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Prey Selection of *Pseudorasbora parva* (Temminck and Schlegel, 1846) in a Freshwater Ecosystem (Lake Eğirdir/Turkey)

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Additional information is available at the end of the chapter

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Abstract

In the present study, food spectrum of the topmouth gudgeon, *Pseudorasbora parva* and its food preference to different prey species were investigated in Lake Eğirdir, Turkey. Fish specimens were collected in April, May, June, July and August (2010–2011). Diet analysis was carried out on 88 fish specimens. The benthic larvae of *Chironomus* sp., the corophiid amphipod *Chelicorophium curvoispinum* and the zooplankton *Nitocra hibernica* were found to dominate food items. In addition, the fish consumed zooplankton (especially cladocera and copepoda), phytoplankton, annelida, malacostraca and insecta species. Unidentified eggs were also found in the stomachs. Phytoplankton, particularly *Gomphonema* ($V = 0.255$, $X^2 = 13.058$, $p < 0.01$) sp. due to its abundance, was a significant component in the 8.0- to 8.9-cm length sized topmouth gudgeon with distinct preference to the cladocerans *Daphnia cucullata* ($V = 0.191$, $X^2 = 7.331$, $p < 0.01$) and *Bosmina longirostris* ($V = 0.228$, $X^2 = 10.404$, $p < 0.01$), annelids ($V = 0.201$, $X^2 = 8.105$, $p < 0.01$) and Trichoptera larvae ($V = 0.157$, $X^2 = 4.963$, $p < 0.01$) in 2010 food diet. In return, invasive species topmouth gudgeon is preferable to Cladoceran in the diet of other planktivorous fish (especially Anatolian endemics *Aphanius anatoliae* type) in Lake Eğirdir. High value of Shannon diversity index was determined in May ($H' = 1.80$) and August ($H' = 1.70$). Fullness index was highest in April, whereas feeding density was lowest in July. Schoener's indices of diet overlap were estimated between different size classes and months for topmouth gudgeon. The high value of these indices ($C = 0.87$) indicates that the species principally feeds on the similar in the size classes >8 cm (8.0–8.9 cm, 9.0–9.9 cm, 10.0–10.9 cm, 11.0–11.9 cm).

Keywords: topmouth gudgeon, feeding, plankton, benthic organisms, Lake Eğirdir, Turkey

1. Introduction

The topmouth gudgeon, *Pseudorasbora parva* (Temminck and Schlegel, 1846) (sub fam. Gobioninae) is a small cyprinid fish distributed in Japan, China, Korea, Hungary, Germany, Serbia, Austria, Greece, Poland, North Africa, Romania, Czech Republic, United Kingdom, Azerbaijan and Ukraine [1–10]. It usually occupies a range of lotic and lentic habitats, including rivers, reservoirs, canals, ponds, shallow lakes and oxbows [11–13]. This species is one of the most effective invasive species to have been introduced into inland waters in Turkey for the past 30 years [14–23]. Generally, the topmouth gudgeon is considered as an important predator on crustaceans, zooplankton, ostracods, molluscs, chironomid larvae, rotifers and benthic organisms. It also feeds on phytoplankton (diatoms and other algae), zooplankton (cladocerans, copepods), the larvae and eggs of native fish species, insects and detritus [7, 24–26]. Although there are some data available on its age, growth, reproduction and habitat [27–33], published information on the diet of topmouth gudgeon is still scarce.

Feeding habits and feeding ecology of topmouth gudgeon were studied by Wolfram-Wais et al. [4] in Neusiedler See (Austria) and Xie et al. [34] in the Biandangtang Lake of China. Hliwa et al. [35] studied the diet of the species in the Kis-Balaton Reservoir, whereas Nikolova et al. [36] investigated seasonal variation in the diet of topmouth gudgeon from shallow eutrophic lakes along River Vit in Bulgaria. Yalçın-Özdilek et al. [37] carried out research on the feeding ecology of the species from Gelingüllü Reservoir and Karakuş [22] studied dietary interactions between non-native species topmouth gudgeon and some native fish species in Sarıçay Stream in Turkey. Didenko and Kruzhylina [10] investigated trophic interaction between topmouth gudgeon and the co-occurring species during summer in the Dniprodzerzhynsk Reservoir in Ukraine.

Asian cyprinid, *Pseudorasbora parva*, causes increased mortality and totally inhibiting spawning of endangered native fish, the European cyprinid *Leucaspius delineatus*. This threat is caused by an infectious pathogen, a rosette-like intracellular eukaryotic parasite that is a deadly, non-specific agent. It is probably carried a vector of an emergent infectious disease and could decrease fish biodiversity in Europe [38].

The topmouth gudgeon is successfully inhabited invasive fish in Lake Eğirdir. However, its feeding properties have not been sufficiently studied yet. The aim of the present study was to determine the diet composition of *Pseudorasbora parva* and its prey selectivity in the Lake Eğirdir, Turkey.

2. Materials and methods

2.1. The study area

Lake Eğirdir is the second largest freshwater reservoir in Turkey with a total of 457 km² (48 km × 16 km) surface area [39, 40] and located in the lakes region, southwestern part of Turkey. The maximum depth of lake is 13 m. The water income of the lake is supported from

underground water source, surface springs, runoff water, rain and small streams. Evaporation and water flow into Lake Kovada through a channel are main outflows of the lake [41]. The lake is an important source of drinking water as well as tourism and agricultural irrigation. The previous fauna and flora studies carried out in the lake yielded a rich biodiversity. According to the QB/T [42], the Rotifera index showed that the lake has mesotrophic features in terms of zooplankton. Carlson's trophic state index also supports that the lake shows both mesotrophic and eutrophic characteristics. Annual mean concentration of chlorophyll-a ($3.0 \pm 0.2 \text{ mg/m}^3$) also supported the proposed trophic status of the lake [43]. Zooplanktonic organisms, which is significant part of the lakes, consisted of Rotifera (40 species), Cladocera (22 species) and Copepoda (3 species). Rotifers, *Poyarthra dolichoptera* and *Keratella cochlearis* known as indicator of mesotrophic conditions, were reported to occur predominantly in the lake [43].

A total of 129 algal taxa belonging to six groups Ochrophyta (65 species), Chlorophyta (30 species), Charophyta (13 species), Cyanophyta (12 species), Euglenophyta (6 species) and Myzozoa (3 species) were determined [44]. The average abundance of 24 zoobenthic species was recorded recently as 4.195 individuals/m². Dominant species were Oligochaeta with 53.4% relative density. The proportions of Insecta, Bryozoa and Malacostraca were reported as 17.6%, 11.7% and 10.6%, respectively [45].

In the first and most comprehensive study on lake, it was reported that the lake fish fauna consisted of 10 different (*Cyprinus carpio*, *Schizothorax prophyllax*, *Varicorhinus pestai*, *Acanthorutilus handlirschi*, *Vimba vimba*, *Thylognathus klatti*, *Aphanius chantrei*, *Cobitis taenia*, *Nemachilus angorae*, *Pararhodeus niger*) species [46]. In fact nine species occurs in the lake since *S. prophyllax* and *V. pestai* are synonyms of each other. Perch (*Sander lucioperca*) was the first fish introduced into the lake in 1955. A total of nine different non-native species were reported at different times over a period of about 70 years. Today, there are totally 14 fish species (2 native, 6 endemic, 7 non-native) belonging to 8 families in the lake. These species are listed as *Cyprinus carpio*, *Vimba vimba* (native), *Oxynoemacheilus mediterraneus*, *Seminemacheilus ispartensis*, *Cobitis turcica*, *Capoeta pestai*, *Pseudophoxinus egridiri*, *Aphanius anatoliae* (endemic), *Atherina boyeri*, *Carassius gibelio*, *Pseudorasbora parva*, *Knipowitschia caucasica*, *Gambusia holbrooki* and *Sander lucioperca* (non-native) [41, 47–49].

2.2. Specimen sampling and data analysis

Fish samples were collected between April and August in the years of 2010 and 2011. All fish caught by the gill nets and purse seine were evaluated in the diet study. Fishing nets with mesh size 10, 16, 45 and 0.9 mm were used. Sampling was performed at two different sites (**Figure 1**), one in the southern of the lake (St 1, 5–7 m of depth) and the other in the southeast (St 2, with 2–5 m depth). Fish specimens were measured to the nearest 0.1 mm fork length (FL) and weighed to the nearest 0.001 g. The contents of the stomach were removed and the empty stomach was reweighed to the nearest 0.001 g. A total of 88 topmouth gudgeon were analyzed. Each prey item was determined to the lowest possible taxonomic level and counted. Proportion of full and empty stomachs was also determined. Volume calculation was used in Malacostraca, Annelida and Insecta. In addition, average volume was estimated [50] for *Disparalona rostrata*, *Chydorus sphaericus* and *Nitocra hibernica*, *Mesocyclops leuckarti* ($1.0 \times 10^7 \mu^3$), *Graptoleberis testudinaria*, *Alona*

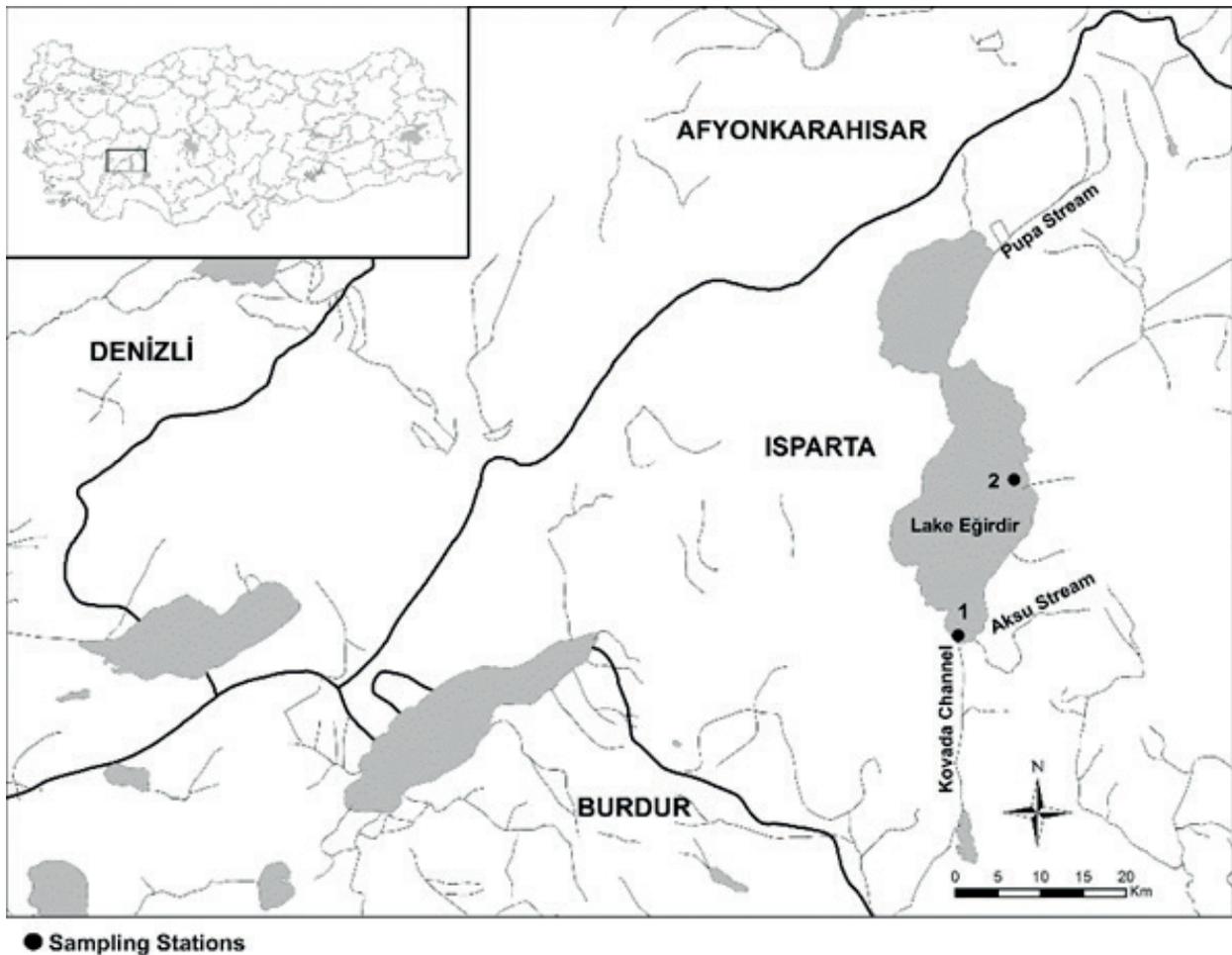


Figure 1. Location of the Lake Eğirdir and sampling sites.

quadrangularis, *Alona guttata*, *Coronatella rectangula*, *Pleuroxus aduncus* and Nauplii ($5.0 \times 10^7 \mu^3$), *Bosmina longirostris* ($4.0 \times 10^7 \mu^3$), *Daphnia cucullata* ($1.0 \times 10^8 \mu^3$), *Gomphonema* sp., ($6.0 \times 10^4 \mu^3$) and *Pediastrum* sp. ($8.0 \times 10^3 \mu^3$). All topmouth gudgeon caught were divided into six size classes according to fork length (FL) measuring 6.0–6.9 cm, 7.0–7.9 cm, 8.0–8.9 cm, 9.0–9.9 cm, 10.0–10.9 cm and 11.0–11.9 cm. Fish weight were classified into four groups: ≤ 5.0 g, 5.1–9.9 g, 10.0–14.9 g and ≥ 15.0 g.

Feeding intensity (stomach fullness) was estimated by $I_F = (W_{SC}/W_F) \times 10,000$ [51]. Where, I_F is the fullness index, W_{SC} is the weight of the stomach contents and W_F is the weight of the fish. Percentage and frequency of occurrence were used to estimate the dietary importance of each prey category [52, 53]. The percentage of the relative importance index [54] and three-dimensional graphical representations [55] were used to express prey importance. $IRI_i = (N_i\% + W_i\%) \times O_i\%$, where W_i and N_i are the total net weight and number of prey and O_i is the number of stomachs containing prey i . Shannon-Weaver (H') were used to evaluate the variety of foods in stomach. This index provides a general indication of changes in species diversity [56]. In the first step of statistical analysis, the normality of data was tested for each parameter using the Shapiro-Wilk test, and it was shown that dataset was

non-normally distributed. Therefore, those non-normally distributed data were compared using Wilcoxon signed-rank test, followed by Tukey-Kramer honestly significant difference test (HSD). Wilcoxon test displayed a Wilcoxon rank sums test if there were two groups and a Kruskal-Wallis nonparametric one-way analysis of variance if there were more than two groups. To estimate prey selectivity of topmouth gudgeon, Pearre’s selection index (V) [57] was calculated.

$$Va = \frac{(ad * be) - (ae * bd)}{\sqrt{(a * b * d * e)}}$$

Where Va is Pearre’s index for topmouth gudgeon selectivity of species a, a_d is relative abundance of species a in the diet, b_e is the relative abundance of all other species in the environment, a_e is the relative abundance of species a in the environment and b_d is the relative abundance of all other species in the diet. $a = a_d + a_e$, $b = b_d + b_e$, $d = a_d + b_d$, $e = a_e + b_e$. The selection index (Va) is statistically tested using the chi-squared test. ($X^2 = n * V^2$) where, $n = a_d + a_e + b_d + b_e$. Diet similarity among size classes and months was estimated using the Schoener Overlap Index (C) [58]. $C = 1 - 0.5 \sum |px_i - py_i|$; where px_i and py_i are the proportions by number of prey type i in the diets of groups (length or season) x and y, respectively. If the C value is bigger than 0.80, it means that the diet of the two groups is similar.

3. Results

3.1. The size and weight ranges of topmouth gudgeon

In this study, topmouth gudgeon ranged from 6.1 to 11.1 cm in fork length (FL) with an average value of 7.71 ± 0.18 cm and their total weight ranged from 3.52 g to 25.49 g, with an average value of 8.13 ± 0.78 g. The number of species, minimum and maximum fork length and minimum and maximum weights from different months in the lake are presented in **Table 1**.

| Sampling date | The number of fish | Fork length (FL, cm) | | Weight (W, g) | |
|---------------|--------------------|----------------------|---------------------|---------------|---------------------|
| | | Min–Max | Mean value \pm SD | Min–Max | Mean value \pm SD |
| April | 9 | 6.2–10.0 | 7.30 ± 0.48 | 3.85–20.17 | 7.65 ± 2.15 |
| May | 46 | 6.1–11 | 7.71 ± 0.18 | 3.52–25.20 | 8.13 ± 0.78 |
| June | 6 | 7.4–11.1 | 9 ± 0.58 | 7.06–25.49 | 11.65 ± 2.80 |
| July | 10 | 6.8–9.6 | 7.88 ± 0.29 | 4.74–13.05 | 7.18 ± 0.82 |
| August | 17 | 6.5–10 | 8.15 ± 0.25 | 3.7–16.2 | 8.48 ± 0.89 |

Table 1. Number of the fish caught during the study, their minimum, maximum and average fork length and minimum, maximum and average weight.

3.2. The diet composition of topmouth gudgeon

The diet of topmouth gudgeon in the lake was found to consist of phytoplankton, zooplankton, Insecta, Malacostraca, Annelida and unidentified eggs (**Table 2**).

Total weight of 1427 prey items was 8.49 g. Insects were the most frequently ingested prey with 66.52% by weight. *Chironomus* sp. (47.42%) was the dominant prey insects followed by *Chelicorophium curvoispinum* (26.26%) and *Chironomus* pupa (11.80%) in terms of weight. Relative Importance Index (IRI) showed that prey Insecta (64.71%) had more importance than the zooplankton prey categories (20.03%) and *C. curvoispinum* (14.78%). *Chironomus* sp. had the highest index value (IRI = 60.80%) followed by *N. hibernica* (IRI = 17.40%). In April and May, the main diet of topmouth gudgeon was composed of zooplankton, Insecta and Malacostraca. Insecta was particularly consumed in relatively high numbers. Insecta was also the main prey item of topmouth gudgeon in June. The main diet of topmouth gudgeon consisted of insect together with zooplankton. However, in August, members of Insecta, Annelida, zooplankton and phytoplankton were the main prey items of topmouth gudgeon (**Figure 2**).

3.3. Fullness, diversity and similarity indices

Maximum fullness index was in April, whereas minimum fullness index was observed in July (**Figure 3**). According to Shannon-Weaver index (H'), the maximum values ($H'=1.80$) were found in May and the minimum values ($H'=0.79$) were determined in April. A Wilcoxon matched-pairs signed rank test was conducted to determine whether there was a spatial difference in the ranking of two stations. The results revealed significant effects of spatial variation on occurrence of *Mesocyclops leuckarti* and nauplii in stomach content ($Z = 3.39$, $p < 0.001$ and $Z = 2.37$, $p < 0.05$, respectively). A post-hoc test using Tukey-Kramer HSD tests showed the significant differences between Station 1 and 2 ($p < 0.05$). The results showed spatial changes of *M. leuckarti* and nauplii in the lake that they were only recorded in stomach content of fishes at Station 1.

A Kruskal-Wallis test was operated to determine whether there was a temporal difference in occurrence of taxa in stomach content. The results of analysis revealed significant differences in occurrence of *C. curvoispinum*, *M. leuckarti* and *N. hibernica* ($\chi^2(4) = 18.54$, $p < 0.01$; $\chi^2(4) = 15.78$, $p < 0.01$ and $\chi^2(4) = 24.09$, $p < 0.001$, respectively). A post hoc rank sums test indicated that there were significant differences between April and all other months for *N. hibernica* and *C. curvoispinum*, whereas significant differences occurred between July and April, May, August for *M. leuckarti* (Tukey-Kramer HSD, $p < 0.05$). Indeed, the ratios of *N. hibernica* and *C. curvoispinum* in stomach content were significantly higher in April, and *M. leuckarti* only occurred in July. This analysis showed that there was a clear temporal variation in occurrence of species. A Kruskal-Wallis test also showed the significant monthly differences for *Alona guttata*, *Chironomus* sp., *Chironomus* (pupa), *Chydorus sphaericus* and *Graptoleberis testudinaria* whose ratios in stomach content were significantly higher in May than the other months. However, a post-hoc test did not correct the significant differences (Tukey-Kramer HSD, $p > 0.05$). A Kruskal-Wallis test revealed that there were significant effects on occurrence of *N. hibernica* in stomach content due to both fish weight and length ($\chi^2(3) = 24.57$, $p < 0.001$ and $\chi^2(5) = 26.88$, $p < 0.001$, respectively). A post hoc rank sums test also corrected that there was a significant difference between the group ≤ 5 g and all other weight groups for *N. hibernica* (Tukey-Kramer

HSD, $p < 0.05$). In addition, Tukey-Kramer HSD showed a significant difference between the length group of 6.0–6.9 cm and 7.0–7.9 cm together with 8.0–8.9 cm ($p < 0.05$). The longer groups (*P.parva*) in whose stomach contents *N. hibernica* was not recorded were not significantly differentiated than length group of 6.0–6.9 cm.

| | N | %N | O | %O | W | %W | IRI | %IRI |
|-----------------------------------|-------------|------------|------------|-------|-------------|------------|----------------|------------|
| Zooplankton taxa | | | | | | | | |
| <i>Alona guttata</i> | 54 | 3.78 | 15 | 16.85 | 0.0027 | 0.0318 | 64.31 | 0.985 |
| <i>Alona quadrangularis</i> | 14 | 0.98 | 8 | 8.99 | 0.0007 | 0.0082 | 8.89 | 0.136 |
| <i>Coronatella rectangula</i> | 6 | 0.42 | 4 | 4.49 | 0.0003 | 0.0035 | 1.91 | 0.029 |
| <i>Daphnia cucullata</i> | 13 | 0.91 | 1 | 1.12 | 0.0013 | 0.0153 | 1.04 | 0.016 |
| <i>Disparalona rostrata</i> | 2 | 0.14 | 1 | 1.12 | 0.0001 | 0.0012 | 0.16 | 0.002 |
| <i>Graptoleberis testudinaria</i> | 32 | 2.24 | 14 | 15.73 | 0.0016 | 0.0188 | 35.57 | 0.545 |
| <i>Pleuroxus aduncus</i> | 2 | 0.14 | 1 | 1.12 | 0.0001 | 0.0012 | 0.16 | 0.002 |
| <i>Bosmina longirostris</i> | 17 | 1.19 | 4 | 4.49 | 0.0006 | 0.0080 | 5.39 | 0.083 |
| <i>Chydorus sphaericus</i> | 43 | 3.01 | 16 | 17.98 | 0.0004 | 0.0050 | 54.26 | 0.831 |
| <i>Mesocyclops leuckarti</i> | 3 | 0.21 | 2 | 2.25 | 0.0000 | 0.0004 | 0.47 | 0.007 |
| <i>Nitocra hibernica</i> | 480 | 33.64 | 30 | 33.71 | 0.0048 | 0.0565 | 1135.74 | 17.397 |
| Nauplii | 1 | 0.07 | 1 | 1.12 | 0.0000 | 0.0000 | 0.08 | 0.001 |
| Insecta | | | | | | | | |
| <i>Trichoptera</i> larvae | 7 | 0.49 | 7 | 7.87 | 0.6200 | 7.3020 | 61.29 | 0.939 |
| <i>Chironomus</i> sp. | 616 | 43.17 | 39 | 43.82 | 4.0260 | 47.4161 | 3969.39 | 60.801 |
| <i>Chironomus</i> (pupa) | 37 | 2.59 | 12 | 13.48 | 1.0020 | 11.8010 | 194.07 | 2.973 |
| Malacostraca | | | | | | | | |
| <i>Chelicorophium curvispinum</i> | 63 | 4.41 | 28 | 31.46 | 2.2300 | 26.2638 | 965.17 | 14.784 |
| Annelida | | | | | | | | |
| Annelid | 15 | 1.05 | 3 | 3.37 | 0.6000 | 7.0664 | 27.36 | 0.419 |
| Phytoplankton | | | | | | | | |
| <i>Gomphonema</i> sp. | 19 | 1.33 | 2 | 2.25 | 0.0000 | 0.0000 | 2.99 | 0.046 |
| <i>Pediastrum</i> sp. | 2 | 0.14 | 1 | 1.12 | 0.0000 | 0.0000 | 0.16 | 0.002 |
| Unidentified | | | | | | | | |
| Unidentified egg | 1 | 0.07 | 1 | 1.12 | 0.0000 | 0.0005 | 0.08 | 0.001 |
| Total | 1427 | 100 | 190 | | 8.49 | 100 | 6528.51 | 100 |

N, prey number; W, prey weight; O, frequency of occurrence and IRI, Relative Importance Index.

Table 2. Diet composition of topmouth gudgeon in Lake Eğirdir between 2010 and 2011.

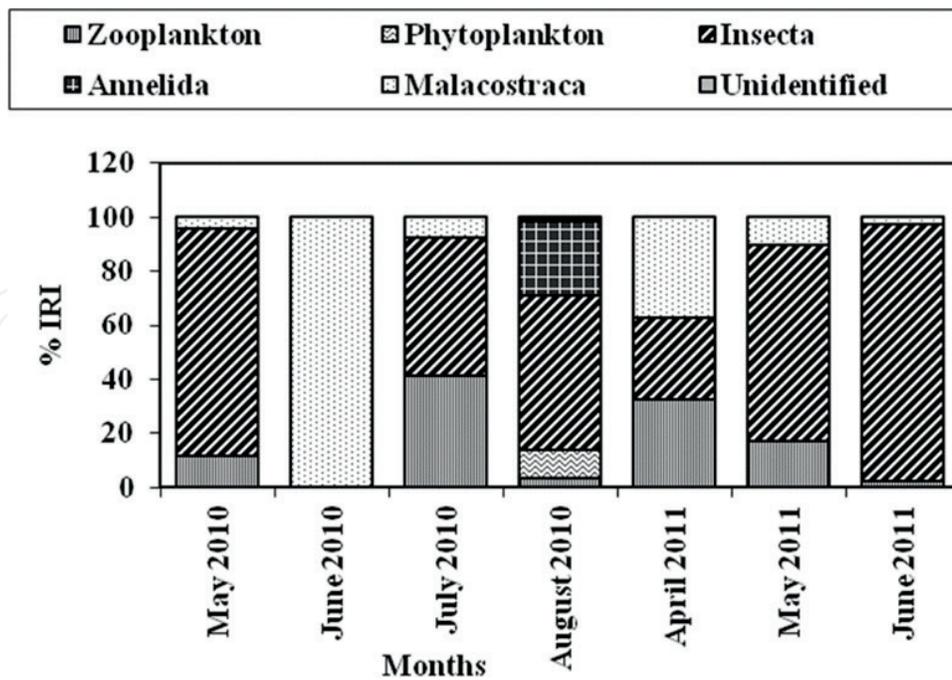


Figure 2. Monthly diet variations of topmouth gudgeon in Lake Eğirdir between 2010 and 2011 (IRI: Relative importance index).

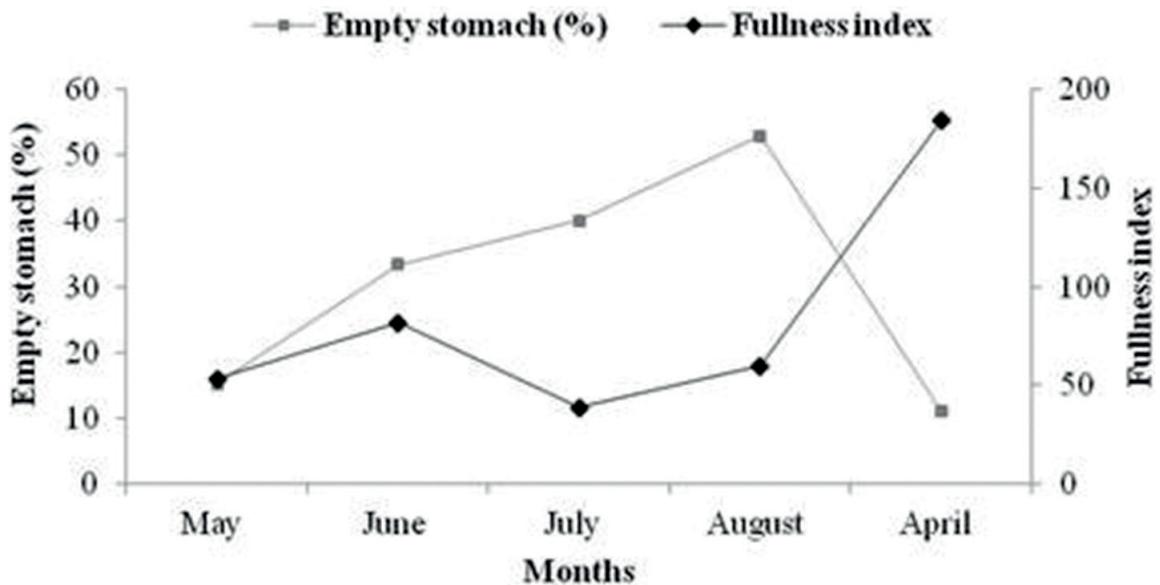


Figure 3. Variations in fullness index and empty stomach of topmouth gudgeon.

Although similar differences were determined for *N. hibernica* and *Chironomus* sp. with a Wilcoxon test, a post-hoc test did not correct the significant differences (Tukey-Kramer HSD, $p > 0.05$). Topmouth gudgeon was significantly different for months because of high Schoener Overlap Index ($C < 0.80$). Diet composition showed similarities between 7.0–7.9 cm and 10.0–10.9 cm ($C = 0.80$) and 8.0–8.9 cm and 10.0–10.9 cm ($C = 0.87$) size classes of topmouth gudgeon.

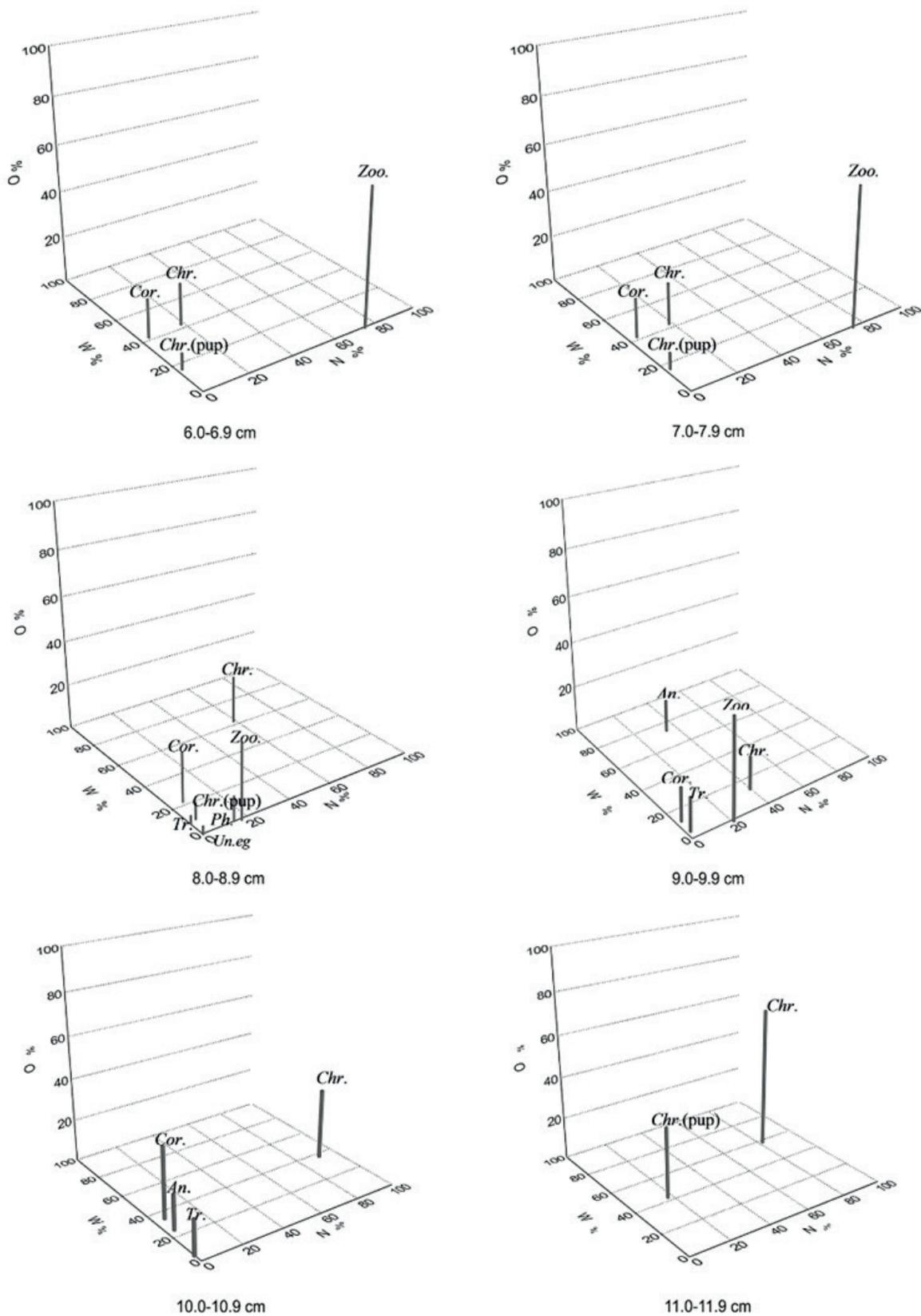


Figure 4. Stomach contents in different size classes of topmouth gudgeon in Lake Eğirdir between 2010 and 2011. Zoo, zooplankton; Chr, *Chironomus* sp.; Chr. (pup), *Chironomus* (pupa); Cor, *C. curvispinum*; Tr, Trichoptera larvae; An, Annelida; Ph, phytoplankton and Un.eg., unidentified egg.

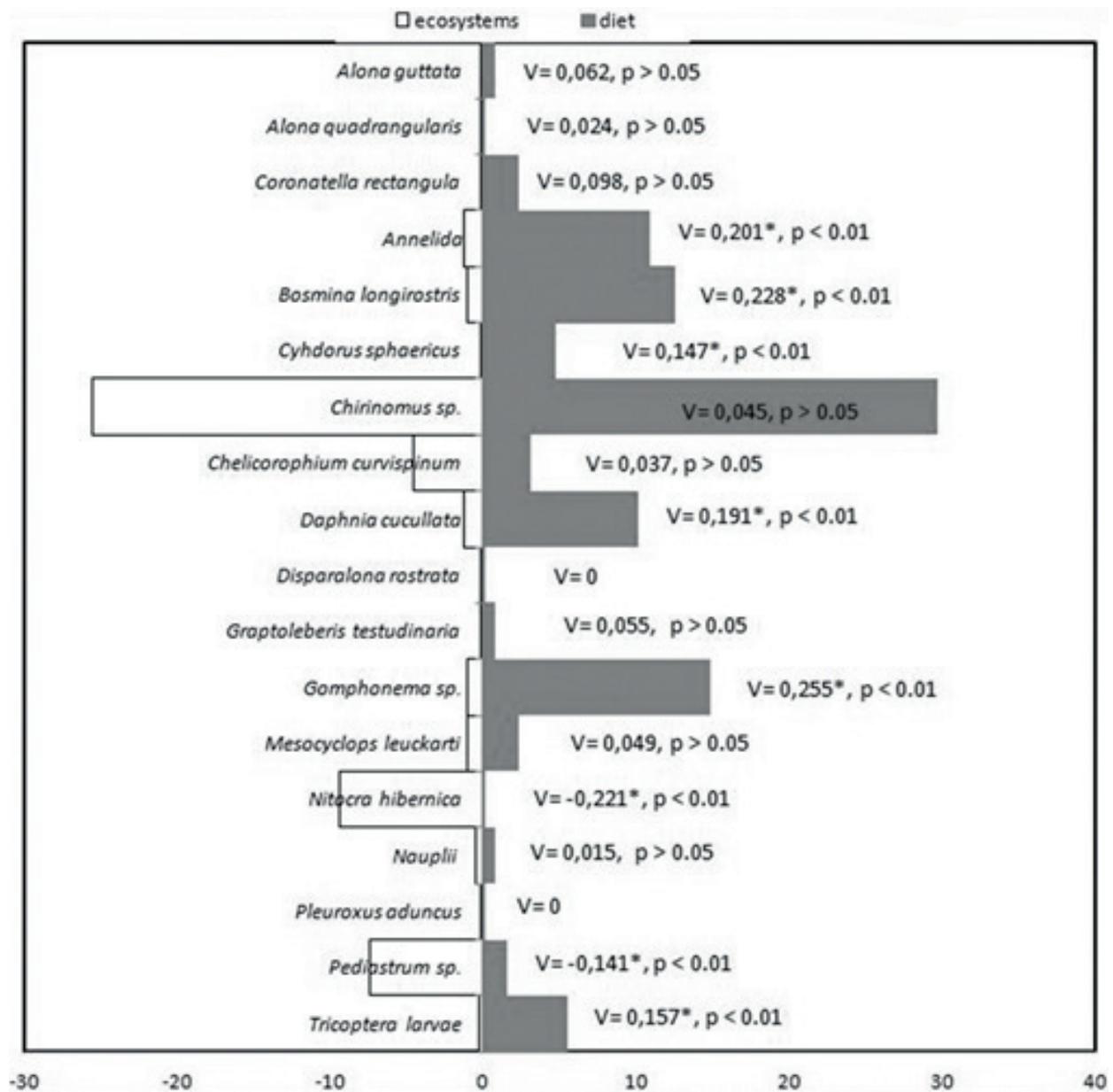


Figure 5. Percentages of the lake ecosystems and diet of topmouth gudgeon in Lake Eğirdir in 2010 (May, June, July, August).

3.4. Different size classes of diet composition

Different size classes of topmouth gudgeon were characterized by different diet compositions (Figure 4). Prey zooplankton species was consumed by 58.90% of the 6.0- to 6.9-cm sized topmouth gudgeon, with a large weight (0.39%) percentage. However, it consumed in the 6.0–6.9 cm size class in the diet in terms of numbers (75.12%). In the stomachs of topmouth gudgeon of the 8.0–8.9 cm size class, only phytoplankton species was determined. In >10 cm sized topmouth gudgeon prey, Insecta species was identified (Figure 4).

3.5. Prey selection

Feeding rates was compared in the diet and in the ecosystems in 2010. *Chironomus* sp. was the commonly abundant prey in the ecosystem; it was a positively selected food item and was not statistically significant. Also, *A. guttata* ($V = 0.062$, $X^2 = 0.781$, $p > 0.05$), *A. quadrangularis* ($V = -0.024$, $X^2 = 0.123$, $p > 0.05$), *C. curvispinum* ($V = -0.037$, $X^2 = 0.277$, $p > 0.05$), *C. rectangula* ($V = 0.098$, $X^2 = 1.931$, $p > 0.05$), *G. testudinaria* ($V = 0.055$, $X^2 = 0.616$, $p > 0.05$), *M. leuckarti* ($V = 0.049$, $X^2 = 0.499$, $p > 0.05$) and nauplii ($V = 0.015$, $X^2 = 0.047$, $p > 0.05$) were found in the ecosystems, but was not preferred by topmouth gudgeon. Similarly, *Pediastrum* sp. ($V = -0.141$, $X^2 = 4.016$, $p < 0.01$) and *N. hibernica* ($V = -0.221$, $X^2 = 9.818$, $p < 0.01$) were avoided by topmouth gudgeon despite their high abundance in the lake Eğirdir ecosystem (Figure 5). Some organisms in the diet of topmouth gudgeon are shown in Figure 6.

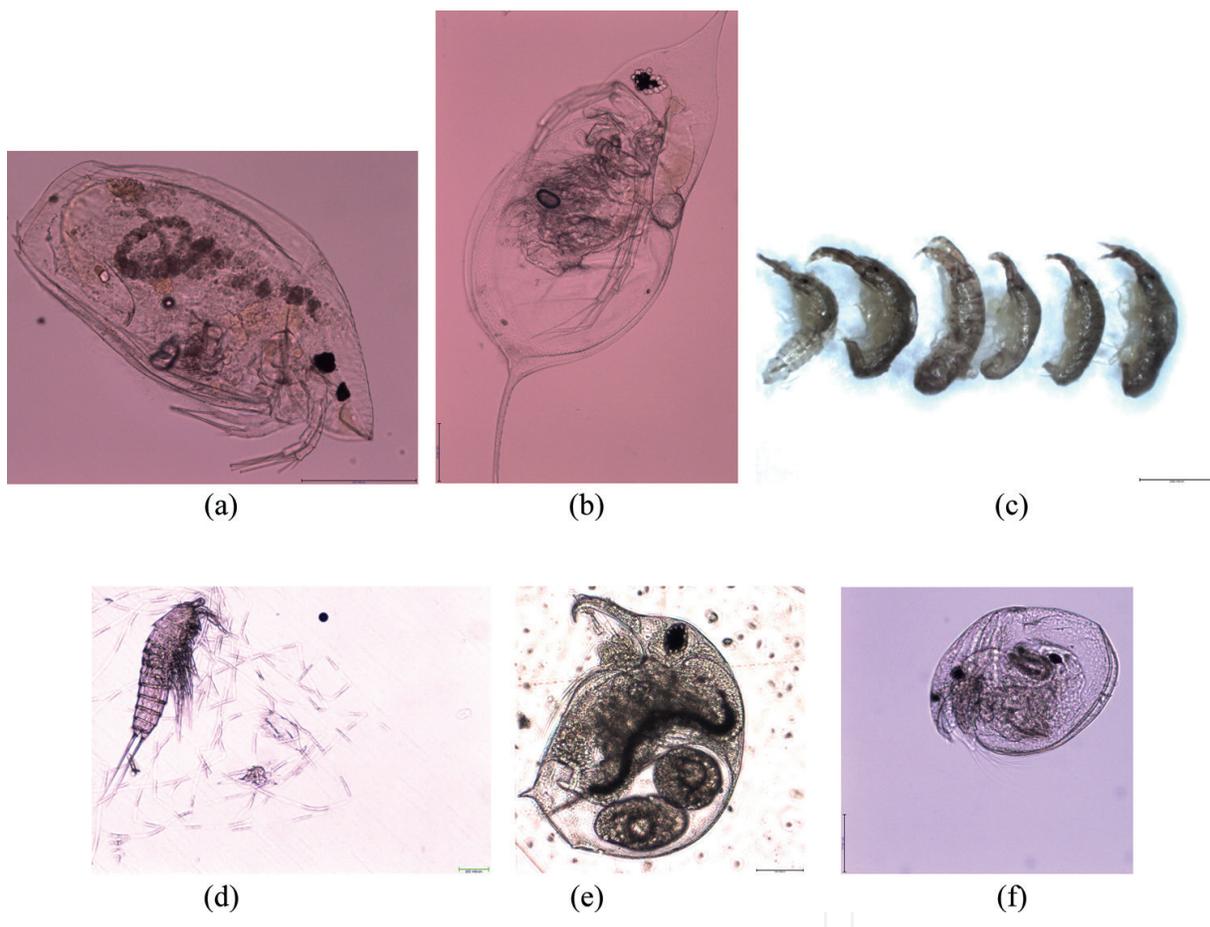


Figure 6. Some organisms in the diet of topmouth gudgeon (a) *G. testudinaria*, (b) *D. cucullata*, (c) *C. curvispinum*, (d) *N. hibernica*, (e) *B. longirostris* and (f) *C. sphaericus* (scale: 100 micron).

4. Discussions

The fish fauna of Lake Eğirdir was previously reported to consist of *Cyprinus carpio*, *Carassius gibelio*, *Tinca tinca*, *Vimba vimba*, *Capoeta pestai*, *Sander lucioperca*, *Alburnus chalcoides*,

Pseudophoxinus egridiri, *Pseudophoxinus handlirschi*, *Cobitis turcica*, *Barbatula mediterraneus*, *Seminemacheilus ispartensis*, *Aphanius anatoliae*, *Gambusia affinis*, *Knipowitschia caucasica*, *Hemigrammocapoeta kemali*, *Atherina boyeri* and *Pseudorasbora parva* [41]. Total of 15 fish species, including *P. parva*, were observed from January to December 2010 in the Lake Eğirdir [59]. Among the 15 recorded fish species, sand smelt *Atherina boyeri* (65.72%), killifish *Aphanius anatoliae* (19.39%) and Caucasian dwarf goby *Knipowitschia caucasica* (3.01%) are not commercially precious. Fishing activities were very limited in the lake and the average of annual catch was approximately 21.19 kg ha⁻¹ in 2010. Fish species, which dominate in the catches, were crucian carp *Carassius gibelio*, pikeperch *Sander lucioperca*, common carp *Cyprinus carpio* and vimba, *Vimba vimba* [60]. Zooplankton abundance in the lake ranged from 42 ± 24 to 3092 ± 2435 individuals L⁻¹ from January to December 2010. Rotifera was the most abundant group dominated mainly by *Polyarthra dolichoptera* and *Keratella cochlearis*. *Bosmina longirostris* was also relatively abundant in the lake. In contrast, *C. sphaericus* showed lower abundance. The zooplankton abundance comprised as follows: Rotifera, 89.62%; Cladocera, 7.78% and Copepoda, 2.60% [43, 59]. The average number of zoobenthic organisms was 4.195 individuals/m², and *Tubifex* spp. were the most abundant taxa with 52.33% abundance, followed by *Chironomus* spp. (17.10%) in the Lake Eğirdir [45].

P. parva had a diversified diet composition mainly with *Chironomus* sp., *N. hibernica*, *Chydorus sphaericus* and *Bosmina longirostris*. We determined that the diet of topmouth gudgeon in Lake Eğirdir was dominated by *Chironomus* sp. *Chironomus* spp. are also one of the most important food in Neusiedler See from Austria [4]. It was also stated that the topmouth gudgeon feeds on Chironomid larvae, Ceratopogonid larvae and Gastropods in Austria. Our results are in accordance with Wolfram-Wais et al. [4] who stated that topmouth gudgeon showed reliance mean to *Chironomus* spp., according to the IRI index. Hliwa et al. [35] observed that the diet of topmouth gudgeon in the Balaton Reservoir was characterized by *Bosmina* sp., *Chydorus* sp., Copepoda and *Daphnia* sp. According to Xie et al. [34], the diet of the topmouth gudgeon from the Biandantang Lake from China was registered by Copepoda, Cladocera, Ostracoda, Chironomid larvae and Mollusca. Generally, these findings have many common points with the present study. However, according to Yalçın-Özdilek et al. [37], the diet of the topmouth gudgeon from Turkey in Gelingüllü Reservoir was based mainly on Cyanobacteria, Insecta and Cladocera.

A minor role of Platyhelminthes in the topmouth gudgeon diet was also observed in Gelingüllü Reservoir by Yalçın-Özdilek et al. [37]. In addition, Karakuş [22] indicated that *P. parva* feeds dominantly on Insecta, detritus, Copepoda and other zooplankton groups, but rarely on Macrophyta, Nematode and Rotifers in Sarıçay Stream, Muğla, Turkey. Additionally, Karakuş [22] found that *P. parva* has a variety of diet spectrum and niche width, further it feeds on higher trophic levels.

Nikolova et al. [36] reported seasonal variations in the diet of *P. parva* from shallow eutrophic lakes along river Vit of Bulgaria. Diet of the topmouth gudgeon was dominated by Diptera/Chironomidae. The role of the Oligochaeta, Ephemeroptera, Copepoda/Calanoida Trichoptera and Nematoda as important additional food resource for topmouth gudgeon was recorded by Nikolova et al. [36]. In our study of temporal variation (monthly) of the diet revealed that the topmouth gudgeon diet in June and August was dominated by *Chironomus* sp., whereas in July there was an increase in the consumption of *Bosmina longirostris*. Gozlan

et al. [7] confirmed that the fish prefers Chironomid larvae in Belgium. The consumption of fish eggs and fish larvae by topmouth gudgeon was well documented [34, 37]. Gozlan et al. [7] reported that eggs of native fish species and larvae were preferred the diet of topmouth gudgeon in China and Germany. In the present study, unidentified egg (1.37%) was also found in stomach contents of the fish. Additionally, the present study showed monthly variations in dominated food items and frequency occurrence of some food items significantly differed from month to month. Diet of topmouth gudgeon showed a great variety of food taxa in May except *Chironomus* sp. and *C. curvispinum*. The fish also preferred *A. quadrangularis*, *C. sphaericus*, *P. aduncus*, Annelida and *Chironomus* sp. (pupa). Shannon's diversity was highest in May and lowest in April. The variety of food in May ($H'=1.80$) was higher than in the other months. In August, Insecta (*Chironomus* sp.), Annelida and Phytoplankton (*Gomphonema* sp.) were determined in the stomach content. The ratio of Insecta was 54.42%. It is important to note that *D. cucullata*, *Gomphonema* sp. and *Pediastrum* sp. were present in stomach only in August. The variety of food in June was less than that in the other months. In addition, zooplankton (*B. longirostris*), Trichoptera larvae and Malacostraca (*C. curvispinum*) were the crucial prey for the feeding of topmouth gudgeon in July. The ratio of Trichoptera larvae was 42.09%. Typically, the dominant food item (frequency of occurrence) was *Chironomus* sp., with 66.67% of total individuals in size classes of 11.0–11.9 cm, followed by *C. curvispinum* (33.33%) in the size classes of 10.0–10.9 cm, *Disparalona rostrata* (1.37%) in the size classes of 6.0–6.9 cm, Annelida (14.29%) in the size classes of 9.0–9.9 cm, Nauplii and *Pleuroxus aduncus* (1.37%) in the size classes 7.0–7.9 cm and *Daphnia cucullata* (3.57%), *Gomphonema* sp. (7.14%) and *Pediastrum* sp. (3.57%) were noticeable in the size classes of 8.0–8.9 cm. Yalçın-Özdilek et al. [37] indicated that topmouth gudgeon individuals with lengths greater than 3 cm mainly consumed Cyanobacteria. The importance of zooplankton, Insecta and Malacostraca in the diet of topmouth gudgeon is differed in different size of fish classes in this study. Larger fish have fewer zooplankton, more insecta and malacostraca in their diet and vice versa for smaller fish.

Wolfram-Wais et al. [4] suggested that the diet of topmouth gudgeon changed with Chironomid larvae, especially epiphytic species in Neusiedler See from Austria. This result is in harmony with our study since the topmouth gudgeon >6 cm fed mainly on *Chironomus* sp. The fish was found to feed on *Chironomus* sp. intensively between April and June in Lake Eğirdir. Fullness index of topmouth gudgeon was also reported to be the highest in summer and spring [37]. Xie et al. [34] showed that topmouth gudgeon fed intensively during summer and autumn. However, fullness index of the topmouth gudgeon was high between April and June in Lake Eğirdir. Dietary overlap of topmouth gudgeon was reported by Yalçın-Özdilek et al. [37] from Gelingüllü reservoir. However, there was no dietary overlap between the smallest size class and the other classes [37]. Xie et al. [34] indicated that diet overlap of topmouth gudgeon individuals was low in summer and autumn. Our study showed that specimens belong to the <8 cm size classes were determined to ingest a great variety of prey items in comparison to other size classes. The specimens with >8 cm consumed mainly Annelida, *Chironomus* (pupa), *C. curvispinum*, Trichoptera larvae, principally *Chironomus* sp. However, zooplankton also was of importance in the diet of <8 cm size classes. Statistical analyses indicated that weight and length have the significant effects on nutrition habits of *Pseudorasbora parva* in Lake Eğirdir. Small-sized individuals preferred to feed on *N. hibernica*, whereas annelida was preferable

food for large fish. *M. leuckarti* was found to be markedly dominant in stomach content of *P. parva* in May. Indeed, *M. leuckarti* showed spread across the temperate zone of the lake in April–June [61]. In addition, Demirhindi [62] and Aksoylar and Ertan [63] reported variation in distribution of *M. leuckarti* in the lake [43]. The rate recorded in the stomach contents showed that *M. leuckarti* changed by sampling sites. *Pseudorasbora parva* fed on harpacticoid copepods *N. hibernica* mainly in May.

The results also indicate that topmouth gudgeon feeds on zoobenthic organisms in the lake. Prey selection showed that *D. cucullata*, *B. longirostris*, Annelida, Tricoptera larvae and *Gomphonema* sp. positively selected by topmouth gudgeon in Lake Eğirdir; therefore, their selection indices were statistically significant ($p < 0.01$). Pearre's selectivity indices showed that *A. guttata*, *C. rectangularis*, *Chironomus* sp., *C. curvispinum*, *G. testudinaria*, *M. leuckarti* and Nauplii were neutrally selected. According to Didenko and Kruzhylina [10], Ivlev's selectivity indices demonstrate that topmouth gudgeon positively selected zooplankters such as *Chydorus sphaericus*, *Alona affinis*, *Pleuroxus* sp. and *Cyclops* sp., but avoided *Bosmina* sp. *Asplanchna priodonta* was also positively selected among rotifers. Anatolian endemics *Aphanius anatoliae* was consumed with a rate of 63.91% in the Lake [64]. In this study, the diatom (from Bacillariophyta) *Gomphonema* sp. according to the selectivity index, diets low statistically significant ($V = 0.225$, $p < 0.01$). Ekmekçi and Kirankaya [17] concluded that *P. parva* develops dense populations in some water bodies and it is blamed for food competition with other species. Moreover, the impact of *P. parva* on natural food structure was shown in terms of zooplankton and zoobenthos and main fish production parameters [65]. Musil et al. [65] found that differences in mean zooplankton members and especially in *Daphnia* density between the seasons of 2003 and 2004 were highly significant in fish ponds (three different ponds). Tarkan [66] informed that the disease vectors, such as *P. parva*, damaging fishing capacity are too large. The topmouth gudgeon has a high reproductive potential and it was uncontrollably introduced into the water resources. In addition, topmouth gudgeon is evaluated in the status of pest species [26].

5. Conclusions

The observations in this study confirm that *P. parva* has diverse diet preferences. Therefore, the topmouth gudgeon should be considered a serious threat to the diversity of food chain in Lake Eğirdir since the fish consumes all kinds of organisms in the chain. In addition, it has a potential to carry a variety of diseases. It also be noted that the fish have abilities to produce eggs in large diameters and grow rapidly in a dense population size in a short time. Sexual dimorphism and nest protection behavior are the other advantages of the fish to become a dominant fish population in the lake. Our study is expected to contribute to better knowledge of diet composition of topmouth gudgeon in Lake Eğirdir for future researches. We hope that future researchers can estimate the possible damages on the biomass and species composition of zooplankton in relation to their considerable consumption by the increasing population of *P. parva* in the lake. Finally, it is important to point out that invasive non-native fish species

should be kept away from natural ecosystems since they constitute a great threat for native fish species for food and breeding grounds.

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