

Green turtle nesting on Trindade Island, Brazil: abundance, trends, and biometrics

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ABSTRACT: Green turtles *Chelonia mydas* nesting at Trindade Island, 1140 km off the coast of Brazil, were monitored discontinuously from 1982/83 to 2008/09. For 7 years during this period, the majority of nesting was monitored, and the number of nests deposited on Trindade varied from 1333 to 5261. Based on these nest counts, Trindade is among the most important known Atlantic nesting sites for green turtles. The population remained stable between 1991 and 2008. Data on female body size, clutch size, internesting intervals, remigration intervals, and hatching success are also presented.

KEY WORDS: Sea turtle · *Chelonia mydas* · Nesting · Biometrics · Atlantic Ocean · Brazil · Trindade · Population size

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INTRODUCTION

Our understanding of the relative importance of sea turtle populations is a dynamic process, modified as new nesting areas are evaluated (Bourjea et al. 2007, Lauret-Stepler et al. 2007). The green turtle *Chelonia mydas* rookery on Trindade Island, Brazil, is one of the last major rookeries in the Atlantic to be characterized. Abundance estimates, population trends, and biometric parameters have been published for other major Atlantic green turtle populations, such as Tortuguero, Costa Rica; Ascension Island, UK; Aves Island, Venezuela; Suriname; and Florida, USA (Schulz 1975, Bjorndal & Carr 1989, Penaloza 2000, Godley et al. 2001, 2002, Seminoff 2004, Troëng & Rankin 2005, Broderick et al. 2006, Chaloupka et al. 2008).

The green turtle is the most abundant species recorded in stranding records along the Brazilian coast (Gallo et al. 2006), and flipper tags have revealed that green turtles foraging in Brazilian waters are derived from different nesting populations (Carr 1975, Lima & Troëng 2001). Except for a few nests recorded annually at nesting beaches in the state of Bahia, a major loggerhead *Caretta caretta* nesting ground in northeastern Brazil (Marcovaldi & Chaloupka 2007), the green turtle nesting areas in Brazil are restricted to the oceanic islands of Trindade, Atol das Rocas, and Fernando de Noronha (Moreira et al. 1995, Bellini et al. 1996, Bellini & Sanches 1996, Marcovaldi & Marcovaldi 1999). Significant genetic structure exists among the 3 rookeries. Based on mtDNA haplotype frequencies, Trindade is significantly different from the other 2

rookeries, but Atol das Rocas and Fernando de Noronha are not significantly different from each other (Bjørndal et al. 2006). These rookeries have been monitored by Projeto TAMAR-ICMBio (the sea turtle conservation program of the Brazilian environmental agency) since 1982 (Filippini & Bulhões 1988, Marcovaldi & Marcovaldi 1999). Although the annual numbers of nests at these sites made it clear that Trindade is the main green turtle nesting ground in Brazil (Moreira et al. 1995), there are no estimates of the rookery size at Trindade. Here, we estimated the annual number of nests and females, evaluated the trend in nesting numbers, and present biometric data for green turtles nesting on Trindade.

MATERIALS AND METHODS

Study area

Trindade Island ($20^{\circ}30' S$, $29^{\circ}20' W$) is on the eastern end of the Vitória-Trindade Submarine Ridge, 1140 km off the coast of the state of Espírito Santo, southeastern Brazil (Fig. 1). The island is 13.5 km² in area and is almost totally composed of volcanic and subvolcanic rocks formed between the end of the Pliocene and the Holocene (Almeida 2002). The coastline consists of algae reefs, narrow beaches, and narrow dunes. The entire extent of the Vitória-Trindade chain is under the influence of the southward flow of the warm Brazil Current (Miranda & Castro Filho 1982). A tropical oceanic climate prevails, ameliorated by eastern and southern trade winds, with mean

water temperatures of $27^{\circ}C$ (DHN 1968). Air temperature is warmest in February and coldest in August (Alves 1998). An almost daily rain, lasting about 5 min, is called 'Pirajá.' Between April and October, cold fronts from Antarctica periodically reach the island (DHN 1968). Green turtles nest on 9 beaches (from 50 to 780 m long), which have varying degrees of rocky barriers that can prevent turtles from reaching the sandy areas to dig their egg chambers. The only human inhabitants on Trindade are personnel of the Brazilian Navy, which maintains a base on the island and provides protection for the nesting green turtles. Trindade has been under the control of the Brazilian Navy since 1957, well before the beginning of sea turtle monitoring on the island and can only be visited with permission from the Navy.

Surveys

Surveys were conducted during 17 non-consecutive nesting seasons, from 1982 to 2009, with large differences in patrol efforts, both temporal and spatial (Table 1). Different expeditions had distinct goals (tagging females, assessing hatching success, mapping emergences both spatially and temporally, or estimating the proportion of nests in relation to the total tracks). Consequently, types of data collected varied among the 17 seasons. Two beaches (Tartarugas and Andradas) were patrolled in all nesting seasons; systematic track counts were not recorded in 1982/83, 1989/90, 1997/98, 2000/01, 2001/02, and 2002/03.

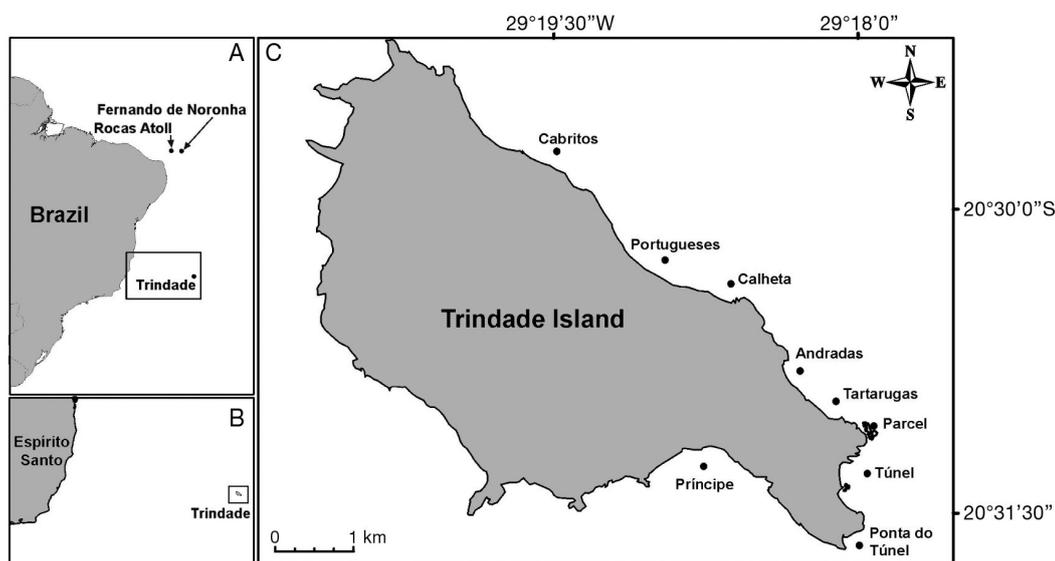


Fig. 1. Study area with the locations of the 9 nesting beaches on Trindade Island

Table 1. *Chelonia mydas*. Number of beaches surveyed and tracks counted, and sampling and nesting periods recorded on Trindade Island in different nesting seasons between 1982 and 2009. Seasons in **bold** were used for analysis of nesting trends. The total number of tracks does not reflect relative abundance among years because temporal and spatial sampling effort varied among years; in some years, effort was directed to tagging nesting females rather than counting tracks. The entire nesting period was determined only for the last 3 seasons. Dates are shown in dd/mm/yy

Season	No. of beaches	Survey dates (dd/mm/yy)	Date first nest seen (dd/mm)	Date last nest seen (dd/mm)	Sampling period (d)	Nesting period (d)	Total track counts
1982/83	2	17/12/82 – 14/2/83	17/12	14/2	59	–	351
1985/86	7	18/2/86 – 12/4/86	18/2	12/4	53	–	722
1989/90	4	13/3/90 – 17/3/90	13/3	17/3	4	–	122
1991/92	7	19/1/92 – 26/5/92	19/1	26/5	127	–	3008
1993/94	5	11/4/94 – 20/7/94	11/4	20/7	100	–	506
1994/95	7	26/10/94 – 1/7/95	26/10	1/7	249	–	3943
1995/96	2	06/10/95 – 23/5/96	06/10	23/5	230	–	5478
1996/97	2	14/12/96 – 13/2/97	14/12	13/2	61	–	1184
1997/98	2	2/1/98 – 11/2/98	2/1	11/2	40	–	39
1998/99	9	5/12/98 – 13/2/99	5/12	13/2	70	–	2014
1999/2000	9	5/12/99 – 4/4/00	5/12	4/4	121	–	10417
2000/01	2	10/12/00 – 12/12/00	10/12	12/12	2	–	2
2001/02	4	18/2/02 – 2/3/02	18/2	2/3	12	–	499
2002/03	2	17/2/03 – 20/2/03	17/2	20/2	3	–	33
2006/07	9	01/10/06 – 30/9/07	15/12	22/6	365	190	9602
2007/08	9	01/10/07 – 30/9/08	14/11	15/6	365	214	3551
2008/09	9	01/10/08 – 30/9/09	21/10	01/7	365	254	5696

Surveys comprised essentially the entire duration of the nesting season in 6 nesting seasons: 1994/95, 1995/96, 1999/2000, 2006/07, 2007/08, and 2008/09. Patrols were conducted by 2 persons on foot, at night, for tagging and measuring females, and during the day, for counting and classifying tracks as nesting or non-nesting emergences. Due to the high number of emergences, not all nesting females were intercepted on the beach. In addition, track identification was sometimes difficult because large numbers of turtles nesting on small beaches caused considerable overlap of tracks, and sometimes nests were destroyed by other females digging their nests. Therefore, the proportion of emergences corresponding to nests is only known with certainty in 4 seasons, when this information was determined for the main nesting beaches (see 'Estimation of nest numbers per season').

When a female green turtle was encountered on a nesting beach, a monel or inconel tag (no. 681 National Tag and Band Co.) was applied to the trailing edge of each front flipper. Curved carapace length (CCL) was measured from the anterior point at midline (nuchal scute) to the posterior tip of the supracaudals (notch to tip; Bolten 1999). Measurements were taken with a flexible tape measure and recorded to the nearest 0.5 cm. Only 1 measurement for each female was used in each season.

Clutch size and hatching success were determined following standard procedures (Miller 1999). Clutch size was estimated by piecing egg shells together

after hatchlings had emerged from the nest. Individual females were not associated with the clutches, so we could not relate body size and clutch size. During 4 seasons (1985/1986, 1993/1994, 1994/1995, and 1995/1996), hatching success was determined for some nests that were identified by observing tracks left by hatchlings emerging from the nest. Hatching success was calculated as the number of hatchlings that hatched out of their egg shell (= the number of empty egg shells in the nest) divided by the total number of eggs in the nest. Hatching success was determined for nests on 2 beaches: Andradas and Tartarugas.

Estimation of nest numbers per season

Annual numbers of nests were estimated for those seasons during which temporal coverage comprised at least the middle (peak) of the season and either the beginning or end of the season (1991/92, 1994/95, 1995/96, 1999/2000, 2006/07, 2007/08, and 2008/09). To estimate the annual numbers of nests deposited on Trindade, we had to develop 2 correction factors. First, because in some years only total tracks were counted without distinguishing between nesting and non-nesting emergences, we needed a correction factor to convert track counts to nest counts. Second, because not all beaches were patrolled in all years, another correction factor was needed to convert the

number of nests on the 2 beaches that were patrolled each year, Tartarugas and Andradas, to the number of nests deposited on all beaches.

We developed the first correction factor by using data from 4 nesting seasons (1999/2000, 2006/07, 2007/08, and 2008/09) during which specific surveys were conducted to determine the proportion of emergences that resulted in nests being deposited on the 2 beaches (Tartarugas and Andradas) which have the greatest nesting activity. One night each week, from 18:30 to 06:30 h, patrols recorded the proportion of emergences that resulted in nests. Emerging females were carefully followed, and the emergences were classified as nesting or non-nesting emergences. Daily patrols were conducted from 5:30 to 11:00 h and from 16:30 to 18:30 h to count and obliterate the tracks to avoid including them in subsequent counts. The mean proportions of nests to total tracks calculated for the 2 main beaches (0.55 for Tartarugas and 0.37 for Andradas) were then used to convert the number of tracks counted on daily patrols to nest counts on those 2 beaches in earlier seasons (1991/92, 1994/95, and 1995/96).

The annual numbers of nests deposited on the 2 main beaches (Tartarugas and Andradas) were estimated following the technique used by Bjørndal et al. (1999). The number of nests was plotted for each day of the season, and the total number of nests for the season was approximated by fitting a cubic smoothing spline ('smooth') to each time series, using the generalized additive model function, *gam()* of S-plus software (version 7.0.3). Based on nest distribution patterns, 15 November and 30 May were selected as the end points of the nesting season, and a value of 0 nests was assigned to each end point. We differentially weighted the actual count values (= 1) and the set end points (= 0.1), with the exception of the 15 November 1991 endpoint, which was given a weight of 1.0 to anchor the curve because there were no data for the beginning of the season.

We developed the second correction factor, to convert the annual number of nests on Tartarugas and Andradas to the total annual number of nests on Trindade, by dividing the nest totals for Tartarugas and Andradas by the proportion of all nests laid on Trindade that are deposited on Tartarugas and Andradas (0.54). This proportion was estimated from the 3 seasons (1999/2000, 2006/07, and 2007/08) during which daily patrols covered all 9 beaches with nesting activity.

To determine whether there was a trend in nest numbers over the years of our study, we used a least squares linear regression model with log link and

autoregression (order 1) error structure to account for any temporal correlation. We used S-plus software (version 7.0.3) for all statistical analyses. For all analyses, $\alpha = 0.05$.

RESULTS

Abundance and trends

Beginning in 1982, nests were recorded on 9 beaches on the Island (Fig. 1), although coverage varied greatly among years both spatially and temporally (Table 1). In the 6 seasons with broad temporal coverage, more than 95% of the emergences occurred during the interval from 1 December through 30 April, with a peak between January and March. The smooths of nesting data from Tartarugas and Andradas beaches (Fig. 2) show similar unimodal patterns among seasons. The mean track density on Tartarugas and Andradas was 3648 tracks km^{-1} (range: 1627 to 4938).

The first correction factor, the proportion of nests in relation to total tracks, was calculated from data for the 2 main beaches (Tartarugas and Andradas) obtained in 4 seasons (1999/2000, 2006/07, 2007/08, 2008/09). This proportion varied from 0.34 to 0.69 with a mean of 0.55 for Tartarugas and from 0.17 to 0.57 with a mean of 0.37 for Andradas (Table 2).

In the 3 seasons during which all beaches were monitored daily (1999/2000, 2006/07, and 2007/08), the 2 major beaches (Tartarugas and Andradas) had 54% of the tracks (range: 52.9 to 55.0%) on the entire island. Therefore, the second correction factor, the relative proportion of nests on Tartarugas and Andradas relative to all 9 beaches on Trindade, was 0.54.

We used the 2 correction factors to estimate the number of nests deposited annually on Trindade, which ranged from 1333 to 5261. Based on a least squares linear regression model with log link and autoregression (order 1) error structure (slope =

Table 2. *Chelonia mydas*. Proportions of nests in relation to total tracks on Tartarugas and Andradas, the 2 major beaches of Trindade Island, based on direct observations during 4 nesting seasons

Beach	Nesting season				Mean
	1999/2000	2006/07	2007/08	2008/09	
Tartarugas	0.572	0.687	0.340	0.586	0.546
Andradas	0.371	0.570	0.172	0.349	0.366