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SHORT COMMUNICATION

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Cephalopods preyed on by loggerhead turtles, *Caretta caretta* (Reptilia: Cheloniidae), from the eastern Tyrrhenian Sea

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Abstract: This study presents the results of the examination of cephalopod remains extracted from the digestive tract of 40 loggerhead turtles, *Caretta caretta*, stranded along the Campanian coasts (Southern Italy, eastern Tyrrhenian Sea). We retrieved the remains of 23 cephalopods from 16 turtles (frequency of occurrence = 40%). They belonged to *Sepia officinalis* (19 specimens) and *Octopus vulgaris* (2 specimens), both of them benthic neritic species, and *Histioteuthis reversa* (2 specimens), an oceanic species. Accordingly, loggerheads appear to feed both on the bottom, seemingly in shallow waters, and in the open seawater column; both on muscular items (*S. officinalis* and *O. vulgaris*) and ammoniacal ones (*H. reversa*). This is the first record of *H. reversa* as a prey of the loggerhead turtle.
***Keywords*:** Mollusca, Cephalopoda, Reptilia, Chelonidae, feeding ecology, Mediterranean Sea

Sažetak: GLAVONOŠCI KAO PLIJEN GLAVATE ŽELVE, *CARETTA CARETTA* (REPTILIA: CHELONIIDAE), IZ ISTOČNOG TIRENSKOG MORA. Ova studija prikazuje rezultate istraživanja ostataka plijena izvađenih iz probavila 40 glavatih želvi, *Caretta caretta*, nasukanih duž obala Kampanije (južna Italija, istočno Tirensko more). Iz 16 kornjača izvadili smo ostatke 23 glavonošca (učestalost pojavljivanja = 40%). Pripadali su vrstama *Sepia officinalis* (19 primjeraka) i *Octopus vulgaris* (2 primjerka), koje su obje bentoske neritičke vrste, kao i oceanskoj vrsti *Histioteuthis reversa* (2 primjerka). Prema tome, čini se da se glavate želve hrane na dnu, vjerovatno u plitkim vodama, kao i u stupcu otvorenih morskih voda; i to mišićavim plijenom (*S. officinalis* i *O. vulgaris*) kao i plijenom bogatim amonijakom (*H. reversa*). Ovo je prvi zapis vrste *H. reversa* kao plijena glavate želve.
***Ključne riječi* :** Mollusca, Cephalopoda, Reptilia, Chelonidae, ekologija ishrane, Sredozemno more

INTRODUCTION

Cephalopods are important elements in oceanic and neritic marine food webs, both as predators of invertebrates and fish and as prey (Clarke, 1996a). As for the latter role, the list of cephalopod predators is quite long and comprises members of several taxa, including Crustacea, Cephalopoda, Osteichthyes, Chondrichthyes, Aves, Mammalia (e.g. Clarke, 1996b; Croxall and Prince, 1996; Smale, 1996; Bello, 1997) as well as Reptilia, namely sea turtles (Bello *et al.*, 2011). Moreover, prey-cephalopods may be roughly subdivided into the category of fast-swimming species (usually provided with muscular tissues) and comparatively slow-swimming ones (often characterized by gelatinous and/or ammonium-rich body tissues that enhance buoyancy) (Clarke, 1996b). The latter are the ones that may be preyed upon by comparatively slow-moving predators, such as sea turtles (Bello *et al.*, 2011).

Sea turtles, including the loggerhead *Caretta caretta* (Linnaeus, 1758), are highly migratory animals that dwell in various habitats throughout their life cycle. In particular, adults change several habitats on an annual basis as they migrate between foraging and breeding sites. These sites might be located several hundreds of kilometres apart, while even during the breeding season individuals may navigate to distances of tens of kilometres from the nesting sites (Margaritoulis *et al.*, 2003; Plotkin, 2003; Schofield *et al.*, 2010).

The loggerhead is the most abundant sea turtle in the Mediterranean Sea, with widespread occurrence over the entire basin (Casale *et al.*, 2018). This species is listed globally as 'vulnerable' with a 'decreasing population trend' in the International Union for Conservation of Nature Red list of Threatened Species (Casale and Tucker, 2017).

Loggerhead turtles are primarily generalist predators that exploit prey items ranging from plankton to fish (e.g. Mortimer, 1982; Bjorndal, 1985; Dodd, 1988; Plotkin *et al.*, 1993; Narazaki *et al.*, 2013; Di Beneditto *et al.*, 2015). Indeed, they are able to forage upon a

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wide variety of invertebrates (mostly crustaceans and molluscs) as well as bony fishes, especially ones that are easy to catch because of their slow-moving habits (Bjorndal, 1996). This opportunistic behaviour is also observed in the Mediterranean Sea (Casale *et al.*, 2008; Lazar *et al.*, 2011; Travaglini and Bentivegna, 2011; Hochscheid *et al*., 2013). Seemingly, the main limitation in the loggerhead's selection of available prey is prey swiftness.

Feeding ecology studies carried out along the Campanian coasts (Southern Italy, Central Tyrrhenian Sea) in 1991-2001 and 1996-2006, showed that the neritic sandy zone off the northern shore provides summer foraging grounds for both late juveniles and adult loggerhead turtles (Bentivegna *et al.*, 2001; Travaglini and Bentivegna, 2011). The present paper deals with the teuthological prey items collected from loggerheads in the years 1998-2000 in order to describe the predatory relationship between the loggerhead turtle and cephalopods in the Central Tyrrhenian foraging grounds, focusing particularly on the possible active predation upon them by these turtles.

MATERIAL AND METHODS

This study was carried out on a dry collection of cephalopod remains extracted from the digestive tract of 40 examined loggerheads stranded along the Campanian coasts (Southern Italy), in the eastern Tyrrhenian Sea, from July 1998 to August 2000, following their accidental death. The curve carapace length (CCL) of these animals ranged from 36.5 to 80.0 cm (mean = 63.8 cm; SD = 10.9 cm). Individual CCLs were recorded before the general necropsy, following Wolke and George (1981), during which the ingested contents were collected from the oesophagus, stomach and intestine of all the examined turtles. Solid prey remains were sampled by rinsing the whole contents with freshwater on a 1 mm mesh sieve. Food items from each turtle were fixed in 70% ethanol and, when dry, sorted and identified to the lowest possible taxon and weighted to the nearest 0.1 g. The rank of each identified prey category was calculated multiplying the percentage occurrence by the percentage dry weight (Plotkin *et al.*, 1993).

Cephalopods remains were stored dry. Subsequently they were trusted to the first author for identification. This was carried out on the beaks, both upper and lower ones, by means of Clarke's (1986) handbook and by comparison with one of the authors (G.B.) beak reference collection. When cephalopod remains consisted of cuttlebone fragments only, they were used to identify the *Sepia* species according to their overall size, width, septa pattern and rear end spine.

Both upper and lower beaks were measured to the nearest 0.1 mm below: hood length of octopus and cuttlefish beaks (UHL and LHL for upper and lower beaks, respectively); rostral length of squid beaks (URL and LRL for upper and lower beaks, respectively). The estimated body mass (EW) of preyed upon cephalopods was derived by the regression equations given by Pérez-Gándaras (1983) for *Octopus vulgaris* Cuvier, 1797 and *Sepia officinalis* Linnaeus, 1758, and by Quetglas *et al.* (2010) for *Histioteuthis reversa* (Verrill, 1880). The identified material is deposited in the Darwin-Dohrn Museum of the Stazione Zoologica Anton Dohrn of Naples (accession code: SZN-MOL0046).

RESULTS AND DISCUSSION

Dry weights of digestive tract contents of individual turtles ranged from 1.91 g to 308.80 g (mean = 45.02 g, SD =380.9); the overall dry weight was 1832.45 g. Forty-one different species of prey were identified. The most numerous taxa were: Mollusca (n = 24 species), Crustacea (n = 16), and Osteichthyes (n = 6). Sea horses, crabs and molluscs from vegetation-free sandy and muddy bottoms provided most part of the diet of the examined turtles. In particular, molluscs were the third highest ranked prey in the loggerhead diet, occurring in 71.8% of the turtles and accounting for 23.6% of total dry weight (see also Bentivegna *et al*., 2001).

Cephalopod remains were found in only 16 of 40 dissected turtles, with a frequency of occurrence of 40.0%. They largely consisted of hard body parts and/or fragments thereof, including beaks, eye lenses and cuttlebones, most of them damaged to some degree by the turtle's digestive process. In particular, all cuttlebones consisted of partly digested fragments. In total, prey items from 23 individual cephalopods were counted. All of them were identified to the species level. They belonged to only three species: *Sepia officinalis* (Sepiida: Sepiidae) (remains of 19 specimens), *Histioteuthis reversa* (Teuthida: Histioteuthidae) (2 specs.) and *Octopus vulgaris* (Octopoda: Octopodidae) (2 specs.) (Fig. 1). Table 1 lists the prey-cephalopods found in the loggerhead digestive tract contents; it also includes details about collection dates, hard part remains and estimated body masses for each prey-cephalopod. After the taxonomical identification of prey, only the well-preserved beaks were deposited in the Zoological Collections of the Stazione Zoologica Anton Dohrn (Naples, Italy); their accession codes are reported in Table 1.

The prey-cephalopod frequency of occurrence for the examined loggerheads ranged from 1 to 3 and the mean value was 1.44 prey items *per* loggerhead containing cephalopods or 0.57 cephalopod prey items *per* loggerhead when taking into account all examined turtles. The mean frequency for *S. officinalis*, the most abundant prey, was 1.19 prey items *per* loggerhead containing cephalopods (or 0.48 for all turtles). As for the other two prey-cephalopods, the mean frequency was rather low, 0.13 prey items *per* loggerhead containing cephalopods (or 0.05 for all turtles), for both items. Four out of six cases of multiple prey-cephalopod involved *S. officinalis*. In the other two cases, the prey item spectra were: *S. officinalis* plus *H. reversa* and *S. officinalis* plus *O. vulgaris*, respectively.

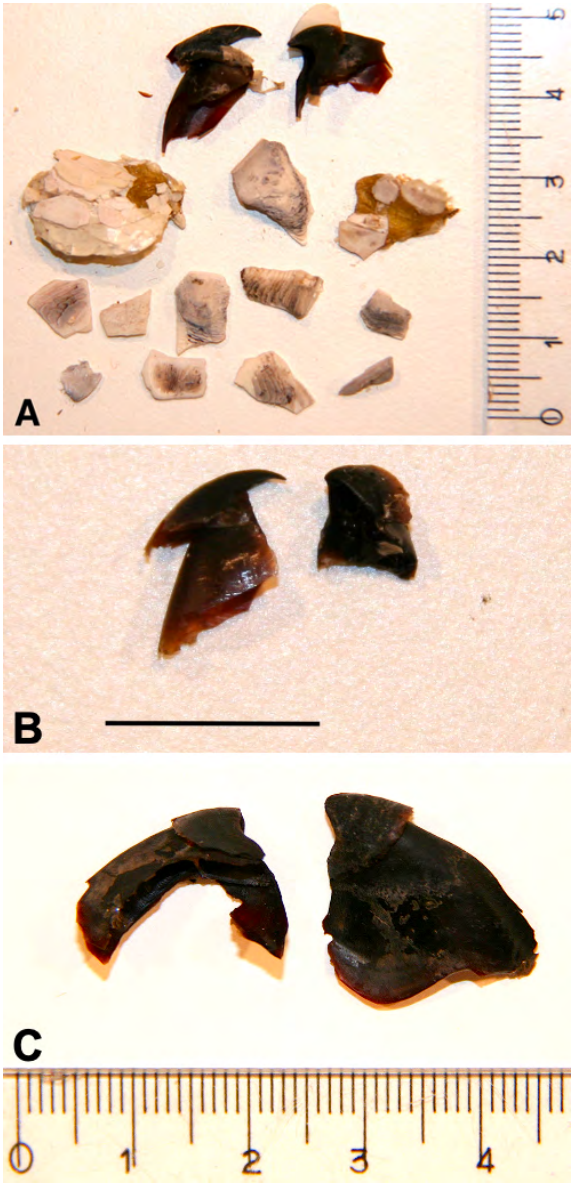

Fig. 1. Remains of cephalopods from the digestive tracts of loggerhead turtles. Pair of beaks and cuttlebone fragments of *Sepia officinalis* from loggerhead specimen no. 14 (**A**). Pair of beaks of *Histioteuthis reversa* from loggerhead specimen no. 12 (scale bar = 1 cm) (**B**). Pair of beaks of *Octopus vulgaris* from loggerhead specimen no. 13 (**C**).

The prey estimated body mass widely ranged from 6.5 g (a cuttlefish) to over a kilogram, that is 1337 g (an octopus). It is interesting that the remains of the smallest and the largest prey items were found in the gut of the same predator, which once again is indicative of the opportunistic feeding behaviour of the loggerhead turtle. Most prey-cephalopod estimated body masses, i.e. 18 out of 20, ranged from 30 to 460 g. The two largest prey items were octopuses, each of which had a body mass on the order of 1 kg.

Present results show that cephalopods may represent a comparatively important prey item of the loggerhead turtle since they were found in the digestive tract of 40.0% of the examined loggerheads. However, the importance in terms of dry weight of cephalopods in the loggerhead diet may be underrepresented in this study, since their remains consisted of hard parts only (beaks and cuttlebones) from the intestinal tracts, with the exception of just one specimen.

The examined turtles had probably been feeding in a near-shore sandy area, prior to their stranding. Indeed, the identification of prey remains contributed to understand where the examined loggerheads had fed: *S. officinalis* and *O. vulgaris* are demersal species, inhabiting neritic waters including the first few meters of depth (Reid *et al.*, 2005 and Norman *et al.*, 2016, respectively), whereas *H. reversa* is oceanic and dwells in the water column from 50 to 630 m during the day, and from 10 to 260 m at night (Roper and Jereb, 2010). Moreover, despite the taxonomic diversity of the preyed-upon cephalopods, since they belong to three different orders, they share the feature of being comparatively slow moving. In particular, *H. reversa* has ammonium-rich tissues and, thanks to its neutral buoyancy, can stand suspended in the water with "a very characteristic posture, in which the arms and tentacles are curled above the head, forming a 'squid ball.' When disturbed, they straighten up and swim rather slowly and obliquely upward" (Michael Vecchione, pers. comm.), therefore, they are an easy prey for turtles. In one case, a loggerhead intestine contained remains of both the latter squid and a cuttlefish, which seem to suggest that it had moved in a short lapse of time from a deep-water area to a shallow neritic ground. It is also possible that the two specimens of *H. reversa* might be discards of trawl fishing operations, therefore ingested by turtles close to the sea surface. Incidentally, *H. reversa* appears to be a new dietary record for the loggerhead turtle.

Several species of cephalopods have been reported as food items of the loggerhead turtle by Dodd (1988) from Azores (*Leachia* sp.), Madeira (*Japetella* sp.), Nova Scotia (*Onychoteuthis banksii*), South Africa (*Spirula* sp.), and Balearic Islands (*Todarodes sagittatus*). Other authors later reported more cephalopods preyed upon by the loggerhead turtle, from the western Mediterranean basin (Tomas *et al.*, 2001) and from Brazilian waters (Di Beneditto *et al.*, 2015). More recent papers about loggerheads from the Mediterranean also recorded *Sepia officinalis* (Casale *et al.*, 2018; Karaa *et al.*, 2018) and *Octopus vulgaris*; the latter cephalopod from the Gulf of Gabes (Tunisia) (Kaara *et al.*, 2018). Other chelonian species appear to feed on cephalopods to a greater degree; e.g. *Chelonia mydas* (Vélez-Rubio *et al.*, 2015), and *Dermochelys coriacea* (Bello *et al.*, 2011).

According to Plotkin *et al.* (1993) and Laurent and Lescure (1994), it is doubtful that loggerheads can capture live fast-swimming animals such as teleost fishes, shrimps and cephalopods. Tomas *et al.* (2001) hypothesized that the cephalopods found in the digestive tract of sea turtles have been eaten not alive, but dead, as discarded by-catch, or ingested by the turtles themselves

Table 1. Cephalopods from the digestive tract of 40 loggerhead turtles, *Caretta caretta*, stranded along the Campanian coasts (eastern Tyrrhenian Sea). N = quantity of prey-cephalopods; U = upper beak; L = lower beak; P = pair of beaks; CB = cuttlebone residuals; n.a. = date not available.

C. caretta specimen #	Date of collection	Stomach / intestine	Prey-cephalopod species	N	Cephalopod residual parts	Estimated weight (g)	Accession code
1	12.7.98	stomach	*S. officinalis*	1	U	130	SZN-MOL0046-1
2	11.6.00	intestine	*S. officinalis*	1	P	142	SZN-MOL0046-2
3	7.8.00	stomach	*S. officinalis*	1	CB	-	-
4	3.8.01	intestine	*S. officinalis* + *H. reversa*	1 1	CB L	- 148	SZN-MOL0046-4
5	2.9.01	intestine	*O. vulgaris*	1	U	966	SZN-MOL0046-5
6	12.11.01	intestine	*S. officinalis*	1	CB + L	34	SZN-MOL0046-6
7	20.5.02	intestine	*S. officinalis*	1	CB	-	SZN-MOL0046-7
8	22.5.02	stomach	*S. officinalis*	2	2 P, 1 lens, CB	58; 185	SZN-MOL0046-8
9	2.6.02	intestine	*S. officinalis*	2	1 lens + CB + 2 P	185; 458	SZN-MOL0046-9
10	7.6.02	intestine	*S. officinalis*	2	CB + 2 P	40; 237	SZN-MOL0046-10
11	7.6.02	stomach	*S. officinalis*	1	1 lens + CB + P	68	SZN-MOL0046-11
12	23.6.02	intestine	*H. reversa*	1	P	73	SZN-MOL0046-12
13	9.8.02	intestine	*O. vulgaris* + *S. officinalis*	1 1	P CB + U	1337 6.5	SZN-MOL0046-13
14	15.8.02	intestine	*S. officinalis*	1	CB + P	334	SZN-MOL0046-14
15	10.6.02	stomach	*S. officinalis*	1	CB + 3 flesh fragments + P	142	SZN-MOL0046-15
16	n.a.	stomach	*S. officinalis*	3	CB + 2 P + 1 U	80; 163; 237	SZN-MOL0046-16

during entrapment in fishing nets. Contrary to them, we believe that loggerheads are capable of actively preying live cephalopods, both benthic shallow water ones (*S. officinalis* and *O. vulgaris*) and, possibly, sluggish midwater ones (*H. reversa*). In fact, the remains of *O. vulgaris* and *S. officinalis* examined in this study were retrieved from loggerheads who had abundantly fed also on the grey swimming crab *Liocarcinus vernalis* (Brachyura: Polybiidae). In the Mediterranean basin, this crab is one of the characteristic-exclusive species of "fine, well-sorted sand" biocenosis (SFBC according to Pérès and Picard, 1964), a bivalve-dominated assemblage that occupies huge areas in large bays from 2.5 m to 25 m. In fact, in the eastern Central Tyrrhenian Sea, in an area quite close to that investigated by us, Minervini *et al.* (1982) found that *L. vernalis* dominated the decapod crustacean community with a peak at 10 m depth. During summer, *S. officinalis*, whose preferred food is represented by crustaceans, migrates to shallow water soft bottom grounds (Reid *et al.*, 2005) including the SFBC, where it exploits the *L. vernalis* population. Therefore, the loggerhead turtle can seemingly forage both on predators (*i.e.* cephalopods) and their prey (*i.e.* crabs).

As regards *O. vulgaris* as a loggerhead prey item, an indirect evidence of this turtle capabilities to actively prey upon the octopus is provided by observations of repeated cleptoparasitism carried out by a female loggerhead, a summer resident in the SW Adriatic Sea, on octopuses caught by skin divers (Elvira Antonucci, pers. comm.). In conclusion, the present results represent a further contribution to understand the interesting feeding ecology of the loggerhead turtle in the Mediterranean Sea.

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