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PROOF RESEARCH PAPER

Feeding biology of pike, *Esox lucius* L., 1758 inhabiting Lake Ladik, Turkey

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Abstract

This study was conducted to determine feeding biology and prey selection of pike inhabiting Lake Ladik (Ladik, Samsun). Sampling was carried out monthly between November 2009 and October 2010. The stomachs of 204 individuals were analyzed and 32.35% of them were empty. Feeding intensity varied by seasons and length group. Fullness index values were the lowest during summer and in large sized pike, while feeding intensity was the highest during autumn and in small specimens. Prey fish dominated the diet in all length groups throughout the year whereas feeding on invertebrates was limited to small pikes. For small, medium and large length individuals, the most preferred prey fish were *Perca fluviatilis* ($V_a = 0.139$, $\chi 2 = 3.86$, $P < 0.05$), *Chondrostoma regium* ($V_a = 0.169$, $\chi 2 = 5.752$, $P < 0.05$) and *Abramis brama* ($V_a = 0.337$, $\chi 2 = 22.731$, $P < 0.01$), respectively. The pike exhibited a specialist feeding strategy on fish. The most important food items of pike were *Scardinius erythrophthalmus*, *Perca fluviatilis* and *Abramis brama*, respectively. Also, it was determined that there were significant positive relationships between prey dimensions-predator size and predator mouth sizes-predator length.

Keywords: Feeding biology, prey selectivity, prey-predator relationships, pike, Lake Ladik.

Introduction

Studies on the food and feeding habits are important for several reasons. They provide better understanding of fish niche in the ecosystem, their food preferences, dietary overlaps (Padmakumar, Bindu, Sreerekha, & Nitta, 2009), effective lake fisheries management (Alp et al., 2008), and functional role of the fish within their ecosystems (Osman, Farrag, El Sayed, & Moustafa, 2013). Feeding habits in fish species usually depend on environmental conditions and thus can be different from one habitat to the other. The same species inhabiting different habitats can demonstrate various feeding habits and forage on different food source (Indira, Prabhu Arachi, & Varadharajan, 2013). In addition, body sizes of prey and predator can have significant effect on predator's feeding success (Juanes, Buckel, & Scharf, 2002). In piscivorous fishes, there are strong relationships between prey's body depth and predator fish's mouth gape size (Hambright, Drenner, McComas, & Hairston, 1991). Besides, prey size consumed by pike is limited by pike gape size and prey body depth (Nilsson & Brönmark, 2000).

The pike, *Esox lucius* L., 1758, is a circumpolar species (Nelson, 2006) which inhabits rivers, lakes and weakly saline waters in the northern hemisphere (Craig, 2008). This species has a large distribution from the Black Sea to central Anatolian lake watersheds in Turkey (Fricke, Bilecenoğlu, & Sarı, 2007). According to Polat, Yılmaz, and Yazıcıoğlu (2012), pike represents the most important target species for commercial fisheries in Lake Ladik, because pike is one of the main livelihoods of local fishermen. Since the pike is considered as a top predator in the food web in most freshwater ecosystems that it occupies (Soupir, Brown, & Kallemeyn, 2000), it plays an important role as regulator in abundance of prey fishes in most of the aquatic environments (Alp et al. 2008). In addition, pike is used for (improving water quality) bio-manipulation (Craig, 2008). The goal of biomanipulation process is to reduce planktivorous fish biomass and to increase size and number of zooplankton. Reduced predation on zooplankton leads to an increased grazing pressure on phytoplankton and consequently improves water quality (Craig, 2008). One way of reducing planktivorous fish biomass is to increase pike population that used to control small-cyprinid species community in eutrophic lake (Prejs, Martyniak, Boroń, Hliwa, & Koperski, 1994).

Management of the piscivorous fish stocks plays a major role in water quality management and sustainable fisheries management (Wysujack, Laude, Anwand, & Mehner, 2001). Thus, studies on the feeding biology, prey selection, and prey-predator relations for top predator species such as pike for fishery and lake management were needed.

Study about feeding ecology and prey selection of European perch, *Perca fluviatilis* (Yazıcıoğlu, Yılmaz, Yazıcı, Erbaşaran, & Polat, 2016) and food items and feeding habits of white bream, *Blicca bjoerkna* (Yazıcıoğlu, Yılmaz, Yazıcı, Yılmaz, & Polat, 2017) was performed in Lake Ladik. However, there is no information on feeding biology of pike in this lake and relationships between prey size-predator length and mouth dimensions of pike inland waters in Turkey. The main objective of the study is to determine the feeding biology and prey selection of pike. This knowledge can provide important tools for lake and fishery management and help in understanding the feeding feature of pike population. For this reason, the feeding biology during seasonal periods and prey selection at length groups were investigated. Furthermore, the first information on relationships between prey-predator length and mouth dimension- predator length was given in this study in Turkey.

Materials and Methods

Study Area

Lake Ladik's surface area coordinates are 40°54′20″N to 40°55′16″N, 35°58′53″E to 36°03′2″E. It is located within the borders of Samsun Province in the central Black Sea region of Turkey. It is 10 km far from east of the Ladik district and situated on the northern side of Akdağ Mountain. Its total surface area, maximum depth, drainage area and altitude are about 10 km^2, 6 m, 141.40 km^2 and 867 m, respectively. The study area is one of the few lakes containing floating islands in the world and it is a natural protected area owing to floating islands (Bulut, 2012; Polat, Yazıcıoğlu, Saygın, Yılmaz, & Zengin, 2015). The lake has been classified as an eutrophic and shallow lake (Apaydin Yagci, Yilmaz, Yazicioglu, & Polat, 2015). The lake's fish species are: common bream (*Abramis brama*), anatolian khramulya (*Capoeta tinca*), white bream (*Blicca bjoerkna*), king nase fish (*Chondrostoma regium*), European chub (*Squalius cephalus*), rudd (*Scardinius erythrophthalmus*), pike (*Esox lucius*), European perch (*Perca fluviatilis*), paphlagonian loach (*Barbatula kosswigi*) and Prussian carp (*Carassius gibelio*) (Uğurlu, Polat, & Kandemir, 2009; Yılmaz et al., 2012).

Fish Sampling and Laboratory Process

Fish samples were caught monthly between November 2009 and October 2010. Sampling was performed using gillnets (100 m long and 2 m deep) with mesh size 20, 25, 30, 35 and 40 mm (knot to knot) and trammel nets (100 m long and 4 m deep) with mesh size 45, 50, 55, 60 and 70 mm (knot to knot). The nets were set at the bottom during approximately 8-10 h and at depths of 2-4 m at different area of lake. Besides, the abundance of the fish in the lake was determined in order to examine food preferences of pike. To estimate fish abundance of lake, the percentage of fish species were determined by using numerical data from catches with gillnets, fyke nets, and trammels net. All caught samples were placed in plastic boxes comprising a formalin solution. In laboratory, the fork length (FL) of each specimen was measured to the nearest 0.1 cm and their weight was determined using digital balance with precision of 0.01 g. The stomachs were removed and preserved in formalin (10%) until the contents were analyzed. Stomach of all individuals was cut and opened. The contents were flushed into a petri dish. All prey items were identified to the lowest possible taxonomic level under dissecting microscopy, counted, and weighed (wet weight with 0.01 g). Also, full and empty stomach weights were measured with a precision of 0.01 g. If prey fish was very digested, pharyngeal bones (pharynx teeth) for cyprinids, opercular bones and scale for percids were used for identification (Wysujack et al. 2001). In addition, the prey fish dimensions (Total body length, PTL; Standard body length, PSL and Body height, PBH) were measured to the nearest 0.1 cm with a caliper. The vertical (M_{VG}) and horizontal (M_{HG}) mouth gape of pike were measured to the nearest 0.1 cm using a caliper rule.

Data Analysis

Feeding intensity was evaluated by the fullness index (FI = weight of stomach content/ weight of fish x100) (Hyslop, 1980). Vacuity index (VI% = the number of empty stomachs/ total number of the examined stomachs x 100) was also calculated (Berg, 1979). Kruskal-Wallis test (K-W test) was used to compare the variation of the feeding intensity between the different seasons and length groups (Zar, 1999). A chi-square test (χ^2) was applied to determine the vacuity index (VI) changes between the seasons and length groups (Zar, 1999). The feeding feature and diet composition of pike was evaluated according to the seasonal and length classes. The specimens were divided into three length classes, small (25.0-40.9 cm FL, n = 84), medium (41.0-56.9 cm FL, n = 109) and large (57.0-72.9 cm FL, n = 11) to determine the variation in feeding habits between length groups Diet composition was investigated using three measures described by Hyslop (1980); (1) percent frequency of occurrence (FO%), (2) percentage by numbers (N%), and (3) percentage by weight (W%). The importance of each food items was identified using the index of

relative importance (IRI) of Pinkas, Oliphant, and Iverson (1971), as modified by Hacunda (1981).

IRI = (N % + W %) x FO %

This index has been expressed as the percentage of each prey item;

IRI % = (IRI / ∑ IRI) x 100

Diet similarity was evaluated by Schoener's overlap index (C_{xy}) (Schoener, 1970): $C_{xy} = 1 - 0.5\left(\sum_{i=1}^{n} \left| p_{xi} - p_{yi} \right|\right)$

Where C_{xy} = overlap between diet of individuals in the length groups or seasons x and y

p_{xi} = proportion of prey i used by size classes or seasons x

p_{yi} = proportion of prey i used by size classes or seasons y

This index ranges from 0 (no prey overlap) to 1 (all prey items in equal rate) and was considered biologically significant when its values exceeded 0.60 (Wallace, 1981).

In order to determine prey preference of pike, prey selection index (V_a) defined by Pearre (1982) was calculated. This index ranges from 1 (strong positive selection) to -1 (strong negative selection). Also, value of zero shows neutral selection. The index was calculated as follows:

$$V_a = \frac{(a_d \times b_e) - (a_e \times b_d)}{\sqrt{a \times b \times d \times e}}$$

Where V_a is Pearre's index for pike selection of prey type i, a_d is relative abundance of prey type i in the diet, b_e is the relative abundance of all other prey in the lake, a_e is the relative abundance of prey type i in the lake, b_d is the relative abundance of all other prey in the diet. The statistical significance of selection index value (V_a) was tested using the chi-squared test (χ2- test). Values without subscripts are expressed as:

$a = a_d + a_e$, $b = b_d + b_e$, $d = a_d + b_d$, $e = a_e + b_e$

Mouth area (M_A) was estimated with the ellipse model (Erzini, Gonçalves, Bentes, & Lino, 1997).

$M_A = 0.25\pi\ (M_{VG} \times M_{HG})$,

where M_A is the ellipse area (cm^2), M_{VG} and M_{HG} are vertical and horizontal mouth gape (cm). The relationships between M_{VG} -M_{HG}, M_{VG}-FL, M_{VG} -FL and M_A-FL (Czerwinski, Gutiérrez-Estrada, Soriguer, & Hernando, 2008) and PTL-FL, PSL-FL, PBH-M_{VG} and PBH-M_{HG} (Magnhagen & Heibo, 2001; Dörner et al., 2003) were calculated using linear regression analysis. One-way analysis of the variance (ANOVA) was used to test the statistical significance of linear regression (Czerwinski et al. 2008).

Results

Size Structure and Feeding Intensity

During the study period, 204 specimens were analyzed, with range of fork length 25.5-70.5 cm and mean length 43.1 cm (Sd= ± 0.57). Out of 204 stomachs examined, 66 stomachs were empty (VI%: 32.35) (Table 1). Percent of empty stomachs (VI%) was highest during summer (38%) and lowest during autumn (25%). The maximum value of VI% was observed in the large sized individuals (45.45%), while the minimum VI% value was determined for small individuals (23.81%) (Figure 1). There were not significant differences among seasonal VI% values (χ^2 = 2.198, P > 0.05) and VI% values of length groups (χ^2 = 5.014, P > 0.05). The mean fullness index (FI) expressing the feeding intensity showed variation among seasons. The highest mean FI was recorded during autumn (1.35) and the lowest mean FI during summer (0.81), followed by winter (0.83). The mean value of FI was highest for the small size class (1.51) and lowest in the large class (0.19)

Table 1. N%, W%, FO%, and IRI% values of prey items in pike during study

Prey items	n	N%	w	W%	F	FO%	IRI	IRI%
Pisces								
European perch	39	27.86	221.30	18.73	33	23.91	1113.97	27.99
Rudd	47	33.57	289.97	24.55	42	30.43	1768.59	44.45
Common bream	24	17.14	596.50	50.49	20	14.49	979.96	24.63
King nase fish	3	2.14	5.19	0.44	3	2.17	5.60	0.14
White bream	3	2.14	36.73	3.11	3	2.17	11.39	0.29
European chub	1	0.72	3.34	0.28	1	0.72	0.72	0.02
Unidentified fish	4	2.86	5.10	0.43	4	2.89	9.51	0.24
Fish remains	-	-	22.11	1.87	46	33.33	62.33	1.56
Invertebrates								
Chironomidae larvae	10	7.14	0.25	0.02	4	2.89	20.69	0.52
Trichoptera larvae	7	5.00	0.11	0.01	1	0.72	3.61	0.10
Odonatae larvae	2	1.43	0.81	0.07	2	1.45	2.18	0.06
Total	140	100	1181.41	100			3978.54	100
Full stomach	138							
Empty stomach	66							
Total stomach	204							

n, prey number; w, prey weight; F, frequency of occurrence; IRI, index of relative importance

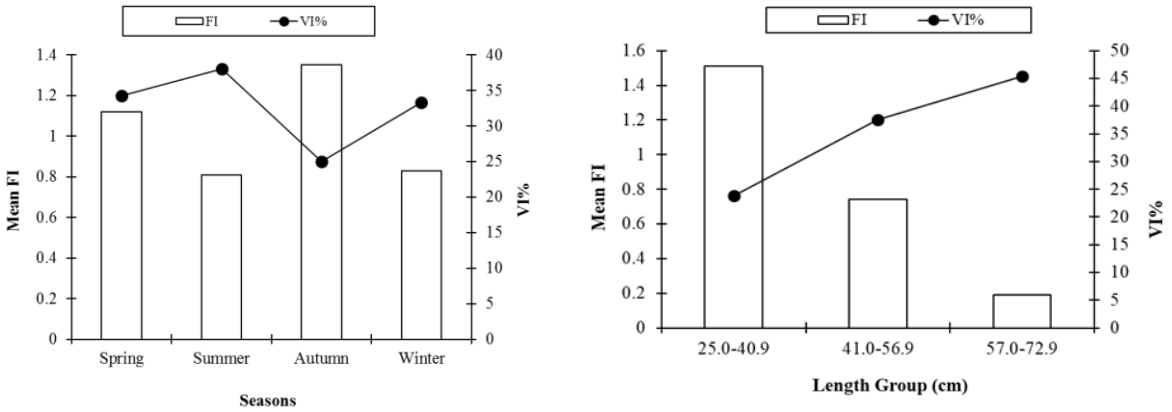

Figure 1. The mean fullness index (FI) and vacuity index (VI %) for seasons and length groups in pike inhabiting Lake Ladik.

(Figure 1). There were significant differences in the mean FI values between seasonal groups (Kruskal-Wallis test, $P<0.05$) and the size groups (Kruskal-Wallis test, $P<0.001$).

General Diet Composition

The diet of pike in Lake Ladik was composed of 10 different food items belonging to two major groups (fishes and invertebrates). A total of 140 identifiable prey items were found in the stomachs of the 138 pikes. The number of food items per non-empty stomach ranged between 1 and 7, with a mean of 1.41 (Sd= ± 0.9477). The mean prey weight per stomach was as 8.56 g (Sd= ± 14.54).

The main food items of pike were fishes. Among them, rudd and European perch were present in highest abundance (N% = 33.57 and N% = 27.86) and had the highest frequency of occurrence (FO% = 30.43 and FO% = 23.91) in the pike stomach, respectively. Common bream and rudd were dominating by weight (W% = 50.49 and W% = 24.55) (Table 1). Invertebrates were also consumed by pike in very low rates. Among those invertebrates, the most consumed food item was Chironomidae larvae by percentage numbers and frequency of occurrence (N% = 7.14 and FO% = 2.89), while Odonatae larvae were dominating by weight (W% = 0.07). According to the IRI%, rudd, European perch and common bream were the most important prey items, respectively. The importance levels of European perch and common bream were similar throughout the year. Other prey taxa had less importance in diet, constituting 2.93% of the total IRI (Table 1). Cannibalism was not observed in pike population.

Seasonal Variations in Diet

The diet of pike showed seasonal variation. The most important food type was prey fishes in all seasons, and the dominant species were European perch, rudd and common bream. White bream was absent from the diet of pike during winter, while king nase fish was not represent during in spring. European chub was only consumed by pike during winter. Similarly, invertebrates were absent from the diet during winter. The most important prey items were European perch (IRI% = 38.42), rudd (IRI% = 34.88) and common bream (IRI% = 22.41) during spring. The main food type was common bream (IRI% = 53.02) and rudd (IRI% = 31.11) during summer and European perch (IRI% = 67.52) and rudd (IRI% = 26.46) during autumn. Rudd (IRI% = 61.11) and common bream (IRI% = 33.22) were the most important prey items during winter (Figure 2).

According to the Schoener's overlap index values, diet overlap was higher than 0.60 between spring and autumn, and spring and winter. There was a very low degree of dietary overlap between the other paired seasons ($C<0.60$) (Table 2).

Diet In Relation to Fish Length

Diet composition varied with length class in pike. Rudd and common bream were present in the diet of all length groups. European chub and king nase fish were consumed by the medium size group. Invertebrates were only consumed by the small size group. The importance of common bream increased with length group in the diet of pike, while importance of European perch and rudd decreased with increasing length. Rudd (IRI% = 51.86) and European perch (IRI% = 38.38) were the most important prey fish in small size class. The most important food item of medium size group was common bream, rudd and European perch with IRI% = 40.28, 33.80 and 20.81, respectively. The most important food item was common bream with IRI% = 67.32 in large size class, followed by rudd (IRI % = 30.53) (Table 3). Schoener's index showed a significant overlap (C= 0.768) in diet of small and medium sized group. A significant dietary overlap was not observed between small-large size group (C= 0.451) and medium-large size group (C= 0.529).

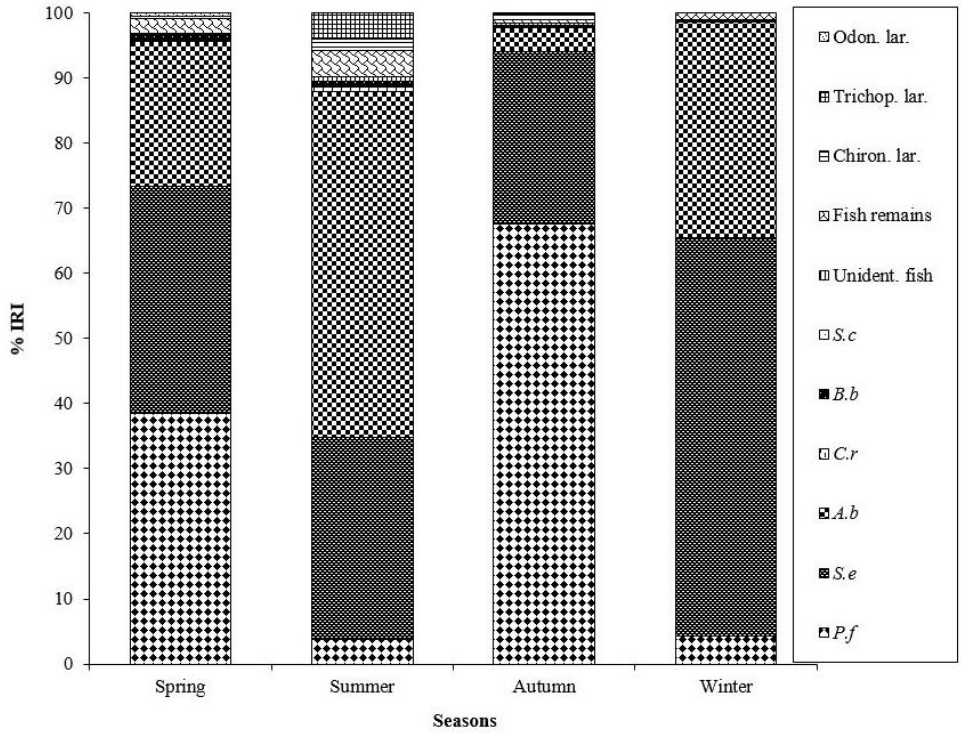

Figure 2. Seasonal variation in the diet composition by IRI % in pike from Lake Ladik (P.f = *Perca fluviatilis*, S.e = *Scardinius erythrophthalmus*, A.b =*Abramis brama*, S.c = *Squalius cephalus*, C.r = *Chondrostoma regium*, B.b = *Blicca bjoerkna*, Odon. lar = Odonatae larvae, Trichop. lar = Trichoptera larvae, Chiron. lar = Chironomidae larvae).

Table 2. Schoener overlap index values of dietary of pike by season

C_{xy}	Spring	Summer	Autumn	Winter
Spring	-			
Summer	0.5635	-		
Autumn	0.7442*	0.5749	-	
Winter	0.6436*	0.5288	0.4749	-

* Statistically significant

Table 3. IRI% values of prey items in pike depending on length groups

Food items	IRI%		
	Small length group (25.0-40.9 cm FL)	Medium length group (41.0-56.9 cm FL)	Large length group (57.0-72.9 cm FL)
Pisces			
European perch	38.38	20.81	-
Rudd	51.86	33.80	30.53
Common bream	6.91	40.28	67.32
King nase fish	-	0.90	-
White bream	0.08	0.75	-
European chub	-	0.11	-
Unidentified fish	0.04	0.88	-
Fish remains	0.88	2.47	2.15
Invertebrates			
Chironomidae larvae	1.43	-	-
Trichoptera larvae	0.25	-	-
Odonatae larvae	0.15	-	-
Full stomach	64	68	6
Empty stomach	20	41	5
Total stomach	84	109	11

Prey Fish Abundance and Prey Selection

The prey community sampling conducted between November 2009 and October 2010 showed that, Rudd was the most abundant fish species with 34.10% in Lake Ladik, followed by European perch with 26.21%, common bream with 24.03%, white bream with 12.26%, Prussian carp with 1.94%, pike with 1.10%, king nase fish with 0.24% and European chub with 0.12% respectively.

According to the prey selection index (V_a), European perch (V_a = 0.139, χ^2 = 3.86, P < 0.05) was the most preferred prey item in small sized group. Similarly, rudd was positively selected but its selection index was not statistically significant (P > 0.05). White bream (V_a = -0.209, χ^2 = 8.786, P < 0.01) was negatively selected by small size pike. Also, common bream (V_a = -0.096) was negatively selected but its selection index was not significant (χ^2 = 1.944, P > 0.05) (Figure 3).

In medium sized group, king nase fish was the most preferred prey fish (V_a = 0.169, χ^2 = 5.752, P < 0.05). Additionally, European perch, common bream and European chub were positively selected but their selection indexs were not statistically significant (P > 0.05). White bream (V_a = -0.147, χ^2 = 4.339, P < 0.05) and common bream (V_a= -0.038) were negatively selected but common bream's selection index was not significant (χ^2 = 0.294, P > 0.05) (Figure 4).

In the large sized class, common bream (V_a = 0.337) was the most preferred prey item and its selection index was statistically significant (χ^2 = 22.731, P < 0.01). Similarly, rudd (V_a= 0.090) was positively selected by large pike but, its selection index was not statistically significant (P > 0.05) (Figure 5).

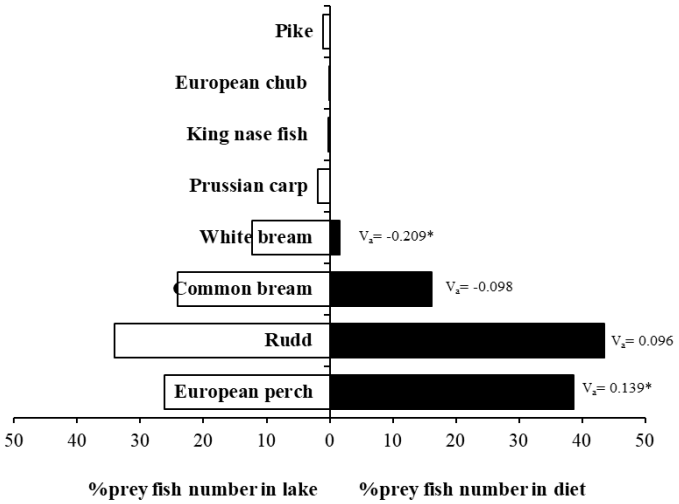

Figure 3. Pearre's selectivity index of the prey fishes in small length group.
* Statistically significant (P<0.05)

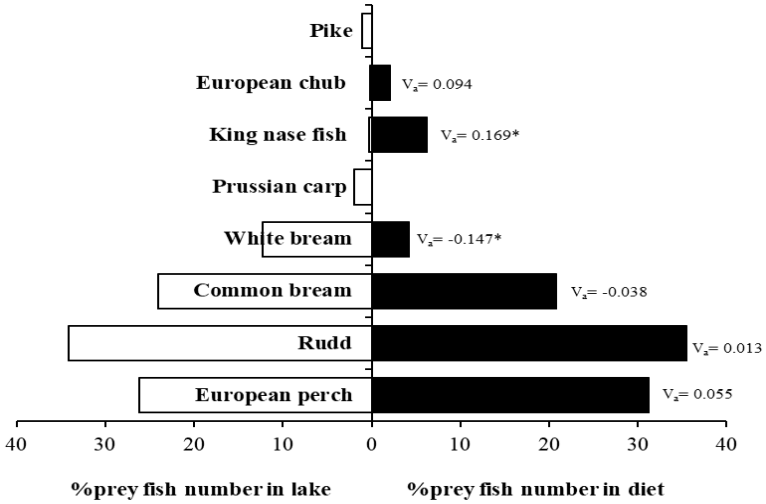

Figure 4. Pearre's selectivity index of the prey fishes in medium length group.
* Statistically significant (P<0.05)

Mouth Dimensions of Pike and Prey-Predator Relationships

The min, max, mean, and standard deviation values of vertical mouth gape (M_{VG}), horizontal mouth gape (M_{HG}), mouth area (M_A), and fork length (FL) in pike samples and the min, max, mean, and standard deviation values of total body length (PTL), standard body length (PSL), and body height (PBH) of prey fishes are summarized in Table 4.

The relationships between M_{VG}-M_{HG}, M_{VG}-FL, M_{VG} –FL, M_A-FL, PTL-FL, PSL-FL, PBH-M_{VG} and PBH-M_{HG} are given in Table 5. The results of all regressions analysis showed positive ($r^2 > 0.57$) and significant linear relationships (ANOVA, $P < 0.001$). Strongest linear relationships were found between PBH- M_{VG} and PBH- $M_{HG,}$ respectively ($P < 0.001$, $r^2 > 0.790$). The maximum PTL was determined as 19.4 cm. The total body length of the fish consumed by pike was up to 22% and 40% of pike length, with a mean of 30% (Table 4). The length of pike was significantly ($P < 0.001$) related to both PTL and PSL. Prey length (PTL and PSL) increased with fork length of pike (Figure 6).

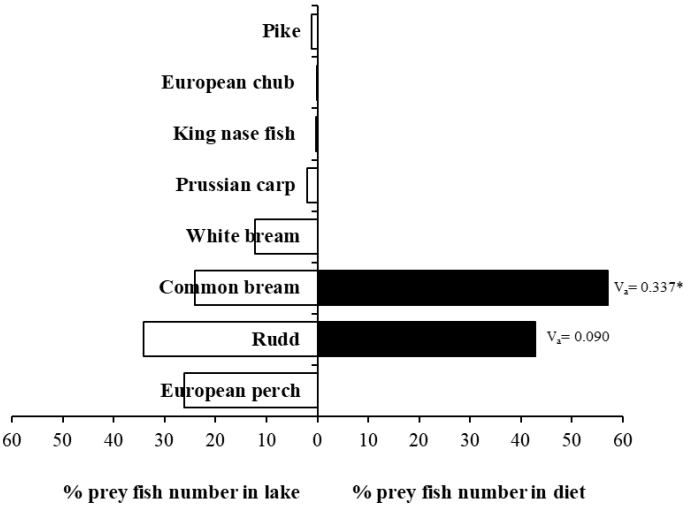

Figure 5. Pearre's selectivity index of the prey fishes in large length group.
* Statistically significant ($P<0.05$)

Table 4. Values of mouth dimensions of predator, prey sizes, and predator length from Lake Ladik

Measurements (cm)	n	Min	Max	Mean	Sd
Vertical mouth gape (M_{VG})	204	3.49	9.40	5.95	1.152
Horizontal mouth gape (M_{HG})	204	2.01	8.80	5.28	1.213
Mouth area (M_A) (cm^2)	204	5.78	64.94	25.64	8.800
Prey total body length (PTL)	41	8.00	19.40	12.01	2.927
Prey standard body length (PSL)	50	6.70	16.40	10.03	2.459
Prey body height (PBH)	49	1.32	5.41	2.88	1.079
Predator length (FL)	204	25.5	70.5	43.1	8.165

n, number of samples; Min, minimum; Max, maximum; Sd, standard deviation

Table 5. Relationships between mouth dimensions (M_{VG}, M_{HG} and M_A)-predator length (FL), prey size (PTL and PSL)-predator length (FL), and prey body height (PBH)-mouth dimension (M_{VG} and M_{HG}) in pike

Relationships	n	a	b	r^2
M_A = a+b.FL	204	-23.502	1.1389	0.757
M_{VG} = a+b.FL	204	0.9227	0.1165	0.681
M_{HG} = a+b.FL	204	-0.0449	0.1234	0.691
M_{VG} = a+b.M_{HG}	204	1.4987	0.8433	0.787
PTL= a+ b.FL	41	-3.1233	0.3805	0.615
PSL= a+ b.FL	50	-0.5476	0.2608	0.576
PBH= a+ b.M_{VG}	49	-2.5901	1.0825	0.822
PBH= a+b.M_{HG}	49	-2.5784	1.1358	0.804

n, number of samples; a and b: parameters of relationship; r^2, coefficient of determination

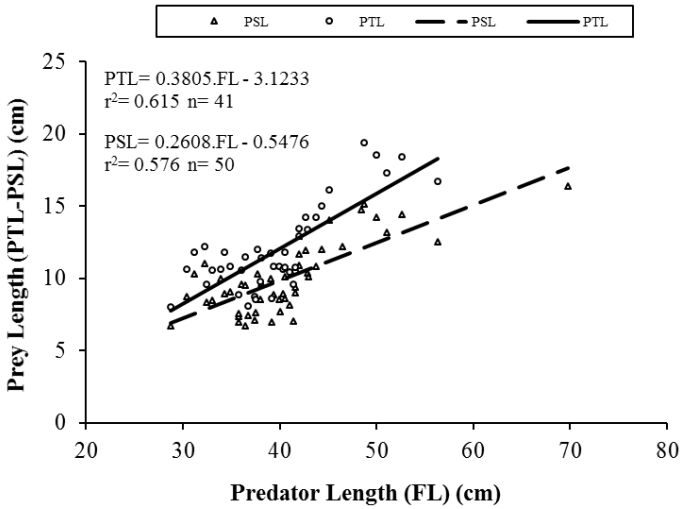

Figure 6. Linear regressions of prey total body length (PTL) and prey standard body length (PSL) on predator length (FL) in pike.

Discussions

In this study, of the 204 stomachs examined, 66 were empty (32.35 %). The percentage of empty stomach (VI%) was lower than in other with 54.5% in The Green River Basin (Tyus & Beard, 1990), 53.5% in Feldberger Haussee (Wysujack et al. 2001), 54.3% in Çivril Lake (Alp et al., 2008), while VI% value was similar with previous researches which 32.8% in Lake Trasimeno (Lorenzoni et al. 2002), 37% in Karamık Lake (Çubuk, Balık, Özkök, & Uysal, 2006). This may be due to differences in sampling method, climate features of the study field, residence time on nets of fish.

Our study indicated that feeding intensity (FI) and vacuity index values (VI%) varied between seasons. According to Bowman and Bowman (1980), the vacuity index (VI%) is an inverse indication of feeding intensity. Similarly, we found that feeding intensity was highest during autumn (1.35) when VI% was lowest (25%), while feeding intensity was lowest during summer (0.81) when VI% was highest (38%). Mann (1976) suggested that the VI% was highest during summer. The vacuity index (VI%) value in Karamık Lake was correspond our finding and it was highest during summer (Çubuk et al. 2006). The variations in feeding intensity (FI) and VI% value by seasons may probably be attributed to high water temperature, which increase digestion rate and metabolism of fish (Yılmaz, Gaffaroğlu, Polat, & Emiroğlu, 2010), decrease foraging activity (Chapman & Mackay, 1990). The increase in the empty stomach ratio (VI%) in summer may be caused by increased rate of metabolism at higher temperature. Many studies reported that there is a simple proportional dependency between feeding intensity and water temperature (Mann, 1976; Chapman & Mackay, 1990; Lorenzoni et al., 2002). Water temperature is known to be one of the main factors influencing the rate of feeding in fishes (Weatherley & Gill, 1987). The feeding intensity also decreased with increasing fish length in Lake Ladik. Similar results have also been found in Çivril Lake (Alp et al., 2008). Chapman, Mackay, and Wilkinson (1989) stated that high feeding frequency was more apparent in small pike and same researchers found out a negative relationship between VI% value and frequency of occurrence of invertebrates.

The pike exhibited mostly a piscivorous feeding feature in Lake Ladik. Besides, insectivorous feeding was also observed at low ratio. Similar feeding habits have been observed in several different habitats (Kangur & Kangur, 1998; Lorenzoni et al., 2002; Amundsen et al., 2003; Persson, Bertolo, & De Roos, 2006). However, the diet of pike inhabiting different habitats has a broad prey food types from invertebrates to vertebrates including mammalian prey (Sammons, Scalet, & Neumann, 1994; Elvira, Nicola, & Almodovar, 1996; Soupir et al. 2000; Liao, Pierce, & Larscheid, 2002). Compared with previous studies (Elvira et al. 1996; Soupir et al. 2000; Çubuk et al. 2006; Alp et al., 2008), which has wide food spectrum, pike exhibited specialist feeding habit in Lake Ladik. These variations in diet composition may resulted from food selection by pike, size of pike, distribution and seasonal abundance of prey, and availability of prey source. Cannibalism (intraspecific predation) did not occur in three size groups of pike in Lake Ladik. The same results were obtained in previous studies (Sammons et al. 1994; Liao et al. 2002; Lorenzoni et al., 2002; Amundsen et al., 2003). It was hypothesized that cannibalism does not appear because of the vulnerability and excess abundance of prey fishes and low density of pike population in this lake. Alp et al. (2008) stated that intraspecific predation was not observed in the small and medium sized pike, but it was significant in large sized group in Çivril Lake. Craig (1996) reported that occurrence

of cannibalism changed depending on availability of prey fish and pike density.

It is generally accepted that pike showed seasonal changes in their diet composition (Soupir et al. 2000; Lorenzoni et al., 2002; Çubuk et al. 2006; Alp et al., 2008). The data of this study verify this statement. Our result indicated that predation on prey fishes varied seasonally in pike and fishes were of high importance in the diet of northern pike during all season. On the other hand, invertebrates consumed by pike was not important in diet, as they were consumed at low rate during all seasons. Similar findings about seasonal variation of feedings were obtained in different pike populations (Sammons et al. 1994; Little, Tonn, Tallman, & Reist, 1998; Soupir et al. 2000; Lorenzoni et al., 2002; Liao et al. 2002; Çubuk et al. 2006; Alp et al., 2008; Flinders & Bonar, 2008). These variations of seasonal diet can be associated to seasonal distribution and availability of the different food sources in habitat. Chapman and Mackay (1990) reported that feeding strategies of piscivorous pike can be modified with availability of different food items that have a high proportion of invertebrate prey.

Prey fishes were the most consumed food type in all length groups. In addition, invertebrates were only eaten by small length pikes. The importance of invertebrates decreased in diet with increasing the length of the pike. Our findings indicated that small pike exhibited a generalist feeding feature, consuming both prey fish and invertebrate, while medium and large individuals were specialists, feeding on prey fish. The specimens larger than 40 cm FL consumed exclusively prey fishes in this lake. Similarly, Alp et al. (2008) stated that large size individuals (> 40 cm FL) fed on prey fishes only while, small (20-30 cm FL) and medium sized (30-40 cm FL) pike consumed both prey fish and invertebrate in Çivril Lake. The pike longer than 50 cm fed solely whitefish (*Coregonus lavaretus*) in Pasvik watercourse (Amundsen et al., 2003) and fed on exclusively prey fish and crayfish in Ruidera Lakes (Elvira et al. 1996). In contrast, Chapman et al. (1989) indicated that foraging on invertebrates was not limited to smaller pike and instead that invertebrates were found in the stomach of 24-60 cm standard body length pike from several lakes in Canada. The several studies also found size-related changes in the feeding of different pike populations (Mann, 1982; Eklöv & Hamrin, 1989; *Sammons et al.* 1994; Kangur & Kangur, 1998; Çubuk et al. 2006). This change based on length may be result from maximum energy requirement and gape-size limited in predator. Hubenova and Zaikov (2013) reported that pike preferred prey fish that can deliver maximum energy with minimum effort made by them in experimental study. According to the experimental study, Nilsson and Brönmark (2000) stated that the relationship between body length and maximum swallow prey depth can be used to estimate gape-size limits.

In this study, European perch was the most preferred prey item in small sized group, while, king nase fish was the most preferred prey fish in medium sized class. In large sized class, common bream was the most preferred food item. White bream and common bream were negatively selected by small and medium size pikes in Lake Ladik. White bream and common bream were negatively selected due to morphology of prey fish and mouth gape size of predator. Many authors reported that pike was selective predator that prefers fishes with elongated, cylindrical body and soft fins in different habitats (Mann, 1982; Nilsson & Brönmark, 2000; Alp et al., 2008). Prey selection may be affected by gape of mouth of predator, dorsal fin ray type and abundance of prey fish, as well as shape, size, and height of their body. The previous studies have reported that pikes preferred soft-rayed fish species (Eklöv & Hamrin, 1989; Tyus & Beard, 1990) and shallow-bodied prey over deep-bodied prey (Nilsson & Brönmark, 1999). Alp et al. (2008) indicated that *Chondrostoma meandrense*, *Gobio gobio* and *Tinca tinca* were the most preferred prey fish, while *Hemigrammocapoeta kemali* and *Aphanius anatolia* were negatively selected by pike in Çivril Lake.

In this study, the estimated linear relations between M_A-FL, M_{VG}-FL, M_{HG}-FL, and M_{VG}-M_{HG} were highly significant (ANOVA, $P< 0.001$). M_A, M_{VG} and M_{HG} tend to increase with predator length. Nilsson and Brönmark (2000) found that gape size was linearly related to total body length in pike population. Magnhagen and Heibo (2001) reported that the size of gape increased with total body length in pike samples. The prey body height (PBH) changed as a function of vertical and horizontal mouth gape in Lake Ladik. Likewise, Magnhagen and Heibo (2001) suggested that mean prey depth and predator gape size were significantly correlated. Nilsson and Brönmark (2000) indicated that prey body depth increased with total body length in pike population.

Our results showed that there was a statically significant relationship between PTL-FL ($P < 0.001$, $r^2 = 0.615$) and PSL-FL ($P < 0.001$, $r^2 = 0.576$). The mean length of prey fish increased significantly with the size of pike in this lake. Findings in this study are consistent with previous studies (Mann, 1982: Little et al. 1998; Wysujavk et al. 2001; Amundsen et al., 2003). Besides, Liao et al. (2002) indicated that large pike tended to consume large prey fish in Spirit Lake. The total body length of prey fishes consumed by pike ranged from 8.0 to 19.4 cm in Lake Ladik. The largest prey fish consumed by pike was common bream. The size of prey fishes was approximately 22-40% of pike's length, with 30% of mean. The pikes are able to consume prey up to between 20 to 60% of their length (Nursall, 1973; Little et al. 1998; Amundsen et al., 2003). The variation in the size of prey fishes may be due to body depth of prey (Nilsson & Brönmark, 2000), gape size of pike (Hart &Hamrin, 1988; Nilsson & Brönmark, 2000) and dorsal fin type of prey fishes (Eklöv & Hamrin, 1989; Tyus & Beard,

1990).

The present study revealed that pike was the selective predator and showed intensively piscivorous feeding feature. The mean length of prey fishes consumed by pike generally increased with predator size. The high biomass of cyprinid species in the Lake Ladik provides a good feeding status for pike population. Predation on cyprinid species is very important for biomanipulation so, pike can be suitable for reduction of cyprinid species. Also, this study demonstrates that since pike fed mostly on fishes during all seasons and all length groups, it can play a major role struggle against eutrophication.

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