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Feeding habits of the striped red mullet, *Mullus surmuletus* in the eastern Adriatic Sea

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Feeding habits of the striped red mullet, Mullus surmutetus *in the eastern Adriatic Sea were investigated. Stomach contents of 203 specimens (11.5 - 32.9 cm TL) collected by bottom trawling were analyzed. Commonly accepted procedures were followed during the diet composition inspection and standard keys were used for food items determination. Examinations showed that 39 identified prey taxa belong to 11 major systematic groups: Crustacea, Gastropoda, Bivalvia, Pisces, Cnidaria, Echinodermata, Polychaeta, Nematoda, Bryozoa, Algae and Rhizaria. The predominant and preferred prey category was decapod crustaceans within all size categories and only in the largest individuals, the dominance of Bivalvia followed by Polychaeta and Crustacea were found. The largest individuals also showed more variety in consumption of different prey categories and a higher mean number of prey items in comparison with smaller fish. No significant differences in prey foraging between males and females ($p>0.05$) and regarding to season ($p>0.05$) were found. Feeding on such wide spectra of prey without significant variations regarding to sex and season suggests that the striped red mullets are able to adapt to shifts in spatio-temporal variations in the abundance of potential prey. Presence of detritus in the digestive tracts is highly related to its foraging behaviour on muddy detritic bottoms.*

Key words: feeding, *Mullus surmuletus*, Adriatic Sea

INTRODUCTION

The food web models are very valuable tools in measuring species' importance in an ecosystem (POLIS & WINEMILLER, 1995; BELGRANO *et al*., 2005; DE RUITER *et al*., 2005). Although they may become very complex resulting in uncertain causal relationships between distinct species, such models allow the estimation of the number of indirect interactions between organisms of the same or different trophic levels and evaluation of the overall trophic 'connectedness' of a single species within an ecosystem.

Among fishes, goatfishes may provide important ecosystem services, including resuspension and the formation of mixed species foraging associations due to their very active foraging behaviour with vigorous stirring up of sediments by their barbells and mouths (RANDALL, 1967; GOLANI & GALIL, 1991; UIBLEIN, 1991; MCCORMICK, 1995; KRAJEWSKI *et al*., 2006). These characteristics of their resource use make the goatfishes essential components of food webs in coastal ecosystems. Goatfishes have relatively rarely been considered in food web models, especially at the level of single species (UIBLEIN, 2007). The reason for this is probably derives from insufficient information on their feeding biology in the respective habitat/area, mostly sandy bottoms adjacent to hard bottoms, including coral reefs.

Despite the lack of biological information (AJEMIAN *et al*., 2016) the striped red mullet, *Mullus surmuletus* Linnaeus, 1758 is a very important species from an economical and ecological point of view in the Mediterranean littoral benthic communities (STAGLIČIĆ *et al*., 2011) and highly exploited species by Mediterranean demersal (REÑONES *et al.,* 1995; MEHANNA, 2009) and small-scale (MATIĆ-SKOKO *et al*., 2011; GFCM, 2015; GFCM, 2017) fisheries. It is distributed in the Eastern Atlantic Sea from the North Sea to Senegal and throughout the Mediterranean and Black seas (WHITEHEAD *et al.,* 1986). The striped red mullet is a bottom-dwelling species, inhabiting shallow soft bottoms, seagrass beds and rocky bottoms (LOMBARTE *et al.*, 2000; BAUTISTA-VEGA, 2008; TSERPES *et al*., 2002), usually between 10 and 80 m. Spawning occurs in spring period (AMIN *et a*l., 2016). Striped red mullet becomes mature after its first year for both sexes (AMIN *et a*l., 2016). Like other goatfishes (HOLLAND *et al*., 1993; MEYER *et al.,* 2000), *M. surmuletus* shows daily short-distance movements within and among foraging and resting sites preying on small benthic invertebrates such as shrimps, amphipods, polychaetes, mollusks and benthic fishes (LABROPOULOU *et al*., 1997; LOMBARTE *et al*., 2000; MEHANNA, 2009). Seasonal migrations and formation of spawning aggregations that are known for sympatric species red mullet, *Mullus barbatus* (MACHIAS & LABROPOULOU, 2002) are not well expressed for *M. surmuletus*. Juveniles are often encountered on soft bottoms, seagrass beds and at different depths than adults, reflecting both horizontal and vertical ontogenetic habitat shifts. While young show a tendency of forming groups, adults usually live solitary or in smaller groups (JARDAS, 1996).

Foraging behaviour and consequently diet are not stable and may significantly change among different habitats, but also during life history. The aim of this study is to investigate ontogenetic shifts and seasonal fluctuations in resource use in the Adriatic Sea striped red mullet, *Mullus surmuletus*, with size-/age-/sex-related change in pray foraging on typical muddy detritic bottoms.

MATERIAL AND METHODS

The total of 203 individuals of *Mullus surmuletus* were caught using bottom trawls (40 mm square mesh size) at depths from 80 to 160 m in the Jabuka Pit area (middle Adriatic: 43°35'30.20"N 15°45'35.38" E). The samples were taken in December 2011 and through 2012 year in the following months: January, February, March, April, May and October. After being caught the specimens were immediately transported to laboratory for examination. All specimens were weighted to nearest 0.1 g and their total length (TL) measured to nearest mm. Sex of every fish was determined. The length-weight relationship was expressed with equation $W=aL^b$; where W is total body weight, L is total length, while *a* and *b* are constants. The gonadosomatic index (GSI) was calculated using equation GSI= (gonad weight/fish weight) * 100.

All specimens (138) that contained prey items were divided in 10 mm TL classes in order to determine frequency and numerical abundance of a certain prey group in stomachs related to fish size. For qualitative and quantitative diet analysis, digestive tracts were weighed (wet weight) and preserved in a 4% formaldehyde for the examination of their contents. Afterwards, in the laboratory, gut contents were identified and the number of empty stomachs was shown as the vacuity index (%VI). Stomach contents were examined under a dissecting microscope using reflected light. Each dietary item was identified to the lowest possible taxon, counted and weighed to the nearest 0.01 g. Item weight was obtained by wet weight method. All fragments of some prey groups were put on previously weighed filter paper and left for a few hours at room temperature. Semidry filter paper was then weighed to a precision of 0.001 g. A true weight was obtained as the diference between wet filter paper together with prey organisms and the known dry filter paper weight. The level

***Table 1**. Percent frequency of occurrence (%F), percent of total number (%N), percent of total weight (%W) and percent index of relative importance (%IRI) for food items in* Mullus surmuletus

Food items			F (%)	N(%)	W(%)	IRI(%)
Crustacea			**54.39**	**58.16**	**65.03**	**81.66**
Non-identified Crustacea			23.91	29.27	40.32	76.54
Decapoda			2.90	6.50	4.52	1.47
Natania	Palaemonetes		0.72	0.41	0.32	0.02
	Penaeidae		0.72	0.81	0.18	0.03
Eucarida	Galatheidae		4.35	2.44	2.44	0.98
		Galathea squamiffera	1.45	0.81	0.32	0.08
		Galathea strigosa	0.72	0.81	0.09	0.03
		Munida rugosa	0.72	0.41	1.45	0.06
	Leucosiidae	*Ilia nucleus*	0.72	0.41	0.18	0.02
		Ebalia sp.	0.72	0.41	0.18	0.02
		Ebalia granulosa	0.72	0.81	0.32	0.04
	Xanthidae		2.17	4.47	4.71	0.92
		Xantho pilipes	0.04	0.031	0.009	0.088
		Xantho poressa	0.72	0.41	0.18	0.02
		Monodaeus couchii	0.72	0.41	0.23	0.02
	Portunidae		2.90	2.44	1.13	0.48
		Bathynectes longipes	0.72	0.41	0.36	0.03
		Macropipus corrugatus	2.17	1.22	2.53	0.38
		Macropipus pusilus	0.72	0.41	1.72	0.07
		Liocarcinus arcuatus	0.72	0.41	0.23	0.02
	Paguridae		0.72	0.41	0.54	0.03
		Parthenopeidae	1.45	0.81	0.32	0.08
	Grapsidae	*Pachygrapsus marmoratus*	0.72	1.63	0.63	0.08
	Pilumnidae	*Pilumnus hirtellus*	1.45	0.81	0.27	0.07
	Majidae	*Pisa nodipes*	0.72	0.81	0.95	0.06
Amphipoda			0.72	0.41	0.90	0.04
Gastropoda			**2.17**	**2.44**	**0.32**	**0.09**
Non-identified Gastropoda			0.72	0.81	0.09	0.03
	Nassariidae	*Hinia sp.*	0.72	0.41	0.05	0.02
	Cerithiidae	*Bittium reticulatum*	0.72	1.22	0.18	0.05
Bivalvia			**13.04**	**18.29**	**8.01**	**6.94**
Non-identified Bivalvia			7.25	9.35	4.43	4.59
	Limidae	*Limulata subovata*	0.72	0.41	0.09	0.02
	Pectinidae	*Palliolum incomparabile*	0.72	0.41	0.05	0.02
	Solemidae	*Solemya togata*	4.35	8.13	3.44	2.31
Pisces			**5.07**	**3.25**	**0.77**	**0.94**
Cnidaria			**1.45**	**0.81**	**0.14**	**0.06**
Anthozoa			1.45	0.81	0.14	0.06

Echinodermata			**3.62**	**4.07**	**4.34**	**1.07**
Echinoidea	Regularia		0.72	0.41	0.09	0.02
		Echinocyanus pusillus	2.90	3.66	4.25	1.05
Polychaeta			**9.42**	**6.10**	**10.63**	**7.25**
Non-identified Polychaeta			9.42	6.10	10.63	7.25
Nematoda			**2.90**	**2.85**	**9.77**	**1.68**
Bryozoa			**2.17**	**1.22**	**0.36**	**0.09**
Non-identified Bryozoa			1.45	0.81	0.32	0.08
		Margaretta cereoides	0.72	0.41	0.05	0.02
Algae			**2.90**	**1.63**	**0.23**	**0.25**
Rhizaria			**0.72**	**0.41**	**0.05**	**0.02**
Foraminifera		*Elphidium crispum*	0.72	0.41	0.05	0.02

of identification depended on the completeness of the food degradation and its condition.

Quantitative analysis is presented using three standard indices: the percentage frequency of occurrence (%F = the number of stomachs containing prey item/ total number of non-empty stomachs x 100); the percentage numerical abundance (%N = the number of prey items of a given prey category in all non- empty stomachs/ total number of prey items in all stomachs x 100); the gravimetric percentage (% W = the weight of prey items of a given prey category in all non- empty stomachs/ total weight of food items in all stomachs x 100) (HYSLOP, 1980). To get more precise results of diet we used the index of relative importance (%IRI), modified by HACUNDA (1981) [IRI = (% N + % W) x % F], expressed as percentage [(IRI / ΣIRI) x 100].

Sexual and seasonal differences in diet were evaluated with multivariate PERMANOVA and non-metric multidimensional scaling (MDS) plot (PRIMER v6). Data were square-root transformed and a similarity matrix was constructed using the Bray-Curtis similarity coefficient.

RESULTS

A total of 203 *Mullus surmuletus* individuals ranged from 11.5 to 32.9 cm TL, with an average of 17.29 cm (±3.34 SD). Weight ranged from 18.39 to 432.25 g, with an average of 68.86 (±49.91 SD). The total sample was represented by 124 male and 79 female individuals. The length distribution of males was from 11.9 to 28.6 cm, with an average of 17.19 cm ± 2.99 SD, while in female individuals TL ranged from 11.5 to 32.9 cm, with an average of 17.38 cm ± 3.84 SD. Both, male and female specimens were divided in the 10 mm TL size classes (Fig. 1). Weight ranged from 14.88 to 275.34 g for males, with an average of 64.75 g ± 38.21 SD, while females' weight ranged from 18.39 to 432.25 g, with an average of 77.11 ± 64.57 SD.

The calculated length-weight equation for the whole sample was $W=0.017TL^{2.871}$ (R^2=0.949). This relationship for males was described by the parameters a=0.022 and b=2.774 (R^2=0.926) and for females by the parameters a=0.013 and b=2.974 (R^2=0.978) (Fig. 2). The gonadosomatic index for both sexes varied from 0.48 to 1.7 and was highest in spring and lowest in autumn (Fig. 3).

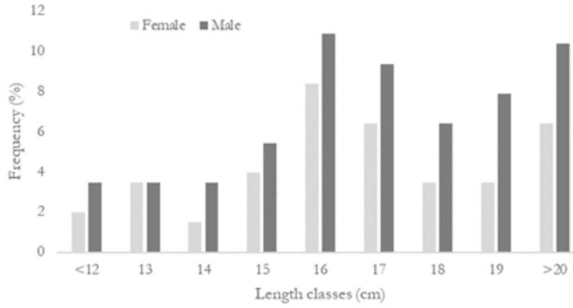

Fig. 1. Frequencies of females and males of Mullus surmuletus according to size classes

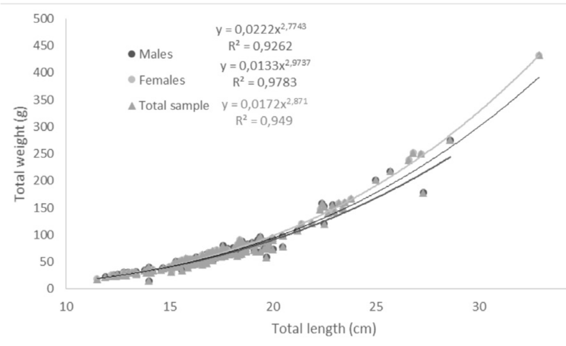

Fig. 2. Length-weight relationship of females and males of Mullus surmuletus

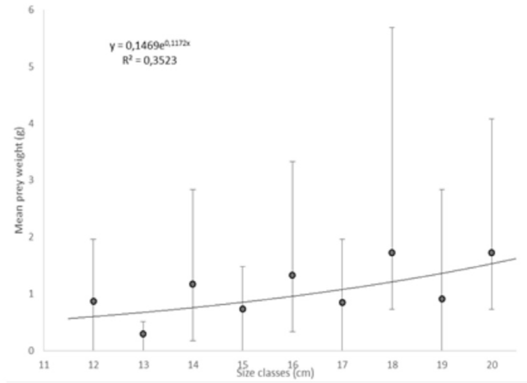

Fig. 4. Distribution of mean prey weight among the size classes in Mullus surmuletus

In total, 65 digestive tracts were empty (%VI=32.02%). The highest number of empty stomachs were recorded during autumn for females (%VI= 28.13%) and during spring for males (%VI= 60.0%). The greatest vacuity index was noticed in size class <12 cm for females with maximum value of 100%, while in larger classes (18, 19 and >20 cm) there were no empty stomachs. The diet of *M. surmuletus* consisted of at least 39 prey taxa belonging to 11 major systematic groups (Crustacea, Gastropoda, Bivalvia, Pisces, Cnidaria, Echinodermata, Polychaeta, Nematoda, Bryozoa, Algae and Rhizaria). The relative importance of different prey groups and taxa is given in the Table 1. According to the index of relative importance crustaceans dominated (%IRI=81.66) and they are the most frequent prey group (%F=54.39), so they can be regarded as the preferred food. Polychaetes (%IRI=7.25) occurred in 9.42% of the analysed specimens. Bivalves (%IRI=6.94) were found in 13.04% of stomachs, and the most numerous species was *Solemya togata* (%F=4.35). According to the frequency of occurrence, polychaetes and bivalves can be considered as secondary food. Other prey groups are categorized as random food.

The weight of ingested material varied with a size of fish, with its maximum of 15.8 g at the length of 18 cm. The lowest value of prey mass (W= 0.03) was noticed in smaller specimens, in 13 cm size class. The average of prey weight was 1.84 g ± 2.08 SD (Fig. 4).

The number of ingested items mostly increased with the fish size classes. Maximal number of ingested prey items (N=40) was recorded in the 16 cm size class. In the smaller size classes (<12, 13, 14 cm) a significantly lower mean number of prey items (1.49) was noticed. In the larger size classes (17,18,19,>20 cm) the average number of ingested prey items was 2.9. In total, the average number of ingested items per fish was 2.46 (± 6.17 SD) (Fig.5).

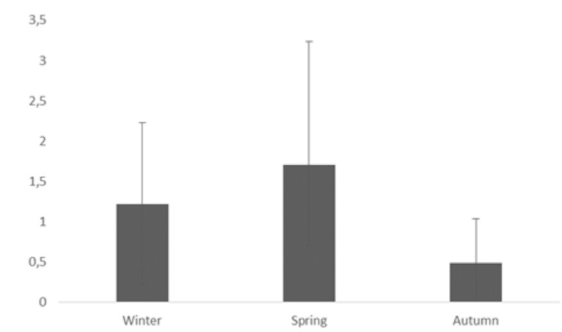

Fig. 3. Sesonal variation of the gonadosomatic index (GSI)

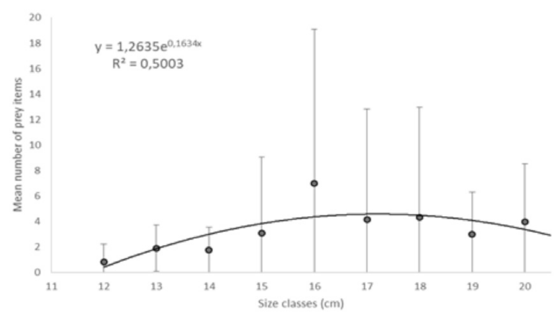

Fig. 5. Relationship between the mean number of prey items and the size classes of Mullus surmuletus

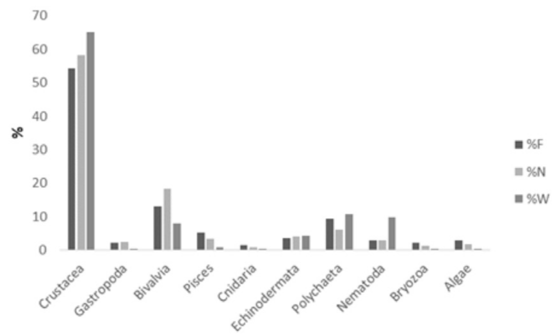

Fig. 6. The frequency of occurrence (F%), numerical abundance (N%) and percentage weight (W%) of main prey categories in Mullus surmuletus

Crustaceans were the predominant prey category regarding frequency (%F=54.38), numerical abundance (%N=58.16) and weight (%W=65.03). Apart from Crustacea, Bivalvia (%F=13.04) and Polychaeta (%F=9.4) had considerably smaller contributions and reached 18.29% and 6.1% by numerical abundances (%N), respectively. Apart from Crustacea (%W=63.05) and Polychaeta (%W=10.63), only Nematoda and Bivalvia slightly contributed in weight of prey items with 9.77% and 8.01%, respectively. Other taxa found within the *M. surmuletus* prey spectra were of less importance (Fig. 6).

Crustaceans were the predominant prey taxa according to %IRI index in all size categories, except in the >20 cm size class, where the most diverse prey composition is recorded. In that size class (>20 cm), the dominant prey category was Bivalvia with 52.54 (%IRI), followed by Polychaeta (%IRI=20.11) and Crustacea (%IRI=17.21) (Fig. 7).

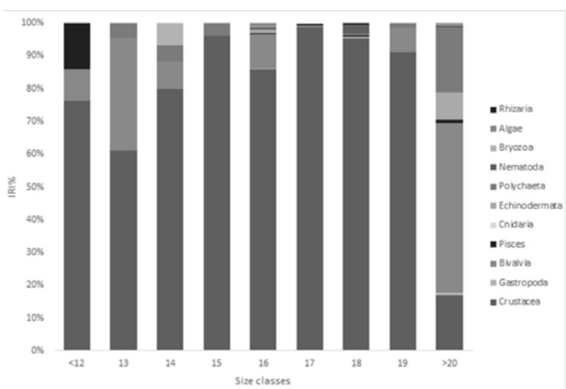

Fig. 7. Composition of Mullus surmuletus diet as a function of size, based on the %IRI values of the major prey groups

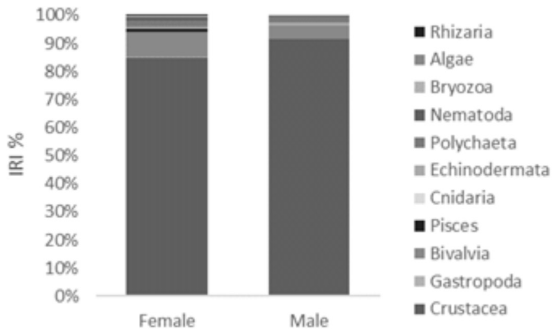

Fig. 8. The diet composition based on IRI% of Mullus surmuletus regarding sex

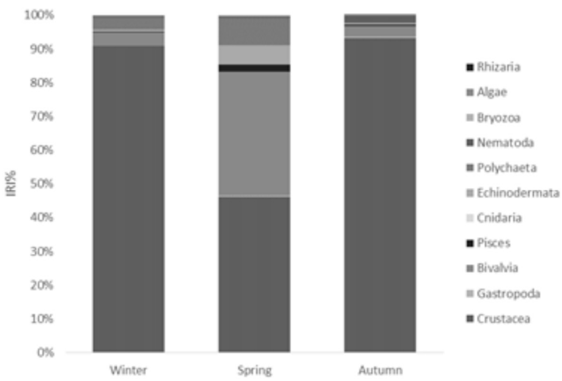

Fig. 9. Seasonal variation of Mullus surmuletus diet based on the %IRI values of the major prey groups

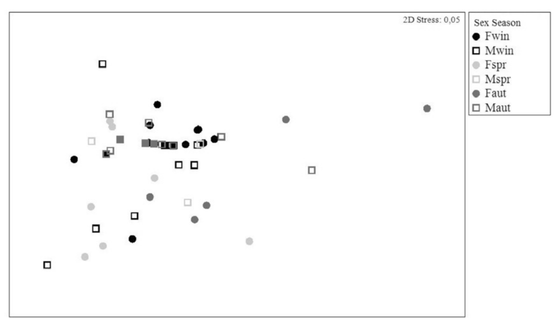

Fig. 10. Multidimensional scaling (MDS) plot of the W prey categories in the stomachs of M. surmuletus (F – female, M – male, win – winter, spr – spring, aut – autumn)

Similar prey spectra dominated by crustaceans with values of %IRI=85.16 for females and %IRI=91.74 for males was recorded. Bivalvia prey group contributed more to females' diet

(%IRI=8.88) than for males (%IRI=4.76). Other prey groups were less represented (Fig. 8).

Similar prey composition in term of %IRI index was recorded during winter and autumn, with the values higher than 90% for Crustacea in both seasons. In the spring period, the striped red mullet showed more diverse prey spectra according to the contribution of other prey groups. Apart from the Crustacea (%IRI=46.19), other prey like Bivalvia (%IRI=35.59), Polychaeta (%IRI=8.07) and Echinodermata (%IRI=5.67) contributed more to the diet in spring than in colder months (Figure 9). However, multivariate PERMANOVA showed similar diet composition regarding sex and season ($p>0.05$) and MDS plot revealed it (Fig. 10).

DISCUSSION

Due to known species-specific differences in goatfish foraging behaviour and diet selection, it may be preferable to include in ecological studies and food web models only those species that have been thoroughly studied (UIBLEIN, 2007), particularly for the often co-occurring red mullet and striped red mullet (LABROPOULOU & ELEFTHERIOU, 1997; AGUIRRE & SÁNCHEZ, 2005). In food web models apart from species-specific differences, it should also be considered whether goatfishes undergo ontogenetic shifts in foraging behaviour, diet, and habitat selection (UIBLEIN, 1991; LABROPOULOU *et al*., 1997).

The diet of the striped red mullet, *Mullus surmuletus,* in the Adriatic had not been studied until now, although generally diet composition data exist in the literature (LABROPOULOU *et al*., 1997; LOMBARTE *et al*., 2000; MEHANNA, 2009; AJEMIAN *et al*., 2016). However, due to growing awareness that goatfishes, particularly *M. surmuletus* in the Mediterranean, are potentially good ecological indicators of anthropogenic impact (UIBLEIN, 2007) and this family is put under the specific request for replenishment of the biological data gap. UIBLEIN (2007) emphasised that goatfishes respond to human-induced factors such as fisheries and habitat modification, as reflected by their abundance, size, weight changes, or changes in their distributional range. Thus, the temperature increase may lead to changes in the reproductive or growth rates and longer warming periods may induce goatfishes to migrate to higher latitudes, as exemplified by *M. surmuletus* in the North Sea (BEARE *et al*., 2004). It is very important to reveal the spatial framework of growth, age, and reproduction for these Mullus species. Since foraging behaviour and feeding itself are essential in shaping all life parameters, the importance of such data is an obvious necessity.

The length and weight range together with length-weight relationship in this study revealed that analyzed *Mullus surmuletus* specimens exhibited negative allometric growth (b=2.871). Previous research conducted by DULČIĆ & KRALJEVIĆ (1996) for *M. surmuletus* within similar length range (15.4 - 30.9 TL), suggested positive allometric growth (b= 3.512). Moreover, other authors (FROSER & PAULY, 1998; MOUTOPOULOS & STERIGIOU, 2002; ARSLAN & ISMEN, 2013) also reported positive allometric growth. Such difference in findings can be a consequence of several factors affecting the sample composition like salinity fluctuations, sex ratio, food availability, season and maturity stage of the inspected fish (SHEPHERD & GRIMES, 1983; PAULY, 1984; CHERIF *et al*., 2007). Generally, lower growth in weight implies higher energy consumption and/or lower energy gain due to the lack of suitable or desirable prey in the habitat. However, this may result in with a lower condition factor that can further affect foraging behaviour and consequently other psychological processes.

Higher percentage of premature and mature individuals and individuals that just spawned in the total sample may affect length–weight relationship due to the higher or lower gonadosomatic index (GSI), respectively. In this study, the average values of GSI increased from winter (GSI=1.22) and reached their maximum (GSI=1.70) in spring, suggesting spawning period in that season. Such results confirm findings of JARDAS (1996) about the spawning period in the May, June and July for *M. surmuletus* on the eastern Adriatic coast. ARSLAN & ISMEN (2013) also noticed an increasing of the gonadosomatic index after winter period, and decreased after May, in the North Aegean Sea. Data from Mediterranean and Atlantic (MORALES-NIN, 1991; CAMPILO, 1992; N´DA & DANIEL, 1993; LAMRINI, 2010; ARSLAN & ISMEN, 2013) also suggested the spawning period during spring, starting in April and May.

Earlier studies (DULČIĆ, 1996; JARDAS *et al.*, 2004) also confirmed that the spawning period might be influenced by feeding intensity, which can be reflected on the vacuity index of the investigated fish. According to the several investigations in the Adriatic Sea (JARDAS & PALLAORO, 1991; DULČIĆ, 1996; JARDAS *et al.*, 2004) the highest values of empty stomachs often appeared during the spawning period for different species. In this study, significantly different numbers of empty stomach by sex and season were recorded but without correlation with the spawning period. Further, LABROPOULOU *et al.* (1997) haven't detected differences in vacuity index among the seasons for *M. surmuletus* in the Mediterranean Sea. Sea temperature can also be a trigger for an ontogenetic migration of larger specimens in deeper water (LABROPOULOU *et al.*, 1997). In accordance to this, VASSILOPOULOU *et al.* (2001) reported that the highest values of the vacuity index in the striped red mullet from the Aegean Sea were found at larger specimens. Similar results have been reported in the north eastern Mediterranean by LABROPOULOU *et al.* (1997), where the maximum of vacuity index (VI=57.89%) was obtained in largest individuals. In this study, males had lower number of empty stomachs in the smaller size categories while no empty stomachs were found in the largest females. Moreover, the highest number of empty stomachs has been recorded in smaller individuals. However, higher percentage of empty stomach can be consequence of the catch method, particularly, trawl survey could affect the vacuity index.

In general, crustaceans were the dominant prey taxa in all analysed indexes, frequency of occurrence, numerical abundance and weight percentage. Bivalvia and Polychaeta were significantly less presented in *M. surmuletus* diet by the mentioned indexes, while other prey taxa were in undistinguished proportions. LABROPULOU & ELEFTHERIOU (1997) studying foraging ecology of demersal fish also found Decapoda as the predominant prey by number and weight in *M. surmuletus* diet. The same was reported by GOLANI & GAIL (1991) and VASSILOPOULOU *et al.* (2001). Despite decapods being the most frequent crustaceans, mysids and euphasids were also numerically important while fish were represented with low contribution (%W=9%) and consumption of cephalopods by larger specimens were observed (VASSILOPOULOU *et al.*, 2001). However, N`DA (1992) observed the important role of the pelagic prey in the diet of the same species on the French Atlantic coast.

Considering the contribution of a specified prey by %IRI, a dietary importance of ingested preys can be determined. Results presented in this study highlighted preference on the Crustacea (%IRI=81.66) following by Polychaeta (%IRI=7.25) and Bivalvia (%IRI=6.94), while other prey taxa were represented with minor importance according to %IRI. However, some prey taxa can consequently be less represented due to the low level of identification. Numerous studies (BEN-ELIAHU & GOLANI, 1990; N´DA, 1992; BADALAMENTI *et al.*, 1993; LABROPULOU & ELEFTHERIOU, 1997; SERRANO *et al.*, 2003) emphasized the importance of motile and carnivorous species in the diet of the striped red mullet. Thus, BAUTISTA-VEGA *et al.* (2008) reported dominance of motile surface and sub-surface deposit feeding polychaetes in the study from the north-west Mediterranean Sea. In general, preying mostly on crustaceans, polychaetes, bivalves, ophiurids and amphipods indicates feeding behaviour of this species. Furthermore, a lot of inorganic material of sediment origin has been found in the digestive tracts of the striped red mullet from the eastern Adriatic Sea. MAZZOLA *et al.* (1999) reported presence of detritus in *Mullus surmuletus* digestive tracts, which can be related to the foraging behaviour of the investigated species. Namely, *M. surmuletus* ingested detritus together with prey organisms detected in the sediment using barbels (LOMBARTE & AGUIRRE, 1997). Definitely, this is a reflection of living on muddy detritic bottoms. Surely, diet comparison of specimens inhabiting different bottoms and depths are necessary in future investigations.

Apart from feeding intensity, the fish size can also influence the prey composition of the diet. A number of authors (GOLANI & GALIL, 1991; GOLANI, 1994; GUILLEN & MARRTINEZ, 1995) recorded different pray selection according to fish size, as well as in the different ontogenetic stadium. While characteristic prey categories for adults were Crustacea (Decapoda) and Mollusca, MAZZOLA *et al.* (1999) noticed the dominance of Copepoda, Polychaeta, Amphipoda and Tanaidacea in juveniles. In our study, the predominant prey category was decapod crustaceans within all size categories and only with the largest individuals the dominance of Bivalvia, followed by Polychaeta and Crustacea was expressed. The largest individuals showed more variety in consumption of different prey categories in comparison with smaller fish. It is a well known phenomenon regarding the changes of diet in larger fish caused by the more diversity in prey selection and consequentially a wider range of ingested organisms (WARE, 1972; ROSS, 1977; STONER & LIVINGSTON, 1984). These changes of diet connected to the fish size can be explained in the striped red mullet with the morphological changes in width and height of its mouth, resulting in a selection of larger prey organisms (ROSS, 1977; STONER & LIVINGSTON, 1984). Those morphological characteristics are in the relation with fish's feeding behaviour, placing the species in adequate trophic niches (LABROPULOU & ELEFTHERIOU, 1997). According to morphological changes, LABROPOULOU *et al.* (1997) have found a predominance of fish and cephalopods in the diet of larger (>161 mm) *M. surmuletus* specimens. Furthermore, for this species BAUTISTA-VEGA *et al.* (2008) recorded a diet shift between medium (110-180 mm) and large (>180 mm) sized fish. They also reported increased consumption of bivalves and ophiuroids for larger specimens in the comparison with other size classes resulting in significantly different diet composition between large specimens and smaller ones. However, no significant differences between small and medium fish were recorded. BAUTISTA-VEGA *et al.* (2008) highlighted size related differences in the striped red mullet diet, with increasing consummation of polychaetes with size, and decreasing percentage of small crustaceans in diet of higher size classes. Our results confirm those conclusions. Both investigations indicated possible strong intraspecific competition between small and medium size fish, since differences in feeding habits in relation to size can influence reduced intraspecific competition among the different size classes fish (GROSSMAN, 1980; LANGTON, 1982, HARMELIN-VIVIEN *et al.*, 1989).

Except the changes in diet composition among size, this species showed differences in the ingested food amount. The quantity of the ingested material can be expressed by prey weight and number of prey items. Our results showed a slightly increasing mean prey weight with the size, but with the maximum at 18 cm size class. Otherwise, we found the lower mean number of prey items in the smaller size classes, in comparison with larger specimens. LABROPOULOU *et al.* (1997) also noticed an increase of mean prey mass in larger specimens, while the mean number of prey items did not differ with the size. Decreasing mean number of prey items and increasing the mean prey weight in larger size classes can be related to the consumption of larger prey taxa, such as fishes and cephalopods. Prey mass and number distribution in first line depended on the complete diet composition among size classes, so according to our results it was evident that the same type of prey is present in all size classes, only larger amounts of prey were ingested in larger individuals. BAUTISTA-VEGA *et al.* (2008) recorded no significant difference in prey mass percentages among seasons, while LABROPOULOU *et al.* (1997) noticed an increase of mean prey mass in larger specimens.

No significant differences in food composition between males and females of *M. surmuletus* were found in the present study ($p>0.05$). Decapods dominated in both sex diet, as the most important diet component for the goatfishes in the Mediterranean Sea (BEN-ELIAHU & GOLANI, 1990; GOLANI & GALIL, 1991; GOLANI, 1994). Also, no significant seasonal changes in diet composition were found in the present study ($p>0.05$), but this may be affected because not all months were covered. However, decapods were also the most important prey category in the both, winter (%IRI= 90.89) and autumn period (%IRI=93.22). In spring, a wider range and higher proportions of some ingested prey taxa, including Crustacea, Bivalvia, Polychaeta and Echinodermata, were recorded. On the other hand, LABROPOULOU *et al*. (1997) for *M. surmuletus* from Cretan coast, found significant differences in diet among seasons. Namely, in the summer period *M. surmuletus* fed more on decapods than in the winter and spring period when amphipods dominated in the fish diet. For other prey taxa, including polychaetes, bivalves and mysids, minor contribution to the observed differences were determined. They emphasized that *M. surmuletus* diet contained a narrow range of prey taxa, suggesting the status of specialist in feeding. These findings are opposite to our results. Surely, the spatial and seasonal differences in food composition can be related to the availability of certain prey organisms in a certain environment. Furthermore, the higher contribution of some prey category in the fish diet can also be linked to the presence of certain ecological trophic categories in the study area (LABROPOULOU *et al*., 1997) and thus not just be a reflection of species preference for specific prey organism but also a reflection of habitat characteristics and potential modifications due to anthropogenic pressure.

Many knowledge gaps still exist in *M. surmuletus* ecology. However, the currently available data suggest that this species may indeed be a suitable habitat indicator and may also qualify as key species in coastal sand-associated ecosystems (UIBLEIN, 1991). Because of considerable intraspecific variations in habitat preferences, food selection, behaviour, and body structure, further exploration, monitoring, and management is still required in the area of its distribution, together with enhancing information exchange and initiating joint research efforts in *M. surmuletus* ecology.

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Ishrana trlje kamenjarke, *Mullus surmuletus* u istočnom Jadranskom moru

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SAŽETAK

Istraživana je ishrana trlje kamenjarke, *Mullus surmuletus* u istočnom dijelu Jadrankog mora. Analiziran je sadržaj želudca 203 jedinke (11.5 – 32.9 cm TL) prikupljenih pridnenom povlačnom mrežom koćom. Opće su prihvaćene metode i ključevi za determinaciju korišteni za određivanje sastava ishrane i determinaciju plijena. Istraživanjem je određeno 39 identificiranih vrsta plijena koji spadaju u 11 glavnih skupina: rakovi, puževi, školjkaši, ribe, žarnjaci, bodljikaši, mnogočetinaši, oblići, mahovnjaci, alge i krednjaci. Dominantna i poželjna kategorija plijena bili su dekapodni rakovi unutar svih veličinskih kategorija, dok je samo kod najvećih jedinki pronađena dominantnost školjkaša, a slijede ih mnogočetinaši i rakovi. Najveće jedinke također su pokazale veću raznolikost u konzumaciji različitih vrsta plijena i prosječno veći broj jedinki plijena u odnosu na manje ribe. Nije pronađena značajna razlika u ishrani između mužjaka i ženki ($p > 0,05$) i s obzirom na sezonu ($p > 0,05$). Hranjenje širokim spektrom plijena bez značajnih varijacija u vezi sa spolom i sezonom sugerira da se trlja od kamena može prilagoditi pomacima u prostorno-vremenskim varijacijama obilja potencijalnog plijena. Prisutnost detritusa u probavnom traktu povezana je s načinom hranjenja istraživane vrste na muljevitim detritičnim dnima.

Ključne riječi: ishrana, *Mullus surmuletus*, Jadransko more