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Effects of Predator Size and Gonad Maturation on Food Preference and Feeding Intensity of *Sander lucioperca* (Linnaeus, 1758)

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Abstract

This study examines temporal changes and predator size-dependent changes in the important dietary groups and feeding intensity of pikeperch *Sander lucioperca*. Monthly experimental fishing operations were conducted for sampling purposes using gillnets with different mesh sizes between July 2009 and June 2010. The results showed significant changes in the important dietary items as a function of predator size. Diptera and mysids were the most important groups for pikeperch smaller than 19 cm, whereas fish were most important for pikeperch larger than 19 cm. The important dietary items also varied significantly over time. The most important dietary groups were mysids during December, January and February; diptera during March and April; and teleosts during the other months. The feeding intensity of pikeperch peaks in October and March and then progressively decreases between October and February. The decrease in feeding intensity was related to the reproductive period.

Keywords: Pikeperch, diet, mysids, diptera, cannibalism.

Sander lucioperca (Linnaeus, 1758)'da Predatör Boyu ve Gonad Gelişiminin Besin Tercihi ve Beslenme Yoğunluğuna Etkisi

Özet

Bu çalışmada *Sander lucioperca*'nın önemli besin öğeleri ve beslenme yoğunluğundaki zamansal değişimler ile avcı boyuna bağlı değişimler ele alınmıştır. Bu amaçla Temmuz 2009 Haziran 2010 tarihleri arasında farklı ağ gözü genişliklerine sahip sade uzatma ağları kullanılmak suretiyle aylık deneysel örneklemeler yapılmıştır. Sonuçlar, predatör boyuna bağlı olarak önemli besin grubunda anlamlı değişimler olduğunu göstermiştir. Sudakların 19 cm'den büyük boy gruplarında balık en önemli besinsel öğeyi teşkil ederken; 19 cm'den küçük bireylerde en önemli besin grubu Dipter ve Mysid olarak belirlenmiştir. Ayrıca önemli besin gruplarında gözlenen zamansal değişimler de anlamlı bulunmuştur. Aralık ve Şubat ayları arasında en önemli besin grubu Mysidlerken, Mart ve Nisan aylarında Dipterler; diğer aylarda ise Teleostların en önemli besin grubunu oluşturduğu saptanmıştır. Sudaklarda beslenme yoğunluğu Ekim ayında en yüksek düzeydeyken; Ekim-Şubat ayları arasında kademeli olarak düşüş göstermiştir. Bu düşüşün üreme dönemiyle ilişkili olduğu tespit edilmiştir. Üreme aktivitesinin ardından beslenme yoğunluğu tekrar yükselmiştir.

Anahtar Kelimeler: Sudak, besin, mysid, dipter, kanibalizm.

Introduction

Predation is one of the major forms of interaction in freshwater populations and can affect all functions of the aquatic ecosystem (Keskinen, 2008). Predation may affect prey populations both directly and indirectly. The direct effects of predation can include the death and/or injury of the prey (Wootton, 1990), the reduction of prey abundance or changes in the prey size-frequency distribution (Turesson *et al.*, 2002). Behavioural alterations in a prey species under predation risk can be an indirect effect of predation. Prey populations can change their feeding behaviour (Magnehagen, 2006) or habitat (Persson *et al.*, 1996) to avoid predation risk. These changes also affect the growth rate of the prey population (Olson, 1996). Besides, the data on feeding ecology of fishes provides more effective fishery researches joining with appropriate models such as Multispecies Virtual Population Analysis. Additionally, in case of known biomass values of prey and predator species, feeding data provides to determine how much biomass have been consumed by predators (Jennings ve ark, 2001). Therefore, this data provides a comparison of predation mortality and fisheries mortality in the exploited populations. On the other hand, the correlation between variation of recruitment and predation could be evaluated (Link ve Almeida, 2000). When the variation of feeding have been efficiently considered in population dynamical models, the predictions will be more accurate (Ulltang, 1996).

The pikeperch *Sander lucioperca* is an Eurasian species extensively distributed in freshwater systems from the Caspian Sea to the Baltic Sea (Säisä *et al.*, 2010). The pikeperch is viewed as a rapacious predator species owing to its morphology and behaviours (Elshoud-Oldenhave, 1979), and various studies report that it affects the population density and behaviours of prey populations after it is introduced into a new ecosystem (Campell, 1992; Brabrand and Faafeng, 1993; Smith *et al.*, 1996; Balık, 1999).

In Turkey, the pikeperch is native only to the Bafra lagoons of the Black Sea and the Terkos and Çekmece lakes in the Marmara region (Balık, 1999). However, it has been stocked in natural and artificial lakes as a fishing management purposes since the 1970s. Seyhan Dam Lake, the southernmost area in which pikeperch occur, is also one of the artificial lakes in which pikeperch are stocked for management purposes. Only a few studies of these stocked populations have been conducted (Balık *et al*., 2006; Becer, 2007) and none of them included the Seyhan Dam Lake.

In this study, the changes of feeding preferences of Pike Perch have been evaluated by considering periods, length classes, maturity and spawning season. Additionally, the temporal changes of feeding intensity and its spawning season dependency have been assessed.

Materials and Methods

The field study reported here was conducted from July 2009 through June 2010. Monthly experimental fishing operations were conducted in different parts of Seyhan Dam Lake using gillnets with different mesh sizes (36, 40, 44, 48, 52, 56 and 60 mm) (Figure 1). A total of 602 pikeperch were caught, 257 of them have empty stomachs (Table 1).

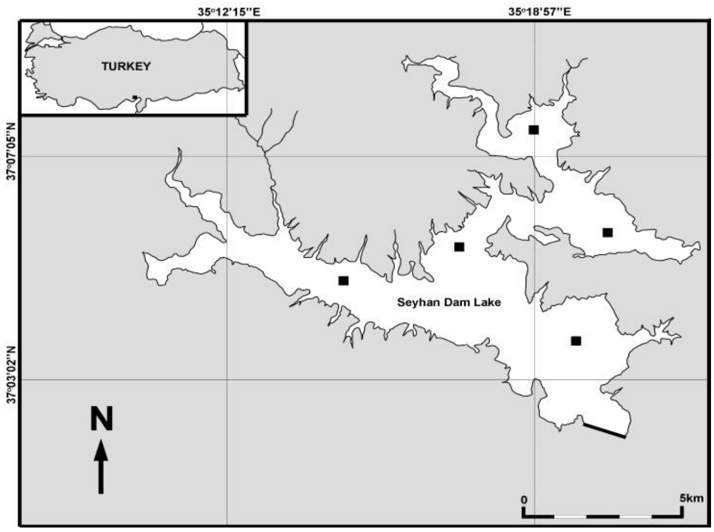

Figure 1. Seyhan Dam Lake and sampling stations (■).

Table 1. Sampling design and distribution of empty stomachs

Operation Date	n	Non-empty	Empty	%
18.07.2007	49	31	18	63.27
17.08.2007	44	26	18	59.09
18.09.2007	50	25	25	50.00
19.10.2007	50	31	19	62.00
17.11.2007	50	37	13	74.00
16.12.2007	34	19	15	55.88
20.01.2008	30	16	14	53.33
15.02.2008	36	12	24	33.33
18.03.2008	57	55	2	96.49
18.04.2008	52	27	25	51.92
14.05.2008	97	39	58	40.21
24.06.2008	53	27	26	50.94

A solution of 4% formaldehyde was injected into the stomach for analysis of the prey. The total length and weight of each specimen collected were measured in laboratory with 1 mm and 1 g respectively. Individual fish were dissected and categorised by sex, and their gonads were weighed. The stomach contents were identified to the lowest taxonomic level. The length, weight and number of all dietary items detected in the pikeperch stomachs were recorded.

The monthly changes in the gonadosomatic Index (GSI= (Gonad Weight / (Body Weight – Gonad Weight) * 100)) were used for determining the timing of the reproductive period (Gibson and Ezzi, 1978).

Three indices were used to quantify the importance of different dietary groups (Berg, 1979; Hyslop, 1980).

a.The percentage frequency of occurrence (%FO) shows the percentage of stomachs in which a dietary group was found relative to the total number of non-empty stomachs.

b. The percentage numerical abundance (%N) shows the relative number of each dietary group as a percentage of the total number of all prey individuals obtained in all the stomach contents investigated.

c. The percentage of prey weight (%W) shows the proportional wet weight of each dietary group as a percentage of all observed dietary groups.

The index of relative importance (IRI) (Hacunda, 1981) and an additional graphical method, the Weighted Resultant Index (R) (Marshall and Elliott, 1997) were used to determine the major dietary groups of pikeperch. The IRI values calculated using the following equation:

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

For calculating the Weighted Resultant Index values, the following equation was used:

$$R = \frac{Q(w_i^2 + fo_i^2)^{1/2}}{\sum_{i=1}^{n} Q(w_i^2 + fo_i^2)^{1/2}} 100$$

In this equation,

$$Q = \frac{45 - |\theta_1 - 45|}{45}$$

$$\theta_1 = tan^{-1}(fo_i / w_i)$$

w_i : Percentage of prey weight of i. prey category

fo_i : Frequency of occurrence of i. prey category

n : total number of dietary categories classified within a given month.

The Q, value in the Weighted Resultant Index, weights the relative importance of each prey category by incorporating the frequency of occurrence and percentage of prey weight. This method decreases the relative influence of large prey items found in few stomachs and small prey items found in many stomachs. By doing so, it provides more reliable results.

In the plot of the Weighted Resultant Index (R) (y-axis) against θ_1 (x-axis), the prey categories farther from the x-axis have a higher relative importance. A high R value indicates not only the frequency of occurrence and the percentage of prey weight are high but also these two values are balanced for a considered prey category. The θ_1=45 value on the x-axis indicates that the frequency of occurrence and the percentage of prey weight are equal. Prey categories with θ_1>45 are those for which the frequency of occurrence has the greatest influence on the relative importance, whereas prey categories with θ_1<45 are those for which the percentage of prey weight plays a decisive role (Marshall and Elliott, 1997).

The effect of spawning on food preferences of pikepearch was tested using a multivariate analysis of variance (MANOVA) (Alpar, 2003). The pikeperch individuals belonging to the same size classes were separated into mature and immature categories during the months in which higher GSI values were observed. The mature individuals obtained during the seasons of gonadal development and spawning were considered to be influenced by spawning motivation. The weight and numerical abundance of the prey categories obtained in the stomach contents of each of the pikeperch individuals were square-root transformed to enable the data to fit a bivariate normal distribution. The vector containing the transformed weight and transformed number was used as the response variable in the MANOVA model. Significant interactions among the explanatory variables, the prey categories and the maturity of the predator would indicate a difference between the food preferences of the mature (i.e. under spawning motivation) and immature individuals.

In order to analyse the food preferences of pikeperch of different sizes, the IRI values were normalised with a square-root transformation and categorised by predator size and dietary groups. A general linear model with all two-way interactions was applied. Significant interaction parameters between sizes and dietary groups would indicate changes in dietary preferences according to size.

The values of the feeding index (FI) were calculated for each month (Jardas *et al*., 2004) to determine the feeding intensity. The feeding index was calculated using the equation

$$\mathrm{FI} = \frac{\text{Total weight of stomach content}}{\text{Total weight of individual}} \times 100$$

The feeding index values were normalised, and the monthly changes in the index were analysed with one-way ANOVA (Sokal and Rohlf, 1969). The significant differences were evaluated with a Duncan multiple comparison test.

Results

During the study period, a total of 602 pikeperch individuals were examined with 257 specimens (42.7%) with empty stomachs. The sizes of the pikeperch collected varied between 14 and 56 cm. Male and female pikeperch reached the first maturity lengths of 25.6 and 26.4 total length respectively in Seyhan Dam Lake (Özyurt *et al*., 2011). The diets of sexually mature and immature individuals included items from the same types of dietary groups (MANOVA; P>0.05). This finding showed that reproductive activities did not affect dietary preferences. A total of 3921 dietary items belonging to 15 different taxonomic groups were identified in the 345 (57.3%) non-empty stomachs. The three main food categories for pikeperch collected from Seyhan Dam Lake were identified as teleosts, mysids and diptera (Table 2). Cyprinids were the most abundant family of teleosts identified. However, *Sander lucioperca* was the most important food item. This finding demonstrates that cannibalism is important among pikeperch (Table 2). The total lengths of the teleosts identified in the stomach contents of the pikeperch varied between 3 and 12 cm.

The food preferences, measured with IRI (Figure 2) and R (Figure 3), show that teleosts were the major group in the pikeperch diet between the May and November. According to the IRI values, the importance levels of teleosts and mysids were similar in the November, whereas the R values indicated that the importance level of teleosts was markedly greater than that of mysids. The reason for this difference is that the IRI values reflected the high N% value of mysids in the November (Table 3). During December and January, the importance of mysids was markedly greater than that of fish according to the IRI values,

Table 2. %FO, %N, %W and IRI values of food items of pikeperch

Dietary	F	%FO	N	%N	W	%W	IRI
Teleost	170	45.70	261	6.66	364.88	72.00	3875.63
S. lucioperca	55	14.78	129	3.29	241.38	47.63	811.72
Carassius sp.	3	0.81	8	0.20	3.87	0.76	0.84
Cyprinus carpio	4	1.08	12	0.31	19.65	3.88	4.85
Acanthalburnus sp.	1	0.27	2	0.05	0.63	0.12	0.05
Aphanius sp.	3	0.81	9	0.23	0.70	0.14	0.32
Rutilus sp.	6	1.61	17	0.43	21.34	4.21	8.08
Gambusia sp.	2	0.54	11	0.28	3.22	0.64	0.53
Tinca tinca	4	1.08	9	0.23	11.48	2.26	2.89
Siluris glanis	1	0.27	2	0.05	17.01	3.36	0.99
Abramis sp.	2	0.54	4	0.10	14.65	2.89	1.73
Teleostei sp.	89	23.92	58	1.48	30.95	6.11	195.71
Mysids	146	39.25	1809	46.14	87.34	17.23	2681.72
Diptera	53	14.25	1848	47.13	54.39	10.73	888.92
Other	3	0.81	3	0.08	0.19	0.04	0.10
Isopods	1	0.27	1	0.03	0.03	0.01	0.01
Odonata	1	0.27	1	0.03	0.02	0.00	0.01
Gastropoda	1	0.27	1	0.03	0.14	0.03	0.02

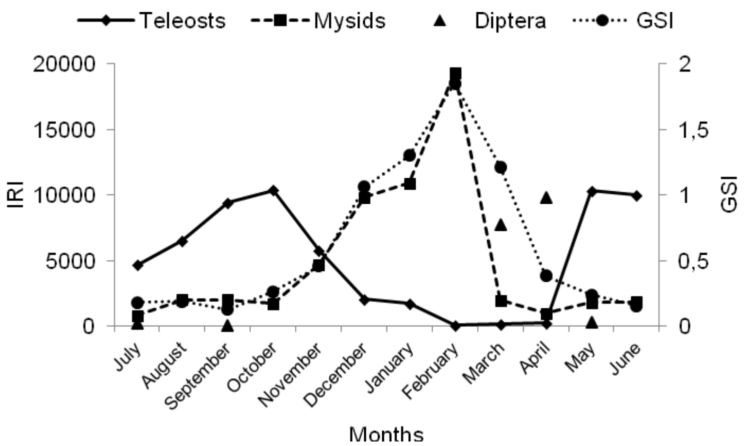

Figure 2. Monthly variation of GSI and IRI index for the main prey group of pikepearch in the Seyhan Dam Lake.

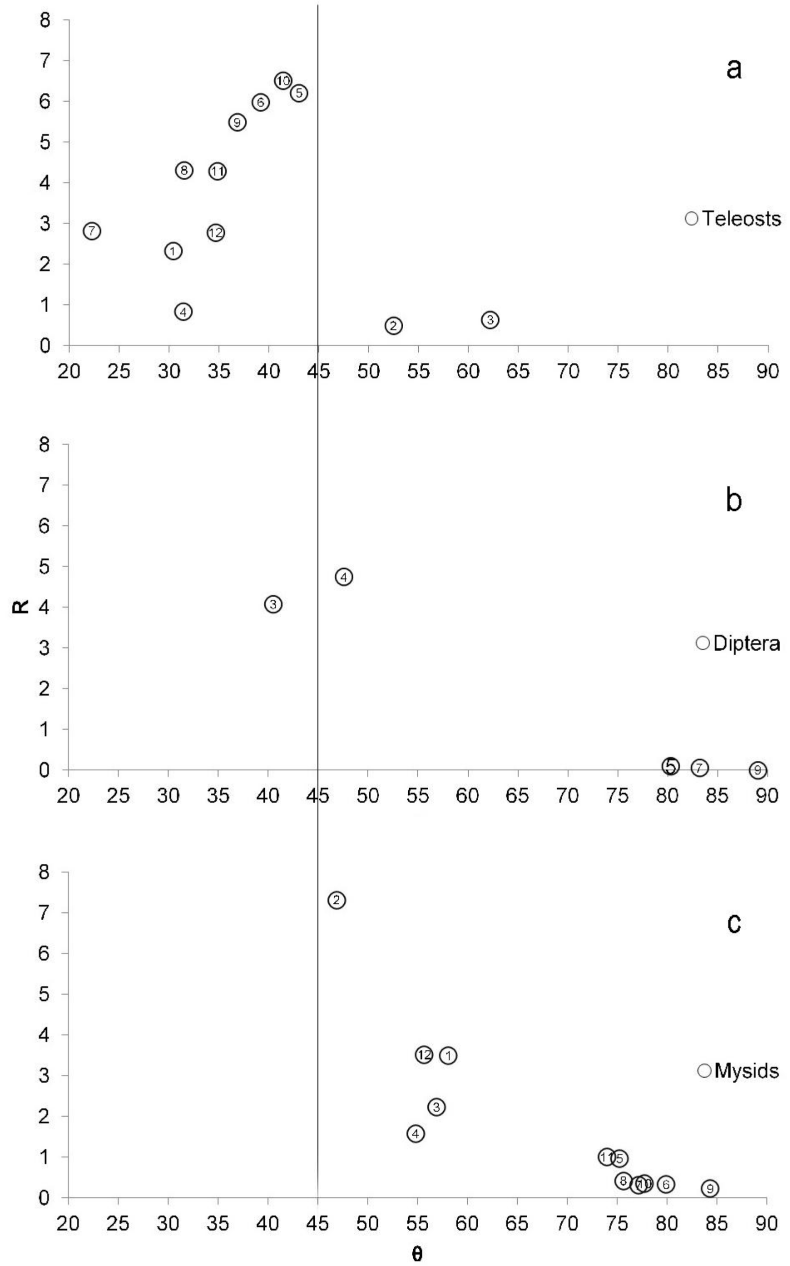

Figure 3. Monthly R values of teleosts (a), mysid (b), dipter (c) as pikeperch prey.

Table 3. Monthly variations in %FO, %N and %W values of dietary groups

Months	Teleosts			Mysids			Diptera		
	%FO	%N	%W	%FO	%N	%W	%FO	%N	%W
July	60.00	25.93	94.83	30.00	38.89	4.42	10.00	35.19	0.76
Aug.	71.43	19.23	94.10	28.57	80.77	5.90	-	-	-
Sep.	66.67	33.90	96.74	29.63	59.32	3.20	3.70	6.78	0.07
Oct.	78.79	28.77	95.10	21.21	71.73	4.90	-	-	-
Nov.	53.85	16.56	85.38	46.15	83.44	14.62	-	-	-
Dec.	35.00	2.79	53.32	65.00	97.21	46.68	-	-	-
Jan.	29.41	1.38	53.32	70.59	98.62	46.68	-	-	-
Feb.	7.69	0.22	6.40	92.31	99.78	93.60	-	-	-
Mar.	14.29	0.79	8.63	39.68	13.63	29.64	46.03	85.58	61.73
Apr.	10.34	1.22	18.18	27.59	12.41	20.89	62.07	86.37	60.92
May	57.41	44.79	85.20	37.04	21.88	13.50	5.56	33.33	1.30
June	75.00	33.33	95.39	25.00	66.67	4.61	-	-	-

whereas the R index indicated a similar dietary relevance of the two groups. The difference between the two indices was also due to the high N% value of mysids during that period. In February, the importance level of mysids was considerably higher than the importance of other dietary groups. In March and April, diptera were the main food category.

The samples included 13 pikeperch smaller than 18 cm and 6 pikeperch larger than 35 cm. Individuals smaller than 19 cm and individuals larger than 35 cm were placed in separate size categories. The ANOVA results showed that the two-way interaction between size and dietary group was highly significant ($P<0.01$). Diptera was the major dietary group for the individuals smaller than 19 cm. In the other size classes, teleosts were the main food category (Table 4).

The monthly changes in the FI were significant ($P<0.01$). Feeding intensity was higher in the October and March. The GSI values increased gradually between the October and February, whereas the FI showed fluctuations with picks in October and March and minimum values in January, February, April, July, August and September (Figure 4). These results indicated that feeding intensity decreased in individuals affected by reproductive motivation.

Discussion

Zooplankton are the first food item in the diet of larval pikeperch (Erm, 1976). Pikeperch become piscivorous during their first summer. When they reach a length of 2 or 3 cm, fish become a very significant part of their diet (Erm, 1976; Thiel, 1987). Mysids may be an important prey item for larger pikeperch, especially if fish larvae are not available (Lehtonen *et al*., 1996). Fish become dominant in the pikeperch diet beginning in the second year of life (Lehtonen *et al*., 1996). However, pikeperch are opportunistic feeders (Salonen *et al*., 1996), and dietary composition may vary among areas (Kangur and Kangur, 1998). For example, smelt and perch are the most important dietary items of pikeperch in boreal lakes (Peltonen *et al*., 1996; Vehanen *et al.*, 1998). Cyprinids are the most important dietary item of pikeperch in the lakes of Middle Europe (Dörner *et al*., 2007). In some lakes of middle Anatolia, such as Beysehir and Egridir Lakes, *Gammarus* sp. and *Mysis* sp. are the most important items in the pikeperch diet (Balık, 1999; Becer and İkiz, 1996).

The results of this study show that the most important dietary groups for the size classes smaller than 19 cm were diptera and mysids and that teleosts were preferred by the larger size groups. The study of Özyurt (2000) showed that the one-year-old pikeperch at Seyhan Dam Lake reached a length of 18-19 cm. Therefore, although the most important dietary groups for the pikeperch until one year of age are diptera and mysids, the dietary preference changes to fish after this age. The change in diet with increasing size is consistent with the observation (Lehtonen *et al*., 1996) that prey such as mysids may be particularly important in the pikeperch diet over the course of several years, especially if no fish larvae are

Table 4. IRI values of the important dietary groups according to predator size classes

Size Classes (cm)	IRI		
	Teleosts	Mysids	Diptera
≥19	1674	2933	5512
20-22	3705	3356	1019
23-25	2843	2141	1108
26-28	3355	3303	506
29-31	5885	14	2013
32-34	6255	152	1727
≥35	4444	2443	693

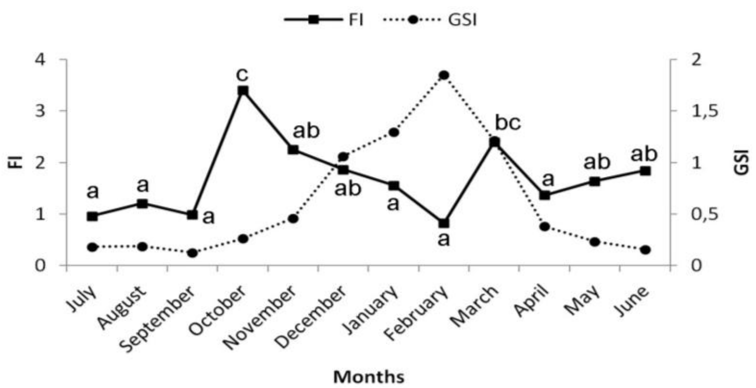

Figure 4. Monthly changes in FI and GSI values. Different letters represent significant differences (Duncan Test, $P<0.05$).

available.

The analysis of the monthly changes in IRI and R values shows that pikeperch strongly preferred teleosts during the period between the May and November and that their preference changed to mysids and diptera during the reproductive period, between the January and March. However, the results of the study showed that this change in preferences was not linked to reproductive activity. This finding supports the hypothesis that the changes in dietary preferences are related to prey availability. Moreover, the fact that cannibalism is frequent among pikeperch may further indicate the difficulty of finding fish prey. High rates of cannibalism indicate that food availability and quality are low (Yılmaz and Ablak 2003; Lappalainen *et al*., 2006). Therefore, cannibalism is viewed as a form of adaptation to insufficient feeding conditions (Nikolskii, 1969). If food availability is low, adult individuals that are unable to feed on zooplankton complete the missing or weak trophic level by consuming younger individuals that feed on zooplankton (Nikolskii, 1969). As shown by this study, teleosts once again become the important dietary group after the reproductive period. The high cannibalism ratio supports the assumption that pikeperch feed on the current year class. The pikeperch is a gape-limited predator (Salonen *et al*., 1996), and the size of its prey can only reach 50% of its own size (Keskiner, 2008). The largest prey found in the stomachs of pikeperch collected in this study were 12 cm long, and one-year-old pikeperch reach a length of 18-19 cm in this area (Özyurt, 2000). Accordingly, it could be hypothesised that the new pikeperch cohort emerging each February of each year in Seyhan Dam Lake is consumed by previous year classes until the members of the new cohort reach a length of 12 cm. This cohort probably reaches a length at which they are no longer vulnerable by December (>12 cm). The previous year classes must then feed on other available dietary groups, namely mysids and diptera. These considerations indicate that the changes in the dietary preferences of pikeperch during the year are related to the abundance of available dietary groups.

It is well known that the feeding intensity of fish changes in relation to reproductive periods. Many studies of various fish species report that feeding intensity increases before and after the reproductive period (Sirotenko and Istomin, 1978; Argillier *et al.*, 2003; Jardas *et al*., 2004) and decreases before spawning (Jardas and Palaro, 1991; Dulcic, 1996; Fordham and Trppel, 1999; Jardas *et al*., 2004; Becer, 2007). These changes are associated with the substantial enlargement of the gonads, which occupy most of the body cavity and compress the stomach (Golikatte and Bhat, 2011). They are also related to physiological changes that occur during the reproductive period (Jardas *et al*., 2004). The results of this study also indicate that pikeperch feeding is very intense before reproduction (during the October). It decreases until the February, when the eggs are laid, and increases again during the 3rd month, after spawning.

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