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# Nest site selection and hatching success of hawksbill and loggerhead sea turtles (Testudines, Cheloniidae) at Arembepe Beach, northeastern Brazil

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**Abstract**

**Nest site selection and hatching success of hawksbill and loggerhead sea turtles (Testudines, Cheloniidae) at Arembepe Beach, northeastern Brazil**. Nest site selection influences the hatching success of sea turtles and represents a crucial aspect of their reproductive process. Arembepe Beach, in the State of Bahia, northeastern Brazil, is a known nest site for *Caretta caretta* and *Eretmochelys imbricata*. For the nesting seasons in 2004/2005 and 2005/2006, we analyzed the influence of beach profile and amount of beach vegetation cover on nest site selection and the hatching success for both species. Loggerhead turtles nested preferentially in the sand zone, while hawksbill turtles demonstrated no preferences for either sand or vegetation zone. Beach vegetation was important in the modulation of nest site selection behavior for both species, but the amount of beach vegetation cover influenced (negatively) hatching success only for the hawksbill, mainly via the increment of non-hatched eggs. Hatching success, outside the tide risk zone, was not influenced by the position of the nests along the beach profile. The pattern of nest distribution by species indicated that management of nests at risk of inundation and erosion by the tide is more important for loggerhead turtles than for hawksbill turtles. Beach vegetation is an important factor in the conservation of these sea turtle species. Nests that are at risk due to tidal inundation and erosion can be translocated to any position along the beach profile without producing any significant effect on hatching success, as long as high densities of beach vegetation cover are avoided for hawksbill nests. It is important to point out that the pattern we report here for distribution of hawksbill nests along the beach profile could be due in part to the influence of pure and hybrid individuals, since there are reports of hybridization among hawksbills and loggerheads to the study site.

**Keywords**: Testudines, Cheloniidae, *Caretta caretta*, *Eretmochelys imbricata*, nesting preference, conservation, Brazil.

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**Resumo**

**Seleção de locais de nidificação e sucesso de eclosão da tartaruga-de-pente e da tartaruga-cabeçuda (Testudines, Cheloniidae) na Praia de Arembepe, nordeste do Brasil.** Em tartarugas marinhas, a seleção de locais de desova influencia o sucesso de eclosão e representa um aspecto crucial de seu processo reprodutivo. A Praia de Arembepe (BA, Brasil) é um local de desova de *Caretta caretta* e *Eretmochelys imbricata*. Durante as temporadas de nidificação de 2004/2005 e 2005/2006, analisamos a influência da posição do ninho ao longo do perfil da praia e da cobertura vegetal sobre a seleção de locais de desova e o sucesso de eclosão das duas espécies. *Caretta caretta* desovou preferencialmente em zonas da praia sem vegetação (zona de areia), enquanto *E. imbricata* não mostrou preferência pela zona de areia nem por locais dotados de cobertura vegetal (zona de vegetação). A vegetação foi importante para o comportamento de seleção de locais de desova para ambas as espécies, mas a quantidade de cobertura vegetal da praia influenciou (negativamente) apenas o sucesso de eclosão de *E. imbricata*, principalmente por meio do aumento de ovos não-eclodidos. Em locais sem risco de erosão e inundação pela ação da maré, o sucesso de eclosão não sofreu influência da posição dos ninhos ao longo do perfil da praia. O padrão de distribuição dos ninhos por espécie indicou que o manejo dos ninhos sujeitos a inundação e erosão pela ação da maré é mais importante para *C. caretta* do que para *E. imbricata*. A vegetação da praia é um fator importante para a preservação dessas espécies de tartarugas marinhas. Os ninhos ameaçados de inundação e erosão poderiam ser transferidos para qualquer outro local ao longo do perfil da praia sem qualquer efeito significativo sobre o sucesso de eclosão, contanto que locais com altas densidades de cobertura vegetal sejam evitados para os ninhos de *E. imbricata.* É importante salientar que o padrão encontrado para a distribuição dos ninhos de *E. imbricata* ao longo do perfil da praia poderia dever-se, em parte, à influência de indivíduos puros e híbridos, já que existem relatos de hibridização entre essa espécie e *C. caretta* para o local de estudo.

**Palavras-chave**: Testudines, Cheloniidae, *Caretta caretta*, *Eretmochelys imbricata*, preferência por locais de nidificação, conservação, Brasil.

## Introduction

Nest site selection by turtles represents a crucial aspect of their reproductive biology as the environment where eggs are incubated directly influences hatchling survival (Ackerman 1997). Some environmental variables, like sand temperature (Yntema and Mrosovsky 1982), sand humidity (McGehee 1990) and rate of gas exchange between the nest and the environment (Ackerman 1980) are directly related to embryonic development. These variables differ across available nesting habitats due to such factors as grain size (Mortimer 1990, Foley *et al.* 2006), beach profile (Hays and Speakman 1993, Kamel and Mrosovsky 2006), and presence (or absence) of vegetation (Janzen 1994). Therefore, selection of a nest site by female turtles directly affects hatching success and thereby reproductive success.

Nest site locations vary among sea turtle species. Studies on leatherbacks (*Dermochelys coriacea*) have shown a great deal of intra-individual variation in nest site selection. For example, a single female will nest at different distances from the high tide line at each oviposition, resulting in a wide dispersion of the nests she produces. Such behavior results in many nests being laid near the high tide line, with a considerable loss of eggs due to beach erosion (Eckert 1987, Kamel and Mrosovsky 2004). On the other hand, studies on hawksbills (*Eretmochelys imbricata*) have detected a more selective nesting behavior, with individual females systematically nesting far away from the high tide line and closer to vegetation (Kamel and Mrosovsky 2005). The differences between these species results in different frequencies of egg loss due to natural phenomena, like beach erosion and incubation environment. The presence of beach vegetation may also affect nest site selection, as some sea turtle populations choose nest sites associated (or not associated) with beach vegetation

(Horrocks and Scott 1991, Hays and Speakman 1993, Hays *et al.* 1995, Kamel and Mrosovsky 2004, 2005, 2006). Usually nesting beaches present a vegetation zone beyond the beach slope, namely on the beach berm. The influence of this vegetation zone on hatching success is poorly evaluated in the scientific literature.

Although populations differ in their choice of nest sites relative to the proximity of vegetation, studies focusing on this phenomenon have usually been restricted to implications for sex determination (Morreale *et al.* 1982, Spotila *et al.* 1987). Studies focusing on hatching success usually compare the open beach zones with vegetated zones (Horrocks and Scott 1991, Kamel and Mrosovky 2005, Karavas *et al.* 2005), without taking into account the effects of the amount of vegetation cover on top of the nests located in vegetated zones.

Understanding the influences of environmental variables, such as vegetative cover, on sea turtles nests is important for nest management. Nest management is a valuable practice adopted in many nesting sites, as it may reduce risks of predation, erosion and/or human threat (Wyneken *et al.* 1988, Eckert and Eckert 1990, Marcovaldi and Laurent 1996, Hitchins *et al.* 2004). Nests at risk due to erosion and flooding by tides are often transported to hatcheries or to safer places on the beach mainly on the beach berm, where the sand is covered by beach vegetation of varying density. This vegetation may influence the variables affecting egg incubation and hatchling emergence (Ackerman 1997, Carthy *et al.* 2003). Therefore, knowledge of the variability of hatching success along a variable vegetation profile is important for evolving management procedures aimed at increasing hatchling production.

The northern coast of state of Bahia, Brazil, including Arembepe Beach, is an important nesting area for sea turtles. Four sea turtle species nest on this beach, the loggerhead (*Caretta caretta*) and the hawksbill being predominant. The International Union for Conservation of Nature have categorized these species are as endangered and critically endangered, respectively (IUCN 2006). The other two species that nest on Arembepe Beach are the olive ridley (*Lepidochelys olivacea*) and the green turtle (*Chelonia mydas*) (Marcovaldi and Marcovaldi 1999). It has been known for many years that at this site nests very close to the high tide line are at risk of erosion and inundation (Marcovaldi and Marcovaldi 1999). Therefore, such nests are transported to higher areas in the same beach on the morning following deposition. To increase the success of nest translocation on Arembepe Beach, a better understanding of species-specific nest site selection and the hatching success resulting from this selection is required. Additionally, although removal of beach vegetation for recreational purposes is common, the impact of vegetation removal on nesting sea turtles is currently unknown.

In this study we compared nest site selection between the loggerheads, *Caretta caretta* (Linnaeus, 1758), and the hawksbills, *Eretmochelys imbricata* (Linnaeus, 1766), on Arembepe Beach as well as the manner in which nest-site selection affects hatching success in these two species. In order to determine suitable areas for translocating nests at risk for both sea turtle species, and to maximize the hatching success of all nests at Arembepe, we evaluated the effects of nest location and vegetation cover on hatching success.

In Bahia's northern coast there are reports of hybridization among hawksbills and loggerheads. Lara-Ruiz *et al.* (2006) detected a frequency of 42% of the hawksbill females sampled in the region as hybrids of this two species. Behavioral comparisons between pure and hybrid hawksbills have not yet been undertaken but if there is a genetic aspect to determination of nesting behavior, it is possible that there are differences between pure and hybrid individuals. Therefore, the pattern we report here for distribution of hawksbill nests along the beach profile could be due in part to the influence of pure and hybrid individuals.

Specifically, we examined the effect of nest-to-vegetation distance and amount of vegetation cover on the success of loggerhead and hawksbill sea turtle nests. We tested the following hypotheses for both species: (i) there is preference for nesting either in exposed sand or in vegetated zones in the beach; (ii) nests are not uniformly distributed along the beach profile; (iii) for nests laid outside the risk zone (where erosion and flooding by tides results in little or no hatching success), hatching success varies with the position of the nest on the beach; and (iv) hatching success is affected by the density of beach vegetation cover around the nests.

## Materials and Methods

### *Study Area*

Arembepe Beach is located on the northern coast of Bahia, Brazil (12º45’45.7’’S, 38º10’05.5’’W) (Figure 1). Along its 3 km length, there is a small amount of urban development. During the summer season (December to March), the beach is used for recreation by large numbers of people, and frequented by a low volume of vehicular traffic. The Brazilian Program for Sea Turtles Conservation and Protection (Projeto TAMAR-ICMBio) has monitored sea turtle nesting activity on this beach since 1983 (Marcovaldi and Marcovaldi 1999).

Sand grains in the study area are medium-sized (0.25 mm). The beach is moderately inclined and reaches a frontal dune (of 4 m average height) fixed by a vegetation cover. The dominant beach vegetation species found on the berm are *Blutaparon portulacoides, Ipomoea asarifolia, I. pes-caprae, Spartina alterniflora, Canavalia rosea, Suriana maritima* and coconuts (*Cocus nucifera*), mostly on the dunes (Figure 2). Arembepe has a tropical climate with a rainy season lasting from March to August, and a dry season from September to February (Mafalda *et al*. 2004). The tide has a medium amplitude of 1.8/1.9 m. Nesting seasons for both species are predominantly from September to March.

### *Field seasons and nest monitoring*

We collected data during the nesting season between August 1st and April 1st in 2004/2005

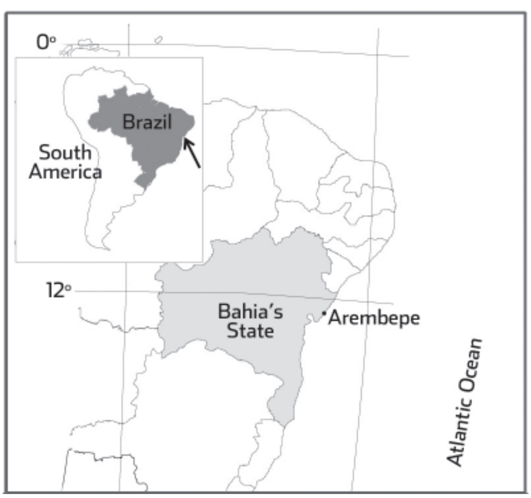


**Figure 1 -** Location of Arembepe Beach in Brazil.


**Figure 2 -** Partial view of Arembepe Beach. (a) sand zone, (b) vegetated zone, (c) dune, (d) stake indicating a nest.

and 2005/2006. Nest monitoring, excavation, translocation, and analysis of nesting distribution along the beach took place in both 2004/2005 and 2005/2006. Analyses of nest site selection and hatching success were only conducted in 2005/2006. Nest monitoring followed Projeto TAMAR-CMBio's methodology (Marcovaldi and Marcovaldi, 1999) and consisted of daily morning beach surveys, performed by a local agent hired by TAMAR. Eggs from nests at risk of tidal inundation and/or erosion (i.e., those very close to the high tide line) were removed from their original location on the morning following oviposition. They were carefully placed in a Styrofoam box in the same orientation in which they were removed from the nest, and then transported to a man-made nest higher than the high tide in the same part of the beach, usually on the berm of the beach. These sites varied in vegetation cover. Eggs were buried again in hand-made nests similar to those built by the turtles. All nests (*in situ* and translocated) were marked and monitored until hatchlings emerged. On the morning following emergence, we excavated nests to identify species and determine hatching success.

*Beach zone preference*

In 2005/2006 in order to analyze species preference for nesting sites, we quantified the availability of sand and vegetated zones (see below) and their use, in terms of proportion of nests per zone. Using a chi-square test, we tested the hypothesis that the proportion of nests laid by each species in the two zones differs from the proportion of available habitat made up by each zone.

To describe the pattern of nesting along the beach profile, we measured the following variables of all nests on the day after nest construction: (i) distance from the center of the nest cavity (=distance from the nest) to the highest tide line of the previous night; (ii) distance from the nest to the edge of the vegetated zone (nest-to-vegetation distance); and (iii) distance from the nest to the dune base (Figure 3). We considered the dune base to be the upper limit of availability of the nesting habitat, as the dune's incline poses difficulties for turtle nesting. The width of available sand zone and available vegetated zone was considered to be the perpendicular distance from the high tide line to the edge of the

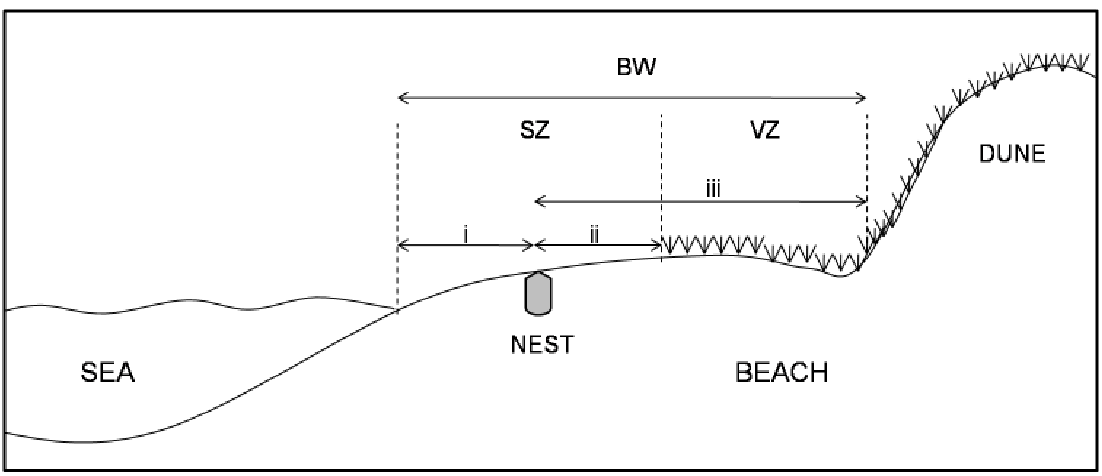


**Figure 3** - Schematic representation of Arembepe Beach profile showing nest site variables measured in the present study. Legend: i = distance between the nest and the high tide line of the prior night; ii = nest-to-vegetation distance; iii = distance between the nest and the dune base; SZ = sand zone; VZ = vegetation zone; BW = beach width.

vegetated zone and the edge of the vegetated zone to the dune base, respectively. The proportion of the total beach width made up by the sand zone and vegetated zone were then calculated for each nest to determine the availability of each zone specific to each individual nest. The sand zone was characterized by the presence of only sand and the vegetation zone had sand and some vegetation covering it. The beach width was considered to extend from the high tide line to the dune base (Figure 3).

We compared the distribution of nests along the beach profile between the two sea turtle species using the nest-to-vegetation distance of each nest (data from 2004/2005 and 2005/2006). We then used a multiple regression test to analyze the influence of the beach width and the size of vegetated zone on the straight distance crawled by the turtle for nesting.

*Hatching success*

Hatching success was calculated as the number of offspring that left their egg shells as a proportion of the total number of the eggs present in the nest (Almeida and Mendes 2007). We excavated the nests on the morning following the emergence of the majority of hatchlings and counted the number of empty egg shells (hatchlings that emerged from the nest), of dead hatchlings (individuals that hatched, but died inside the nest) and non-hatched eggs (intact eggs with or without dead embryos). Hatching success was determined as the ratio of the number of live hatchlings (that had emerged or were still in the nest when excavated) to the total number of eggs in the clutch and calculated using the following equation: empty shells · 100 / (empty shells + dead hatchlings [and their empty shells] + non-hatched).

On the morning following emergence, we took digital pictures of a one square meter area with the nest at its center. Using the Jasc Paint Shop 7 software, we converted each picture to a black and white image in which black pixels represented areas covered by beach vegetation and the white pixels represent sand (Figure 4). We counted the number of white and black pixels per picture using the software *Área* feature, developed by the Physics Statistics and Complex Systems Group from Universidade Federal da Bahia (available at http://www.vivas.ufba.br/Area/Area.rar), and then we calculated the percentage of beach vegetation cover for each nest (Camacho *et al.* 2007).

Based on data collected during the 2005/2006 nesting season and using a multiple regression test, we evaluated the hypotheses that the nest-to-vegetation distance and the percentage of beach vegetation cover around the nest influence the hatching success for each of the two most common species.

In order to better understand the process underlying the effects of the nest-to-vegetation distance and the percentage of beach vegetation cover around the nest, we also evaluated scatter plots of vegetation cover versus the components of the hatching success (percentage of dead hatchlings and of the non-hatched eggs).

For the multiple regression analysis, we used only the nests that were not translocated (that is, only those that were left *in situ*). In order to analyze the effects of management on hatching success, we used an ANOVA to compare the hatching success between nests remaining *in situ* and those translocated (moved to other beach sites).

*Statistical analysis*

We set the significance level at 0.05 for statistical analysis. However, as the same tests were repeated for two species, we adjusted alpha values applying Bonferroni‘s correction (alpha/2) for each set of tests (Quinn and Keough 2004). We treated the following as different sets of tests: nesting zone preference analysis (chi-square test); nesting distribution analysis (multiple regression tests); and hatching success analysis (multiple regression

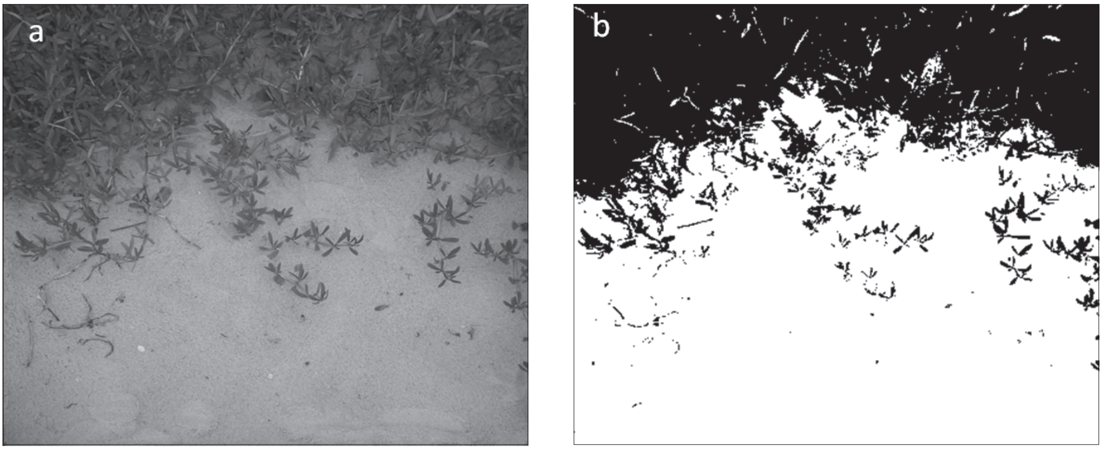

Figure 4 - Example of conversion of the digital picture of one square meter area around the nest (a) into black and white pixeld (b) used to quantify percentage of beach vegetation cover.

tests). All analyses were performed using SPSS 13.0 Software.

## Results

*Nesting and nest management*

Loggerhead nests were more frequent (37 and 78 nests during the 2004/2005 and 2005/2006 nesting seasons, respectively) than hawksbills (34 nests per season) (Table 1). To avoid inundation and erosion risks due to tide movements, 31 loggerhead and five hawksbill nests were translocated from their original sites (Table 1).

*Beach zones preferences*

The availability of sand and vegetated zones on the beach based on measurements taken for both species at individual nests during the 2005/

Table 1 - Number (and percentage) of nests of loggerhead and hawksbill by management type (top) and beach zone (bottom) in Arembepe Beach during 2004/2005 and 2005/2006 nesting seasons.

| | Loggerhead | | | Hawksbill | | |
|---|---|---|---|---|---|---|
| | 2004/2005 | 2005/2006 | Total | 2004/2005 | 2005/2006 | Total |
| *In situ* | 29 (78%) | 55 (71%) | 84 (73%) | 30 (88%) | 33 (97%) | 63 (93%) |
| Relocated | 8 (22%) | 23 (29%) | 31 (27%) | 4 (12%) | 1 (3%) | 5 (7%) |
| Sand zone | 28 (76%) | 67 (86%) | 95 (83%) | 14 (41%) | 18 (53%) | 32 (47%) |
| Vegetation zone | 9 (24%) | 11 (14%) | 20 (17%) | 20 (59%) | 16 (47%) | 36 (53%) |
| **Total** | 37 | 78 | 115 | 34 | 34 | 68 |

2006 nesting season was 62% and 38%, respectively. Loggerheads showed a significant preference for the sand zone ($\chi^2=18.5$; gl=1; $p<<0.001$), while hawksbills showed no preference for either zone ($\chi^2=0.8$; gl=1; $0.5>p>0.25$) (Table 1).

Most of the nests for both species that were laid in the vegetated zone, were in areas with low beach vegetation cover (≤ 10%) (Figure 5).

The distribution of nest-to-vegetation distances differed between the species (Figure 6). Loggerhead nests were more widely distributed across the beach profile, and most of them (83%) were in the sand zone, while hawksbill nests were more frequent (53%) in the vegetated zone (Table 1). For both species, the majority of nesting occurred within 2 m of the edge of the vegetated zone. No nests were found on the dune.

The multiple regression models used to evaluate the effect of beach width and of vegetated zone on the straight-line distance crawled by the sea turtles for nesting were significant both for loggerheads ($F=21.41$; $r^2=0.37$; $p<0.001$) and for hawksbills ($F=24.97$; $r^2=0.62$; $p<0.001$). The tolerance was high for both tests (T=0.986 and T=0.793, respectively) showing that these factors are quite independent from each other. The partial analysis showed that beach width positively influenced the distance crawled by loggerhead ($p<0.001$) and by hawksbills ($p<0.001$), while the width of vegetated zone negatively influenced the distance crawled by loggerheads ($p=0.004$), but did not affect hawksbills ($p=0.080$) (Figure 7).

*Hatching success*

The multiple regression model used to evaluate the effect of the nest-to-vegetation distance (nest position on beach profile) and the percentage of beach vegetation cover, on the hatching success was significant for hawksbills ($F=6.46$; $r^2=0.31$; $p=0.005$) but not for loggerheads ($F=2.42$; $r^2=0.09$; $p=0.100$). The tolerances were high for both tests (T=0.694 and T=0.772, respectively). The partial analysis for hawksbills detected significant (negative) influence of percentage of beach vegetation cover ($p=0.006$) on hatching success, but showed no effect of distance to vegetative cover ($p=0.673$) (Figure 8).

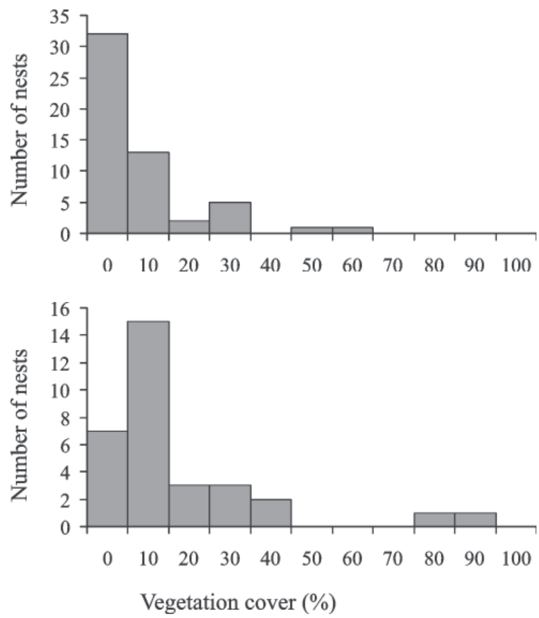


**Figure 5** - Number of nests constructed by percent vegetation covers in Arembepe Beach (2005/2006 nesting season) for loggerhead (top) and hawksbill (bottom). The classes of percentage of vegetation cover were: 0 = 0%, 10 = 1 to 10%, 20 = 11 to 20% etc.

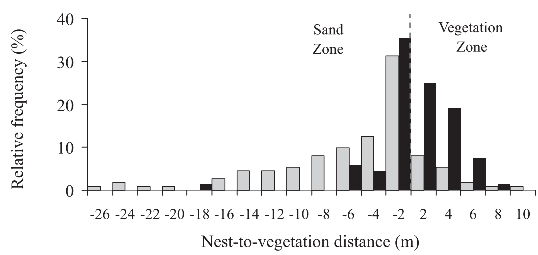


**Figure 6** - Frequency distribution of nest-to-vegetation distance in Arembepe Beach (2004/2005 and 2005/2006 nesting season) for loggerhead (gray bars) and hawksbill (black bars).

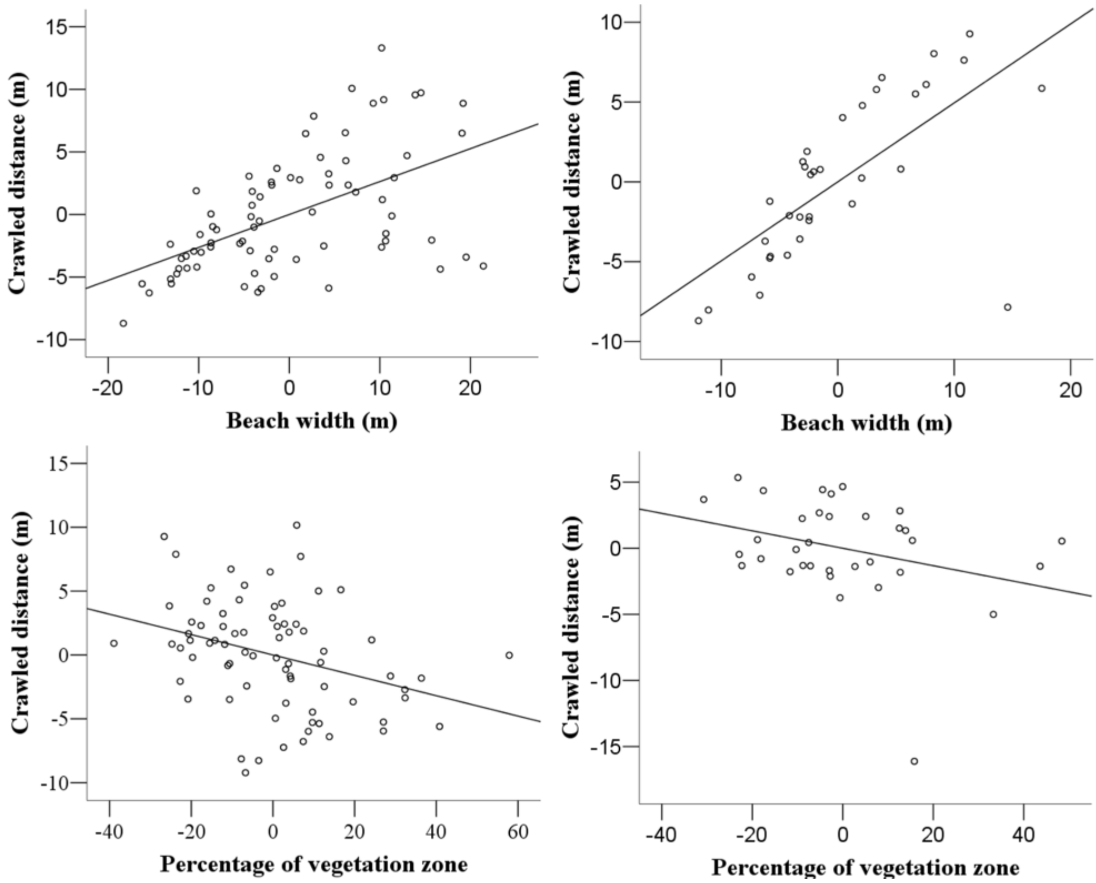


**Figure 7** - Partial regression scatter plots showing the relationship between beach width (m) and straight distance crawled (m) by turtles to nest (top) and between percentage of the vegetation zone and straight distance crawled (m) (bottom) for loggerhead (left) and hawksbill (right) in Arembepe Beach (2005/2006 nesting season). The values are: b=slope, $r^2$=coefficient of determination, p=probability. Values on both axes represent residuals.

To better understand the negative effect of beach vegetation cover on hawksbill hatching success, we evaluated scatter plots of this factor against both the percentage of dead hatchlings and the percentage of non-hatched eggs (Figure 9). The percentage of dead hatchlings tended to decline with increasing percentage of beach vegetation cover. The percentage of non-hatched eggs tended to increase with increasing vegetation cover. Therefore, problems related to survival before hatching seemed to be the main cause for the significant relationship detected.

The hatching success of loggerhead nests left *in situ* (75.9±19.6%; n=84) was significantly higher (F=7.189; p=0.008) than of translocated nests (65.3±16.6%; n=31). For hawksbills, such a comparison was not possible due to the small number of translocated nests (n=5).

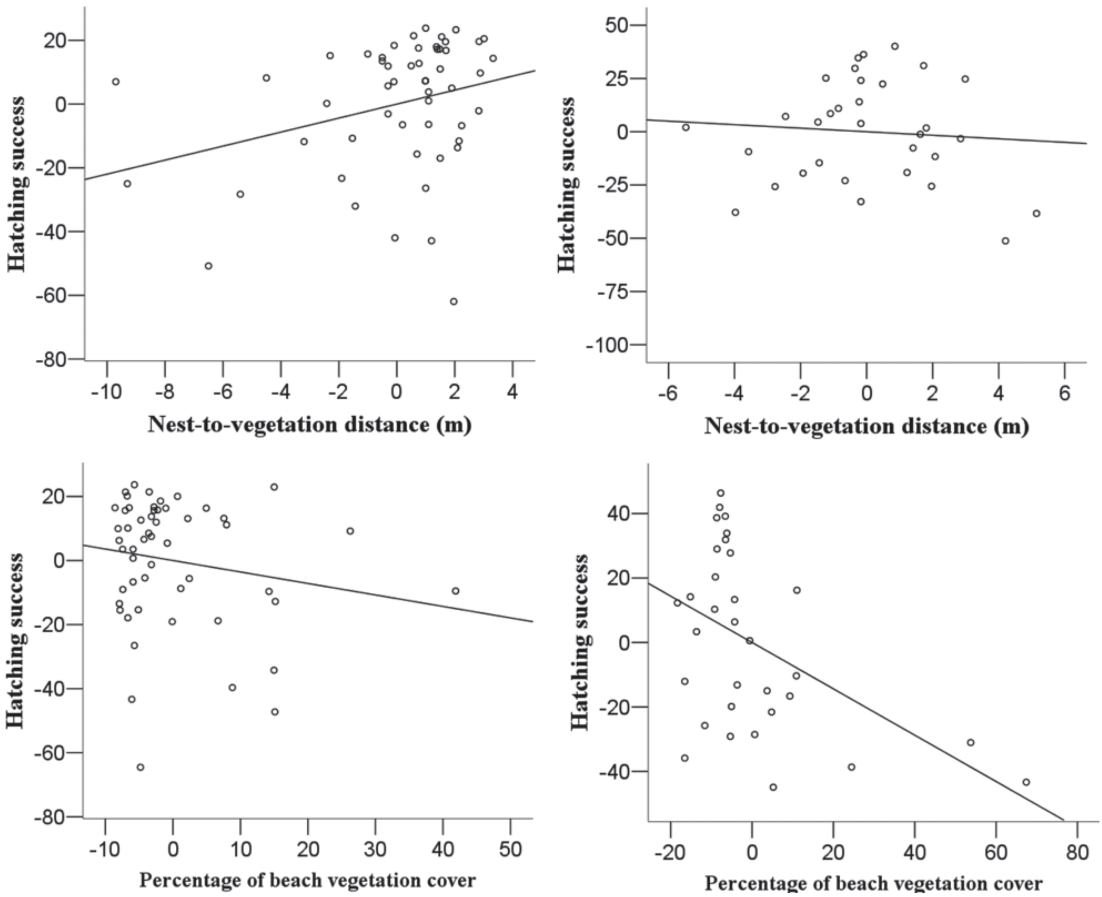


**Figure 8** - Partial regression scatter plots showing the relationship between nest-to-vegetation distance (m) and hatching success (%) (top) and between percentage of beach vegetations cover and hatching success (%) (bottom) for loggerhead (left) and hawksbill (right) in Arembepe (2005/2006 nesting season). The values are: b=slope; $r^2$=coefficient of determination; and p=probability. Values on both axes represent residuals.

## Discussion

Most nests recorded at Arembepe Beach in both seasons were of loggerheads. Bahia's northern coast is the main nesting area for the species in Brazil and one of the most important in the world (Marcovaldi and Chaloupka 2007). The hawksbill is the species responsible for the second highest number of nests in the Bahia northern coast, which represents its main and almost exclusive nesting site on the Brazilian coast (Marcovaldi *et al.* 2007).

In Arembepe, loggerheads nested preferentially in the sand zone, which is devoid of beach vegetation, while hawksbills presented no preferences either for the sand or the vegetation zone). Our methodological approach of evaluating preferential nesting zones based on the quantification of the availability of habitat (Lawlor 1980) is not normally found in the

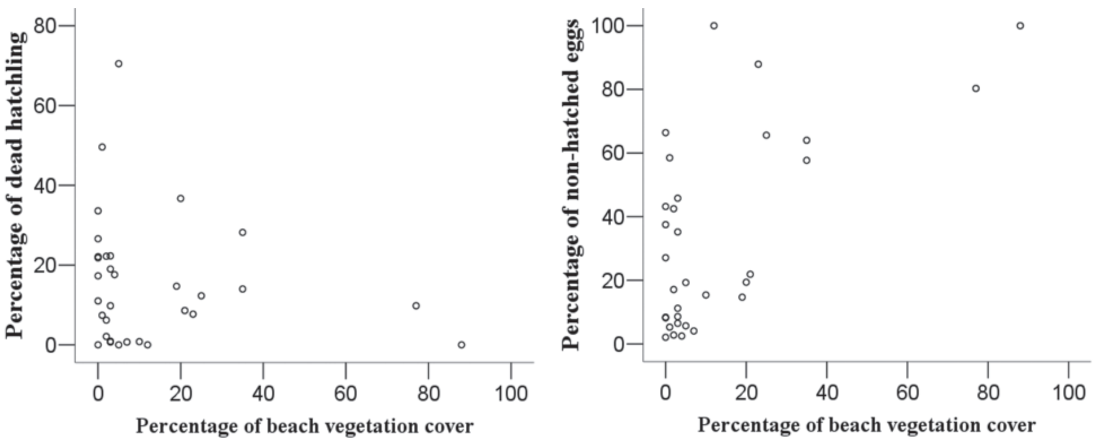


**Figure 9** - Scatter plots showing the relationship between percentage of dead hatchlings and percentage of beach vegetation cover (left) and between percentage of non-hatched eggs and percentage of beach vegetation cover (right) for hawksbill in Arembepe (2005/2006 nesting season).

literature on sea turtles (Whitmore and Dutton 1985, Bjorndal and Bolten 1992, Blamires *et al.* 2003).

The frequency distribution of nests along the beach profile in Arembepe was different between species. Similar to the results of Hays and Speakman (1993) for the Mediterranean Sea and Hays *et al*. (1995) in Southeast Florida, the loggerheads nested predominantly in the sand zone, and most nests were found close to, but not within, the vegetation zone. Loggerhead females tended to crawl longer distances to nest in wider places on the beach, but tended to crawl shorter distances when the vegetation zone was wider. This suggests that vegetation may represent a landmark for unfavorable nesting habitat for this species. At variance with our results, Garmestani *et al*. (2000) reported that 111 of 236 loggerhead nests found in the Ten Thousand Islands, Florida were laid in the vegetation zone.

Hawksbills nested with equal frequency in the sand and vegetated zones. Occurrence of hawksbill nests in the vegetation zone is reported in other areas as well (Witzell 1983, Horrocks and Scott 1991, Kamel and Mrosovsky 2005, 2006). Most of the nests found outside the vegetation zone (as far away as 2 m) were very close to the periphery of this zone, showing that the species nested at greater distances from the sea than loggerheads. Indeed as the beach width increased, hawksbills nested farther from the sea. The relative widths of the vegetation and sand zones did not significantly affect the nesting by female hawksbills. In the present work, we evaluated population preferences not individual preferences. It is possible that there are individual differences in nesting site selection, as recorded for another hawksbill population in the Caribbean (Kamel and Mrovsky 2005).

Although most records of hawksbill nests indicate an association with the vegetation zone (Witzell 1983, Horrocks and Scott 1991, Kamel and Mrosovsky 2005), in Arembepe such nests occurred in areas with low percentages of beach vegetation cover. Usually, published works evaluate vegetation cover only as a subjective categorical variable (with and without vegetation cover) and do not quantify its amount. Kamel and Mrosovsky (2005) evaluated the amount of vegetation cover, but unlike in our study, they evaluated the amount of cover by forest because at this Caribbean site hawksbill females nest in the area between the beach sand and the edge of the forest.

In our work, we followed Ackerman (1997), who suggested that the incubation environment is influenced by factors acting as far as 50 cm from the nest's center, and hence we evaluated percentage of vegetation cover in an area of one square meter around each nest based on quantification by digital pictures. Our methodology, based on Camacho *et al.* (2007), can be used to quantify the amount of ground vegetation covering the nests. However, it does not allow quantification of the taller mid-canopy or canopy vegetation for cases where nests are located under trees (Kamel and Mrosovsky 2005).

Many studies have evaluated nest site selection by sea turtles and its relationship to hatching success (Mortimer 1982, Withmore and Dutton 1985, Horrocks and Scott 1991, Hays and Speakman 1993, Wang and Cheng 1999, Garmestani *et al.* 2000, Wood and Bjorndal 2000, Ferreira-Junior *et al.* 2003, Kamel and Mrosovsky 2005). Those focusing on loggerheads and hawksbills generally did not find any association between hatching success and beach zones (Garmestani *et al.* 2000, Kamel and Mrosovsky 2005) or environmental variables, such as temperature, humidity, conductivity, or elevation (Wood and Bjorndal 2000). However, Hays and Speakman (1993) detected a positive association between distance to the sea and hatching success of loggerhead nests in Mediterranean beaches. Also Horrocks and Scott (1991) observed that hatching success of hawksbill nests in Barbados was highest on the beach's slope where most nests were located, and decreased above and below this location. These authors also detected that the hawksbill nests in Barbados were more frequent in the vegetation zone and that hatching success was higher there. However, Kamel and Mrosovsky (2005), at Guadeloupe, found no significant differences between the hatching success in vegetated and sand zones, although most of the nests were associated with the vegetated zone. In Brazil, Ferreira-Junior *et al.* (2003) reported that, when the nests subject to tide erosion were excluded from analyses, the loggerhead hatching success in Espírito Santo (Southeast Brazil) was higher for nests located in the open beach than for those located at the berm, which is normally covered with beach vegetation.

Similar to the results of Mortimer (1982) for green turtles at Ascension Island, we found no relationship between hatching success and the location of nests along the beach profile for hawksbills and loggerheads, nor did we observe increased hatching success in the areas with the highest concentration of nests. So we can conclude that in Arembepe there is no obvious relationship between nesting sites and hatching success. However, our results apply only to nests located above the tide line, where they are free from risks of erosion and flooding, because nests that are at risk by flooding are moved (Table 1). The hatching success in nests located below or very close the tide line would tend to be zero.

Similar to the results of Karavas *et al.* (2005), we found that beach vegetation cover had no influence on loggerhead hatching success, despite their avoidance of vegetation zones. On the other hand, hawksbill hatching success tended to reduce with increasing percentage of beach vegetation cover due mainly to the larger number of unhatched eggs in their nests. This significant result for Arembepe hawksbills, however, should be interpreted cautiously: it could represent either a spurious pattern due to the low numbers of nests in highly vegetated areas or a true pattern. If a true pattern, we should expect some level of avoidance of highly vegetated areas by hawksbills, which does not seem to be the case. An experimental study based on the relocation of nests in areas with different percentages of beach vegetation cover could solve this question. Several authors have reported that roots surround eggs in vegetated zones (Whitmore and Dutton 1985, Witherington 1986, Hays and Speakman 1993), a fact that we also noticed in the vegetation zone at Arembepe Beach. These roots could in some way interfere with development as there is more root infiltration in vegetated areas than in open areas (Witherington 1986), and therefore, less water may be available for use by the incubating eggs (Carthy *et al.* 2003). To our knowledge, there have been no specific studies on the effects of roots on the survival of sea turtle embryos. In our study there was a tendency for the proportion of dead hatchlings to decline as vegetation cover increased suggesting that the primary negative effect of vegetation is during the embryo development phase.

Loggerhead hatching success in both nesting seasons was higher for *in situ* nests than for those translocated. However, even if nest translocation has a negative effects on hatching success (Eckert and Eckert 1990, Marcovaldi and Laurent 1996, Marcovaldi *et al.* 1999, Almeida and Mendes 2007), it may still be worthwhile to adopt the approach as a conservation strategy for nests at high risk of tide erosion, inundation, and thus, total loss.

Besides hatching success, other reproductive parameters are relevant for nest management, and must be taken under consideration. Hatchling sex ratio is one of them. But in this study we did not measure the effect of beach zones and vegetation cover on this parameter.

Useful conservation guidelines specific to this nesting beach can be derived from our results: (1) loggerhead nests near the high tide line and at risk of erosion and inundation can be translocated to the berm of the beach in order to increase overall hatching success; (2) to achieve maximum hatching success, hawksbill nests at risk should not be translocated to areas with dense beach vegetation cover; and (3) beach vegetation should be preserved as it influences nest distribution for both species.

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