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FOOD AND FEEDING HABITS OF THE BLACKSPOTTED SMOOTH-HOUND, *MUSTELUS PUNCTULATUS* (ELASMOBRANCHII: CARCHARHINIFORMES: TRIAKIDAE), FROM THE NORTHERN ADRIATIC

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Background. The blackspotted smooth-hound, *Mustelus punctulatus* Risso, 1826, has been regularly caught in the northern Adriatic Sea, although a decreasing trend in its catches was observed off the coast of Slovenia within the last decade. The knowledge of feeding behaviour of elasmobranch fish species, through understanding of the local food web structure, contributes to better and more efficient fish stock assessment and ecosystem modelling. This study is a first step in determining the prey consumption by the blackspotted smooth-hound in the area.
Materials and methods. A total of 151 blackspotted smooth-hounds caught by commercial fishermen in the Gulf of Trieste from 4 June 2002 to 4 June 2003 were examined in this study. The stomach contents were removed, sorted and identified to the lowest possible taxon using identification keys. Preys were counted and weighed. Frequency of occurrence (F%), relative abundance (N%), the percentage by weight (W%), the Index of Relative Importance (IRI), and its standardized value (%IRI) were calculated following standard procedures. For comparing the diet between four different size classes we calculate average prey weight, dietary diversity, average meal, and trophic level for each size class.
Results. A total 130 fish stomachs contained prey items. Crustaceans were the most important prey items (IRI% = 56.14), whereas cephalopods were the second mostly preyed animals (IRI% = 20.2). Teleost fish and bivalves were also found in the stomachs. The most important prey species was *Solecurtus strigillatus*. Larger sharks consumed larger preys. Male and female sharks consumed similar food. Juvenile individuals consumed predominantly crustaceans, while cephalopods were more important in the diet of adult individuals. The calculated trophic index (TROPH) of *M. punctulatus* from northern Adriatic Sea was 3.7, showing that it is a highly carnivorous species.
Conclusion. This study is a first step in determining prey consumption by *Mustelus punctulatus* which is, despite the fact that is still common in the area, a rather poorly known species. For elucidating the role of benthic sharks in the study area the further step would be to study the diet of a closely related common smooth-hound *M. mustelus.*

Keywords: Elasmobranchii, Triakidae, *Mustelus punctulatus,* feeding habits, trophic level, northern Adriatic

INTRODUCTION

Three species of the genus *Mustelus* Linck, 1790 (family Triakidae) are known in the Adriatic Sea as in other Mediterranean regions: the common smooth-hound, *Mustelus mustelus* (L.); the starry smooth-hound, *M. asterias* Cloquet, 1821; and the blackspotted smooth-hound, *M. punctulatus* Risso 1826 (see Branstetter 1984). In the northern Adriatic Sea, *M. mustelus* and *M. punctulatus* used to be regularly caught (Lipej et al. 2004) and the latter fish was known to be very common in the channel area and open sandy and muddy bottoms down to 200 m depth. In contrast captures of *M. asterias* were relatively rare (Karlovac 1978, Jardas 1996). Similar patterns were reported from the Slovenian coastal waters where *M. mustelus* and *M. punctulatus* were considered to be rather common in the area (Marčeta 1996).

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However, Jardas et al. (2008) noted that *M. punctulatus* had already been depleted in the western Adriatic, although still occurring in stable numbers in some areas of the eastern Adriatic. Off the coast of Slovenia, *M. punctulatus* is facing a drastic population decline, probably due to overexploitation. Investigations conducted in the area allow us to observe a decreasing trend in smooth-hounds during the last decade.

A junior synonym of *Mustelus punctulatus* is *M. mediterraneus* Quignard et Capapé, 1972 (see Quignard and Capapé 1972). Earlier *M. punctulatus* used to be confused with its congener *M. mustelus*. Branstetter (1984) noted that *M. punctulatus* is known throughout the Mediterranean, however, it was not recorded by Capapé et al. (2000) off the Languedocian coast. *M. punctulatus* was reported from the Aegean and Mediterranean coasts off Turkey, where the species is considered quite abundant (Kabasakal 2002). In the eastern Atlantic, *M. punctulatus* was reported south of the Strait of Gibraltar, off the coast of Senegal, where the species is considered rather abundant (Cadenat and Blache 1981, Capapé et al. 1996).

The reproductive biology and diet of the black spotted smooth-hound were only studied from the specimens caught in the Gulf of Tunis (Capapé and Quignard 1977a, b) and southward in the Gulf of Gabès (Saïdi et al. 2009a). Some additional information, on the reproductive biology of the specimens from the Senegalese coast was provided by Capapé et al. (1996), and on the diet composition of the specimens from eastern Adriatic Sea—by Jardas et al. (2007a).

Despite the fact that *M. punctulatus* is still among the most abundant sharks in the northern Adriatic Sea, our knowledge on this fish is far from complete. The aim of this paper was to present the qualitative and quantitative analysis of the diet of the species based on specimens caught in the area. The presently reported study brings new data on the feeding habits of the fish, and also tries to assess its environmental role. It is a first step in determining prey consumption by the black spotted smooth-hound in the area, which is the main information for improving local fishery monitoring and management.

MATERIALS AND METHODS

Fieldwork. Sharks, *Mustelus punctulatus,* were collected between 4 June 2002 and 4 June 2003 with two types of trammel nets, one used for flatfish (mesh size 80–84 mm) and the other used for sharks (mesh size 140 mm). Altogether 39 sampling cruises were performed in the open waters of the southern part of the Gulf of Trieste (Fig. 1). The great majority of specimens were caught in May and June. Once landed, sharks were measured, identified and sexed. After measurements, stomachs were removed from the rest of the body, labelled in plastic bags and at deeply frozen without delay.

Laboratory analysis. All measured specimens were discriminated on the basis of sex, juveniles, and adults. Juveniles were considered those males and females, which were smaller than 90 cm and 100 cm of the total length, respectively (sensu Capapé and Quignard 1977a). Prey items in each stomach were sorted and determined to the lowest possible taxonomic level. When the prey remaining in the stomach were partly digested, the prey count was based on the number of different typical parts such as beaks for cephalopods, claws and legs for different crustaceans, carapaces of decapod crabs, foot for bivalves and whole vertebral column and otoliths for teleost species. Wet weights were measured to nearest 0.1 g.

Data analysis. For assessing the diet in relation to size of sharks, all specimens were grouped in four size classes (SC): I = specimens smaller than 60 cm in total length, II = specimens from 60 to 80 cm, III = specimens from 81 to 100 cm, and IV = specimens larger than 100 cm.

For the description of the diet composition, we calculated: the Vacuity Index (VI= number of empty stomachs/total number of stomachs x 100), relative frequency of occurrence (%*F* = number of stomachs containing prey *i* / total number of full stomachs × 100), relative numerical abundance (%*N*= number of prey *i* / total number of prey × 100) and relative gravimetric composition (%*W* = weight of prey *i* / total weight of all prey × 100) according to the standard procedure. The index of relative importance (IRI) of Pinkas et al. (1971), as modified by Hacunda (1981), was used:

$$\mathrm{IRI} = \%F \times (\%N + \%\mathrm{W})$$

This index, that integrates the three previous percentages, allows an interpretation much more real for food by minimizing the skews caused by each one of these percentages. The contribution of each prey in the diet was also estimated with the Index of Relative Importance (IRI) and its standardized value (%IRI) (Pinkas et al. 1971, Cortés 1997) as:

$$\mathrm{IRI} = (\%\mathrm{N} + \%\mathrm{W})\ \%\mathrm{F} \quad \mathrm{IRI_f}\% = 100\mathrm{IRI_f} / \sum \mathrm{IRI_f}$$

where $\mathrm{IRI_f}$ is the IRI value for each prey category f.

Fig. 1. Map of the studied area with sampling sites where *Mustelus punctulatus*, were caught from June 2002 to June 2003

Prey species were stored in decreasing order according to their relative IRI (%IRI = IRI of prey *i* / ΣIRI of all prey × 100) contribution and then cumulative %IRI was calculated. In this order, the %IRI of first prey were gradually added to obtain 50% or more, these items are main food; this calculation is pursued until another 25% or more is obtained, these items are called secondary food; the other items are accidental food.

Dietary diversity was calculated by using the Shannon–Wiener diversity index. To compare the diet between four different size classes we calculated the average prey weight for a single size class dividing the total biomass by the number of prey items. Additionally, we calculated also the average meal for the size group, dividing the total biomass by the total number of full stomachs.

The trophic level for any consumer species *i* is (Pauly et al. 2000, Pauly and Christensen 2000, Pauly and Palomares 2000):

$$\mathrm{TROPH}_i = 1 + \sum_{i=1}^{G} DC_{ij} \cdot \mathrm{TROPH}_j$$

Where TROPH_j is the fractional trophic level of prey *j*, DC_{ij} represents the fraction of *j* in the diet of *i* and *G* is the total number of prey species.

RESULTS

The size of blackspotted smooth-hound, *Mustelus punctulatus*, collected during one year period ranged between 50 to 135 cm total length (Table 1). More than 60% of collected specimens were juveniles (Table 1). Among the 151 stomachs collected 21 were empty (VI = 13.9%). However, in adults (specimens bigger than 100 cm) this proportion is much bigger (VI = 27.5%) than in juveniles (9.8% for the SC smaller than 60 cm TL, 6.5% for the SC from 60 to 80 cm TL and 6.9% for SC from 81 to 100 cm TL). The differences between fullness of stomachs were tested by Wilcoxon test. There is no significant difference between sexes (W = 2316.5, not significant), while between juveniles and adults, the difference is statistically significant (P = 0.03728, W = 3089.5; $P < 0.05$). The mean number of prey species found in all stomachs was 3.06, whereas the number of prey species for full stomachs was 3.56.

The diet of the blackspotted smooth-hound consisted of 27 different prey taxa. The main represented taxonomic groups were crustaceans, cephalopods, polychaetes, bivalves, and teleost fishes (Table 2). Crustaceans were the most frequently eaten taxonomic group, constituting 55.6% of the total IRI. Alternative prey groups were cephalopods (19.5% IRI) and bivalves (12% IRI). Teleost species constituted 9.2% of the total IRI.

The preferred prey species in term of frequency of occurrence and abundance was the bivalve *Solecurtus strigillatus* (F% = 36.9, N% = 16.2), followed by the crab *Ethusa mascarone* (F% = 23.0%, N% = 11.1) (see Table 2) and the mantis shrimp (*Squilla mantis*) (F% = 16.9%, N% = 5.5). The most important preys in term of biomass was *Eledone moschata*, other cephalopods and clupeid species with approximately 13% of the total biomass. The food diversity calculated with Shannon–Wiener diversity index was rather high, amounting to 0.82.

The differences in diet between sexes were not significant ($\chi2$; $P \leq 1$) (Table 3). The diet of juvenile specimens and adult ones resulted to be significantly different in this species ($\chi2$; $P \leq 0.01$). Juvenile specimens are preying mainly on crustaceans (IRI %= 73.7), while adults prefer to prey on cephalopods with IRI% = 57.8 (Fig. 2). The same could be seen when analyzing the four size classes of blackspotted smooth-hound. The smallest size class (I)

Table 1

General parameters characterising the studied sample of *Mustelus punctulatus* from North Adriatic

Parameter	Value
Number of specimens	151
Number of females	51
Number of males	100
Juveniles [%]	60.3
Juvenile males [%]	53
Juvenile females [%]	78.1
TL [cm] range	50–135
Mean TL [cm] ± SD	80.2 ± 22.4

Table 2

Food items found in the stomachs of *Mustelus punctulatus* from North Adriatic)

HT	Lower taxon	Index			
		F%	N%	W%	IRI%
Crustacea	*Ethusa mascarone*	23.0	11.1	1.0	8.5
	Pilumnus sp.	0.8	0.4	0.1	0.1
	Liocarcinus depurator	13.0	5.0	1.4	2.5
	Xantho sp.	1.5	0.4	0.1	0.0
	Ebalia sp.	2.3	0.9	0.0	0.1
	Brachyura gen. sp.	25.4	7.8	1.0	6.7
	Anomura gen. sp.	3.8	1.3	0.5	0.2
	Callianassa tyrrhena	2.3	0.6	0.2	0.1
	Upogebia sp.	2.3	0.9	0.4	0.1
	Thalassinidea gen. sp.	9.2	3.8	1.6	1.5
	Natantia gen. sp.	6.9	2.6	0.8	0.7
	Decapoda gen. sp.	0.8	0.2	0.1	0.1
	Squilla mantis	16.9	5.5	8.7	7.3
	Crustacea gen. sp.	13.8	5.2	1.9	3.0
Cephalopoda	*Loligo vulgaris*	1.5	0.6	3.7	0.2
	Eledone moschata	6.9	2.2	13.9	3.4
	Sepia officinalis	3.8	1.1	5.0	0.7
	Sepiola sp.	16.1	6.8	3.0	4.8
	Cephalopoda gen. sp.	10.0	3.0	13.2	4.9
AP	*Clupea pilchardus*	5.4	2.6	3.6	1.0
	Clupeidae gen. sp.	23.8	9.6	13.1	16.4
P	*Aphrodite aculeata*	0.8	0.2	0.3	0.1
	Glycera rouxii	12.3	4.1	2.8	2.6
	Polychaeta gen. sp.	10.7	3.3	3.7	2.2
M	*Solecurtus strigillatus*	36.9	16.2	11.0	30.5
	Gibbula sp.	0.0	0.0	0.0	0.0
I	Invertebrata gen. sp.	6.1	2.2	7.9	1.9

HT = higher taxon AP = Actinopterygii; P = Polychaeta; M = Mollusca (other).

consisted of juveniles which were smaller than 60 cm. Smaller sharks prefer to prey on crabs and other crustaceans, whereas bigger sharks focused their diet more on molluscs, such as bivalves and cephalopods (Fig. 3). The prey size was correlated to predator size. Large cephalopods such as cuttlefish *Sepia officinalis*, squid *Loligo vulgaris*, and octopus *Eledone moschata* were preyed especially by the largest sharks (Fig. 3). This is evident also if we calculated the average prey weight and the average meal. The calculated average prey weight was 17.2 g for the size class I, 19.7 g for the size class II, and 29.8 g for size classes III and IV. The calculated average meal was also increasing with size class. The average meal for the size class I was 51.2 g, for the size class II 80.7 g, for the size class III 111.4 g, and for the size class IV 94.3 g.

The TROPH of *M. punctulatus* from northern Adriatic Sea was 3.7 (± 0.6), indicating that the species could be considered as carnivore with a preference for large decapods, cephalopods and teleost species (3.7 < TROPH < 4.5).

DISCUSSION

The presently reported study shows that *Mustelus punctulatus* from the northern Adriatic was rather a voracious species referring to the low values of the Vacuity Index for total sample, juveniles and adults, and males and females. Additionally, VI significantly increased with size showing that large blackspotted smooth-hounds from the studied area were more active feeders than the small specimens. These differences could also be explained by the prey availability in the biological environment.

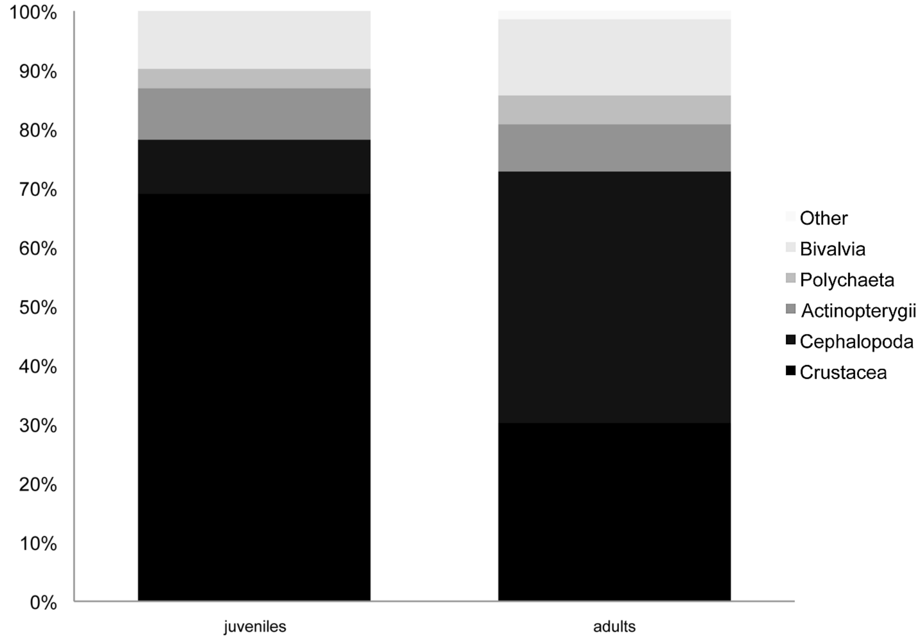

Fig. 2. Ontogenetic differences in the diet of *Mustelus punctulatus,* expressed as %IRI, in diet of juvenile and adult specimens

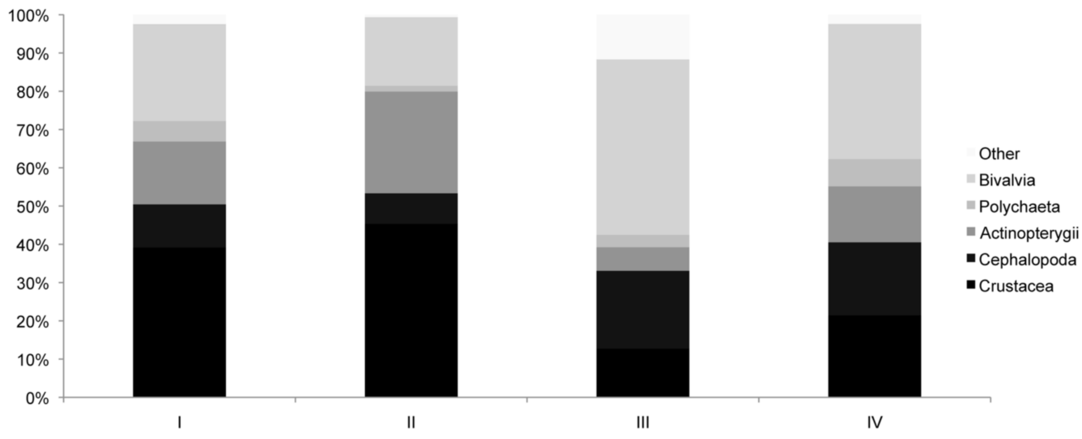

Fig. 3. Diet of four size classes of *Mustelus punctulatus,* expressed as %IRI; I = size class I (specimens smaller than 60 cm in total length), II - size class II (specimens from 60 to 80 cm), III = size class III (specimens from 81 to 100 cm), IV = size class IV (specimens bigger than 100 cm)

For instance Heithaus (2004) noted that small sharks inhabit nursery areas in the early stages of their life, however these productive areas are the object of a both intense intra and interspecific competition pressure for food. Small sharks are less experienced feeders than the larger ones and techniques of prey captures cannot be neglected, even if small specimens were more able to find prey buried into sediments or by excavations (see Wetherbee and Cortés 2004). Similar patterns were observed in *M. punctulatus* collected in Tunisian waters from northern (Capapé and Quignard 1977b) and southern areas (Saïdi et al. 2009a).

In contrast, no significant differences were recorded in VI of sampled males and females, which is in agreement with Saïdi et al. (2009a) for specimens from southern Tunisian waters, adding that foraging habits were similar for both sexes, encountering similar preys in the wild. However, Capapé and Quignard (1977b) reported seasonal changes of VI in diet of male *M. punctulatus* from the Gulf of Tunis (northern Tunisia), which fed a bit less during the breeding period, and in females at the time of parturition. Similar pattern was reported by Capapé (1977) in the bull ray, *Pteromylaeus bovinus* (Geoffroy Saint-Hilaire, 1817), inhabiting the same areas. Additionally, feeding intensity and reproductive activity appeared to be more linked in elasmobranch oviparous species, such as the small-spotted catshark, *Scyliorhinus canicula* (L.), according to Craik (1978) and Jardas (1979), probably due to the fact that females reduced feeding period in favour of egg-laying, and migrated toward bottom areas where sufficient food was available for their young after hatching. Cyclic feeding patterns linked to reproductive cycle avoided dietary overlap among sympatric species inhabiting similar habitats from deep-sea bottoms where food availability was rather reduced. Such phenomenon was reported for gulper shark, *Centrophorus granulosus* (Bloch et Schneider, 1801); velvet belly, *Etmopterus spinax* (L.); and the blackmouth catshark, *Galeus melastomus* Rafinesque, 1810, from northern Tunisian waters (Capapé et al. 2003).

In the area studied the blackspotted smooth-hound is a coastal shark species preying on a variety of food categories, mainly benthic crustaceans, cephalopods, and clupeid fishes. Despite the high number of taxonomic groups found in their diet, there were only few prey categories amounting to more than 10% of IRI. From this standpoint, blackspotted smooth-hound could be defined as an opportunistic species (sensu Wetherbee and Cortés 2004), preying on the diverse organisms available in its environment. Smaller specimens tend to feed more on crustaceans, especially different species of crabs, while adult specimens prey on bivalves and cephalopods. Additionally, clupeid species such as the European pilchard, *Sardina pilchardus* (Walbaum, 1792), were also recorded. The diet of this shark confirms that the blackspotted smooth-hound is a benthic dweller, seeking its prey on sandy and muddy bottom. These ontogenetic changes in feeding habits were described in fishes, especially in elasmobranch species, as a consequence of the regular increase of swimming speed with size, experience with preys, movements patterns and ability of large specimens to capture larger preys (Wetherbee and Cortés 2004). These changes could also depend on the diet diversity available in the wild and also of latitudinal variations. For instance Capapé and Quignard (1977b) and Saïdi et al. (2009a) noted that juvenile *M. punctulatus* from Tunisian waters fed on crustaceans and adults rather fed on teleosts and a bit less on molluscs, in agreement with observations from the eastern Adriatic (Jardas et al. 2007a). Additionally, similar pattern was observed for the common smooth-hound *M. mustelus* (L.) from the Tunisian coast (Saïdi 2009 b), while in specimens from the eastern Adriatic Sea, Jardas et al. (2007b) noted that with growth the proportion of teleost preys increased while this of crustacean preys decreased.

M. punctulatus is a shark with body type 2 sensu Wilga and Lauder (2004), having the greatest range of swimming speeds with fins highly manoeuvrable over their swimming range. The species is therefore well adapted to pelagic life; this could probably explain the presence of clupeids in stomachs, however accidental ingestion of these fishes during trawling could not be totally excluded. According to Motta (2004), many large predator sharks had bladelike cutting teeth which do not allow them to digest shell pieces. By contrast the crushing-type dentition is a characteristic of *Mustelus* species, having teeth low exhibiting cutting edges with bluntly rounded

Table 3

Major groups of food items found in the stomachs of female and male *Mustelus punctulatus* from North Adriatic

Food item	Index							
	F%		*N*%		*W*%		IRI%	
	F	M	F	M	F	M	F	M
Invertebrata	8.5	4.8	3.4	1.6	13.8	5.6	1.7	0.4
Polychaeta	21.3	24.0	7.5	7.7	7.0	6.8	3.6	3.8
Bivalvia	36.2	37.4	16.3	16.2	12.5	10.5	12.0	10.9
Cephalopoda	27.6	36.1	12.8	14.1	32.3	41.5	14.4	22.1
Crustacea	76.6	74.6	48.5	47.3	16.5	19.1	57.5	54.6
Actinopterygii	31.9	25.3	11.5	12.6	17.6	16.3	10.7	8.0

F% = relative frequency of occurrence; *N*% = relative numerical abundance; *W*%= relative gravimetric composition; IRI% = % of important prey items; F = female; M = male.

apices (Capapé and Quignard 1972, Cappetta 1986), adapted to triturate shells of molluscs and carapaces of crustaceans (see Wheeler and Jones, 1989). The juvenile specimens are preying more on crustaceans, while in adult cephalopods and bivalves represented the most important prey categories. All morphological adaptations explain why is *M. punctulatus* a species utilizing both benthic and pelagic preys, with wide spread dietary spectrum. The ontogenetic changes avoid dietary overlap and consequently intraspecific competition pressure for food.

The calculated TROPH value of 3.7, showed that following the classification of Stergiou and Karpouzi (2002) the blackspotted smooth-hound is a carnivore species, feeding on crustaceans, cephalopods, and other preys, such as teleosts and molluscs, all included at the very top of the food pyramid. TROPH value of *M. punctulatus* was close to the value recorded by Cortés (1999), which was 3.8. The interval for top predators such as elasmobranch species is generally ranged between 3.10 and 4.70 (Cortés 1999), while for many marine mammals ranged between 3.20 and 4.50 (Pauly et al. 2000). These results showed that *M. punctulatus* utilized similar resources as other high-level marine consumers.

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