

Food and Feeding Habits of the Pikeperch, *Sander lucioperca* (Linnaeus, 1758), Population from Lake Eğirdir (Turkey)

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Abstract: The stomach contents of 986 pikeperch, *Sander lucioperca* (Linnaeus, 1758), collected from Lake Eğirdir in Turkey were investigated between March 2001 and February 2002. Thirteen taxonomic categories were identified from the 1745 prey items analysed. It was determined that the diet of pikeperch in Lake Eğirdir consisted of some fish species (*Knipowitschia* sp., *Aphanius anatoliae anatoliae*, *Gambusia affinis*, *Nemacheilus lendli*, *Carassius gibelio*, and *Sander lucioperca*), odonats (*Calopteryx splendens*), mysids (*Mysis*), amphipods (*Gammarus*) and dipterans (*Chironomus*). Of these prey categories, fish was more important than the others. In particular, *Knipowitschia* sp. and *A. a. anatoliae* were the primary prey for the pikeperch. The proportions of vertebrates and invertebrates in the diet composition of pikeperch in the 150-190 mm length class were found roughly equal. The importance of vertebrates (especially prey fish) in the diet of the pikeperch in Lake Eğirdir increased with increasing body size of fish, but, at the same time, the importance of invertebrates decreased. Pikeperch longer than 300 mm consumed only fish, frogs and odonats. The cannibalism rate was 0.6%. In addition, it was found that the diet of the pikeperch in Lake Eğirdir considerably changed from season to season.

Key Words: Pikeperch, *Sander lucioperca*, food, feeding habit, Lake Eğirdir

Eğirdir Gölü'ndeki (Türkiye) Sudak, *Sander lucioperca* (Linnaeus, 1758) Populasyonunun Besin ve Beslenme Alışkanlıkları

Özet: Bu çalışmada, Mart 2001 ile Şubat 2002 tarihleri arasında Eğirdir Gölü'nden yakalanan 986 sudak, *Sander lucioperca* (Linnaeus, 1758) örneğinin mide içeriği incelenmiştir. Analiz edilen 1745 besinin 13 taksonomik kategoriye ait oldukları tespit edilmiştir. Sudak balıklarının başlıca besinlerini; bazı balık türleri (*Knipowitschia* sp., *Aphanius anatoliae anatoliae*, *Gambusia affinis*, *Nemacheilus lendli*, *Carassius gibelio*, *Sander lucioperca*), odonat (*Calopteryx splendens*), mysid (*Mysis*), amphipod (*Gammarus*) ve diptera (*Chironomus*) örnekleri oluşturmuştur. Bu besin kategorilerinden balıklar, diğerlerine göre daha önemlidir. Özellikle *Knipowitschia* sp. ve *A. a. anatoliae*, Eğirdir Gölü'ndeki sudağın en önemli besinleridir. Omurgalı ve omurgasız organizmaların 150-190 mm boy sınıfındaki sudakların besin kompozisyonundaki oranları hemen hemen eşit bulunmuştur. Eğirdir Gölü'ndeki sudağın beslenmesinde, omurgalıların (özellikle yem balıkları) oranı balık büyüklüğündeki artışa bağlı olarak artar iken, omurgasızların önemi azalmıştır. Sudağın 300 mm'den büyükleri sadece balık, kurbağa ve odonatlar ile beslenmektedirler. Kanibalizm oranı % 0,6 olarak saptanmıştır. Ayrıca, Eğirdir Gölü'ndeki sudak beslenme rejiminin mevsimlere göre önemli oranda değiştiği belirlenmiştir.

Anahtar Sözcükler: Sudak, *Sander lucioperca*, besin, beslenme alışkanlıkları, Lake Eğirdir

Introduction

The pikeperch, *Sander lucioperca* (Linnaeus, 1758), is a specialised piscivore that switches to a fish diet the first summer at a length of about 50-100 mm (Popova and Sytina, 1977; Willemsen, 1977; Hansson et al., 1997). Piscivory is often an important structuring force in freshwater ecosystems. Prey fish populations are directly affected by predation of piscivorous fish, e.g., a reduction in population density or an alteration in the size structure.

In addition, prey fish may change their behaviour, e.g., foraging behaviour, microhabitat use, and activity pattern, in response to predators (Turesson et al., 2002). Both direct lethal effects and indirect behavioural effects of piscivorous fish on prey fish populations may in turn have complex effects on lower trophic levels. Thus, an interaction between predator and prey should be well observed in freshwater systems inhabited by predators.

According to Sarihan (1970), prior to the introduction of the pikeperch, there were 10 fish species in this lake. These species were *Cyprinus carpio*, *Vimba vimba*, *Capoeta pestai* (*Varicorhinus pestai*), *Pseudophoxinus handlirschi* (*Acanthorutilus handlirschi*), *Crossocheilus klatti* (*Thylognatus klatti*), *Phoxinellus zeregii* (*Pararhodeus niger*), *Schizothorax prophyllax*, *Cobitis taenia*, *Nemacheilus angorae* and *Aphanius chantrei*. The pikeperch was introduced into this lake in 1955 in order to utilise forage fish production and to increase the value of the fisheries (Akşiray, 1961; Sarihan, 1970). Pikeperch at first grew well and reproduced rapidly in the lake and then they became the dominant fish species of the lake (Sarihan, 1970). The annual catch of pikeperch in Lake Eğirdir was about 100 t at the beginning of the 1960s. It increased gradually until the end of the 1970s and rose to 482 t in 1979 (Ekmeççi and Erk'akan, 1997). However, the annual pikeperch catch has decreased gradually since the early 1980s and it was only 50 t in 2001 (Balık et al., 2002). Furthermore, by the late 1980s, 7 of the original 10 native species had disappeared from the lake because of predation by the introduced pikeperch.

At the beginning of the 1990s, the silver crucian carp, *Carassius gibelio*, was accidentally introduced into Lake Eğirdir. In a few years at the end of the 1990s this species became the dominant fish species and replaced pikeperch in the lake (Balık et al., 2004a). In addition, *K. caucasica* lives in this lake and this species is also an introduced species. These new introduced fish species naturally affected the populations and production values of the other fish species in the lake. The productivity of fish species may be affected by excessive increases or decreases in piscivorous fish in their habitats. Therefore, especially changes in the density and diet of pikeperch should be carefully observed continuously. For this reason, in this study the diet and feeding behaviour of the pikeperch in Lake Eğirdir were investigated.

Materials and Methods

Lake Eğirdir is located in south-west Anatolia in Turkey. It has a surface area of 468 km² and is at an altitude of 918 m. The mean depth of Lake Eğirdir is about 8-9 m. Fish specimens were collected monthly in 4 different localities of Lake Eğirdir (Figure 1) between March 2001 and February 2002. Fishing was carried out

with gillnets of mesh size (stretched mesh) of 36, 40, 44, 50 and 64 mm and trammel nets of mesh size of 56, 80, 100, 120 and 140 mm. The fork length of each pikeperch was measured to the nearest millimetre. The stomachs of the specimens were immediately removed and put in a plastic bag separately and then fixed in 4% buffered formalin (Buije and Houthuijzen, 1992) and labelled. Thereafter, stomachs were opened in the laboratory and their contents were analysed. Prey items were identified to the lowest taxonomic level possible.

Fish specimens were divided into 4 length groups (150-190, 200-240, 250-290 and 300-340 mm) to analyse their size-dependent dietary variations. In addition, seasonal variations in diet were investigated. Percent number and frequency of occurrence were used to estimate the dietary importance of each prey category (Duarte and García, 1999; García-Berthou, 2001; Hurst and Conover, 2001):

Percent number = $100 \cdot \frac{\text{The number of prey } i}{\text{The number of all identifiable preys}}$

Frequency of occurrence = $100 \cdot \frac{\text{The number of stomachs with prey } i}{\text{The number of stomachs with food item}}$

Unidentified food items were not used in the calculations. Diet similarity among length classes and seasons was investigated using the Schoener Overlap Index (Schoener, 1970) (C):

$$C_{xy} = 1 - 0.5 \cdot \sum |p_{xi} - p_{yi}|$$

where p_{xi} and p_{yi} 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 2 groups is similar.

The extent of the diet was calculated using the diversity index of Shannon-Wiener (H):

$$H' = - \sum p_i \cdot \log_2 p_i$$

where p_i is the proportion by the number of prey type i . This index has adequate sensitivity for detecting changes in species diversity and provides a general indication of the relative magnitude of trophic specialisation (Berg, 1979).



Figure 1. Map of Lake Eğirdir showing sampling localities.

Results

The diet composition of pikeperch

During the study, the stomachs of 986 pikeperch 150-340 mm in length were examined. The number, mean lengths and weights of pikeperch samples are given in Table 1.

It was determined that 46.8% of them were empty. A total of 1745 intact organisms representing 13 species belonging to 8 prey categories were analysed in the stomachs (Table 2). Of these categories, only fish consisted of 6 different species. Each of the other prey categories was represented by only one prey species.

The diet of pikeperch mainly consisted of fish, odonats, mysids, amphipods and dipterans, respectively (Table 2 and Figure 2). The most important prey for the pikeperch in Lake Eğirdir were 2 fish species, *Knipowitschia* sp. and *Aphanius anatoliae anatoliae*, both in terms of percentage and frequency of occurrence.

Table 1. The number (n), mean fork length (FL) and weight (W) of pikeperch samples by length classes.

Length class (mm)	n	FL \pm SD (Min.-Max.)	W \pm SD (Min.-Max.)
150-190	492	178 \pm 10 (150-190)	57 \pm 15 (33-219)
200-240	356	213 \pm 13 (200-240)	95 \pm 22 (50-175)
250-290	117	266 \pm 13 (250-290)	187 \pm 32 (78-263)
300-340	21	315 \pm 13 (300-340)	314 \pm 64 (201-460)

Table 2. Diet of pikeperch in Lake Eğirdir: percentage and frequency of occurrence of the main prey components. Number of stomach analysed = 503; total number of prey in the stomach contents = 1745.

Prey category	Scientific name	Percentage	Frequency of occurrence
Fish	<i>Knipowitschia</i> sp.	24.4	20.9
	<i>Aphanius anatoliae anatoliae</i>	21.8	25.1
	<i>Gambusia affinis</i>	3.8	7.2
	<i>Nemacheilus lendli</i>	1.7	4.2
	<i>Carassius gibelio</i>	0.2	0.6
	<i>Sander lucioperca</i>	0.2	0.6
	Total	52.1	58.6
Frog	<i>Rana</i>	2.2	5.8
Leech	<i>Hirundo</i>	0.1	0.2
Odonat	<i>Calopteryx splendens</i>	18.8	15.3
Dipterian	<i>Chironomus</i>	5.1	6.0
Mysid	<i>Mysis</i>	12.7	11.3
Amphipod	<i>Gammarus</i>	8.9	7.4
Gastropod	<i>Graecoanatica</i>	0.1	0.4

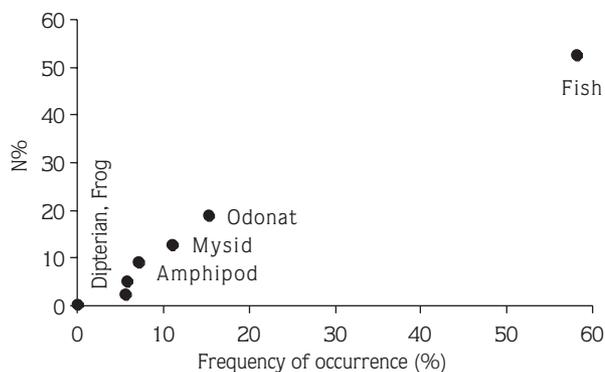


Figure 2. Relative importance of the stomach contents.

Diet variation by fish size

It was determined that prey fish were the most important food for the pikeperch of 150-340 mm length. Frequencies of occurrence of fish category were nearly the same in all length classes for the fish specimens examined, but their percentages increased with pikeperch length. As shown in Figure 3, the most important preys of individuals in the 150-190 mm and 200-240 mm length classes consisted of some fish species, odonats, mysids and amphipods. According to the Schoener Overlap Index (C), the feeding of pikeperch in these 2 length classes was also similar (C = 0.833). However, except for the relation between these length groups

(150-190 and 200-240 mm) the other comparisons for all the length classes were significantly different (C < 0.8) from each other (150-190, 200-240, 250-290 and 300-340 mm).

In addition to prey fish, pikeperch in the 250-290 mm length class also fed on odonats, frogs, mysids and dipterans. In the stomachs of pikeperch of the 300-340 mm length class only fish, frogs and odonats were found. According to the Shannon-Wiener Index, prey diversity of the 300-340 length class was the lowest (H = 1.884, 1.894, 1.752 and 1.460 for the length classes of 150-190, 200-240, 250-290 and 300-340 mm, respectively). Odonats were important for the feeding of pikeperch smaller than 300 mm, but their importance was significantly lower in the 300-340 mm length class. Amphipods and mysids were consumed only by the pikeperch smaller than 250 mm length. Frogs were generally important for the feeding of the pikeperch above 250 mm length.

Seasonal variation of diet composition

The rates of empty stomachs were nearly the same in spring and summer, while they were less than autumn and winter. However, this rate increased gradually from summer to winter (Table 3).

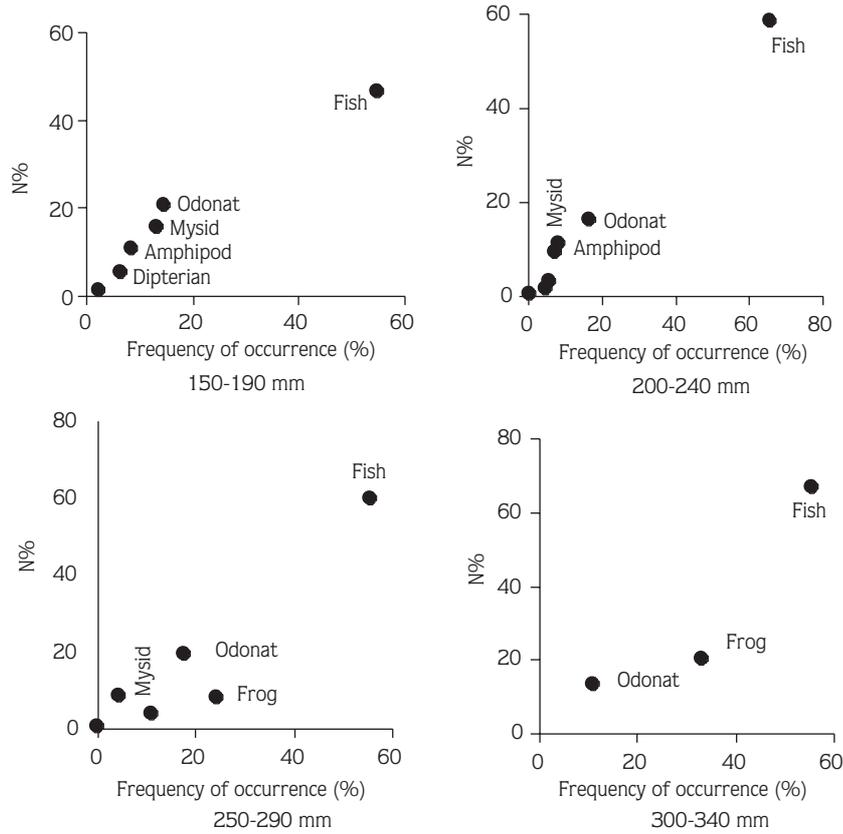


Figure 3. Relative importance of the stomach contents in length classes.

Table 3. Seasonal variations of the percentages of empty stomachs.

	Spring	Summer	Autumn	Winter
No. of stomachs examined	191	409	308	78
No. of stomachs with prey	103	218	154	28
% empty stomachs	46.1	46.7	50.0	64.1
Fork length range (FL, mm)	150-320	150-340	150-330	160-340
FL ± SD	200 ± 34	207 ± 33	201 ± 37	209 ± 37
Weight range (W, g)	33 - 346	42 - 393	28 - 376	38 - 460
W ± SD	86.8 ± 50.2	91.4 ± 53.0	92.9 ± 58.1	102.9 ± 77.8
Water temperature (°C)	10 - 20	20 - 26	10 - 21	0 - 7

The seasonal trends of percentage and frequency of occurrence for prey categories are shown in Figure 4. In spring, the most important prey was *A. a. anatoliae* from fish category. Dipterans, mysids and amphipods were also important prey during this season. Both percentages and

frequency of occurrence of the fish category decreased from spring to summer. The variety of prey in summer was higher than in the other seasons ($H' = 1.393, 1.885, 1.334$ and 1.247 for spring, summer, autumn and winter, respectively). All prey groups were present in the

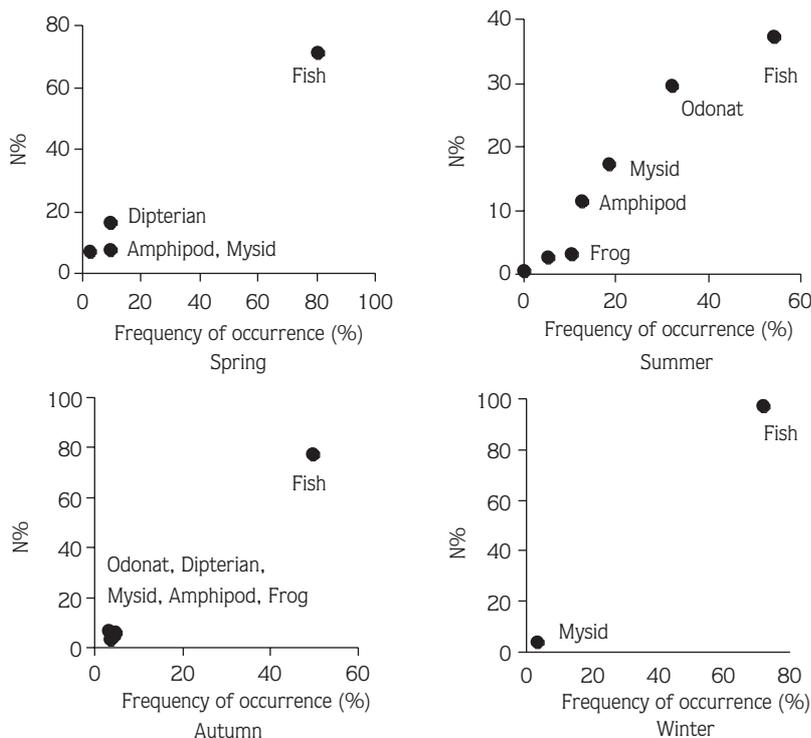


Figure 4. Relative importance of the stomach contents by seasons.

stomachs in this season. In autumn, *Knipowitschia* sp. from prey fish was the most important prey for the feeding of pikeperch. Mysids, odonats, dipterans, amphipods and frogs were the other important prey during this season. In winter, the variety of prey was lower than that in the other seasons. In this season, only some fish species and mysids were observed in the stomach contents. The proportion of fish was 96.7%.

Fish was the most important prey category in all seasons. The importance of the other prey categories varied from season to season. Frogs and dipterans were represented only in the summer and autumn diets. In addition, leeches and gastropods were observed only in the summer diets. These variations in the diet compositions of seasons and Schoener Overlap Index values showed that there was no feeding similarity among the seasons ($C < 0.80$).

Discussion

The results of this study showed that the diet of the pikeperch in Lake Eğirdir consisted mainly of some fish

species (52.1%), odonats (18.7%), mysids (12.7%), amphipods (8.9%) and dipterans (5.0%). Of these food items, fish were more important than the others. Especially *Knipowitschia* sp. (24.4%) and *A. a. anatoliae* (21.8%) were the primary prey fish for the pikeperch in Lake Eğirdir. Similarly, *Knipowitschia* sp. was also found to be the most important prey fish for the pikeperch in Demirköprü Dam Lake in Turkey (Sarı, 1995). The diet of the pikeperch in Lake Eğirdir was investigated by Campbell (1992) in 1988 and 1989. He reported that the diet consisted of mysids, gammarids, isopods and fish. In the same lake, Ekmekçi and Erk'akan (1997) found that the pikeperch of 20-30 cm length usually ate amphipods, mysids, crayfish, insects and their own young about 10 years ago.

In the length class of 150-190 mm, the stomach contents consisted of roughly equal proportions of fish and invertebrates. The proportions of invertebrates in the diet composition of pikeperch in the 200-240, 250-290 and 300-340 mm length classes were 40.2%, 32.3% and 13.3%, respectively. It is clear from these values that the importance of invertebrates decreased gradually with

the increase in pikeperch size and it is replaced by fish and frogs. Hansson et al. (1997), Balık (1999), and Yılmaz and Ablak (2003) have also found similar results in Baltic Sea areas, in Lake Beyşehir and in Hirfanlı Dam Lake in Turkey, respectively. The diet of pikeperch of 200-290 mm length in Lake Eğirdir consisted of fish (mostly *Knipowitschia* sp. and *A. a. anatoliae*), odonats, mysids, amphipods and frogs. However, pikeperch of 300-340 mm length consumed only *Knipowitschia* sp., *A. a. anatoliae* and *N. lendli* of prey fish, frogs and odonats. Invertebrate preys except odonats were important only for the feeding of pikeperch smaller than 300 mm. In terms of percentage, the rate of fish in the diet of pikeperch of 150-190 mm length class was 46.4% and it increased with pikeperch size. As pointed out by Popova and Sytina (1977), the pikeperch can become piscivorous within a few months after hatching, and by 4-10 cm long it begins to eat the fry of other fishes. It may continue feeding on mysids and gammarids up to age 2, even while feeding on the young of other fishes, and especially if these invertebrates are abundant and prey fish are scarce.

The cannibalism rate in this study was 0.6% for the pikeperch population. This rate was reported as 96% by Campbell (1992) for the pikeperch in the same lake at the end of the 1980s. According to Ekmekçi and Erk'akan (1997), the cannibalism rate was 1%-5% for individuals smaller than 35 cm in 1991. This rate was 44% for pikeperch larger than 35 cm and 100% for individuals larger than 40 cm. In Ekmekçi and Erk'akan's (1997) study on changes in the pikeperch population 8 of 10 native fish species had disappeared from the lake for various reasons. Pikeperch in the lake tended to cannibalise because of the decrease in prey fish species. In addition, it was stressed that the rate of small individuals in the pikeperch population increased due to intensive fishing pressure. These comparisons showed that the diet composition of the pikeperch in Lake Eğirdir changed significantly over the last decade and the cannibalism decreased. In recent years, this situation may be attributed to the prey abundance of the pikeperch in the lake. The average cannibalism rate for other some pikeperch populations was reported as 0.14% in Lake IJssel and 4% in Veluwemeer in the Netherlands (Willemsen, 1977), 20.9% in Lake Beyşehir in Turkey (Balık, 1999) and 40.5% in Hirfanlı Dam Lake (Yılmaz and Ablak, 2003). These variations of cannibalism rates in Lake Eğirdir indicated that the pikeperch eat their own

young when only forage fish were scarce. It seems that in recent years the population of prey fishes (especially *Knipowitschia* sp. and *A. a. anatoliae*) increased together with the increasing stock density of the silver crucian carp in Lake Eğirdir, and the pikeperch preferred to eat these prey fish instead of their own young.

The ratios of empty stomachs were similar in spring and summer, but increased from summer to winter. Likely, this was related to the low water temperature in the winter period. During the study, the water temperature of the lake decreased to 4-5 °C in winter, while it increased to 25-26 °C in summer. In spring, pikeperch fed on fish, dipterans, mysids and amphipods. Especially *A. a. anatoliae* was the most important prey for feeding pikeperch in this season. The importance of fish decreased from spring to summer and it was replaced especially by odonats, mysids and amphipods. All prey varieties were represented in this season. In autumn, the percentage of prey fish increased again. About 65% of diet composition consisted of only *Knipowitschia* sp. from prey fish. Contrary to fish, the importance of invertebrates decreased in this season. The winter diet of pikeperch consisted of only fish and mysids.

As pointed out by Keskinen and Marjomäki (2004), the pikeperch is a flexible predator. The size and species of prey consumed changes with pikeperch sizes and the availability prey spectrum. The seasonal diet compositions showed that the diet and feeding habits of the pikeperch in Lake Eğirdir changed considerably from season to season. Although their summer diets included all the prey taxa, in the winter diets only some fish species and mysids were found. The variability in the seasonal trends of the various prey categories is also related to the seasonal availability of the different food sources (Lorenzoni et al., 2002). In summer and autumn, about 50% of the pikeperch were piscivorous or carnivorous while this rate was more than 70% in winter and spring. It is clear that the interaction between prey and predator is very important in the lakes inhabited by pikeperch, because the pikeperch is an ambush-pursuit predator that feeds at low light intensities or even at night (Popova and Sytina, 1977). The daily ration of pikeperch during the most intensive feeding period constitutes 4.5%-5.5% of the body weight and decreases to 0.5% during periods of less intensive feeding. The annual ration is 200%-250% of its body weight (Popova and Sytina, 1977).

Consequently, the diet of the pikeperch in Lake Eğirdir has changed significantly over the last decade. In addition, their average condition factor increased from the 1970s ($K \approx 0.9$) to 2002 ($K=0.992$) because of an increase in the number and abundance of prey fish such as *Knipowitschia* sp., *A. a. anatoliae*, *G. affinis* and *N. lendli*, and a decrease in the pikeperch population (Balık et al.,

2004b). If the pikeperch excessively increase or prey fish excessively decrease in the lake, the rate of cannibalism among the pikeperch may increase again, affecting negatively the lake fishery. Therefore, the populations of fish species and the diet composition of pikeperch should be observed continuously for economic fisheries and the future of fish species in the lake.

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