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The effects and interactions of three invasive fish species introduced to the aquatic ecosystem of a Turkish Lake (Eğirdir Lake)

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Abstract We studied feeding behavior and prey selection of topmouth gudgeon (*Pseudorasbora parva*), big-scale sand smelt (*Atherina boyeri*) and pike-perch (*Sander lucioperca*) in Lake Eğirdir, the second largest freshwater lake in Turkey. Fish specimens were collected between January and August in 2010 and 2011 using gill-nets and purse seines. A total of 941 specimens were analyzed for stomach contents analysis. We expressed the importance of the food items present in their guts with the relative importance index (IRI) and estimated their diet selectivity indices with Pearre's index. *Pseudorasbora parva* had a diverse diet comprising mainly *Nitokra hibernica* (copepod), *Chydorus sphaericus*, and *Bosmina longirostris* (cladoceran) (each, at $p < 0.01$), but *Chironomus* sp. (insect) was not a significant component of its diet ($p > 0.05$). Big-scale sand smelt often preferred *B. longirostris, N. hibernica*, and *Alona quadrangularis* (each at $p < 0.01$). Pike-perch positively, but not statistically significant, selected *Atherina boyeri* ($p > 0.05$), *Carassius gibelio* was not preferred by pike-perch as food item ($p > 0.05$). Our results indicate that invasive species altered the food chain in Lake Eğirdir. Thus, because these fish species constitute a major threat for native fish species for food and breeding grounds, extensive care should be taken to prevent invasive fish species entering lakes in Turkey.

Keywords Food chain · Gudgeon (*Pseudorasbora parva*) · Big-scale sand smelt (*Atherina boyeri*) · Pike-perch (*Sander lucioperca*) · Zooplankton · Anatolia

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Introduction

The pike-perch, *Sander lucioperca*, is a carnivorous fish species present in brackish-water and freshwater habitats in the temperate waters of western Eurasia. Among percids, this predator has become important for local fisheries (Popova and Sytina 1976; Balık and Geldiay 2002; Becer and İkiz 2007). However, its introduction has consequences for the native fishes. After its introduction into Turkish lakes, a general collapse in the native fish population was reported. During the course of its introduction, *S. lucioperca*

were distributed to approximately 20 regions, including Antalya, Burdur, Big Menderes, Meriç-Ergene, Kızılırmak, Konya Closed, Marmara, Sakarya, and Seyhan stream basins (Tarkan et al. 2015). Researchers have investigated *S. lucioperca* both within their native and non-native areas (Campbell 1992; Nolan and Britton 2018). One of the outcomes of studies has been the reported loss of native fishes in Central Asian lakes, with the extirpations due, no doubt, to the high predation by pike-perch on zooplankton (Willemsen 1977; Peltonen et al. 1996; Lehtonen et al. 1996; Yılmaz and Ablak 2003; Specziár 2005; Balık et al. 2006; Kangur et al. 2007; Apaydın Yağcı et al. 2014). *S. lucioperca* were also reported to consume macroinvertebrates along with these prey items most frequently encountered in the diets of smaller individuals (Hansson et al. 1997; Argillier et al. 2012).

The euryhaline, big-scale sand smelt, *Atherina boyeri*, is a common fish species in freshwater ecosystems, coastal lagoons, and estuarine waters of the Mediterranean and Atlantic (Koutrakis et al. 2004; Leonardos and Sinis 2000; Doulka et al. 2013). *A. boyeri* were recorded in approximately 30 water bodies from Orontes River, Antalya, West Mediterranean, East Mediterranean, Big Menderes, Euphrates—Tigris, Gediz, Kızılırmak, Konya Closed, North Aegean, Marmara, Sakarya, Seyhan, and Yeşilırmak stream basins (Tarkan et al. 2015; İlhan and İlhan 2018; Çevik et al. 2018). Since its introduction into freshwater lakes, it has developed dense populations. With food preferences for small crustaceans that are both planktonic and benthonic, *A. boyeri* is an opportunistic carnivore (Vizzini and Mazzola 2005). It has become acclimatized and is expanding its range, so it is now occupying the ecological niches of other pelagic fish species in Trichonis Lake (Chrisafi et al. 2007).

P. parva was recorded in Romania in the early 1950s (Wildekamp et al. 1997; Kotusz and Witkowski 1998). Subsequently over the next 40 years, it spreads into the River Danube and other European countries (Banerescu 1999; Gozlan et al. 2010; Grabowska et al. 2010). Currently, *P. parva* has been recorded in approximately 70 water bodies including Meriç-Ergene, Marmara, Susurluk, North Aegean, Gediz, Big Menderes, West Mediterranean, Antalya, Sakarya, West Blacksea, Kızılırmak, Konya Closed, East Mediterranean, and Ceyhan stream basins in Turkey (Erk'akan 1984; Barlas and Dirican 2004; Yeğen et al. 2015; Özcan and Tarkan 2019; Ozulug et al. 2019). While *P. parva* mainly feeds on zooplankton such as Cladocera, Copepoda, and Rotifera, Bacillariophyta and Cyanobacteria were identified in high proportions in the foregut contents of this species by (Yalçin-Özdilek et al. 2013). After the introduction of pike-perch in 1955, irreversible damage arose in the fishery of Lake Eğirdir. Additional changes occurred when the silver crussian carp (in 1996), big-scale sand smelt (in 2003), and *P. parva* (in 2011 and 2014) were introduced into the lake (Küçük et al. 2009; Yerli et al. 2013; Yağcı et al. 2014; Yeğen et al. 2015).

To understand the impact of these three invasive fish species in Turkish inland waters, we studied their feeding behavior and prey selection in Lake Eğirdir. Thus, the specific objectives of the study were to compare the dietary composition of three invasive species and to document their feeding preferences.

Materials and methods

Study area and sampling

Lake Eğirdir is located in southern Anatolia and covers a total area of about 47.250 ha, with a maximum depth of 13 m at 918 m altitude (Yarar and Magnin 1997). Pike-perch and big-scale sand smelt were collected monthly from January 2010 to December 2010. At four stations of Lake Eğirdir, (Turkey) by Using gillnets of mesh sizes and purse-seine of 6, 10, 16, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 80, and 100 mm. Gillnet nets were set in the evening and retrieved from the water in the morning. Thus, we collected fish over a period of approximately 12–15 h. Also, we collected samples of topmouth gudgeon at the same four stations between March 2010 and June 2011 (Fig. 1). A total of 241 pike-perch, 612 big-scale sand smelt, and 88 *P. parva* individuals were collected monthly at four stations (Fig. 1). The stomachs of the specimens were immediately preserved in a plasticbucket containing 4% formalin (Buijse and Houthuijzen 1992), and their contents were analyzed in a laboratory. The fork length (FL) of species was measured to the nearest millimeter and weighed (W) to the nearest gram. Percentage number and frequency of occurrence were used to estimate the dietary selection of each prey

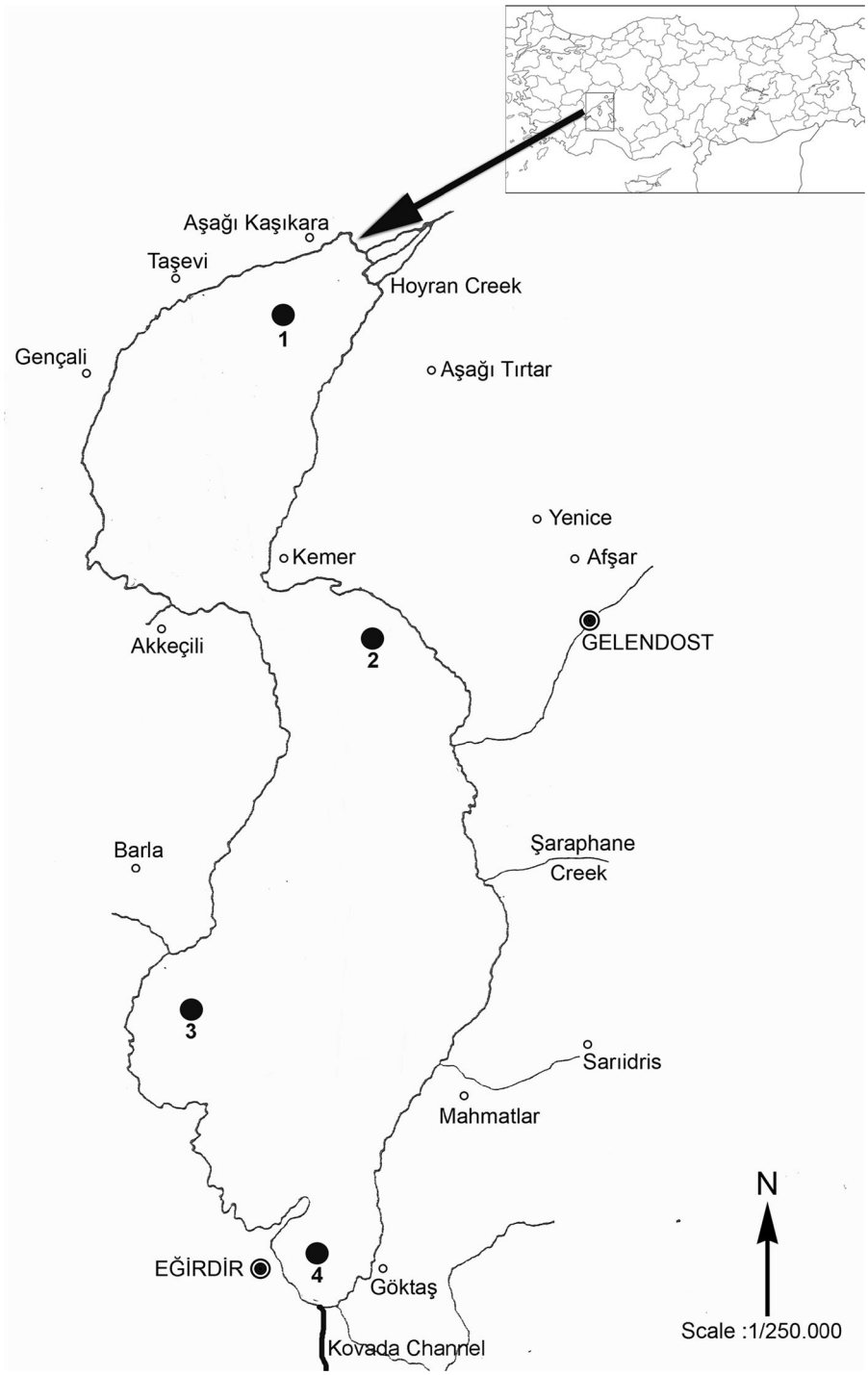

Fig. 1 Study area and sampling sections

category. Frequency of occurrence (*Fpi*): ($N_I i/N_p$), the percentage of the IRI (Pinkas et al. 1971) was used to express prey selection: IRIi = (Ni % + Wi%)* Oi%.

To estimate prey preference of fish species, the prey selection index V proposed by Pearre (1982) was calculated. The index was determined as follows:

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

where *Va* is Pearre's index for three invasive species selection of species *a*, *ad* is relative abundance of species *a* in the diet, *be* is the relative abundance of all other species in the environment, *ae* is the relative abundance of species *a* in the environment, and *bd* is the relative abundance of all other species in the diet. $a = ad + ae$, $b = bd + be$, $d = ad + bd$, $e = ae + be$. The selection index (*Va*) was statistically tested using the Chi-squared test. ($\chi 2 = n * V2$). Where, $n = ad + ae + bd + be$.

Results

The size and weight composition

We examined 612 stomachs of big-scale sand smelt. Of these, the stomachs of 563 (91.99%) individuals were full and 49 (8.01%) were empty. A total of 241 stomachs of pike-perch were examined, of which 162 (67.2%) and 79 (32.8%) were full and empty, respectively. A total of 88 stomachs of topmouth gudgeon were examined of which 65 (73.8%) and 23 (26.2%) were full and empty, respectively (Table 1).

Diet composition of invasive fishes

In this study, we compared the stomach contents composition of three invasive fish species in Lake Eğirdir using relative importance index (IRI %) and frequency of occurrence (O %). According to the relative importance index, Pike-perch preferred *A. boyeri* (67.2%) with about 19.6% of their diet being the remains of other organisms. *P. parva*, preferred mainly *Chironomus* sp., (60.8%), *N. hibernica* (17.4%), and *C. curvispinum* (14.8). According to the frequency of occurrence, sand smelt predominantly preferred remains of other organisms (61.1%), *C. curvispinum* (42.8%), *B. longirostris* (38.5%), *N. hibernica* (30.2%), remains of Arthropoda (30.02%), *M. leuckarti* (20.4%), remains of insects (18.5%), and *A. quadrangularis* (10.1%) (Table 2). The diet of pike-perch in Lake Eğirdir included fish species, insects, and other organisms. Fish were found in the stomachs of 97 pike-perch; these included *Aphanius iconii, Knipowitschia caucasica, Pseudophoxinus egridiri, Pseudorasbora parva, Seminemacheilus ispartensis, A. boyeri*, and *Carassius gibelio*. The index (IRI) indicated that fishes ad prey had a greater importance (80.30%) than the other prey categories, i.e., remains of organisms (19.60%) and insects (0.09%). Phytoplankton, Arachnida, fishes, Annelida, and unidentified organisms showed a minor role in the *A. boyeri* diet. The diet of *P. parva* comprised phytoplankton, zooplankton, Insecta, Arthropoda, Annelida, and unidentified eggs. IRI found that Insecta as prey (64.71%) had more importance than the zooplankton (20.05%) and *Chelicorophium curvispinum* (14.78%). *Chironomus* sp. had the highest index value (IRI = 60.80%) followed by *N. hibernica* (IRI = 17.40%). In general, *Bosmina longirostris* was the dominant prey in the diet of sand smelt in Lake Eğirdir. The frequency of occurrence of *B. longirostris* was the highest (38.54%), followed by *N. hibernica* (30.20%), and *Mesocyclops leuckarti* (20.43%). *C. curvispinum* were ingested by big-scale sand smelt (42.81%), while remains of insects (18.47%) and unidentified organisms also were present in the diet (61.10%). Phytoplankton, Arachnida, fishes, and unidentified organisms played a minor role in the *A. boyeri* diet. (Table 2).

Table 1 Number of invasive fishes caught in Lake Eğirdir, 2010: fork length (FL), weight (W)

Species	Number of sampled fish	FL: Range (min–max) (cm)	W: Range (min–max) (g)	Full stomach fish number (%)
Atherina boyeri	612	2.5–9.9	0.12–9.9	563 (92)
Sander lucioperca	241	21.6–77.0	10.5–43.6	162 (67)
Pseudorasbora parva	88	6.1–11.1	3.5–25.5	65 (74)

Fishes caught in Eğirdir Lake, 2010: Fork length (FL), Weight (W)

Table 2 Diet composition of invasive fishes in Lake Eğirdir, Turkey (O): frequency of occurrence, and (IRI): relative importance index (main groups, titles and important numerical values are shown in bold)

Invasive species/stomach content	*Sander lucioperca* (pike-perch)				*Atherina boyeri* (big-scale sand smelt)				*Pseudorasbora parva* (topmouth gudgeon)			
Fishes	O	O %	IRI	IRI %	O	O %	IRI	IRI %	O	O %	IRI	IRI %
Aphanius iconii	9	5.56	42.85	0.63	1	0.18	0	0	0	0	0	0
Knipowitschia caucasica	6	3.70	40.00	0.59	14	2.49	0	0	0	0	0	0
Pseudophoxinus egridiri	2	1.23	1.89	0.03	0	0	0	0	0	0	0	0
Pseudorasbora parva	1	0.62	1.05	0.02	0	0	0	0	0	0	0	0
Seminemacheilus ispartensis	8	4.94	57.66	0.85	0	0	0	0	0	0	0	0
Atherina boyeri	67	41.36	4539.14	**67.21**	5	0.89	0	0	0	0	0	0
Carassius gibelio	4	2.47	31.41	0.47	0	0	0	0	0	0	0	0
Fish remains	69	42.59	709.02	**10.50**	7	1.24	0	0	0	0	0	0
Unidentified							0	0				
Unidentified egg	0	0	0	0	20	3.55	0	0	1	1.12	0.08	0.001
Fish eggs	0	0	0	0	2	0.36	0	0	0	0	0	0
Unidentified organisms	0	0	0	0	9	1.60	0	0	0	0	0	0
Other												
Debris of *Myriophyllum spicatum*	5	3.09	0.16	0.00	0	0	0	0	0	0	0	0
Nematoda	2	1.23	0.00	0.00	0	0	0	0	0	0	0	0
Remains of organisms	87	53.70	1323.78	**19.60**	344	**61.10**	0	0	0	0	0	0
Zooplankton												
Acroperus harpae	0	0	0	0	5	0.89	0	0	0	0	0	0
Alona guttata	0	0	0	0	3	0.53	0	0	15	16.85	64.31	0.99
Alona quadrangularis	0	0	0	0	57	**10.12**	0	0	8	8.99	8.89	0.14
Coronatella rectangula	0	0	0	0	4	0.71	0	0	4	4.49	1.91	0.03
Alonella excisa	0	0	0	0	2	0.36	0	0	0	0	0	0
Alonella nana	0	0	0	0	2	0.36	0	0	0	0	0	0
Alona affinis	0	0	0	0	2	0.36	0	0	0	0	0	0
Bosmina longirostris	0	0	0	0	217	**38.54**	0	0	4	4.49	5.39	0.08
Camptocercus uncinatus	0	0	0	0	1	0.18	0	0	0	0	0	0
Ceriodaphnia quadrangula	0	0	0	0	8	1.42	0	0	0	0	0	0
Chydorus sp.	0	0	0	0	6	1.07	0	0	0	0	0	0
Cyhdorus sphaericus	0	0	0	0	30	5.33	0	0	16	17.98	54.26	0.83
Daphnia cucullata	0	0	0	0	17	3.02	0	0	1	1.12	1.04	0.02
Disparalona rostrata	0	0	0	0	22	3.91	0	0	1	1.12	0.16	0.002
Graptoleberis testudinaria	0	0	0	0	10	1.78	0	0	14	15.33	35.57	0.55
Leydigia leydigi	0	0	0	0	7	1.24	0	0	0	0	0	0
Macrothrix laticornis	0	0	0	0	4	0.71	0	0	0	0	0	0
Moina micrura	0	0	0	0	1	0.18	0	0	0	0	0	0
Monospilus dispar	0	0	0	0	12	2.13	0	0	0	0	0	0
Pleuroxus aduncus	0	0	0	0	3	0.53	0	0	1	1.12	0.16	0.002
Unidentified Cladocera	0	0	0	0	6	1.07	0	0	0	0	0	0
Asplanchna priodonta	0	0	0	0	4	0.71	0	0	0	0	0	0
Keretella cochlearis	0	0	0	0	16	2.84	0	0	0	0	0	0
Lecane sp.	0	0	0	0	1	0.18	0	0	0	0	0	0

Table 2 continued

Invasive species/stomach content	*Sander lucioperca* (pike-perch)				*Atherina boyeri* (big-scale sand smelt)				*Pseudorasbora parva* (topmouth gudgeon)			
Fishes	O	O %	IRI	IRI %	O	O %	IRI	IRI %	O	O %	IRI	IRI %
Trichocerca sp.	0	0	0	0	1	0.18	0	0	0	0	0	0
Trichocerca similis	0	0	0	0	3	0.53	0	0	0	0	0	0
Unidentified Rotifera	0	0	0	0	2	0.36	0	0	0	0	0	0
Mesocyclops leuckarti	0	0	0	0	115	**20.43**	0	0	2	2.25	0.47	0.007
Eucyclops speratus	0	0	0	0	7	1.24	0	0	0	0	0	0
Nauplii larva	0	0	0	0	11	1.95	0	0	1	1.12	0.08	0.001
Nitokra hibernica	0	0	0	0	170	**30.20**	0	0	30	33.71	1135.74	**17.40**
Unidentified Copepoda	0	0	0	0	3	0.53	0	0	0	0	0	0
Phytoplankton									0	0	0	0
Chlorophyta	0	0	0	0	1	0.18	0	0	0	0	0	0
Pediastrum sp.	0	0	0	0	4	0.71	0	0	1	1.12	0.16	0.002
Cymatopleura sp.	0	0	0	0	1	0.18	0	0	0	0	0	0
Cymbella sp.	0	0	0	0	2	0.36	0	0	0	0	0	0
Gomphonema sp.	0	0	0	0	15	2.66	0	0	2	2.25	2.99	0.05
Arachnida												
Acaridae	0	0	0	0	4	0.71	0	0	0	0	0	0
Arthropoda												
Remains of Arthropoda	0	0	0	0	169	**30.02**	0	0	0	0	0	0
Chelicorophium curvispinum	0	0	0	0	241	**42.81**	0	0	28	31.46	965.17	**14.78**
Gammarus sp.	0	0	0	0	62	11.01	0	0	0	0	0	0
Insecta												
Anisoptera	0	0	0	0	1	0.18	0	0	0	0	0	0
Calopteryx splendens	5	3.09	5.69	0.08	40	7.10	0	0	0	0	0	0
Chrinomus larvae	0	0	0	0	40	7.10	0	0	0	0	0	0
Chironomus sp.	1	0.62	0.19	0.00	0	0	0	0	39	43.82	3969.39	**60.80**
Chrinomus pupa	0	0	0	0	10	1.78	0	0	12	13.48	194.07	2.973
Ephemeroptera	0	0	0	0	6	1.07	0	0	0	0	0	0
Diptera (Adult)	0	0	0	0	9	1.60	0	0	0	0	0	0
Odanata (Adult)	0	0	0	0	2	0.36	0	0	0	0	0	0
Odanata larvae	1	0.62	0.38	0.01	0	0	0	0	0	0	0	0
Hemiptera	0	0	0	0	1	0.18	0	0	0	0	0	0
Plecoptera	0	0	0	0	3	0.53	0	0	0	0	0	0
Tricoptera (Larvae)	0	0	0	0	1	0.18	0	0	7	7.87	61.29	0.94
Remains of insects	0	0	0	0	104	**18.47**	0	0	0	0	0	0
Annelida												
Annelid	0	0	0	0	0	0	0	0	3	3.37	27.36	0.42

According to Pearre's (1982) prey selection index (V), *Atherina boyeri* individuals exhibited positive selection to *B. longirostris, A. Quadrangularis,* and *N. hibernica*, but V was negative for *A. boyeri, A. anatoliae,* Insecta, *Keratella cochlearis, Trichocerca similis,* and Copepod *Nauplii* larva (Apaydın Yağcı et al. 2018a). While the most abundant prey species in the lake (*Chironomus* sp.) was ingested by *P. parva* (Apaydın Yağcı et al. 2018b), this food item this was not a statistically significant component of its diet.

Table 3 Comparison of food items in various pike-perch population (main groups and titles are shown in bold)

Authors/the study regions	Diet composition	Authors/the study regions	Diet composition
Campbell 1992; Becer and İkiz, 1997 **(Eğirdir Lake, Turkey)**	*Mysid*	Peltonen et al. 1996; Kangur et al. 2007 **(Võrtsjärv Lake, Southern Finland)**	*Alburnus alburnus*
	Gammarus		*Perca fluviatilis*
	Isopod		*Rutilus rutilus*
	Chironomid		*Gymnocephalus cernuus*
	Chironomid pupa		*Osmerus operlanus*
	Chironomid larvae		*Abramis brama*
	Gastrapoda		*Sander lucioperca*
	Dreissena polymorpha	Specziár 2005 **(Balaton Lake, Hungary)**	**Diet composition**
	Cobitis taenia		*Diaphanosoma mongalianum*
	Vimba vimba		*Leptodora kindtii*
	Sander lucioperca		*Limnomysis benedeni*
	Pontastacus leptodactyllus		*Dikerogammarus* sp.
	Asellus sp.		*Corophium curvispinum*
	Odanata		*Gymnocephalus cernuus*
	Ephemeroptera		*Lepomus gibbosus*
	Lumbricus sp.		*Alburnus alburnus*
	Turbellaria	Willemsen, 1977 **(Ijssel Lake, Netherlands)**	**Diet composition**
	Xeptohygula pfeirferi		*Gymnocephalus eperlanus*
	Radix sp.		*Osmerus operlanus*
	Nemacheilus angorae		*Perca fluvuatilis*
	Rana		Cyprinid
	Hirundo		Zooplankton
	Calapteryx splendens		Chironomid
	Knipowitschia sp.		*Neomysis* sp.
	Aphanius iconii		*Sander lucioperca*
	Gambusia holbrooki	**Present Research**	
	Nemacheilus lendli		Chironomus sp.
	Carassius gibelio		Odanata larvae
Balık 1999; Apaydın Yağcı et al. 2006 **(Beyşehir Lake, Turkey)**	**Diet composition**		*Calapteryx splendens*
	Mysis sp.		*Aphanius iconii*
	Gammarus sp.		*Knipowitschia caucasica*
	Lumbricus sp.		*Pseudophoxinus egridiri*
	Chironomidae		*Pseudorasbora parva*
	Odanata		*Seminemacheilus ispartensis*
	Hirudo		*Atherina boyeri*
	Sander lucioperca		*Carassius gibelio*
	Knipowitschia caucasica		Nematoda
	Atherina boyeri		*Myriophyllum spicatum* remains

Table 3 continued

Authors/the study regions	Diet composition	Authors/the study regions	Diet composition
	Carassius gibelio		Organism remains
	Tinca tinca		
	Fish and organism remains		
Yılmaz and Ablak, 2003 **(Hirfanlı Dam Lake, Turkey)**	**Diet composition**		
	Mysis		
	Gammarus		
	Isopoda		
	Diptera larva, pupa		
	Fish remains		
	Odanata nimf		
	Fish and organism remains		
	Fibrous algae		

Also, while *Alona guttata, A. quadrangularis, C. curvispinum, Coronatella rectangula, Graptoleberis testudinaria, M. leuckarti*, and nauplii were present in the ecosystems, these animals were not chosen by topmouth gudgeon. Likewise, *Pediastrum* sp. Additionally, *N. hibernica* was also not preferred in the diet of topmouth gudgeon despite their high abundance in the lake Eğirdir ecosystem (Apaydın Yağcı et al. 2018b). According to the prey selectivity index of pike-perch, the prey *P. parva, S. ispartensis, A. boyeri*, and *Calopteryx splendens* were positive, but their selection indices were not statistically significant. *A. anatoliae* and *Chironomus* sp. were a common prey in the lake, but negatively selected by the pike-perch. *P. egridiri* and *C. gibelio* were negatively selected; their selection indices were not statistically significant (Apaydın Yağcı et al. 2014).

Discussion

The diet of *A. boyeri* was comprised primarily of zooplankton, followed by Arthropods and other food items such as insects, phytoplankton, fishes, and arachnids. Compared to other studies (Bartulović et al. 2004a; Doulka et al. 2013) reporting that sand smelt is an opportunistic predator, our study indicated that sand smelt fed mainly on planktonic and benthic invertebrates, Bartulović et al. (2004a) showed copepods (45%), gammarids, and amphipods (34%) to be the dominant prey of *A. boyeri* in the Mala Neretva River. Similar to our study, Doulka et al. (2013) identified a positive selection for zooplankton in Lake Trichonis, whereas *Aphanius anatoliae* were negatively selected by sand smelt in Eğirdir Lake, although they were the most abundant prey fishes (Apaydın Yağcı et al. 2018a).

Approximately 67% of *S. lucioperca* individuals had full stomachs. Studies on the diet of pike-perch from different regions show that the prey are similar (Table 3).

P. parva had a diet comprising mainly of *Chironomus* sp., *N. hibernica, C. sphaericus*, and *B. longirostris* (Apaydin Yağcı et al. 2018b). We found that the diet of topmouth gudgeon in Lake Eğirdir was dominated by *Chironomus* sp. Results of our study are similar to Wolfram-Wais et al. (1999) who stated according to the IRI index that *Chironomus* spp are one of the most important food item in Neusiedler See (Austria). Hliwa et al. (2002) showed that the diet of *P.parva* in the Balaton Reservoir was composed of *Bosmina* sp., *Chydorus* sp., Copepoda, and *Daphnia* sp. Besides, *P.parva* from Turkey in Gelingüllü Reservoir fed mainly on Cyanobacteria, Insecta, and

Cladocera (Yalçin-Özdilek et al. (2013). The role of the Oligochaeta, Ephemeroptera, Copepoda/Calanoida, Trichoptera, and Nematoda were reported as important food resources for *P. parva* by Nikolova et al. (2008), whereas eggs of native fishes and their larvae were reported by Gozlan et al. (2010) in China and Germany. Likewise, the impact of *P. parva* on zooplankton and components of the zoobenthic community was also reported by Musil et al. (2014). Didenko and Kruzhylina (2015) showed using Ivlev's selectivity indices that *P.parva* positively selected zooplankters such as *C. sphaericus*, *Alona affinis*, *Pleuroxus* sp., and *Cyclops* sp., but avoided *Bosmina* sp. *A. priodonta* was also positively selected among rotifers. Prey selection indices showed that *D. cucullata, B. longirostris*, Annelida, Trichoptera larvae, and *Gomphonema* sp. were positively selected by *P.parva* in Lake Eğirdir. Also, their selection indices were statistically significant. Pearre's selectivity indices indicated that *A. guttata, C. rectangula, Chironomus* sp., *C. curvispinum, G. testunidaria,* and *M. leuckarti* were neutrally selected (Apaydin Yağcı et al. 2018b).

The purpose of our study was to assess the impact of three invasive fish species on Lake Eğirdir as a proxy for other inland Turkish waters. We found that the dominant prey items of big-scale sand smelt and topmouth gudgeon were zooplankton, insects, and arthropods, and the diet of pike-perch often included fish species as prey. These invasive species pose a danger for native fishes and care should be taken to prevent their introduction to other Turkish waters.

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