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# Temporal Nesting Variation of Sea Turtles Species at the Eastern Coast of Inhaca Island

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**Abstract:** Understanding the temporal variation of sea turtles nests and the processes driving those variations is of extreme importance to improve the efficiency of the monitoring and management measures at the nesting beaches. In that perspective the present study aimed to describe the temporal nesting activity of two sea turtle species at Inhaca island based on the long-term database on sea turtle nidification (~27 years).

A total of 530 loggerhead and leatherback nests were recorded, of which approximately 64% (equivalent to 340 nests) were loggerhead's (15.45 ± 10.41 per year) and 36% (equivalent to 190 nests) were leatherback's (8.64 ± 7.72 per year). the mean annual nest numbers between both species were significantly different ($t = 2.467$, $df = 42$ and $p < 0.05$). loggerhead turtles laid more nests than leatherback turtles.

Results showed that the number of nests was not equally distributed along the nesting seasons. Inter-annual variability in the number of nests laid by loggerhead and leatherback turtles was observed during the study period.
loggerhead and leatherback nesting activities were restricted to the summer months (October-March). The nesting peaks of loggerhead turtles occurred a month later and were shorter (November and December) than those of leatherback turtles which spanned through October, November and December.

**Key words:** Nesting activity, temporal nest distribution, annual nest distribution, seasonal nest distribution, re-migration intervals, sea turtles, Inhaca Island

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# 1. Introduction

Most sea turtles are non-annual breeders, with very few nesting in straight years (Broderick *et al*., 2002, Broderick *et al*., 2003, Botha 2010). Usually, each female turtle lays 2 to 4 clutches of 50 to 150 eggs in a breeding season and undertake long cyclical migrations between feeding grounds and nesting sites at variable intervals (Broderick *et al*., 2002, Godley *et al*., 2002, Broderick *et al*., 2003). The interval between successive nesting seasons is called re-migration interval (Solow *et al*., 2002, Troëng and Chaloupka, 2007) and have been quantified for many sea turtles populations and species (Hughes 1995 cited by Hays 2000, Broderick *et al.*, 2003). Depending on the particular population, re-migration intervals can take between 2 to 5 years (Hays 2000, Broderick *et al*., 2002, Solow *et al.*, 2002, Troëng and Chaloupka 2007). In populations that breed yearly, variations in the environmental conditions (specially the feeding conditions) can affect the breeding performance of an individual. However, in species that do not breed yearly, such conditions might determine: (1) whether or not an individual breeds in a given year, (2) influence the survival of the offsprings and therefore (3) play an important role in the subsequent breeding or postponement to a future year (Broderick *et al*., 2001). Feeding conditions are crucial in influencing the body condition of the female turtles between nesting years and can lead to lower or higher re-migration intervals (Hays 2000, Broderick *et al*., 2001). Therefore, female turtles must accumulate energy to migrate from feeding grounds to nesting sites between the nesting seasons and still have enough energy to lay several clutches (Hays 2000, Broderick *et al*., 2003). Successful nesting may occur if energy reserves exceed a certain limit (Broderick *et al.,* 2003). Besides the necessity of achieving a threshold body condition, the variability of re-migration intervals can also result in a breeding synchrony between female turtles of the same population, as individuals in the same stock tend to experience similar conditions (Sollow *et al*., 2002).

Most sea turtles populations are seasonal breeders. The nesting seasons coincides with the summer months (Hamann *et al*., 2003, Botha 2010). However, even in those populations that nest throughout the year there is a clear annual peak, as a result of the seasonality of the environmental conditions (Godley *et al*., 2002, Botha 2010). By nesting in the warmer months sea turtles are improving the chances of a successful incubation, as the development of sea turtles embryos depends on specific thermal limits (Baker-Gallegos *et al*., 2009, Howard *et al*., 2014).

Understanding the temporal nest distribution of sea turtles and the processes driving seasonal and inter-annual variations in nesting frequencies can help to improve the efficiency of the monitoring and

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management measures at the nesting beaches (Broderick *et al*., 2001, Pegas and Stronza 2010). Additionally the identification of the probable nesting peak months would help promote sea turtle based tourism and contribute to the conservation of sea turtles populations (Tisdell and Wilson 2002). In that perspective the present research aimed to describe the temporal nesting activity of sea turtles at Inhaca Island, using the long-term database on sea turtle nidification. Although the data on sea turtle nidification in Inhaca has already been used by other authors (Louro 2014, Tärnlund 1999), this study is particularly valuable because despite the characterization of the yearly and monthly patterns, it also tries to explore the factors behind those patterns. The specific objectives of the study were: (1) describe the temporal variation of sea turtles nest numbers along the nesting years and nesting months (2) compare the nest frequencies of loggerhead and leatherback turtles along the nesting years and (3) identify the nesting peak months for each species.

**Hypothesis**

1, Studies conducted in the vicinity of Inhaca Island (at the Maputo Special Reserve, Malongane, Ponta do Ouro and Tongoland (Hughes 1974, Kyle and Lombard 2004, Magane 2006, Videira *et al*., 2008, 2010 and 2011, Pereira *et al*., 2009) have reported that nests of loggerhead turtles are more abundant than nests of leatherback turtles. According to Hughes (1974) and Tärnlund (1999), these differences result from the higher number of loggerhead turtles along the WIO region, which in turn might be related to the population stocks at the Indian Ocean. Thus, if the population stock of loggerhead turtles is higher than leatherback's, the first hypothesis of this study would be that the number of loggerhead turtles nesting at the east coast of Inhaca Island is higher than the number of nesting leatherback turtles.

2, It has been reported that loggerhead and leatherback turtles have different range of temperature tolerance, with leatherbacks having a wider temperature tolerance compared to loggerheads (Kemf *et al*., 2000). Therefore, the nesting peak months of loggerheads will be different from the nesting peak months of leatherbacks.

## 2. **Methodology**

*Study Area*

The study area comprised the entire eastern coast of Inhaca Island, which includes the administrative post of Inguane, KaNyaka Municipal district, Maputo City, Mozambique.

Inhaca Island is a distorted H-shaped island, located 32 km east of Maputo. It extends 12.5 km from its northern point - Ponta Mazondue, to the southern-eastern point - Ponta Torres, and it's about 7 km across the widest part in the central area, occupying a surface of about 40 $Km^2$ (Kalk 1995 and Bandeira et al., 2014). The eastern coast of the Island faces the Indian Ocean while the western coast faces Maputo Bay (Kalk 1995 and De Boer 2000). The Island is located between Northing 7128699.79m – 714699.79m and Easting 36489048.02m – 499964.43m (Kalk 1995 and De Boer 2000) (Fig. 1).

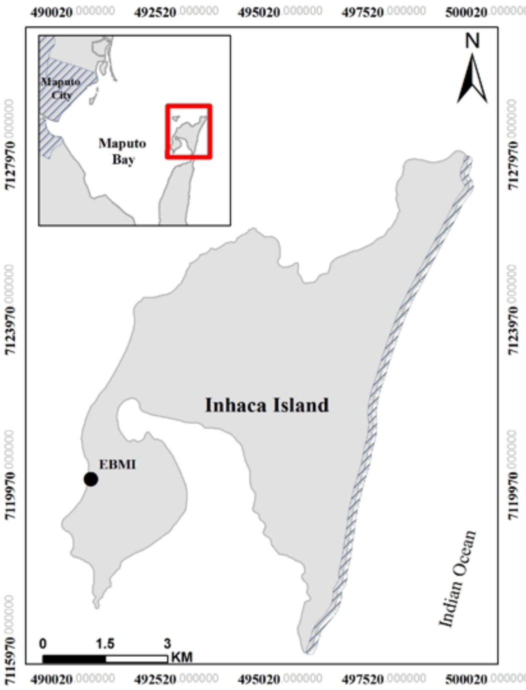


**Figure.1**. Location of the study area, Eastern coast of Inhaca Island, Maputo Province, Mozambique.

*Sampling procedure*

The data used for this study was the annual reports obtained from the long-term monitoring of sea turtles database collected by the Marine Biological Research Station of Inhaca (MBRS). The monitoring has been running since 1987.

After preliminary data examinations, only 22 sea turtle nesting seasons could be used to describe and determine the annual variability between the nesting seasons and only 20 nesting seasons could be used to analyze the frequencies of nests along the nesting months. Data from the remaining 5 nesting seasons was missing (1988/89, 1997/98, 2009/2010, 2011/12 and 2012/13). The annual reports of Inhaca's sea turtles monitoring program were consulted to obtain information on the number of emergencies, number of nests, the deposition and hatching dates for each species.

*Data analysis*

All statistical analysis was performed using SPSS version 20.

*Yearly variation of loggerhead and leatherback nest numbers*

Data on the number of nests per year was used to characterize loggerhead and leatherback's nest frequencies along the 22 years timeframe using descriptive statistics (minimums, maximums, mean number of nests and standard deviation). This was done for each species.

To compare the proportion of nests between loggerhead and leatherback turtles along the nesting seasons a t-student test was conducted (Reis *et al*., 2006).

*Monthly variation of loggerhead and leatherback nest numbers*

The deposition dates, were used to obtain the number of nests per month and thus identify the nesting peak months per species. One-way ANOVA was used to determine if there were significant differences between the numbers of nests laid per month for each species (Reis *et al*., 2006). Since ANOVA results revealed significant differences in the number of nests per month, post-hoc analysis (Fisher's least significant difference test) was further performed to determine the nesting peak months (Pestana and Gageiro, 2008).

## 3. Results

*Yearly variation of loggerhead and leatherback nest numbers*

During the timeframe of 1987-2014, a total number of 530 nests were recorded, of which 340 were from loggerhead turtles and 190 were from leatherback turtles (equivalent to about 64% and 36% of the total nests laid in Inhaca respectively).

The number of loggerhead's nests per year varied along the nesting seasons from a minimum of 1 nest in 2002/03 to a maximum of 43 nests in 2007/08. The mean number of loggerhead nests laid per year was 15.45 ± 10.41 (SD) (Figure 3). On the other hand, the number of leatherback's nests along the nesting seasons varied from a minimum of no nests (zero), to a maximum of 29 nests in the nesting seasons of 2005/06 and nesting season of 1992/93 respectively.

The mean number of nests per year was 8.64 ± 7.72 (SD) (Appendix I, Table 1). Significant differences were observed in the nest abundance between loggerhead and leatherback turtles throughout the 22-year study period ($t = 2.467$, $df = 42$ and $p < 0.05$). Loggerhead turtles laid significantly more nests than leatherback turtles in the eastern coast of the Island.

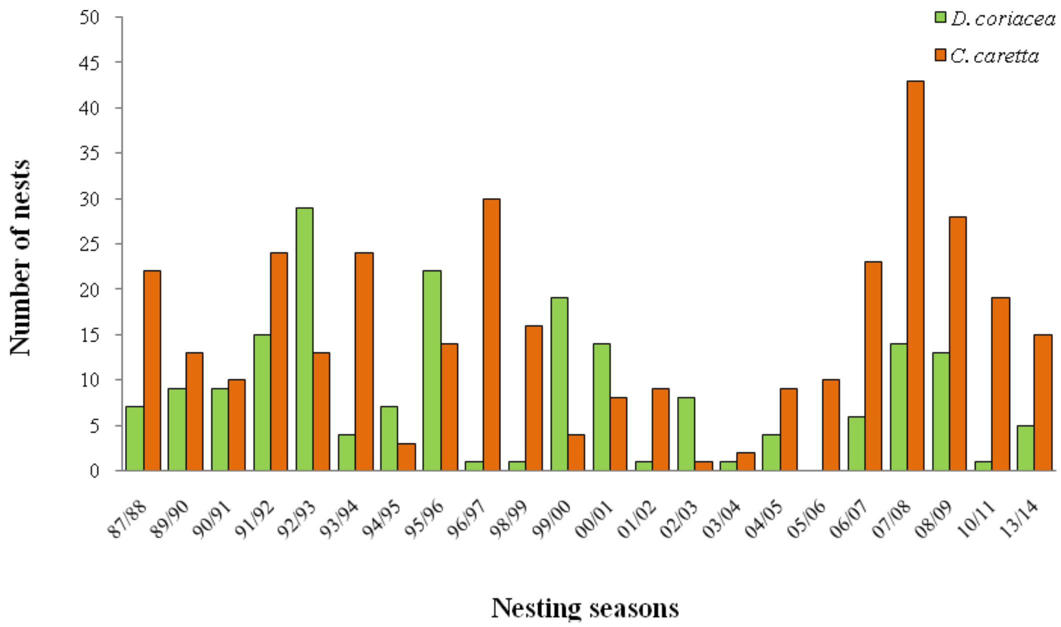


**Figure 2**. Temporal variation of loggerhead and leatherbacks nest numbers at Inhaca Island during the 22-year study period.

Figures 2 show that the number of loggerhead and leatherbacks nests was not equally distributed along the nesting seasons. This variation suggests an irregular pattern of nest distribution through the years, with years with lower number of nests and years with higher number of nests. Additionally, the nesting peaks of loggerhead turtles did not coincide with those of leatherback turtles. When there was a nesting peak for one species, few species came to nest from the other species and vice versa. However, between the nesting seasons of 2004/05 and 2013/14, loggerhead and leatherback nesting peaks appeared to coincide.

*Monthly variation of loggerhead and leatherback nest numbers*

Loggerhead and leatherbacks nesting activities was mainly restricted to the period of October until March.

*Loggerhead's nest numbers*

The number of loggerheads nests increased from October to December when it attained the peak and decreased towards March (Figure 3). The minimum values were recorded in March and October.

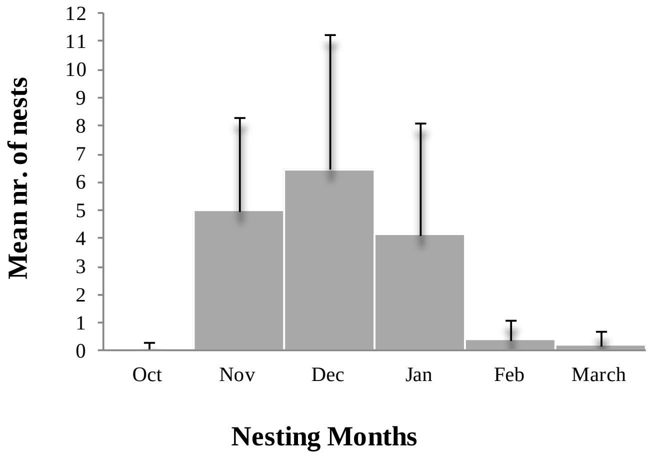


**Figure 3.** Mean number of loggerheads nests and standard deviation values along the nesting months.

October, February and March had significant lower means when compared to November, December and January. Significant statistical differences were observed in the mean number of nests between the nesting months (F (5,102) = 14.197, $p < 0.05$). The mean number of nests laid in October, February and March was statistically different from the mean number of nests laid in November, December and January. November and December were the months when nesting peaks occurred, with no statistical difference between them.

*Leatherback's nest numbers*

Leatherback turtles had a higher average number of nests in November, followed by December and October (Figure 4). The lowest number of nests was recorded in March followed by February.

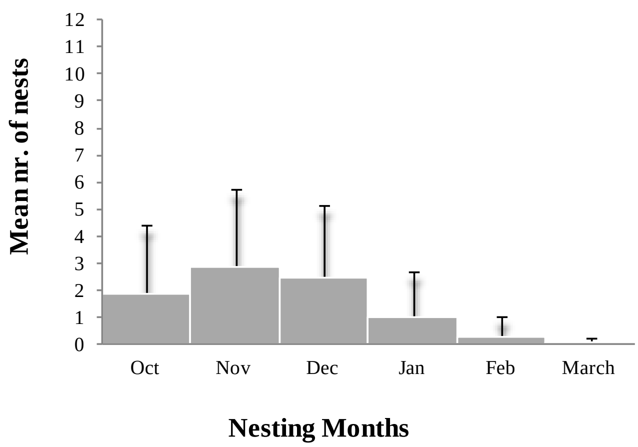


**Figure 4.** Mean number of leatherbacks nests and standard deviation values along the nesting months.

Significant differences were observed in the mean number of nests between the nesting months ($F (5,102) = 4.791$, $p < 0.05$). February and March had significant lower means than October, November and December. The mean number of nests in January does not differ from the number of nests in October, but do differ from the mean number of nests laid in November and December. The mean number of nests laid in October, November and December did not differ statistically. Those three were the months when nesting peaks occurred.

## 4. Discussion

*Yearly variation in loggerhead and leatherback's nest numbers*

A total of 530 nests were reported using the long-term database on sea turtles nidification in Inhaca Island (~22 years). However, loggerhead's nests were significantly higher than leatherback's nests, which is in agreement with the hypothesis that loggerhead turtles are more abundant than leatherback turtles in the eastern coast of Inhaca. Studies conducted in the vicinity of Inhaca Island, such as in the Maputo Special Reserve (MRS) (Magane, 2006), Malongane (Kyle and Lombard, 2004), Ponta do Ouro (Videira *et al*., 2008, 2010 and 2011, Pereira *et al*., 2009) and Tongoland (Hughes, 1974) presented the same trend. These results were also supported by Hughes (1974) and Tärnlund (1999), who states that loggerhead is the most numerous sea turtle species along the WIO region. Additionally, it has been estimated that the worldwide population numbers of loggerhead turtles is superior to those from leatherback turtles. Loggerhead nesting females range between 40 000 and 50 000, while leatherback nesting females range between 34 000 and 36 000 (Sea Turtle Conservancy, 2015)[1].

According to Bustard (1972) cited by Magane (2006), leatherbacks are the most threatened of all sea turtles species. They were once the most abundant of the 7 living sea turtles species but have suffered substantial population declines in many parts of the world (Pritchard 1982, Rafferty *et al*., 2011, Theodorakou 2013). It has been estimated a global reduction of about 67% in the global population of leatherback turtles in the last two decades (Rafferty *et al*., 2011, Theodorakou 2013). The worldwide decline in leatherback populations has been mainly attributed to anthropogenic threats such as incidental catch during fishing activities causing adult deaths, egg poaching and habitat degradation (Ferraroli *et al*., 2004, Theodorakou 2013). Because leatherback turtles are the most migratory sea turtle species (McLellan *et al*., 2009), they're probably more vulnerable to fisheries bycatch. Natural processes such as beach location, tidal inundation, low hatching success and egg loss due to beach erosion and bacterial infestation should also be considered (Bell *et al*., 2003, Theodorakou 2013).

[1] Results based on nesting beach monitoring reports and publications from 2004.

It has been reported that leatherback turtles have an average hatching success lower than all other sea turtle species (approximately 50% success rate against approximately 80% by the other sea turtles species) (Nordmoe *et al*., 2004, Rafferty *et al*., 2011) which results from high levels of embryonic death (Bell *et al*., 2003, Theodorakou 2013). However, further research is required to understand the cause of the high levels of embryonic death.

The inter-annual variability in loggerhead and leatherback's nest numbers observed during the study period occurs because sea turtles individuals do not breed yearly (Hays 2000, Solow *et al*., 2002). Sea turtles undertake cyclical migrations between feeding grounds and nesting sites (Broderick *et al*., 2002), spending on average 2 to 5 years at the foraging grounds before nesting (Hays 2000, Broderick *et al*., 2002, Solow *et al*., 2002, Troëng and Chaloupka 2007). As "capital breeders"[2], female turtles must accumulate energy for reproduction and the associated energetic costs of migration. I.e., energy reserves must exceed a fixed body condition threshold value in order to engage in reproduction (Hays 2000, Broderick *et al*., 2001, Broderick *et al*., 2003, Rivalan *et al*., 2005, Troëng and Chaloupka 2007). According to Hays (2000), if this threshold is not attained, sea turtles might not engage in reproduction, either because: (1) they have not enough energy reserves to complete the migration, or (2) they have not enough energy reserves to lay several clutches and consequently their transport costs per clutch will be high. However, this threshold is not fixed, in fact it may vary in response to the environmental factors that affect sea turtles body condition. Feeding conditions may have fundamental role in influencing the body condition of a female turtle. In this turn, it is expected that the processes leading variations in the feeding areas are closely related to the breeding biology of sea turtles and probably to the forces driving the variations in the re-migration intervals (Hays 2000, Broderick *et al*., 2001). This theory might explain differences between sea turtles species re-migration intervals. In the specific case of this study, although it was not measured, it seemed like loggerhead and leatherbacks re-migration intervals were different, with loggerheads re-migration intervals being lower than those from leatherback turtles. If re-migration intervals are related to the foraging opportunities which are driven by the environmental conditions, species with higher trophic status such as loggerhead turtles, which feeds on benthic organisms such as mollusks and crustaceans, are expected to have lower re-migration intervals, as their dietary components do not necessarily change with the environmental conditions. On the other hand, species feeding at the intermediate level, such as leatherback turtles, are likely to be more prone to environmental influences than the benthic system and therefore have higher re-migration intervals (Broderick *et al*., 2001).

[2] Organisms who gather the energy that will be invested in reproduction prior to reproduction (Rivalan *et al*., 2005).

For most of the study period (1987-2003), the annual peaks of loggerhead and leatherback turtles did not coincide (overlap), but this tendency had changed during the subsequent period (2003/04 to 2013/14 nesting seasons) (Figure 3.1). Studies conducted in the nesting beaches located in the vicinity of Inhaca Island, such as Malongane (Kyle and Lombard, 2004) and Ponta do Ouro (Videira *et al*., 2008, 2010 and 2011, Pereira *et al*., 2009) did not present the same tendency. Therefore, further research is required to understand the reason behind those temporal patterns.

*Monthly variation of loggerhead and leatherback's nest numbers*

During the study period, loggerhead and leatherback's nest activities occurred between October and March (Figure 3.2 and Figure 3.3), which coincide to the warmer months of the year. These findings were similar to the results obtained in the nesting beaches near Inhaca, such as: Maputo Special Reserve (Magane, 2006), Malongane (Kyle and Lombard, 1996) and Tongoland – South Africa (Hudges, 1974). According to Hamman *et al*., (2003), nesting seasons are constrained temporally and usually coincide with the warmer months. By nesting in warmer months sea turtles are ensuring successful developing of sea turtles embryos, as their development depends on specific thermal limits (usually sand temperatures below 25ºC and above 35ºC inhibit the embryo development) (Baker-Gallegos *et al*., 2009, Howard *et al*., 2014). The temperature of the sand where the nest was placed may also influence the duration of incubation, with "warmer nests" hatching quicker than cooler ones. Furthermore, temperature might affect the length of the internesting interval, with warmer temperatures decreasing sea turtles internesting intervals and cooler temperatures increasing sea turtles internesting intervals (Hays *et al*., 2002). In suma, it is likely that nesting seasonality is a result of female turtles adjusting their reproductive activity to match with the requirements that most contribute to maximize reproductive fitness (Cheng *et al*., 2009).

Besides the nesting seasonality, loggerhead and leatherback turtles presented clear peak months along the nesting months (between October and December). The nesting peaks of loggerhead turtles were one month later and shorter (November and December) than those of leatherback turtles which spanned through October, November and December. According to Kemf *et al*., (2000) leatherback turtles have an unusually wide latitudinal range, ranging from tropical and subtropical waters to relatively cold (10º C) waters. On the other hand, loggerhead turtles are mainly found in the warmer coastal tropical and subtropical waters. Assuming that leatherback turtles have a wide range of temperature tolerance, it was expected that they would nest over an extended period than loggerhead turtles which seems to have a lower range of temperature tolerance**.**

## 5, Conclusions

Two species of sea turtles nest at Inhaca Island (loggerhead and leatherback turtles), of which loggerhead was the turtle species with more nests.

Nest activities were restricted to the summer months (October to March). The nesting peaks of loggerhead turtles occurred in November and December while the nesting peaks of leatherback turtles were longer than those from loggerhead turtles, occurring in October, November and December.

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