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DIET OF MEDITERRANEAN MORAY, *MURAENA HELENA* (ACTINOPTERYGII: ANGUILLIFORMES: MURAENIDAE), FROM THE NORTH-EASTERN TUNISIAN COAST (CENTRAL MEDITERRANEAN)

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Background. The feeding behaviour of Mediterranean moray, *Muraena helena* Linnaeus, 1758, from the coast of Tunisia (central Mediterranean) is poorly know and this study is a first step in determining prey consumption by *M. helena* as main information for improving fishery monitoring and management in the study area.
Materials and methods. Of the 411 sampled Mediterranean morays, 237 were males and 174 females. The stomach contents were removed, sorted, identified to the lowest possible taxon, counted, and weighed. For diet description, we calculated vacuity index (V_I), abundance (mean number of preys) (N_M), frequency of occurrence ($F_{\%}$), relative abundance ($N_{\%}$), and frequency by weight ($W_{\%}$). The contribution of each prey in the diet was also estimated with Index of Relative Importance (IRI) and its standardized value (%IRI). The trophic level (TROPH) was calculated for total sample to determine the diet of the species, but it was also related to the sex, size, and seasons.
Results. The relation between the total length and the total body weight showed a positive allometry for both males and females. V_I presented high values, for total sample, sex, size, and season. *Muraena helena* under study consumed a variety of prey items including 3 higher taxa, 13 families, and 20 species. Osteichthyans were the dominant preys with 15 taxa, representing 96.84% of weight, 78.83% of number, 84.21%, of frequency, and %IRI = 98.51. Crustaceans and cephalopods and sea grass were also ingested by *M. helena*, with lower %IRI (0.65, 0.66), and no ontogenetic changes in the diet were recorded related to sex, size, and seasons. The most common prey species were *Diplodus annularis* (Linnaeus, 1758) and *D. vulgaris* (Geoffroy Saint-Hilaire, 1817) with %IRI = 28.52 and 7.45, respectively while *Serranus cabrilla* (Linnaeus, 1758) was also consumed with %IRI = 1.84. The calculated TROPH was 4.27 (SE = 0.74); changes were recorded with seasons but not significantly different.
Conclusion. *Muraena helena* is a carnivorous species feeding on prey items representing three higher taxa, osteichthyans being the most common in stomach contents and such findings suggest that it should be considered as a piscivorous species. The high value of trophic level pointed out that *M. helena* is a top predator.

Keywords: Osteichthyes, allometric growth, vacuity index, feeding habits, trophic level, habitat

INTRODUCTION

Mediterranean moray, *Muraena helena* Linnaeus, 1758, is widely distributed in the eastern Atlantic from the British Isles to the Straits of Gibraltar (Quéro et al. 2003) and further south from the coast of Morocco (Lloris and Rucabado 1998) all the way to the Gulf of Guinea (Blache et al. 1970). Its range covers also Cape Verde, the Canary Islands, Azores, and Madeira (Smith and Böhlke 1990). Mediterranean moray has also been reported throughout the Mediterranean Sea, and it is rather considered a by-catch species due to its low commercial value (Bauchot 1986, Fischer et al. 1987). *Muraena helena* is ubiquitous and constitutes one of the dominant species in the fish communities in outer islands of the middle and southern Adriatic (Matić-Skoko et al. 2011). In Tunisian waters the species was first reported by Gruvel (1926). At present,

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the fish is most frequently captured in the northern areas, and appears to be very rare in the southern Gulf of Gabès (Bradai et al. 2004).

Mediterranean morays are found from shallow coastal waters to a depth of 800 m, commonly between 100 and 300 m, on rocky bottoms. During the days they hide in holes in the bottom slope lurking for their prey. At night they are more eager to leave their hiding spots for a short time, but only in a close perimeter (Jiménez et al. 2007, Matić-Skoko et al. 2011). Such typical behaviour of this fish explains why in Tunisian waters *Muraena helena* is commonly caught rather in the northern areas where rocky and/or coralligenous bottoms are predominant (Castany 1955), than in the southern areas, known for their sandy or sandy-muddy bottoms (Bradai et al. 2004). *Muraena helena* is known to be a nocturnal top predator feeding mainly on fishes, cephalopods, and crustaceans, and playing an important ecological role in rocky benthic communities (Bauchot 1986, Matic-Skoko et al. 2010). Consequently, it appears that food composition and feeding habits of the *M. helena* were up to date only poorly investigated and probably due to the fact that their cryptic habitat make difficult to collect (Reece et al. 2010, Matić-Skoko et al. 2011).

The main purpose of the presently reported study was to provide more detailed data about the diet composition and the feeding habits of *Muraena helena* from the north-eastern coast of Tunisia, based on recent captures. Another goal was to study its possible impact on the comestible fish fauna in the area. We also intended to analyse seasonal variations in the diet composition of *M. helena* and understand how the feeding intensity related to sex and size. Additionally, this study constitutes a first step in determining prey consumption by *M. helena* from the northern Tunisian coast, which is the main information for improving fishery monitoring and management in the study area.

MATERIALS AND METHODS

Fieldwork. A total of 411 Mediterranean moray eels, *Muraena helena*, were sampled between January 2008 and December 2010 in the fish markets of Zarzouna, close to Bizerte in northern Tunisia and Kelibia, in northern Cape Bon. All specimens were captured off the northern and north-eastern Tunisian coast, including the Gulf of Tunis (Fig. 1), by commercial fishing boats using trawl, over sandy-, muddy-, and rocky bottoms, at depths ranging from 50 to 150 m, basing on information provided by experienced fishermen who perfectly know the fishing area. All fresh specimens were measured for total length (TL) to the nearest 1 mm and total body weight (W_B) was recorded for each specimen to the nearest 1 g.

Laboratory analysis. As soon as Mediterranean moray eels were collected, the stomach contents were removed by dissection, sorted, and identified to the lowest taxonomic level (species level when possible) using taxonomic keys and field guides (Riedl 1963, Perrier 1964, 1975, Fischer et al. 1987, Louisy 2002, Quéro et al. 2003). The prey items were counted and weighed to the nearest decigram after removal of surface water by blotting on tissue paper. What could not be directly identified in the laboratory was preserved in 10% buffered formalin, to be later identified by specialists. Additionally, to detect possible variation in food composition related to size, the *Muraena helena* sample was separated into two size classes, to obtain, if possible, two size classes having a quasi-similar number of specimens, looking for possible size differences. The first class (class 1) consisted of 223 specimens ranging from 427 to 697 mm TL, the second class (class 2) included 188 specimens from 700 to 1092 mm TL. The diet of Muraena *helena* was studied chronologically on seasonal basis. Samples were separated according to the sex, to show if variations occurred in the diet, between males and females.

Data analysis. Test of normality of the sample was performed by using Shapiro–Wilk's test, with $P < 0.05$. Chi square test was used to determine significance ($P < 0.05$). A histogram is plotted in Fig. 2, showing numbers of males and females sampled for the present study; it is divided into classes of 50 mm size length. The relation between the total length (TL) and the total weight (W_B) was used as a complement for feeding studies following Froese et al. (2011). Linear regression was expressed in decimal logarithmic coordinates and correlations were assessed by least-squares regression, males and females were considered separately, ANCOVA was used to compare curves for sexes. Comparison of means were carried out by using Student's *t*-test and Kruskal–Wallis's *t*-test. These two latter tests, ANOVA and ANCOVA were performed by using logistic model STAT VIEW 5.0.

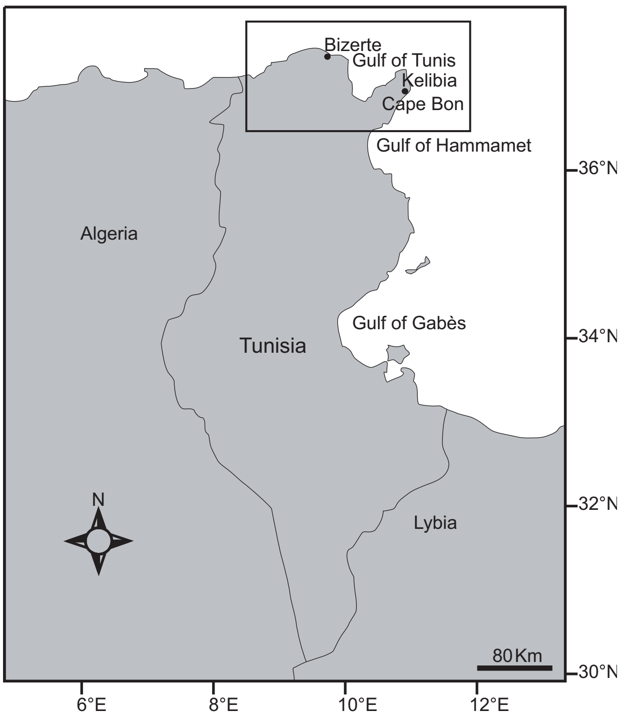

Fig. 1. Sampling area (rectangle) of *Muraena helena* (north-eastern Tunisian coast)

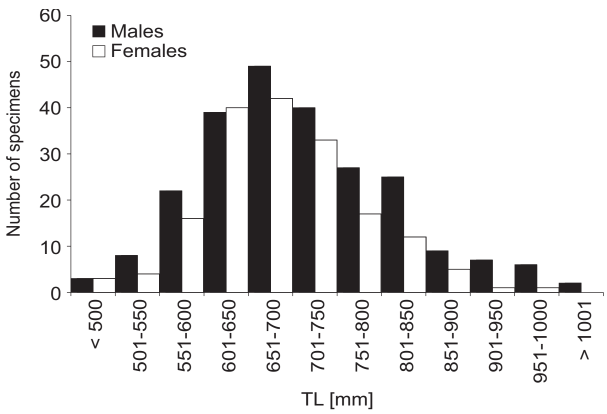

Fig. 2. Number of males and females in respective length classes (total length, TL) of *Muraena helena* from the north-eastern Tunisian coast

The analyzes of food composition and feeding habits of *Muraena helena* were carried out using the following indices: vacuity index (V_I), abundance (mean number of prey items) (N_M), frequency of occurrence ($F_\%$), relative abundance ($N_\%$), gravimetric frequency ($W_\%$) (Hyslop 1980, Zander 1982, Rosecchi and Nouaze 1987):

$$V_I = 100 N_{se} \cdot N_{st}^{-1}$$

where N_{se} is the number of empty stomachs and N_{st} is the total number of stomachs;

$$N_M = N_{TP} \cdot N_{TS}^{-1}$$

where N_{TP} is the total number of consumed prey items and N_{TS} is the total number of stomachs;

$$F_\% = N_{SPI} \cdot N_{TFS}^{-1}$$

where N_{SPI} is the number of stomachs containing a prey item *i* and N_{TFS} is the total number of full stomachs

$$N_\% = N_{PI} \cdot N_{TP}^{-1}$$

where N_{PI} is the number of each prey item *i* and N_{TP} is the total number of preys and:

$$W_\% = W_{PI} \cdot W_{TPI}^{-1}$$

where W_{PI} is the weight of each prey item *i* and W_{TPI} the total weight of all prey items.

The index of relative importance (IRI) of Pinkas et al. (1971), as modified by Hacunda (1981) was also used:

$$IRI = F_\%(N_\% + W_\%)$$

This index, integrating the three previously mentioned parameters, is more objective because it minimizes the skews caused by individual indices it incorporates.

IRI is expressed as a percentage to qualify the diet as %IRI

$$\%IRI = 100(IRI \cdot \sum IRI)^{-1}$$

All indices listed above contribute to a better understanding of the importance of individual prey items in the feeding habits of the fish species under study.

The trophic level, otherwise known as TROPH (Pauly et al. 1998, Pauly and Christensen 2000, Pauly and Palomares 2000) for any consumer species *i* is:

$$\text{TROPH}\,i = 1 + \sum_{J=1}^{G} \text{DC}ij \times \text{TROPH}\,j$$

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.

The TROPH and standard errors (SE) of *Muraena helena* in the study area were calculated using TrophLab (Pauly et al. 2000); a stand alone Microsoft Access routine for estimating trophic levels, downloadable from FishBase (Froese and Pauly 2014). Statistical differences ($P < 0.05$) in basic diet composition as a function of size and season were established by applying a Chi-square test (Sokal and Rohlf 1987).

RESULTS

Sample description. Of the 411 sampled Mediterranean morays, 237 specimens were males and 174 other specimens were females, the former significantly outnumbered the latter ($\chi^2 = 63$, df = 1, $P < 0.05$). The seasonal collection of the observed *Muraena helena* is presented in Table 1 and its distribution in Fig. 2, with $W = 0.97$ and $P < 0.0001$, using Shapiro–Wilk's test; it allows to state that the studied sample came from a normally distributed population. Males ranged from 485 to 1092 mm TL, and weighed from 161 to 3000 g; females ranged from 472 to 976 mm TL and weighed from 187 to 2084 g. The relation between the total length (TL) and the total body weight W_B showed significant difference between males and females ($F = 5.92$, df = 1, $P = 0.0153$). The relations for males were: $\log W = 3.40 \cdot \log TL - 6.88$, $r = 0.96$, $n = 237$, and for females, $\log W = 3.11 \cdot \log TL - 6.07$, $r = 0.92$, $n = 174$ (Fig. 3).

Overall analysis of the diet. Of the 411 stomachs examined, 297 were empty, with $V_I = 72.26\%$, and significantly outnumbered full stomachs containing food or remains of food ($\chi^2 = 183$, df = 1, $P < 0.05$). A total of 137 prey

Table 1

The numbers of of *Muraena helena* collected in respective seasons from the north-eastern Tunisian coast

Sex	Total length [mm]	Fish numbers collected in individual seasons				Total
		Spring	Summer	Autumn	Winter	
Males	472–697	28	16	10	66	120
	700–1092	47	15	17	38	117
	Total	75	31	27	104	237
Females	472–697	28	11	13	51	103
	700–1092	25	10	10	26	71
	Total	53	21	23	77	174
	Grand total	128	52	50	181	411

items were recorded in the 114 full stomachs with N_M = 1.20 ± 0.46, showing that *Muraena helena* consumed a large variety of prey items including 3 higher taxa, 13 families, and 20 species. Osteichthyans were the dominant preys found in stomach contents with 15 taxa, representing 96.84% of weight, 78.83% of the number, 84.21% of the frequency, and %IRI = 98.51. Crustaceans, cephalopods, and sea grass were also ingested by *M. helena*, with lower %IRI (0.65, 0.66, and 0.16).

Of the 15 osteichthyan species identified in the stomach contents, 6 belonged to the family Sparidae (Table 2) and analysis based on feeding index, %IRI, showed that annular seabream, *Diplodus annularis* (Linnaeus, 1758) and two banded seabream, *D. vulgaris* (Geoffroy Saint-Hilaire, 1817) were the most commonly ingested, with %IRI = 28.52 and 7.47, respectively. A serranid species *Serranus cabrilla* (Linnaeus, 1758) was also substantially consumed with %IRI =10.59. All other osteichthyan species were scarcely ingested with very low %IRI.

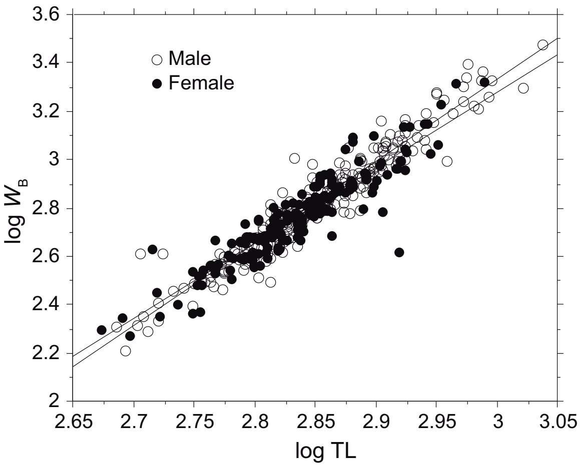

Fig. 3. Relations between the total body weight (W_B) and the total length (TL) of the fish expressed in logarithmic co-ordinates for male and female *Muraena helena* from the north-eastern Tunisian coast

Table 2

Diet composition of *Muraena helena* collected from the north-eastern Tunisian coast and its principal parameters for total sample

HT	Prey item (family)	Prey item (species)	$N_{\%}$	$W_{\%}$	$F_{\%}$	%IRI
Osteichthyes	TOTAL		78.83	96.84	84.21	98.51
	Clupeidae	*Sardina pilchardus*	4.37	1.14	5.26	1.11
		Sardinella aurita	4.37	2.91	5.26	1.47
	Congridae	*Conger conger*	0.72	0.09	0.87	0.02
	Serranidae	*Serranus cabrilla*	7.29	24.21	8.77	10.59
	Carangidae	*Trachurus mediterraneus*	0.72	0.64	0.87	0.04
	Mullidae	*Mullus surmuletus*	1.45	1.42	1.75	0.19
	Sparidae	*Boops boops*	0.72	0.16	0.87	0.029
		Dentex maroccanus	1.45	5.09	1.75	0.44
		Diplodus annularis	15.32	29.32	16.66	28.52
		D. vulgaris	8.02	12.11	9.64	7.45
		Pagrus pagrus pagrus	1.45	5.91	1.75	0.49
		Sarpa salpa	1.45	3.76	1.75	0.35
	Labridae	*Labrus bimaculatus*	0.72	0.74	0.87	0.049
		L. viridis	1.45	1.47	1.75	0.19
	Soleidae	*Solea solea*	0.72	0.05	0.87	0.026
	Unidentified		28.46	7.75	34.21	47.49
Crustacea	TOTAL		8.75	0.57	10.52	0.65
	Sicyoniidae	*Sicyonia carinata*	0.72	0.06	0.87	0.004
	Portunidae	*Liocarcinus* sp.	1.45	0.18	1.75	0.01
	Unidentified		6.56	0.32	7.89	0.36
Cephalopoda	TOTAL		8.02	2.26	9.64	0.66
	Sepiidae	*Sepia officinalis*	0.72	0.26	0.87	0.005
	Octopodidae	*Octopus defilippi*	1.45	1.24	1.75	0.003
	Unidentified		5.83	0.74	7.01	0.3
P	Posidoniaceae		4.37	0.31	5.29	0.16

HT = higher taxa, P = Plantae, $N_{\%}$ = relative abundance [%], $W_{\%}$ = gravimetric frequency [%], $F_{\%}$ = frequency of occurrence [%], %IRI = index of relative importance.

Unfortunately, some osteichthyan preys were not identified because they were partially or totally digested, %IRI = 47.49 for this category of items is the highest recorded. Two taxa were identified for both crustacean and cephalopod species, a single one for sea grass removed from stomach contents of *Muraena helena* (Table 2). Additionally, the calculated TROPH was 4.27 (SE = 0.74).

Diet related to sex. Of the 237 stomach contents examined in males, 163 were empty with V_I = 68.77%, whereas of the 174 stomach contents examined in females, 134 were empty with V_I = 77.01%. V_I values were not significantly different between males and females (χ^2 =2.00, df = 1, $P < 0.05$). Additionally, the mean number of prey items ingested by males, $N_M = 1.22 \pm 0.48$, was very close to this calculated for females, $N_M = 1.18 \pm 0.45$ and no significant differences were found between them (*t*-test = 0.793, df = 112, $P = 0.43$)

Osteichthyans, were preferentially ingested by both males and females, with $W_{\%}$ reaching 96.29 and 97.98, respectively, and with %IRI of 98.13 and 98.91, respectively (Table 3); it appears that males preferentially fed on *Diplodus annularis* with %IRI = 48.29, while females preferentially fed on *Diplodus vulgaris* and *Serranus cabrilla* with %IRI = 15.80 and 23.60, respectively; by contrast, crustaceans and cephalopods were infrequently consumed by both males and females, for each of them %IRI exhibited low values (Table 3). Values of trophic level did not show significantly differences with sex; the TROPH was 4.24 (SE = 0.73) for females and 4.23 for males (SE = 0.74) with $\chi^2 = 0.0001$, df = 1, $P < 0.05$.

Diet related to size. The size class 1 comprised 223 specimens between 472 and 697 mm TL, with V_I = 77.13%; the class 2 included 188 specimens between 700 and 1092 mm TL, with V_I = 66.48%; the V_I values calculated for classes 1 and 2

Table 3

Diet composition of males and females of *Muraena helena* collected from the north-eastern Tunisian coast and its principal parameters

HT	Prey item (family)	Prey item (species)	Males				Females			
			$N_{\%}$	$W_{\%}$	$F_{\%}$	%IRI	$N_{\%}$	$W_{\%}$	$F_{\%}$	%IRI
Osteichthyes	TOTAL		77.77	96.29	83.78	98.13	80.85	97.98	85	98.91
	Clupeidae	*Sardina pilchardus*	5.55	1.56	6.75	1.87	2.12	0.29	2.5	0.19
		Sardinella aurita	5.55	3.68	6.75	2.43	2.12	1.34	2.5	0.28
	Congridae	*Conger conger*	1.11	0.14	1.35	0.06	—	—	—	—
	Serranidae	*Serranus cabrilla*	4.44	16.9	5.4	4.49	12.76	35.07	15	23.60
	Carangidae	*Trachurus mediterraneus*	—	—	—	—	2.12	1.97	2.5	0.33
	Mullidae	*Mullus surmuletus*	1.11	0.19	1.35	0.07	2.12	0.43	2.5	0.21
	Sparidae	*Boops boops*	1.11	0.23	1.35	0.07				—
		Dentex maroccanus	1.11	5.21	1.35	0.33	2.12	4.48	2.5	0.57
		Diplodus annularis	20	37.38	21.62	48.29	6.38	12.78	7.5	4.72
		D. vulgaris	5.55	8.56	6.75	3.71	12.76	19.42	15	15.88
		Pagrus pagrus pagrus	2.22	8.79	2.7	1.15	—	—	—	—
		Sarpa salpa	2.22	5.59	2.7	0.82	—	—	—	—
	Labridae	*Labrus bimaculatus*	1.11	1.10	1.35	0.11	—	—	—	—
		L. viridis	1.11	1.03	1.35	0.11	2.12	2.35	2.5	0.36
	Soleidae	*Solea solea*	1.11	0.08	1.35	0.06	—	—	—	—
	Unidentified		24.44	4.08	31.08	34.52	36.17	1.52	42.5	52.71
Crust.			10	0.67	10.81	0.77	6.38	0.36	7.5	0.32
	Sicyoniidae	*Sicyonia carinata*	1.11	0.09	1.35	0.01	—	—	—	—
	Portunidae	*Liocarcinus* sp.	2.22	0.27	2.7	0.04	—	—	—	—
	Unidentified		6.66	0.3	8.1	0.38	6.38	0.36	7.5	0.32
Ceph.			10	2.76	12.16	1.04	4.25	1.22	5	0.178
	Sepiidae	*Sepia officinalis*	1.11	0.4	1.35	0.01	—	—	—	—
	Octopodidae	*Octopus defilippi*	2.22	1.85	2.7	0.07	—	—	—	—
	Unidentified		6.66	0.51	8.1	0.39	4.25	1.22	5	0.178
P	Posidoniacea		2.22	0.26	2.7	0.04	8.51	0.42	10	0.58

HT = higher taxa, Crust. = Crustacea, Ceph. = Cephalopoda, P = Plantae, $N_{\%}$ = relative abundance [%], $W_{\%}$ = gravimetric frequency [%], $F_{\%}$ = frequency of occurrence [%], %IRI = index of relative importance.

were not significantly different with χ^2 = 0.79, df = 1, $P < 0.05$. Additionally, the mean number of preys ingested by specimens from class I, N_M = 1.24 ± 0.47 and those of class 2, N_M = 1.142 ± 0.45, did not show significant differences between them (t = 0.37, df = 112, P = 0.71).

For both size classes, Osteichthyes exhibited the highest %IRI values, amounting to 97.17 and 99.24, respectively, but without significant changes (χ^2 = 0.021, df = 1, $P < 0.05$), and *Diplodus annularis* was the species the most commonly consumed by *Muraena helena*, in number: $N_{\%}$ = 11.11 and $N_{\%}$ = 18.91, in weight: $W_{\%}$ = 27.6 and $W_{\%}$ = 30.06, and in %IRI: 3.66 and 4.37, respectively. Although the trophic level was lower in class 1 than in class 2: 4.19 and 4.24, respectively, the differences between both values appeared to be not significant (χ^2 = 0.0003, df = 1, $P < 0.05$) (Table 4).

Diet related to season. Significant seasonal changes were observed in V_I values during spring (60.93%), summer (92.30%) autumn (64.00), and winter (76.8%), with χ^2 = 76.36, df = 3, $P < 0.05$. The abundance of prey items (N_M) was 1.18 ± 0.44 for spring, 1.25 ± 0.50 for summer, 1.16 ± 0.38 for autumn, and 1.23 ± 0.53 for winter, and there were no significant differences between those values (H = 0.15, df = 3, P = 0.98) (Table 5).

During all seasons *Muraena helena* preferentially fed on osteichthyan species; with very high values of %IRI; the lowest %IRI value was 96.35 and it was recorded in summer. Ontogenetic changes in diet were especially observed in winter, species belonging to 6 families of osteichthyans, 2 families of cephalopods and a single one of crustaceans.

The TROPH of *M. helena* showed seasonal changes, 4.19 (SE = 0.72) in spring, 4.25 (SE = 0.74) in summer,

Table 4

Diet composition of *Muraena helena* collected from the north-eastern Tunisian coast and its principal parameters—separately for two length classes

HT	Prey item (family)	Prey item (species)	Length class (total length) [mm]							
			472–697				700–1092			
			$N_{\%}$	$W_{\%}$	$F_{\%}$	%IRI	$N_{\%}$	$W_{\%}$	$F_{\%}$	%IRI
Osteichthyes		TOTAL	73.01	94.16	84.31	97.17	83.78	98.01	87.3	99.24
	Clupeidae	*Sardina pilchardus*	4.76	1.03	5.88	1.37	4.05	1.19	4.76	0.94
		Sardinella aurita	7.93	8.53	9.8	6.48	1.35	0.49	1.58	0.11
	Congridae	*Conger conger*	—	—	—	—	1.35	0.13	1.58	0.09
	Serranidae	*Serranus cabrilla*	7.93	26.52	9.8	13.57	6.75	23.22	7.93	8.98
	Carangidae	*Trachurus mediterraneus*	1.58	2.14	1.96	0.29	—	—	—	—
	Mullidae	*Mullus surmuletus*	1.58	0.47	1.96	0.16	1.35	1.83	1.58	0.19
	Sparidae	*Boops boops*	—	—	—	—	1.35	8.46	1.58	0.09
		Dentex maroccanus	1.58	5.26	1.96	0.54	1.35	5.01	1.58	0.38
		Diplodus annularis	11.11	27.6	13.72	21.34	18.91	30.06	14.28	26.41
		D. vulgaris	4.76	9.46	5.88	3.36	10.81	13.26	12.69	11.54
		Pagrus pagrus pagrus	—	—	—	—	2.7	0.22	3.17	1.33
		Sarpa salpa	1.58	0.53	1.96	0.16	1.35	5.15	1.58	0.38
	Labridae	*Labrus bimaculatus*	1.58	2.46	1.96	0.31	—	—	—	—
		L. viridis	—	—	—	—	2.7	2.1	3.17	0.57
	Soleidae	*Solea solea*	1.58	0.18	1.96	0.13	—	—	—	—
	Unidentified		26.98	9.91	33.33	49.4	29.72	6.82	34.92	48.18
Crust.		TOTAL	12.69	0.9	15.68	1.47	5.4	0.42	6.34	0.23
	Sicyoniidae	*Sicyonia carinata*	1.58	0.2	1.96	0.02	—	—	—	—
	Portunidae	*Liocarcinus* sp.	1.58	0.14	1.96	0.02	1.35	0.2	1.58	0.01
	Unidentified		9.52	0.56	11.76	0.81	4.05	0.22	4.76	0.12
Ceph.		TOTAL	9.52	4.68	11.76	1.15	6.75	1.21	7.93	0.39
	Sepiidae	*Sepia officinalis*	—	—	—	—	1.35	0.38	1.58	0.03
	Octopodidae	*Octopus defilippi*	1.58	2.79	1.96	0.06	1.35	0.57	1.58	0.04
	Unidentified		7.93	1.89	9.8	0.66	5.4	0.25	4.76	0.32
P	Posidoniacea		4.76	0.27	5.88	0.2	4.05	0.34	4.76	0.13

HT = higher taxa, Crust. = Crustacea, Ceph. = Cephalopoda, P = Plantae, $N_{\%}$ = relative abundance [%], $W_{\%}$ = gravimetric frequency [%], $F_{\%}$ = frequency of occurrence [%], %IRI = index of relative importance.

4.15 (SE = 0.71) in autumn, and 4.22 (SE = 0.73) in winter, however these differences were not significant (χ^2 = 0.0013, df = 3, $P < 0.05$).

DISCUSSION

The presently reported study points out that *Muraena helena* caught off the north-eastern Tunisian coast showed high values of the vacuity index (V_I), for the whole sample, but also for both sexes, size, and seasons. Conversely, Matić-Skoko et al. (2010) noted that in 267 specimens caught by bottom long-lines in the southern Adriatic, all stomachs were full; Anastasopoulou et al. (2013) reported a V_I of 33% for European conger, *Conger conger* (Linnaeus, 1758), from the eastern Ionian Sea, which inhabits similar bottoms as *M. helena*. These differences could not be explained by a high biodiversity of local fauna and the prey items availability, for instance low V_I values were reported in studies recently carried out in same area on top predators such as blackbellied angler, *Lophius budegassa* Spinola, 1807, and small-spotted catshark, *Scyliorhinus canicula* (Linnaeus, 1758), by Negzaoui-Garali et al. (2008) and Mnasri et al. (2012), respectively. Additionally, the relation between the total length and the total body weight showed a positive allometric growth, *b* values being 3.40 and 3.11 for males and females, respectively, and similar patterns were reported by Jiménez et al. (2007) for *M. helena* from the Canary Islands. So, the regular growth increments of *M. helena* suggest that the species found favourable environmental parameters and probably sufficient food to develop in its habitat which is the marine area of the north-eastern Tunisian coast, similar patterns were found for other marine areas (Karpouzi and Stergiou 2003). Consequently, the role of the biological environment should be ruled out concerning high V_I values recorded in this study and could rather be explained by fishing methods. All sampled specimens were caught by trawling, which occurred when they were outside their hiding holes in the bottom—hunting for preys. *Muraena helena* is known to forage not only near the bottom, but also in the water column (Matić-Skoko et al. 2011). This suggests that some specimens have not succeeded in capturing and eating prey item prior to be caught themselves, and consequently their stomachs were found empty, when examined. Additionally, the captured *M. helena* could spent a long time in nets before it was collected, and the consumed prey items were entirely or partially digested. These latter patterns explained also why unidentified osteichthyan preys exhibited a relatively high %IRI, reaching 47.79 (see Table 2).

The vacuity index (V_I) did not show significant difference between males and females although a supplementary amount of energy was required by adult females during reproduction processes. Similarly, no significant changes of V_I related to size were recorded despite the fact large specimens are more experienced feeders (Wetherbee and Cortés 2004) and larger amount of food is required for larger specimens to assume energetic demands (Galis et al. 1994, Karachle and Stergiou 2011). Wetherbee and Cortés (2004) noted that seasonal shifts presumably reflect both migration of preys and their predators, although such patterns are limited in the study area, they could not be totally ruled out. Additionally, V_I values showed seasonal significant changes, probably due to both feeding intensity and sampling, the numbers of specimens collected varied for each season, but also due to prey availability and other biological features such as the reproductive processes which could influence prey items consumption. Similar patterns were recorded for *Lophius piscatorius* Linnaeus, 1758 and *Scyliorhinus canicula* (Linnaeus, 1758), top predators which inhabit the same area (Negzaoui-Garali et al. 2008, Mnasri et al. 2012).

Muraena helena from the north-eastern Tunisian coast fed mainly on osteichthyans (%IRI = 98.51), while crustaceans (%IRI = 0.65) and cephalopods (%IRI = 0.66) were secondary preys, and occasionally ingested sea grass (%IRI = 0.16) was of minor importance as fish food. Similar patterns were observed for diet in relation to sex. Males and females fed preferentially on osteichthyans and no ontogenetic changes were recorded between them. Additionally, osteichthyans constituted the main preys for *M. helena* in both small and large specimens; however the small specimens fed on small species which inhabited the water column, generally pelagic such as European pilchard, *Sardina pilchardus* (Walbaum, 1792); round sardinella, *Sardinella aurita* Valenciennes, 1847; and Mediterranean horse mackerel. *Trachurus mediterraneus* (Steindachner, 1868); conversely, the larger specimens fed on larger osteichthyans such as *Conger conger* and sparid species, mainly *Diplodus annularis* and *D. vulgaris*. The occurrence of *C. conger* in stomach contents could also be considered as the result of a competition pressure for food between two sympatric species, inhabiting similar biotopes. With special regard to elasmobranch species, Wetherbee and Cortés (2004) noted that larger predators fed on larger preys, similar patterns concern also osteichthyan species (Juanes and Conover 1994, La Mesa et al. 2007). *Muraena helena* mainly fed on osteichthyan species throughout the year, however ontogenetic changes in diet were recorded in summer at species level because large sparids were not found in the stomach contents, additionally no cephalopod species were found in the stomach contents during spring and summer, such phenomenon could be due to low prey availability.

Our results were consistent with the results of Matic-Skoko et al. (2010) who studied feeding habits and trophic status of *Muraena helena* from the Adriatic Sea and noted that recognizable preys of 14 different taxa were identified and grouped in 6 classes, indicating that osteichthyans constituted the main preys. However, Matic-Skoko et al. (2010) recorded *Phycis phycis* (Linnaeus, 1766) as the dominant osteichthyan prey and reported the occurrence of several crustacean preys, and also gastropods and bivalves, conversely these latter preys were not found in the stomach contents in our study. These ontogenetic changes between *M. helena* from the north-eastern

Table 5

Seasonal changes of diet of *Muraena helena* collected from the north-eastern Tunisian coast and its principal parameters

HT	Prey item (family)	Prey item (species)	Spring $N_{\%}$	Spring $W_{\%}$	Spring $F_{\%}$	Spring %IRI	Summer $N_{\%}$	Summer $W_{\%}$	Summer $F_{\%}$	Summer %IRI	Autumn $N_{\%}$	Autumn $W_{\%}$	Autumn $F_{\%}$	Autumn %IRI	Winter $N_{\%}$	Winter $W_{\%}$	Winter $F_{\%}$	Winter %IRI
Osteichthyes		TOTAL	77.96	97.83	84	98.57	80	99.63	96.35		76.19	97.19	83.33	98.17	80.76	95.26	88.09	98.48
	Clupeidae	*Sardina pilchardus*	1.69	0.8	2	0.15	20	23.16	17.79		—	—	—	—	5.76	1.66	7.14	1.66
		Sardinella aurita	3.38	3.16	4	0.81	40	14.07	44.58		20	23.16	25	1.47	3.84	2.07	4.76	0.88
	Congridae	*Conger conger*	1.69	0.21	2	0.11	—	—	—		—	—	—	—	—	—	—	—
	Serranidae	*Serranus cabrilla*	10.16	41.73	12	19.4	20	62.4	33.97						5.76	13.58	7.14	4.33
	Carangidae	*Trachurus mediterraneus*	—	—	—	—	—	—	—		4.76	3.35	5.55	1.7	—	—	—	—
	Mullidae	*Mullus surmuletus*	—	—	—	—	—	—	—		—	—	—	—	3.84	4.09	4.76	1.18
	Sparidae	*Boops boops*	—	—	—	—	—	—	—		—	—	—	—	1.92	0.46	2.38	0.17
		Dentex maroccanus	—	—	—	—	—	—	—		4.76	18.17	5.55	4.81	1.92	4.56	2.38	0.48
		Diplodus annularis	10.16	18.06	12	10.55	—	—	—		14.28	16.2	16.66	19.22	23.07	52.3	23.8	56.29
		D. vulgaris	8.47	12.4	10	6.5	—	—	—		14.28	18.56	16.66	20.7	5.76	8.68	7.14	3.23
		Pagrus pagrus pagrus	—	—	—	—	9.52	30.67	—		—	—	—	16.89	—	—	—	—
		Sarpa salpa	3.38	8.45	4	1.47	—	—	—		—	—	—	—	—	—	—	—
	Labridae	*Labrus bimaculatus*	1.69	1.66	2	0.2	—	—	—		—	—	—	—	—	—	—	—
		L. viridis	1.69	1.73	2	0.21	—	—	—		—	—	—	—	1.92	2.01	2.38	0.29
	Soleidae	*Solea solea*	—	—	—	—	—	—	—		—	—	—	—	1.92	0.15	2.08	0.155
	Unidentified		33.59	9.57	42	59.11	—	—	—		23.8	7.93	27.77	33.34	25	5.65	30.95	29.76
Crust.		TOTAL	6.77	0.35	8	0.38	20	0.36	25	3.64	9.52	0.05	11.11	0.72	9.61	1.14	11.9	0.81
	Sicyoniidae	*Sicyonia carinata*	1.69	0.13	2	0.02	—	—	—	—	—	—	—	—	—	—	—	—
	Portunidae	*Liocarcinus* sp.	—	—	—	—	—	—	—	—	—	—	—	—	3.84	0.53	4.76	0.13
	Unidentified		5.08	0.21	6	0.21	20	0.36	25	3.64	9.52	0.05	11.11	0.72	5.76	0.6	7.14	0.28
Ceph.		TOTAL	—	—	—	—	—	—	—	—	9.52	2.63	11.11	0.91	7.69	3.14	9.52	0.67
	Sepiidae	*Sepia officinalis*	—	—	—	—	—	—	—	—	—	—	—	—	1.92	0.77	2.38	0.04
	Octopodidae	*Octopus defilippi*	—	—	—	—	—	—	—	—	4.76	2.09	5.55	0.25	1.92	2.42	2.38	0.06
	Unidentified		—	—	—	—	—	—	—	—	4.76	0.54	5.55	0.2	13.84	0.21	4.76	0.12
P	Posidoniacea		6.77	0.53	8	0.39	—	—	—	—	4.76	0.11	5.55	0.18	1.92	0.16	2.38	0.03

HT = higher taxa, Crust. = Crustacea, Ceph. = Cephalopoda, P = Plantae, $N_{\%}$ = relative abundance [%], $W_{\%}$ = gravimetric frequency [%], $F_{\%}$ = frequency of occurrence [%], %IRI = index of relative importance.

Tunisian coast and from the Adriatic Sea are probably due to latitudinal differences, especially physical parameters, biological environment and prey availability, additionally sampling cannot be ruled out. Anastasopoulou et al. (2013) noted that as its sympatric species—*Muraena muraena*—*Conger conger* mainly fed on osteichthyans but noted also that crustaceans and cephalopods played an important role in the diet of this species. Similar patterns were recorded for *C. conger* from other marine species, considering crustaceans as occasional preys, conversely, they were classified as preferential preys by Abi-Ayad et al. (2011) suggesting that such differences may be attributed to latitudinal differences in prey availability or sampling deficiency and the fact that some preys were totally or partially digested should not be ruled out.

Following the classification of fishes in functional groups based on trophic levels (Stergiou and Karpouzi 2002 Karachle and Stergiou 2011), Mediterranean moray is a carnivorous species which mainly consumes osteichthyans, although the V_I calculated in this study revealed high values, it could also considered as a voracious species. Additionally, crustaceans and cephalopods played a minor role in its diet, and the species should be classified as a piscivorous species. Stergiou and Karpouzi (2002) did not assign a value to the trophic level of *Muraena helena*, but this of *Conger conger* ranged between 3.20 and 3.49. Matic-Skoko et al. (2010) noted that *M. helena* from the Adriatic Sea was mainly a piscivore with a trophic level of 4 and up, and similar value was given for specimens from Balearic Islands in north-western Mediterranean (Coll et al. 2012), and were close to this recorded in the present paper: 4.27 (SE = 0.74). Consequently TROPH value of *Muraena helena* from the north-eastern Tunisian coast should be included among those estimated for carnivorous species such as elasmobranch species ranging between 3.10 and 4.70 (Cortés 1999), and many marine mammals ranging between 3.20 and 4.50 (Pauly et al. 1998). The results herein included showed that *M. helena* is a top predator which utilized similar resources as other high level marine consumers which inhabit the same marine area, such as *Lophius piscatorius*, *Scyliorhinus canicula*, and common torpedo *Torpedo torpedo* (Linnaeus, 1758) with TROPH of 4.54, 3.93, and 3.78, respectively (Negzaoui-Garali et al. 2008, Mnasri et al. 2012, El Kamel-Moutalibi et al. 2013).

However, although the relative abundance of *Muraena helena* off the northern coast of Tunisia was reported (Bradai et al. 2004), its potential importance in the area remains poorly known, as in other Mediterranean areas, except for the frequencies in the captures of recreational and commercial fisheries (Morales-Nin et al. 2005, Ordines et al. 2005). Conversely, its role as a top predator has not been adequately investigated and therefore, its trophic position in the rocky bottoms ecosystems within the entire Mediterranean is high. The high trophic level of *M. helena* shows that the species is able to execute its control over the coastal communities, as it was the case for shark species (Cortés 1999), this suitable hypothesis needs confirmation, probably due to a lack of studies. Unfortunately, *M. helena* was rarely taken into account in surveys about the functioning of coastal ecosystems such those given by Valls et al. (2012), that will allow to consider it as one of the most important species in the trophic relations of the Mediterranean coastal areas.

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