

## Nesting and Conservation Management of Hawksbill Turtles (*Eretmochelys imbricata*) in Northern Bahia, Brazil

MARIA ANGELA MARCOVALDI<sup>1</sup>, CLAUDIA F. VIEITAS<sup>2</sup>, AND MATTHEW H. GODFREY<sup>1</sup>

<sup>1</sup>Fundação Pró-TAMAR, Caixa Postal 2219, Salvador, Bahia, 40210-970, Brazil

[Fax: 55-71-876-1067; E-mail: protamar@e-net.com.br];

<sup>2</sup>Rua Jacupiranga 57, São Paulo, São Paulo, 01440-050, Brazil

**ABSTRACT.** – In Brazil, the primary nesting area for hawksbill turtles (*Eretmochelys imbricata*) is the northern part of the coast of Bahia State. The Brazilian Sea Turtle Conservation Program (TAMAR-IBAMA) has five research and conservation stations in this area, protecting about 200 km of beaches. Data from 7 nesting seasons (1990–91 to 1996–97) are presented. During the hawksbill nesting season (October through March), beaches are patrolled daily and nests are either kept *in situ* (16%), transferred to protected beaches (10%), or transferred to open-air beach hatcheries in TAMAR-IBAMA stations (74%). Peak nesting occurs in January and February and average clutch size is 136.4 eggs. Mean emergence period in days varied across years for nests incubated *in situ* (52.67–57.81), transferred to protected beaches (52.40–55.06), and transferred to open-air beach hatcheries (51.29–56.79). Mean emergence success also varied among seasons for nests incubated *in situ* (51.67–78.06), transferred to protected beaches (43.81–52.22), and transferred to open-air beach hatcheries (32.55–64.75). Brazilian nesting hawksbill females are larger than those elsewhere (mean curved carapace length, 97.4 cm; mean curved carapace width, 89.6 cm) but the mean clutch size is typical of the species.

**KEY WORDS.** – Reptilia; Testudines; Cheloniidae; *Eretmochelys imbricata*; sea turtle; emergence success; nesting; conservation; Brazil

Sea turtles were once considered an abundant resource throughout their range and, for many years, their meat and eggs served as an important resource for coastal peoples in many areas (National Research Council, 1990). Hawksbill turtles (*Eretmochelys imbricata*), in particular, were sought in various regions throughout the world, mainly because of their beautiful carapaces. Hawksbill shell, also known as tortoiseshell, is used to make ornaments and jewelry. In Brazil, the common name for hawksbill is *tartaruga de pente*, which literally means “turtle of comb,” referring to one of the shell’s uses in this country. This species is considered threatened with extinction in Brazil (Pinto, 1996) and critically endangered internationally (Baillie and Groombridge, 1996).

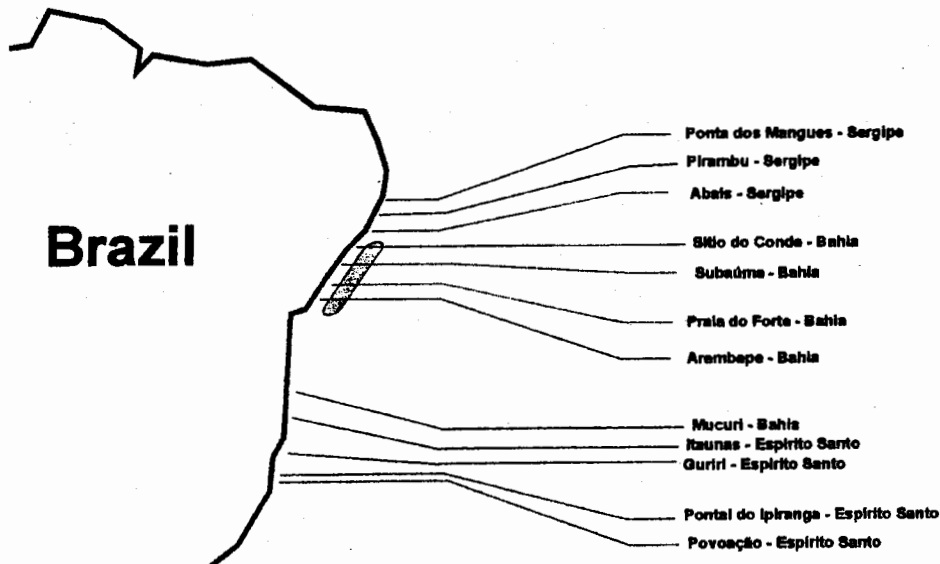
Slaughter of nesting females, poaching of eggs, manufacture of shell ornaments, coastal development, and incidental fisheries capture has reduced the species almost to extinction along the Brazilian coast. Only in a few places do populations of hawksbills still remain. Occasional nesting is recorded by the Brazilian Sea Turtle Conservation Program (TAMAR-IBAMA) as far south as Espírito Santo State and as far north as Ceará State, but regular nesting occurs mainly in the northern part of the coast of Bahia State (Fig. 1). For example, in the 1995–96 nesting season, only 9 hawksbill nests were recorded in Sergipe to the north of Bahia, and 5 nests were seen in Espírito Santo, to the south. In the same season, more than 200 nests were encountered in the northern part of the coast of Bahia, with more than 90% of those nests being laid on beaches that are monitored by the TAMAR-IBAMA bases of Arembépe and Praia do Forte.

Besides hawksbills, loggerheads (*Caretta caretta*), olive ridleys (*Lepidochelys olivacea*), and green turtles (*Chelonia mydas*) also nest in northeastern Bahia, where the overall sea turtle nesting season extends from August to April (Marcovaldi and Laurent, 1996). This paper describes hawksbill nesting in northern Bahia, Brazil, where TAMAR-IBAMA has been working continuously since 1982, with special emphasis on data obtained from 1990 through 1997.

### MATERIALS AND METHODS

**Study Area.** — TAMAR-IBAMA has five research and conservation stations in the northern coast of Bahia: Itapoan (analyzed here with Arembépe Station), Arembépe, Praia do Forte, Subaúma, and Sítio do Conde (Fig. 2), protecting about 200 km of beaches. The shoreline consists mainly of sandy beaches with rock bars and sandstone barrier reefs occurring intermittently in the sublittoral. The supralittoral is characterized by sand dunes with herbaceous and shrubby vegetation, with an extended coconut plantation running behind it. Small rivers sporadically cut through this area, dividing it into different beaches. A more detailed description of Praia do Forte beach is found in Marcovaldi and Laurent (1996).

**Data Collection.** — Field work takes place from 15 September to 15 March every year, when the beaches are monitored daily by fisherman and/or biologists and students (Marcovaldi and Laurent, 1996). Each station is divided into Intensive Study Areas (ISA) and Conservation Areas (CA), as shown in Fig. 2.



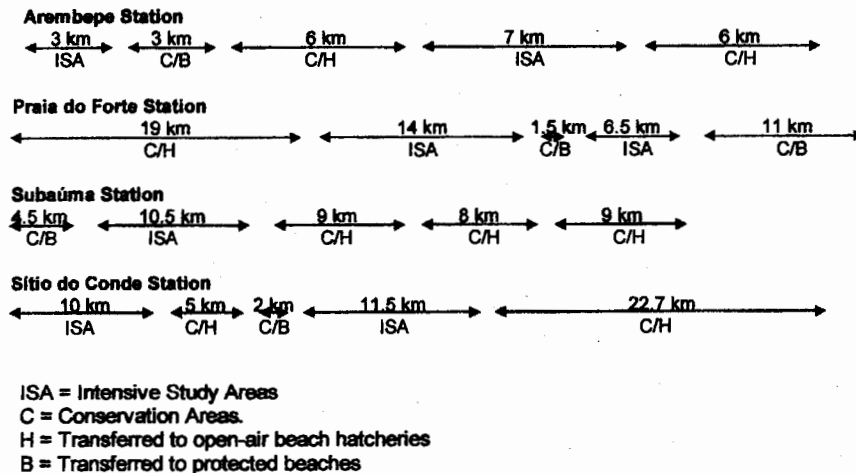
**Figure 1.** TAMAR-IBAMA stations on the Atlantic coast of Brazil. Shaded area represents the primary nesting beaches for hawksbills, found in the northern part of Bahia State.

Nests were left *in situ* in ISAs and marked by stakes. In areas with a high threat of predation by the crab-eating fox (*Cerdocyon thous*), a plastic mesh (1 x 1 m, with openings of 7 cm) was placed over each clutch and buried 5 cm deep in the sand. Nests considered to be threatened by high tides were transferred to higher locations on the same beach.

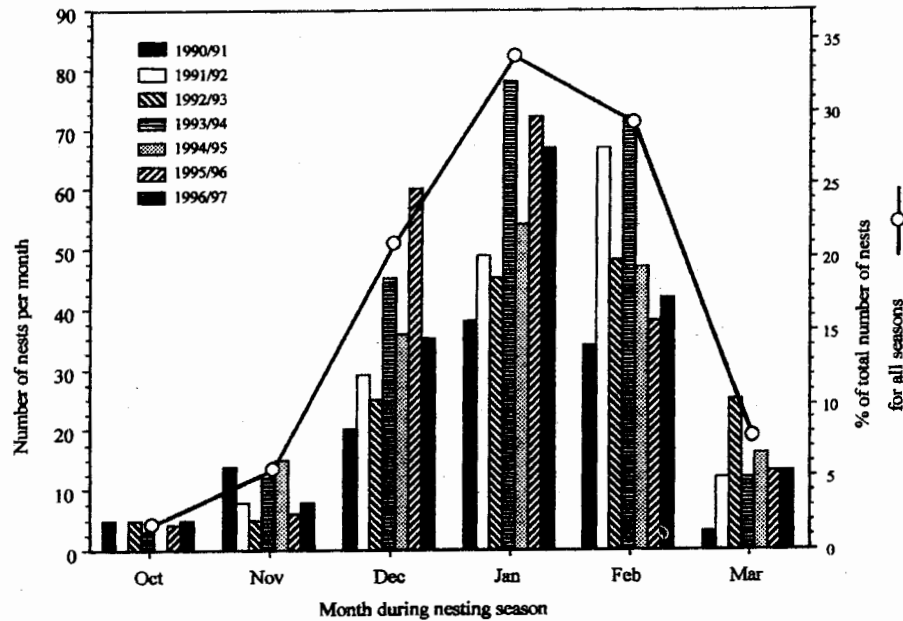
Nests in CAs were subject to a variety of threats, such as inappropriate coastal development, erosion, or lack of access by research personnel. For these reasons, eggs were transferred either to protected beaches in the ISA, or to centrally located open-air beach hatcheries at each TAMAR-IBAMA station. CA beaches were patrolled daily by fishermen hired by TAMAR-IBAMA. Each fisherman was responsible for approximately 5 km of beach, from which he collected any nests laid the night before. Nests were transferred individually in Styrofoam boxes. The boxes were brought to a TAMAR-IBAMA biologist either directly

or indirectly via another fisherman (with greatest effort being taken to ensure transference within 12 hours of oviposition), following which the clutches were relocated to an incubation site (open-air beach hatchery or protected beach). Hatchery and management practices are described in more detail elsewhere (Marcovaldi and Laurent, 1996).

The following parameters were recorded for every nest: date of laying, original location, total number of eggs (for *in situ* nests this was estimated by counting unhatched eggs plus empty egg shells after emergence), date of hatchling emergence (when the majority of hatchlings emerged on the sand surface), number of live hatchlings (either counted directly from nests incubated in hatcheries, or indirectly from empty egg shells from nests incubated on the beaches), number of dead hatchlings, and number of unhatched eggs (opened to evaluate the embryonic stage). Emergence success was calculated as the ratio of the number of live



**Figure 2.** Study area of TAMAR-IBAMA stations with different management protocols on different sections of each beach.



**Figure 3.** Numbers of hawksbill nests in Bahia, Brazil. Data come from Arembepe and Praia do Forte stations (which receive more than 90% of all hawksbill nests laid in Bahia). The line shows the relative percentage of nests laid in each month, based on all 7 nesting seasons (1990–91 to 1996–97) combined.

hatchlings (emerged or still in the nest when excavated) to the total number of eggs in the clutch. Emergence period was calculated as the number of days between night of oviposition and night of emergence.

During some nights, biologists and students patrolled the beaches with the highest concentration of nests, and marked nesting hawksbills with Monel tags (#681, National Band Co.) and measured curved carapace length (nuchal notch to posteriormost marginal tip) and maximum curved carapace width with a flexible measuring tape.

**Data Analysis.** — All data were stored in dBase-4 files and analyzed using Instat (2.03) and MS Excel (98) software. Comparisons were made using 2-tailed unpaired t-tests or one way analyses of variance (ANOVA), followed by Student-Newman-Keuls (SNK) post hoc tests. When the assumptions for parametric statistical tests were violated, nonparametric tests were used. Emergence success data were transformed using arcsine transformation prior to analysis (Zar, 1984).

## RESULTS AND DISCUSSION

**Seasonal Distribution of Nesting.** — The nesting season for *E. imbricata* in northern Bahia extends from October to March, peaking between December and February (Fig. 3). Marcovaldi and Laurent (1996) reported that February was the peak nesting season for hawksbill turtles in Praia do Forte, based on nesting data from 1987 through 1993. The current study presents data from 1990 through 1997; the overall peak for these 7 nesting seasons occurred in January (Fig. 3). Further analysis of the data revealed that the weeks with the greatest number of nests occurred in late January or early February.

Daytime nesting has been recorded on nine occasions at Praia do Forte Station in the last five seasons and at least four records from Arembepe. In three of these, the female nested in the presence of numerous observers. Hawksbills are typically nocturnal nesters, although daytime nesting may also occur (Groombridge, 1982; Witzell, 1983). In the Seychelles, diurnal nesting seems to be the typical behavior for this species (Diamond, 1976).

**Emergence Period.** — There was little difference in mean emergence period between the different beaches, with the exception that the emergence period of *in situ* nests was

**Table 1.** Emergence success and emergence period for hawksbill clutches incubated in different sites (IS: *in situ*; HY: hatchery; TB: transferred to protected beaches) at different TAMAR-IBAMA stations, for the combined nesting seasons 1990–91 through 1996–97. Mean values are followed by  $\pm$  SE and sample size. Statistical analyses (ANOVA or Kruskal-Wallis) were performed within years, among means for the different stations. \* = statistically significant differences between groups.

	Emergence Success (%)			Emergence Period (days)		
	IS	HY	TB	IS	HY	TB
Praia Forte	56.98 $\pm 1.80$ 220	45.89 $\pm 1.70$ 215	48.66 $\pm 3.28$ 59	54.79* $\pm 0.22$ 206	53.89 $\pm 0.32$ 199	53.79 $\pm 0.49$ 58
Arembepe	55.92 $\pm 2.26$ 150	44.68 $\pm 1.24$ 518	45.01 $\pm 9.75$ 10	53.77 $\pm 0.47$ 146	53.71 $\pm 0.23$ 476	53.10 $\pm 0.96$ 10
Subaúma	62.01 $\pm 6.78$ 18	44.19 $\pm 4.08$ 46	40.94 $\pm 4.28$ 31	51.59* $\pm 0.79$ 17	54.43 $\pm 0.39$ 44	51.80 $\pm 0.54$ 30
Sítio Conde	62.90 $\pm 16.5$ 6	37.74 $\pm 3.73$ 42	52.39 $\pm 6.91$ 16	53.20 $\pm 0.22$ 5	54.12 $\pm 0.71$ 41	53.88 $\pm 0.78$ 16
Test statistic	F=0.77	F=0.34	F=0.95	F=3.95	KW=3.87	F=2.58
p value	p>0.05	p>0.05	p>0.05	p<0.01	p>0.05	p>0.05

**Table 2.** Average emergence period per nesting season for hawksbill clutches in Bahia, Brazil. Mean values are followed by  $\pm$  SE and sample size. Clutches were grouped by incubation site: *in situ* (undisturbed on the nesting beach), hatchery (relocated to open-air beach hatcheries), and transferred (relocated to a protected beach area). Statistically significant differences between groups in a single year are indicated by similar symbols (\*, †). Differences among mean emergence periods were significant across seasons (one-way ANOVA,  $p < 0.0001$ ; K-W = Kruskal-Wallis).

Nesting season	<i>In situ</i>	Hatchery	Transferred	<i>p</i> value; test
1990-91	52.67 $\pm$ 0.66 (18)	52.71 $\pm$ 0.26 (84)		$p > 0.05$ ; t-test
1991-92	57.84 $\pm$ 0.45 (32)	56.79 $\pm$ 0.27 (152)		$p > 0.05$ ; t-test
1992-93	52.74 $\pm$ 0.61 (19)	53.04 $\pm$ 0.28 (141)		$p > 0.05$ ; t-test
1993-94	54.33 $\pm$ 0.37 (79)*	53.34 $\pm$ 0.26 (143)*		$p < 0.05$ ; t-test
1994-95	53.32 $\pm$ 0.31 (79)*	51.29 $\pm$ 0.39 (70)*	52.47 $\pm$ 0.52 (40)	$p < 0.001$ ; ANOVA
1995-96	53.53 $\pm$ 0.30 (92)*	51.89 $\pm$ 0.45 (75)*	52.40 $\pm$ 0.53 (40)	$p < 0.05$ ; K-W
1996-97	56.50 $\pm$ 0.45 (54)*†	55.92 $\pm$ 0.67 (99)*	55.06 $\pm$ 0.51 (34)†	$p < 0.05$ ; K-W

**Table 3.** Average emergence success per nesting season. Mean values are followed by  $\pm$  SE and sample size. Clutches were grouped by incubation site: *in situ* (undisturbed on the nesting beach), hatchery (relocated to open-air beach hatcheries), and transferred to protected beaches (relocated to a protected beach area near the original nest site). Statistically significant differences between groups in a single year are symbolized by \* or †. (K-W = Kruskal-Wallis; M-W = Mann-Whitney).

Nesting season	<i>In situ</i>	Hatchery	Transferred	<i>p</i> value; test
1990-91	53.04 $\pm$ 5.22 (18)	50.72 $\pm$ 2.76 (86)		$p > 0.05$ ; t-test
1991-92	78.06 $\pm$ 3.41 (32)*	64.75 $\pm$ 1.71 (154)*		$p < 0.001$ ; t-test
1992-93	64.46 $\pm$ 5.41 (22)*	39.37 $\pm$ 1.88 (146)*		$p < 0.0001$ ; M-W
1993-94	52.69 $\pm$ 3.07 (88)*	32.55 $\pm$ 2.05 (166)*		$p < 0.0001$ ; M-W
1994-95	51.67 $\pm$ 3.14 (82)*	33.90 $\pm$ 2.79 (88)*	43.81 $\pm$ 3.68 (41)	$p < 0.001$ ; K-W
1995-96	52.12 $\pm$ 2.42 (92)*	39.51 $\pm$ 2.76 (81)*	45.12 $\pm$ 3.97 (40)	$p < 0.01$ ; ANOVA
1996-97	64.63 $\pm$ 3.51 (60)*†	50.41 $\pm$ 2.56 (105)*	52.22 $\pm$ 4.55 (35)†	* $p < 0.01$ ; † $p < 0.05$ ; ANOVA

significantly shorter in Subaúma than in Praia do Forte (Table 1). There were significant differences among mean emergence periods across nesting seasons (Table 2). The clutches of the 1991-92 and 1996-97 seasons had the longest incubation periods. Within individual nesting seasons, there were differences in mean emergence period among the nests grouped according to incubation technique. In all seasons in which significant differences were seen, nests in hatcheries showed slightly shorter emergence periods. Because of the general inverse relationship between incubation temperature and emergence period of marine turtle nests (Mrosovsky and Yntema, 1980), shorter emergence periods in the hatcheries suggest that these had slightly warmer sand temperatures than the nesting beaches. On the other hand, a previous study found no difference in sand temperatures between hatcheries and nesting beaches during the 1994-95 nesting season at Praia do Forte (Naro et al., 1996). It is unclear whether or not slight differences in emergence period reflect a difference in mean sex ratio of clutches incubated in the hatcheries and on the nesting beaches. Given that most of the emergence periods are quite short (< 55 days), it is likely that both hatcheries and nesting beaches are producing a majority of female hatchlings and that management practices used here are not influencing sex ratios, regardless of small differences in means (Marcovaldi et al., 1997).

**Emergence Success.** — The average emergence success of hawksbill nests in Bahia is generally < 70% (Tables 1 and 3), which is lower compared to loggerhead nests found on the same beach (D'Amato and Marczewski, 1993). This value is also relatively low compared to other hawksbill nesting populations, such as the following: Tortuguero, Costa Rica, 91.6% (Bjorndal et al., 1985); US Virgin Is-

lands, 83.7% (Hillis, 1990); Seychelles, 86% (Diamond, 1976), Milman Island, Australia, 79.9% (Loop et al., 1995).

Within the Bahia population, there were no significant differences in emergence success among the different TAMAR-IBAMA stations, for nests subject to all three incubation strategies (*in situ*, transferred to hatcheries, and transferred to protected beaches) (Table 1). There was significant variation over the nesting seasons in mean emergence success of *in situ* nests ( $F = 6.967$ ,  $p < 0.0001$ ) and nests transferred to the hatcheries ( $F = 30.967$ ,  $p < 0.0001$ ), but not for clutches transferred to protected beaches ( $F = 1.410$ ,  $p > 0.05$ ) (Table 3). The clutches in the 1991-92 nesting season had the highest success rate, both *in situ* and in the hatchery. Within individual nesting seasons, clutches in the hatcheries produced fewer hatchlings on average than nests incubated on the beach. These differences were statistically significant for all seasons except 1990-91. Marcovaldi and Laurent (1996) found a similar result analyzing hawksbill nests incubated at Praia do Forte between 1987 and 1993. In 1994-95, TAMAR-IBAMA began to move some threatened nests to protected beaches rather than to the centrally

**Table 4.** Results of statistical comparison between emergence rates per month of clutches incubated in hatcheries and those incubated *in situ*.

	Nov	Dec	Jan	Feb	Mar
1990-91	n.s.	n.s.	n.s.	n.s.	n.s.
1991-92	n.s.	n.s.	$p < 0.001$	n.s.	n.s.
1992-93	n.s.	n.s.	n.s.	n.s.	$p < 0.01$
1993-94	n.s.	$p < 0.001$	$p < 0.0001$	$p < 0.05$	n.s.
1994-95	n.s.	n.s.	$p < 0.01$	$p < 0.05$	n.s.
1995-96	n.s.	n.s.	$p < 0.05$	n.s.	n.s.
1996-97	n.s.	$p < 0.05$	n.s.	$p < 0.05$	n.s.

**Table 5.** Morphometric and reproductive data for hawksbill turtles nesting in Bahia, Brazil, with data from other populations for comparison. CCL = curved carapace length.

Nesting area	CCL (n)	Eggs/clutch (n)	Source
Brazil	97.4 (34) <sup>a</sup>	136.4 (1335)	This study
Guyana	87.7 (23) <sup>b</sup>	158.1 (7)	Witzell, 1983
Colombia	90.7 (4)	—	Witzell, 1983
Nicaragua	80.1 (32) <sup>b</sup>	—	Witzell, 1983
Costa Rica	88.8 (180) <sup>b</sup>	158.0 (93)	Bjorndal et al., 1985
US Virgin Is.	87.6 (16)	148.8 (45)	Hillis, 1990
Mexico	93.3 (15)	149.0 (60)	Rodríguez et al., 1993
Oman	76.8 (48) <sup>b</sup>	97.2 (9)	Witzell, 1983
Seychelles	89.5 (9)	182.0 (9)	Diamond, 1976
Australia	81.7 (360)	124.1 (310)	Loop et al., 1995
Solomon Is.	84.3 (85)	137.5 (175)	Witzell, 1983

<sup>a</sup> Eight turtles were measured for CCL and CCW on two or more occasions between 1990 and 1997. For each turtle with multiple measurements, data were averaged prior to calculating an overall population mean presented in the table.

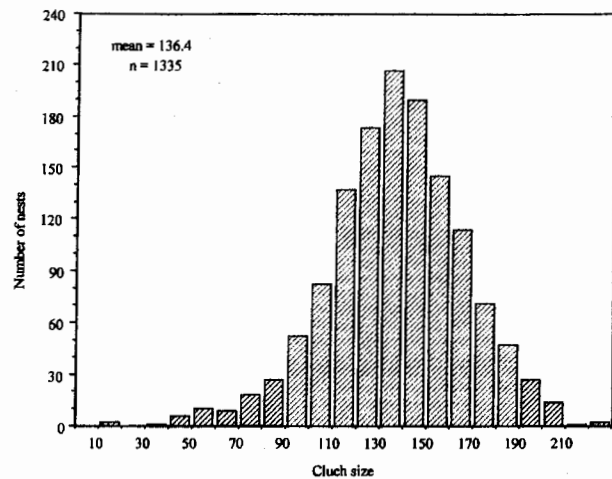
<sup>b</sup> Straight-line carapace length (SCL) values were converted to CCL by using the following formula:  $CCL = 1.0534 \times SCL^{0.9986}$  (van Dam and Diez, 1998).

located open-air beach hatcheries, in order to leave the nests in a more natural condition, and this resulted in higher emergence rates compared to clutches moved to the hatchery (Table 3). Nests transferred to protected beaches are not relocated sooner than nests transferred to hatcheries, but in some situations they spend less time in transit, which may explain some of the differences between the mean hatching success of the groups. Unfortunately, the practice of relocation to protected beaches is not always possible, as some beaches are too developed, too heavily used to provide safe areas for incubation, too isolated, or are still threatened by poaching.

When seasons are analyzed by month, differences in mean emergence success were found among incubation sites within months (Table 4). Statistically significant differences were found only between nests incubated in hatcheries and nests incubated *in situ*. In general, differences in mean emergence success between these two groups were significant during the months of January and February, with fewer hatchlings produced by nests in the hatcheries.

One possible explanation for this difference is that higher incubation temperatures may result in lower survival rates for hawksbill eggs. Interestingly, clutches in 1991–92 had the highest mean emergence success and longest emergence periods (Table 2). Sand temperatures in Bahia vary across the nesting season, and nests laid in December, January, and February experience warmer sand temperatures than those laid earlier or later in the season, as indicated by changes in incubation periods of the nests (Marcovaldi et al., 1997). However, a study of thermal characteristics of the beach and the hatchery at Praia do Forte found no major differences between the sites in 1994–95 (Naro et al., 1996). It is not known whether there have been thermal differences between the sites in other seasons or for other beaches.

A second possible reason for differences in success rates may be that bacteria levels in hatchery sand increase



**Figure 4.** Histogram of clutch size for hawksbill nests laid in northern Bahia. Clutch size was determined either by nest excavation after emergence (for *in situ* nests) or by counting eggs during relocation to hatcheries.

during a nesting season, due to the high density of clutches, which in turn lowers the success of eggs moved there later in the season. However, this cannot explain why mean success rates in March were not significantly different between the two groups. In any case, the lower emergence rates for the hatcheries should not be taken as an argument against their use. In many places in Bahia and elsewhere in Brazil, beaches are unsuitable for incubating nests *in situ*. Relocation to hatcheries ensures that at least some hatchlings are produced from those nests that otherwise would have produced none (Baptistotte, 1995).

A third possibility is that higher temperatures in January and February may have resulted in a shorter developmental time needed by freshly laid eggs to reach the stage when the yolk migrates and adheres to the vitelline membrane (Blanck and Sawyer, 1981). This would mean that eggs which were transferred in warmer months might be more susceptible to damage from relocation than eggs moved in cooler months, even though nearly all clutches were moved within 12 hours of deposition.

**Adult Female Size.** — Average curved carapace length (CCL) for nesting females was 97.4 cm (range, 86–110) and average curved carapace width was 89.6 cm (range, 79–104) (Table 5). On average, Brazilian hawksbills are larger than other nesting populations of hawksbills in the Atlantic and elsewhere (Table 5).

**Clutch Size.** — Mean clutch size was 136.4 eggs, with a range of 16–224 (Fig. 4). Brazilian clutches were larger than those at Milman Island, Australia (Loop et al., 1995), but smaller than at Tortuguero, Costa Rica (Bjorndal et al., 1985) (Table 5). General reviews of clutch sizes of hawksbill nesting populations show that the mean for the Brazilian population is roughly average (Witzell, 1983; Márquez, 1990).

Although the ANOVA analysis revealed significant differences ( $p < 0.05$ ) in mean clutch size among years (Table 6), SNK post hoc tests showed no differences be-

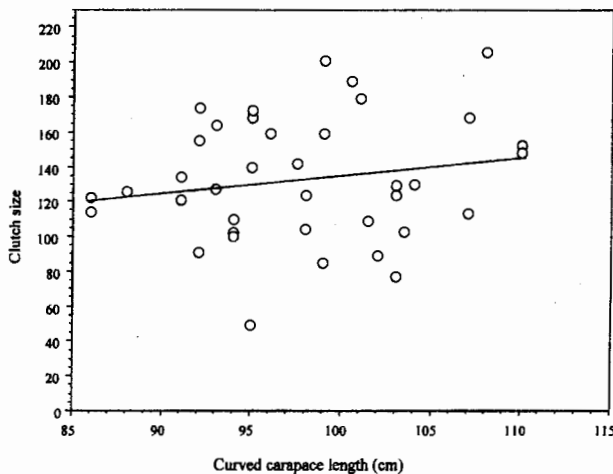
**Table 6.** Average clutch size per nesting season for hawksbills nesting in Bahia, Brazil.

	1990/91	1991/92	1992/93	1993/94	1994/95	1995/96	1996/97
mean	138.88	139.91 <sup>ab</sup>	137.92	137.22	132.09 <sup>ac</sup>	132.19 <sup>bd</sup>	138.64 <sup>cd</sup>
± SE	2.72	2.05	2.19	1.87	2.17	1.81	2.18
range	50–202	59–224	48–222	17–212	16–204	56–202	44–206
n	104	186	168	253	211	213	200

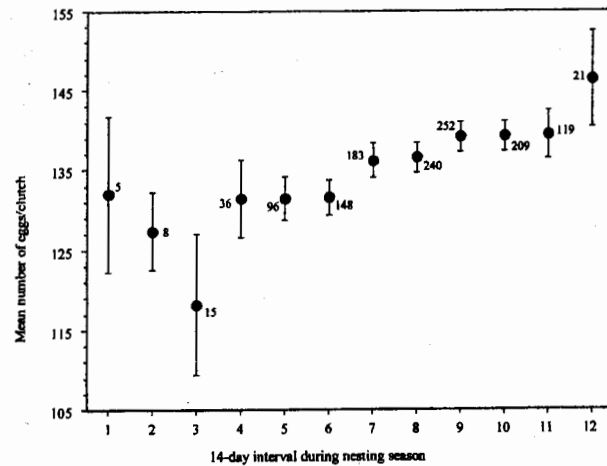
Note: A one-way ANOVA revealed significant differences among mean clutch sizes from the different seasons ( $F = 2.391$ ,  $p < 0.05$ ), although post-hoc SNK tests revealed no differences between means. Individual t-tests between individual means revealed significant differences between the years with the lowest and highest means, as indicated by similar superscript letters (a, b =  $p < 0.01$ ; c, d =  $p < 0.05$ ).

tween years. Subsequent t-tests between years showed differences between the extremes (2 smallest and 2 largest means). Similar results have been found in clutches of loggerheads (Frazer and Richardson, 1985), green turtles (Bjorndal and Carr, 1989), and leatherbacks (Tucker and Frazer, 1994). As in other marine and freshwater turtles, hawksbill clutches remain relatively constant from year to year. This is probably the result of several different factors, including ecological, environmental, and evolutionary pressures (Frazer and Richardson, 1985).

When individual clutch size is analyzed against julian date for all seven seasons, the positive slope of the linear regression line ( $y = 0.11x + 124.4$ ,  $r^2 = 0.01$ ) is significantly different from zero ( $p < 0.0001$ ), which indicates an increase in clutch size across the nesting season. Clutch size was also grouped by 14-day periods and means were calculated for each period. Mean clutch size increased significantly as the nesting season progressed (Fig. 5). The 14-day period for sorting the clutch values ensures that not more than one clutch from an individual female in one season is included in calculation for mean clutch size. Although we do not know the mean interesting interval for this population of hawks-



**Figure 6.** Linear relationship between curved carapace length and clutch size for individual hawksbill turtles ( $n = 38$ ) nesting in Bahia, Brazil, between 1990–91 and 1996–97. The slope of the regression line ( $y = 0.931x + 42.12$ ,  $r^2 = 0.027$ ) is not significantly different from zero ( $F = 1.01$ ,  $p > 0.05$ ).



**Figure 5.** Increase in mean clutch size for hawksbill turtles grouped by 14-day periods, for 7 nesting seasons (1990–91 to 1996–97). Means across season are significantly different ( $p < 0.05$ , one-way ANOVA). Regression analysis revealed that the slope of the linear regression line ( $y = 1.65x + 123.3$ ,  $r^2 = 0.69$ ) is significantly different from zero ( $p < 0.001$ ). Numbers next to points indicate number of clutches contributing to each group mean.

bills, individuals at other nesting sites tend to nest every 14 days (Márquez, 1990). Tucker and Frazer (1994) suggested that most reports of increasing or decreasing clutch size of marine turtles across nesting seasons may be spurious, because sample sizes were small or the studies were not long-term. This is not the case for our study, where clutch size data come from seven consecutive seasons, and total sample size is 1335. This seasonal increase strongly contrasts with seasonal decreases in clutch size reported in long-term studies of loggerheads (Frazer and Richardson, 1985) and leatherbacks (Tucker and Frazer, 1994).

A strong correlation between carapace length and clutch size among hawksbill populations was reported by Hirth (1980). However, as shown in Fig. 6, a weak relationship between carapace length and clutch size was found within the Brazilian population. A similar weak relationship was also found within other nesting population of hawksbills at Tortuguero, Costa Rica (Bjorndal et al., 1985), Campbell Island, Australia (Limpus et al., 1983), Milman Island, Australia (Loop et al., 1995), and in the Seychelles (Garnett, 1978). Body size may limit reproductive output, but fluctuating environmental factors may also influence the total number of eggs in each clutch (Gibbons et al., 1982).

**Hybrids.**—Natural hybridization between *E. imbricata* and *Caretta caretta* has been reported for juvenile individuals from Bahia (Conceição et al., 1990). More recently, out of a sample of 18 hawksbills, 12 adults and hatchlings had genetic markers reported to be specific to loggerhead turtles (Bass et al., 1996, A. Bass, *pers. comm.*). It is not known how widespread this hybridization is in the Bahia hawksbill population, nor whether it is a recent phenomenon or due to older crossings between the two species several generations earlier. Preliminary studies suggest that some of the hybrids were at least second generation (Bass et al., 1996). It is

unclear whether hybridization may be correlated with some of the atypical features of this population of hawksbills (e.g., larger CCL, lower emergence success). Further study is needed to clarify these questions.

**Conclusions.** — In Brazil, most hawksbill nests are concentrated in the northern coast of Bahia. Data from 7 consecutive seasons suggests that the number of nests laid annually in Bahia are not currently decreasing (Table 6), although we do not know how these numbers compare to historical levels. The hatching success of Brazilian hawksbill nests is relatively low, compared to other nesting populations of hawksbills. Projeto TAMAR-IBAMA continues to monitor and protect nesting females and their developing eggs, and is currently investigating potential biotic and abiotic causes for, and the means to mitigate, the low emergence success of Brazilian hawksbill nests.

#### ACKNOWLEDGMENTS

PETROBRAS is the official sponsor of TAMAR-IBAMA, which is also co-managed by Fundação Pró-TAMAR. We thank TAMAR-IBAMA staff and interns for gathering data over the years. Special thanks to Alessandro Santos for assistance with compiling data stored in the database.

#### LITERATURE CITED

- BAILLIE, J., AND GROOMBRIDGE, B. 1996. IUCN Red List of Threatened Animals. Gland: IUCN, 368 pp.
- BAPTISTOTTE, C. 1995. Aclarification of the activities of Projeto TAMAR, Brazil. *Chelonian Conservation and Biology* 1:328-329.
- BASS, A.L., GOOD, D.A., BJORNALD, K.A., RICHARDSON, J.I., HILLIS, Z.M., HORROCKS, J.A., AND BOWEN, B.W. 1996. Testing models of female reproductive migratory behavior and population structure in the Caribbean hawksbill turtle, *Eretmochelys imbricata*, with mtDNA sequences. *Mol. Ecol.* 5:321-328.
- BJORNALD, K.A., AND CARR, A. 1989. Variation in clutch size and egg size in the green turtle nesting population at Tortuguero, Costa Rica. *Herpetologica* 45:181-189.
- BJORNALD, K.A.; CARR, A.; MEYLAN, A.B., AND MORTIMER, J.A. 1985. Reproductive biology of the hawksbill *Eretmochelys imbricata* at Tortuguero, Costa Rica, with notes on the ecology of the species in the Caribbean. *Biol. Conserv.* 34:353-368.
- BLANCK, C.E., AND SAWYER, R.H. 1981. Hatchery practices in relation to early embryology of the loggerhead sea turtle, *Caretta caretta* (Linné). *J. Exper. Mar. Biol. Ecol.* 49: 163-177.
- CONCEIÇÃO, M.B., LEVY, J.A., MARINS, L.F., AND MARCOVALDI, M.A. 1990. Electrophoretic characterization of a hybrid between *Eretmochelys imbricata* and *Caretta caretta* (Cheloniidae). *Comp. Biochem. Physiol. B* 97:275-278.
- D'AMATO, A.F., AND MARCZWSKI, M. 1993. Aspectos da biologia de tartarugas marinhas (Cheloniidae) na região de Praia do Forte, município de Mata de São João, Bahia, Brasil, durante o período reprodutivo 1990-1991. *Arq. Biol. Technol. (Curitiba)* 36:513-519.
- DIAMOND, A.W. 1976. Breeding biology and conservation of hawksbill turtles, *Eretmochelys imbricata* L., on Cousin Island, Seychelles. *Biol. Conserv.* 9:199-215.
- FRAZER, N.B., AND RICHARDSON, J.I. 1985. Seasonal variation in clutch size for loggerhead sea turtles, *Caretta caretta*, nesting on Little Cumberland Island, Georgia, USA. *Copeia* 1985:1083-1085.
- GIBBONS, J.W.; GREENE, J.L., AND PATTERSON, K.K. 1982. Variation in reproductive characteristics of aquatic turtles. *Copeia* 1982:776-784.
- GROOMBRIDGE, B. 1982. The IUCN Amphibia-Reptilia Red Data Book, Part 1. Testudines, Crocodylia, Rhynchocephalia. Gland: IUCN, 426 pp.
- HILLIS, Z.M. 1990. Buck Island Reef National Monument Sea Turtle Research Program: 1989 — the year of hawksbills and hurricanes. In: Richardson, T.H., Richardson, J.I., and Donnelly, M. (Comp.) Proceedings of the Tenth Annual Workshop on Sea Turtle Biology and Conservation. NOAA Tech. Mem. NMFS-SEFC-278, pp. 15-20.
- HIRTH, H.F. 1980. Some aspects of the nesting behavior and reproductive biology of sea turtles. *Amer. Zool.* 20:507-523.
- LIMPUS, C.J.; MILLER, J.D.; BAKER, V., AND MCLACHLAN, E. 1983. The hawksbill turtle, *Eretmochelys imbricata* (L.), in north-eastern Australia: the Campbell Island rookery. *Austral. Wildl. Res.* 10:185-197.
- LOOP, K.A.; MILLER, J.D.; AND LIMPUS, C.J. 1995. Nesting by the hawksbill turtle (*Eretmochelys imbricata*) on Milman Island, Great Barrier Reef, Australia. *Wildl. Res.* 22:241-252.
- MARCOVALDI, M.A., AND LAURENT, A. 1996. A six year study of marine turtle nesting at Praia do Forte, Bahia, Brazil, with implications for conservation and management. *Chelonian Conservation and Biology* 2:55-59.
- MARCOVALDI, M.A., GODFREY, M.H., AND MROSOVSKY, N. 1997. Estimating sex ratios of loggerhead turtle in Brazil from pivotal incubation duration. *Can. J. Zool.* 75:755-770.
- MÁRQUEZ, M.R. 1990. FAO species catalogue. Vol. 11. Sea turtles of the world. An annotated and illustrated catalogue of sea turtle species known to date. FAO Fisheries Synopsis, No. 125, 81 pp.
- MROSOVSKY, N., AND YNTEMA, C.L. 1980. Temperature dependence of sexual differentiation in sea turtles: implications for conservation practices. *Biol. Conserv.* 18:271-280.
- NARO, E.F.S., MROSOVSKY, N., AND MARCOVALDI, M.A. 1996. Thermal profiles of marine turtle hatcheries and nesting areas at Praia do Forte, Brazil. *Bull. Ecol. Soc. Amer.* 77:320.
- NATIONAL RESEARCH COUNCIL. 1990. Decline of the Sea Turtles: Causes and Prevention. Washington: National Academy Press, 259 pp.
- PINTO, W.D. 1996. Legislação federal de meio ambiente. Brasília: Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis, 2081 pp.
- RODRÍGUEZ R., E., DURÁN N., J.J., AND RODRÍGUEZ R., R. 1993. Protección e investigación de la tortuga Carey (*Eretmochelys imbricata*) durante la temporada de anidación 1990, en el Refugio Faunístico de Ría Celestún, Yucatán. In: Frazier, J. (Ed.) Memorias del IV Taller Regional sobre Programas de Conservación de Tortugas Marinas en la Península de Yucatán. Universidad Autónoma de Yucatán, pp. 99-111.
- TUCKER, A.D., AND FRAZER, N.B. 1994. Seasonal variation in clutch size of the turtle, *Dermochelys coriacea*. *J. Herpetol.* 28:102-109.
- VAN DAM, R.P., AND DIEZ, C.E. 1998. Caribbean hawksbill turtle morphometrics. *Bull. Mar. Sci.* 62:145-155.
- WITZELL, W.N. 1983. Synopsis on the biological data of the hawksbill turtle *Eretmochelys imbricata* (Linnaeus, 1766). FAO Fisheries Synopsis 137:1-78.
- ZAR, J.H. 1984. Biostatistical Analysis. London: Prentice Hall, 718 pp.

Received: 13 July 1998

Reviewed: 16 November 1998

Revised and Accepted: 20 December 1998