Is the presence of "marambaias" along the Ceará – Brasil coast in juvenile green turtle (*Chelonia mydas* L) feeding grounds important for their conservation?

Suzana Morais[1], Luís Cancela da Fonseca[2,3] & Karim Erzini[2,4]

[1] FAIAL TERRA MAR, Lda, Ribeira da Lombega 253, 9900-329 Faial. summorais@yahoo.com; [2] FCMA, Universidade do Algarve, Campus de Gambelas, 8005-139 Faro; [3] Laboratório Marítimo da Guia/IMAR, Estrada do Guincho, 2750-374 Cascais. lfonseca@ualg.pt; [4] CCMar, Universidade do Algarve, Campus de Gambelas, 8005-139 Faro. kerzini@ualg.pt

Abstract

The Ceará coast is one of the most important feeding habitats for juvenile green turtles. The presence of artificial reefs along the coast and the abundance of flora species characteristic of their diet, are both factors that contribute to their occurrence. However, sand encroachment along the Ceará coast is causing the destruction of natural reefs and reducing the number of available habitats, which has a negative impact on fishing. To counter this trend, the fishermen of Almofala community build artificial reefs, named "marambaias". Depending on the target species, these "marambaias" are built in different ways with different materials. Nowadays, sea turtles are accidentally caught during "marambaia" fishing operations, and for this reason six different "marambaias" were studied, to understand the relationships between these structures and the presence/absence of turtles. This work was carried out in cooperation with the TAMAR/IBAMA project. The results suggest that "marambaias" are relevant alternative habitats in areas where natural reefs have become scarce, and may be favorable for the conservation and management of green turtles.

Resumo

O litoral do Ceará constitui um dos habitats de alimentação mais importantes para os juvenis de tartaruga-verde, que ocorrem no Brasil. A presença de recifes naturais ao longo da costa e a abundância de espécies de flora marinha típicas da dieta deste réptil são factores que possibilitam a sua ocorrência. Esta costa encontra-se num processo de assoreamento que conduz à destruição dos recifes naturais, reduz o número de habitats disponíveis e tem repercussões negativas na rentabilidade da pesca. Para contrariar esta tendência os pescadores da zona costeira de Almofala constroem recifes artificiais, a que chamam "marambaias", feitas de diferentes formas e com materiais distintos consoante as espécies-alvo a capturar. Acidentalmente são capturadas tartarugas marinhas pelo que, no âmbito de um trabalho conjunto com o Projecto TAMAR/IBAMA, a sua presença foi monitorizada em 6 marambaias diferentes, de forma a aferir que tipo de relação existe entre estas estruturas e a presença/ausência de tartarugas. Os resultados obtidos sugerem que as marambaias constituem habitats alternativos relevantes em áreas onde os recifes naturais se tornaram escassos e, pelo menos para a tartaruga-verde, poderão ser favoráveis à respectiva gestão e conservação.

Introduction

Marine turtles originated in the Triassic, some 180 million years ago (Azevedo, 1983; Pritchard, 1997), when the dinosaurs started their terrestrial dominance. Over time, marine turtles evolved and acquired adaptations perfecting locomotion in water (Musick & Limpus, 1997; Pritchard, 1997). Seven species of these reptiles exist today: *Dermochelys coriacea* (leatherback turtle), *Chelonia mydas* (green turtle), *Natator depressus* (flatback turtle), *Erectmochelys imbricata* (hawksbill turtle), *Caretta caretta* (loggerhead turtle), *Lepidochelys olivacea* (olive ridley) and *Lepidochelys kempi* (Kemp's ridley).

The life cycles of all sea turtles include periodic migrations between feeding grounds and areas where they reproduce. Mature females abandon feeding grounds at certain times and migrate to the beaches where they were born to lay their eggs in nests excavated in the sand, returning afterwards to the feeding grounds (Carr, 1967, 1975; Azevedo, 1983). Juveniles and sub-adults of many populations are found in coastal feeding grounds that may be dozens or thousands of kilometers from the beach where they were born (Carr, 1975; Miller, 1996).

According to Bjorndal (1999), although only 1% of their lifetime is spent in the nesting areas, approximately 90% of the literature concerning the biology of these reptiles is based on studies carried out in the nesting areas, with the lack of studies on other aspects of their biology and ecology especially important given the numerous threat these species face today (Azevedo, 1983; Pritchard, 1999; Meylan & Meylan, 1999). All marine turtle species are classified as threatened or critically threatened (IUCN, 2007).

Human activity continues to be the biggest threat to the survival of marine turtle populations world-wide. A number of factors have contributed to the decline or even the disappearance of turtle populations. The most important factors include: indiscriminate hunting for food, pollution, human occupation of coastal areas and associated activities that affect both female turtles during the nesting period and the survival of the hatchlings, and capture in fishing gears such as gillnets, trawls and longlines (Howe *et al*., 2004; Pritchard, 1997; Lutcavage *et al*, 1997; George, 1997; Carr, 1967).

Along the coast of Brazil, almost all fishing gears deliberately or accidentally catch sea turtles: pelagic and bottom trawls, lobster nets, “arruaneira” nets, fish corrals, hook and line gear, and diving (Lima,1998). According to Lima (1998), the currently prohibited “arruaneira” nets, along with fish corrals are the gears that inflict the greatest mortality on sea turtles.

The “arruaneira” nets (“Aruanã” means fish with a shell) are nets specifically used to catch green turtles (*C. mydas*). These nets are set during the day near artificial reefs or near natural rocky reefs. The fish corrals are deployed after the winter and are the most commonly used fishing gear in the region (Marcovaldi *et al*., 2001). Fish corrals, are constructed in lines perpendicular to the coast from wood and wire, and are non-selective.

These factors, together with excessive catches recorded along the Brazilian coast over several decades lead to the creation of TAMAR (Brazilian Program for the Conservation and Protection of Sea Turtles), by IBAMA (Brazilian Institute of the Environment and Natural Resources).

Since 1980 TAMAR has developed several strategies for the conservation of sea turtles, protecting close to 1100 km of Brazilian coastline, through 21 research stations located in feeding and nesting grounds of these reptiles. The growth in catches for commercialization of shells and eggs by the Almofala (Ceará) community motivated the TAMAR Project to install a base there in 1991 (“Base de Alimentação e Registos Não Reprodutivos”). The development of a project such as TAMAR was only possible through environmental education and social insertion programs, promoting new ways of subsistence for the local communities (Marcovaldi & Marcovaldi, 1999).

The objective of this study was to study the influence of artificial reefs used by a coastal fishing community of the state of Ceará on the permanence of sea turtles, mainly *C. mydas*, near the coast.

Methodology

Study area

The coastline of Almofala, in the Northeast coast of the State of Ceará, houses a human community that has in artisanal fishing, followed by coconut and cashew production, its most important economic activities. A sandy landscape predominates in this region, with extensive areas of temporary ponds formed in the rainy season, with narrow zones of mangroves, sandbanks and large areas of coconut trees. The morphology of the beach is characterized by long and narrow strips of sand that are periodically altered. The granulometry varies between fine sand, in the regions near to the beaches, to coarse sand and gravel in the more interior regions. In the surf zone marine reefs that are completely covered during the high tide rise from the sea bed.

Natural reefs are rocky formations on the sea floor that can reach the surface. Their form can vary, with coral reefs being the most attractive and best known. Normally, reefs alter the hydrological environment in such a way that their influence extends a considerable distance in the water column (Wolanski & Hammer, 1988).

An artificial habitat is defined as any structure of anthropogenic origin present in the marine environment by accident or deployed deliberately. Although these structures are usually built with the purpose of creating areas to attract and concentrate fish fauna, forming fishing grounds, they have been constructed for many purposes worldwide (Santos, 1997).

The construction of artificial reefs is very common along the Ceará coast, where they are known as "marambaias". In the Almofala community, forty fishermen each possess an average of 10 of these artificial reefs, giving a total of four hundred along only 20 km of coastline.

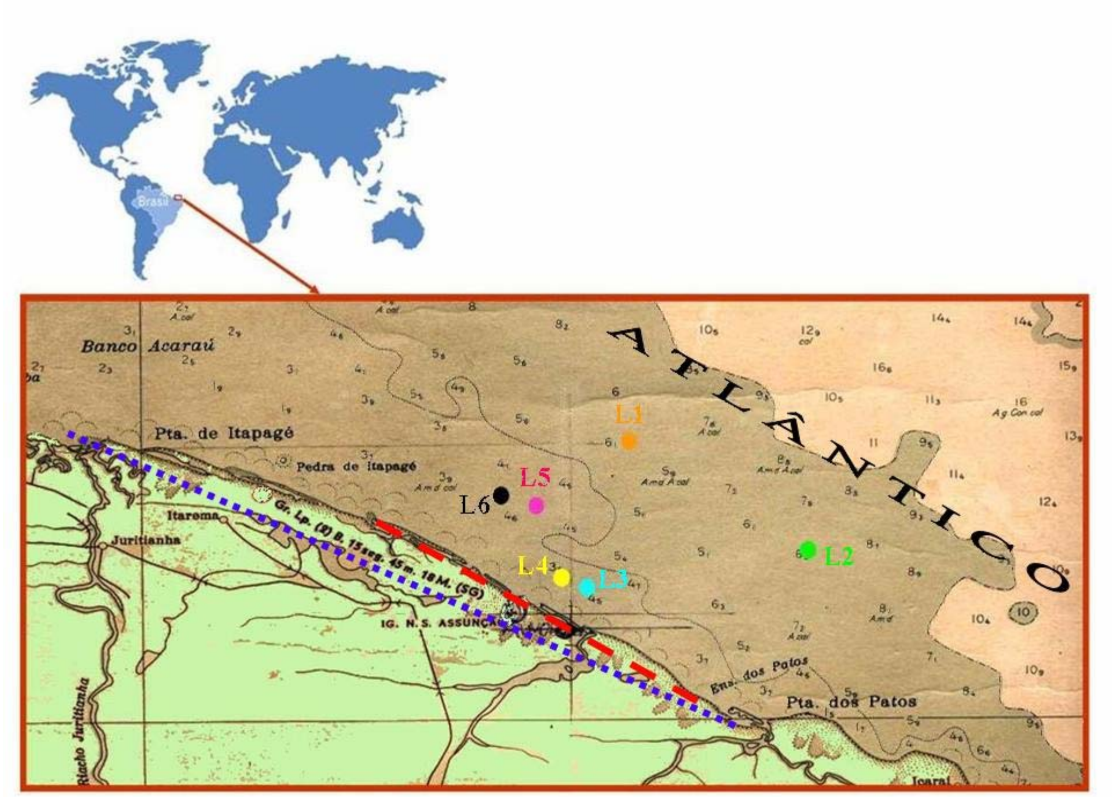

Fig. 1 – Geographic location of the area of the TAMAR area of intervention in Almofala (▪▪▪▪▪▪▪▪▪▪);the artificial reef study area (- - - - - -)and the six "marambaias" sampled (Source: Projecto TAMAR). Site 1 - ●; Site 2 - ●; Site 3 - ●; Site 4 - ●; Site 5 - ●; Site 6 - ●.

These “marambaias” are artificial habitats constructed by the local fishermen at different distances from the shore in order to attract fish and lobsters that can then be caught and sold in the local markets. Depending on the type of fish targeted, these structures are constructed with a variety of materials deployed in different manners, in at least three types of constructions: i) with *Rhizophora racemosa* (green mangrove), *Rhizophora mangle* (red mangrove) and *Avicennia shaueviana* (button mangrove), in the form of a bonfire; ii) with tires (of bicycles, cars and trucks) piled together on the bottom; iii)with rocks, bicycle frames, car and truck bodies, ovens, and sacks of sand. All these constructions constitute extensive biotopes that attract and support a variety of species of marine flora and fauna.

The northeast coast of Brazil (Ceará - Almofala) constitutes one of the most important feeding grounds for four of the five species of sea turtles (*Chelonia mydas*, *Erectmochelys imbricata*, *Caretta caretta*, *Lepidochelys olivacea*) that are found in Brazilian waters (Marcovaldi *et al*., 1995; Lima *et al*., 1996). This is due to a number of factors, of which the most important are the natural richness of the area, the presence of numerous natural reefs and the abundance of algae and marine plants that make up the diet of the green turtle (Ferreira, 1968; Marcovaldi, *et al*. 1995; Lima, *et al*., 1996). This is the most common of the sea turtle species, making this one of the preferred areas for feeding, growth, shelter and rest (Lima, *et al*., 1996).

In the past, “marambaias” were constructed in order to catch sea turtles by diving or by nets, especially during the night when the turtles rest and are least active. At dawn they were brought to the beaches where they would be slaughtered for sale in the local markets. Nowadays, the majority of the sea turtles caught in the “marambaias” are taken to the installations at the base of the TAMAR project in Almofala, where they are measured, weighed, tagged and then released (Lima, 1998).

Following preliminary trips with “marambaia” fishermen of the Almofala community, six of the artificial reefs were chosen for this study. The six “marambaias” selected for studies were located at different depths and distances from the coast and were constructed from a variety of materials. The exact location of each artificial reef was recorded by GPS (Fig. 1).

Data collection

From January to July 2002, daily monitoring was carried out in areas protected and conserved by the TAMAR Project in order to record the occurrence of accidentally caught sea turtles, live sea turtles on the beach and dead sea turtles. In addition, rafts and sail boats (Fig. 2) landing catches from “marambais” and other gear were also monitored.

Fig. 2 – Typical Almofala coast raft with a sail used for fishing the marambais

All accidentally caught sea turtles were identified to the species, and standard morphometric measurements recorded following the TAMAR/IBANA protocol. Following Bolten (1999) the morphometric measurements were recorded to the nearest lowest mm using a measuring tape: i) the curved carapace length (CCL), measured from the anterior point at midline (nuchal scute) to the posterior tip of the supracaudals; ii) the curved width of the carapace (CCW), measured at the maximum width of the carapace (Fig. 3).

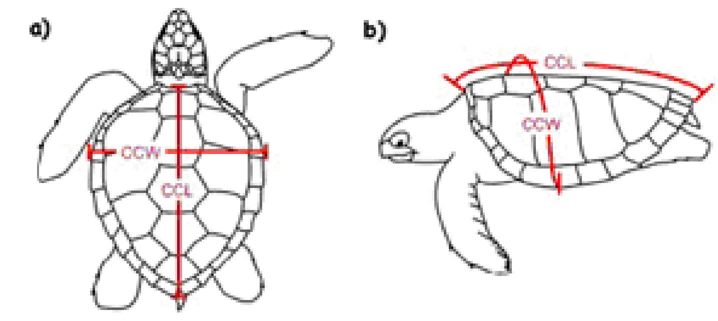

Fig. 3 –Sea turtle measurements: curved carapace width (CCW) and length (CCL). Dorsal (a) and lateral (b) views.

For the sampling, the area (m^2), volume (m^3) and height above the bottom (m) of the reefs, minimum and maximum depth (m) during the tidal cycle, and diversity in terms of species richness of algae, plants, invertebrates and fish, as well as the presence of sea turtles were recorded. Depth (m) was measured with a 10 m nylon string marked at 1 m intervals and weighted at one end with a lead weight. Depths were recorded at maximum high tide and low tide by dropping the weighted end to the bottom from the surface. The areas (m^2) and volume (m^3) of the reefs were estimated based on their geometric shape, heights, widths and lengths.

Algae and marine plants were sampled by snorkeling on the reefs and within the surrounding area (10 m radius). All the samples were preserved in 4% formaldehyde and identified in the Laboratório de Macroalgas e Herbário Ficológico do Instituto de Ciências do Mar of the Universidade Federal do Ceará (LABOMAR). The algae were classified according to Wynne (1998), and the marine angiosperms according to Oliveira *et al*. (1983).

The inventories of the fish and invertebrate fauna were carried out by periodically accompanying the fishermen aboard their rafts and sail boats and identification of the species caught with the cast nets and hook and line gear used, and by direct underwater observations by diving. Species were identified *in situ* following the visual census methods recommended by Santos (1997). The icthyofauna was identified based on Pereira, (1979), Szpilman, (1991) and Sampaio, (1996). Relevant information on their ecology and distribution was obtained from www.fishbase.com.

The presence of sea turtles was recorded according to the methodology suggested by Diez & Ottenwalder (1999): i) observation from the boat of sea turtles at the surface and/or when they rise to the surface to breath; ii) faeces at the surface near the reef; iii) underwater observation; iv) remains of algae and plants indicating recent feeding activity in the vicinity (Bjorndal, 1980). The sea turtles were identified following Pritchard & Mortimer (1999).

Data anaysis

The percent occurrence of the different species found in the area and of three size classes of *C. mydas* were calculated: adults (CCL $\geq$ 95 cm), juveniles (CCL <60 cm) and sub-adults (60 $\leq$ CCL <95 cm). The data were used to construct matrices of the presence (1) or absence (0) of the different *taxa* for the sampling locations. As for the characteristics of the "marambaias", these were grouped with data on numbers of the different *taxa* in quantitative data matrices. From these matrices, symmetric similarity and correlation matrices were calculated: Jaccard coefficient of similarity (qualitative data) and the Bravais-Pearson coefficient of correlation (Sneath & Sokal, 1973; Legendre & Legendre, 1984; Krebs, 1999). Hierarchical clustering, using the UPGMA method was applied to these matrices in order to group sites and site descriptors (Sneath & Sokal, 1973; Gauch, 1982; Legendre & Legendre, 1984), and to investigate the relationships between them. Version 2.02 of the NTSYS software of Applied Biostatistics, Inc. (Rohlf, 1998) was used.

The correlations between symmetric matrices of the same type (cophenetic coefficient of correlation - Sneath & Sokal, 1973), were calculated and used to create a new symmetric matrix of correlations. This matrix was subsequently used in a new hierarchical analysis with the aim of comparing all the groups of the sites obtained through the different analyses (Cancela da Fonseca, 1989), thereby establishing parallelism between them. The existence of greater similarity between structures should reflect ecological similarities between locations and similarity in terms of the respective communities for each of the groups of descriptors considered.

Results

Capture of sea turtles

During the course of this study in the conservation and protection area (40 Km of coast between Almofala and Volta do Rio) managed by TAMAR, with a base station in Almofala, serving all of the state of Ceará, a total of 665 fish corral landings and the landings of 205 canoes and rafts were surveyed. Of these, 126 were landings of "marambaia" catches. A total of 43 "marambaia" fishing trips were made on board sailing rafts.

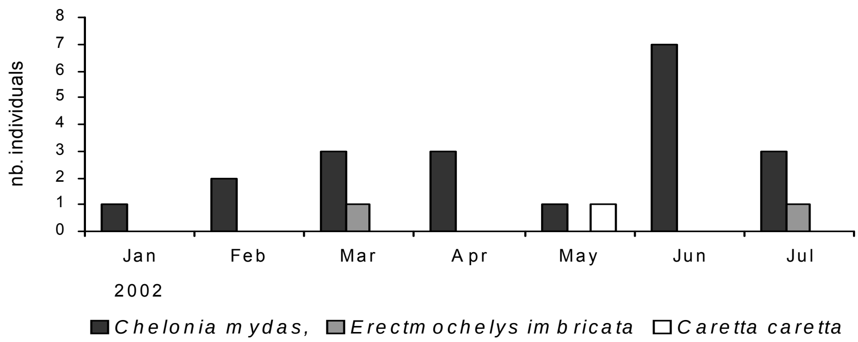

Fig. 4: Number of individuals of each species of sea turtle caught by month in the artificial reef study sites: Almofala –Boca da Barra, from Janeiro - Julho de 2002

A total of 85 sea turtles (95% live and 5% dead), belonging to three species: *C. mydas*, (90,6%) *C. caretta* (5,9%) e *E. imbricata* (3,5%) were recorded. Of these, 23 were accidental captures in the "marambaia" study areas. June was the month with the highest catches (30%), while the lowest catches were recorded in January (4%). Catches consisted of: *C. mydas (*87,0%), *C. caretta* (8,7%) and *E. imbricata* (4,3%) (Fig. 4).

These results provide further evidence of the importance of this area for *C. mydas*. The smallest individual caught of this species had a curved carapace length (CCL) of 21,5 cm, while the CCL for the largest individual recorded was 110 cm. The analysis of the CCL distribution clearly shows that the Almofala coast is particularly important for juveniles (Fig. 5), with the smallest size class clearly dominating, while the occurrence of adults (all males) was rare (3%).

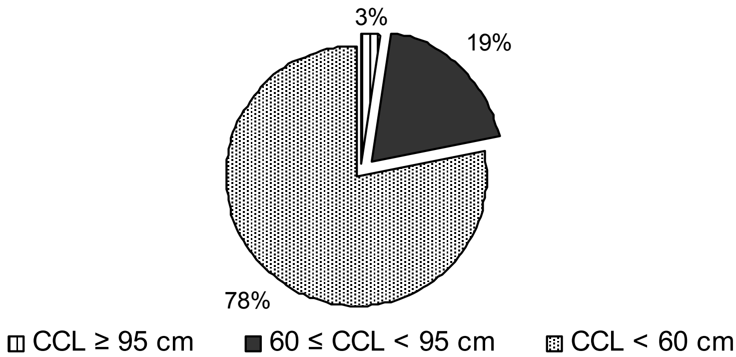

Fig. 5 – Percent distribution by curved carapace length (CCL) size classes of captured *C. mydas*.

"Marambaias"

The descriptive characteristics of the marambaias of each of the locations sampled in this study (Table 1) demonstrate the great diversity of these structures in terms of area, volume and shape. The artificial reef structures ranged from an approximately rectangular shape at location 5, to a pyramid shape at location 3.

The construction material was also highly variable, consisting of practically anything that could be transported and sunk, including tires, junk, rocks and wood. Location 5 was constructed largely of tires, while location 3 consisted of mangrove wood pile on top of rafts and bicycle tires.

Table 1 – Characteristics of the sampled "marambaias": maximum and minimum depths (m), area (m^2), volume (m^3) and height (m).

Characteristics / Site	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
Maximum depth (m)	8.5	6.5	5	7	5.5	8
Minimum depth (m)	5.5	3.5	2.5	4	2.5	5
Area (m^2)	27	13.5	7	21	5	16.5
Volume (m^3)	13.5	6.75	3.5	10.5	5	8.3
Height (m)	0.5	0.5	1.5	0.5	1	0.5

Twenty species of algae and one marine plant were identified at the six sampling sites (Table 2). Of the algae found, Rhodophyta dominated, with the greatest number of species (65%), mainly of the Rhodomelaceae and Gracilariaceae families (20% each). Chlorophyta and Phaeophyta were less important, with 20% and 15% respectively. The only Spermatophyte present was *Halodule wrightii*.

Table 2 –Marine flora recorded at the sampling locations: *taxa* and respective abbreviations (x –species present).

Species of flora - abbreviations		Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
Caulerpa prolifera	Cpro				x		x
Caulerpa sertularioides	Cser			x	x		x
Codium isthmocladum	Cist	x	x				
Avrainvillea elliotii	Aell	x	x	x	x	x	x
Dictyota menstrualis	Dmen			x			
Lobophora variegata	Lvar					x	
Sargassum vulgare	Svul		x			x	
Bryothamniom seaforthii	Bsea		x				
Bryothamniom triquentum	Btri		x			x	
Laurencia obtusa	Lobt		x				x
Osmundaria obtusiloba	Oobt		x	x	x	x	x
Corallina oficinalis	Coff		x				
Jania adhaerens	Jadh		x				
Halymenia elongata	Helon					x	
Gracilaria blodgettii	Gblo		x				
Gracilaria domingensis	Gdom		x				
Gracilaria cervicornis	Gcer		x	x			
Gracilariopsis lemaneiformis	Glem		x				
Hypnea musciformis	Hmus		x				x
Meristiella echinocarpum	Mect		x				
Halodule wrightii	Hwri				x	x	x

Invertebrates and fish were also recorded at the “marambaias” and the surrounding areas (Table 3).

Regarding the invertebrates, two species of commercially important decapod crustaceans were found: *Panulirus argus* and *Panulirus laevicauda*. These spiny lobsters are an important source of income for the fishing community and the main reason for the success of the “marambaias” as a fishing method. One species of sponge, two groups of cnidarian Hexacorallia (corals and actinia) and two groups of echinoderms, Asteroidea (sea stars) and echinoderms (sea urchins), at times very abundant, were recorded.

Apart from the lobsters, fish represent the main source of income for the local fishermen. A total of forty six species of fish, belonging to ten orders and twenty five families were recorded during the course of this study (Table 3). Of the 25 families, the most representative in terms of species were Haemulidae (20%), followed by Lutjanidae (11%), Caranjidae (9%) and Scombridae (7%). The least represented families were Ostracidae, Pomacanthidae and Aniidae (with 4%), followed by the remaining 18 families (3% each).

Table 3 – Marine fauna present on the artifical reefs: *Taxa* and common names (x – species present).

Common Names	Invertebrate *Taxa*	abbreviations	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
Esponjas	Porifera	Pori	x				x	
Coral Cérebro	Scleractinia	Scle			x	x		
Pólipos	Actiniaria	Acti					x	
Lagosta	*Panulirus argus*	Pard		x	x	x	x	x
Lagosta	*Panulirus laevicauda*	Plev		x		x	x	x
Estrelas do mar	Asteroidea	Aste	x	x			x	
Ouriços do mar	Echinoidea	Echi	x	x	x			x
	Species of fishes							
Ferrujo	*Anisotremus virginicus*	Avir			x	x	x	x
Salema	*Anistrenus virginicus*	Anvi				x		
Raia Pintada	*Atlantoraja castelnaui*	Acas	x			x		x
Xaréu	*Caranx hippos*	Chip	x		x		x	
Xaréu Preto	*Caranx lugubris*	Clug	x		x	x		x
Cação de Escamas	*Carcharhinus limbatus*	Clim	x		x		x	
Parum	*Chaetodon striatus*	Cstr	x	x	x			x
Palombeta	*Chloroscoslombrus chysurus*	Cchy	x		x	x	x	
Coró	*Conodon nobilis*	Cnob		x		x	x	x
Raia Lisa	*Dasyatis americana*	Dame	x			x		x
Bonito	*Euthynnus alletteratus*	Eall	x					
Bagre Amarelo	*Genidens barbus*	Gbar	x					
Cação Lixa	*Ginglymostoma cirratum*	Gcir	x					
Moreia	*Gymnothorax moringa*	Gmor	x		x	x		x
Xila	*Haemulon aurolineatum*	Haur	x	x	x	x	x	x
Cambuba	*Haemulon flavolineatum*	Hfla	x		x		x	
Biquara	*Haemulon plumieri*	Hplu	x		x	x	x	
Macassa	*Haemulon sciurus*	Hsci	x		x	x		x
Sapruna	*Haemulon steindachneri*	Hsei				x		x
Peixe Agulha	*Hemirhamphus brasiliensis*	Hbra				x		
Bagre Branco	*Hexanematichthys herzbergii*	Hher	x		x	x		
Mariquita	*Holocentrus ascensionis*	Hasc	x	x	x	x		x
Baiacu Cofre	*Lactophys trigonus*	Latr	x					
Baiacu	*Lactuphryus triconus*	Ltri	x	x				
Ceoba	*Lutjanus analis*	Lana	x	x		x	x	x
Caranha	*Lutjanus griseus*	Lgri	x				x	
Ariacó	*Lutjanus purpureus*	Lpur	x		x	x		x
Pargo	*Lutjanus synagris*	Lsyn					x	
Arenque	*Lycengraulis grossidens*	Lgro					x	
Camarupim	*Megalops atlanticus*	Matl	x					
Guaiuba	*Ocyurus chrysurus*	Ochr	x		x		x	x
Canguito	*Orthopristis ruber*	Orub		x	x	x		x
Barbudo	*Polydactylus virginicus*	Pvir	x			x		
Beija Moça	*Pomacanthus arcuatus*	Parc			x			x
Parum Dourado	*Pomacanthus paru*	Ppar	x	x		x		x
Enchova	*Pomatomus saltatrix*	Psal	x				x	
Piolho de Cação	*Remora remora*	Rrem	x					
Peixe Sabão	*Rypiticus saponaceus*	Rsap					x	
Sardinha	*Sardinella brasiliensis*	Sbra	x		x	x	x	
Cavala	*Scomberomorus cavalla*	Scav	x					
Peixe Serra	*Scomberomorus maculatus*	Smac	x				x	
Olhão	*Selar crumenophthlmus*	Scru	x					
Peixe Galo	*Selene setapinnis*	Sset	x					
Galo do Alto	*Selene vomer*	Svom	x					
Batata	*Sparisoma chrysopterum*	Schr		x				
Lanceta	*Trysitops lepidopoides*	Tlep	x	x	x		x	x

Table 4 summarizes the biological descriptors for each of the study sites. The number of different *taxa* found and the presence of sea turtles in each site shows that: i) site 1, located at greater depth, with a larger area (27 m^2) and volume (13,5 m^3) had the highest fish diversity (35 species); ii) site 2 had the highest marine flora diversity (15 species) and the greatest occurrence of sea turtles; iii) site 3 had the highest "marambaia" (1,5 m) and was the shallowest; iv) site 5 had the greatest number of invertebrate *taxa*.

Table 4 – Numbers of species of fish and marine flora, invertebrate taxa and sea turtles present in each site: EI – *E. imbricata*; CM – *C. mydas*.

Characteristics / Site	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
Nº of fish species	35	10	19	21	18	18
Nº of marine flora species	2	15	5	5	7	7
Nº of invertebrate *taxa*	3	4	3	3	5	3
Presence of sea turtles	EI	CM	-	CM	-	CM

Multivariate analysis

The study of the similarity (Jaccard coefficient) of the six sampling sites, based on the presence or absence of species of flora, invertebrate *taxa*, species of fish and sea turtles, allowed the identification of different groups and spatial organization based on the similarity matrices. The correlations between all possible pairs of symmetric similarity matrices resulted in a symmetric correlation matrix from which a new hierarchical grouping allowed the comparison of the structures at the different sites, for each group of descriptors used separately.

The new hierarchical analysis (Fig. 6) showed three distinct levels: i) one groups the structures based on the marine flora and the fish at each site; ii) another grouping is similar to the above and is based on the sea turtle *taxa*; iii) the third is independent of the other two levels and is associated with the invertebrate *taxa*. Regarding the first level, the association between structures based on flora and fish descriptors reflects organization in terms of similar ecological structure, indicating that the communities react similarly to the environmental conditions.

The results show that the association between the artificial structures, revealing spatial differences for the 3 biological groups considered (sea turtles, icthyofauna and flora), at the approximately 50% level, may be due to: i) the fact that the analysis based on the presence or absence of sea turtles (Jaccard coefficient) separated one group consisting of sites 3 and 5 where the presence of turtles was never detected, from another group where turtles were detected (site 1 with *Erectmochelys imbricata*, and sites 2, 4 e 6, with *Chelonia mydas*); ii) identical associations for the groupings of fish, sea turtles, invertebrate *taxa* and marine flora, with sites 3 and 5 belonging to the same group and 2, 4 and 6 forming another group; iii) sites 4 and 6 are the most similar in terms of flora and fish diversity.

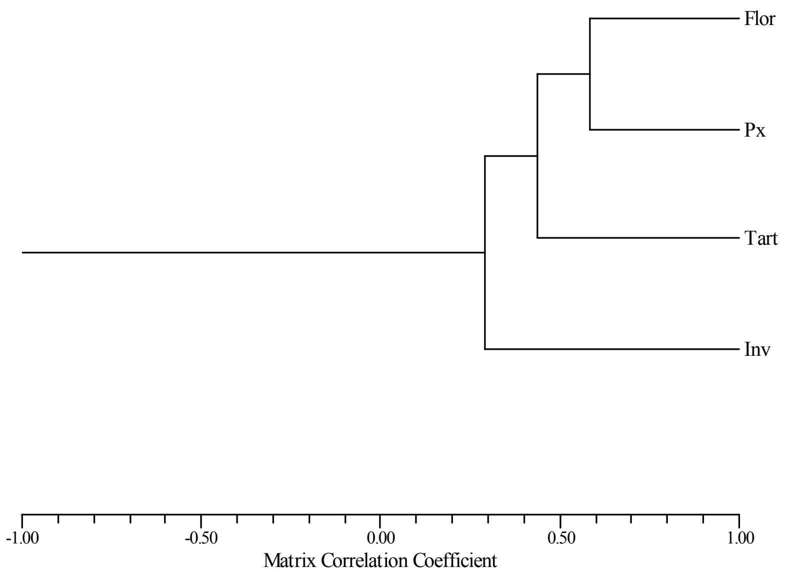

Fig. 6 – Dendrogram resulting from the hierarchical analysis of the spatial sturcture revealed by the different descriptors (species of fish, flora, invertebrate *taxa*) at the 6 sampling sites (cophenetic coefficient of correlation), showing grouping of the descriptors based on the hierarchical similarity of the structures between sites (Q mode).

The results suggest a relationship between the reptiles and the fish or the flora, depending on the case. This seems to be confirmed by the relationships between the structures of the communities that are based on the descriptors of the different taxonomic groups considered.

The analysis based on the different species of algae and marine plants and the occurrence of the green turtle *C. mydas* (Jaccard coefficient, R mode analysis) resulted in four main groups (Fig. 7), with one where *C. mydas* is associated with *Caulerpa prolifera* (Cpro) and then successively with *Caulerpa sertularioides* (Cser), *Halodule wrightii* (Hwri) and with a sub-group consisting of *Avrainvillea ellioti* (Aell) and *Osmundaria obtusiloba* (Oobt).

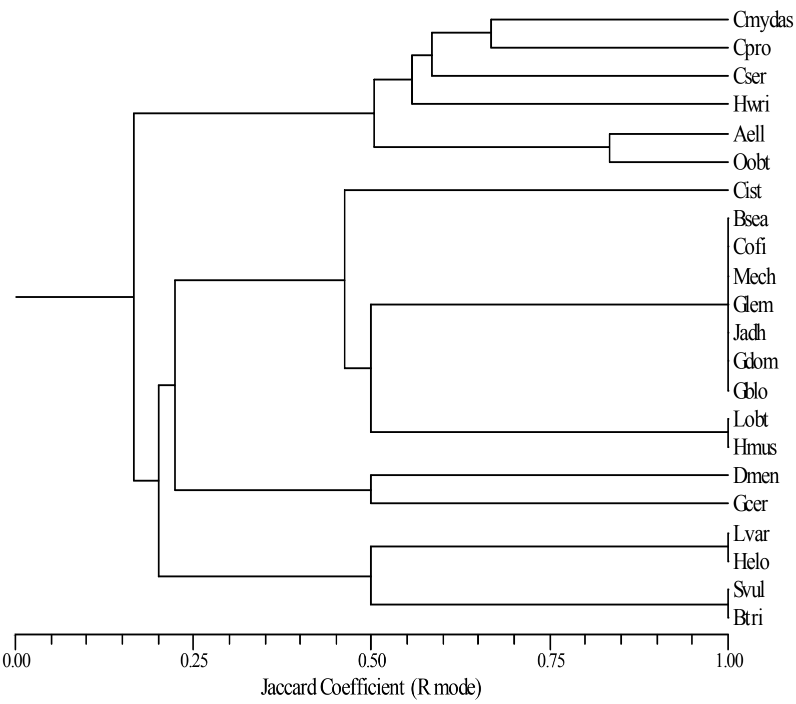

Fig. 7 - Dendrogram resulting from hierarchical analysis (R mode) based on binary taxonomic descriptors (species of flora and *Chelonia mydas*) and the Jaccard coefficient, at the 6 sampling sites along the Almofala coast.

The hierarchical analysis (R mode) based on the symmetric correlation matrix (Bravais-Pearson correlation coefficient), that was built from the distribution by site of the descriptors given in Tables 1 and 4, resulted in the identification of the following groups (Fig. 8):

- Depth, area and volume of the reefs, together with the number of fish species present group with *E. imbricata*;
- The number of marine flora species grouped with *C. mydas*;
- The number of invertebrate *taxa* and the height of the “marambaias” that are not integrated in the previous group;

These last two descriptors, despite being grouped with *C. mydas* and marine flora, are too far to be considered part of this group.

Reef depth is associated with the first group, along with area and volume of the “marambaias”, variables that at site 1 are linked to the greater fish diversity recorded. The presence of *E. imbricata* only at site 1 (cf. Table 4) may indicate that this species, represented largely by juveniles as shown by the CCL values, may not approach the coast or shallow depths as much as *C. mydas*.

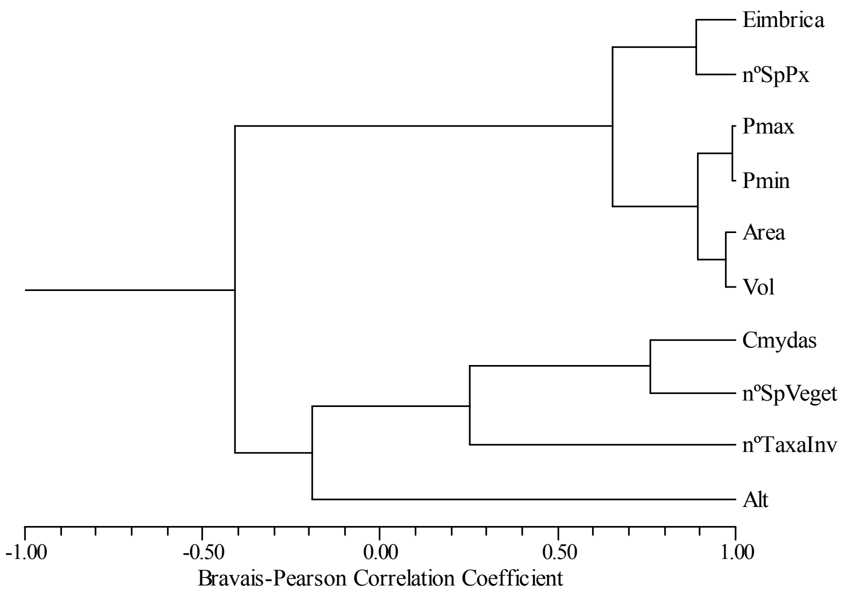

Fig. 8 – Dendrogram resulting from the hierarchical analysis (R mode; Bravais-Pearson correlation coefficient) based on quantitative descriptors of the 6 sampling locations along the Almofala coast. Data following Tables 1 and 4.

Discussion

With 85 sea turtles recorded, another successful TAMAR "Base de Alimentação e Registos Não Reprodutivos de Almofala" survey was completed in 2002. During the course of this survey, three of the four species of sea turtles occurring in Ceará were recorded (Marcovaldi *et al*, 1995, Lima *et al*,. 1996). *C. mydas*, accounting for 87% of the catches, was the most common species, with a peak in June and July, confirming the findings of TAMAR campaigns since 1996 that showed this species to be the most commonly caught (Lima *et al*., 1996; Lima, 2000) and the most abundant along the northeast coast of Brazil (Ferreira, 1968; Marcovaldi, *et al*., 1995; Lima, *et al*., 1996).

This species migrates from the nesting grounds to the feeding grounds, with the most important migratory period being the first semester of the year in the Ceará coast. Based on the results of tagging, telemetry and DNA analysis, there is evidence that the population feeding along this stretch of the Brazilian coast nests in Costa Rica, Suriname, Nicaragua and Ascension Island (Mortimer & Carr, 1987; Hays, *et al*., 1999; Lima, *et al*., 1999; Lima & Troëng, 2001).

Musick & Limpus (1997) report that juveniles of *C. mydas* remain in the coastal areas of their feeding grounds where they shelter in reefs. This was confirmed by the finding that juveniles dominated the recorded occurrences (78%). This is probably due in part to the abundance of artificial and natural reefs in the area. *C. mydas* in northeast Nicaragua return at night to the reefs for rest and shelter after a day spent grazing on sea grass beds (Bass *et al*., 1998). Feeding activity also takes place during the day on the "Paulista" coast (Sazima & Sazima, 1983). Bjorndal (1980) reports that Union Creek sea turtles start to leave their shelters at depths of approximately 7 m shortly after dawn, returning to rest between peaks of feeding activity. Thus, it is likely that the "marambaias" are also being used by these reptiles, especially the juveniles, as shelters for protection from large predators such as sharks and for resting between periods of peak feeding activity.

Diez & Ottenwalder (1999) list several indicators of sea turtle feeding grounds: benthic algae and other different types of marine vegetation, sponges, mollusks, fish and some crustaceans. The presence of encrusted sponges, tunicates, bryozoans, mollusks and algae torn from the coral reefs reveals the presence of *E. imbricata* (Bjorndal, 1985), while extensive sea grass beds and/or benthic algae indicate are associated with the occurrence of *C. mydas* (Bjorndal, 1980; Sazima & Sazima, 1983; Musick & Limpus, 1997).

In order to investigate whether or not marambaias can constitute feeding grounds for sea turtles along the Almofala coast, marine flora and fish species, along with invertebrate *taxa* were characterized at six of these artificial reefs and the surrounding areas. Some 74% of the fish species and 67 % of the macrophytes recorded are associated with reef systems (Liining, 1990; Spzilman, 1991), supporting the hypothesis that these artificial reefs create a favorable habitat for many species, compensating, in part, the loss of natural habitat. In fact, a process of sand encroachment along this coast has destroyed natural reefs and has had a negative effect on the fishing activities.

Balazs (1982) reported finding *Sargassum vulgare* and *Caulerpa sp*, in the stomach contents of some individuals of *C. mydas*. Sazima & Sazima (1983) found *Caulerpa sertularioides* and *Hypnea musciformes* in the stomachs of *C. mydas*. *Gracilaria sp* is also quoted as a part of green turtle feeding items (Limpus & Limpus, 2000). Other species found in the diet of *C. mydas* in Ceará include *Gracilariopsis lemaneiformis*, *Gracilaria domingesis*, *Hypnea musciformis*, *Osmundaria obtusiloba*, *Briothamniom triquentum*, *Caulerpa prolifera*, *Codium isthmocladum*, *Caulerpa* *sertularioides*, *Sargassum vulgare* and *Lobophora variegate.* According to these authors, half the species of algae recorded in the current study are found in the diet of juvenile green turtles, supporting the hypothesis that in addition to serving as shelters, "marambaias" may also be important feeding grounds for this species, especially so for the typically herbivorous *C. mydas* (Plotkin, 2003).

The species of marine flora sampled are commonly found in rocky or coral reefs in the feeding grounds of *C. mydas* (Sazima & Sazima, 1983; Lohmann & Lohmann, 1998). In addition to the fact that the majority of the species are found in coral reefs, 81% are pan-tropical and 19% tropical (Liining, 1990). Limpus & Reed (1985) noted that *C. mydas* feeds on benthic algae in reef areas, with red algae (Pritchard, 1997), green and brown algae (Ferreira, 1968; Bjorndal, 1980), found in their stomachs.

The two species of green algae, *Caulerpa prolifera* (Cpro) and *Caulerpa sertularioides* (Cser) and the marine phanerogam *Halodule wrightii* (Hwri) which were found together with *C. mydas* in the "marambaias" (cf. Fig. 7), form part of the diet of this species (Ferreira, 1968; Mortimer, 1982). In Australia, Bjorndal (1985) identified the red algae *Hypnea musciformes*, and the two species of *Caulerpa* found in this study in the stomach contents of juveniles of *C. mydas*, and also reported that *Halodule wrightii* is the most representative phanerogam in the diet of this species in all the western Atlantic.

E. imbricata was grouped with the number of species of fish, depth and area and volume of the reefs. This species tends to be found in deeper reef areas where it feeds on fish and organisms such as sponges, tunicates and mollusks (Bjorndal, 1997; Mortimer, 1982). According to Santos (1997), the colonization of artificial reefs by fish is associated with depth of the water column above the reefs, with more species the greater the depth.

The relatively large number of fish species recorded on the "marambaias" (46) may be due to the age of the structures (at least 6 years old in all cases), which is enough time for colonization to reach an equilibrium (Santos, 1997). Also, the lack of natural reefs in the study area may also be a factor, making the artificial habitats particularly attractive to certain species.

During the course of this work it became clear that "marambaias" constructed from mangroves piled and scattered on the bottom are the most attractive structures for *C. mydas*. Limpus *et al*. (1994) and Limpus & Limpus (2000) found that this species feeds on benthic algae and algae that are typical of mangroves (*Aviccinia sp.*) in Austrália, while Read (1991) reported that juvenile *C. mydas* from Moreton Bank (Queensland) preferred algae from mangrove areas to phanerogams. Thus, juvenile green turtles prefer reefs that are not too high and that are constructed predominantly of mangroves.

The analysis allowed the evaluation of habitat selectivity of juveniles and sub-adults and the identification of characteristics of attractive artificial reefs in the Ceará coast. The reefs at sites 3 and 5 were constructed differently from the rest and were the only ones where no sea turtles were recorded. The site 3 reef was constructed in the form of a bonfire while that of site 5 was built largely of tires. While these reefs are attractive to spiny lobsters, they do not favor the occurrence of sea turtles.

In the past, large numbers of sea turtles, especially *C. mydas*, were caught in the "marambaias" by hook and line, free diving and the "aruaneira" turtle nets (Lima, 1998). Although this is no longer the case, these structures are used as shelter and for resting by sea turtles, and therefore it is important to understand the potential threat of accidental capture, given the large number of these artificial structures along the Ceará coast. The continued monitoring of the large number of artificial reefs is an essential component of the TAMAR conservation program that was initiated in 1991 in Almofala.

The results show that: i) "marambaias" constitute shelters for sea turtles in the feeding grounds, providing resting places in between periods of feeding, allowing them greater proximity to the coast and providing protection from the large predators, especially sharks; ii) the occurrence of species of fish and algae associated with the diet of the juvenile sea turtles suggests that the artificial reefs and the immediate surrounding areas are potential feeding grounds; iii) monitoring and control of activities associated with "marambaias" is fundamental for the conservation of these species of sea turtles, given the potential threat of accidental capture during the course of fishing activity on the artificial reefs; iv) careful use of these structures may play a fundamental role in the conservation and management of these species, given that the artificial reefs provide suitable alternative habitat to the natural reefs that are being lost to sand encroachment; v) it is possible to construct "marambaias" for the capture of high value commercial species such as spiny lobsters that are at the same time not attractive to sea turtles, thereby avoiding or minimizing accidental captures and contributing to their conservation.

In conclusion, “marambaias”, in addition to providing a large number of shelters in the sea turtle feeding grounds of the Ceará coast, are alternative habitats in areas where natural reefs are becoming scarce. Thus, the artificial reefs are of interest for conservation and management, especially for green turtle juveniles and sub-adults, the species that is clearly the most abundant in this area.

Acknowledgements

This study would not have been possible without the collaboration and help of several people. We are particularly grateful for the constant help and support of Dr. Eduardo Lima, coordinator of the base of the TAMAR/IBAMA Project in Ceará and Dr[a]. Norma Pinheiro, Botany technician of the LABOMAR Institute, and to Dr[a]. Francisca Marques da Cruz, for her help with the field work. We are also indebted to “marambaia” fishermen of the Almofala community for their help and support.

References

Azevedo, A.A. 1983. As tartarugas Marinhas do Litoral Brasileiro. *Ciência Hoje*, 5: 32-35.

Balazs, G.H. 1982. Growth rates of immature green turtles in the Hawaiian Archipelago. *In* Biology and conservation of sea turtles (K. A. Bjorndal, ed.), p. 117–125. Smithsonian Inst. Press, Washington, D.C.

Bass, A.L., Lagueux, C.J. & Bowen, B.W. 1998. Origin of Green Turtles, *Chelonia mydas*, at "Sleeping Rocks" of the Northeast Coast of Nicaragua. *Copeia*, 4: 1064-1068.

Bjorndal, K.A. 1980. Nutrition and Grazing Behaviour of the Green Turtle, *Chelonia mydas*. *Marine Biology*. *University of Florida*. 56: 147-154.

Bjorndal, K.A. 1985. Nutritional Ecology of Sea Turtles. *Copeia*, 3: 736-751.

Bjorndal, K.A. 1991. Digestive Fermentation in Green Turtles, *Chelonia mydas*, feeding on algae. *Bulletin of Marine Science*, 48(1): 166 - 171.

Bjorndal, K.A. 1997. Foraging Ecology and Nutrition of Sea Turtles. In: Lutz, P.L. & Musick, J.A. (eds). *The Biology of Sea Turtles*. CRC Press, Boca Raton. pp 199-231.

Bjorndal, K.A. 1999. Priorities for research in foraging habitats, *In*: Eckert, K.L., Bjorndal, K.A., Abreu-Grobois, F.A. & Donnelly (Eds.). *Research and management techniques for the conservation of sea turtles*. IUCN/SSC Marine Turtle Specialist Group Publication, 4: 12-14.

Bolten, A.B. 1999. Techniques for measuring sea turtles. *In* Eckert, K.L., Bjorndal, K.A., Abreu-Grobois, F.A. & Donnelly (Eds.). *Research and Management Techniques for the Conservation of Sea Turtles*. IUCN/SSC Marine Turtle Specialist Group Publication. 4: 110–114.

Cancela da Fonseca, L. 1989. *Estudo da influência da "abertura ao mar" sobre um sistema lagunar costeiro: A lagoa de Santo André*. Tese de Doutoramento, Universidade de Lisboa. X + 355pp.

Carr, A. 1967. *The Sea Turtle: so excellent a fisher*. University of Texas Press. 280 pp

Carr, A.1975. The Ascension Island Green Turtle Colony. *Copeia*, 3: 547–555.

Diez, C.E. & Ottenwalder, J.A. 1999. Habitats Surveys. *In* Eckert, K.L. Bjorndal, K.A., Abreu-Grobois, F.A. & Donnelly (Eds.). *Research and Management Techniques for the Conservation of Sea Turtles*. IUCN/SSC Marine Turtle Specialist Group Publication. 4: 41–44.

Ferreira, M.M. 1968. Sobre a Alimentação da Aruanã, *Chelonia mydas*, ao Longo da Costa do Estado do Ceará. *Arquivo Estadual de Biologia Marítima da Universidade Federal do Ceará*, 8(1): 83–86.

Ferreira, M. M. & Pinheiro, F. V. 1970. Quarta Contribuição ao Inventário das Algas Marinhas Bentónicas do Nordeste Brasileiro. *Arquivo de Ciências do Mar. Universidade Federal do Ceará*. 10(2): 189 - 192.

Gauch, Jr. H.G.. 1982. *Multivariate Analysis in Community Ecology*. Cambridge Uni. Press. Cambridge. X + 298pp.

George, R.H. 1997. Health problems and diseases of sea turtles. *In* Lutz, P. & Musick, J. (Eds.). *The Biology of Sea Turtle*. CRC Press, Boca Raton. Florida. Pp 363 – 385,

Hays, G.C, Luschi, P. Papi, F., Seppia, C. & Marsh, R. 1999. Changes in Behaviour During the Inter-nesting Period and Post-nesting Migration for Ascension Island Green Turtles. *Marine Ecology Progress Series*, 189: 263 - 273.

Howe, S.A., Asfaha, B. & Kemp, J.M. 2004. Turtle Strandings in the Southern Eritrean Red Sea. *Marine Turtle Newsletter*, 103: 4-7.

IUCN. 2007. International Union for Conservation of Nature Resources. IUCN Red List of Threatened Species. *In*: http://www.iucnredlist.org (acedido a 05/05/2007).

Krebs, C.J. 1999. *Ecological Methodology*. University of British Columbia. 2ªEd. Benjamin. Commings. p 620

Legendre, L. & P. Legendre 1984. *Écologie Numérique. I. – Le traitement multiple des données écologiques. II – La structure des données écologiques.* (2ème ed.). Masson Ed. Paris. 260pp; 335pp.

Lining, K., 1990. Seaweeds: their environment, biogeography and ecophysiology. John Wiley & Sons, Inc., New York, pp 527

Lima, S.M., Cavalcante, N.C. & Evangelista, L.E.V. 1996. *Dados de Ocorrências de Tartarugas Marinhas em Almofala*, Ceará, Brasil. 1pp.

Lima, S.M.. 1998. *Artes, Armadilhas e Formas de Pesca que Provavelmente Capturam Tartarugas Marinhas em Áreas de Alimentação e Desova*. Almofala, Ceará. Brasil. 29pp.

Lima, S.M., Lagueux, C.J., Castro, D. & Marcovaldi, M.A. 1999. From one feeding Ground to Another: Green Turtle Migration Between Brazil and Nicaragua. *Marine Turtle Newsletter*, 85: 10.

Lima, S.M. 2000. Espécies de tartarugas marinhas ocorrentes no litoral de Almofala – Ceará. *In* Congresso Brasileiro de Zoologia. 24pp.

Lima, S.M. & Troëng, S. 2001. Link Between Green Turtles Foraging in Brazil and Nesting in Costa Rica. *Marine Turtle Newsletter*, 94: 9.

Limpus, C.J. & Reed, P.C. 1985. The green turtle, *Chelonia mydas*, in Queenslands: a preliminary description of the population structure in a Coral Reef feeding grounds. *In* Griggs, G. & Shine, R. (eds.) *Biology of Australiasian Frogs and Reptiles*. Summy Beauthy e Sons. Sydney. 47pp.

Limpus, C.J. & Limpus, D.J. 2000. Mangroves in the diet of *Chelonia mydas* in Queensland, Australia. *Marine Turtle Newsletter*, 89: 13 – 15.

Limpus, C.J., Couper, P.J. & Read, M.A. 1994. The green turtle, *Chelonia mydas*, in Queensland: population structure in a warm temperate feeding area. *Memories of the Queensland Museum*, 35(1): 139 - 154.

Lohmann, K. J. & Lohmann, C. M. F. 1998. Migratory Guidance Mechanisms in Marine Turtles. *Journal of Avian Biology*, 29: 585 - 596.

Lutcavage, M.E., Plotkin, P., Witherington, B. & Lutz, P.L. 1997. Human Impacts on Sea Turtle Survival. in Lutz, P.L. & Musick, J.A. (Eds.). *The Biology of Sea Turtle*. CRC Press. Boca Raton. Florida. Pp 87 – 403

Marcovaldi, M.A., Silva, A.C.C.D., Gallo, B.M.G., Baptistotte, C., Bellini, C., Lima, E.H.S.M., De Castilhos, J.C., Thomé, J. C.A. & Sanches, T.M.S. 1995. Sea Turtle

Feeding Grounds of Brazil. *Proceedings of the 18th International Symposium on Sea Turtle Biology and Conservation*: 150 - 152.

Marcovaldi, M.A. & Marcovaldi, G.G. 1999. Marine Turtles of Brazil - The History and Structure of Projecto TAMAR/IBAMA. *Biological Conservation*. (91): 35 – 41

Marcovaldi, G., Marcovaldi, M.A., Tomé, J., Patiri, V., Coelho, C. 2001. Armadilha; Algumas artes de pesca ameaçam as tartarugas marinhas nas áreas de alimentação. Tamar, (24): 21.

Meylan, A. B. & Meylan, P. A. 1999. Introduction to the Evolution, Life History, and Biology of Sea Turtles. *In* Eckert, K. L. Bjorndal, K.A., Abreu-Grobois, F.A. & Donnelly, M. (Eds.). *Research and Management Techniques for the Conservation of Sea Turtles*. IUCN/SSC Marine Turtle Specialist Group Publication. 4: 3 - 5.

Miller, J. 1996. Reproduction in Sea Turtles. *In* Lutz, P.L. & Musick, J.A. *The Biology of Sea Turtle*. CRC Press. Boca Raton. Florida. p 51 – 71

Mortimer, J.A. 1981. The feeding ecology of the West Caribbean green turtle (*Chelonia mydas*) in Nicaragua. *Biotropica*. (13): 49 - 58.

Biotropica 13:49-58

Mortimer, J.A. 1982. *Feeding Ecology of Sea Turtles*. *In* Bjorndal, K.A (Ed.). *Biology of Sea turtles.* Washington, D.C.. Smithsonian Institution Press p 103 - 109

Mortimer, J.A. & Carr, A. 1987. Reproduction and Migration of the Ascension Island Green Turtle (*Chelonia mydas*). *Copeia*. (1987): 103 – 113.

Musick, J. & Limpus, C. 1997. Habitat Utilisation and Migration in Juvenile Sea Turtle. *In* Lutz, P. L. & Musick, J. A. (Eds.) *The Biology of Sea Turtle*. CRC Press. Boca Raton. Florida. p 137 – 164.

Oliveira, E.C., Pirani, J.R., Giulietti, A.M.. 1983. The Brazilian sea grasses. *Aquatic Botany*. 16: 251 – 267.

Oliveira, E.C., Horta, P.A., Amancio, C.E. & Santanna, C.L. 2003. *Algas e angiospérmicas marinhas bênticas do litoral Brasileiro*. Instituto de Biociências da Universidade de São Paulo. São Paulo. Brasil *In*: http: //www.algasbrasil.com (acedido a 10 /12/ 2003).

Pereira, R. 1979. Peixes da nossa terra. São Paulo. Nobel. 1ª ed. 129pp.

Plotkin, P. 2003. Adult Migration and Habitat Use. *In* Lutz, P.L., Musick, J.A. & Wineken, J. (Eds.) *The Biology of Sea Turtle*.. CRC Press Boca Raton. Florida. p 225 – 241

Pritchard, P. C. H. 1997. Evolution, Phylogeny, and Current Status. *In* Lutz, P. L. & Musick, J. A. (Eds.) *The Biology of Sea Turtle*.. CRC Press. Boca Raton. Florida. p 1 – 28

Pritchard, P. C. H. & Mortimer, J. A. 1999. Taxonomy, External Morphology, and Species Identification. in Eckert, K. L., Bjorndal, K.A., Abreu-Grobois, F.A. & Donnelly. M. (Eds.) *Research and Management Techniques for the Conservation of Sea Turtles*. IUCN/SSC Marine Turtle Specialist Group Publication. 4: 21 - 38.

Read, M. A. 1991, *Observations on the Feeding Ecology of Immature Green Turtles* Chelonia mydas*, in the Moreton Banks Region of Moreton Bay, South-east Queensland*, Honours thesis, University of Queensland.

Rollf, F. J. 1998. NTSYSpc: Numerical Taxonomy and Multivariate Analysis System. Exeter Software, Ny.

Sampaio, J. R. 1996. *Índice dos peixes marinhos brasileiros*. Ictiologia Brasil. Fortaleza. Gráfica Editora. 124pp.

Santos, M.N. 1997. Ichthyofauna of the artificial reefs of the Algarve coast. Exploitation strategies and management of local fisheries. Tese de Doutoramento, Universidade do Algarve. 289pp.

Sazima, I. & Sazima, M. 1983. Aspectos do Comportamento Alimentar e Dieta da Tartaruga Marinha, *Chelonia mydas*, no Litoral Norte Paulista. *Boletim do Instituto Oceanográfico*, 32(2):199 – 203.

Sneath, P.H. & Sokal, R.R. 1973. *Numerical taxonomy. The principles and practice of numerical classification*. Freeman, San Francisco. 573 pp.

Szpilman, M. 1991. *Guia Pratico de Identificação dos Peixes do Litoral Brasileiro*. Aqualung Confecção Ltd. Brasil. 284pp.

Wynne, M.J. 1998. *A checklist of benthic marine algae of the tropical and subtropical western Atlantic: first revision*. Nova Hedwigia. Stuttgart. 155pp.

Wolanski, E. & Hammer, W. 1988. Topographically controlled fronts in the ocean and their biological influence. *Science*: (241):177-181

www.fishbase.com, consulted on October 24, 2003.