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FEEDING HABITS OF THE MEDITERRANEAN POOR COD *TRISOPTERUS MINUTUS CAPELANUS* (LACEPÈDE) (PISCES: GADIDAE) FROM THE EASTERN CENTRAL ADRIATIC

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ABSTRACT

The stomach contents of poor cod Trisopterus minutus capelanus *(Lacepède) were taken at monthly intervals off the eastern Central Adriatic coast (Croatia) between March 2003 and January 2004. A total of 273 specimens were analysed to determine diet according to fish size and season. The basic food consists of crustaceans (Mysidacea and Decapoda) and teleosts. Feeding habits varied with size: decapods and fish were more abundant in the stomachs of larger specimens. Moderate seasonal variation in food habits was recorded.*

Key words: *Trisopterus minutus capelanus*, poor cod, feeding habits, Adriatic Sea

ABITUDINI ALIMENTARI DELLA BUSBANA *TRISOPTERUS MINUTUS CAPELANUS* (LACEPÈDE) (PISCES: GADIDAE) DELL'ADRIATICO CENTRO – ORIENTALE

SINTESI

Tra marzo 2003 e gennaio 2004 è stato effettuato un esame a intervalli mensili del contenuto dello stomaco di busbane Trisopterus minutus capelanus *(Lacepède) pescate nelle acque croate del Medio Adriatico. Per accertare le abitudini alimentari di questa specie, in relazione alle loro dimensioni e alla stagione, sono stati esaminati 273 esemplari. Il cibo principale era costituito da crostacei (Mysidacea e Decapoda) e teleostei. Le abitudini alimentari variavano a seconda delle dimensioni: decapodi e pesci erano più abbondanti nello stomaco degli esemplari più grandi. Nelle abitudini alimentari sono state registrate anche moderate variazioni stagionali.*

Parole chiave: *Trisopterus minutus capelanus*, busbana, abitudini alimentari, Mare Adriatico

INTRODUCTION

The poor cod, *Trisopterus minutus capelanus* (Lacepède), is one of the most abundant endemic fish species in the Mediterranean Sea. Its distribution extends to the eastern Atlantic Ocean off the coast of Morocco, whereas north of Gibraltar the subspecies *Trisopterus minutus minutus* is found. However, recent genetic analysis (Mattiangeli *et al.*, 2000) supports the classification of Atlantic and Mediterranean poor cod as distinct taxa and the close relationship between the Mediterranean poor cod and bib *Trisopterus luscus* (Linnaeus, 1758).

The poor cod is among the most abundant gadoid fishes in the Central Adriatic. Here it is actively exploited by bottom trawlers on muddy or sandy-muddy bottoms at depths ranging from 40 to 250 m (Jardas, 1996). Despite its commercial value and abundance in the fisheries of Mediterranean countries, little is known about the trophic ecology of the Mediterranean poor cod. Planas & Vives (1952) made some observations on its diet off the Mediterranean coast of Spain, while Politou *et al.* (1989) presented some preliminary information on the feeding habits of the species in the Euboikos and Pagassitikos Gulfs in Greece. Politou & Papaconstantinou (1994) reported on the feeding ecology of poor cod from the eastern coast of Greece. Biagi *et al.* (1992) made some observations in the northern Tyrrhenian Sea, while Gramitto (1999) presented data on the feeding habits and estimation of daily ration of poor cod in the Adriatic Sea. Morte *et al.* (2001) studied the poor cod's feeding habits off the eastern coast of Spain (western Mediterranean).

The main goal of this study was to present information on the feeding ecology of poor cod *T. m. capelanus* in the Central Adriatic (eastern coast), including the systematic and detailed study of its prey, and the influence of predator size and seasonal variations in the stomach contents.

MATERIAL AND METHODS

Monthly samples of *T. m. capelanus* were collected from diurnal commercial catches landed in the port of Šibenik; the catches were taken by trawl (type "tartana") at 50 to 175 m depth in the area of Vis Island and Jabuka Pit (Blitvenica area) between March 2003 and January 2004. A total of 273 specimens (108 females, 41 males) with a total length between 8.3 cm and 24.0 cm were measured, dissected and their stomachs removed and preserved in 4% formaldehyde. Upon opening, stomach contents were preserved in a 70% ethanol solution. A few fish showing evidence of regurgitation were excluded from the study.

In the laboratory, identification of prey was carried out at the lowest possible taxonomic level. We registered the number and wet weight of food items after removing surface water by blotting it on tissue paper.

The distribution of each feeding item in the diet was determined by the frequency of occurrence (F %), numerical composition (Cn %) and biomass composition (Cw %) (Hyslop, 1980). The percentage of empty stomach (V) was also recorded. Indices of relative importance (Pinkas *et al.*, 1971) (IRI= (%N + %W) %F) and main food items (MFI = ((%N + %F)/2) %W) (Zander, 1982) were calculated for each consumed prey item. To assess potential diet changes with respect to size, fish were divided into two size classes according to age classes: small (≤14 cm) and large (≥14.5 cm).

The proportional food overlap between the size classes and seasons was calculated using the Schoener overlap index (1970):

$$a=1-0.5\,(\Sigma_{i-1} |p_{xi}-p_{yi}|)$$

where p_{xi} and p_{yi} are the biomass composition indices of prey (i) in the diets of size classes x and y, respectively. The index has a minimum value of zero when no overlap occurs and a maximum value of one when all prey are shared in equal proportions by two size classes. Statistical differences in diet composition as a function of size and season were assessed using the chi-square χ^2 test (Sokal & Rohlf, 1981). The significance of variation of the mean number of prey and weight per stomach was tested by analysis of variance (ANOVA).

RESULTS

Emptiness index

Of the 273 stomachs of *T. m. capelanus* examined, 20 were empty (7.32 %). This percentage did not vary significantly over the year (χ^2 = 1.17, df = 3, P >0.05). However, the emptiness index varied significantly with poor cod size (χ^2 = 7.56, df = 1, P <0.05). Somewhat higher value of this index was obtained in the smaller group (smallest specimens).

Overall composition of the diet and variation in stomach contents relative to fish length

The stomach contents of the poor cod consisted of at least 37 different prey species, with a low average number of prey per stomach (2.49) and low average weight of prey per stomach (0.37). The food consisted almost exclusively of crustaceans and fish, the former constituting a much greater part then the latter. The crustaceans were mainly mysids and decapods *(Peneus* sp., *Alpheus glaber).* The fish were mainly gobiids. Less abundant crustaceans included copepods, euphausiids and stomatopods. Other taxa found in the stomach con

Tab. 1: Prey registered in the stomach of** T. m. capelanus **(small size group ≤14 cm) (F % – frequency of occurrence, Cn % – numerical composition, Cw % – biomass composition) (No. = 96).
Tab. 1: Plen, zabeležen v želodcu moliča** T. m. capelanus **(skupina manjših primerkov ≤14 cm) (F % – frekvenca pojavljanja, Cn % – številčna sestava, Cw % – sestava biomase) (No. = 96).

Food items	**F (F %)**	**N (Cn %)**	**W (Cw %)**
Polychaeta			
Aphrodite acuelata	1 (1.04)	1 (0.35)	0.01 (0.06)
Tunicata			
Appendicularia	1 (1.04)	1 (0.35)	0.01 (0.06)
Crustacea			
Mysidacea	41 (42.70)	115 (41.21)	0.72 (4.53)
Euphausiacea	2 (2.08)	2 (0.71)	0.01 (0.06)
Stomatopoda			
Squilla sp.	5 (5.20)	6 (2.15)	0.23 (1.44)
Decapoda			
Penaeidae			
Penaeus sp.	35 (36.45)	77 (27.59)	5.97 (37.57)
Penaeus kerathurus	1 (1.04)	1 (0.35)	0.12 (0.75)
Parapenaeus longirostris	3 (3.12)	3 (1.07)	0.52 (3.27)
Total Penaeidae	39 (40.62)	81 (29.03)	6.61 (41.59)
Alpheidae			
Alpheus sp.	7 (7.29)	8 (2.86)	1.15 (7.23)
Alpheus glaber	10 (10.41)	12 (4.30)	1.21(7.61)
Total Alpheidae	17 (17.70)	20 (7.16)	2.36 (14.85)
Pasiphaeidae			
Pasiphea sivado	3 (3.12)	4 (1.43)	0.16 (1.00)
Pandalinae			
Plesionika martia	1 (1.04)	1 (0.36)	0.04 (0.25)
Pandalina brevirostris	1 (1.04)	2 (0.71)	0.04 (0.25)
Total Pandalinae	2 (2.08)	3 (1.07)	0.08 (0.50)
Hippolytidae			
Lysmata seticaudata	1 (1.04)	1 (0.36)	0.08 (0.50)
Nephropidae			
Nephrops norvegicus	2 (2.08)	2 (0.72)	0.86 (5.41)
Paguridea			
Pagurus sp.	1 (1.04)	1 (0.36)	0.01 (0.06)
Albuneidae			
Albunea carabus	1 (1.04)	1 (0.36)	0.02 (0.12)
Portunidae			
Macropipus sp.	1 (1.04)	1 (0.36)	0.04 (0.25)
Xanthidae			
Xantho sp.	2 (2.08)	2 (0.72)	0.04 (0.25)
Goneplacidae			
Goneplax rhomboides	8 (8.33)	9 (3.23)	2.07 (13.02)
Decapoda	15 (15.63)	21 (7.53)	1.78 (11.20)
Total Crustacea	140 (145.83)	269 (96.76)	15.06 (94.77)
Pisces			
Gobius sp.	3 (3.12)	3 (1.07)	0.49 (3.08)
Pisces	4 (4.16)	4 (1.43)	0.32 (2.01)
Total Pisces	7 (7.29)	7 (2.51)	0.81 (5.09)
Algae (Phaeophyta)	1 (1.04)	1 (0.36)	0

Tab. 2: Prey registered in the stomach of *T. m. capelanus* ***(large size group ≥14.5 cm) (F % – frequency of occurrence, Cn % – numerical composition, Cw % – biomass composition) (No. = 177).***
Tab. 2: Plen, zabeležen v želodcu moliča *T. m. capelanus* ***(skupina večjih primerkov ≥14,5 cm) (F % – frekvenca pojavljanja, Cn % – številčna sestava, Cw % – sestava biomase) (No. = 177).***

Food items	**F (F %)**	**N (Cn %)**	**W (Cw %)**
Polychaeta			
Aphrodite acuelata	4 (2.26)	5 (1.24)	0.05 (0.08)
Bryozoa	4 (2.26)	4 (0.99)	0.03(0.05)
Crustacea			
Mysidacea	18 (10.16)	41 (10.22)	0.04 (0.07)
Copepoda			
Nauplia	1 (0.56)	1 (0.25)	0
Stomatopoda			
Squilla desmaresti	2 (1.13)	2 (0.49)	0,03 (0,05)
Squilla sp.	1 (0.56)	1 (0.25)	0,14 (0,24)
Total Stomatopoda	3 (1.69)	1 (0.25)	0,17 (0,30)
Decapoda			
Penaeidae			
Penaeus sp.	59 (33.33)	103 (25.68)	9.56 (17.01)
Penaeus kerathurus	5 (2.82)	5 (1.24)	1.3 (2.31)
Stenopus spinosus	2 (1.13)	2 (0.49)	0.19 (0.33)
Metapenaeus monoceros	1 (0.56)	1 (0.25)	0.09 (0.16)
Gennades elegans	1 (0.56)	1 (0.25)	0.11 (0.19)
Parapenaeus longirostris	4 (2.26)	4 (0.99)	1.03 (1.83)
Total Penaeidae	72 (40.67)	116 (28.92)	12.28 (21.85)
Alpheidae			
Alpheus sp.	29 (16.38)	33 (8.23)	6.42 (11.42)
Alpheus glaber	26 (14.69)	28 (6.98)	6.15 (10.94)
Total Alpheidae	55 (31.07)	61 (15.21)	12.57 (22.36)
Pasiphaeidae			
Pasiphea sivado	5 (2.82)	9 (2.24)	0.72 (1.28)
Pandalinae			
Pandalina brevirostris	1 (0.56)	1 (0.25)	0.01 (0.07)
Nephropidae			
Nephrops norvegicus	11 (6.21)	11 (2.74)	5.68 (10.10)
Palinuridea			
Polycheles typhlops	1 (0.56)	1 (0.25)	0.3 (0.53)
Portunidae			
Macropipus depurator	2 (1.13)	2 (0.49)	0.11 (0.19)
Xanthidae			
Xantho sp.	2 (1.13)	2 (0.49)	0.06 (0.10)
Goneplacidae			
Goneplax rhomboids	23 (12.99)	27 (6.73)	4.54 (8.07)
Crangonidae			
Crangon crangon	1 (0.56)	1 (0.25)	0.07 (0.12)
Palaeomonidae			
Paleomon sp.	3 (1.69)	3 (0.74)	0.08 (0.14)
Galatheidea			
Munida sp.	3 (1.69)	3 (0.74)	0.12 (0.21)
Isopoda			
Ligia italica	1 (0.56)	1 (0.25)	0.23 (0.40)

Epicaridea	1 (0.56)	1 (0.25)	0.01 (0.01)
Decapoda	33 (18.64)	53 (13.21)	3.73 (6.63)
Total Crustacea	236 (133.33)	337 (84.03)	40.72 (72.45)
Pisces			
Gobius sp.	23 (12.99)	27 (6.73)	8.01 (14.25)
Engraulis encrasicolus	1 (0.56)	1 (0.25)	2.8 (4.98)
Other fish	22 (12.43)	23 (5.73)	4.59 (8.16)
Fish eggs	1 (0.56)	1 (0.25)	0
Total Pisces	47 (26.55)	52 (12.96)	15.4 (27.4)
Algae (Phaeophyta)	3 (1.69)	3 (0.74)	0

tents, but of lesser importance, were bryozoans, polychaetes, tunicates and algal remains. According to IRI, Penaeidae represented the highest portion.

Tables 1 and 2 show the frequency of occurrence, numerical composition and biomass composition of all prey items found in small (≤14 cm) and large (≥14.5 cm) size groups. Tables 3 and 4 show the values of IRI and MFI for small (≤14 cm) and large (≥14.5 cm) size groups.

Tab. 3: *T. m. capelanus.* ***The values of IRI and MFI (No. = 96).***
Tab. 3: *T. m. capelanus.* ***Vrednosti IRI in MFI indeksov (No. = 96).***

Food items	**MFI**	**IRI**
Polychaeta	0.044056	0.438912
Tunicata	0.044056	0.38912
Crustacea		
Mysidacea	190.1429	1953.897
Penaeidae	1448.818	2869.374
Alpheidae	184.7364	389.9475
Goneplacidae	75.29081	135.4406
Other Decapoda	405.0783	938.0181
Total Crustacea	11496.21	27932.8
Pisces	24.97957	55.46411
Algae	0	0.373357

According to IRI and MFI, the main food of smaller poor cod specimens consisted of Mysidacea, Penaeidae, Alpheidae, Goneplacidae and other Decapods, while larger specimens fed on Decapoda (Penaeidae, Alpheidae) and pisces (Gobiidae). Although the average number of prey per stomach decreased from the smallest individuals to the largest, no significant differences were found (F = 5.85, df = 272, P >0.05). The average prey weight per stomach, however, increased significantly (F = 234.33, df = 272, F <0.001) from the smallest to the largest size classes. The value of various prey types varied with poor cod size: in Penaeidae, Alpheidae and Pisces it increased with the increasing poor cod size but decreased in mysids and Goneplacidae. There was a clear tendency for mysids (χ^2 = 124.82, P <0.001), Goneplacidae (χ^2 = 78.54, P <0.001) and "other crustaceans" (χ^2 = 38.68, P <0.001) to be mostly consumed by the small specimens. The chi-square test revealed significant differences among poor cod size classes with respect to decapods (χ^2 = 96.43, df = 2, P<0.001) and teleosts (χ^2 = 98.39, P <0.001) due to the low number of prey in the small size class. The importance of mysid species decreased as predator size increased. An opposite trend was evident for the main decapod and teleost species, whose IRI increased considerably as the predator grew.

Tab. 4: *T. m. capelanus.* ***The values of IRI and MFI (No. = 177).***
Tab. 4: *T. m. capelanus.* ***Vrednosti IRI in MFI indeksov (No. = 177).***

Food items	**MFI**	**IRI**
Polychaeta	0.156	3.01887
Bryozoa	0.08694	2.37489
Crustacea		
Penaeidae	760.46	2065.55
Alpheidae	517.622	1167.69
Nephropidae	45.2673	79.8582
Goneplacidae	79.6823	192.465
Other Decapoda	105.731	370.1587
Total Crustacea	7874.94	20866.1
Pisces	541.483	1071.96

Seasonal variation in diet

The average number of prey per stomach was significantly lower in the winter (F = 64.70, df = 272, P <0.001), whereas the mean stomach weight was constant through the year (F = 4.55, df = 272, P >0.05). The relative importance of *T. m. capelanus* prey groups changed seasonally, although decapod crustaceans were the dominant food in all seasons. According to IRI (4133.29) and MFI (1318.781) values, Penaeidae were dominant during the spring, while Alpheidae (IRI = 982.348, MFI = 397.788) were dominant during the autumn. Mysids were present in the stomach contents of poor cod throughout the year (χ^2 = 20.33, df = 3, P <0.001). Teleosts appeared most frequently in spring

(MFI = 865.833, IRI = 1887.436, χ^2 = 12.50, P<0.01). Goneplacidae were frequent in the spring and autumn diet (MFI = 30.965, IRI = 69.229, MFI = 98.292, IRI = 205.142), while Nephropidae dominated during the spring (MFI = 128.341, IRI = 274.248).

Diet overlap

The diet overlap, calculated on the basis of prey weight (Cw %), among fishes of different length groups in each season was moderate (0.62). Only in spring, a relatively high dietary overlap (0.76) was noted between size classes (Tab. 5).

Tab. 5: Proportional food overlap coefficients of** T. m. capelanus **between seasons and size classes.
Tab. 5: Koeficienti proporcionalnega prehranskega prekrivanja moliča** T. m. capelanus **med letnimi časi glede na posamezne velikostne razrede te vrste.

	≤14.0 cm	≥14.5 cm
Winter		
≤14.0 cm	0.78	
≥14.5 cm	0.25	0.57
Spring		
≤14.0 cm	0.96	
≥14.5 cm	0.56	0.76
Summer		
≤14.0 cm	0.74	
≥14.5 cm	0.15	0.45
Autumn		
≤14.0 cm	0.78	
≥14.5 cm	0.22	0.51

DISCUSSION

Our study of *T. m. capelanus* in the eastern Central Adriatic shows that decapods (mostly shrimps, Penaeidae, Alpheidae, Goneplacidae) constitute the main identifiable prey. Mysids, although dominant in number, constitute only a small percentage by weight. Teleosts such as gobiids are also important, but only in larger size classes.

In general, our results agree with previous studies carried out in the Adriatic (Županović & Jardas, 1989; Gramitto, 1999) and other Mediterranean areas (Biagi *et al.*, 1992; Politou & Papaconstantinou, 1994; Morte *et al.*, 2001). Euphausiacea, found in the stomachs during this study, were not found in the stomachs of poor cod collected on the continental shelf of the Central Adriatic, where they were replaced by other crustaceans (Mysidacea and Amphipoda) (Gramitto, 1999). The found eggs and pleopods and occasional fragments of legs of large Decapods, or bites of fish meat together with detritus suggest that poor cod also feeds on dead organisms found on the sea floor, possibly trawler discards. The sporadic finds of remains of *T. m. capelanus* may be either the result of this behaviour or cannibalism, which had been previously confirmed by Gramitto (1999). The poor cod has a well developed barbel and long soft pelvic rays, indicating that it is adapted to feed mainly near the bottom. Moreover, its mouth is designed for quick suction of prey above the bottom (Mattson, 1990). The diet consists of benthic species *(A. glaber, Nephrops norvegicus, Gobius* sp.) or species living just above the bottom. Most of these preys live buried in the substratum. Prey-search must therefore be active, and the fish has to sweep its pelvic fin over the bottom to locate prey, as do other members of the family Gadidae (Marshall & Cohen, 1973).

The preference for bigger prey types as predator size increases in this species results in the replacement of some small food organisms (Mysidacea and Euphasiacea) by others of bigger size *(A. glaber*, teleosts). Similar results have been reported for other Mediterranean areas (Politou & Papaconstantinou, 1994; Gramitto, 1999; Morte *et al.*, 2001), although there are certain differences in the diet. Armstrong (1982) reported a gradual increase of *N. norvegicus* of the 0^+ age class in the stomach contents with increasing predator size. In this study, *N. norvegicus* was found in the stomachs of both size classes (≤14.0 cm, ≥14.5 cm) and confirms the previous findings. Gramitto (1999) reported that small Norway lobsters were found in the stomachs of large poor cod specimens only four times in the Adriatic, even though the fish feeds intensively on other burrowing decapods of similar size living on "Nephrops grounds", such as *A. glaber*. The same author explained this with the behaviour of both predator and prey.

The low percentage of empty stomachs agrees with the observations of previous investigators for other areas (Biagi *et al.*, 1992; Politou & Papaconstantinou, 1994; Gramitto, 1999; Morte *et al.*, 2001). The low values of the vacuity index and the finding of filled stomachs all day round suggest that the poor cod is a continuous feeder, as hypothesised by Biagi *et al.* (1992) for the Tyrrhenian Sea. The analysis of stomach fullness in the 24 hours showed that *T. m. capelanus* is a continuous feeder, also if some periodicity can be detected probably linked to different availability of the prey, due to their diet behaviour pattern (Gramitto, 1999). Reproduction, which takes place in the winter and early spring, seems to have little effect on vacuity, as this was constant throughout the year. Similar findings, as far as the Adriatic is concerned, have been reported by Gramitto (1999), whereas Politou & Papaconstantinou (1994) found a seasonal cycle with a maximum vacuity in winter off the eastern coast of Greece.

The poor cod's feeding habits changed seasonally. These changes could be due to the different depths of sampling sites, which are difficult to assess when samples are provided by professional fishermen. In this study, however, the fish were collected over a narrow depth range (50 to 175 m), where the structure of bottom communities is probably quite similar. Other factors should also be considered, such as temporal variation in abundance and/or prey availability of prey. A number of authors have shown that, as the density of particular prey type declines, a predator may switch to another, more abundant prey (Hume & Northcote, 1985; Davidson, 1986). Unfortunately, no data on the distribution and abundance of crustaceans are currently available to determine the food web in the area of investigation.

PREHRANJEVALNE NAVADE MOLIČA *TRISOPTERUS MINUTUS CAPELANUS* (LACEPÈDE) (PISCES: GADIADE) V VZHODNEM SREDNJEM JADRANU

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POVZETEK

V mesečnih intervalih med marcem 2003 in januarjem 2004 je bila pregledana vsebina želodcev moličev Trisopterus minutus capelanus *(Lacepède), ujetih v hrvaških vodah vzhodnega srednjega Jadrana. Da bi ugotovili prehranjevalne navade te vrste glede na velikost primerkov in letne čase, je bilo skupaj pregledanih 273 primerkov. Njihovo osnovno hrano so sestavljali raki (Mysidacea in Decapoda) in prave kostnice, glede na velikost primerkov pa je bilo v želodcih večjih moličev ugotovljenih več deseteronožcev in rib kot v želodcih manjših primerkov. V prehranjevalnih navadah te vrste so bili zabeleženi tudi zmerni odkloni glede na posamezne letne čase.*

Ključne besede: *Trisopterus minutus capelanus*, molič, prehranjevalne navade, Jadransko morje

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