Size and seasonal diet variation of European anchovy Engraulis encrasicolus (Linnaeus, 1758) in the southeast Black Sea

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Size and seasonal diet variation of European anchovy *Engraulis encrasicolus* (Linnaeus, 1758) in the southeast Black Sea

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Abstract: The diet of the European anchovy *Engraulis encrasicolus* was studied in the southeast Black Sea region of Turkey during the autumn, winter and spring seasons. Examination of the stomach contents of 526 specimens (total length ranging from 6.9-13.8 cm) confirmed that *E. encrasicolus* is a zooplanktivorous fish species. Among the 38 identified prey items, 71% were classified as zooplankton. The predominant prey groups of the zooplankton were fish eggs and larvae, and Ctenophorans followed by copepods. Data analysis revealed significant differences in the prey species composition between different seasons (ANOSIM, $R = 0.229$, $p < 0.001$) and between fish length classes (ANOSIM, $R = 0.073$, $p < 0.001$). The prey species that constituted the majority of the diet changed significantly with the season. SIMPER analysis revealed that the prey item contributing the most to the differences between seasons and length classes was fish eggs. The results of this study could be used to describe the diversity of prey species and intraspecific food competition in the Black Sea.

Résumé : *Variabilité de la taille et du régime alimentaire de l'anchois européen* Engraulis encrasicolus *(Linnaeus, 1758) de Mer Noire méridionale.* Le régime alimentaire de l'anchois européen *Engraulis encrasicolus* a été étudié dans la partie méridionale turque de la Mer Noire en automne, hiver ainsi qu'au printemps. L'examen des contenus stomaux de 526 spécimens (longueur totale de 6,9 à 13,8 cm) confirme que *E. encrasicolus* est une espèce planctonophage. Parmi les 38 proies identifiées, 71% appartiennent au zooplancton. Les groupes de proies dominantes étaient les œufs et larves de poissons, ainsi que les Cténophores suivis des copépodes. L'analyse des données a révélé des variations entre saisons significatives (ANOSIM, $R = 0,229$, $p < 0,001$) ainsi qu'entre classes de taille (ANOSIM, $R = 0,073$, $p < 0,001$). Les proies dominantes ont varié en fonction des saisons. L'analyse SIMPER a montré que les œufs de poissons constituent la proie contribuant le plus aux variations entre saisons et entre classes de taille. Les résultats de cette étude permettent de connaitre la diversité des proies ainsi que de comprendre la compétition intraspécifique pour la nourriture en Mer Noire.

Keywords: Feeding ecology ● Small pelagic fish ● Stomach content ● Zooplanktivorous

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Introduction

The diet of the European anchovy *Engraulis encrasicolus* (Linnaeus, 1758) has been well investigated in the Mediterranean Sea (Tudela & Palomera, 1997; Plounevez & Champalbert, 2000; Borme et al., 2009; Costalago et al., 2012 & 2014; Brosset et al., 2016; Zorica et al., 2016) and the north-east Atlantic Ocean (Plounevez & Champalbert, 1999; Raab et al., 2011). However, relatively little work has been done to investigate its diet in the Black Sea (Bulgakova, 1996 and papers cited therein), with no recent records. The European anchovy is a commercially important small pelagic fish, distributed worldwide in temperate zones, which accounted for nearly 10.5 million tonnes of marine fish production in 2009 (Palomera et al., 2007; Eurofish, 2012; Ganias, 2014; Costalago, 2015). According to a Eurofish International Organization report (2012), the Black Sea and the Mediterranean area contribute 5% of the world's anchovy catch. Besides its economic importance, it has a significant role in the Black Sea food web, as a planktivorous fish (Bacha & Amara, 2009); it ensures the transfer of energy from lower to higher trophic levels (Ozdamar et al., 1991; Coll et al., 2007; Ganias, 2014).

Anchovy populations are subject to considerable fluctuations caused by environmental changes that result in decreasing or increasing trends in the anchovy population (Palomera et al., 2007; IUCN, 2015). Anchovy abundance has appeared to increase in the North Sea (Raab et al., 2011; Petitgas et al., 2012) whereas in the Black Sea (Turkey) its decrease in abundance has led to a gradual decrease in production since 2011. In 2014, 96440 tonnes were caught, a decrease of 46.3% compared with the previous year (TÜİK, 2015). Therefore, understanding anchovy feeding ecology in the Black Sea is urgently needed to allow better ecosystem management (Tudela & Palomera, 1997; Plounevez & Champalbert, 2000; Bacha & Amara, 2009). The knowledge of the feeding habits of a fish may play a key role in research on the following ecological issues: (i) prey selection, (ii) predator-prey size relationships, (iii) distribution of feeding types with latitude, (iv) ontogenetic diet shifts, and (v) species invasions (Stergiou & Karpouzi, 2002).

The aim of this study was to describe the diet of *E. encrasicolus* in the Black Sea and to compare it with other areas (e.g., Mediterranean Sea and Atlantic Ocean). The feeding habits of *E. encrasicolus* were determined during the autumn, winter and spring seasons. The results of this study can be used in multispecies and ecosystem-based models.

Materials and Methods

Fish sampling

Monthly samples of *E. encrasicolus* were collected along the Trabzon-Rize coast from the southeast Black Sea region of Turkey from September 2013 to April 2014 using a commercial purse-seine net (mesh size 10-16 mm; Fig. 1). Stomach contents were analysed by season. The seasons were defined as follows: autumn (September, October and November), winter (December, January and February) and spring (March and April). The stomach contents of *E. encrasicolus* were not investigated during the summer as the fishing season is closed in the Black Sea from April 15th to September 1st. Immediately after capture, the fish were fixed in 70% alcohol and transferred to the laboratory.

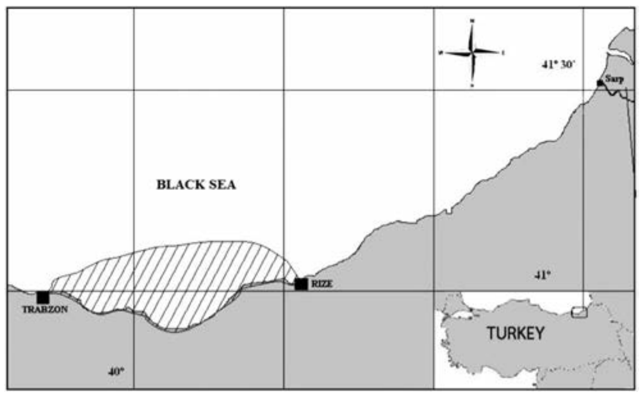

Figure 1. Map of the study area.

Laboratory analysis

A total of 526 *E. encrasicolus* specimens (169 males and 357 females) were analysed (Fig. 2). The total length of each individual fish was measured to the nearest 0.1 cm and weighed (wet weight) to the nearest 0.1 g. Finally, the fish were dissected and their stomachs were extracted. A longitudinal cut was made across the stomach and the contents were transferred into a Petri dish. The stomach contents were identified at the lowest possible taxonomic level. Prey items were counted and measured with a Nikon SMZ1000 stereomicroscope mounted with a Nikon DS–FI1 camera (Hynes, 1950; Hyslop, 1980).

Diet analysis

E. encrasicolus were divided into four length classes (6.1-8 cm, 8.1-10 cm, 10.1-12 cm, 12.1-14 cm). The diet of *E. encrasicolus* was investigated seasonally (autumn, winter, spring) and according to the four determined length classes.

The qualitative dietary analysis was carried out using the

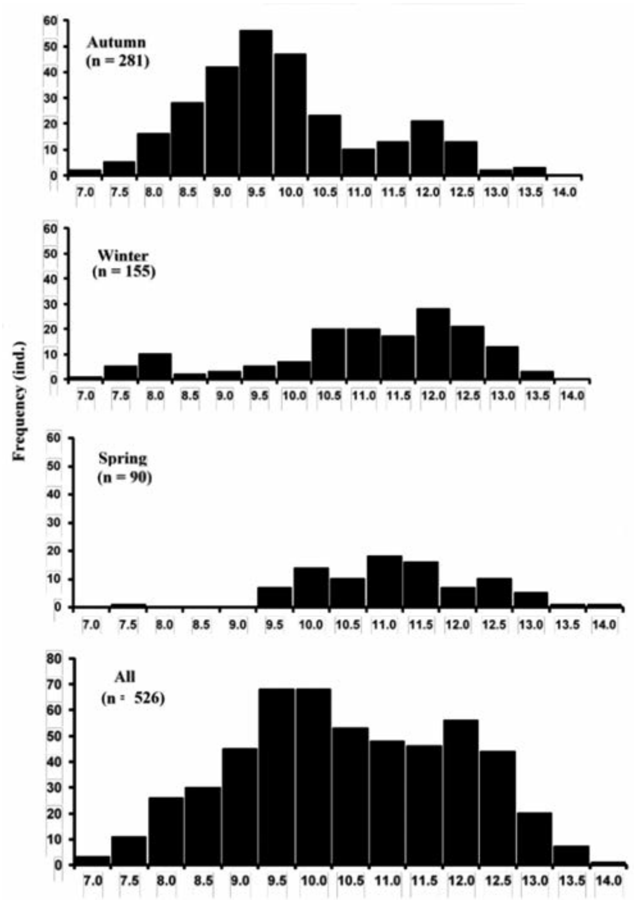

Figure 2 *Engraulis encrasicolus*. Total length frequency distribution of European anchovy captured in the southeast Black Sea region of Turkey from September 2013 to April 2014.

percentage prey group occurrence frequency (*F%*) and percentage prey group numerical frequency (*N%*) (Hyslop, 1980; Cortés, 1997). The *N%* and *F%* were calculated as:

$$F = \frac{n}{N_s} \times 100 \quad (1)$$

$$F = \frac{n^i}{N_p} \times 100 \quad (2)$$

where n is the number of fish of a particular food type, N_s is the total number of fish containing food in their stomach, is the total number of prey in a food group, and N_p is the total number of all prey groups.

The stomach fullness was determined visually according to Kitsos et al. (2008) using a scale ranging from 0 to 100% with empty as (0%), moderately full (25%), half full (50%), quite full (75%) and very full (100%).

The differences in the composition of stomach contents among seasons and fish sizes (cm) were estimated using a one-way analysis of similarity (ANOSIM) (Clarke & Warwick, 1994) and construction of a dendrogram. The most abundant prey species that were primarily responsible for an observed difference between seasons were determined using similarity percentages (SIMPER) (Clarke & Warwick, 1994). A one-way ANOVA was used to determine the differences between length classes. The multivariate analyses were carried out using PAST 2.14 software (Hammer et al., 2001) and Minitab 17 (Computer software, State College, PA: Minitab, Inc. www.minitab.com).

Results

The stomach fullness increased from autumn to spring. No empty stomachs were recorded in the spring season. Overall, 3.80% of stomachs were empty (6.41% in autumn and 1.29% in winter); of the remaining 96.19% of stomachs, 73.95% were moderately full, 19.77% half full and 2.47% quite full (Fig. 3). The empty stomachs were removed before the qualitative dietary analysis was performed.

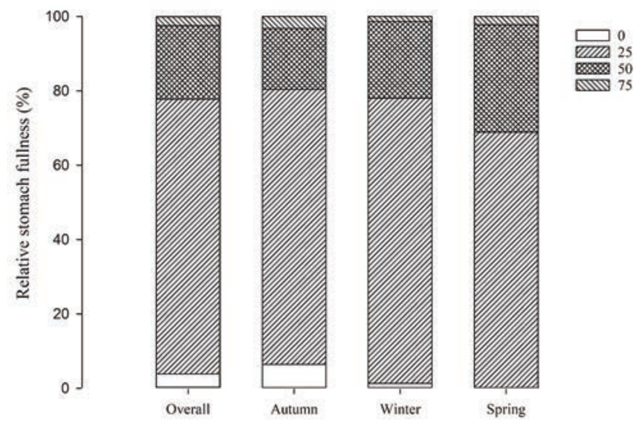

Figure 3. *Engraulis encrasicolus*. Seasonal stomach fullness ratio (empty, 0%; moderately full, 25%; half full, 50%; and quite full, 75%) of European anchovy (*Engraulis encrasicolus*) sampled from September 2013 to April 2014 from the Black Sea.

Overall diet composition

The *E. encrasicolus* diet mainly consisted of zooplankton, phytoplankton, and microplastic. A total of 38 prey items (27 zooplankton, 9 phytoplankton, 1 others, 1 microplastic) was identified (Table 1). For zooplankton, *N%* = 88.34, and *F%* = 78.04 of the diet. The dominant zooplankton prey groups were fish eggs and larvae (*N%* = 30.89, *F%* = 22.42), and Ctenophorans (*N%* = 14.68, *F%* = 12.63) followed by copepods (*N%* = 12.95, *F%* = 9.34). The predominant zooplankton species (individual prey items) were fish eggs (25.8 *N%*) followed by *Calanus* sp.

Table 1. *Engraulis encrasicolus*. Contribution (%) of prey groups and species in European anchovy diet. *F%*: percentage of prey groups occurrence frequency. *N%*: percentage of prey groups numerical frequency.

Prey groups	*N%*	*F%*	Prey groups	*N%*	*F%*
PHYTOPLANKTON					
Cyanophyceae			**Nemertea**		
Oscillatoria sp.	0.57	0.39	*Nemertea* sp.	2.52	5.15
Chlorophyceae			**Ctenophora**		
Spirulina sp.	0.10	0.26	*Mnemiopsis leidyi*	1.85	4.32
Dinophyceae			*M. leidyi* ephyra	8.59	1.61
Ceratium furca	0.04	0.13	*M. leidyi* planula	0.04	0.13
Noctiluca scintilans	0.02	0.06	*P. pileus*	3.34	4.51
Protoperidinium sp.	0.49	0.84	*B.ovata*	0.84	2.00
Bacillariophyceae			*B.ovata* planula	0.02	0.06
Chaetoceros sp.	0.04	0.13	**Cnidaria**		
Licmophora sp.	0.08	0.26	*A. aurita* planula	0.06	0.19
Navicula sp.	0.04	0.13	**Bivalvia**		
Rhizosolenia sp.	0.21	0.71	*Mytilus* sp. veliger	3.08	6.19
ZOOPLANKTON			**Gastropoda**		
Copepoda			Gastropod trochophore	0.41	1.10
Copepoda egg	0.92	1.48	**Polychaeta**		
Calanus sp.	12.03	7.86	Polychaeta adult	0.29	0.90
Cirripedia			Polychaeta larvae	2.09	5.15
Cirripedia naupli	0.10	0.32	**Decapoda**		
Cladocera			Crab larvae	0.16	0.45
Evadne sp.	0.31	0.90	Unidentified decapod larvae	0.20	0.45
Podon sp.	0.55	1.10	Shrimp larvae	2.91	6.12
Chaetognatha			**Fish egg-larvae**		
Sagitta setosa	0.92	2.71	Fish egg	25.81	8.96
Appendicularia			*E.encrasicolus* larvae	0.39	1.29
Oikopleura sp.	3.92	8.25	Unidentified fish larvae	4.69	12.18
Rotifera			**OTHERS**		
Brachionus sp.	0.16	0.52	Fish scale	17.10	8.51
Nematoda			**MICROPLASTIC**		
Nematoda sp.	1.85	4.45	Fiber	3.28	0.26

(12.03 *N%*), and *Mnemiopsis leidyi* A. Agassiz, 1865 ephyra (8.59 *N%*).

The contribution of phytoplankton to the total bulk of the diet was 2.9 *F%* (1.6 *N%*). Neither *F%* nor *N%* values differed greatly for any given phytoplankton species. The dominant phytoplankton species were *Oscillatoria* sp. (0.57 *N%*, 0.39 *F%*) followed by *Protoperidinium* sp. (0.49 *N%*, 0.84 *F%*) and *Rhizosolenia* sp. (0.21 *N%*, 0.71 *F%*) (Table 1).

Diet composition in different seasons

The body sizes of *E. encrasicolus* captured for stomach content analysis during the different seasons are shown in figure 2. The mean size (± SE) of *E. encrasicolus* in the autumn, winter and spring seasons was 9.69 ± 0.079 cm (n = 281), 10.90 ± 0.124 cm (n = 155) and 10.97 ± 0.117 cm (n = 90), respectively.

More prey items were found during autumn (31 prey items) and winter (30 prey items) compared with the spring season (23 prey items) (Table 2). In the spring, Ctenophorans (e.g., *M. leidyi* ephyra: 36.45 *N%*, 6.36 *F%*) were the main prey group, whereas during autumn and winter, fish eggs and larvae made the largest contribution (autumn: 34.07 *N%*, 24.57 *F%*; winter: 38.30 *N%*, 20.66 *F%*) (Table 2).

The variation in the diet composition of *E. encrasicolus* during different seasons was statistically significant. The dendrogram showed a high percentage of similarity (> 85%) between autumn and winter that was also confirmed by ANOSIM (R = 0.092), indicative of a similar diet (Table 3 & Fig. 4a). According to SIMPER analysis, the items that contributed the most to the total bulk of the diet in the different seasons were fish eggs and fish scales (Table 3).

Table 2. *Engraulis encrasicolus*. Seasonal distribution of prey group occurrence frequency (*F%*) and numerical frequency (*N%*) for the prey groups observed in European anchovy stomachs.

	Seasons					
	Autumn		Winter		Spring	
Prey groups	***N%***	***F%***	***N%***	***F%***	***N%***	***F%***
PHYTOPLANKTON						
Cyanophyceae						
Oscillatoria sp.	0	0	0	0	2.40	1.53
Chlorophyceae						
Spirulina sp.	0	0	0.14	0.32	0.17	0.51
Dinophyceae						
Ceratium furca	0	0	0.09	0.32	0	0
Noctiluca scintilans	0.06	0.19	0	0	0	0
Protoperidinium sp.	0.17	0.57	1.04	1.58	0	0
Bacillariophyceae						
Chaetoceros sp.	0.11	0.38	0	0	0	0
Licmophora sp.	0.06	0.19	0.09	0.32	0.08	0.25
Navicula sp.	0	0	0.09	0.32	0	0
Rhizosolenia sp.	0.33	1.14	0.19	0.63	0.08	0.25
ZOOPLANKTON						
Copepoda						
Copepoda egg	0.39	0.38	1.80	3.00	0.17	0.51
Calanus sp.	3.10	8.76	20.41	7.73	10.77	6.87
Cirripedia						
Cirripedia naupli	0	0	0.24	0.79	0	0
Cladocera						
Evadne sp.	0.17	0.57	0.62	1.74	0	0
Podon sp.	0.11	0.38	1.00	2.05	0.41	0.51
Chaetognatha						
Sagitta setosa	0.17	0.57	1.47	4.10	1.08	3.31
Appendicularian						
Oikopleura sp.	1.16	3.24	4.18	8.99	7.62	13.74
Rotifera						
Brachionus sp.	0.28	0.95	0.09	0.32	0.08	0.25
Nematoda						
Nematoda sp.	1.33	3.43	2.80	6.15	0.99	3.05

	Seasons					
	Autumn		Winter		Spring	
Prey groups	***N%***	***F%***	***N%***	***F%***	***N%***	***F%***
Nemertea						
Nemertea sp.	0.72	1.71	3.61	7.26	3.31	6.36
Ctenophora						
Mnemiopsis leidyi	2.88	7.05	2.04	4.73	0	0
M. leidyi ephyra	0	0	0	0	36.45	6.36
M. leidyi planula	0.11	0.38	0	0	0	0
P. pileus	7.13	9.71	1.99	3.00	0	0
B.ovata	1.55	3.62	0.71	1.89	0	0
B.ovata planula	0.06	0.19	0	0	0	0
Cnidaria						
A. aurita planula	0.11	0.38	0.05	0.16	0	0
Bivalvia						
Mytilus sp. veliger	1.38	4.00	3.75	7.57	4.47	6.87
Gastropoda						
Gastropod trochophore	0.22	0.76	0.28	0.63	0.91	2.29
Polychaeta						
Polychaete adult	0.06	0.19	0.47	1.42	0.33	1.02
Polychaete larvae	1.16	3.05	1.61	4.73	4.31	8.65
Decapoda						
Crab larvae	0	0	0.09	0.32	0.50	1.27
Unidentified decapod larvae	0.55	1.33	0	0	0	0
Shrimp larvae	1.38	4.57	3.23	5.05	4.64	9.92
Fish egg-larvae						
Fish egg	30.59	12.57	34.46	9.94	3.56	2.54
E.encrasicolus larvae	0.17	0.57	0.24	0.79	0.99	3.05
Unidentified fish larvae	3.32	11.43	3.61	9.94	8.62	16.79
OTHERS						
Fish scale	31.91	16.95	9.59	4.26	8.04	4.07
MICROPLASTIC						
Fiber	9.29	0.76	0	0	0	0

Diet composition in relation to fish size

The widest variety of prey items was consumed by 8.1-10 cm fish (n = 35), followed by *E. encrasicolus* of 10.1-12 cm (n = 33) (Table 4). In the present study, however, the diet of the largest *E. encrasicolus* size class (12.1-14 cm) comprised 29 different types of prey items. The smallest *E. encrasicolus* class (6.1-8 cm) consumed a total of 21 types of different prey species.

The variation in diet composition according to the length class (fish size) was also determined with dendrogram and ANOSIM tests, which showed that the diet of the 8.1-10.0 cm class was slightly different from the others (similarity 87.2%; R = 0.082; Table 5 & Fig. 4b). Using SIMPER analysis, it was found that fish eggs and fish scales were the food items that contributed the most to discriminating the size classes.

Discussion

Overall diet composition

The diet of *E. encrasicolus* in the Black Sea differs from *E. encrasicolus* in the Mediterranean Sea and Atlantic Ocean.

Table 3. *Engraulis encrasicolus*. One-way ANOSIM results of the stomach content among seasons (R values and significance level p). Global $R = 0.2291$, $p < 0.001$. SIMPER results showed the average dissimilarities (%) and the food items contributing most to the dissimilarity and their contribution ratios to the average dissimilarities between seasons.

Groups	One-way ANOSIM			SIMPER					
	R value	*p* value	Average Dissimilarity %	Discriminating food item 1	Contribution (%)	Discriminating food item 2	Contribution (%)	Discriminating food item 3	Contribution (%)
Autumn-Winter	0.09259	0.0001	76.19	Fish egg	32.94	Fish scale	23.47	*Calanus* sp.	18.7
Autumn-Spring	0.3201	0.0001	91.21	Unident. fish larvae	27.15	Fish scale	20.94	*M.leidyi* ephyra	16.52
Winter-Spring	0.2747	0.0001	91.3	*Calanus* sp.	23.51	Unident.fish larvae	21.23	Fish egg	18.95

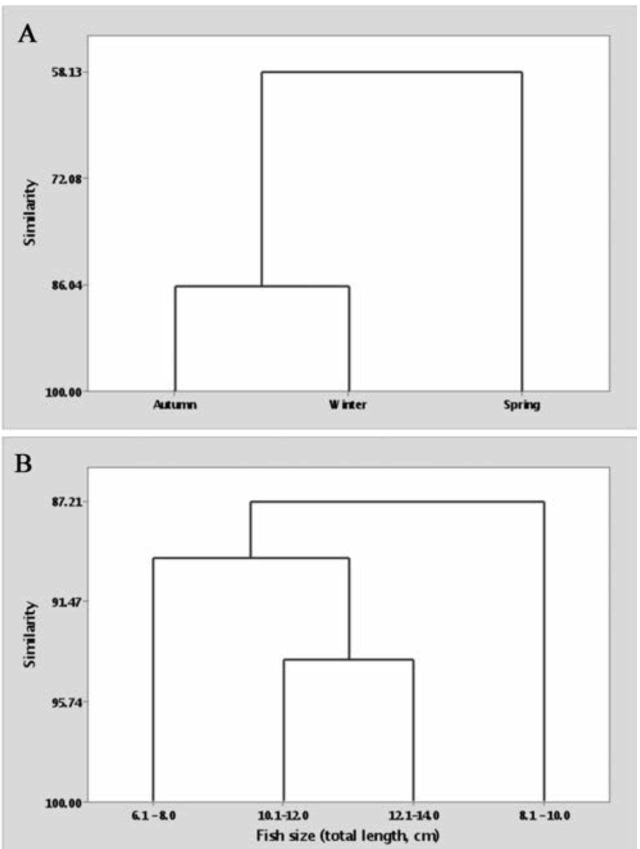

Figure 4. *Engraulis encrasicolus*. Dendrogram (based on percentage of prey groups numerical frequency $N\%$ values) of diet similarities of European anchovy among different seasons (a) and length classes (b).

In the Black Sea, the species primarily consumes fish eggs and larvae ($N\% = 30.89$, $F\% = 22.42$), and Ctenophorans ($N\% = 14.68$, $F\% = 12.63$). This study reveals the presence of Ctenophorans in the diet of *E. encrasicolus* for the first time. Furthermore, other studies have reported only a rare contribution of fish larvae to the diet of *E. encrasicolus* in other waters (the Gulf of Lions, Plounevez & Champalbert, 2000; the North and Baltic Seas, Raab et al. 2011; the Adriatic Sea, Zorica et al., 2016).

In the Black Sea, copepods also contribute substantially to the diet of the *E. encrasicolus*, being the third most frequent prey item ($N\% = 12.95$, $F\% = 9.34$). However, several studies, including a study from the Black Sea (Bulgakova, 1993), show copepods as the first most frequent prey items found in the *E. encrasicolus*, diet (the Adriatic Sea, Borme et al., 2009 and Zorica et al., 2016; the Bay of Biscay, Costalago et al., 2012 and Bachiller & Irigoien, 2015; the North and Baltic Seas, Raab et al., 2011; the Izmir Bay, Ünlüoğlu, 1995 and Uçkun et al., 2003). The abundance of copepod species in the diet in the Black Sea was not as low as in Kiel Bay (western Baltic Sea), where the main prey items were diatoms *Coscinodiscus* sp. and crustaceans (Schaber et al., 2010). The presence of phytoplankton in the gut of *E. encrasicolus* corroborates the sporadic feeding that has been described by other authors (Mikhman & Tomanovich, 1977; James & Findlay, 1989; Bulgakova, 1993).

Diet composition in relation to seasons and length classes

Seasonal variations were observed in the diet of *E. encrasicolus*. Uçkun et al. (2003) and Bacha & Amara (2009) found copepods as the dominant prey items in the diets of *E. encrasicolus* throughout the year. However, in contrast to these studies, the prey species that constituted the majority of the diet changed significantly with season in the present study. From autumn to spring, the number of *Oikopleura* sp. abruptly increased, with a decrease in fish eggs and fish scales in term of $F\%$ and $N\%$ (Table 2). Similar to adult fish in the present study, the late *E. encrasicolus* larva diet also included a higher quantity of appendicularians (57.9%) in the summer (Chícharo et al., 2012). The contribution of appendicularians to the diet of *E. encrasicolus* at different developmental stages (e.g., late-larvae, juveniles and adults) has been studied by Costalago et al. (2012) in the Gulf of Lions. Their data showed the opposite pattern, with a decreasing contribution of

Table 4. *Engraulis encrasicolus*. Diets composition in relation to length classes (fish size). Prey group occurrence frequency (*F%*) and prey group numerical frequency (*N%*).

Prey groups	Length classes							
	6.1-8 cm (n: 40)		8.1-10 cm (n: 211)		10.1-12 cm (n: 203)		12.1-14 cm (n: 72)	
	N%	*F%*	*N%*	*F%*	*N%*	*F%*	*N%*	*F%*
PHYTOPLANKTON								
Cyanophyceae								
Oscillatoria sp.	0	0	0.42	0.49	0.55	0.42	1.19	0.31
Chlorophyceae								
Spirulina sp.	0	0	0.07	0.25	0.13	0.28	0.12	0.31
Dinophyceae								
Ceratium furca	0.20	0.95	0.07	0.25	0	0	0	0
Noctiluca scintilans	0	0	0.07	0.25	0	0	0	0
Protoperidinium sp.	2.03	3.81	0.49	0.74	0.25	0.69	0.24	0.31
Bacillariophyceae								
Chaetoceros sp.	0	0	0.14	0.49	0	0	0	0
Licmophora sp.	0	0	0.07	0.25	0.13	0.42	0	0
Navicula sp.	0	0	0	0	0.04	0.14	0.12	0.31
Rhizosolenia sp.	0	0	0.28	0.99	0.17	0.55	0.36	0.93
ZOOPLANKTON								
Copepoda								
Copepoda egg	0.20	0.95	0.42	0.25	1.19	1.66	1.43	2.80
Calanus sp.	8.74	9.52	5.59	9.38	16.36	7.35	12.75	6.54
Cirripedia								
Cirripedia naupli	0	0	0	0	0.08	0.28	0.36	0.93
Cladocera								
Evadne sp.	0.41	1.90	0.42	0.99	0.25	0.83	0.24	0.62
Podon sp.	0	0	0.14	0.49	0.72	1.11	1.07	2.18
Chaetognatha								
Sagitta setosa	1.22	4.76	0.70	2.47	0.85	2.36	1.31	3.12
Appendicularia								
Oikopleura sp.	1.02	3.81	2.03	5.68	4.83	10.40	6.32	8.10
Rotifera								
Brachionus sp.	0	0	0.21	0.74	0.13	0.42	0.24	0.62
Nematoda								
Nematoda sp.	2.64	8.57	0.77	2.47	1.87	4.16	3.22	6.23
Nemertea								
Nemertea sp.	0.20	0.95	0.42	1.48	2.71	5.96	6.91	9.35
Ctenophora								
Mnemiopsis leidyi	4.47	12.38	1.75	4.69	1.57	3.88	1.31	2.18
M. leidyi ephyra	2.03	0.95	15.64	0.74	8.14	2.50	1.67	0.93
M. leidyi planula	0	0	0.07	0.25	0.04	0.14	0	0
P. pileus	7.52	11.43	3.63	6.42	2.33	2.91	3.22	3.43
B.ovata	0.81	2.86	0.56	1.48	0.93	2.22	1.07	1.87
B.ovata planula	0	0	0.07	0.25	0	0	0	0
Cnidaria								
A. aurita planula	0.20	0.95	0.14	0.49	0	0	0	0
Bivalvia								
Mytilus sp. veliger	0.81	1.90	2.65	4.44	3.22	6.66	4.77	8.72
Gastropoda								
Gastropod trochophore	0	0	0.49	1.23	0.38	1.11	0.60	1.25
Polychaeta								
Polychaete adult	0	0	0.14	0.49	0.42	1.25	0.36	0.93
Polychaete larvae	1.22	4.76	0.77	2.22	2.20	5.96	4.53	7.17
Decapoda								
Crab larvae	0.20	0.95	0	0	0.30	0.83	0	0

Table 4 (end).

Unidentified decapod larvae	0	0	0.14	0.49	0.25	0.55	0.24	0.31
Shrimp larvae	1.02	3.81	1.33	4.44	2.80	6.66	7.03	7.79
Fish egg-larvae								
Fish egg	51.83	14.29	20.60	11.85	26.83	7.77	16.57	6.23
E.encrasicolus larvae	0	0	0.56	1.98	0.47	1.53	0.12	0.31
Unidentified fish larvae	1.63	5.71	4.89	15.80	4.87	12.21	5.60	9.66
OTHERS								
Fish scale	11.59	4.76	26.96	14.32	12.29	6.66	17.04	6.54
MICROPLASTIC								
Fiber	0	0	7.33	0.74	2.67	0.14	0	0

Table 5. *Engraulis encrasicolus*. Comparison of diet composition among size classes by one-way ANOSIM (R and p values) and SIMPER. Global $R = 0.0732$, $p < 0.001$.

Length groups	One-way ANOSIM			SIMPER					
	R value	*p* value	Average Dissimilarity %	Discriminating food item 1	Contribution (%)	Discriminating food item 2	Contribution (%)	Discriminating food item 3	Contribution (%)
6.1-8/8.1-10 cm	0.06629	0.0312	70.14	Fish egg	32.26	Fish scale	25.46	*Calanus* sp.	12.41
8.1-10/10.1-12 cm	0.02388	0.0001	71.29	Fish egg	28.29	Fish scale	27.2	*Calanus* sp.	15.8
8.1-10/12.1-14 cm	0.0818	0.0009	72.71	Fish scale	29.94	Fish egg	26.43	*Calanus* sp.	16.34

appendicularians during the summer, whereas their contribution to the diet increased from winter to autumn in the present study. Such differences in the diet of *E. encrasicolus* between seasons might be caused by the presence of certain food groups in the environment during a specific season (Ünlüoğlu, 1995). In this study, during the spring season, ctenophores (*M. leidyi* ephyra: 36.45 *N%*, 6.36 *F%*) were the dominant prey item, followed by fish eggs and larvae (13.17 *N%*, 22.39 *F%*); whereas fish eggs and larvae (collectively) were the dominant items in autumn (34.07 *N%*, 24.57 *F%*) and winter (38.30 *N%*, 20.66 *F%*) (Table 2).

A wide variety of prey species were found in the diet during winter (n = 31) and autumn (n = 30). Similar to the results of the present study, Bacha & Amara (2009) also reported the presence of more prey types in the diet of *E. encrasicolus* during winter (n = 36) and autumn (n = 30).

Analysis of the diet composition of *E. encrasicolus* in relation to body size showed that a wider variety of species were found in 8.1-10 cm size fish and surprisingly fewer prey types were found in the stomachs of larger fish (12.1-14 cm). Excluding the smallest fish (6.1-8 cm), the variety of different species decreased with increasing fish size (Table 4). The smallest size *E. encrasicolus* had the smallest variety of prey species. In contrast, no such influence of predator size on the diet composition of *E. encrasicolus* in the Adriatic Sea was observed (Zorica et al., 2016).

Conclusions

Most of the studies cited in this manuscript have reported copepods as the predominant prey item in the diet of *E. encrasicolus*. However, according to the present study, copepods were not the predominant prey item in the diet of *E. encrasicolus* in the Black Sea. According to Bulgakova (1996), anchovies consume any available food when zooplankton are unavailable. Hence, a possible reason for such changes in the diet composition might be the abrupt decrease in the population of anchovies in the Black Sea. To confirm this, further research is required to investigate the feeding habits of other predators in the Black Sea that consume zooplankton (mainly copepods). The results of this study could be used for ecosystem-based management of *E. encrasicolus* and to describe the diversity of prey and interspecific food competition in the Black Sea.

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