Long-term changes in body size of green turtles nesting on Trindade Island, Brazil: Signs of Recovery?

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Abstract

Trindade Island is an important wildlife refuge in the South Atlantic Ocean and hosts the largest nesting population of green turtles (*Chelonia mydas*) in Brazil, about which temporal ecological dynamics are still not well understood. The present study examines 23 years of nesting for green turtles at this remote island to evaluate annual mean nesting size (MNS) changes and post-maturity somatic growth rates. Our results show a significant decrease in annual MNS over the study; Whereas MNS during the first three consecutively monitored years (1993-1995) was 115.1 ± 5.4 cm, during the last three years (2014-2016) it was 111.2 ± 6.3 cm. There was no significant change in post-maturity somatic growth rate over the course of the study; the mean annual growth rate was 0.25 ± 0.62 cm/year. These findings suggest an increase in the relative proportion of smaller, presumptive neophyte nesters appearing in Trindade during the study period.

Keywords: Conservation; mean nesting size; population ecology; body size; Southwestern Atlantic Ocean; time-series; monitoring.

1. Introduction

Oceanic islands often host high species richness and biodiversity, and due to their remoteness, such areas, when pristine, have the potential to offer refugia for sensitive and conservation-dependent wildlife populations (Fonseca et al., 2006). Yet approximately one-third of all currently endangered vertebrates are associated with oceanic islands (Fonseca et al., 2006), and many insular species are already extinct (Heinen et al., 2018). Therefore, understanding ecological and demographic changes in island wildlife populations is fundamental for determining their population status and recovery potential, and for identifying potential drivers of ecological change.

Trindade is a remote oceanic island in the Southwest Atlantic Ocean (SWAO), considered one of the most important refuges for marine fauna in this region (Almeida, 2001), and highlighted by the Convention on Biological Diversity (1992) as an ecologically and biologically relevant area (Dutra et al., 2012). The island hosts the largest nesting assemblage of green turtles (*Chelonia mydas*) in Brazil and the second largest rookery in the SWAO, making the protection of this site crucial for the conservation of the species (Almeida et al., 2011a). Trindade Island was discovered by colonial explorers in 1501 or 1502, marking the beginning of four centuries of anthropic impacts that ultimately resulted in substantial negative impacts on local biodiversity (Gasparini, 2004; Morh et al., 2009; Alves and Silva, 2016). Perhaps the most devastating event was the introduction of pigs (*Sus* sp.) and goats (*Capra* sp.) in 1700 by the astronomer Edmond Halley (Copeland, 1882; Alves, 1998; Duarte and Horta, 2012). It is believed that soon after their introduction, pigs became voracious predators of green turtle eggs deposited in nests along the beaches of Trindade (Barth, 1958). This chronic depredation of eggs was considered an important factor in the decrease in abundance of the local nesting population of green turtles (Barth, 1958).

Like most sea turtles, green turtles have late sexual maturation and a long lifecycle (Bolten, 2003). Atlantic green turtles reach maturity at curved carapace lengths (CCLs) ranging from 89.7 cm to 108.0 cm (Almeida et al., 2011a; Colman et al., 2015), which equates to 15–28 years in age based on skeletochronology and the known-year marking of young turtles and their recapture as adults (Zug et al., 2002; Bell et al., 2005; Colman et al., 2015). This slow maturation creates distinct conservation challenges for the species, as it reduces the likelihood that an individual can survive the myriad of human threats to reach reproductive age (Mazaris et al., 2017). Coupled with the fact that adult females nest only every ca. 3 years in the SWAO (Almeida et al., 2011b), delayed sexual maturity in green turtles contributes to the species' vulnerability because it requires that conservation efforts must be undertaken for decades or more for populations to recover from human-induced reductions in population size (Gosh et al., 2016). In the SWAO, including Brazilian waters, green turtle conservation status was recently updated to 'least concern' on the IUCN Red List (IUCN, 2019) and to 'almost threatened' in the Red Book of Brazilian Fauna (ICMbio, 2022).

The TAMAR Project started monitoring green turtles nesting on Trindade in 1982. Since then, the project has estimated between 558 to 3559 visits per annum by green turtles to the island (Marcovaldi and Marcovaldi, 1987; Medeiros et al., 2022). The Trindade Island green turtle nesting population is thought to be relatively stable based on ongoing monitoring efforts (Medeiros et al., 2022), contrasting the widespread increasing trends for green turtle nesting populations in the Atlantic (García-Cruz et al., 2015; Mazaris et al., 2017). However, this apparent stable status was inferred from a comparison of past (Almeida et al., 2011b) and present (Medeiros et al., 2022) studies that used different techniques, thus presenting a major caveat to this finding. Considering that the Trindade Island green turtle nesting population was thought to suffer extreme losses due to an introduced predator (i.e. pigs) more than a century ago (Alves et al., 2011), and in light of the eradication of this predator in the more recent past, it is possible that Trindade green turtles are in a not yet described recovery phase due to higher survival rates of eggs and neonates on the island during recent decades.

Determining long-term trends in abundance for sea turtle nesting populations typically requires consistent on-beach monitoring, and robust counting of nesting individuals, over many decades (National Research Council, 2010). However, there may be demographic measurements other than annual abundance that can yield inferences, albeit indirectly, about population trends. For example, Hays et al. (2022) show that a decrease in mean body size of about 2.4 cm—from 83.2 to 80.8 cm—for loggerhead turtles (*Caretta caretta*) nesting in the Cape Verde Islands was due to an influx of first-time nesters as the annual population size expanded. A similar mean body size decrease was found for green turtles nesting at Ascension Island in the South Atlantic, as the population underwent a significant increase in abundance from 1973 to 2012 (Weber et al., 2014). Yet despite these examples and the potential for body measurements to reveal demographic shifts indicative of population growth and recovery, so far the have been no efforts to monitor changes in mean body size of nesting green turtles at Trindade Island.

Here we analyze 23 season of nesting beach monitoring data for green turtles at Trindade Island collected across a 32-year interval (1985–2016). Our goals were to evaluate annual body size distributions and mean nesting sizes (MNSs), and adult female somatic growth rates each year, to determine the extent to which these demographic parameters changed over the course of the study. Using annual MNS as a simple biological indicator to track long-term demographic changes, we hypothesized that if the population is in a recovery phase, there would be a gradual decrease in annual MNS stemming from greater numbers of smaller, neophyte nesters each year of the study. If so, our results can yield novel insights about population trends for Trindade Island green turtles that were not previously considered despite decades of monitoring at this remote nesting site. Our results also add relevant data for the conservation and management of green turtles in Brazil and the SWAO, and provide a glimpse as to how the eradication of a voracious island predator (i.e., pigs) may benefit local sea turtle nesting colonies.

2. Methodology

2.1. Study Area

Trindade Island (20º30’S, 29º20’W) is located 1160 km east of the Brazilian coast and is part of the Vitória-Trindade oceanic island chain in the Southwestern Atlantic Ocean region (Serafini et al., 2010; Fig. 1). Trindade is 13.5 km^2 in area, with interior terrain dominated by rocky mountains, and coastal areas comprised of sand and pebble beaches (SECIRM, 2012). Marine environments around the island are influenced by warm sea currents (Brazilian current; Stramma, 1991) with a mean sea surface temperature of 27ºC and mean wave heights between 1.0 and 2.0 meters (Pianca et al., 2010). The climate is tropical oceanic, with an average annual air temperature of 25°C, with the warmest conditions usually in February (monthly mean = 30°C), and coolest periods in August (monthly mean = 17°C; Mohr et al., 2009).

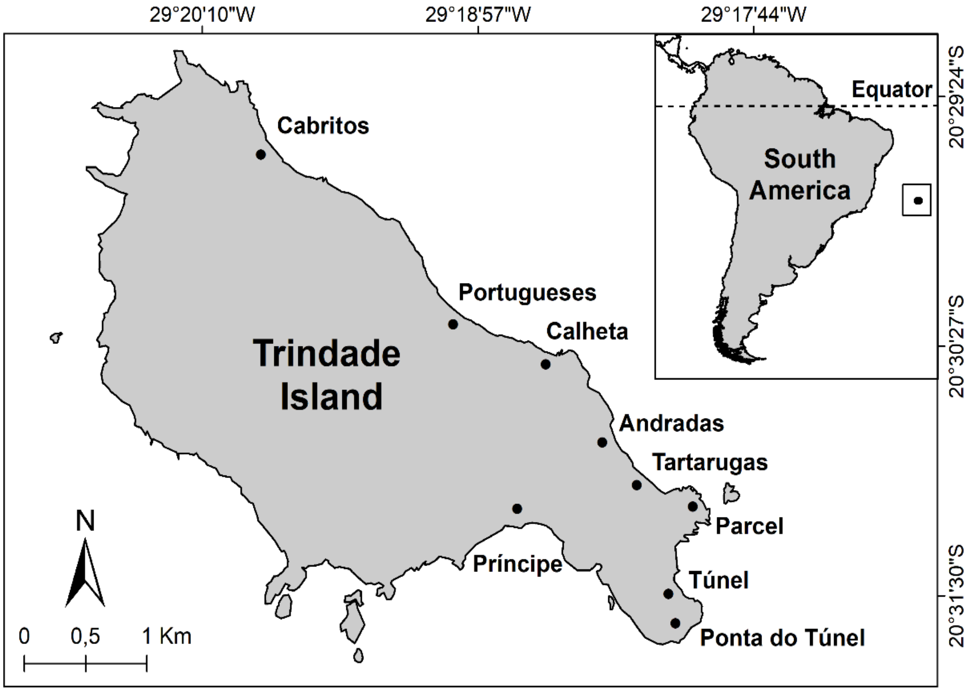

Figure 1. Location of the nine green turtle nesting beaches monitored on Trindade Island, South Atlantic Ocean. Data for this study are derived primarily from Andradas and Tartarugas.

2.2. Green Turtle Sampling

This study assessed a green turtle nesting dataset spanning 32 years (1985–2016), with body size data collected for 6132 nesting females across 23 reproductive seasons; 9 seasons were not monitored due to logistic challenges. Nightly monitoring occurred from December to February, primarily on the beaches of Andradas and Tartarugas, and sporadically (due to logistic constraints) on seven other beaches (Fig. 1, Supplementary Table S1). Encountered adult females were measured from the nuchal notch to the posterior-most edge of the carapace (i.e., curved carapace length, CCL) using a flexible tape with 0.1-mm precision (Marcovaldi and Marcovaldi, 1999). Each turtle was tagged on the first large proximal scale of each front flipper (i.e. double-tagged) with Inconel tags (Style 681, National Band Company, Kentucky USA; Almeida et al., 2011a). We note that tag loss can happen with green turtles, although

Colman et al. (2015) reports a tag loss rate of only 0.6% for loss of both tags during a study of double-tagged adult green turtles. In the present study, green turtles that lost a single tag were re-tagged in the appropriate front flipper.

2.3. Body Size Distribution

Each nesting turtle measured during a breeding season was represented only once in the respective annual dataset. For individuals encountered more than once in a season, the mean CCL was used (Phillips et al., 2021). With these data on individual size measurements, we evaluated the annual body size distributions for each year of the study to gain an understanding about changes in the body size structure for the population. Body size frequency distributions were represented graphically (Kaps and Lamberson, 2004) for each of the 23 breeding seasons to gauge potential long-term changes in the proportion of neophyte vs. experienced adult nesters. For this exercise we used 108.0 cm CCL—the maximum size at maturation for SWAO Atlantic green turtles (Almeida et al., 2011a; Colman et al., 2015)—as the putative threshold for distinguishing between the neophytes and experienced nesters. We recognize the inherent caveats of using a single size threshold for a dynamic population, due to the variability in female maturation size for any given population (Turner Tomaszewicz et al., 2022); however, without unequivocal knowledge about reproductive histories for each turtle we deem this size threshold to be a reasonable approximation for the population.

2.4. Mean Nesting Size

Building off the inspection annual body size distributions, we also calculated the mean body size of nesting females (i.e. mean nesting size, MNS) for each season. As with size frequency calculations, for turtles that were captured on multiple occasions, we used the mean of all measurements in analyses. To determine potential changes in annual MNS we used a generalized additive model (GAM) (Hastie, 2020). Here, the GAM was used to test for changes in mean CCL (response variable) across years (predictor variable). For this, we built the model containing the variables "CCL ~ year".

2.5. Post-maturity Somatic Growth Rate

To evaluate the effect of body size and year on post-maturity somatic growth rates for the Trindade Island nesting population, first we calculated the annual growth rate (AGR) for each individual observed during two or more nesting seasons following Le Gouvello et al. (2020):

$$AGR = \frac{CCL_{last} - CCL_{first}}{Number\ of\ Years}$$

where CCL_{last} and CCL_{first} are the curved carapace lengths (cm) of the turtle upon its final and initial measurements, respectively, and *Number of Years* is the total ordinal days between first and last measurement divided by 365 days.

Generalized linear models (GLMs) were used to test for differences in individual post-maturity growth rates across all years of the study. We assumed a quasipoisson data distribution, and used GLMs with growth rate as the response variable, and time and initial body size (CCL) as predictor variables. We compared the null model "rate~1" with the model containing the variables "rate~CCL + time", "rate~CCL", and "rate~time". The best model took into account the explanatory power residual deviance.

Modeling analyses were performed in R (R CORE TEAM, 2017), using the packages ' mgcv ', 'ggplot2' and 'ggthemes' (Wickham, 2016).

3. Results

3.1. Annual Body Size Distribution

Overall, 6132 individual turtles were measured during this study, with an annual range of 10–625 (mean = 267±183) green turtles encountered. When examining the annual body size frequency distributions for nesting green turtles we found a clear increase in the proportion of smaller, putative neophyte nesters (black portion of graphs) as the years progressed. Annual nesting populations had between 8% and 41.6% of females with CCL<108cm, our putative threshold for distinguishing between the neophytes and experienced nesters, and there was a gradual increase in the annual proportion of females with CCL<108 cm as the study progressed (Fig. 2). In turn, the proportion of ‘large’ females with CCL>120cm was greatest during the initial years of monitoring, with observed maximum values of 36.7%, and decreased in later years, to as low as 5% (2013) (Fig. 2). Reflective of these shifts in body size, we also observed a gradually more-pronounced bi-modality in the CCL frequency distribution, with distinct groups of smaller and larger nesting females (Fig. 2).

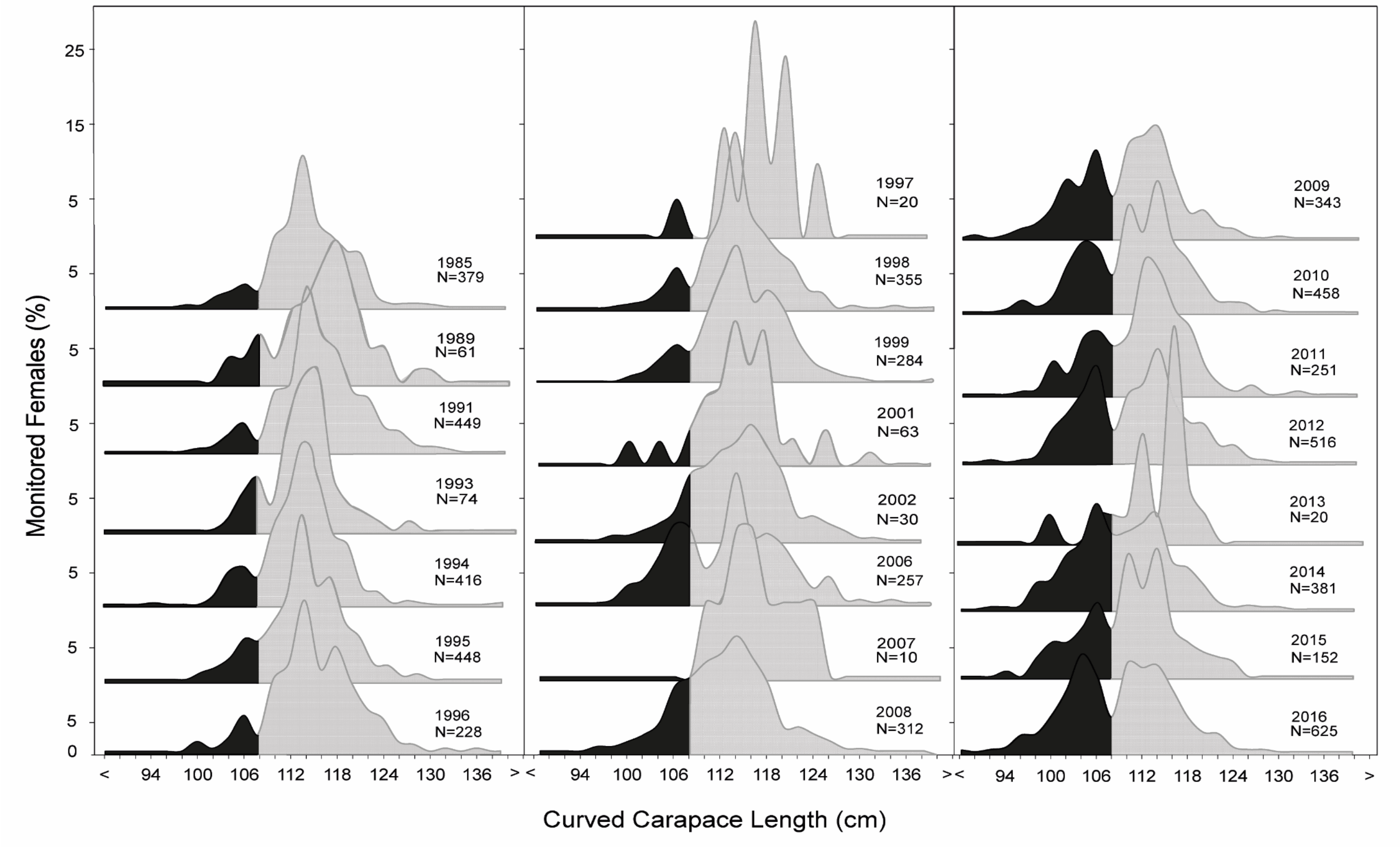

Figure 2. Curved carapace length frequency distribution for adult female *Chelonia mydas* on Trindade Island during 23 nesting seasons interspersed from 1985 to 2016. Black shading indicates CCL frequencies of the putative neophytes, based on a maximum recruitment size of 108 cm CCL for the South Atlantic (Avens and Snover, 2013); Gray shading delimits the adult sizes considered to be post-recruits (i.e. experienced nesters). See ‘reproductive seasons’ in Figure 3B.

3.2. Mean Nesting Size

For the 23 years of monitoring results, GAM analyses identified significant differences in annual CCL frequency structure and mean CCL of nesting females ($p < 0.0001$, with model explanatory power [pseudo R^2] of 0.718 and deviance of 75%; Table 1, Fig. 3). The overall mean CCL of measured females across all years was 113.3 cm (n = 6132, range = 89.1–144.2 cm; SD =6.3). There was an evident increase in the proportion of smaller females as the study progressed (Fig. 3A), which resulted in a monotonic declining trend in MNS among measured female green turtles (Fig. 3B). The MNS during the first three consecutively monitored years (1993–1995; = 1 nesting remigration interval, Almeida et al., 2011b) was 115.1 ± 5.4 cm CCL (range = 95.2–143.5 cm, n = 938), and during the last three years of data (2014–2016), it was 111.2 ± 6.3 cm CCL (89.3–132.2 cm, n = 1158). It is interesting to note that, in addition to the 4-cm difference in MNS between these two periods, the maximum CCL of nesting females during 1993–1995 (143.5 cm CCL) was more than 10 cm larger than the maximum CCL recorded during 2014–2016 (132.2 cm CCL; Supplementary Table S2).

Table 1. Results of the analysis of deviance applied to the generalized additive model fit to describe the variations in mean annual CCL throughout the study. Note: standard error 'Std.Error', estimated degree of freedom 'Edf', reference degree of freedom 'Ref.Df', Z for statistics, X^2 for Chi-square p for statistics.

	Estimate ß	**Std.Error**	**Z**	**P**
Intercept	113.9	0.2314	492.1	<0.001
Smooth term	**Edf**	**Ref.Df**	**X2**	**P**
Year	2.5	3.152	56.92	<0.001

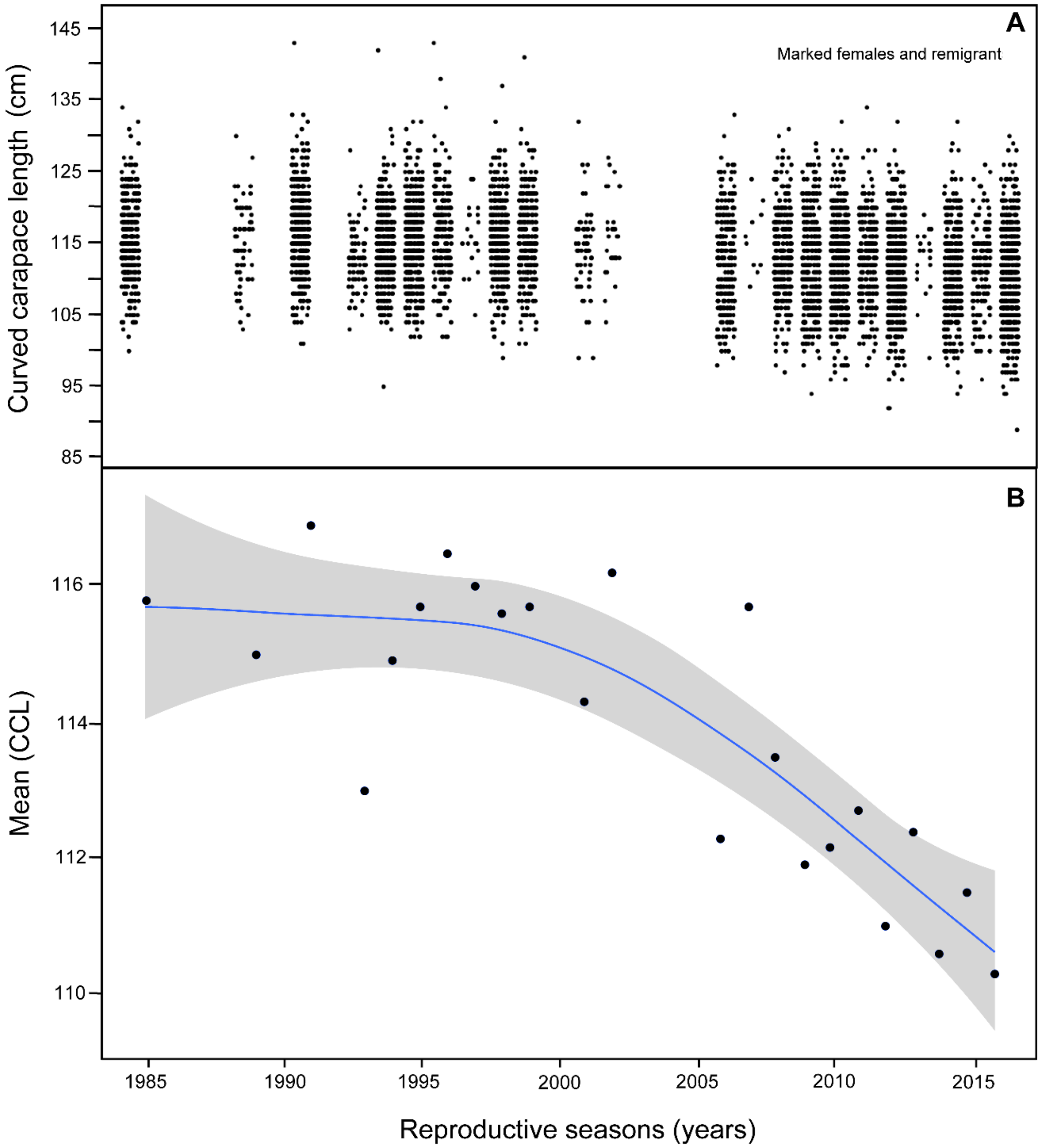

Figure 3. A, Curved carapace lengths (CCL) for green turtles (*Chelonia mydas*) nesting at Trindade during 23 nesting seasons interspersed from 1985 to 2016. B, variability in annual mean nesting size (CCL) tested using a generalized additive model with standard deviation analysis of female CCL ($p < 0.01$).

3.3. Post-maturity Somatic Growth

A total of 570 female green turtles were measured during multiple nesting seasons during the study. Of these females, 52 % (n=299) did not show post-maturity growth. The interval between the first and last measurements for any single turtle ranged from 2 to 32 years. Individual-based post-maturity annual somatic growth rate ranged from 0.02 to 9 cm/year, with a mean of 0.25 ± 0.62 cm/year; there was no relationship with sampling year nor with female CCL_{first} (Table 2). Moreover, there was no explanatory power between post-maturity annual growth rates when compared to time (Model 3: ß = -0.166; p = 0.455) and CCL (Model 2: ß = 0.016; p = 0.347; Table 2). The null model showed the best explanatory power.

Table 2. Selection of generalized linear models in relation to post-maturity growth rates p < 0,001. Note: Df reference of degree of freedom and F for statistics.

Model selection	Resid. Df	Resid Dev	Df	Deviance	F	P value
Model null: rate ~1	569	372.75	_	_	_	_
Model 1: rate~ccl + time	567	371.02	2	1.728	0.583	0.558
Model 2: rate ~ ccl	568	371.45	1	-0.424	0.287	0.592
Model 3: rate ~ time	568	371.91	0	- 0.458	_	_

4. Discussion

Our study reveals several important demographic parameters for Trindade green turtles, including their annual mean nesting size (MNS) and range in body size across 23 different nesting seasons, as well as trends in somatic growth rates among turtles encountered during two or more nesting seasons. These findings show the value of long-term tagging programs at nesting beaches for studying sea turtle demography and population status. The data also highlight the importance of mark-recapture records for understanding how sea turtle status may change through time (e.g. Stokes et al., 2014).

4.1. Changes in Mean Body Size

We demonstrate a trend of reduced mean nesting size of reproductive green turtles at Trindade Island, a remote location in the Southwestern Atlantic Ocean. In the early 1980s there was a greater relative proportion of large females, with relatively few smaller-bodied new recruits, although the proportion of smaller turtles increased in the later years of this study (Fig. 2). There are multiple potential reasons for this reduction in body size, although we suggest this proportional increase in smaller turtles arriving at Trindade each year was due to increased recruitment and the presence of greater numbers of neophyte (i.e. first time) nesters, which are usually smaller than older females (Le Gouvello et al., 2020; Hays et al., 2022). Recovering sea turtle populations elsewhere in the Atlantic as well as in the Pacific have shown similar nesting female mean body size reductions, and these demographic shifts too have been attributed to increases in the relative proportion of neophyte nesters (García-Cruz et al., 2015; Piacenza et al., 2016; Hays et al., 2022). Moreover, the magnitude of the overall decrease in annual mean CCL (–3.9 cm) found for Trindade Island green turtles is similar to the 4.5 cm decrease found for a recovering green turtle population at Ascension Island in the South Pacific. An increase in the proportion of smaller nesting females following significant conservation efforts and population increase has also been reported for leatherback turtles (*Dermochelys coriacea*) at Espirito Santo, Brazil (Colman et al., 2019).

While we suggest reductions in MNS and changes in body size frequency are probably the result of increased neophyte nesters, additional considerations are warranted to evaluate the efficacy of this theory. As noted above, there was a long history of pig depredation of green turtle eggs and hatchlings at Trindade (Barth, 1958; Alves and Silva, 2016), which likely reduced population sizes to all-time lows. A timeline taking into account pig eradication efforts and green turtle maturation ages suggests that the pulse of putative neophyte nesters was likely the result of pig eradication (Supplementary Fig. S1). Eradication efforts started in 1965 (Alves, 1998) and likely took several years, perhaps as long as a decade, to achieve a complete removal of pigs. If we consider that the mean time from neritic recruitment (ca. 30 cm CCL) to adulthood is about three decades for green turtles at Fernando de Noronha, the nearest neighboring major green turtle rookery in Brazil (Colman et al., 2015), then the initial surviving cohorts of green turtles coinciding with eradication would have been expected to show up as adult nesting females in the early-to-mid 2000s, which is consistent with our data showing significantly smaller mean nesting sizes by 2006. We note that there is a slight increase in the proportion of smaller females prior to 2006, which we attribute to variability in maturation age (e.g. Bell et al., 2005; Patrício et al., 2014). In the eastern Pacific, for example, Turner Tomaszewicz et al. (2022) found that some green turtles matured in as little as 17 years.

We acknowledge that increases in the proportion of smaller turtles at Trindade Island may also be due to other factors besides the positive effects of conservation (Mazaris et al., 2017; Hays et al., 2022). For example, one driver for such change could be differential at-sea mortality from fisheries bycatch, with the larger green turtles interacting with fisheries at a greater rate. Both artisanal and industrial fisheries are widespread throughout the region, and green turtles are known to interact with a variety of gear types (Marcovaldi et al., 2006). However, there is no evidence of a size bias among the turtles that interact with these fisheries. Changes in female CCL frequency could also stem from extrinsic factors such as habitat degradation (e.g. marine pollution, climate change) disproportionately impacting larger turtles, reducing prey availability and/or increasing competition for resources (Bjorndal et al., 2000a, Balazs and Chaloupka, 2004). This possibility seems less likely considering the lack of any change in somatic growth rate partially related to habitat quality (Bjorndal et al., 2000).

While the exact drivers for the observed change in mean body size may be unclear, the fact that nesting turtles have gotten smaller at Trindade Island has important implications for the reproductive output of the population. Such changes in body size relative frequencies may have important ecological consequences related to a population's reproductive output potential (Shackell et al., 2010; Romanuk et al., 2011; Brost et al., 2015). For instance, larger females may have greater potential reproductive output, due to increased internal space to produce more eggs (Brost et al., 2015; Cameron et al., 2016; Mortimer et al., 2022), and in turn, populations with increased proportions of neophyte nesters may have a net decrease in per-individual fitness (Le Gouvello et al., 2020).

4.2. Effects of Pig Eradication

Whereas the true impact of introduced rats on Trindade Island green turtle survival and population size are unknown due to the historic timeline of pigs introduction (prior to record keeping or nesting beach monitoring), there is little doubt that the introduction of pigs had a devastating negative impact on the green turtle population. Nest predation by pigs is currently a significant conservation challenge for many sea turtle populations around the world (Fowler, 1979; Engeman et al., 2005; Longo et al., 2009). For example, in Georgia (USA), predation by introduced pigs was identified as having the greatest impact among egg predators on loggerhead turtle nests (*Caretta caretta*, Butler et al., 2020). Similarly, pigs were the primary culprit responsible for the loss of 89.6% of all nests deposited by flatback (*Natator depressus*), olive ridley (*Lepidochelys olivacea*), and hawksbill (*Eretemochelys imbricata*) turtles in Western Cape York Peninsula, Australia (Whytlaw et al., 2013). Moreover, and consistent with our theory about the benefits of pig eradication on Trindade to local green turtles, pig removal at Keewaydin Island (Florida, USA) resulted in a decrease from 41.6% to 27.7% in green turtle/loggerhead nest loss in just two years, and to 9.4% after four years (Engeman et al., 2014, 2019). Such positive signs after the eradication of rats on other nesting beaches suggests that the removal of rats on Trindade had a profound positive influence on the local green turtle population. However, unfortunately there is no information about female abundance prior to 1982, nearly two decades after the eradication of pigs (in 1965). To shed light on this important topic, we recommend continued monitoring to ensure that future changes in population size are well-understood, especially in relation to the first year of monitoring in 1982.

4.3. Maximum Body Size of Nesting Females

Another interesting finding in the present study is that the maximum size of green turtles encountered (143.5 cm CCL) is 10 cm larger than that largest female found nesting elsewhere in the Atlantic Ocean (Fig. 4). The reasons for this substantial 'maximum size' disparity are unclear, but may relate to differing harvest histories among the different SWAO nesting populations. Although Trindade Island green turtles were likely heavily impacted by introduced pigs, which impacted egg and neonate survival, the remote nature of the island perhaps lessened the access for turtle hunters, making it more difficult to actively target the largest of individuals, which was often the case during historical directed take (Carr and Caldwell, 1956; Pritchard, 1980). We note that this maximum size for our study population is from the early portion of our study period (1991); nevertheless, such differences in harvest history could still manifest today in some populations, considering the long-lived nature of sea turtles. Alternative scenarios for this maximum size disparity be also relate to differences in forage habitat quality and/or intraspecific competition in foraging areas among the different nesting assemblages, since growth is dependent on density and availability of food (Bjorndal et al., 2000).

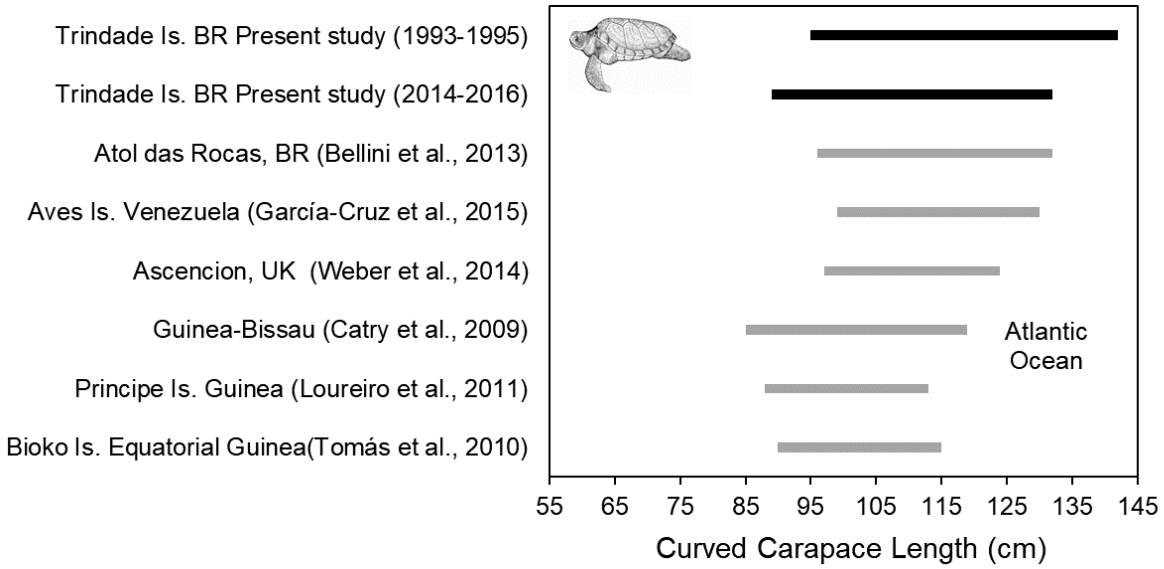

Figure 4. Comparison of curved carapace length (cm) ranges (horizontal bars) for *Chelonia mydas* nesting at Trindade Island (black bars) and other locations (grey bars) in the Atlantic Ocean.

4.4. Somatic Growth

With a mean annual growth rate of 0.25 ± 0.6 cm/year, adult female green turtles at Trindade Island appear to grow slower than their counterparts at other nesting rookeries in the Atlantic Ocean (0.3–0.9 cm/year; Omeyer et al., 2017). The drivers for annual growth often relate to extrinsic factors such as habitat quality (Diez and Van Dam, 2002). However, green turtles nesting at Trindade use the same foraging areas as those from other nesting rookeries in the South Atlantic (Proietti et al., 2012), thus any negative influence of poor habitat on somatic growth likely would have affected these other nesting subpopulations as well. Instead, perhaps the location of Trindade Island requires that green turtles expend greater amounts of energy to access this offshore locality, such that greater nutrient proportions are routed for the production of eggs rather than somatic growth. Whatever the reason, it is apparent that the intrinsic and/or extrinsic factors influencing growth were constant through time, as we demonstrated that post-maturity female growth rates did not change over the 32-year duration of this study. In contrast, Le Gouvello et al. (2020) found that the somatic growth of female loggerheads nesting in South Africa did change over time. The reasons for the disparate adult growth patterns are unclear and warrant further study

4.5. Conservation Measures

The TAMAR project has been protecting sea turtles at nesting and feeding areas throughout Brazil for over four decades (Colman et al., 2019). People’s greater awareness, coupled with better protection of coastal and feeding environments, likely contributed to the stabilization and putative recovery of the green turtle nesting population at Trindade. In addition to pig eradication, important conservation actions that likely contributed to this positive situation include increased sanctions and penalties for capture, killing, egg collection, and habitat disturbance imposed by the Environmental Crimes Law nº 9.605, of 12 February 1998 (Brazil, 1998); the categorization of sea turtles as endangered species by IBAMA Ordinance nº 1.522, of 19 December 1989 (Brazil, 1989); and the required mitigation of incidental bycatch in fishing gear as stated in Law nº 31 of December 2004 (Brazil, 2004). Along with this increased environmental oversight, outreach and education campaigns developed by TAMAR were instrumental for the protection of green turtles and other sea turtle species along the Brazilian coast.

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