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Cephalopod Ingestion by Juvenile Green Sea Turtles (*Chelonia mydas*): Predatory or Scavenging Behavior?

Immediately after emerging from eggs on sandy beaches, most sea turtle hatchlings disperse into the sea to enter a pelagic life-phase that may last several years (Meylan and Meylan 1999). During this stage, individuals are believed to associate with convergent oceanic fronts which accumulate floating structures (e.g., debris or algal mats such as *Sargassum* or *Macrocystis*; Nichols et al. 2001) that concentrate small pelagic animals (Carr 1987). Recent studies on the diet of post-hatchling Green Sea Turtles (*Chelonia mydas*) in the Pacific Ocean found no evidence of the association of this species with algal mats, but confirmed the importance of pelagic organisms in the diet of these animals (Boyle and Limpus 2008; Parker et al. 2011).

Asides from young turtles, pelagic ecosystems are comprised of many other organisms, including roaming predators like tuna, billfish, sharks, and dolphins (Dambacher et al. 2010). Oceanic cephalopods (e.g., squids) are also important components of pelagic food chains and serve as food for most of these predators (Clarke 1996; Croxall and Prince 1996; Klages 1996; Smale 1996) as well as for opportunistic scavengers (Croxal and Prince 1994). Because Green Sea Turtles seem to act as opportunists during their open ocean stage of life (Boyle and Limpus 2008), cephalopods might constitute as a complementary food source to their normal diets of cnidarians, gastropods, and crustaceans (Boyle and Limpus 2008; Parker et al. 2011).

Pelagic cephalopods have already been reported in the Green Sea Turtle's diet (e.g., Parker et al. 2011; Seminoff et al. 2002). For example, Parker et al. (2011) considered the presence of fisheries-caught squids in the diet of oceanic Green Sea Turtles as evidence of opportunistic feeding by the turtles on fishing-gear catches. However, implications of these observations and other possible explanations of how turtles may eat pelagic cephalopods have remained poorly discussed topics in the literature.

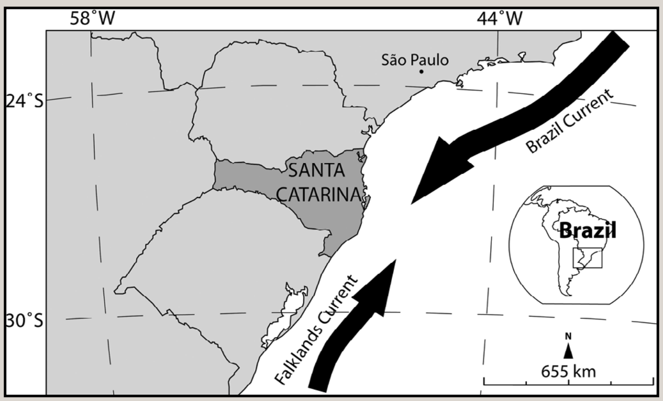

Fig. 1. Map of south Brazil indicating Santa Catarina state (dark shading), and the two converging oceanic currents, Brazil Current and Falklands Current.

The southern region of Brazil (Fig. 1) suffers direct influence of the Subtropical Convergence, an encounter of the cold-water, nutrient-rich Falklands Current with the warm-water, oligotrophic Brazil Current (Castro and Miranda 1998). Hence, the region is the southern limit of occurrence of many tropical marine species, including fishes (Carvalho-Filho 1999) and mangrove trees (Sobrinho et al. 1969). Its rocky reefs, mangroves, estuaries, bays, lagoons, and oceanic waters are also important feeding grounds for marine turtles, especially the Green Sea Turtle, *Chelonia mydas* (Almeida et al. 2011; Bugoni et al. 2003; Guebert-Bartholo et al. 2011). The only genetic assessment of a coastal green turtle juvenile population from southern Brazil indicated a mixed stock population, composed mainly from the rookeries of Ascension and Aves islands (Proietti et al. 2009).

Here we report the occurrence of cephalopod beaks in the gastrointestinal tracts of stranded juvenile *Chelonia mydas* in South Brazil and discuss possibilities regarding when and how the turtles ingested the cephalopods. To achieve this objective we consider how life-history traits could have influenced the

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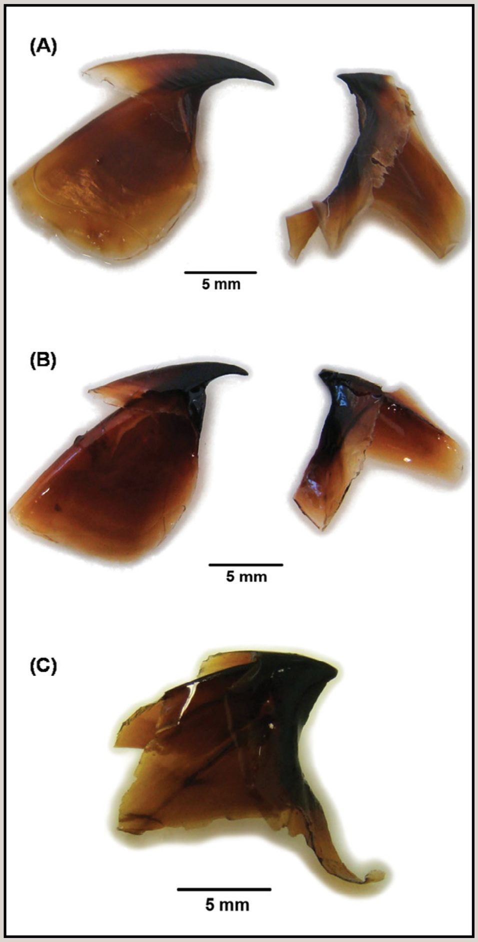

Fig. 2. Cephalopod beaks found in the guts of Green Sea Turtles in South Brazil. (A) Upper (left) and lower (right) beaks from *Chiroteuthis* sp. 1; (B) Upper and lower beak from *Chiroteuthis* sp. 2; (C) Lower beak from *Histioteuthis atlantica*. (©Roberta Santos).

Table 1. Information regarding cephalopod beaks found in the diet of stranded Green Sea Turtles in Santa Catarina, southern Brazil. CCL = curvilinear carapace length; ML = mantle length.

Individual	CCL (cm)	Gut region	Species identified	ML (mm)	Mass (g)
CT03	29.5	Stomach	*Chiroteuthis* sp. 1	–	–
			Chiroteuthis sp. 2	109.2	33.2
CT05	33	Stomach	*Histiotethis atlantica*	86.3	158.9
			Histioteuthis corona corona	79.6	137.3
CT08	23.5	Intestine	*Chiroteuthis* sp. 1	–	–
CT12	32.5	Stomach	*Chiroteuthis veranyi*	116.6	40.3
			Chiroteuthis veranyi	123.9	48.4
			Chiroteuthis veranyi	114.1	37.9
			Chiroteuthis veranyi	104.3	28.9
			Chiroteuthis veranyi	119.0	42.9
			Chiroteuthis veranyi	109.2	33.2
			Histioteuthis sp. 1	115.3	–
			Histioteuthis sp. 1	109.0	–
CT13	28.3	Intestine	*Histioteuthis* sp. 1	105.9	–
			Chiroteuthis veranyi	109.2	33.2
			Chiroteuthis veranyi	114.1	37.9
			Chiroteuthis veranyi	128.8	54.3
			Chiroteuthis veranyi	106.8	31.0
S/CT	–	Intestine	*Histioteuthis* sp. 1	244.1	–

possibility of these organisms coming into contact and whether this interaction occurred with the cephalopods alive (i.e., predation) or dead (scavenging).

Materials and methods.—A total of 27 Green Sea Turtles were found stranded along the coast of Santa Catarina State, southern Brazil, during a dietary study between 2006 and 2009. Gut contents were collected and dietary items were analyzed. Cephalopod beaks were encountered and singled out for this study. All beaks were identified at least to the genus level, based on beak morphology only, since there were no tissues remaining around any of the beaks (Fig. 2). Lower rostral length (LRL) and upper rostral length (URL) were measured to estimate the cephalopod's mantle length (ML, in mm) or ML and body mass (in g) using the regression equations of Clarke (1986) and Lu and Ickeringill (2002). All necropsied turtles had their curvilinear carapace length (CCL in cm) measured.

Results and discussion.—A total of 19 cephalopod beak pairs were found in the stomachs of three turtles and intestines of three others out of the 27 turtles analyzed (22%). Although some of them were cracked, most beaks were in relatively good condition and could be measured. All beaks pertained to six different morphospecies of squids (Cephalopoda: Teuthida) from two genera, *Chiroteuthis* (Chiroteuthidae) and *Histioteuthis* (Histhioteuthidae; Table 1). *Chiroteuthis* spp. had an average ML of 114.6 mm (SD 7.7 mm) and an average mass of 38.8 g (SD 8.0 g), according to the regression by Clarke (1986). *Histioteuthis* spp. had an average ML of 123.4 mm (SD 60.7 mm), although mass was estimated only for two individuals which were identified at the species level (Table 1), according to the regression by Lu and Ickeringill (2002).

The families Chiroteuthidae and Histioteuthidae are comprised of oceanic medium-depth to deep-water gelatinous squids (Young and Roper 1998; Young and Vecchione 2007). Both have ammonia-mediated fluctuation mechanisms (Voight et al. 1994), apparently undergoing ontogenetic and diel vertical migrations in the water column of offshore habitats (Roper and Young 1975). These animals are commonly found in the diet of pelagic predators such as tuna (Salman and Karakulak 2009), swordfish (Hernández-Garcia 1995), blue and short-fin mako sharks (Vaske-Júnior and Rincón-Filho 1998), petrels (Klages and Cooper 1997), albatrosses (Croxall and Prince 1994), and porpoises (Ohizumi et al. 2003). However, this is the first record of these families of cephalopods in the diet of Green Sea Turtles.

We hypothesize three possibilities regarding how turtles that ate oceanic cephalopods were found along the coast of Santa Catarina: 1) that turtles died while in the pelagic life-stage and were carried by oceanic currents to the shore; 2) that turtles were already recruited to the coast when they died, but the squids were ingested when they were still in the pelagic habitat; and 3) that these turtles manifest the uncommon life-history pattern in which individuals move constantly between coastal and pelagic habitats. This last pattern has recently been observed for Green Sea Turtles in the Pacific (Hatase et al. 2006; Parker et al. 2011; Seminoff et al. 2008) but so far there is no evidence that it may also occur in the South

Atlantic. Thus our discussion is based on the first two possibilities, of which the second one seems to be supported by two independent lines of evidence. First, cephalopod beaks are composed of chitin, which is almost indigestible to stomach acids, in contrast to the soft tissues that are rapidly digested; thus beaks may accumulate for months or years in the stomachs of vertebrates (Hernández-Garcia 1995). Therefore, these beaks might have accumulated in the turtles' stomachs while they inhabited pelagic waters, long before stranding. Second, the turtle's carcasses were not extensively decomposed, attesting that they died shortly before stranding.

Given that these squids were probably eaten before the turtles recruited to the coast, another question arises: whether these events occurred as scavenging or predation events? Other sea turtles, like the Loggerhead (*Caretta caretta*), are known to scavenge, for example, on dead fishes (Limpus et al. 2001; Limpus et al. 2008). Swimming organisms like fishes and squids have already been found in Green Sea Turtles' diets elsewhere (Bugoni et al. 2003; Parker et al. 2011; Seminoff et al. 2002) and in addition, this turtle species is known to opportunistically eat objects that float, as evidenced by the enormous amount of floating debris ingested by turtles in different places around the world (e.g., Guebert-Bartholo et al. 2011; Plotkin and Amos 1990). As a result, it is plausible that these animals, when inhabiting oceanic habitats, could eat floating carcasses of fishes or squids. It is noteworthy that squids from the families Chiroteuthidae and Histioteuthidae reproduce in large aggregations with post-spawning mass mortality (Jackson and Mladenov 1994; Rocha et al. 2001), circumstances in which they serve as an important food source for pelagic animals such as albatrosses (Croxall and Prince 1994). Whether or not these events result in floating dead squids at the surface is still unclear (Croxall and Prince 1994).

It is also important to consider the association of squids and sea turtles with commercial fishing practices in the open ocean. Individuals of *Histioteuthis* are relatively common by-catch in deep-water trawling operations in southeast and south Brazil (Perez et al. 2004) and may be discharged into the open sea. In addition, gut contents from eviscerated predatory fishes caught in long-lines may be a source of pelagic cephalopods for Green Sea Turtles (Vaske-Júnior and Rincón-Filho 1998). These fishes have the ability to dive deeply, swim rapidly, and locate prey and therefore are very efficient in capturing large numbers of pelagic squids (Hernández-Garcia 1995).

Regarding the possibility of predation, it is known that captive green turtles are capable of preying upon slow-swimming animals, such as cnidarians and ctenophores (Heithaus et al. 2002), injured fishes (G. O. Longo, pers. obs.), and even octopuses (Caldwell 2005). *Chiroteuthis* spp. and *Histioteuthis* spp. are slow-swimming squids with fragile muscles and bioluminescence (Young and Roper 1998; Young and Vecchione 2007). Despite inhabiting deep-waters during the day, during the night these organisms may be found in shallow waters (Roper and Young 1975). In fact, Green Sea Turtles are more active during the day (Hays et al. 2000, 2002), but there are records of nocturnal deep dives with unknown function (Rice and Balazs 2008) as well as records of individuals foraging at night (Jessop et al. 2002). This suggests that small juvenile Green Sea Turtles and pelagic squids might encounter one another during their lives and, therefore, that these cephalopods could be actively preyed upon by Green Sea Turtles.

Given the lack of information on the natural history of squid from the families Chiroteuthidae and Histioteuthidae and the pelagic life-stage of *Chelonia mydas* in waters of the Southwestern Atlantic, it is not possible to determine if individuals are scavenging or actively pursuing prey. We therefore suggest that studies focusing on the diet of Green Sea Turtles caught in oceanic fisheries (e.g., long-lines) and on the species foraging over eviscerated guts of fishes may yield important insights about the real importance of this interaction.

Pelagic deep sea squids are indispensable food sources for some marine pelagic predators (e.g., Clarke 1996; Croxall and Prince 1996). Although the number of analyzed turtles (27) is relatively small compared to the total number of stranded turtles in the region (147 animals from 2006 to 2009; Projeto TAMAR/ICMBio, unpubl. data), at least ten other non-analyzed dead or live in-treatment Green Sea Turtles had ingested cephalopod beaks, as noted during necropsies or examinations of feces for garbage (E. T. E. Yoshida, pers. comm.). Thus the described interaction might be common in the study region and we believe it could also occur in other parts of the southwestern Atlantic. If squids are commonly ingested through active predation or scavenging behavior, pelagic cephalopods may be an important energy and nutrient source for small juvenile Green Sea Turtles inhabiting oligotrophic waters.

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