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Diet of Sea Turtles in Southern Brazil

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Sea turtles are widely distributed throughout the tropical and temperate seas and oceans around the world, and have received much attention from researchers. Most investigations, however, have focused on the brief period when these reptiles remain on land, during the egg-laying period of the females and while the young are hatching (Plotkin et al., 1993), and studies such as feeding site activities have been neglected (Limpus and Walter, 1980).

In Brazil this is certainly the case. For years, the emphasis has been upon studies at reproductive sites in the northeast and southeast regions, coordinated by project TAMAR/IBAMA - National Marine Turtle Conservation Program (Marcovaldi and Marcovaldi, 1999). Studies on diet and foraging behavior in Brazilian waters are scarce, including Ferreira (1968) and Sazima and Sazima (1983) on the adult green turtle *Chelonia mydas*, and Pinedo et al. (1998) who analyzed 28 digestive tracts of *Caretta caretta*, *Dermochelys coriacea*, *Chelonia mydas*, *Eretmochelys imbricata*, and *Lepidochelys olivacea*. Reviews of the feeding habits of sea turtles around the world have been presented by Mortimer (1982), Bjorndal (1985, 1997), Dodd (1988), and Hirth (1997). Despite the significant advances achieved during the last two decades in understanding marine turtle feeding ecology, Bjorndal (1997) considered that there are still many gaps in our understanding, with little progress made in elucidating the diet and foraging habits of some species. We therefore considered it important to obtain information from the feeding grounds of each discrete population in order to interpret their biology and to eventually manage these populations, thus keeping them in balance with human pressures. In this study we present an assessment of the diet of the green turtle (*Chelonia mydas*), loggerhead (*Caretta caretta*), and leatherback (*Dermochelys coriacea*), with additional comments about their foraging habits in southern Brazilian waters.

Study Site. — This study was carried out along 150 km of beach between Pinhal (30°15'S; 50°15'W) and Lagoa do Peixe (31°20'S; 51°05'W). One study tour included a larger part of the coast, about 620 km long, between Torres (29°20'S; 49°44'W) and Arroio Chuí (33°45'S; 53°22'W), both in the southernmost Brazilian state of Rio Grande do Sul (Fig. 1). It is a continuous sandy beach interrupted only by the Lagoa dos Patos and the Tramandaí river inlets. The beach is composed of fine quartz sand and has a low gradient (2°). During periods of heavy rainfall, a large number of ephemeral creeks break the frontal dunes and drain landward depressions (Calliari, 1997a). The gently sloping continental shelf (2 m/km) has a width of 100–180 km, composed mostly of unconsolidated substrates, such as fine sand and mud (Calliari, 1997b). Substantial hard substrates for algae and invertebrates settlement are located only in Torres, Arroio Chuí, and the jetties at the mouth of Lagoa dos Patos. The southern Brazilian continental shelf is influenced by the Subtropical Convergence, formed by the southward-flowing Brazil Current, transporting tropical water, and the coastal branch of the northward-flowing Malvinas (Falkland) Current, transporting subantarctic water (Garcia, 1997).

Methods. —We surveyed the above beaches from August 1997 to July 1998 and recorded all stranded sea turtles. Specimens in good condition were measured (curved carapace length, CCL) and the digestive tract removed from the esophagus to the initial portion of the large intestine, preserved in 70% ethanol, and dietary items identified in the laboratory. Food items were identified to the lowest taxonomic level, and their importance in the diet presented as frequency of occurrence (FO%) and numerical proportion (N%). The minimum number of dietary items was obtained using whole individuals or their fragments, except for vegetable matter, polychaetes, and fish eggs, whose numbers were not possible to determine.

Results and Discussion. — We found 92 stranded sea turtles and measured 56 green turtles, 16 loggerheads, and 2 leatherbacks, and collected 38, 10, and 2 gut contents, respectively. The CCL of green turtles ranged from 28 to 50 cm (mean = 37.7 ± 3.1 [s.d.] cm, $n = 56$) indicating a juvenile

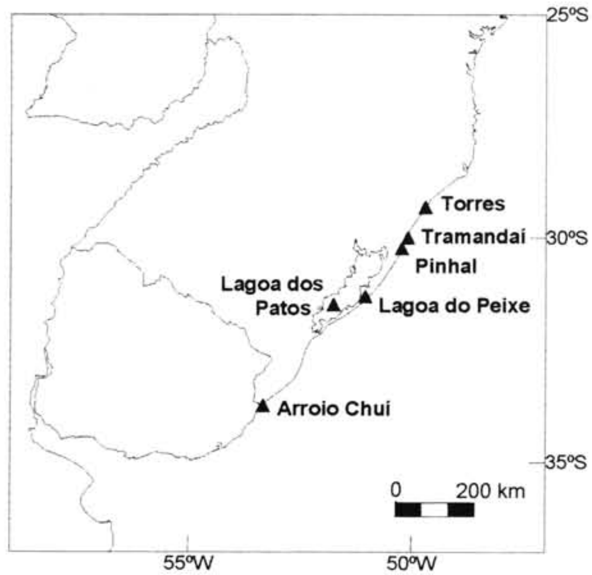

Figure 1. Study region in southern Brazil (Rio Grande do Sul) with beaches sampled between August 1997 and July 1998.

Table 1. Frequency of occurrence (FO%) and contribution in number (N%) of food items found in the digestive tract of green turtles (*Chelonia mydas*) ($n = 38$ turtles, 267 total dietary items) and loggerhead turtles (*Caretta caretta*) ($n = 10$ turtles, 199 total dietary items) in southern Brazil, from August 1997 to July 1998.

Food Items	*Chelonia mydas* FO%	*Chelonia mydas* N%	*Caretta caretta* FO%	*Caretta caretta* N%
Mollusks	**60.5**	**41.6**	**70.0**	**14.1**
Pelecypods	57.9	35.2	30.0	2.0
Gastropods	18.4	6.0	50.0	11.6
Scaphopods	2.6	0.4	0.0	0.0
Unidentified mollusks	0.0	0.0	10.0	0.5
Fish	**21.1**	...	**80.0**	**5.0**
Trichiurus lepturus	0.0	0.0	40.0	2.0
Paralonchurus brasiliensis	0.0	0.0	10.0	1.0
Unidentified fish	2.6	0.4	20.0	2.0
Eggs	18.4	...	0.0	0.0
Crustaceans	**23.7**	**16.9**	**40.0**	**72.4**
Brachyura (crabs)	**10.5**	**1.9**	**20.0**	**2.0**
Hepatus pudibundus	0.0	0.0	10.0	0.5
Libinia spinosa	0.0	0.0	10.0	0.5
Portunidae crabs	5.3	0.8	0.0	0.0
Unidentified crabs	5.3	1.1	10.0	1.0
Anomura	**5.3**	**0.8**	**20.0**	**57.8**
Loxopagurus loxochelys	2.6	0.4	10.0	0.5
Emerita brasiliensis (adults and larvae)	2.6	0.4	10.0	57.3
Dendrobranchiata shrimp	**0.0**	**0.0**	**10.0**	**1.0**
Isopods	**2.6**	**0.8**	**20.0**	**12.6**
Excirolana armata (adults and larvae)	2.6	0.8	10.0	11.6
Politolana eximia	0.0	0.0	10.0	1.0
Unidentified isopod	2.6	0.8	0.0	0.0
Amphipods	**2.6**	**0.4**	**0.0**	**0.0**
Cirripeds (barnacles)	**13.2**	**16.2**	**0.0**	**0.0**
Lepas anatifera	7.9	15.0	0.0	0.0
Lepas sp.	2.6	0.4	0.0	0.0
Unidentified barnacles	2.6	0.8	0.0	0.0
Scyphozoans (jellyfish)	**7.9**	**1.1**	**0.0**	**0.0**
Polychaetes	**0.0**	...	**10.0**	...
Insects	**7.9**	**1.9**	**0.0**	**0.0**
Odonata (dragonflies)	2.6	0.4	0.0	0.0
Coleoptera (beetles)	2.6	0.4	0.0	0.0
Unidentified insects	5.3	0.8	0.0	0.0
Echinoderms				
Mellita quinquiesperforata	**2.6**	**0.4**	**0.0**	**0.0**
Vegetation	**36.8**	...	**0.0**	**0.0**
Green algae	**10.5**	...	**0.0**	**0.0**
Ulva sp.	10.5	...	0.0	0.0
Unidentified green algae	2.6	...	0.0	0.0
Terrestrial grass				
Luziola peruviana	**26.3**	...	**0.0**	**0.0**
Unidentified items	**7.9**	...	**0.0**	**0.0**
Empty digestive tracts	**15.8**	...	**10.0**	...

stage resident in shallow water and neritic habitats (Hirth, 1997). The southern Brazilian coast and Lagoa dos Patos are important developmental habitats for the green turtle (*sensu* Carr et al., 1978). The CCL of loggerheads ranged from 63 to 97 cm (mean = 73.4 ± 10.2 cm, $n = 16$) and were classified as adults and subadults based on the minimum CCL (75 cm) of adults on Brazilian nesting beaches (Barata et al., 1998). The two leatherbacks measured 135 and 136 cm, considered as small adults or subadults.

A high frequency of anthropogenic debris was found in stomachs of green turtles (60.5%), accounting for the death of 13.2% of turtles by gut obstruction. Plastics were also found in loggerhead and leatherback stomachs. Detailed data from anthropogenic debris ingestion and interactions with fishing activities have been provided in a separate paper (Bugoni et al., 2001). Six digestive tracts of green turtle contained no food (15.8%). The large amount of ingested plastic bags explains the absence of food and indicates abnormal feeding by these individuals.

The most frequent foods ingested by green turtles were, in order of importance: mollusks, vegetation (mostly the terrestrial grass *Luziola peruviana*, but also the green algae *Ulva* sp.), crustaceans, and fish eggs (Table 1). Seagrass beds at different locations around the world are commonly used by green turtles as foraging areas. In the study area seagrass beds occur in Lagoa dos Patos (Phillips, 1992), being a likely feeding ground for juvenile green turtles, as indicated by Soto and Beheregaray (1997) and Pinedo et al. (1998). It is interesting to note that we found no seagrass in the digestive tracts, only the terrestrial grass *Luziola peruviana*. Leaves, rhizomes, and roots of terrestrial grass were found attached to fish eggs. This grass is commonly found in edges of lagoons, river inlets, and freshwater marshes (Cordazzo and Seeliger, 1988). It is frequently observed on the beach, along the drift line, after heavy rain events. This grass, as well as other terrestrial debris, is carried out to the sea through river mouths. Lignified terrestrial debris deposited offshore within effluents of river mouths were also ingested by Nicaraguan and Costa Rican green turtles (Mortimer, 1982). This suggests that green turtles, besides feeding inside the lagoon, also feed in coastal marine waters.

Bjorndal (1997) pointed out that during the first years of life green turtles have pelagic habits, entering benthic foraging areas at a size ranging from 20 to 25 cm CCL in the Western Atlantic. Our information about its diet indicates that during the juvenile stage this species is omnivorous, half-way between the carnivorous diet of their first years of life (Hirth, 1971) and the preponderantly herbivorous diets of the adult (Carr, 1961; Hirth, 1971; Mortimer, 1982; Sazima and Sazima, 1983). Data presented also agree with the trophic status of green turtles in Mediterranean Sea, assessed by stable isotopes, which suggests a substantial consumption of animal matter by green turtles (Godley et al., 1998). Additionally, we suggest green turtles ingest animal matter unselectively along with plant matter (e.g., fish eggs), and selectively, as indicated by the large amount of mollusks and crustaceans (e.g., crabs and mollusks) found in their stomachs.

Fish, crustaceans, and mollusks were the main organisms found in loggerheads (Table 1). One loggerhead digestive tract was empty. The presence of mollusks was deduced mainly through fragments of undigested shells. The loggerhead has mandible and head adaptations to facilitate crushing hard-shelled organisms (Hendrickson, 1980), and the fragmented state made it difficult to identify those to lower taxa. Additionally, the occurrence of hermit crabs together with large gastropod shells and the absence of opercula could indicate ingestion of empty shells. Some mollusk shells could also be ingested together with mud or sand, found in two stomachs. These obstacles limit the extent to which we can draw meaningful inferences about mollusk ingestion by loggerheads. Our analysis of the loggerhead diet indicates that at this age the species is a generalist carnivore, with a trend towards benthic foraging, which agrees with other authors (Acevedo et al., 1984; Dodd, 1988; Plotkin et al., 1993; Tomas et al., 2001). Our results are also similar to those of Pinedo et al. (1998), and similarly indicate demersal feeding on the neritic shelf. According to Dodd (1988), fish can be intentionally ingested when found dead, or incidentally when they capture medusae. Brongersma (1972), however, doubted that loggerheads can capture fish, but related the presence of sygnathid fish found in stomachs to the low speed and mass death which occur in this group. Plotkin et al. (1993) also questioned the capacity to capture live fish and shrimp in the water column. As a source of dead fish, Shoop and Ruckdeschel (1982) and Tomas et al. (2001) strongly suggested loggerheads feeding on fish bycatch discharged overboard. Evidence supporting the hypothesis that loggerheads ingest dead animals was presented by Fotheringham (1980), who mentioned the presence of *Nassarius acutus*, a necrophage gastropode, in the digestive tract of a loggerhead that had eaten fish. Similarly, Shaver (1991), Frick (1997), and Frick and Mason (1998) also found *Nassarius* spp. in the stomachs of Kemp's ridley sea turles (*Lepidochelys kempi*). The hypothesis of loggerheads feeding on dead fish was also substantiated in the present study, where co-occurrence between fish and the necrophage isopod *Politolana eximia* was found. On the other hand, the necrophage isopod *Excirolana armata* is a common inhabitant of the intertidal zone (Gianuca, 1997), and was probably feeding inside the carcasses of stranded turtles.

We only found one spider crab, *Libinia spinosa*, in the two gut contents of leatherback turtles examined. Frazier et al. (1985) and Gudynas (1980) also recorded this species in the leatherback's diet. According to Frazier et al. (1985), this is suggestive of these turtles being a specialized feeder upon soft-bodied pelagic invertebrates because this crab is a common commensal of Discomedusae. Commensal crustaceans and fish are frequently reported in stomach contents of leatherbacks (Bjorndal, 1997).

In this study 92 dead sea turtles were found in a one-year period, while Pinedo et al. (1998), monitoring a similar extension in the same area between 1992 and 1995, found 220 stranded turtles. The large number of stranded turtles suggests that southern Brazil is an important feeding ground for loggerhead and leatherback sea turtles, and a developmental habitat for green turtles. As previously pointed out (Bugoni et al., 2001), sea turtles in this area are under severe risk due to fishing activities and pollution. Studies linking feeding and nesting sites are urgently required to improve conservation efforts.

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Radiotransmitter Attachment Technique for Box Turtles (*Terrapene* spp.)

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Terrestrial chelonians are often difficult to locate and monitor under natural conditions because many species are cryptic in coloration and behavior. For example, the eastern box turtle (*Terrapene carolina carolina*) has a carapace often spotted with yellow or orange, and brown or black, a pattern that easily blends into substrate of leaf litter. In addition, eastern box turtles bury themselves in leaf litter (i.e., in forms) and spend long periods underground in burrows. In the northeastern United States, eastern box turtles may be easily overlooked during visual surveys and marked individuals often cannot be relocated with any regularity (pers. obs.). Radiotelemetry, which allows observers to relocate an individual on demand, has become an essential tool for studying the movements, home range, habitat use, and other characteristics of box turtles and other chelonians that are difficult to locate and observe.

Application of radiotelemetry to the study of small animals, such as terrestrial turtles, can be challenging. Biologists must consider not only the objectives and constraints of the study, but also the welfare of the animals; many universities and research institutions now require that methods used in live-animal studies be reviewed and approved by an institutional animal care and use committee before implementation. Most studies require that a radiotransmitter remain attached to an individual for an extended period of time; however, the radiotransmitter and attachment must not affect the behavior, physiology, reproductive success, or survival of the study animal if accurate observations are to be obtained. In the case of box turtles, the radiotransmitter and attachment must not excessively burden the animal, become entangled in vegetation, increase rate of detection by predators, pose an obstruction to burrowing, or disrupt copulation or other behaviors. Methods of attachment, such as adhesives or hardware, must be nontoxic and should not increase chances of infection or disease, cause significant injury or developmental abnormalities, or produce potentially damaging amounts of heat. Ideally, the method of attachment should allow the radiotransmitter to