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FEEDING HABITS OF THE STRIPED RED MULLET, *MULLUS SURMULETUS* LINNAEUS, 1758, IN THE EASTERN CENTRAL ADRIATIC

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ABSTRACT

The feeding habits of the striped red mullet Mullus surmuletus *in the eastern central Adriatic, in respect of season and fish size, were examined. Stomach contents of 348 specimens, 58 to 250 mm TL, collected by beach seine (called migavica) from July 1993 to June 1994, were analysed. Feeding intensity was high throughout the study period and varied significantly between the size classes. Mysidacea predominated in the mullet's diet. The composition of the prey ingested varied with predator size. Fish and cephalopods occurred exclusively in the diet of specimens larger than 185 mm TL. Diets varied seasonally. Amphipods were the most important prey group in winter and spring. Decapod crustaceans predominated during the summer, Mysidacea during the autumn. The results indicated that the striped red mullet fed on narrow range of prey items and could be considered a specialist.*

Key words: *Mullus surmuletus*, feeding habits, ontogeny, central Adriatic

ABITUDINI ALIMENTARI DELLA TRIGLIA DI SCOGLIO *MULLUS SURMULETUS* LINNAEUS, 1758, IN ADRIATICO CENTRO-ORIENTALE

SINTESI

Nell'articolo vengono esaminate le abitudini alimentari della triglia di scoglio Mullus surmuletus *dell'Adriatico centro-orientale in relazione alla stagionalità e alle dimensioni del pesce. È stato analizzato il contenuto stomacale di 348 individui, da 58 a 250 mm di lunghezza totale, raccolti con una rete da spiaggia (chiamata migavica) tra luglio 1993 e giugno 1994. L'intensità alimentare è risultata alta durante tutto il periodo di studio ed è variata significativamente in relazione alle dimensioni degli esemplari. Nella dieta di* M. surmuletus *ha prevalso l'ordine Mysidacea. La composizione delle prede ingerite è variata con le dimensioni del predatore, pertanto i cefalopodi sono stati ritrovati esclusivamente nella dieta di esemplari di dimensioni maggiori a 185 mm. La dieta è variata stagionalmente. Gli anfipodi sono risultati il gruppo più importante di prede durante l'inverno e la primavera. I crostacei decapodi hanno predominato durante l'estate, mentre i misidiacei durante l'autunno. I risultati indicano che la triglia di scoglio si nutre di un limitato range di prede e può venir considerata uno specialista.*

Parole chiave: *Mullus surmuletus*, abitudini alimentari, ontogenesi, Adriatico centrale

INTRODUCTION

The study of the feeding habits of fish contributes to the knowledge of intra- and interspecific trophic relationships and thus leads to a better understanding of the structure and dynamics of marine communities. When commercially exploited species are involved as predators and/or as main prey species, the study of their feeding habits is a basic step for multispecies assessment approaches.

The striped red mullet is distributed along the eastern Atlantic from the English Channel to the northern part of West Africa and the Mediterranean Sea down to a depth of 400 m or more (Bauchot, 1987), inhabiting sand and soft substrates at depths of less than 100 m (Jardas, 1996).

The biology of the striped red mullet has not been studied extensively and only few papers deal exclusively with this species. N'Da (1992) and N'Da & Deniel (1993) studied its diet and sexual cycle, respectively, on the Brittany coast. Renones *et al.* (1995) examined its growth and reproduction off the island of Majorca. Despite its high commercial value, very little is known about the trophic ecology and behaviour of the striped red mullet. The literature on diet only points out that benthic invertebrates comprise the main dietary component (Gharbi & Ktari, 1979; Golani & Galil, 1991; N'Da, 1992; Golani, 1994). Labropoulou *et al.* (1997) pointed out that crustaceans predominated in the mullet's diet on the Cretan shelf and this species could be considered a specialist.

The main objective of this paper is to determine seasonal changes in trophic biology of the striped red mullet on a annual basis and to identify feeding trends of this species in the eastern central Adriatic.

MATERIALS AND METHODS

Samples were taken during four seasonal beach seine (called "migavica") survey cruises conducted by the Institute of Oceanography and Fisheries with the aid of professional fishermen in the area of the eastern central Adriatic (Šibenik area – Krapanj Island, Žaborić, Žirje Island; Split area – islands of Čiovo, Šolta, Mali Drvenik and Veli Drvenik) (Fig. 1). The cruise periods were as follows: 1 - July 1993, 2 - December 1993, 3 - April 1994, and 4 - June 1994.

A number of specimens (25-30) per area in each season were fixed immediately after capture in 8% buffered formalin for a subsequent stomach contents analysis. The specimens were taken to the laboratory, measured to the nearest mm (TL-total length) and weighed to the nearest 0.1 g. The stomachs were removed and the contents wet-weighed. Prey items were identified to the lowest possible taxonomic level, counted under a binocular microscope and weighed to the nearest 0.01 g.

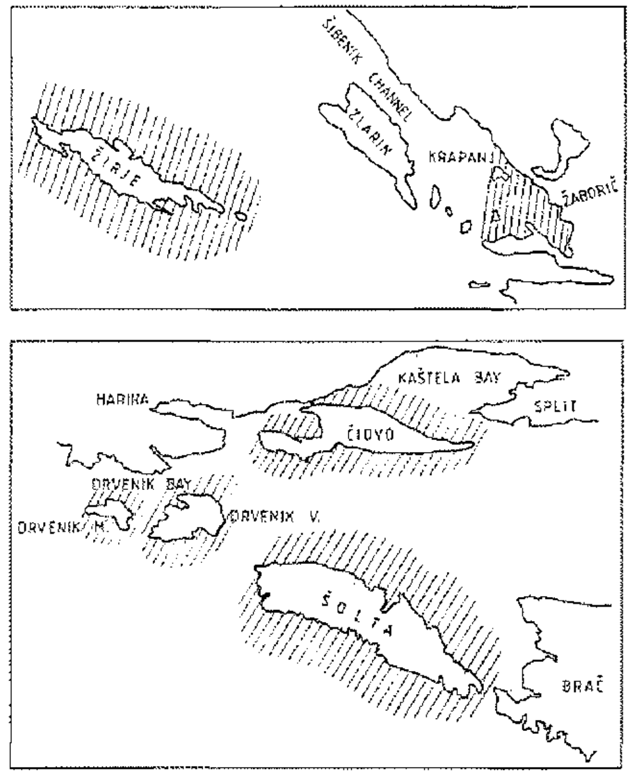

Fig. 1: Location of sampling stations in the eastern central Adriatic (Šibenik area - Krapanj Island, Žaborić, Žirje Island; Split area - Islands of Šolta, Čiovo, Mali Drvenik and Veli Drvenik).
Sl. 1: Lokacije vzorčišč v vzhodnem srednjem Jadranu (Šibeniško območje - otok Krapanj, Žaborić, otok Žirje; Splitsko območje - otoki Šolta, Čiovo, Mali Drvenik in Veli Drvenik).

Total length ranged from 58 to 250 mm (mean value = 134.7±33.6 mm). In order to evaluate size related variations in food habits, specimens were placed in 10 mm size classes as proposed by Labropoulou *et al.* (1997). The number of specimens per size class ranged between 25 and 66.

Numerous indices have been described for expressing the importance of different prey in the diets of fish quantitatively (Hyslop, 1980). Those used in the present study were:

- vacuity index (VI), *i.e.* number of empty stomachs divided by total number of stomachs multiplied by 100;
- percentage frequency of occurrence (F) based on the number of stomachs in which a food item was found, expressed as percentage of the total number of non-empty stomachs;
- percentage numerical abundance (C_n), *i.e.* the number of each prey item in all non-empty stomachs in a sample, expressed as percentage of the total number of food items in all stomachs in a sample;

- percentage gravimetric composition (C_w), *i.e.* the wet weight of each prey item, expressed as percentage of the total weight of the stomach contents in a sample.

The main food items were identified using the index of the relative importance (IRI) of Pinkas *et al.* (1971), as modified by Hacunda (1981):

$$IRI = (C_n + C_w) \times F$$

This index was expressed as $\%IRI = (IRI / \Sigma IRI) \times 100$. Prey were sorted in a decreasing order according to their percentage IRI contribution, and then cumulative %IRI was calculated. Cluster analysis employing Bray-Curtis similarity index (Field *et al.*, 1982) was performed on the standardised IRI values to describe ontogenetic and seasonal variations of food habits. Since all immature specimens smaller than 140 mm TL, corresponding to 55.7% of the total, could not be sexed, no attempt was made to detect dietary differences between sexes.

Niche breadth for the utilisation of food resources was calculated according to the Shannon-Wiener index (Krebs, 1989):

$$H' = \Sigma (p_i) (\ln p_i)$$

where p_i is the proportion of a specific prey category for the n categories of prey listed. Statistical differences in basic diet composition and stomach fullness as a function of size and season were established by applying a chi-squared test to the recorded values. One-way ANOVAs were used to compare the mean number and mean weight of prey items among the size classes and the a posteriori Tukey's test was employed to locate the source of any differences (Zar, 1984).

RESULTS

A total of 348 specimens were analysed. Of the total number of stomachs examined, 86 were empty (24.71%). The proportion of empty stomachs varied significantly among the size classes of fish examined ($P<0.001$), with the maximum of 49.88% for the largest fish (TL greater than 185 mm). Although empty stomachs were found throughout the year, the seasonal vacuity index did not differ significantly ($P>0.05$).

The diet of striped red mullet consisted of at least 66 different prey species belonging to five groups (Mysidacea, Amphipoda, Decapoda, fish, Polychaeta). The relative importance of the different prey groups with a contribution to the percentage IRI greater than 1 is given in Table 1. Mysidacea were the most important prey group, constituting 24.76% of the total IRI and made an important contribution to the diet (%IRI = 20.1), followed by amphipods (%IRI = 15.9), decapods (%IRI = 15.79) and fish (%IRI = 9.65). Among the decapods, Reptantia made an important contribution to the diet (%IRI = 8.73). The fact that the diet of the striped red mullet is dominated by few prey species is also supported by the low value of the Shannon-Wiener diversity index ($H' = 0.88 \pm 0.04$). Although the percentage IRI of the various prey groups varied with fish size, the chi-squared test revealed no significant difference ($P>0.05$) when the data for the large size classes were omitted. The «others» category included primarily cephalopods which occurred exclusively in the diet of large fish.

The total amount of food ingested, as shown by the mean weight of stomach contents, varied significantly among the size classes ($P<0.001$). No significant differences emerged among the size classes when the mean number of prey items per stomach was examined ($P>0.05$). However, the results have shown a tendency to increase the mean number of prey items towards larger size classes (differences not significant with Tukey's test). Dietary breadth increased with fish size for specimens larger than 170 mm TL, which indicates a tendency of more generalised feeding during later growth stages. Cluster analysis based on IRI values discriminated two main groups: fish with TL of 58-170 mm (group I, average similarity 85.0) and those with TL greater than 170 mm (group II, average similarity 80.9) (Fig. 2). However, the high similarity between the two groups discriminated by cluster analysis is indicative of slow and gradual changes in the diet composition with fish size.

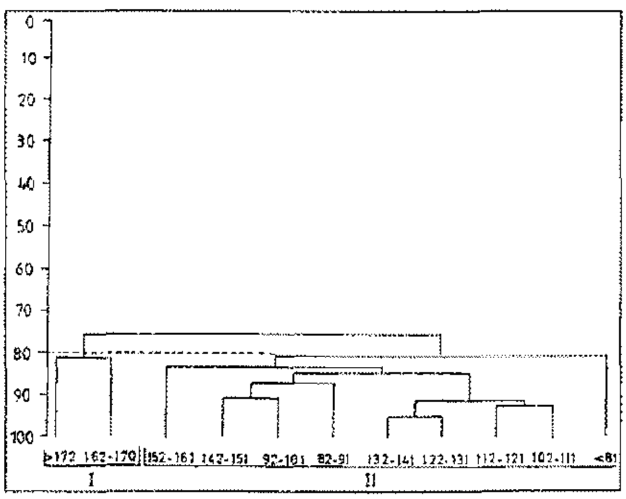

Fig. 2: Dendrogram of IRI values showing classification by *Mullus surmuletus* ***size into main groups.***
Sl. 2: Dendrogram vrednosti IRI – razvrstitev progastih bradačev v glavne velikostne skupine.

Tab. 1:** **Percentage contribution of prey groups in** Mullus surmuletus **diet (C_n is percentage numerical composition; C_w is percentage gravimetric composition; F is frequency of occurrence; IRI is index of relative importance).
Tab. 1:** **Odstotni delež različnih skupin plena v prehrani progastega bradača** Mullus surmuletus **(C_n je odstotek numerične sestave; C_w je odstotek gravimetrične sestave; F je frekvenca pojavljanja; IRI je indeks relativne pomembnosti).

Prey category / *Kategorija plena*	C_n	C_w	F	IRI	%IRI
Crustacea					
Decapoda					
Natantia	2.40	4.60	39.90	279	4.08
Reptantia	4.80	9.80	40.90	597	8.73
Brachyura	1.50	3.80	38.50	204	2.98
Total / *Skupaj*	8.70	18.20	41.30	1080	15.79
Mysidacea	21.9	8.1	45.9	1377	20.1
Isopoda	10.3	9.3	23	452.4	6.6
Amphipoda	18.1	6.3	44.5	1086	15.9
Polychaeta	3.10	10.40	43.40	586	8.56
Bivalvia	2.1	0.1	37.3	82.1	1.2
Echinodermata	2.1	0.1	46.5	102	1.5
Teleostei					
Gobius sp.	0.9	1.5	39.3	94.3	1.38
Callionymus sp.	9.5	3.7	21.3	280.8	4.1
Pomatoschistus sp.	2.70	4.70	38.60	286	4.17
Total / *Skupaj*	13.10	9.90	99.2	661.1	9.65
Others / *Druge vrste plena*	2	6.2	15.7	129	1.9
No. of stomachs examined / *Št. pregledanih želodcev*	348				
No. of empty stomachs / *Št. praznih želodcev*	86				
Mean fish total length (mm) / *Srednja celotna dolžina rib (mm)*	134.7				
Mean stomach content weight (g) / *Srednja teža vsebine želodcev (g)*	0.52				
Mean number of prey items per stomach / *Srednje število lovnih vrst na želodec*	5.23				

The striped red mullet's feeding habit varied seasonally. Amphipods were the most important prey group in the winter (%IRI = 45) and spring (%IRI = 55.2). Decapod crustaceans predominated during the summer, while Mysidacea were predominant during the autumn. A chi-squared test revealed significant differences between the ingestion of Mysidacea ($\chi^2 = 9.6$, $P<0.05$) and amphipods ($\chi^2 = 8.3$,$P<0.05$), and also between the ingestion of amphipods and decapods ($\chi^2 = 7.1$, $P<0.05$). No significant seasonal differences were detected for other prey items. Diet breadth showed no significant overall effect of the seasons ($P>0.05$). Although seasonal influences were also examined as a function of fish size, no significant differences were found in size composition of the specimens throughout the year ($P>0.05$).

DISCUSSION

The presence of many common benthic and epibenthic organisms of appropriate size, such as mysids, decapods, polychaets and amphipods, further implies that the striped red mullet normally feeds on zoobenthos. This study indicates that the species relies almost exclusively on mysids, amphipods, decapods and fish, although eaten regularly were of minor importance. Other studies pointed out that crustacean decapods were major components in the striped red mullet's diet (Ben-Aliahu & Golani, 1990; Golani & Galil, 1991; Golani, 1994; Labropoulou *et al.*, 1997). This difference could be related to the probable differences in food availability between the areas involved. However, our results are not consistent with those of Gharbi & Ktari

(1979) and N'Da (1992) who reported that the striped red mullet's diet included a wider range of prey taxa with polychaets preferential. These differences may, in part, be due to the fact that in both studies dietary analysis was based on the frequency of occurrence and the numerical abundance of prey items, which are markedly influenced by small food items that may occur in high numbers but constitute of low biomass (Hall *et al.*, 1990). The availability and accessibility of prey are the factors that determine the importance of certain species in the diet of fishes. They could explain differences in diet at different times of the year and between different areas.

Most of the prey species found in the striped red mullet's diet usually live on sediment, while a few of them construct tubes in the sediment; they are normally open at both ends, and when feeding, may emerge completely or only partially from these tubes (Labropoulou *et al.*, 1997). No bottom sediment was found in the stomachs examined, which is in agreement with the findings of Labropoulou *et al.* (1997), so according to both studies it could be assumed that the striped red mullet consumes prey, which is active on the sediment surface, or selects individual infaunal prey items from the substrate.

The striped red mullet's diet is dominated by a relatively few items according to the recorded low value of the Shannon-Wiener diversity index in the present study, and the species could be considered a specialist. The striped red mullet, like all mullids, uses barbels to assist in foraging and prey capture (Ben-Eliahu & Golani, 1990), so it may be that the importance of the barbels in foraging behaviour has led to the restricted trophic diversity of this species, to small-size and slow-moving invertebrates that inhabit the soft sediments.

Relatively low values of the vacuity index throughout the sampling period indicate that the feeding intensity is high and that the seasons do not affect food intake, which is also evident from the study by Labropoulou *et al.* (1997). The high percentage of empty stomachs found in large size classes suggests that the feeding intensity is more pronounced in smaller specimens. Feeding intensity and frequency are directly correlated with meal size and digestion time. It is well known that for most demersal fish species there is a tendency for fish size to increase with depth, within their depth range. Juvenile stages occur in shallower, warmer waters, while older fish are found at greater, colder depths where they may benefit from lower metabolic cost and greater longevity. The high percentage of empty stomachs for the larger specimens may partially reflect an ontogenetic migration to the deeper waters, where temperature decreases significantly, which is in agreement with the observations and explanations made by Labropoulou *et al.* (1997). Many of the demersal fishes show a decrease in the feeding rate as the temperature drops (Tyler, 1971). Because of the reduced abundance of the prey and the lowered metabolism of the fish, predation on benthos was probably at a minimum during the winter. Environmental conditions are favourable during the warmer months and the food supply may be abundant enough to support the expanded fish community without competitive interactions. Trophic ontogeny in the striped red mullet could be also explained in terms of fish morphology. Ontogenetic changes in mouth size were expressed by relative mouth length (mouth length/total fish length) (Ross, 1978). Trophic ontogeny in the striped red mullet proceeds as a continuum of dietary changes rather than by distinct segregation of food resources between size classes (Labropoulou *et al.*, 1997). Golani & Galil (1991) pointed out that although larger fish are able to capture relatively larger prey, the morphological constraints such as the toothless upper jaw, the small mouth size and gape and the foraging behaviour impose certain limitations on the diet of this species and restrict their food to small benthic animals. Food specialisation and dietary breadth are a result of evolutionary development of unique feeding behaviour, morphology and mouth structure, which interact with the size, distribution and abundance characteristics of certain types of the available benthic fauna.

The observed seasonal changes in the relative importance of preferred prey probably reflect fluctuations of the available prey in the environment. Prey availability, however, is not only a function of its abundance in the habitat but also of its size, behaviour, density and relative abundance of the preferred prey items in the exploited habitats (Caragitsou & Papaconstantinou, 1988).

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PREHRANA PROGASTEGA BRADAČA *MULLUS SURMULETUS* LINNAEUS, 1758 V VZHODNEM DELU SREDNJEGA JADRANA

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POVZETEK

Avtor je v vzhodnem delu srednjega Jadrana opravil raziskavo o prehrani progastega bradača Mullus surmuletus *Linnaeus, 1758, s posebnim ozirom na letne čase in velikost rib. Pregledana je bila vsebina želodcev osebkov, ki so bili ujeti s potegačo v obdobju med julijem 1993 in junijem 1994 in so merili od 58 do 250 mm (celotna dolžina). Intenziteta prehranjevanja je bila v času preiskave razmeroma visoka in je vključevala različne velikostne kategorije. Mizidni raki (Mysidacea) so bili prevladujoča kategorija plena. Sestava prehrane je bila odvisna od velikosti bradačev. Tako so se ribe in glavonožci pojavljali le v prehrani osebkov, večjih od 185 mm. Prehrana progastega bradača se je spreminjala z letnimi časi. Postranice (Amphipoda) so bile najpomembnejše pozimi in spomladi, raki deseteronožci (Decapoda) poleti, mizidni raki pa jeseni. Rezultati te preiskave kažejo, da se progasti bradač prehranjuje le z omejenimi vrstami plena, kar pomeni, da ga v tem pogledu lahko štejemo med specialiste.*

Ključne besede: progasti bradač, prehrana, ontogenija, vzhodni Jadran

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