Marine Turtle Newsletter

Issue Number 137 *April 2013*

Green turtle incidentally captured in a fishing weir, along the coast of Almofala, Ceara, Brazil (see pages 5-9; photo: Image Bank - Projeto TAMAR/Ceará-Brazil).

ISSN 0839-7708

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Sea Turtles in the Waters of Almofala, Ceará, in Northeastern Brazil, 2001–2010

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Projeto Tamar-ICMBio (TAMAR), the Brazilian sea turtle conservation program (Marcovaldi and Marcovaldi 1999), established a conservation and research station at Almofala Beach, northeastern Brazil in 1992 (Marcovaldi 1993). Almofala is a foraging area for sea turtles: green (*Chelonia mydas*), loggerhead (*Caretta caretta*), leatherback (*Dermochelys coriacea*), hawksbill (*Eretmochelys imbricata*) and olive ridley (*Lepidochelys olivacea*), the same five species that occur in other places in Brazil (Marcovaldi & Marcovaldi 1999). About 85% of the sea turtles recorded at Almofala are green turtles, and both juvenile and adult-sized green turtles regularly occur there, which distinguishes Almofala from green turtle foraging areas in southern Brazil, where individuals of that species are generally juveniles (e.g. Gallo *et al*. 2006). The central objective of TAMAR's conservation actions at Almofala is to deal with the incidental capture of sea turtles by artisanal fisheries; this is carried out through monitoring, research, educational activities with local communities and the development of economic alternatives for them (Lima 2001).

Here we present an integrated summary of sea turtle data gathered by the Almofala station, focusing on the carapace size distribution of each species and connections between Almofala and other known nesting or foraging locations in the Atlantic Ocean.

Study area and period. Almofala Beach (2°56'17"S, 39°48'51"W; Fig. 1) is situated in the municipality of Itarema, in western Ceará, northeastern Brazil. The coastline monitored by the Almofala station is about 40 km long. For operational reasons, the fieldwork coverage has varied over the years. Here we present data gathered between 2001 and 2010. Starting in 2001, a noticeable increase in fieldwork occurred as more trained people started working for TAMAR at Almofala, facilitating increased effort in monitoring for both incidental captures of sea turtles in fishing gear and turtle strandings.

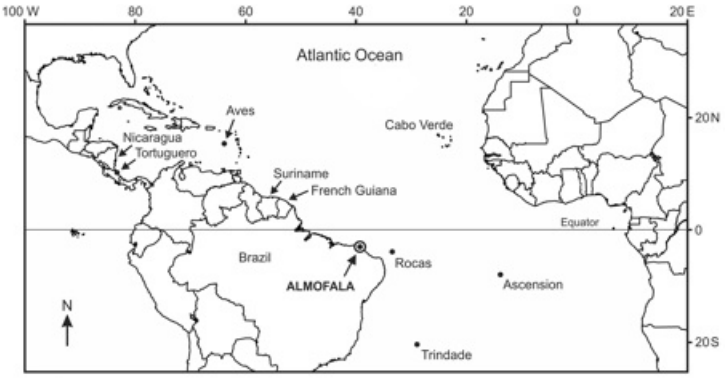

Figure 1. Map of the central part of the Atlantic Ocean, showing the location of Almofala in Brazil and the locations of some other sites mentioned in the text.

Field methods and modes of turtle observation. The focus of monitoring effort in Almofala has been the fish weir (in Portuguese: "curral de pesca"), a traditional type of fish trap that also incidentally captures turtles. This is a non-selective kind of gear, capturing mostly Atlantic thread herring (*Opisthonema oglinum*; "sardinha-bandeira"), Atlantic bumper (*Chloroscombrus chrysurus*; "palombeta"), largehead hairtail (*Trichiurus lepturus*; "espada"), Spanish mackerel (*Scomberomorus maculatus*; "serra"), ladyfish (*Elops saurus*; "ubarana"), crevalle jack (*Caranx hippus*; "xaréu"), little tunny (*Euthynnus alletteratus*; "bonito") and tarpon (*Megalops atlanticus*; "camurupim"). Each weir is about 30–50 m in length and up to 8 meters high, built of wood stakes partially embedded into the sea-floor and wire mesh. A fence about 50 m long leads fish into the weir. The weirs are placed about 0.5–1 km from the coast, at depths from 3 to 8 m. Turtles incidentally caught in weirs can swim within the weir and reach the surface of the water to breathe, and most are alive when encountered by fishermen who check the weirs daily. TAMAR has established a partnership with the local fishermen, by which members of the TAMAR staff, at the fishermen's invitation, go with them in their canoes up to the weirs to look for incidentally captured turtles and collect data on them. During these trips, TAMAR personnel participate in the fishing operations inside the weir, working side by side with the fishermen. As at other TAMAR stations, Almofala's fishermen take part in the conservation program voluntarily, without monetary compensation or direct gain; their participation is entirely based on their understanding of the aims of the program and collaborative attitude with TAMAR (Gallo *et al*. 2006).

Sea turtles in Almofala have also been incidentally captured by hook and line, cast nets, set nets, drift nets, trawl nets, beach seines, fish pots and lobster pots, but these fishing methods have relatively few interactions with sea turtles in this area (about 4% of the captures in fisheries are due to these fishing methods). During the operations to check the daily fish catch in weirs, turtles spotted outside the weirs are sometimes caught by the fishermen through free diving; this is not a regular activity of the fishermen, who catch these turtles just to bring them to TAMAR's attention (these turtles are handled by TAMAR in the same way as turtles captured by other means). Furthermore, TAMAR staff respond to sea turtles (either alive or dead) that are found stranded on beaches or floating in the water. The whole stretch of beach within the station's area is monitored for sea turtle strandings year round, by TAMAR personnel on foot or four-wheel motorcycle.

Data collection. All turtles were whenever possible identified to species by TAMAR personnel; severely decomposed turtles could not always be identified to species. Curved carapace length (CCL) was measured with a flexible plastic measuring tape (accuracy = 0.1 cm) from the anterior point at midline (nuchal scute) to the posterior tip of the supracaudal scutes; only turtles with the carapace intact, non-deformed and free of tumors or epibionts that could interfere with the carapace measurement were actually measured and included in the CCL analyses. An incidentally captured leatherback could not be removed from the water to be measured. All live turtles were given a metal flipper tag on the trailing edge of each front flipper, except for leatherback turtles, which were tagged on the hind flippers (inconel tags style 681 have been used at Almofala from 1996 on; tags manufactured by National Band and Tag Co., USA). We replaced flipper tags on recaptured turtles that were missing a tag or had tags in poor condition. Turtles incidentally captured in weirs or captured through free diving around weirs were released in the water outside the weirs after being measured and tagged, unless they exhibited signs of needing rehabilitation at the TAMAR station due to health problems. Live turtles captured by other means were taken to the station for measurement, tagging and rehabilitation whenever necessary.

Data analysis. When analyzing CCL distributions, only the first measurement of each turtle was considered. Whenever necessary for the comparison of Almofala's data with data found in the literature, straight carapace lengths were converted to CCLs using the formulas of Teas (1993). For olive ridley turtle carapace length conversions, we applied the formula for Kemp's ridleys (*Lepidochelys kempii*) from Teas (1993). Two CCL distributions were compared by means of a nonparametric Mann-Whitney test (Conover 1999); the significance level was alpha = 0.05. Statistical analyses were carried out with the software R 2.15.2 (R Core Team 2012). The base map in Fig. 1 was created by using the Maptool program (http://www.seaturtle.org). Distances between Almofala and some nesting beaches were estimated by means of the software Google Earth (http://earth.google.com).

Results and Discussion. Between 2001 and 2010 there were 1860 records of sea turtles at Almofala (Table 1), involving 1668 individual turtles. Records of green turtles (n = 1600) represented 86.4% of 1852 records in which the species was identified. Among the records obtained through incidental capture in fisheries (n = 1533), 90.4% (n = 1386) were obtained through captures in fish weirs, and in 99.6% (n = 1381) of the captures in weirs, the turtle was found alive. Strandings amounted to 16.8% (n = 312) of the total number of records (Table 1). A total of 1570 turtles were identified to species and had their CCL measured (Fig. 2). The only leatherback

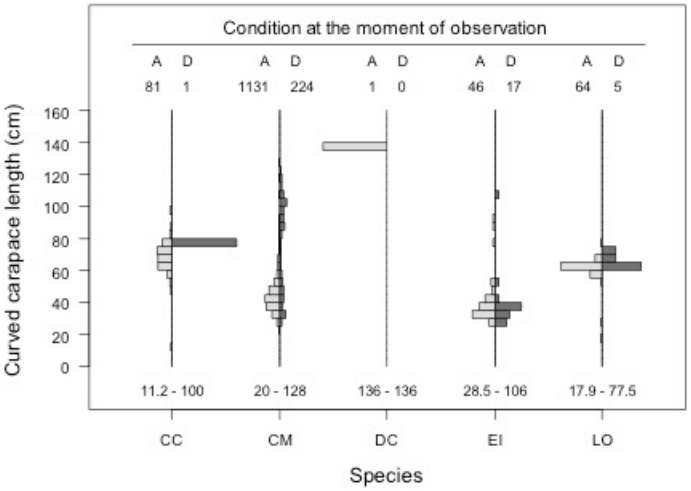

Figure 2. Curved carapace length (CCL) distribution by species and condition (either alive or dead) at the moment of observation, Almofala, Ceará, Brazil, 2001–2010 (N = 1570 turtles). A = alive (light bars), D = dead (dark bars). Codes for species as in the legend of Table 1. Sample sizes for each species and condition are shown at the top of the graph. Each bar graph shows the relative frequency distribution of CCL, so all bar graphs have the same total area, regardless of the actual sample sizes. The bottom row of numbers shows minimum and maximum CCL (cm) for all turtles of each species, both alive and dead.

Mode of Observation	Species (alive/dead)						
	CC	CM	DC	EI	LO	NI	Total
Fisheries	91 / 0	1319 / 14	1 / 0	42 / 2	62 / 0	2 / 0	1517 / 16
Stranded	1 / 1	28 / 226	1 / 0	16 / 21	6 / 6	0 / 6	52 / 260
Unknown	1 / 0	8 / 5	0 / 0	1 / 0	0 / 0	0 / 0	10 / 5
Total	93 / 1	1355 / 245	2 / 0	59 / 23	68 / 6	2 / 6	1579 / 281

Table 1. Records of sea turtles according to the mode of observation and condition (either alive or dead) at the moment of observation, Almofala, Ceará, Brazil, 2001–2010 (n = 1860 records). Species: CC = Caretta caretta, CM = Chelonia mydas, DC = Dermochelys coriacea, EI = Eretmochelys imbricata, LO = Lepidochelys olivacea, NI = not identified.

turtle that was measured (CCL = 136 cm) was a male, found alive floating in the water in September 2002.

The minimum CCL of green turtles nesting on Rocas Atoll, Brazil, was 96 cm (Bellini *et al*. in press), and it was 89.1 cm on Ascension Island, UK and 73.5 cm at Tortuguero, Costa Rica (Hirth 1997). This indicates that both juvenile and adult green turtles were likely found at Almofala (Fig. 2). Green turtles found alive were generally juveniles, while, in smaller numbers, both juvenile and adult-sized green turtles were found dead (Fig. 2). Dead green turtles were generally found stranded, in contrast to those found alive, which were generally captured in fish weirs (Table 1). For green turtles stranded dead (and also for dead turtles of other species stranded at Almofala), the location of their death is unknown, since ocean currents could bring carcasses to Almofala from faraway locations (Epperly *et al*. 1996).

Genetic analyses of mitochondrial DNA indicated that juvenile green turtles that inhabit the Almofala region originate largely from Ascension Island (United Kingdom), with possible contributions from other rookeries in the Atlantic, mainly Tortuguero (Costa Rica), Matapica (Suriname), Aves Island (Venezuela) and Trindade Island (Brazil) (Naro-Maciel *et al.* 2007). Green turtles flipper-tagged on nesting beaches in Suriname and French Guiana were found in northeastern Brazil mainly off the Ceará coast, and many of them at Almofala (Pritchard 1973, 1976; Schulz 1975). Flipper and satellite tagging indicated post-nesting movements of green turtles that nested on Ascension Island in the mid-Atlantic to the northeastern Brazilian coast, including Ceará (Luschi *et al*. 1998; Mortimer & Carr 1987). The possibility exists that the northeastern Brazilian coast is a foraging area for green turtles that nest on Rocas Atoll (Bellini *et al.* in press). Conventional flipper tagging indicated movements by green turtles in each direction between Ceará and several locations in the Caribbean (Lima *et al.* 2008).

Among the loggerheads, all were found alive, except for one (Table 1). The minimum CCL of loggerheads nesting in Brazil was 83 cm (Kotas *et al*. 2004), 70 cm in Cape Verde (Ballell-Valls & López-Jurado 2004) and 80.5 cm in SE USA (Dodd 1998). This suggests that loggerheads found at Almofala were mostly juveniles, although some may have been relatively small adults (Fig. 2). The natal origin of loggerheads found at Almofala is unknown. The nearest significant nesting beaches are in Sergipe and northern Bahia, in Brazil, about 1300 km away from Almofala (distance measured along the coastline, Marcovaldi & Chaloupka 2007). Post-nesting loggerheads from northern Bahia were tracked up to the northeastern coast of Brazil including Ceará (Marcovaldi *et al*. 2010).

There were only two leatherback records in the Almofala region in the study period. The natal origin of leatherbacks found at Almofala is unknown. Brazil hosts a small leatherback rookery in Espírito Santo, approximately 2300 km away from Almofala (distance measured along the coastline), with about 10 nesting females each season on average (Thomé *et al*. 2007). The large leatherback rookery in French Guiana and Suriname, in northern South America, with thousands of nests each year (Fossette *et al*. 2008), is located about 1700 km away from Almofala (geodesic distance), and therefore closer to Almofala than the Brazilian rookery.

For hawksbills, the CCL distribution at Almofala is approximately the same for turtles either alive or dead (Fig. 2).The natal origin of hawksbills at Almofala is unknown. In the southwestern Atlantic, the main hawksbill nesting sites are located in Brazil in northern Bahia and Sergipe and in Rio Grande do Norte (Marcovaldi *et al*. 2007), although turtles classified as hawksbills in Bahia could actually be either hawksbill-loggerhead or hawksbill-olive ridley hybrids (Lara-Ruiz *et al*. 2006). A hybrid hawksbill-loggerhead turtle satellite-tagged while nesting in northern Bahia was tracked up to the Ceará coast (Marcovaldi *et al*. 2012). In Brazil, the minimum CCL of nesting hawksbill turtles was 86 cm in northern Bahia (Marcovaldi *et al*. 1999) and 83 cm in Rio Grande do Norte (Santos *et al*. 2010). Elsewhere in the Atlantic, hawksbills with CCL as small as 65.7 cm were recorded nesting in Nicaragua (Witzell 1983). This indicates that hawksbills found at Almofala were mostly juveniles (Fig. 2).

The CCL distribution is also approximately the same for olive ridley turtles found either alive or dead (Fig. 2). The natal origin of olive ridleys found at Almofala is unknown. In the southwestern Atlantic, significant olive ridley nesting occurs in Sergipe and Bahia, northeastern Brazil (da Silva *et al*. 2007), and in French Guiana and Suriname (SWOT Team 2009-2010). An olive ridley satellite-tagged on a nesting beach in Sergipe moved north along the Brazilian coastline and was tracked past the Ceará coast (da Silva *et al*. 2011). An olive ridley flipper-tagged on a nesting beach in Suriname was found on the northeastern coast of Brazil (Pritchard 1973). The minimum CCL of olive ridleys nesting in Sergipe and Bahia was 62.5 cm (da Silva *et al*. 2007), and it was 67.7 cm in Suriname (Reichart 1993). This indicates that the olive ridleys found at Almofala were nearly always subadult or adult turtles (Fig. 2).

At Almofala, the green turtle is the only species for which information is available on the genetic composition of the population and on possible natal origins of the turtles (see references above). Tissue samples of individuals of all species are being collected by TAMAR at Almofala for genetic analyses.

The data here presented have originated mainly from incidental captures in coastal fisheries, as well as strandings, and may not be representative of the whole assemblage of sea turtles in the wide Almofala region. The principal fishing gear monitored by TAMAR at Almofala is the fish weir, built at depths < 8 m. The location of weirs has most likely influenced the observed CCL distribution of the different species. Considering only the first capture of each individual turtle, the mean CCL of green turtles captured in fish weirs at Almofala in 1994-1996 (years outside the study period; in these years, the green turtle was also the main species captured at Almofala) was 72.4 cm (median = 74, SD = 26.6, range = 27-120, n = 115), and it was 47.6 cm in 2004-2006 (median = 44.4, SD = 14.6, range = 26.4-121, n = 192; TAMAR, unpublished data); the CCL distributions between the two periods were significantly different (Mann-Whitney test, n = 307, $p < 0.0001$). The smaller CCL in the second period can be attributed, at least in part, to changes in fishing practices by the fishermen. To decrease construction costs, after 1996 fishermen began to place the weirs at shallower depths, closer to the shoreline. Weirs in shallower depths can be built with smaller amounts of construction material. It is possible that larger green turtles remain further offshore, relative to smaller green turtles, so weirs constructed at shallower depths, closer to the shoreline, would have a smaller probability of capturing larger green turtles. This may be also true for loggerheads and hawksbills. Post-nesting female loggerheads traveled from northern Bahia, Brazil, to the coast of Ceará, and settled in foraging areas usually located in waters between 25 and 50 m deep (Marcovaldi *et al*. 2010). Similarly, post-nesting hawksbill-loggerhead hybrid turtles from northern Bahia settled in foraging areas on the northeastern Brazilian coast that were usually at depths between 20 and 35 m (Marcovaldi *et al*. 2012). Juvenile and adult leatherbacks are primarily open sea dwellers (Eckert *et al.* 2012), so the paucity of leatherback records in coastal areas of Ceará is likely a reflection of their habitat use. Juvenile and adult olive ridleys are also known to inhabit the open sea. Satellite-tagging of olive ridley females on a nesting beach in Sergipe, Brazil (at latitude 10°42'S), showed that two turtles (out of 10 turtles that were initially satellite-tagged) made post-nesting movements to ocean points just north of the Equator and farther than 1000 km from the Brazilian mainland coast (da Silva *et al*. 2011).

At Almofala there is an intersection of green turtle populations derived from nesting beaches on Ascension Island, Suriname and French Guiana, and possibly Trindade Island, Tortuguero, Aves Island and other sites. There are also connections between Almofala and other green turtle foraging areas in southern Brazil and in Argentina, as all these foraging areas host juveniles of that species originating largely from Ascension Island, with possible contributions from other nesting sites in the Atlantic (Naro-Maciel *et al.* 2007; Proietti *et al*. 2012; Prosdocimi *et al*. 2012). For sea turtles of other species found at Almofala, their natal origins remain unknown, but it is likely that some are derived from nesting locations outside Brazil, thus reinforcing the importance of Almofala in an international context for sea turtle conservation and research.

Acknowledgments. Data collection was authorized by the Chico Mendes Institute for Biodiversity Conservation (ICMBio) under license number 14122, issued by the Biodiversity Authorization and Information System (SISBIO). We thank the fishermen of Almofala's local communities who have collaborated with TAMAR over the years, and also the TAMAR staff and trainees who collected the data. We also thank CETAS - Centro de Triagem de Animais Silvestres/ IBAMA/CE, NUFAU - Núcleo de Fauna/IBAMA/CE, Parque Nacional de Jericoacoara and Prefeitura Municipal de Itarema. Our thanks to Eugenia Naro-Maciel, Neca Marcovaldi and an anonymous reviewer for critical comments and suggestions that improved the text. We made use of the Sea Turtle Online Bibliography maintained by the Archie Carr Center for Sea Turtle Research, University of Florida, USA. Projeto TAMAR, a conservation program of the Brazilian Ministry of the Environment, is affiliated with ICMBio, and is co-managed by Fundação Pró-TAMAR.

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