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DIET COMPOSITION OF A GREEN TURTLE, *CHELONIA MYDAS*, FROM THE ADRIATIC SEA

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The green sea turtle (*Chelonia mydas*) is a foraging specialist, with strong tendency towards herbivory of neritic-stage individuals. Due to lack of data on the feeding ecology of this species in the Mediterranean, we analysed diet composition of one juvenile green turtle with the curved carapace length of 40.0 cm, found dead in the eastern Adriatic Sea (Croatia) in December 2001. The turtle has dominantly feed upon benthic polychaetes *Chaetopterus variopedatus* (69.8%), while seagrass (*Cymodocea nodosa*) and algae accounted for 11.1% of the total wet mass. Species composition and their vertical distribution showed that the turtle was in the post-pelagic stage and has foraged in the shallow coastal waters. We discuss our results in the light of recent recoveries of *C. mydas* juveniles in Albania and Greece, and suggest the existence of an Ionian-Adriatic developmental pathway of green turtles from reproductive habitats in the eastern Mediterranean Sea.

Key words: sea turtles, *Chelonia mydas*, diet, development, Adriatic Sea, Mediterranean

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Zelena želva (*Chelonia mydas*) je specijalist u ishrani, sa snažnom tendencijom neritičkih stadija prema herbivornosti. Zbog potpunog nedostatka podataka o ekologije ishrane ove vrste u Sredozemlju, proveli smo analizu sadržaja probavila jedne zelene želve zakrivljene dužine karapaksa 40 cm, nađene uginule u istočnom Jadranu (Hrvatska) u prosincu 2001. Dominantan plijen predstavljao je pridneni mnogočetinaš *Chaetopterus variopedatus* (69.8%), dok su morske cvjetnice (*Cymodocea nodosa*) i alge sačinjavale 11.1% ukupne mokre mase sadržaja probavila. Sastav vrsta i njihova vertikalna

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raspodjela pokazali su da je kornjača bila u post-pelagičkoj razvojnoj fazi, hraneći se u plitkim obalnim vodama. Rezultati su raspravljeni u svjetlu novih nalaza juvenilnih primjeraka *C. mydas* u Albaniji i Grčkoj, što ukazuje na postojanje jonsko-jadranskog razvojnog puta zelenih želvi iz reproduktivnih staništa u istočnom Sredozemlju.

Ključne riječi: morske kornjače, *Chelonia mydas*, ishrana, razvoj, Jadransko more, Sredozemlje

The green turtle, *Chelonia mydas* (Linnaeus, 1758), belongs to a group of sea turtle species with the oceanic-neritic developmental pattern, characterized by an early juvenile phase occurring in the oceanic zone and latter shift to near shore neritic waters (BOLTEN, 2003; ARTHUR *et al*., 2008). This shift in habitat use during ontogeny is followed by shifts in the diet, from epipelagic omnivorous or carnivorous feeding strategy of the oceanic juveniles to a strong tendency towards herbivory of the neritic stage green turtles (BJORNDAL, 1980, 1997; MORTIMER, 1981; HIRTH, 1997; LÓPEZ-MENDILAHARSU *et al*., 2005; RUSSELL & BALAZS, 2009; CARRIÓN-CORTEZ *et al*., 2010). The diet composition at different neritic feeding habitats depends on the composition and availability of local plant communities, and to some extent by foraging preferences, especially for certain species of red algae (FUENTES *et al*., 2006; LÓPEZ-MENDILAHARSU *et al*., 2008; ARTHUR & BALAZS, 2008; RUSSELL & BALAZS, 2009; CARRIÓN-CORTEZ *et al*., 2010).

The recruitment to neritic habitats in green turtles generally occurs at small sizes, between 30 and 40 cm in the carapace length (MUSICK & LIMPUS, 1977; BJORNDAL & BOLTEN, 1988; HIRTH, 1997), with duration of the oceanic stage of one to 10 years (MORTIMER, 1995). Age at sexual maturity is estimated at 26 (FRAZER & LADNER, 1986) to 40 years (LIMPUS & CHALOUPKA, 1997), after which they commence breeding migrations between foraging grounds and nesting areas that are undertaken every few years (HIRTH, 1997). During non-breeding periods adults reside at coastal neritic feeding areas which are sometimes shared with juvenile developmental habitats (LIMPUS *et al*., 1994; LÓPEZ-MENDILAHARSU *et al*., 2005; CARRIÓN-CORTEZ *et al*., 2010), and for which they exhibit strong site fidelity (BRODERICK *et al*., 2007).

The green turtles are listed as Endangered throughout their range (IUCN, 2010). In the Mediterranean Sea green turtles form genetically distinct population (BOWEN *et al*., 1992; ENCLADA *et al*., 1996) that suffered heavy exploitation over the past century (SELLA, 1995). BRODERICK *et al*. (2002) estimated that 339 – 360 green turtles nest annually in the Mediterranean, with rookeries in Turkey and Cyprus accounting for about 99% of the regional nesting effort (KASPAREK *et al*., 2001). If a recently discovered population in Syria is added (104 nests laid in 2004; REES *et al*., 2008), than Mediterranean green turtle population counts between 1116 and 1185 nesting females, assuming the clutch frequency of 1.9 – 3.5 clutches per season and 3-years remigration interval (BRODERICK *et al*., 2002).

Although the major nesting areas of green turtles in the Mediterranean are well known (KASPAREK *et al*., 2001; REES *et al*., 2008), there is a lack of data on the biology and distribution of this species in marine habitats. Post-nesting satellite tracking of adult females has shown that the waters of Cyprus, Israel, Egypt and Libya host neritic foraging and witnering habitats for adults (GODLEY *et al*., 2002; BRODERICK *et al*., 2007). Juvenile green turtles have been recorded throughout the Mediterranean (MARGARITOULIS *et al*., 1992; LAURENT *et al*., 1997; GODLEY *et al*. 1998a,b; GIANGUZZA

et al., 2000; MESCHINI, 1997; ORUÇ, 2001; LAZAR *et al*., 2004a), but the locations of developmental habitats are not clearely defined. Their existance have been documented only in the eastern Mediterranean, in Lakonikos Bay in the Peloponnesus, Greece (MARGARITOULIS & TENEKETZIS, 2003), in the waters off the Fethiye beach in Turkey (TÜRKOZAN & DURMUS, 2000), and along the southeastern coast of Turkey near Syria (YALÇIN-ÖZDILEK & AUREGGI, 2006). No study addressed the issue of feeding ecology of green turtles in the region, beside observations by DEMETROPOULOS & HADJICHRISTOPHOROU (1995).

With this paper we present analysis of diet composition of one juvenile green turtle (notch-tip Curved Carapace Length, CCL = 40.0 cm), reported in LAZAR *et al*. (2004a). The turtle was found dead, incidentally captured in gillnet, 1 km east from the City of Trpanj, along the northeastern coast of the Pelješac Peninsula in Croatia (eastern Adriatic Sea; Fig. 1), on the 14th December 2001. We performed general necropsy (WYNEKEN, 2001) and isolated content of the whole digestive tract (oesophagus, stomach and intestines) by rinsing in the clear water on a 1 mm mesh sieve (FORBES, 1999). The whole digestive sample was preserved in 76% ethanol and latter examined under the stereomicroscope. Taxonomic identification was preformed to the lowest taxon possible (ERCEGOVIĆ, 1957; RIEDEL, 1963); the nomenclature used follows the European Register of Marine Species (COSTELLO *et al.*, 2008). We

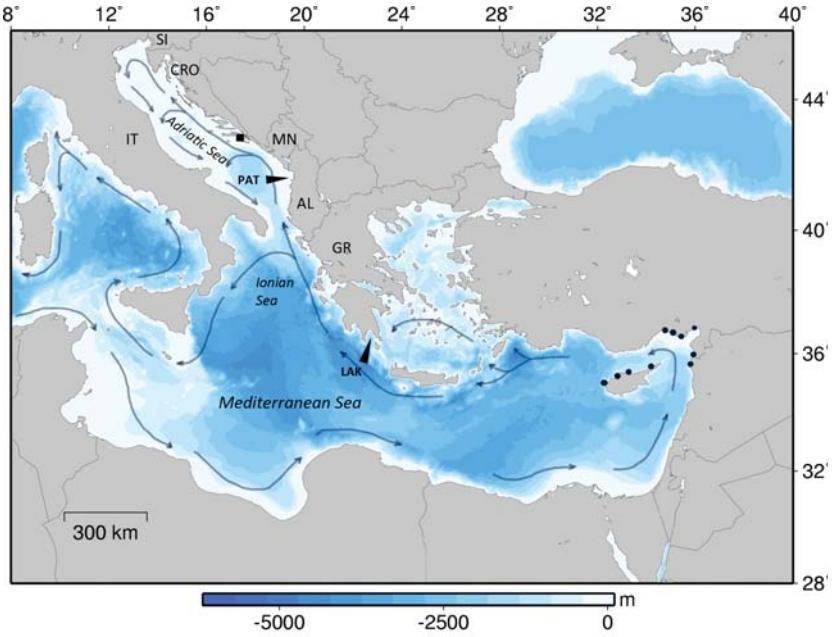

Fig. 1. The eastern Mediterranean Sea with the locations of two developmental habitats of green turtle *Chelonia mydas* (PAT, Patok Bay; LAK, Lakonikos Bay) along the Ionian – Adriatic developmental pathway [■ finding of the specimen from this paper; ●, nesting beaches of green turtles in the Mediterranean, after CASALE & MARGARITOULIS (2010); →, direction of prevailing surface sea currents, simplified from MENNA & POULAIN (2010); IT, Italy; SI, Slovenia; CRO, Croatia; MN, Montenegro; AL, Albania; GR, Greece].

determined wet mass (w.m.) of identified taxonomic groups by weighing to ± 0.1 g and calculated their mass percentage in the diet. Abundance of identified species of algae was visually estimated and expressed as the relative contribution (%) of each species within the algae group.

The wet mass of digestive tract content was 172.3 g. The turtle has dominantly feed upon animal matter (69.8%), while marine plants, both algae and seagrass, accounted for 11.1% of the total w.m. (Tab. 1). Within animal prey we recorded only benthic polychaetes, represented with a tube worm *Chaetopterus variopedatus*. This species lives permanently in tough flexible tubes with open end protruding slightly from the substratum. In the Adriatic Sea, it inhabits soft bottoms between one and 400 m in depth (ZAHTILA, 1995), and is common in the meadow of *Cymodocea nodosa*. Digestive tract contained only fragments of tubes up to 3 cm in length, which made counting of ingested individuals impossible. However, according to appearance and composition, unidentified organic remains found in the guts were most likely of animal origin, possibly belonging to digested bodies of C. *variopedatus*; hence, the proportion of animal matter in the diet is most likely underestimated. The second highly ranked prey in terms of wet mass was seagrass *C. nodosa*, which was identified upon fragments of leaves of about 2 cm in length, found in the stomach. In the south-eastern Adriatic *C. nodosa* grows on sandy bottoms up to 10 m in depth (RIEDEL, 1963; BAKRAN-PETRICIOLI, 2007), forming small meadows from a few square meters to maximum of one hectare. C. *variopedatus* and *C. nodosa* accounted together 78.7% of turtle diet and were the most important dietary items. Contribution of marine algae was low, with the prevalence of red algae, mostly *Rhodymenia ardissonei* (Tab. 1). All identified algae belonged to epilithic species with communities developed on the rocky bottom of the infralittoral zone.

In most neritic habitats green turtles exhibit very specialised diet, feeding primarly on macroalgae and/or seagrass (BJORNDAL, 1980; MORTIMER, 1981; SEMINOFF *et al.*, 2002; LÓPEZ-MENDILAHARSU *et al.*, 2005; FUENTES *et al.*, 2006; RUSSELL & BALAZS,

Tab. 1. Diet composition of a juvenile green turtle, *Chelonia mydas*, from the eastern Adriatic Sea, Croatia. The numbers in parentheses refer to estimated relative abundance (%) of identified species within the algae group.

Diet component	Wet Mass (g)	Mass %
Vascular plants	15.3	8.9
Plantae, Magnoliidae		
Cymodocea nodosa (Ucria) Ascherson		
Algae	3.8	2.2
Rhodophyta, Florideophyceae		
Rhodymenia ardissonei Feldmann		(80.0)
Chylocladia verticillata (Lightfoot) Bliding, 1928		(10.0)
Chromista, Phaeophyceae		
Dictyota linearis (C. Agardh) Greville		(10.0)
Animal matter		
Polychaeta	120.3	69.8
Chaetopterus variopedatus Cuvier, 1827		
Unidentifiable organic remains	32.9	19.1

2009; CARRIÓN-CORTEZ *et al*., 2010). Likewise, seagrass (*C. nodosa*) was also reported as the only component in the diet of three juvenile green turtles (CCL = 30–50 cm) from Mediterranean (Cyprus; DEMETROPOULOS & HADJICHRISTOPHOROU, 1995). However, at many sites this sea turtle species also consume marine invertebrates (SEMINOFF *et al*., 2002; CARRIÓN-CORTEZ *et al*., 2010), with the highest contribution of animal prey (tunicates, crustaceans and molluscs) being recorded so far in the Colombian waters (71.1%, calculated from AMOROCHO & REINA, 2007). The existence of such differences in the prey composition within and between different marine regions, including the Mediterranean, supports a conclusion by CARRIÓN-CORTEZ *et al*. (2010) according to which post-pelagic green turtles have the capability to adopt different feeding strategies, possibly in response to local abundance and type of available benthic resources.

Vertical distribution of species recorded in the diet, especially of *C. nodosa* which develops on maximum 10 m deep bottoms, showed that a green turtle in our study foraged in the shallow coastal waters. If all benthic taxa recorded are pooled together, 80.9% of the diet was based upon benthic species, indicating that the turtle was in the post-pelagic stage. The CCL of this individual coincides with the distribution of size-at-ontogenetic habitat shift recorded in other populations of green turtles (MUSICK & LIMPUS, 1977; BJORNDAL & BOLTEN, 1988; HIRTH, 1997). Based upon the size distribution, LAZAR *et al*. (2004a) hypothesized about possible role of the southern Adriatic Sea as an oceanic habitat for green turtles in the Mediterranean. This pelagic zone of the Adriatic, with the mean depth of 449 m and the maximum depth of 1330 m (CUSHMAN-ROISIN *et al*., 2001), seems to host critical habitats for some large pelagic vertebrates like Cuvier's beaked whale (HOLCER *et al*., 2007) and leatherback sea turtle (LAZAR *et al*., 2008), or their oceanic developmental stages, such as green and loggerhead sea turtles (LAZAR *et al*., 2004a; CASALE *et al*., 2005). Certainly, the number of Adriatic green turtle records is low in comparison to loggerhead turtle (PASTORELLI *et al*., 1999; LAZAR & TVRTKOVIĆ, 1995; LAZAR *et al*., 2004a; HAXHIU, 2005). This is the result of depleted and small nesting population (BRODERICK *et al*., 2002) and possible misidentification of juvenile greens as loggerhead turtles (LAZAR *et al*., 2004a), as well as of possible preferences of turtles for the warmer waters of southern Mediterranean. Nonetheless, subsequent findings of juvenile green turtles in the Patok Bay in Albania (CCL < 50 cm; HAXHIU, 2005, 2010), together with discovery of a developmental habitat in the Ionian Sea, Greece (mean CCL = 36.4 cm, range = 30.0–67.0 cm; MARGARITOULIS & TENEKETZIS, 2003), suggest the existence of an Ionian-Adriatic developmental pathway of green turtles from reproductive habitats in the eastern Mediterranean (Fig. 1), most likely influenced by direction of the prevailing sea currents (MENNA & POULAIN, 2010). In both Albania and Greece juvenile green turtles were recovered in the shallow bays. Our dietary analysis showed that such small juveniles are already in the post-pelagic stage and feed on the sea floor. In case of loggerhead turtles, juveniles show fidelity to neritic areas, and once settled to one area, change to other neritic areas is unlikely (CASALE *et al*., 2007). If juvenile green turtles follow the same fidelity pattern which is shown to exist in adult females of both species (BRODERICK *et al*., 2007), then the southern Adriatic may also host neritic developmental habitats for this endangered species.

Identification of critical habitats and connections between rookeries and foraging grounds is underlined as one of the research priorities for sea turtles on the global

level (BJORNDAL, 1999; HAMANN *et al.*, 2010). Although the Adriatic Sea is recognized as a key critical habitat for Mediterranean loggerheads (LAZAR & TVRTKOVIĆ, 2003; MARGARITOULIS *et al.*, 2003; CASALE *et al.*, 2004; LAZAR *et al.*, 2004b), recent body of evidence suggest that it might also play a role in the life history of green turtles in the region. Despite relatively rare records, more effort should therefore be given to research into *at-sea* biology of this species in the Adriatic, as well as in other critical marine habitats throughout the Mediterranean Sea.

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