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Diet of Olive Ridley Sea Turtles, *Lepidochelys olivacea* (Eschscholtz, 1829), in the Waters of Sergipe, Brazil

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1 Abstract. – **We investigated the diet of olive ridleys**
2 **(*Lepidochelys olivacea*) in Sergipe, northeast Brazil. Stomach contents from 30 stranded animals showed ridleys in the region were benthic carnivorous, consuming mainly crustaceans and fish. Results are valuable to understand the feeding and foraging habitats of this population and to help clarify possible threats in the region.**

Marine migrants play important roles in ecosystems. Many of them are of conservation concern, mainly due to anthropogenic threats such as incidental capture in fisheries (bycatch), pollution, and climate change (Baum et al. 2003; Soykan et al. 2008; Hawkes et al. 2009; Hamman et al. 2010). For effective conservation, an adequate understanding of their ecology is needed, both spatially and temporarily. Diet studies are important to identify likely resources and feeding areas; knowledge of these aspects is integral for effective sea turtle conservation. This information can help to guide management decisions toward the conservation of critical habitats (López-Mendilaharsu et al. 2005; Hamman et al. 2010) and assess potential overlap with threats such as fisheries bycatch (Seney and Musick 2007).

In the western Atlantic Ocean, olive ridley turtles (*Lepidochelys olivacea* (Eschscholtz, 1829) have a wide distribution, nesting mainly along the coasts of Suriname, French Guiana, and northeastern Brazil. In Brazil, the largest nesting area can be found along the state of Sergipe (Silva et al. 2007; Fig. 1). Olive ridley turtles are currently classified as Vulnerable by the International Union for Conservation of Nature (IUCN 2013) and as endangered by the Brazilian Red List of Threatened Species (Machado et al. 2008; Castilhos et al. 2011).

Globally, adult olive ridley turtles use a wide variety of foraging areas including pelagic and benthic habitats (Plotkin 2010; Silva et al. 2011). Satellite tracking has shown behavioral plasticity among populations (Rees et al. 2012), and adults have been reported either as remaining in oceanic conditions, diving at depths of up to 400 m (Swimmer et al. 2006), or using coastal and continental shelf areas (McMahon et al. 2007; Whiting et al. 2007). In the western Atlantic, they are believed to feed in shallow and productive areas near estuarine zones (Pritchard and Trebbau 1984; Reichart 1993). The ridley's diet has been investigated in Venezuela (Wildermann and Barrios-Garrido 2012) and in southern Brazil by two reported juvenile specimens incidentally caught by pelagic longline fisheries (Pinedo et al. 1998; Serafini et al. 2002). In the Pacific Ocean, detailed studies have been conducted in Mexico (Montenegro Silva et al. 1986) and Papua New Guinea (Spring and Gwyther 1999). Observations have been reported in the eastern Pacific (Fritts 1981; Kopitsky et al. 2004) and west coast of the United States (Marquez 1990). Individuals have also been captured, albeit rarely, in fisheries operating in the waters of Sri Lanka and India (Bjorndal 1997). Few studies have considered the specific dietary habits of olive ridley turtles (Mortimer 1982). This information is valuable to understand their feeding habitats within different regions, identify critical foraging areas, and to inform conservation strategies.

The present study described the olive ridley's diet on the coast of Sergipe, Brazil, through the analysis of stomach contents from stranded turtles. The possible overlap between feeding and fishing areas in the region, which might be occurring as a result of their foraging behavior, was also discussed.

Methods. — The state of Sergipe, in northeastern Brazil (lat 10°30′30″S, long 36°23′27″W and lat 11°20′32″S, long 37°20′32″W), has approximately 163 km of coastline. At 3 field stations (Abaís, Pirambu, and Ponta dos Mangues; Fig. 1), conservation strategies are carried out by Projeto TAMAR (the Brazilian Sea Turtle Conservation Program), which includes a record of sea turtle strandings. From August 2008 to September 2009, beaches in Sergipe were monitored according to a standard methodology for fieldwork described by Marcovaldi and Marcovaldi (1999). Stranded sea turtles were recorded and, due to storage matters, the animals had only their stomachs and not the entire digestive tract removed. Adult turtles were sexed according to morphological analysis of secondary sexual characteristics; however, 46% of turtles sampled remained of undetermined sex. Carcasses in an advanced stage of decomposition were not considered in the present analysis.

Stomach contents were sorted using a 1-mm fine mesh sieve, rinsed under running water (Guebert 2008), and fixed in an aqueous solution of formalin (10%). Prey groups were identified to the lowest possible taxonomic level according to Menezes and Figueiredo (1980), Melo

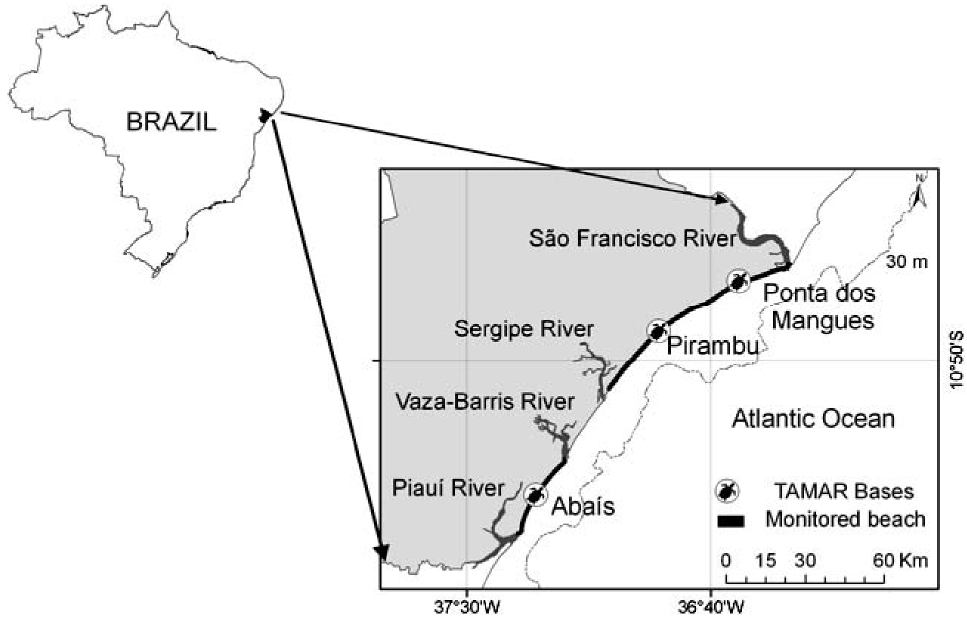

Figure 1. Map showing the location of the 3 TAMAR field stations in the state of Sergipe and the study area.

(1996), Rios (1994), and Vaske-Júnior (2006). Food items were placed into 6 major categories: Teleostei (fish), Crustacea, Mollusca, Sediment, Digested Organic Matter (DOM), and Unidentified Material (Table 1). Entire sample volume and relative volume of each prey group were calculated through water displacement in a graduated cylinder to the nearest 10 ml (Seminoff et al. 2002). Empty stomachs were excluded from the analysis. Percent occurrence (frequency, %FO) and relative volume (%RV) were determined for each prey category, using the formulas:

$$\%FO = \left(F_i/F_j\right) \times 100,$$

where F_i is the number of samples containing the item *i*, and F_j is the total number of samples and

$$\%RV = \left(V_i/V_j\right) \times 100,$$

where V_i is the volume of the food item *i* and V_j is the total volume of all samples.

Results. — The curved carapace lengths of sampled turtles ranged between 61 and 74 cm (mean: 68.1 cm ± 3.3 SD, *n* = 30; Fig. 2) and 28 (93.3%) presented sizes similar to or greater than the smallest nesting olive ridley documented for the region (62.5 cm; Silva et al. 2007). Regarding stomach contents, 16 (53%) had some food content and 14 (47%) were empty. Table 1 presents the results for the taxonomic classification, overall frequency of occurrence (%FO), and relative volume (%RV) of items found in *L. olivacea* stomachs.

Teleostei and Crustacea were the main groups found in the stomachs, with 7 taxa identified among the crustacean prey; the crab common name, *Persephona lichtensteinii* (Brachyura, Leucosiidae) and the blue crab *Callinectes* spp. (Brachyura, Portunidae) were the most-frequent species, being present in 25% and 12.5% of all analyzed samples, respectively (Table 1). Other species were also 4
found such as the crab common name, *Persephona punctata* Linnaeus, 1758 (Brachyura, Leucosiidae), the box crab *Calappa sulcata* Rathbun, 1898 (Brachyura, Callapidae), and individuals from the Majidae family (Fig. 3). Fragments of shrimps (infraorder Caridae) were also found. Molluscs were represented by pieces of bivalve shells such as the eared ark clam (*Anadara notabilis* Röding, 1798) and beaks of cephalopods (*Histioteuthis* sp.). In the sediment there were pieces of Bryozoan species from the genera *Metrarabdotos* (Metrarabdotosidae), *Celleporaria* (Lepraliellidae), and *Reteporellina* (Phidoloporidae) as well as calcareous fragments and eroded shells (overall frequency of occurrence 25%). Among fish, the bigtooth corvina (*Isopisthus parvipinnis* Cuvier, 1830) and a species from the genus *Cynoscion* were found, together with fragmented individuals from the Clupeidae and Ariidae families.

Of the 30 animals 12 were female, 4 were male, and 14 could not be sexed. Regarding the females, 10 were in the reproductive stage with eggs in development, and 4 of those with eggs had food in their stomach (mainly the Leucosiid crab *Persephona lichtensteinii*, the molluscs *A. notabilis*, and beaks of the cephalopod *Histioteuthis* sp., as well as sediment and DOM). Between the 4 males, one of them had an empty stomach while the other 3 individuals had crabs (*Callinectes* sp. and *Callapa sulcata*), fish (*Cynoscion* sp.), and DOM.

Discussion. — The broadly carnivorous and generalist feeding behavior of olive ridleys reported here has been previously observed (Mortimer 1982; Márquez 1990; Reichart 1993; Spring and Gwyther 1999) and confirms the use of varied items in the species diet. The

Table 1. Taxonomic classification, overall frequency of occurrence (%FO), and relative volume (%RV) of items found in *Lepidochelys olivacea* stomachs (n = 16). Common names, when known, are shown in brackets. 3

Food items	(%)FO	(%)VR
Phylum Arthropoda		
Subphylum Crustacea	56.25	24.7
Class Malacostraca		
Order Decapoda		
Infraorder Brachyura		
Family Leucosiidae		
Persephona lichtensteinii	25	3.47
Persephona punctata	6.25	2.02
Family Callapidae		
Callapa sulcata (box crab)	6.25	1.01
Callapidae	6.25	0.22
Family Portunidae		
Callinectes sp. (blue crab)	12.5	14.59
Family Majidae		
Majidae	6.25	2.24
Infraorder Dendrobranchiata		
Family Penaeidae		
Penaeidae	6.25	1.12
Phylum Chordata		
Subphylum Vertebrata		
Class Ostheichtyes (Fish)	31.25	59.5
Family Sciaenidae		
Cynoscion sp. (*pescadinha*)	18.75	48.82
Isopisthus parvipinnis (bigtooth corvina)	6.25	2.24
Family Clupeidae		
Clupeidae	6.25	3.92
Family Ariidae		
Ariidae	6.25	6.73
''Fish fragments''	6.25	0
Phylum Mollusca	12.5	2.7
Class Bivalvia		
Family Arcidae		
Anadara notabilis (eared ark clam)	6.25	0.44
Class Cephalopoda		
Order Teuthida		
Family Histioteuthidae		
Histioteuthis sp.	6.25	2.24
Sediment	25	8.3
Digested Organic Matter	37.5	4.4
Unidentified Material	6.25	0.4

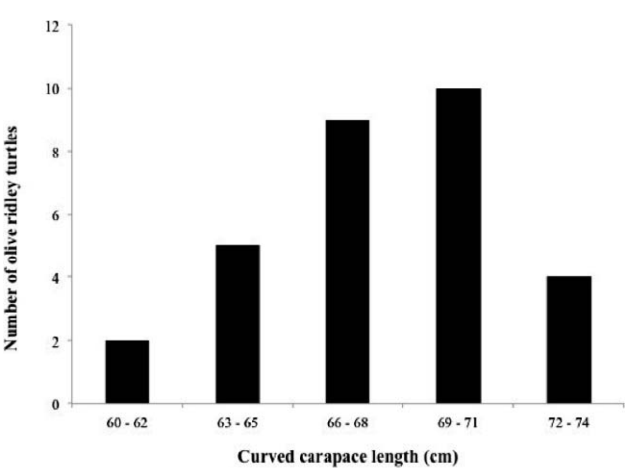

Figure 2. Length–frequency distribution of olive ridley sea turtles stranded along the coast of Sergipe, with sizes ranging from 61 to 74 cm curved carapace length (n = 30), and which had stomachs collected.

results obtained here support the findings by Wildermann and Barrios-Garrido (2012) in Venezuela. The significant presence, in both studies, of crustaceans and specifically the crab from the genus *Callinectes*, indicates that these items constitute important food resources for olive ridleys in the western Atlantic. Prey groups such as fish and crustaceans were also cited as important items for olive ridleys in the Pacific Coast of Mexico (Montenegro Silva et al. 1986). Although in the present study the crustaceans were the most-frequent food category, they had moderate volume, whereas fish were moderately frequent but had the highest volume. This suggests fish might have a greater importance in the ridley's diet in the region.

Benthic species of crustaceans such as *P. lichtensteinii*, and demersal fishes such as *I. parvipinnis* (Ostheichtyes, Sciaenidae), were consumed by turtles in this study; they are also reported as bycatch species in the shrimp fishery carried out in the region (Carvalho 2007; Romero et al. 2008. Turtles feeding on discarded bycatch by fisheries have been reported in other regions and

Figure 3. Examples of Crustaceans found in *Lepidochelys olivacea* stomachs. From left to right: *Callapa sulcata*, *Persephona lichtensteinii*, and shrimp from Infraorder Caridae (Photos: L.P. Colman).

associated with an increased risk of incidental turtle mortality (Tomas et al. 2001; White 2004). Small-scale fisheries operating in near-shore water can have high bycatch impacts on populations, especially if there is an overlap between feeding and breeding areas (Alfaro-Shigueto et al. 2011; Wallace et al. 2013).

The results from satellite-tracked turtles in the region suggest the existence of a spatial overlap between areas used by the turtles during their internidal period (interval between two consecutive postovipostions) and fishery activities (Silva et al. 2011). The presence, in the turtles' stomachs, of preys reported as bycatch species in the region indicates that a spatial overlap of feeding and fishery areas could also exist. Thus, negative interactions between turtles and fisheries might be occurring, possibly leading to some of the stranding events of turtles examined in this study. The likely cause of death for turtles sampled was not available; however net pieces attached to flippers, knife cuts made on the plastron, and the presence of stranded turtles in good body condition and with eggs ready for being laid suggests interactions with fisheries could be the cause of death, at least for some of the animals. The olive ridley nesting population in Sergipe has been increasing (Silva et al. 2007). However, capture by coastal fisheries still represents a major threat (Thomé et al. 2003), calling for effective conservation strategies and enforcement of existing legislation (Silva et al. 2010). Studies such as this one are important to highlight possible fishery interactions which might be occurring as a result of the foraging strategy of this species in the region.

It is generally accepted that female turtles do not feed during the reproductive period (Bjorndal 1985; Hays, Broderick et al. 2002; Goldberg et al. 2013; but see Balazs
5 1980; Tucker and Read 2001). However, the question remains unresolved, as variation among species and some behavioural plasticity within species can occur, probably shaped by local resource conditions (Hays, Glen et al.
6 2002) near the nesting areas. Satellite tracking of olive ridleys in Sergipe (Silva et al. 2011) indicates that this species uses the area along the Brazilian continental shelf during the internesting period, moving actively within the region. Stomach contents from 4 reproductively active females studied here contained benthic prey items typically found in shallow muddy substrata. This indicates that reproductive females in Sergipe might be taking advantage of the presence of suitable prey in the vicinity of the nesting beach and foraging during the internesting period. Results obtained here should be interpreted with caution, due to the small sample size, and more-comprehensive studies would be valuable to achieve a better understanding regarding this question.

In conclusion, diet studies are valuable for identifying feeding resources and understanding spatial ecology, both of which are key for informing species conservation strategies. Different techniques—such as conventional diet studies, satellite tracking, and stable isotopes analysis could be integrated—thus providing much-needed information for sea turtles from in-water habitats. These results could combine to fill highlighted knowledge gaps (Hamann et al. 2010) and identify priority conservation areas, information which should be considered in regional and national management plans.

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