentration during summer (Figure 3a). There was also a significant difference between fall and winter (Tukey test; $p = 0.05$). On the other hand, nylon did not present significant variations between seasons ($F = 1.86$; $p = 0.14$) (Figure 3b).

The two-way ANOVA test showed a significant influence of the “area” factor on wastes stranding variation (Table 1). Variation in solid waste stranding according to season showed high standard deviations. The factors “season” and “season with area” presented no difference. But “area” had a significant influence on this variation. These differences indicate that the influence

of the factors “area” and “season” are stronger when considered alone than together; it stresses the sampling areas location relevance over temporal changes. Data normality was verified with Shapiro-Wilk test ($W = 0.97$; $p = 0.05$) and Levene’s test showed the homoscedasticity variation ($F = 0.59$; $p = 0.87$).

TABLE 1: Results from two-way ANOVA testing season and area influence on debris stranding at the Ratonés mangrove, Santa Catarina Island (Brazil).

Factors	F	p
Season	1.422	0.245
Area	5.750	0.001
Season vs. Area	0.587	0.803

Figure 4 shows the fluctuation in amounts of solid waste strandings during seasons in each area. Areas 1 and 2 had higher amounts in summer, while Area 3 concentrated the stranding on fall. Area 4 had a small and growing variation from spring to winter. Area 2 had fewer wastes and the fact that the confidence interval reaches negative amplitude reflects this very low amount on fall.

FIGURE 3: Average of solid waste stranded for plastic (a) and nylon (b) components throughout the seasons at the Ratonés mangrove, Brazil. Boxes correspond to standard deviation, bars to confidence interval of 95% and black dots are outliers.

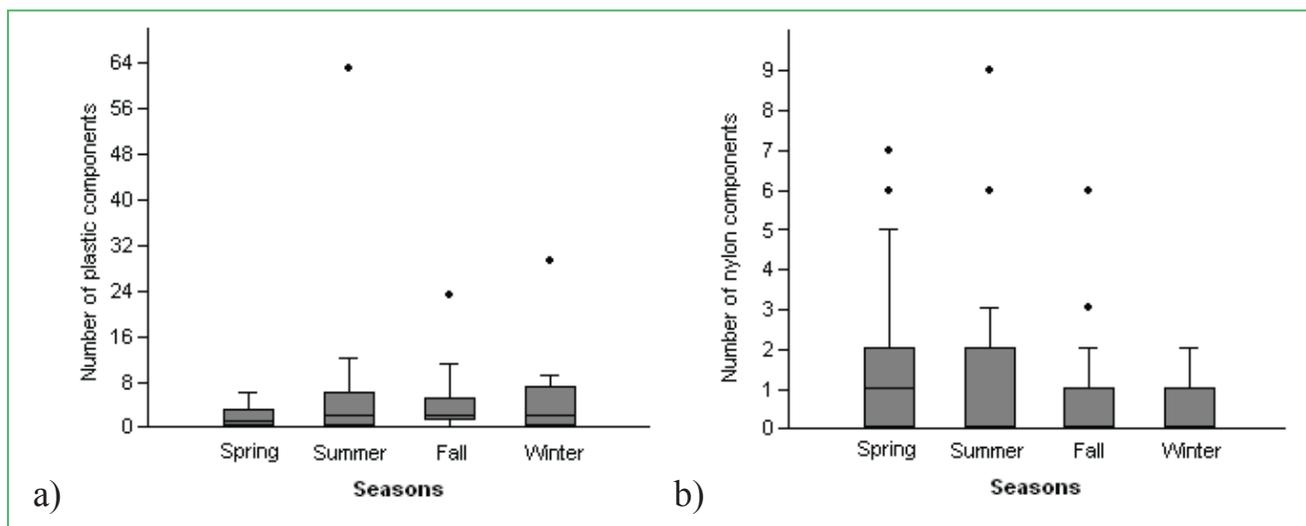
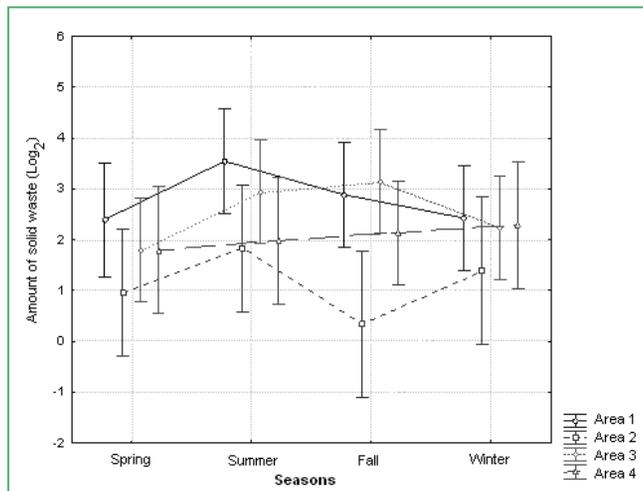


FIGURE 4: Fluctuation in solid waste stranding during seasons at four studied areas, Ratonés mangrove (Brazil). Variations represent a 95% confidence interval.



Discussion

Plastic and nylon items represented 80% of waste stranding, as other researches already found out in coastal environments (e.g. GREEN; WEBBER, 1996; DEBROT et al., 1999; DERRAIK, 2002; ARAÚJO; COSTA, 2004; SANTOS et al., 2005; IVAR DO SUL; COSTA, 2007; CORDEIRO; COSTA, 2010; MACHADO; FILLMANN, 2010; NETO; FONSECA, 2011; PORTZ et al., 2011; THIEL et al., 2011; TOURINHO; FILLMANN, 2011). Plastic products have become one of the major pollutants in the 21st century (IVAR DO SUL; COSTA, 2007) because they are lightweight, strong, durable, cheap (WEHLE; COLEMAN, 1983; LAIST, 1987), and also have great versatility (DERRAIK, 2002). All these features led them to achieve commercial success and consumption increase in this “plastic age” (THOMPSON et al., 2009).

There were significant differences in temporal strandings only for plastic. On the other hand, nylon and the wastes total did not have significant temporal variation. These results could be explained by the waste sources dynamics. High values of plastic on summer could be related to population increase because of tourism and its connection to waste production. In the South Atlantic coast, several researches revealed tourist and fishing activities as major causes of marine

pollution temporal accumulation (BARNES; MILNER, 2005; IVAR DO SUL; COSTA, 2007; MACHADO; FILLMANN, 2010; WIDMER; HENNEMANN, 2010; CARVALHO-SOUZA; TINÔCO, 2011; NETO; FONSECA, 2011; PORTZ et al., 2011; TOURINHO; FILLMANN, 2011; VIEIRA et al., 2011).

Highest stranding in Areas 1 and 2 can be due to direct exposition to marine currents (VIEIRA et al., 2011). Area 2 had fewer residues, possibly because of *Spartina alterniflora* Loisel (Poaceae) effect (VIEIRA et al., 2011). Locations with *Spartina alterniflora* Loisel (Poaceae) dense edges in front seem to have less solid waste inside the mangrove forest, perhaps because this grass formation acts as a mesh barrier. Negative amplitude of confidence intervals in Area 2 may reflect low stranding in three seasons at this area. Vieira et al. (2011) found out the existence of spatial patterns in solid waste stranding distribution; however, this study reports the lack of a well established temporal variation.

During winter, windy and rainy weather in days previous to data collection may have contributed to light weight materials stranding, such as plastics. Wind and rain in days previous to data collection during summer and spring were also observed, thus contributing to solid waste presence in areas exposed to marine currents (Areas 1 and 2).

The main concern arising from this information is that solid waste stranding is occurring throughout the year in the whole region. Most wastes consist of synthetic products which are difficult to be degraded in the natural environment. Solid waste stranding can affect fish oviposition in grass (*Spartina* spp.) and pneumatophores. Human wastes cause significant threats to the marine ecosystem, representing danger not only to the biota, but also to social activities and people’s health (OIGMAN-PSZCZOL; CREED, 2007; NETO; FONSECA, 2011).

Seasonal variation scenarios with regard to solid waste stranding need continued studies, with comparison between different years (e.g. NETO; FONSECA, 2011; PORTZ et al., 2011; SANTANA-NETO et al., 2011). We also emphasize the variations found in sites close to urbanized areas (Areas 1 and 3) and the transitional

effect between ecosystems (Area 4), according to discussions of Vieira et al. (2011). Constant educational projects involving communities and tourists that use the region are mandatory, as well as actions towards impacts related to intense urbanization mitigation, such as goods consumption, with consequent waste production and illegal waste dump.

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