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Summertime Foraging and Feeding by Immature Loggerhead Sea Turtles (*Caretta caretta*) from Georgia

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Bjorndal (1997) thoroughly reviewed the literature on the foraging ecology and nutrition of sea turtles. However, much work is still needed to determine the feeding and foraging habits of sea turtles throughout the southeastern USA north of Florida and south of Virginia. Several studies have reported diet selection in sea turtles from Georgia, USA. (Ruckdeschel and Shoop, 1988; Frick, 1997; Creech and Allman, 1998; Frick and Mason, 1998; Pete and Winn, 1998; Frick et al., 1999; Shoop et al., 1999). One of these studies presented data on the quantity of prey items ingested by *Lepidochelys kempii* (Creech and Allman, 1998). The other studies either reported stomach contents with no supporting quantitative data or they only reported anecdotal feeding observations. Here we report and quantify the digestive tract contents of 12 immature loggerhead turtles (*Caretta caretta*) from Georgia, USA. Additionally, we suggest the possible methodology utilized by *Caretta* to obtain the observed prey items.

Methods. — Carcasses of *Caretta caretta* were collected from Wassaw Island (31°53.4'N, 80°58.4'W), Little Cumberland Island (30°57.2'N, 81°25.5'W), and Blackbeard Island (31°28.4'N, 81°13.1'W) along the Georgia coast from 1995 through 1999. Data collected from stranded turtles included: date, time, location, species identity, condition of specimen, curved carapace length and width, and if possible, sex (via gonadal examination). In order to record the location within the digestive tract where a particular prey item was found, twist ties were placed to isolate the esophagus, the stomach, and the intestines (see Wolke and George, 1981). These sections of the digestive tract were then removed and placed into separate collection bags containing 70% isopropyl alcohol. Contents were emptied and sieved through a 1-mm fine mesh colander and rinsed with isopropyl alcohol into the collection bag, which originally housed the sample. Sections of the digestive tract that were emptied were then placed back into their original collection bag until a microscopic analysis could be performed to determine the presence of digested jellyfish via nematocyst occurrence.

Sieved samples were identified and grouped to the lowest taxon possible. Items that could not be identified were grouped into an 'unidentified' category. The sorted samples were allowed to air dry for 24–48 hrs and air-dry mass was then recorded for each pooled sample group. Percent occurrence and percent air-dry mass was also calculated for each species present.

Microscopic investigation (magnification up to 1000x) was used to locate nematocysts within the digestive tract. Digestive tract scrapings and the remains of isopropyl alcohol used for storage and rinsing of the digestive tract, were utilized for microscopic analysis (see Van Nierop and den Hartog [1984] and den Hartog and Van Nierop [1984] for similar methodology).

Results. — Twelve loggerheads were collected from three barrier islands in Georgia from 1995 to 1999: Wassaw Island ($n = 9$), Little Cumberland ($n = 2$), and Blackbeard Island ($n = 1$). Specimens were found throughout the summer from May to July. All loggerheads sampled were immature with curved carapace lengths ranging from 59.4 to 77.0 cm (mean = 66.9 cm). Sex was determined, via gonadal examination, for 8 of the 12 turtles sampled. A female biased sex ratio (7 females: 1 male) was observed. Judging from the amount of body fat present, visual inspection of the viscera, and relatively little barnacle fouling, all of the turtles examined appeared to be healthy prior to death.

Air-dry masses of digestive tract contents from individual *Caretta* ranged from 0.47 to 3452.81 g (mean = 310.6 g; total mass = 10.03 kg). Contents obtained from the esophagus and stomach proved to be the most identifiable as most food items were only partially digested. Intestinal contents were much more fragmented and digested. However, a large percentage (ca. 60%) of the contents collected from the intestines were identifiable and were included into calculations with the stomach and esophageal contents. Anthropogenic debris was absent from all digestive tracts.

Seven different prey groups were recognized from the digestive tract contents of *Caretta* (Table 1). Crabs constituted the highest percentage of all digestive tract specimens encountered, occurring in 100% of the samples and representing 78.2% of the pooled total air-dry mass. Nine different crab species were recognized overall (Table 2). Spider crabs (*Libinia* sp.) and stone crabs (*Menippe mercenaria*) represented the bulk of the air-dry mass from crabs at 23.4% and 22.1%, respectively. These two species also had a high percent occurrence relative to other crab species present (58.3% and 41.7%, respectively). In addition to the aforementioned species, other walking crabs were identified as major prey items (*Calappa flammea*, *Hepatus epheliticus*, and *Persephona mediterranea*). Portunid, or swimming crabs (*Callinectes sapidus* and *Portunus spinimanus*), represented the least common crab species prey item except for the flat-clawed hermit crab (*Pagurus pollicaris*). Interestingly, striped hermit crabs (*Clibinarius vittatus*) were found in 33.3% of the digestive tract samples. This represents the highest percent occurrence of hermit crabs reported from *Caretta* thus far.

Mollusks were the second highest ranked prey item found in digestive tract samples (Tables 1 and 3). Gastro-

Table 1. Percent occurrence and percent air-dry mass of prey items identified from digestive tract contents of immature *Caretta caretta* in Georgia, USA ($n = 12$). Total mass for percentages = 10.03 kg.

Prey group	% Occurrence	% Air-dry mass
Crabs	100.0	78.2
Mollusks	83.3	11.1
Horseshoe crab (*Limulus polyphemus*)	75.0	8.3
Barnacles	41.7	0.2
Anemones	25.0	0.7
Ghost shrimp (*Callianassa biformis*)	25.0	0.2
Jellyfish	25.0	0.6
Unidentified	17.2	0.7

pods represented the bulk of observed mollusks. Knobbed whelks (*Busycon carica*) and Atlantic moon snails (*Polinices duplicatus*) represented 86.4% of the total air-dry mass from mollusks.

Horseshoe crabs ranked high in occurrence (75%) but accounted for only a minor percentage of the overall air-dry mass (8.3%). Such a low air-dry mass percentage may be attributed to the amount of each individual horseshoe crab consumed. Only the legs of *L. polyphemus* were observed in most samples.

Cnidarians (jellyfish and anemones) occurred in 50% of the digestive tract samples but only accounted for 1.3% of the total air-dry mass (Table 1). Due to the high digestibility of cnidarians, likely their importance as a prey item is underestimated. Anemones (*Aiptasia pallida*, *Calliactis tricolor*, and *Paranthus rapiformis*) were identified from individuals found within the esophagus and stomach. In one sample, a single jellyfish (*Aurelia aurita*) was obtained from the esophagus and subsequently identified from the gonadal structure. The presence of all other jellyfishes (*Aurelia aurita* and *Chrysaora quinquecirrha*) was determined through microscopic analysis of nematocysts within the digestive tract lining and/or from the digestive fluid/ preservative mixture left over in the collection bags. A ctenophore, *Mnemiopsis mccradyi*, was found in one of the samples and was identified by the presence of 'ctenes' or comb plates.

Barnacles (*Chthamalus fragilis*) occurred in 41.7% of the digestive tract samples but contributed the lowest percentage to the overall air-dry mass (0.2%; Table 1). Ghost shrimps (*Callianassa biformis*) also ranked fairly low in their importance as a prey item consumed by loggerheads. Barnacles were commonly found affixed to the carapace fragments of crabs and on the shell fragments of gastropod mollusks. Interestingly, ghost shrimp were only found from digestive tract samples that also contained the anemone *Paranthus duplicatus*. However, some samples containing *P. duplicatus* did not contain ghost shrimp.

Table 2. Percent occurrence and percent air-dry mass of crabs identified from digestive tract contents of immature *Caretta caretta* in Georgia, USA ($n = 12$). Total mass for percentages = 7.84 kg.

Prey species	% Occurrence	% Air-dry mass
Spider crabs (*Libinia* sp.)*	58.3	23.4
Calico box crab (*Hepatus epheliticus*)*	41.7	20.3
Stone crab (*Menippe mercenaria*)*	41.7	22.1
Striped hermit crab (*Clibinarius vittatus*)	33.3	0.9
Flamed box crab (*Calappa flammea*)*	25.0	11.0
Mottled purse crab (*Persephona mediterranea*)*	25.0	2.1
Blotched swimming crab (*Portunus spinimanus*)*	16.7	0.9
Blue crab (*Callinectes sapidus*)*	16.7	1.0
Flat-clawed hermit crab (*Pagurus pollicaris*)	8.3	0.3
Unidentified	41.7	18.0

* brachyuran crab

Discussion. — The prey items consumed by the loggerheads examined are common inhabitants of the nearshore environment along the southeastern USA coast (South Carolina, Georgia, and north Florida) during the summer months of May through July (Ruppert and Fox, 1988). Walking crabs and horseshoe crabs appear to be an important prey item for loggerheads. Portunid or swimming crabs are also sought, but to a lesser extent; perhaps due to the difficulty that may exist in catching these relatively fast swimmers. The presence of hermit crabs within the digestive tract contents suggests that certain gastropod mollusks may be misrepresented as important prey items. Perhaps the shells of gastropods may have actually housed hermit crabs rather than snails, although the shells of gastropod mollusks were found in samples not containing hermit crabs. However, observations of captive loggerheads feeding upon hermit crabs have shown that often times a hermit crab will flee its shell as a turtle manipulates the shell in its jaws (MGF, *pers. obs.*), and in most cases the turtle continued to consume the gastropod shell even though the crab had fled. Additionally, most samples containing gastropod shells lacked the horny plates, or opercula, used by *Busycon* and *Polinices* to occlude their shell opening. The presence of opercula confirms that gastropod shells found within the digestive system contained the animals that constructed the shells and not hermit crabs, a secondary tenant of gastropod shells. On only three occasions were opercula found within digestive tract samples that also contained *Busycon* and *Polinices* shells. Only one of the aforementioned samples contained *Busycon* shells, opercula, and hermit crabs. However, it should be noted that the opercula associated with *Polinices* are much thinner and more fragile than those of *Busycon* and may have been too fragmented during consumption and digestion for positive identification. Nonetheless, the possibility exists that the importance of gastropod mollusks in the diet of *Caretta* may be misrepresented within this study and possibly also in

Table 3. Percent occurrence and percent air-dry mass of mollusks identified from digestive tract contents of immature *Caretta caretta* in Georgia, USA ($n = 10$). Total mass for percentages = 1.11 kg.

Prey species	% Occurrence	% Air-dry mass
Knobbed whelk (*Busycon carica*)	41.7	83.2
Mud snail (*Ilyanassa obsoleta*)	41.7	0.5
Moon snail (*Polinices duplicatus*)	33.3	3.2
Channeled whelk (*Busycon canaliculatum*)	25.0	0.5
Slipper snail (*Crepidula fornicata*)	25.0	0.3
Soft-shelled clam (*Sphenia antilliensis*)	25.0	0.1
Great heart cockle (*Dinocardium robustum*)	8.3	0.7
Unidentified	17.8	11.6

past studies that report both gastropod mollusks and hermit crabs from digestive tract samples. Determining whether or not *Caretta* is ingesting mollusks or hermit crabs is important to clarify if one is to investigate the amount of nutrition a turtle receives from its overall diet.

Abdomens from consumed crabs were also present within the stomach contents of ca. 70% of the loggerheads examined. Although we were unable to use abdomens for species identification, they did allow us to determine the sex of some of the consumed crabs. Abdominal segments play an important role in reproduction for brachyuran crabs (see Table 1 for brachyurans consumed; Williams, 1984). The abdomen houses the male crab's reproductive organs and supports brooding eggs in females. Abdomens appear elongated in male brachyurans and rounded in females. During the summer, a female crab may contain millions of spongy eggs beneath its abdomen (i.e., *Callinectes sapidus*; Williams, 1984). Interestingly, ca. 65% of the abdomens found within *Caretta* digestive tracts belonged to female crabs. It is quite possible that these female crabs may have been brooding eggs when they were consumed even though no brachyuran eggs were found in the microscopic analysis of the digestive tract. The high digestibility of crab roe would account for its absence in our samples. Additionally, the majority of *L. polyphemus* legs encountered in our samples appeared to have belonged to females. Male *L. polyphemus* have a modified pair of hooked walking appendages (pedipalps) that are used to attach to the female during amplexus (Ruppert and Fox, 1988). Females have unhooked pedipalps. Hooked pedipalps were absent in ca. 75% of the samples containing horseshoe crab legs. It is possible that *Caretta* did not ingest hooked pedipalps during the consumption of male *Limulus*. Yet, chelicerae (feeding appendages located in front of the pedipalps) and walking legs (located immediately behind the pedipalps) were present in all samples containing horseshoe crab legs. This suggests that the absence of hooked pedipalps would indicate that primarily female *L. polyphemus* were consumed. Horseshoe crabs also brood eggs during the summer and may have been gravid when consumed. A gravid crab would undoubtedly provide a much more substantial source of nutrition than one without eggs.

Ruckdeschel and Shoop (1988) surveyed the gut contents of 137 loggerheads stranded on Cumberland Island, Camden County, Georgia, and found no *Limulus* legs from any of their samples. However, Lutcavage and Musick (1985) found *Limulus* to be a common prey item of loggerheads sampled in Virginia and Layne (1952) provided evidence of *Limulus* consumption by *Caretta*. Similarly, Shoop et al. (1998) indicated that fish, fish bones and (commercial) shrimp (possibly shrimp trawler by-catch or trawl net derived) are occasionally found packed within the gastrointestinal tract of some stranded loggerheads examined on Cumberland Island. None of the loggerheads examined during our study contained commercial shrimp or fish.

Plotkin et al. (1993) reported that the highest occurrence of brachyuran crabs consumed by loggerheads in Texas was during the summertime. This also coincides with the breeding of brachyurans from the Gulf of Mexico (Heard, 1982). However, more detailed studies are needed to determine whether or not *Caretta* is in fact consuming gravid crabs. Additionally, more studies are needed to determine if *Caretta* feeds on brachyurans outside of the summer months in Georgia. In areas where loggerheads feed upon brachyurans year-round, it may be possible to determine to what extent loggerheads benefit from the crab's reproductive cycle, if at all.

Bivalve and gastropod mollusks were also highly represented in the digestive tract contents of *Caretta*. Whelks (*Busycon* sp.) and Atlantic moon snails (*Polinices duplicatus*) are common within the marshes and nearshore environments at depths up to 18 m (Ruppert and Fox, 1988). As previously mentioned, their occurrence in the diet of *Caretta* may be misrepresented since hermit crabs are often times found utilizing their discarded shells (Williams, 1984). However, we have no reason to believe that the animals themselves are not being consumed since their appearance to a turtle would not be unlike that of a hermit crab. With the exception of a single great heart cockle (*Dinocardium robustum*), it is our belief that the other ingested mollusks (*Crepidula fornicata*, *Ilyanassa obsoleta*, and *Sphenia antilliensis*) as well as barnacles (*Chthamalus fragilis*) were consumed incidentally through the sediment surface or as epibionts on larger mollusks or even hermit crabs.

The presence of jellyfish and their nematocysts suggest that loggerheads also feed within the water column during the summer months. Moon jellies (*Aurelia aurita*) and sea nettles (*Chrysaora quinquecirrha*) are the most common jellyfish in the nearshore waters of the southeastern USA from May through August (Calder, 1977). Digestive tract samples containing jellyfish or their nematocysts also contained brachyuran crabs. However, the brachyurans associated with *Aurelia* and *Chrysaora* were juveniles (*Libinia* sp. and *Persephona mediterranea*) that have been documented as commensals on jellyfish until their adult lifestage where they then shift towards a benthic existence (Williams, 1984). Some digestive tracts containing *Chrysaora* also contained the warty comb jelly, *Mnemiopsis mccradyi*, a common prey item of *Chrysaora* (Ruppert and Fox, 1988). Only one turtle was sampled that had consumed jellyfish (*Aurelia*) as well as benthic gastropods. Apparently loggerheads shift between pelagic foraging and benthic foraging within the same season. Shifts in their foraging methodology may occur due to individual turtle preference or because of changes in prey abundance.

Other cnidarians consumed by *Caretta* were the anemones *Aiptasia pallida*, *Calliactis tricolor*, and *Paranthus rapiformis*. *Aiptasia* and *Calliactis* are common epibionts of hermit crabs. Both species were found from digestive tracts also containing hermit crabs (*Clibanarius vittatus* and *Pagurus pollicaris*). *Paranthus* is a burrowing anemone commonly referred to as the 'sea onion' due to its appearance when it contracts its body into a tight ball and floats to a new burrowing location via wave action (Ruppert and Fox, 1988). It is easy to picture a loggerhead seizing the opportunity to prey upon *Paranthus* as it floats passively within the water column. However, some specimens of *Paranthus* were found in digestive tract contents also containing ghost shrimp (*Callianassa biformis*), and other burrowing species (*Busycon carica*, *Dinocardium robustum*, *Menippe mercenaria*, and *Polinices duplicatus*). These prey items suggest that loggerheads in Georgia (or other areas in the southeastern U.S) might actively dig for prey items similar to loggerheads performing infaunal mining in Australia (Preen, 1996). *Callianassa* seems to be too small (3 cm) to be actively sought by a subadult loggerhead and may have been ingested inadvertently while the turtle was consuming other burrowing organisms. Possibly such burrowing specimens were initially displaced by shrimp trawlers and subsequently consumed by *Caretta*.

During the summer months (May–July) in Georgia and possibly in similar and adjacent marine habitats in South Carolina and north Florida, immature loggerheads forage in pelagic and benthic habitats of the nearshore environment, including the salt marsh. Based upon the natural history of the prey items observed *Caretta* may obtain its food in a variety of ways. By perusing and scanning the benthic environment a loggerhead could easily obtain the crabs and mollusks that constitute the bulk of its diet. However, the majority of these animals have also been documented to construct shallow burrows within the bottom sediment (Fox and Ruppert, 1985). Additionally, the occurrence of deeper burrowing shrimp and anemones within the loggerhead's diet also suggest that digging may be performed to obtain prey items. Future studies are needed to address diet selection and foraging by loggerheads during the months outside of the summertime in Georgia. Moreover, studies are needed which address diet selection in all adult sea turtles occurring in Georgia.

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