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Diet and feeding of juvenile common two-banded sea bream, *Diplodus vulgaris* (Teleostei: Sparidae), in the eastern central Adriatic Sea

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Abstract

The diet and feeding of juvenile common two-banded sea bream, *Diplodus vulgaris*, in the eastern central Adriatic Sea was studied to better understand local ecosystem dynamics in this region. Stomach contents of 140 individuals with total length (TL) between 22 and 106 mm, collected by small beach seines from February to November, were analysed. Food items identified in stomachs belonged to 16 prey groups: Copepoda, Gastropoda, Teleost eggs, Ostracoda, Polychaeta, Bivalvia, unidentified Crustacea, Amphipoda, Decapoda, Cumacea, Echinoidea, Anisopoda, Euphausiacea, Mysidacea, Branchiopoda and Isopoda. Overall, planktonic copepod crustaceans were the most important prey group (percentage index of relative importance, %IRI = 78.9), followed by gastropods (%IRI = 14.9). All other prey groups had much lower %IRI values and thus were of less importance. Fish size was an important factor influencing food composition. Planktonic copepods were the most important prey in juveniles of smaller sizes (up to 76 mm TL), whereas large-sized juvenile individuals (>76 mm TL) mainly consumed benthic prey, such as gastropods, polychaetes and bivalves. Feeding intensity was very high as indicated by the low vacuity index.

Introduction

The common two-banded sea bream, *Diplodus vulgaris* (Geoffroy Saint-Hilaire, 1817) (Teleostei: Sparidae) is a demersal species distributed in the Mediterranean Sea and along the eastern Atlantic coast from France to Senegal, including the Madeira, the Azores and Canary Islands (Bauchot and Hureau, 1986). Adults are abundant in the sublittoral rocky bottoms down to 100 m depth, whereas the juveniles inhabit shallow coastal areas (Jardas, 1996; Correia *et al*., 2011). In the Adriatic Sea, this species spawns in autumn during October and November (Dulčić and Kovačić, 2020). After a short period spent in the water column, they settle (Loy *et al*., 1998). The settlement occurs after 2–2.5 months of the larval planktonic stage and it is most intensive from November to February (Vigliola *et al*., 1998; Correia *et al*., 2011; Altin *et al*., 2015).

Published information on food and feeding habits of the common two-banded sea bream is scarce and available information is mainly focused on adult populations (Sala and Ballesteros, 1997; Gonçalves and Erzini, 1998; Pallaoro *et al*., 2006; Osman and Mahmoud, 2009). The diet of juvenile common two-banded sea bream was studied in the western Mediterranean (Rossechi, 1987), Portuguese waters (Horta *et al*., 2004) and the North Aegean Sea (Altin *et al*., 2015). The only information on the diet of juvenile *D. vulgaris* in the Adriatic Sea is from Dobroslavić *et al*. (2013), who studied the diet overlap of juveniles in three sparid species, including *D. vulgaris*, in the southern part of the eastern Adriatic Sea.

Information on diet and feeding habits of juveniles is important not only to fulfil the existing gap in biological studies of this species in the Adriatic Sea, but also as an input for further studies on food webs and trophic levels necessary for understanding the overall ecosystem (Altin *et al*., 2015). Besides, presented data on food and feeding characteristics of the young two-banded sea bream provide useful information for juvenile production of this species in aquaculture. The aim of this study was not only to analyse the diet composition of the juvenile common two-banded sea bream in the central Adriatic Sea, but also to examine, for the first time, changes of diet and diet-related behaviour of juvenile *D. vulgaris* in relation to their size.

Materials and methods

Samples of the juvenile common two-banded sea bream were collected from the central eastern Adriatic channel area, well known as a nursery area of *D. vulgaris*. The position of sampling stations was defined using random scheme with finally six sites being chosen, three of them on the coastal line and three around islands: Lavsa (43°45′11″N, 15°22′13″E), Studenjak (43°45′35″N, 15°22′47″E), Sovlja (43°45′56″N, 15°43′43″E), Žaborić (43°39′44″N, 15°56′44″E), Sićenica (43°30′06″N, 16°01′03″E) and Lojena (43°49′18″N, 15°15′01″E) (Figure 1). All sampling sites share similar biotic and abiotic characteristics (Pérès and Gamulin-Brida, 1973). A small beach seine specially designed for the collection of small

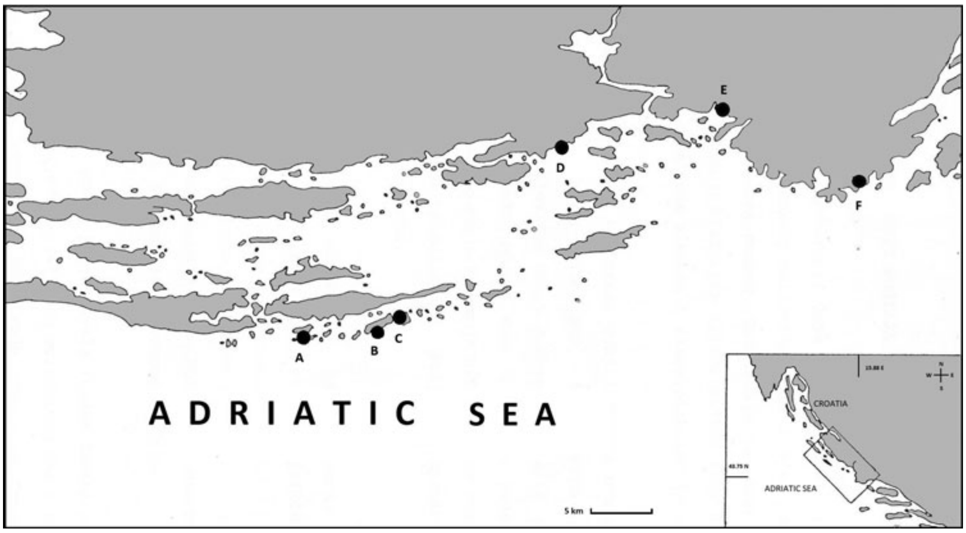

Figure 1. Study area and sampling bays of juvenile *Diplodus vulgaris* in the eastern central Adriatic Sea: (A) Lojena; (B) Studenjak; (C) Lavsa; (D) Sovlja; (E) Žaborić; (F) Sićenica.

individuals was used. The net was 50 m long and 30–170 cm high, with cod-end mesh size of 4 mm. Samples were collected during daylight hours. One sampling event per location occurred in the months listed in Table 1. The mean hauling duration was 45 min. Depths at the sampling sites ranged from 0 to 5 m. In shallow parts of the sampling stations the bottom was rocky with benthic algae while deeper parts were with sand muddy bottom and meadows of seagrass *Posidonia oceanica* and *Cymodocea nodosa*.

A total of 140 juveniles were collected from February to November in 2009. Immediately after capture, whole specimens were preserved in 4% formalin solution. In the laboratory, total length (TL) was measured to the nearest millimetre, and body weight to the nearest 0.01 g. Individual age of each analysed specimen was determined by reading sagitta otolith rings under a stereomicroscope at ten-fold magnification. Based on that, two age groups were defined, 0^+ and 1^+ (Table 1). In addition, stomachs were dissected and their contents were analysed. As the prey had been highly digested, it was determined to the level of taxonomy group. Inorganic matter and detritus were excluded from the analysis. Prey group abundance and blotted wet mass (±0.001 g) of each prey were recorded. In this study, the indices used were (Hyslop, 1980):

Vacuity index (VI) = number of empty stomachs divided by total number of stomachs multiplied by 100;
Percentage frequency of occurrence (%*F*) = number of stomachs in which a food item was found divided by total number of non-empty stomachs multiplied by 100;

Table 1. Month of samples, age group, number of catch specimens, TL range (mm) of juvenile *Diplodus vulgaris*

Month	Age group	Number of specimens	TL range (mm)
February	0^+	9	22–27
May	0^+	19	31–44
June	0^+	45	29–52
July	0^+	23	46–83
September	1^+	15	71–81
October	1^+	15	74–97
November	1^+	14	70–106

Percentage numerical composition (%*N*) = total number of a particular prey item in all non-empty stomachs divided by total number of food items in all stomachs multiplied by 100;
Percentage gravimetric composition (%*W*) = total wet mass of a particular prey item in all non-empty stomachs divided by total mass of stomach contents multiplied by 100.

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

$$\mathrm{IRI} = \%F \times (\%N + \%W)$$

The index was expressed as $\%\mathrm{IRI} = \left(\mathrm{IRI}/\sum \mathrm{IRI}\right) \times 100$.

Prey groups were sorted in the decreasing order according to IRI and then the cumulative %IRI was calculated.

The feeding breadth was calculated by the Shannon–Wiener diversity index *H'* (Krebs, 1989):

$$H' = -\sum_{i=1}^{S} p_i \times \ln p_i$$

where p_i is the proportion of a specific prey category for the *n* categories of the listed prey. In practice, for biological communities *H'* does not exceed 5.0 (Krebs, 1989).

To get a better insight into ontogenetic changes of feeding behaviour in juveniles and evaluate variations in food composition and feeding habits as a function of size, individuals were separated into three length classes: (I) 22–44 mm TL ($n = 59$), (II) 44–76 mm TL ($n = 37$) and (III) 76–106 mm TL ($n = 36$).

Proportional food overlap between length classes was calculated using Schoener's (1970) dietary overlap index: $C_{xy} = 1 - 0.5\sum|P_{xi} - P_{yi}|$, where P_{xi} and P_{yi} are the proportion of prey *i* (based on %IRI) found in the diet of groups *x* and *y*. This index ranges from 0 (no prey overlap) to 1 (all food items in equal proportions). Schoener's index values above 0.6 indicate significant overlap (Wallace, 1981).

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Table 2. Diet composition from 132 non-empty stomachs of juvenile *D. vulgaris* (%*F*, frequency of occurrence; %N, percentage numerical composition; %W, percentage gravimetric composition; IRI, index of relative importance; %IRI, percentage index of relative importance)

Food items	%*F*	%*N*	%*W*	IRI	% IRI
Copepoda	68.9	79.4	20.0	6848.6	78.9
Gastropoda	22.7	6.1	51.0	1296.1	14.9
Teleosts eggs	27.2	4.1	0.7	130.5	1.5
Ostracoda	18.1	3.3	3.3	119.4	1.4
Polychaeta	14.4	1.3	5.5	97.9	1.1
Bivalvia	9.8	1.0	8.0	88.2	1.0
Unidentified Crustacea	9.8	1.7	2.0	36.2	0.4
Amphipoda	9.1	1.0	1.5	22.7	0.3
Decapoda	5.3	0.4	3.2	19.6	0.2
Cumacea	3.8	0.5	0.8	4.9	0.1
Echinoidea	2.3	0.2	1.7	4.3	0.1
Anisopoda	3.0	0.4	0.7	3.3	<0.1
Euphausiacea	3.0	0.2	0.8	3.0	<0.1
Mysidacea	2.2	0.1	0.6	1.5	<0.1
Branchiopoda	3.0	0.2	0.1	0.9	<0.1
Isopoda	1.5	0.1	0.1	0.3	<0.1

Results

Diet composition

Frequency of occurrence, abundance, gravimetric composition and IRI values of prey organisms found in the stomachs are shown in Table 2. Food items identified in stomachs belonged to 16 different prey groups: Copepoda, Gastropoda, Teleost eggs, Ostracoda, Polychaeta, Bivalvia, unidentified Crustacea, Amphipoda, Decapoda, Cumacea, Echinoidea, Anisopoda, Euphausiacea, Mysidacea, Branchiopoda and Isopoda. Planktonic copepod crustaceans occurred in 68.9% of stomachs that contained food, and represented 79.4% of total prey number and 20.0% of the total prey weight. Gastropods occurred in 22.7% of the stomach examined and represented 6.1% by number and 51% by weight of the total prey. Planktonic copepod crustaceans were the most important prey group ingested, constituting 78.9% of the total IRI, followed by gastropods (%IRI = 14.9). Other prey groups had much lower %IRI (<2%) and were thus of less importance.

Of the total number of stomachs examined ($n = 140$), eight were empty (VI = 5.7%). The Shannon–Wiener diversity index (H') of prey groups in the total sample was 0.97.

Food in relation to fish size

The TL of the examined fish ranged from 22 to 106 mm (Figure 2).

The %IRI changed depending on the size of juveniles (Figure 3). In the first length class copepods dominated the diet (%IRI = 98.2), whereas other prey groups were of minor importance, and all together accounted for only 1.8% of food found in stomachs (Table 3, Figure 3A). In the second length class (up to 76 mm) planktonic copepods were the most important prey (%IRI = 53.1) followed by gastropods (%IRI = 25.2). Other categories of prey, including eggs of Teleosts, Polychaeta, Ostracoda, Bivalvia and other food groups, had much lower %IRI in this length class when compared to the first length class (Table 4, Figure 3B). In the third group, with the largest analysed juveniles, importance of copepods decreased significantly (%IRI = 4.0). In the stomachs of these specimens (over 76 mm TL), gastropods markedly dominated (%IRI = 78) and were followed by polychaetes (%IRI = 5.2) and bivalves (%IRI = 5.2). All other groups, primarily crustaceans, accounted for 5.6% (Table 5; Figure 3C). Teleost eggs and ostracods showed the highest value in the second length class (Table 4). Planktonic euphausiids and mysids were found only in stomachs of fish with TL up to 76 mm while unidentified crustaceans, Amphipoda and Cumacea were present in small quantities in stomachs of juveniles of all length classes.

Schoener's overlap index indicated differences in diets between the largest fish (>76 mm TL) and both smaller size groups of up to the 76 mm in TL. On the contrary, high values of overlapping (0.77) were found for the two first size groups of fish, 22–44 and 44–76 mm TL, where the diet was dominated by planktonic copepod crustaceans (Table 6).

Discussion

The composition of food suggests that juvenile common two-banded sea bream inhabiting eastern part of the central Adriatic Sea is a carnivorous species with the dominance of zooplanktonic organisms in the diet. Planktonic copepod crustaceans were the

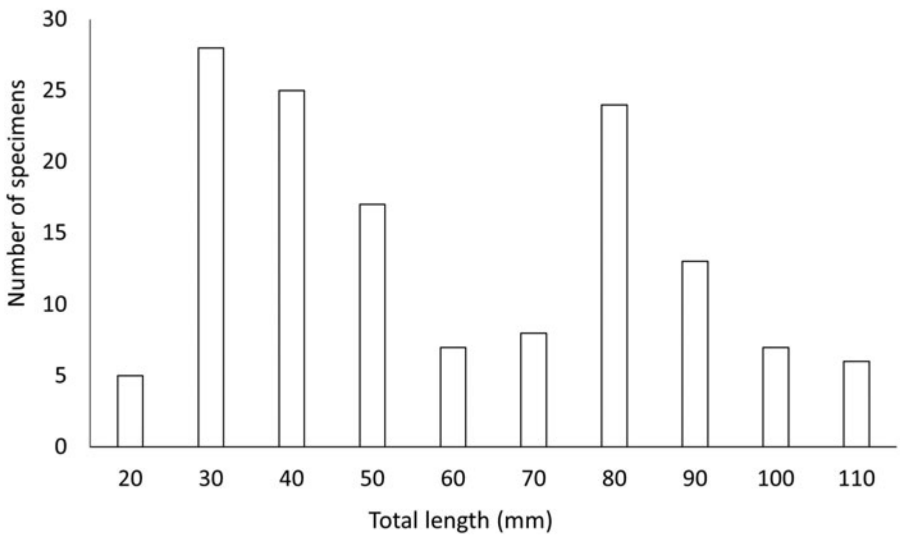

Figure 2. Length-frequency distribution of sampled juvenile *D. vulgaris* from the eastern central Adriatic Sea ($n = 140$).

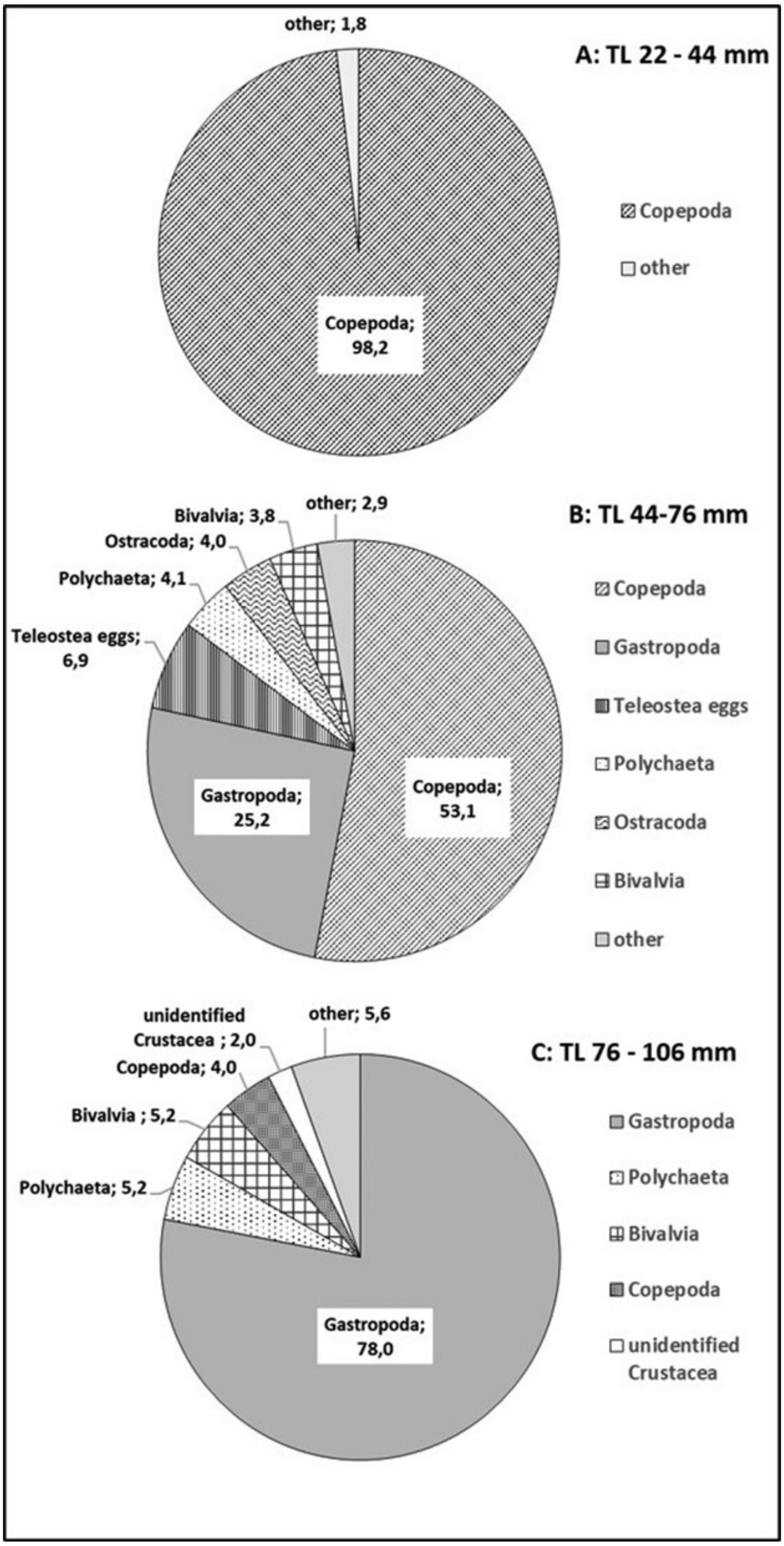

Figure 3. Composition of juvenile *D. vulgaris* diet for three length classes: (A) I – 22–44 mm TL, (B) II – 44–76 mm TL, (C) III – 78–106 mm TL, based on %IRI values for major prey groups. Group 'others' includes prey groups with very small %IRI (<2%) in each length class.

most abundant prey constituting 78.9% of the total IRI and thus can be considered as the primary food source (Rosecchi and Nouaze, 1987). Based on the total IRI, gastropods were the second most important prey while other prey groups were of less importance. The low value of Shannon–Wiener index ($H' = 0.97$) indicates the low diversity of food and proves that only few prey groups are relevant for juvenile *D. vulgaris* diet.

Similarly, in previous studies copepods were dominant prey found in stomachs of juvenile *D. vulgaris* sampled in the south Adriatic (Dobroslavić *et al.*, 2013) and in the North Aegean seas (Altin *et al.*, 2015). Moreover, copepods are an important prey for juvenile stages of many Adriatic fishes such as *Oblada melanura* (Pallaoro *et al.*, 2004), *Chromis chromis* (Dulčić, 2007), *Trachurus trachurus* and *Trachurus mediterraneus* (Šantić *et al.*, 2013), *Sarpa salpa* and *Boops boops* (Dobroslavić *et al.*, 2013). In contrast, in the Mediterranean French waters small teleosts and decapods were the most frequent prey in the juvenile *D. vulgaris* diet (Rossechi, 1987). Juvenile individuals of *D. vulgaris* sampled in Portuguese waters fed on amphipods, mysids and algae (Horta *et al.*, 2004). Generally, variations in prey consumption may be related to the geographical and environmental characteristics as well as to the presence and availability of food resources in the different areas.

Table 3. Diet composition of juvenile *D. vulgaris* in length class 22–44 mm LT (59 non-empty stomachs) (%*F*, frequency of occurrence; %N, percentage numerical composition; %W, percentage gravimetric composition; IRI, index of relative importance; %IRI, percentage index of relative importance)

Food items	%*F*	%*N*	%*W*	IRI	%IRI
Copepoda	91.5	94.0	86.6	16,529.4	98.2
Ostracoda	22.0	1.4	4.3	125.4	0.75
Teleosts eggs	25.4	2.5	1.5	101.6	0.6
Unidentified Crustacea	16.9	1.0	2.0	50.7	0.3
Cumacea	5.0	0.4	2.4	14.0	0.1
Amphipoda	3.4	0.3	1.2	5.1	<0.1
Euphausiacea	1.7	0.2	1.0	2.0	<0.1
Mysidacea	1.7	0.2	1.0	2.0	<0.1

The diet of juvenile *D. vulgaris* corresponds well with the distribution patterns and abundance of copepods in the Adriatic Sea. These small-sized epiplanktonic crustaceans in very large number inhabit surface sea layers, and are especially abundant in the offshore and inshore waters of the Adriatic Sea during the spring, summer and autumn (Gamulin, 1979; Regner, 1985, 1991) which corresponds, for the most part, with the time of *D. vulgaris* sampling in this study.

Feeding intensity is positively related to the degree and index of fullness, and negatively related to the percentage of empty stomachs (Bowman and Bowman, 1980). The low values of the VI (5.7%) indicate that the feeding intensity of juvenile *D. vulgaris* is very high. Similarly, in the eastern central Adriatic Sea, low values of VI were reported for juveniles of *O. melanura* (Pallaoro *et al*., 2004), *C. chromis* (Dulčić, 2007), *T. mediterraneus* and *T. trachurus* (Šantić *et al*., 2013). The VI of juvenile *D. vulgaris* is much lower than that in adults (%VI = 18.4; Pallaoro *et al*., 2006) and this is in an agreement with the general assumption that in all species high feeding intensity is more pronounced in smaller individuals with the highest growth rates. This high feeding frequency in small individuals is also related to the fact that small prey in stomachs of juveniles is digested faster than the larger items represented in the diet of large fish (Chapman *et al*., 1988), i.e. feeding intensity and frequency are directly correlated with meal size and digestion time (Grove and Crawford, 1980).

Table 4. Diet composition of juvenile *D. vulgaris* in length class 44–76 mm LT (37 non-empty stomachs) (%*F*, frequency of occurrence; %N, percentage numerical composition; %W, percentage gravimetric composition; IRI, index of relative importance; %IRI, percentage index of relative importance)

Food items	%*F*	%*N*	%*W*	IRI	%IRI
Copepoda	70.0	45.4	6.1	3605.0	53.1
Gastropoda	27.0	11.4	52.0	1711.8	25.2
Teleosts eggs	35.1	12.3	1.1	470.3	6.9
Polychaeta	21.6	4.7	8.3	280.8	4.1
Ostracoda	16.2	11.8	4.8	268.9	4.0
Bivalvia	16.2	3.4	12.7	260.8	3.8
Unidentified Crustacea	8.1	2.6	2.3	39.6	0.6
Amphipoda	10.8	1.8	1.7	37.8	0.6
Anisopoda	8.1	2.2	2.0	34.0	0.5
Euphausiacea	8.1	1.1	2.5	29.1	0.4
Decapoda	5.4	0.8	3.3	22.1	0.3
Mysidacea	5.4	0.7	1.6	12.4	0.2
Cumacea	5.4	1.1	1.0	11.3	0.2
Isopoda	5.4	0.7	0.6	7.0	0.1

Table 5. Diet composition of juvenile *D. vulgaris* in length class 76–106 mm LT (36 non-empty stomachs) (%*F*, frequency of occurrence; %N, percentage numerical composition; %W, percentage gravimetric composition; IRI, index of relative importance; %IRI, percentage index of relative importance)

Food items	%*F*	%*N*	%*W*	IRI	%IRI
Gastropoda	55.5	43.3	70.7	6327.0	78.0
Polychaeta	30.5	7.6	6.2	420.9	5.2
Bivalvia	19.4	10.3	11.3	419.0	5.2
Copepoda	27.7	11.4	0.5	329.6	4.0
Unidentified Crustacea	22.2	5.7	1.8	166.5	2.0
Teleosts eggs	22.2	5.7	0.2	130.9	1.6
Amphipoda	16.6	4.7	1.5	102.9	1.3
Decapoda	13.8	2.8	4.6	102.1	1.3
Ostracoda	13.8	5.2	0.7	81.4	1.0
Echinoidea	5.5	1.4	2.3	20.3	0.2
Branchiopoda	8.3	1.4	0.1	12.6	0.1
Cumacea	2.7	0.5	0.1	1.6	<0.1

Fish size was an important factor affecting the diet of juveniles *D. vulgaris*. A size-related diet changes were observed during stomach content analyses and were therefore presented in three separate length classes. The stomach content analyses clearly indicated changes in prey selection with increasing body length. A prominent shift in the feeding habits was recorded from the second to third length class (~76 mm TL, Schoener's overlap index = 0.41), with the decrease in predation on planktonic copepods and an increase of benthic, larger-sized, prey such as gastropods, polychaetes and bivalves. So, the juvenile two-banded sea bream, not only changed the categories and size of the prey, but also the feeding behaviour and habitat by switching gradually from feeding in the water column with small pelagic crustaceans to feeding on the sea bottom in search of larger benthic prey. Trophic shift of juvenile *D. vulgaris* can also be explained in terms of fish morphology. Width and height of the mouth are linearly related to fish size and increased body and mouth size permit the capture of a broader range of prey size and prey type (Ross, 1978). Besides, development and differentiation of teeth is very important, especially molars, with increasing size. Onofri (1986) relates the type of food in *D. vulgaris* with the characteristics of their denture adapted for grinding of hard animal shells. The development of the tooth thus also explains a high proportion of animals with hard exoskeletons, such as larger Crustacea, Gastropoda and Bivalvia, in the diet of larger juveniles. The trophic shift also required important shape changes, mostly related to their swimming capacity and different feeding behaviour (Loy *et al*., 1998). Results in the present study confirm this

Table 6. Proportional food overlap coefficients (Schoener's index) of the diet between length classes of juvenile *D. vulgaris*

Length class (mm)	22–44	44–76
44–76	0.77	–
76–106	0.10	0.41

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feeding behaviour; larger-sized juveniles of *D. vulgaris* (>44 mm TL) gradually change their prey types when compared to the smallest individuals. Increased prey size with increasing fish size optimizes the energy input for growth (Stoner and Livingston, 1984). This is especially evident in the largest fraction of the analysed juveniles (TL over 76 mm) where planktonic copepods are only a small fraction of the prey (%IRI = 4.0) and, on the contrary, benthic groups, primarily gastropods become the most important food (%IRI = 78.0). It was previously found that in the Adriatic Sea adult individuals of *D. vulgaris* feed on various prey items including mostly benthic organisms such as echinoids, decapods, gastropods and bivalves (Pallaoro *et al.*, 2006), and the same has been confirmed for adult *D. vulgaris* in the Mediterranean Sea (Sala and Ballesteros, 1997; Gonçalves and Erzini, 1998).

Conclusions

Small juveniles of *D. vulgaris* (ca. 20–50 mm TL) feed upon planktonic crustaceans, almost exclusively copepods. After a short period spent in the water column, they descend and start searching for prey in benthos (ca. 50–80 mm), at first only occasionally and still mainly feeding on copepods. Larger juveniles, towards the end of the first year of their life (0^+) and especially during the second year of their life (1^+), switch to food and feeding habits very similar to their adults, i.e. they feed on larger prey and mainly consume benthic organisms such as gastropods, bivalves and polychaetes.

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Author's contribution. SKŠ: formulating the research question, designing and caring out the study, analysing the data, interpreting the findings and writing the article (drafting, reviewing and editing), final approval of version to be published. MŠ: analysing the data, interpreting the findings and writing the article (drafting, reviewing and editing), final approval of version to be published.

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Data. The data that support the findings of this study are available from the corresponding author, SKŠ, upon reasonable request.

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