VIE ET MILIEU - LIFE AND ENVIRONMENT, 2007, 57 (1/2) : 27-33

DIET OF *GOBIUS VITTATUS* (GOBIIDAE) IN THE NORTHERN ADRIATIC SEA

M. KOVAČIĆ

Prirodoslovni muzej Rijeka, Lorenzov prolaz 1, HR-51000 Rijeka, Croatia
Marcelo.Kovacic@public.srce.hr

GOBIUS VITTATUS
DIET
SEASONAL CHANGES
ONTOGENETIC SHIFT
FEEDING SELECTIVITY

ABSTRACT. – The Goby *Gobius vittatus* is a carnivore and generalist which feeds on a wide variety of prey items, particularly on polychaetes, gastropods, copepods, ostracods and bivalves. The intensity of feeding was lowest in autumn and the diet spectrum was broadest in summer. There were high seasonal differences in biomass and number of almost all major prey items. Smaller specimens fed mostly on meiofauna, and large fish preferred macrofauna. The breadth of diet increased with fish size.

INTRODUCTION

The striped goby, *Gobius vittatus* Vinciguerra, 1883 is a poorly known Mediterranean gobiid species. The species was considered rare (Tortonese 1975) or very rare (Jardas 1985) due to the lack of data. Morphology and habitat of this species are known from only a few papers published since species description, based on one or two collected specimens (Kovačić 2004). Heymer & Zander (1978) described habitat, diet and morphology on 21 specimens from Banyuls-sur-Mer (France). The results on diet were restricted to frequency and abundance analyses of food on 17 specimens collected during two summer months. Morphology, habitat preferences and diet from these papers, which are the only known data on biology and ecology of the striped goby, were summarized by Miller (1986). The aim of the present research was to provide data on diet of *G. vittatus*, including diet composition, feeding selectivity, and seasonal and ontogenetic diet shifts, and to compare different methods for diet analysis.

MATERIAL AND METHODS

Seven hundred and four specimens of *G. vittatus* were obtained on three locations (Stara voda, Oštro and Selce) in the Kvarner area of the Northern Adriatic Sea, from April 2001 to March 2002 (Fig. 1). All fish were collected between 8 and 20 m depth, using a hand net and anaesthetic quinaldine during SCUBA dives. Twenty specimens were collected at each location during one dive every month. In two attempts in January on the location Oštro, only four specimens were collected due to bad weather and low temperature. Therefore, the total sample of 704 specimens was collected at three locations in twelve months. All specimens were killed by over-anaesthetization with quinaldine and fixed in 65% alcohol. Both specimens of *G. vittatus* and available food were collected during the same dive in August and September 2001 at each of the three locations. Four microhabitats were recognised as possible source of food at positions were *G. vittatus* was collected: plankton, scyaphilic phyton, photophilic phyton and psammon. The phyton samples were scraped from rocky surfaces (0.01 m^2) into plastic bags with a solid frame. The psammon samples were collected from an area of 0.01 m^2 to the depth of 2 cm by pulling plastic bags with a solid frame through the sand. Samples of plankton were obtained by draining 3 l containers with air from scuba diving regulator and filling them up with sea water from the water column 0-0.3 m above the bottom. Phyton and psammon were fixed in 65% alcohol. Sea water from the containers was filtered through a 100 µm mesh and the samples collected on the net were also fixed in 65% alcohol.

Total length (L_t) of all individuals was measured to the nearest 0.1 mm (later grouped in 5 mm length classes) and wet mass weighed (W) to the nearest 0.001 g after blotting dry on absorbent paper. The specimens were dissected under low

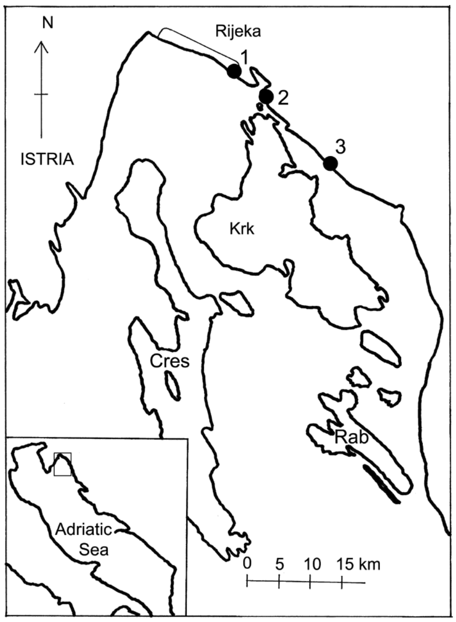

Fig. 1. – The Kvarner area, Croatia. Collecting sites: (1) Stara voda, (2) Oštro and (3) Selce.

power binocular microscope for the removal of gut. Guts were dissected and their entire content sorted to relevant taxonomic units, which were then counted. Sorted prey items and unidentifiable residue were weighed wet to the nearest 10 µg (Ohaus AP250D) after blotting dry on absorbent paper. Assigned wet masses independent of the animal's size were used for very small animals (Halacaridae, Ostracoda < 1 mm, Copepoda < 1 mm), estimated as average mass from weighing of larger sample of specimens. Weight of the entire gut content (W_{GC}) was calculated as the sum of weight of all prey items and of weight of unidentifiable residue. The samples of available food were kept in Rose Bengal (1 g in 1 l 65% alcohol) for 24 h. Plankton samples were then sorted to relevant taxonomic units, which were counted. Very light organisms of available food in samples of sands and aufwuchs were extracted by a modified elutriation method (Boisseau 1957). The remaining material was checked for larger and heavier organisms. Separated organisms of psammon and phyton were then assorted to relevant taxonomic units, which were counted.

The quantitative importance of different prey in the diet was expressed as follows: occurence frequency in percentage *(%F)*, number in percentage *(%N)*, mass in percentage *(%W)* (Hynes 1950, Berg 1979). The subjective point methods (Hynes 1950, modified by Joyeux *et al.* 1991) was also applied as an alternative method for the determination of amount of the food items in terms of matter. Results of percentage mass were compared with point percentages *(%P)*. Points were given to preys after Joyeux *et al.* (1991), Pampoulie & Bouchereau (1996) and Bouchereau & Guelorget (1999). Points for taxa not present in listed papers were assigned from listed taxa of similar size. The main food index (I_{MF}), modified with wet mass, was calculated to combine the three methods used *(%F, %N, %W)* (Kovačić 2001). Feeding intensity was investigated using fullness index (I_F) (Hureau 1970). Seasonal changes and ontogenetic shift in the diet breadth were calculated using Levin's standardised index (B_i) (Krebs 1989). The index range from 0 to 1; low values indicate diets dominated by few prey items and high values indicate generalist diets (Krebs 1989). Measure of niche overlap was used to describe overlap between diet and prey offer in surrounding microhabitats (Zander & Hagemann 1987). The simplified Morisita's index (C_{ik}) was calculated to compare overlap between ingested food and available food of four possible food sources (Krebs 1989). The overlap increases as the Morisita's index increases from 0 to 1. Overlap is generally considered to be biologically significant when the value exceeds 0.60 (Xie *et al.* 2000). The 95% confidence limits of diet overlap and breadth were estimated using the jackknife method (Krebs 1989). Feeding selectivity (*Sel*) was evaluated according to Shorygin as mended by Berg (1979). Seasonal changes and ontogenetic shift in the diet composition were analysed by *%N* and *%W* and in feeding intensity by the fullness index (I_F). A chi-square test was used to establish possible significant differences in the diet composition by fish size and month. Whenever classes with expected frequencies less than five occurred, expected and observed frequencies for those classes were pooled with adjacent class to obtain large enough expected frequencies (Sokal & Rohlf 1995). Two-ways ANOVA was used to assess seasonal and ontogenetic differences in I_F. Total length and season were considered to be fixed factors. Homogeneity of variance was tested with Levene's test, and normality was tested with Kolmogorov-Smirnov test. I_F was log-transformed to satisfy the ANOVA assumptions. The mean and the confidence limits are displayed as the antilogarithm of the mean and the confidence limits of the log-transformed data (Sokal & Rohlf 1995). Tukey's test was used for post-hoc comparisons after ANOVA. Data analyses were carried out by the Excel 2002 and the SPSS 9.0 program.

RESULTS

Diet

The gut contents of the 704 fish ($19.2 \leq L_t \leq 54.0$) contained 26 taxa (Table I). The other material found in the gut, consisting mostly of sand and bits of shell, rarely of algae and foraminifera, was considered unintentional intake. The most frequently occurring prey items *(%F* > 30%) were Copepoda, Gastropoda, Bivalvia, Polychaeta and Ostracoda (Table I). All other taxa appeared in less than 15% of the analysed guts. The most numerous food were Copepoda, followed by Gastropoda, Bivalvia and Ostracoda, together constituting almost 3/4 of all specimens in the prey (Table I). The results based on percentage mass *(%W)* were quite different from results of percentage number *(%N)* and percentage frequency *(%F)*. Gravimetrically, Polychaeta,

Table I. – Diet spectrum of *G. vittatus* and quantitative contribution of items; *%F*: occurrence frequency; *%N*: relative number; *%W*: relative biomass; *%P*: points in percentage; I_{MF}: main food index.

Prey	%F	%N	%W	%P	I_{MF}
Hydrozoa	3.4	0.5	0.2	0.1	0.7
Gastropoda	38.1	14.1	10.8	2.7	16.8
Bivalvia	35.8	13.8	8.4	2.6	14.5
Polyplacophora	1.0	0.1	0.2	0.0	0.3
Polychaeta	35.1	5.8	27.3	44.0	23.6
Sipunculidae	1.0	0.2	3.5	1.2	1.4
Halacaridae	9.7	3.5	0.7	0.7	2.1
Copepoda	46.2	31.2	1.3	3.0	7.1
Ostracoda	30.4	13.4	0.8	1.3	4.1
Leptostraca	0.1	0.0	1.5	0.4	0.3
Decapoda larvae	14.5	2.7	4.0	13.1	5.9
Natantia	2.3	0.3	3.3	1.5	2.1
Paguridea	4.0	0.9	14.9	4.2	6.0
Galatheidea	1.8	0.3	1.3	1.3	1.2
Brachyura	1.3	0.2	2.0	0.9	1.2
Mysidacea	9,7	1.7	6.6	1.6	6.1
Cumacea	7.1	1.4	0.8	2.7	1.8
Tanaidacea	7.7	1.3	0.6	0.2	1.7
Isopoda	12.6	4.0	1.4	7.7	3.4
Gammaridae	14.2	3.5	4.0	6.6	6.0
Caprellidae	4.1	0.7	0.6	1.4	1.2
Bryozoa	0.1	0.0	0.1	0.0	0.1
Echinoidea	1.6	0.2	0.8	0.0	0.8
Ophiuroidea	0.3	0.0	0.0	0.0	0.1
Ascidiacea	0.1	0.0	0.0	0.0	0.1
Pisces	1.0	0.1	4.8	2.6	1.6

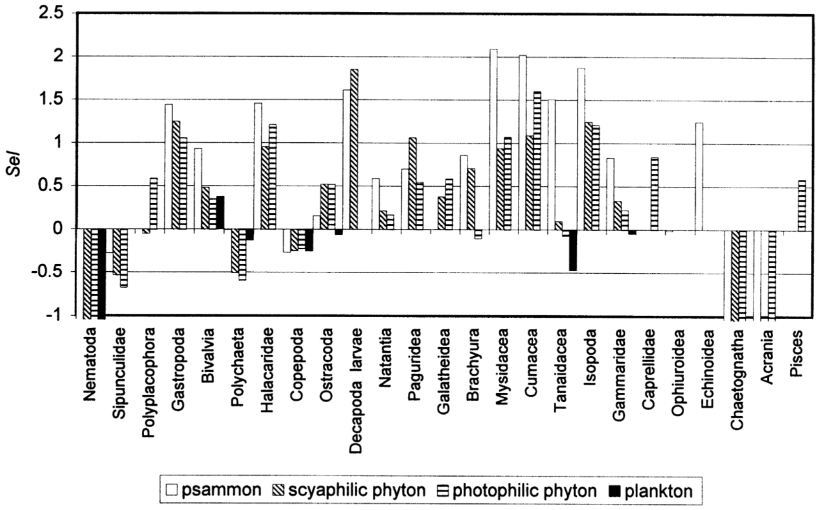

Fig. 2. – The feeding selectivity (*Sel*) of *G. vittatus*. Positive values mean preference, negative non-preference, -1 = total avoidance (meaning the component of the offered food was not preyed on by the fish).

Table II. – Top, ontogenetic shift and seasonal changes in the fullness index of *G. vittatus* (I_F, backtransformed mean and, in parentheses, 95% confidence intervals of log-transformed data; L_t: total length in mm). Middle, analysis of variance of the fullness index of *G. vittatus* (I_F) *versus* length classes (5 mm), seasons; and length classes and seasons; Wi = winter, Sp = spring, Su = summer, Au = autumn. Bottom, seasonal changes and ontogenetic shift in the diet breadth of *G. vittatus* (Levin's standardised index B_i). Ranges in parentheses: 95% jackknife confidence intervals.

L_t classes (5 mm)	*n*	I_F	*n*	Season	I_F
<25	15	0.33 (0.20-0.53)	180	Spring	0.51 (0.45-0.58)
25	57	0.39 (0.32-0.49)	180	Summer	0.39 (0.34-0.44)
30	116	0.33 (0.29-0.39)	180	Autumn	0.23 (0.20-0.27)
35	116	0.40 (0.34-0.48)	164	Winter	0.41 (0.32-0.49)
40	138	0.33 (0.27-0.40)			
45	198	0.38 (0.33-0.44)			
50	64	0.40 (0.32-0.50)			

Source of variation	d.f.	MS	F	*P*	Tukey test
Season	3	2.77	17.85	<0.001	Wi=Sp=Su>Au
L_t classes (5 mm)	6	0.22	1.44	0.20	
L_t classes * season	14	0.23	1.50	0.10	

L_t classes (5 mm)	*n*	Classes L_t (mm)	B_i	*n*	Season	B_i
<25	15	20	0.10 (0.06-0.15)	180	Spring	0.17 (0.14-0.20)
25	57	25	0.12 (0.11-0.14)	180	Summer	0.35 (0.34-0.37)
30	116	30	0.18 (0.16-0.20)	180	Autumn	0.27 (0.25-0.29)
35	116	35	0.16 (0.13-0.19)	164	Winter	0.15 (0.14-0.17)
40	138	40	0.23 (0.20-0.25)			
45	198	45	0.24 (0.22-0.27)			
50	64	50	0.33 (0.31-0.34)			

Paguridea and Gastropoda dominated, and made up over 1/2 of total prey biomass (Table I). The point method produced subjective distortion of most important food items in terms of matter (Polychaeta, Decapoda larvae, Isopoda and Gammaridae), compared to wet mass (Table I). The calculation of the three estimated measures in main food index, I_{MF} revealed three leading taxa: Polychaeta, Gastropoda and Bivalvia (Table I). Wide diet range, comprising 26 higher taxa, was confirmed quantitatively with low I_{MF} values for all prey items.

Feeding selectivity

The overlap between ingested food and available food of all four possible food sources was biologically significant (simplified Morisita's index, in parentheses 95% confidence intervals): plankton 0.804 (0.794-0.816), photophilic phyton 0.767 (0.746-0.789), scyaphilic phyton 0.749 (0.726-0.772) and psammon 0.700 (0.671-0.729). Therefore, feeding selectivity was checked on all four possible food sources. The selectivity index showed the preference or non-preference of distinct components

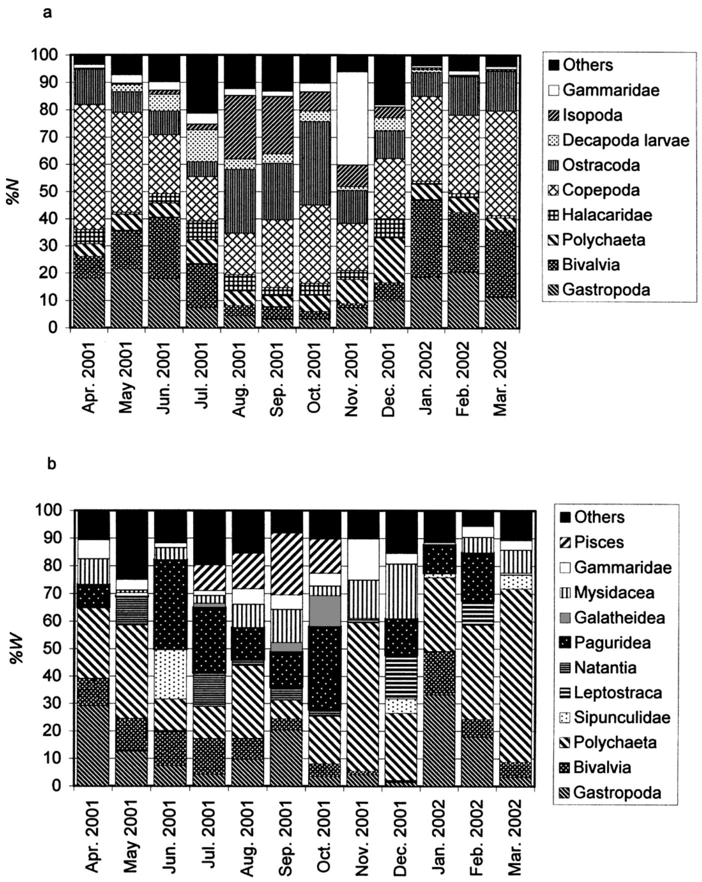

Fig. 3. – Monthly numerical *(%N)* (a) and gravimetrical (%*W*) (b) composition of diet of *G. vittatus* from April 2001 to March 2002.

among the prey offer (Fig. 2). Copepoda and Polychaeta were non-preferred, and Nematodes, Chaetognatha and Amphioxus were completely avoided. *G. vittatus* showed preference to almost all other taxa in the diet, mostly different taxa of molluscs and crustaceans (Fig. 2).

Seasonal variation

The intensity of feeding for *G. vittatus* varied seasonally (Table II). The fullness index (I_F) was significantly lower in autumn, compared with the other three seasons (Table II). Percentage mass (%*W*) and percentage number (%*N*) were rather different within each month (Fig. 3) and the diet composition of both indices varied over the months (Fig. 3). Highly significant seasonal differences (chi-square test, d.f. = 11, $P < 0.001$) were found in biomass and number of all major preys in the diet (Fig. 3), except in number of polychaetes (chi-square test, d.f. = 11, $P < 0.01$) and mass of bivalves (chi-square test, d.f. = 11, $P < 0.05$). The mass of gammarids in the diet was the only variable that did not fluctuate significantly over the months (chi-square test, d.f. = 11, $P > 0.05$). Numerically, the dominant preys in winter and spring were Copepoda, Gastropoda and Bivalvia. During summer, the number of Ostracoda and Isopoda in the diet grew, and they became the dominant preys with Copepoda. Copepoda and Ostracoda were the most numerous preys during autumn as well, except in November, when a high number of Gammaridae was found in the diet (Fig. 3). Gravimetrically, the dominant preys in spring were Polychaeta, Gastropoda and Bivalvia. The gravimetric picture varied during summer and autumn. Polychaeta and Paguridea were almost constantly important in the diet in mass terms in these months. However, the diet was also influenced by one-month high biomass of some taxa (Leptostraca, Natantia, Mysidacea, Gammaridae, fishes), and it was biased by large specimens of some taxa (fishes, Leptostraca). Polychaeta, Gastropoda and Paguridea were the most important preys in mass terms in winter (Fig. 3). Diet breadth (Table II) was highest in the summer and lowest in winter and spring.

Ontogenetic shifts

No significant difference in the fullness index (I_F) was found among the size classes (Table II). Within each size class, percentage mass (%*W*) and percentage number (%*N*) were quite different (Fig. 4). The comparison of size classes showed highly significant differences (chi-square test, d.f. = 5, $P < 0.001$) in number of all major preys in the diet (Fig. 4), except Halacaridae (chi-square test, d.f. = 6, $P > 0.05$). The most numerous prey of young *G. vittatus* was Ostracoda, followed by Copepoda and Isopoda (Fig. 4). The importance of Ostracoda decreased with growth, and numerically the dominant preys of medium size classes became Copepoda and Bivalvia. Large fish, besides these two prey groups, ate numerous Gastropoda (Fig. 4). Although percentage mass (%*W*) of the various taxa varied with size (Fig. 4), there were significant differences only among Bivalvia, Paguridea, fishes (chi-square test, d.f. = 3, $P < 0.001$), Ostracoda (chi-square test, d.f. = 1, $P < 0.01$) and Copepoda (chi-square test, d.f. = 1, $P < 0.05$). Gravimetrically, Mysidacea and Ostracoda dominated in the diet of the youngest *G. vittatus*. In medium size classes the most important preys in terms of mass were Polychaeta, Bivalvia and Gastropoda, while Polychaeta and Paguridae were dominant for the largest fish (Fig. 4). The breadth of diet increased with fish size (Table II).

DISCUSSION

The striped goby is a carnivore, as are most gobies (Miller 1986). Qualitative (26 taxa found in the diet) and quantitative (I_{MF} for all the taxa less than 25) data in this research proved that this species is a generalist. Most

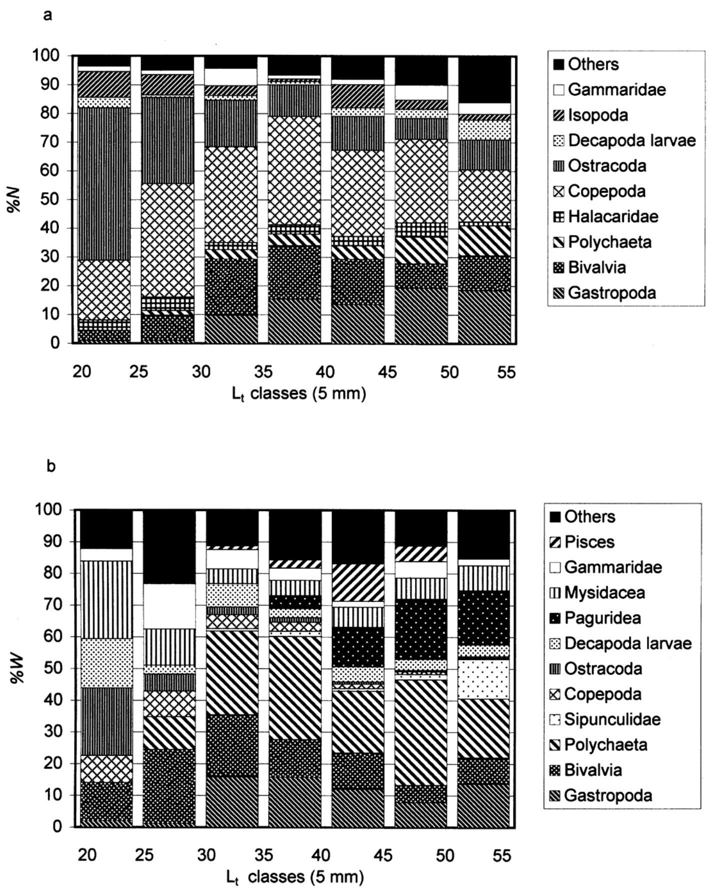

Fig. 4. – Numerical (%*N*) (a) and gravimetrical (%*W*) (b) composition of diet according to L_t (5 mm size classes) of *G. vittatus*.

gobiid species generally consume crustaceans, polychaetes and molluscs (Grossman *et al.* 1980), as was shown in this study for the striped goby as well. The only published data on the diet of striped goby were provided by Heymer & Zander (1978). Their results on diet were restricted to frequency and abundance analyses of food for 17 specimens from Banyuls (France) collected during two summer months. Among the four leading taxa of prey of the present research, only polychaetes and copepods were present in food from Banyuls (France). On the other hand, sessile organisms, important in food at Banyuls- were not present (sponges) or were insignificant (algae) in the present research. *G. vittatus* from the Kvarner area was predator and picker. The diet composition showed no grazing activities as it was described in Heymer & Zander (1978). The striped goby in the present work mostly fed on benthic organisms, but it also hunted free water hyperbenthic fauna like mysids. Considerable differences in diet composition of the striped goby between Heymer & Zander (1978) and the present study showed limited significance of single research for the knowledge on general feeding habits and preferences of the species. Large differences in diet composition among samples have also been found within the same species for *Gobius cobitis* Pallas (Gibson 1968, 1970, 1972), *Gobius geniporus* Valenciennes and *Gobius* cf. *xanthocephalus* Heymer & Zander (wrongly as *Gobius auratus* Risso) (Zander & Hagemann 1989, Zander & Heymer 1992) and *Gobius paganellus* Linnaeus (Dunne 1978).

The feeding selectivity, seasonal and ontogenetic diet shift of the striped goby were unknown before the present research. No dominant food source for the striped goby was found among four distinct possible food sources and overlap of the gut content was biologically significant with all these microhabitats. The striped goby showed no feeding selectivity based on size or behaviour of the taxa, except for the avoidance of some infaunal taxa (nematods, sipunculids and amphioxus). Meiofauna and macrofauna were present among preferred as well as non-preferred prey. The striped goby therefore has unspecialized feeding habits.

Low feeding intensity in autumn, during the period of decrease of the sea water temperature, as well as for the striped goby, has also been noticed for other gobiid species (Collins 1981, 1982, Joyeux *et al.* 1991, Kovačić 2001). For all these species this is also the postspawning period (Miller 1986, Kovačić 2001), when the gonadosomatic index reaches its lowest value for both sexes and specimens are in spent or recovering spent stages (Collins 1981, 1982, Kovačić 2001). Different results on seasonal changes of feeding intensity in temperate gobies were found by Vesey & Langford (1985) and Laffaille *et al.* (1999). Hamerlynck & Cattrijsse (1994) noticed variation in the diet breadth for *P. minutus* and *P. lozanoi* similar to the present results on the striped goby, with high values in summer and autumn, and low values in spring. The reduced diet spectrum of the striped goby in winter and spring resulted from high numerical dominance (> 70%) of polychaetes, gastropods and bivalves in the diet. The level of predation on polychaetes, gastropods (%*W*) and copepods (%*N*) was important throughout the year, while high consumption of other taxa was markedly seasonal. Constant increase of diet breadth along with the growth of the striped goby was the result of increased capability of larger fish to use food at different size. Percentage mass (%*W*) and percentage number (%*N*) showed a quite different pattern of diet composition during growth. Large differences in diet composition among size classes have also been found for other European marine gobies: *G. cobitis* (Gibson 1970), *G. geniporus* (Zander & Heymer 1992), *G. paganellus* (Mazé 2004), *G. roulei* (Kovačić 2001), *P. minutus* and *P. lozanoi* (Hamerlynck & Cattrijsse 1994). Numerically, meiofauna was more important among most of the size classes, while macrofauna prevailed gravimetrically among most of the size classes in this research. However, the trend related to growth was clear with the smaller specimens feeding mostly on meiofauna, and large fish preferring macrofauna. The complete or partial switch from feeding on meiofauna to macrofauna related to growth was previously observed for other *Gobius* species: *G. bucchichi* Steindachner (Bouchereau & Guelorget 1999), *G. cobitis* (Gibson 1970), *G. geniporus* (Zander & Heymer 1992), *G. paganellus* (Dunne 1978) and *G. roulei* (Kovačić 2001).

Different results on importance of food taxa between percentage mass (%*W*) and percentage number (*%N*) in the present study proved the importance of determination of the amount of the consumed food in terms of matter. Diet analyses which provide just frequency and numerical data, give incomplete and even incorrect picture on importance of taxa in the diet (Table I). In the present comparison of the wet mass method and the point methods, the point methods gave a subjective distortion of the most important food items in terms of matter. However, even with this distortion the point method showed the importance of some taxa, like polychaetes, that were underestimated by frequency and numerical data. Only 1/3 of European marine gobiid species have any published data on the species diet (Kovačić 2001). Well studied diets with details on seasonal patterns, ontogenetic shifts, prey selection or spatial variations are restricted to several species of *Gobius, Gobiusculus* and *Pomatoschistus* genera that are easily accessible by conventional collecting methods (trawls, drift nets, collecting in tidal pools, etc.) (Kovačić 2001). On the other hand, SCUBA diving remains the only presently possible technique for collecting samples of most European marine gobies to study species diet.

ACKNOWLEDGEMENTS. - I am grateful to R A Patzner for criticism and comments on this paper. Diving assistance was provided by M Arko-Pijevac.

REFERENCES

Berg J 1979. Discussion of the methods of investigating the food of fishes, with reference to a preliminary study of the prey of *Gobiusculus flavescens* (Gobiidae). *Mar Biol* 50: 263-273.

Boisseau MJ-P 1957. Technique pour l'étude quantitative de la faune interstitielle des sables. *C R Congr Soc Sav Paris, Sect Sci* 82: 117-119.

Bouchereau JL, Guelorget O 1999. Régime alimentaire de deux Gobiidae (Pisce; Teleostei) sympatriques *Gobius bucchichi* et *Millerigobius macrocephalus* des Bouches de Bonifacio. *Cah Biol Mar* 40: 263-271.

Collins SP 1981. Littoral and benthic investigations on the west coast of Ireland – XIII. The biology of *Gobiusculus flavescens* (Fabricius) on the Connemara coast. *Proc R Irish Acad* 81 B (7): 63-87.

Collins SP 1982. Littoral and benthic investigations on the west coast of Ireland – XIV. The biology of the painted goby, *Pomatoschistus pictus* (Malm) on the Connemara coast. *Proc R Irish Acad* 82 B (7): 21-37.

Dunne J 1978. Littoral and benthic investigations on the west coast of Ireland – IX (Section A: Faunistic and ecological studies). The biology of the rock-goby, *Gobius paganellus* L., at Carna. *Proc R Irish Acad* 78 B (12): 179-191.

Gibson RN 1968. Food and feeding relationship of littoral fish in the Banyuls region. *Vie Milieu* 19: 447-456.

Gibson RN 1970. Observations on the biology of the giant goby *Gobius cobitis* Pallas. *J Fish Biol* 2: 281-288.

Gibson RN 1972. The vertical distribution and feeding relationships of intertidal fish on the Atlantic coast of France. *J Anim Ecol* 41: 187-207.

Grossman GD, Coffin R, Moyle PB 1980. Feeding ecology of the bay goby (Pisces: Gobiidae). Effects of behavioural, ontogenetic, and temporal variation on diet. *J Exp Mar Biol Ecol* 44: 47-59.

Hamerlynck O, Cattrijsse A 1994. The food of *Pomatoschistus minutes* (Pisces, Gobiidae) in the Belgian coastal waters, and a comparison with the food of its potential competitor *P. lozanoi*. *J Fish Biol* 44: 753-771.

Heymer A, Zander CD 1978. Morfology and ecology of *Gobius vittatus* Vinciguerra, 1883, and its possible mimicry relationship to *Blennius rouxi* Cocco, 1833 in the Mediterranean. *Z Zool Syst Evol* 16: 132-143.

Hureau JC 1970. Biologie comparée de quelques poissons antarctiques (Nototheniidae). *Bull Inst Océanogr Monaco* 68: 1-244.

Hynes HBN 1950. The food of freshwater sticklebacks (*Gasterosteus aculeatus* and *Pygosteus pungitius*), with a review of methods used in studies of food of fishes. *J Anim Ecol* 19: 35-38.

Jardas I 1985. Check list of the fishes (sensu lato) of the Adriatic Sea (Cyclostomata, Selachii, Osteichthyes) with respect to taxonomy and established number (in Croatian). *BioSist* 11 (1): 45-74.

Joyeux JC, Tomasini JA, Bouchereau JL 1991. Le régime alimentaire de *Gobius niger* Linné, 1758 (Teleostei, Gobiidae) dans la lagune de Mauguio - France. *Ann Sci Nat Zool* 13 ser 12: 57-69.

Kovačić M 2001. The biology of Roule's goby in the Kvarner area, northern Adriatic Sea. *J Fish Biol* 59 (4): 795-809.

Kovačić M 2004. Biology and ecology of *Gobius vittatus* (Gobiidae, Pisces) in the Adriatic Sea (in Croatian). Ph D Thesis, Univ Zagreb, 177 p.

Krebs CJ 1989. Ecological Methodology. HarperCollins Publishers, New York, 654 p.

Laffaille P, Feuntuen É, Lefeuvre JC 1999. Compétition alimentaire entre deux espèces de gobies, *Pomatoschistus lozanoi* (de Buen) et *P. minutus* (Pallas), dans un marais salé macrotidal. *C R Acad Sci Paris Sci Vie* 322: 897-906.

Mazé RA 2004. Seasonal and ontogenetic diet shifts in an intertidal population of *Gobius paganellus* (Teleostei, Gobiidae) from the Cantabrian coast. *Vie Milieu* 54 (1): 1-6.

Miller PJ 1986. Gobiidae. *In* Whitehead PJP, Bauchot ML, Hureau JC, Nielsen J, Tortonese E eds, Fishes of the North-eastern Atlantic and the Mediterranean, Vol 3, UNESCO, Paris: 1019-1085.

Pampoulie C, Bouchereau JL 1996. Eléments de systématique et de biologie de deux Gobiides (poissons Téléostéens), *Chromogobius quadrivittatus* (Steindachner, 1863) et *Chromogobius zebratus zebratus* (Kolombatović, 1891) des bouches de Bonifacio (Corse, France). *Icthyophysiol Acta* 19: 153-178.

Sokal RR, Rohlf FJ 1995. Biometry. WH Freeman and company, New York, 850 p.

Tortonese E 1975. Osteichthyes (Pesci ossei), Parte seconda. Fauna d'Italia, Vol 11. Calderini, Bologna, 636 p.

Vesey G, Langford TE 1985. The biology of the black goby, *Gobius niger* L in an English south-coast bay. *J Fish Biol* 27: 417-429.

Xie S, Cui Y, Zhang T, Li Z 2000. Seasonal patterns in feeding ecology of three small fishes in the Biandantang Lake, China. *J Fish Biol* 57 (4): 867-880.

Zander CD, Hagemann T 1987. Predation impact and ecological efficiency of *Pomatoschistus* spp. (Gobiidae, Pisces) from a clay/sand ecotone of the Western Baltic Sea. *Zool Anz* 218: 33-48.

Zander CD, Hagemann T 1989. Feeding ecology of littoral gobiid and blennioid fish of the Banyuls area (Mediterranean Sea). III. Seasonal variations. *Scient Mar* 53: 441-449.

Zander CD, Heymer A 1992. Feeding habits of *Gobius auratus* and other benthic small-sized fish from the French Mediterranean coast under regard of some alternating parameters. *Zool Anz* 228: 220-228.

Received April 26, 2005
Accepted October 21, 2005