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FOOD OF PIKE, *Esox lucius* L., IN LAKE PEIPSI

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Abstract. The distribution of the predatory pressure of pike over different prey species in large eutrophic L. Peipsi was studied. In 1995–98, 415 pike with a standard length of 21.5–105 cm were dissected and their stomach contents were analysed. Of the examined stomachs 42–45% were empty. The diet of pike included at least eight prey fish species, the most frequent being ruffe, smelt, and perch. The same species dominated in the diet numerically. Smelt was the commonest fish species in the diet of smaller pike (Sl < 40 cm). The proportion of smelt decreased in the food of pike with size, whereas that of ruffe increased. Cannibalism did not play an important role in the recent feeding of pike. In comparison with data from 1960–63 (Pihu, E. 1966. The importance of pike, perch, pikeperch and burbot as biological control in Lake Peipsi–Pskov. In *Hydrobiological Researches*, Vol. 4, pp. 235–248. Valgus, Tallinn (in Russian)), the proportion of pikeperch in the food of pike was greater.

Key words: pike, diet composition, size-related changes, Lake Peipsi.

INTRODUCTION

Northern pike, *Esox lucius* L., is a top piscivore of freshwater ecosystems in North America and Eurasia (Raat, 1988; Treasurer & Owen, 1991; Craig, 1996). Pike is common in diverse fish assemblages, which may include cyprinids, percids, and salmonids (Treasurer, 1998). Although pike inhabit a wide climatic range and their distribution area in Eurasia extends to the Arctic and thus are found at temperatures as low as 0.1°C, they are best adapted to shallow, moderately productive mesotrophic-eutrophic fresh waters (Casselman, 1996). This species is most successful in lakes with abundant aquatic vegetation (Grimm, 1989). Pike tend to inhabit the littoral zone (Grimm, 1981) and depend on vegetation and clear water to catch their prey (Van Densen & Grimm, 1988).

In Estonian lakes, pike is the most common predatory fish, and its ecological importance is great. This fish species is unpretentious and resistant to several unfavourable living conditions, particularly to poor oxygen conditions. Pike is also very tolerant to low pH and to high organic matter content (Pihu, 1993). In large eutrophic L. Peipsi pike is of high commercial and recreational interest, although its proportion in the fish catches was modest (1.8–5.3% of annual fish catches in 1935–98).

Fish commonly depress their prey populations (Winfield et al., 1993). Pike is one of the main piscivorous fishes (beside pikeperch, *Stizostedion lucioperca* (L.); burbot, *Lota lota* (L.); and perch, *Perca fluviatilis* L.), whose role in controlling the populations of coarse fish and in maintaining a balanced fish community structure (in which consumption of prey fish by piscivorous fish equals the production of unwanted prey fish) in lakes is great (Adams, 1991; Salonen et al., 1996). Benndorf (1990) pointed out that piscivores may be able to reduce the abundance of prey species, but the prerequisites for this are a high biomass and a wide range of piscivores (e.g. 30–40% of the biomass consisting of pikeperch, pike, perch, and eel, *Anguilla anguilla* (L.)) in the waterbody. The diet of fish depends on a variety of factors such as species identity, fish size and age, patterns of activity of fish, prey size and abundance, and the co-occurrence of competing species (Lawlor, 1980; Baltanas & Rincon, 1992).

The present study discusses the diet of pike in L. Peipsi in 1995–98. The results are compared with data from 1960–63 (Pihu, 1966). The aim of the study was to consider the distribution of predatory pressure of pike over different prey species. The frequency of occurrence of prey species, as well as the number and restored weight of food items per individual are given. For a better assessment of the dietary importance of a prey group, an index of relative importance (Pinkas et al., 1971; Hacunda, 1981) was calculated. Size-related changes in the diet of pike are discussed.

STUDY AREA

Lake Peipsi in the broad sense, with a surface area of 3555 km^2, is one of the largest lakes in Europe (Jaani, 1996). It is situated on the border of Estonia and Russia. This largest international lake in Europe is divided into three unequal and morphometrically different parts: the biggest northern L. Peipsi *s.s.* (2611 km^2, mean depth 8.3 m and maximum depth 12.9 m at water level 30.01 m above sea level), southern L. Pihkva (708 km^2, maximum depth 5.3 m), and the narrow strait-like L. Lämmijärv connecting them (236 km^2, 15.3 m).

Lake Peipsi *s.s.* belongs to unstratified eutrophic lakes with mesotrophic features, L. Lämmijärv has some dyseutrophic features, while L. Pihkva is strongly eutrophic (Nõges et al., 1996). Annual water regime is characterized by the

highest water in spring, the average range of yearly fluctuations of water level being 1.15 m (Jaani, 1996). Unstable summer stratification is often disturbed by waves and currents. The ice-free period lasts usually from April to November. Maximum surface temperatures are commonly reached in July and measure on average 21–22 °C in the open region and up to 27–28 °C on shallows in some years.

The fish community of L. Peipsi is diverse: there are 33 permanent fish species and one lamprey species in the lake or in the lower reaches of its inlets (Pihu, 1996). Lake Peipsi offers more or less favourable living conditions for different ecological groups of fish. Considering its fish productivity and annual catches, L. Peipsi surpasses all large lakes in North Europe (Pihu, 1996).

The stock and catch of pike are quite scanty in L. Peipsi. This waterbody, poor in macrophytes, is not a very suitable habitat for pike. Moreover, there are few good spawning places for pike in the lake, especially with low water level (Efimova, 1966).

According to official data, the total catch of fish in the Estonian part of L. Peipsi was 3613 t in 1998, of which pike made up 98 (2.7%). The main commercial fishes were smelt (*Osmerus eperlanus* L.), perch, and pikeperch (Fig. 1). The legal size of pike in the lake is 40 cm, and the commercial pike population consists of about ten generations.

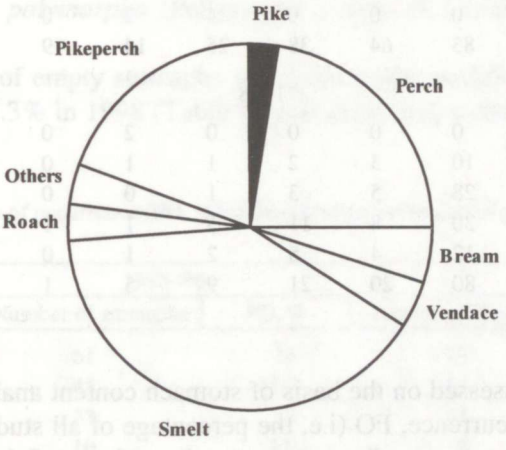

Fig. 1. Weight percentage of pike and other valuable fishes in commercial catches in L. Peipsi in 1998.

MATERIAL AND METHODS

From May 1995 to November 1996, 254 pike (Table 1) with a standard length (Sl) of 25–105 cm and from February to October 1998, 161 pike (Sl 21.5–98 cm) were dissected and their stomach contents were analysed. In 1998 we succeeded in investigating only a small number of bigger pike (Sl > 40 cm). The fish were caught in the open part of L. Peipsi *s.s.* with a Danish seine (18–22 mm cod-end mesh size) and an experimental trawl (10–14 mm cod-end mesh size). Prey fish or their remains were counted, measured, and identified. Some specimens of partly digested prey fish, not recognizable by external morphology, were not identified to the species.

Table 1. Number (*n*) and standard length (Sl, cm) of the studied pike from L. Peipsi

Month	Sl, cm									*n*
	< 30	30–39	40–49	50–59	60–69	70–79	80–89	90–99	100 <	
					1995–96					
May	0	0	2	0	1	0	0	0	0	3
June	0	1	0	5	0	0	0	0	0	6
July	6	29	17	4	0	0	1	0	0	57
August	8	35	21	9	4	4	2	1	0	84
September	0	8	14	12	5	3	1	0	1	44
October	1	10	10	8	11	5	5	3	1	54
November	0	0	0	0	4	2	0	0	0	6
Total	15	83	64	38	25	14	9	4	2	254
					1998					
February	0	0	0	0	0	2	0	0	0	2
July	9	10	3	2	1	1	0	0	0	26
August	8	28	5	3	1	0	0	2	0	47
September	5	30	8	11	5	1	1	0	0	61
October	1	12	4	5	2	1	0	0	0	25
Total	23	80	20	21	9	5	1	2	0	161

The diet was assessed on the basis of stomach content analysis and expressed as frequency of occurrence, FO (i.e. the percentage of all studied fish in which a certain prey species occurred), average number of prey fish and their restored weight per individual as well as the percentage of the number and weight of prey (i.e. the number or weight of each prey species expressed as the percentage of the number and weight of all observed prey species, respectively). The length–weight ratio of the fish species sampled from the lake (Kangur, 2000) was used to estimate the restored weight of the prey fish in the stomach according to their standard length.

To evaluate the importance of a food taxon the index of relative importance, IRI (Pinkas et al., 1971; Hacunda, 1981), was calculated. This index assists in evaluating the relationship of the various food items found in stomachs. It combines the numerical, weight, and FO measurements into one value and enables to rank each prey species. The formula is as follows:

$$IRI = (N + W) \times FO,$$

where N is numerical percentage, W is weight percentage, and FO is percentage frequency of occurrence. For comparison, the diet of pike of different ages with a standard length of < 40 cm (i.e. the most numerous group) were used. The Pearson correlation analysis was used to measure the relationship between the length of the predator and the length of the prey fish.

RESULTS

Composition of the diet

Pike becomes a piscivorous predator during its first summer. This fish consumed different food organisms in L. Peipsi. The diet of pike included at least eight prey fish species: smelt, ruffe (*Gymnocephalus cernuus* (L.)), perch, roach (*Rutilus rutilus* (L.)), pikeperch, pike, vendace (*Coregonus albula* (L.)), and bream (*Abramis brama* (L.)). In addition, two pikes had taken invertebrates: a shell of *Dreissena polymorpha* (Pallas) and a larva of Odonata were found in their stomachs.

The proportion of empty stomachs was quite stable in different years: 42.5% in 1995–96 and 45.3% in 1998 (Table 2). All dissected stomachs contained on

Table 2. Frequency of occurrence (FO, %) of prey species in the diet of pike from L. Peipsi

Prey species	1995–96		1998	
	Number of stomachs	FO, %	Number of stomachs	FO, %
Ruffe	61	24	20	12.4
Smelt	45	17.7	53	32.9
Perch	33	13	14	8.7
Roach	10	3.9	4	2.5
Pikeperch	10	3.9	4	2.5
Vendace	8	3.1	0	0
Bream	0	0	1	0.6
Invertebrates	2	0.8	0	0
Pike	1	0.4	0	0
Unidentified	1	0.4	0	0
Empty	108	42.5	73	45.3

the average (± SE) 1.05 ± 0.09 prey fish, while fish that had taken food had swallowed on the average 1.84 ± 0.12 prey items according to the data of 1995–96 and 1.72 ± 0.15 items in 1998. Only a few prey fishes were dominating in the diet of pike both with respect to FO and numerically. The most frequent prey fishes were ruffe, smelt, and perch (Table 2). The same species dominated in the diet of pike also numerically (Table 3).

Pike consumed fish of different size (Fig. 2), being able to consume big fish. The mean length of the prey fish of pike varied, depending on the species,

Table 3. Number of specimens (*n*) of prey species in the diet of pike from L. Peipsi

Prey species	1995–96		1998	
	n	%	*n*	%
Ruffe	107	39.8	36	23.7
Smelt	80	29.7	92	60.5
Perch	36	13.4	14	9.2
Pikeperch	17	6.3	4	2.6
Vendace	14	5.2	0	0
Roach	11	4.1	5	3.3
Bream	0	0	1	0.7
Invertebrates	2	0.7	0	0
Pike	1	0.4	0	0
Unidentified	1	0.4	0	0
Total	269	100	152	100

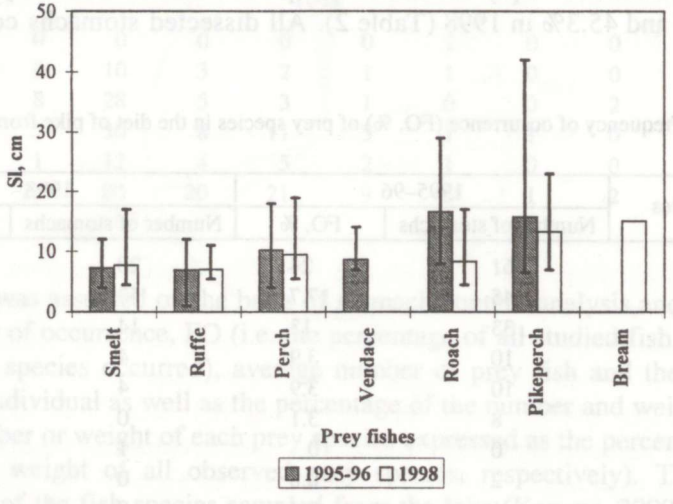

Fig. 2. Mean length and length range of prey fishes in the diet of pike from L. Peipsi.

between 7.0 and 16.6 cm. The largest consumed fish (pikeperch) engulfed by a pike with Sl of 101 cm was 42 cm long, but the Sl of the most frequently consumed pikeperch was 11 cm.

According to IRI of various food items in the stomach, three most important prey fishes for pike in L. Peipsi were ruffe, smelt, and perch, but the weight percentage was higher in case of pikeperch (Table 4).

Table 4. Weight percentage and index of relative importance (IRI) of different food items in stomachs of pike from L. Peipsi in 1995–96 and 1998

Prey species	1995–96		1998	
	Weight, %	IRI	Weight, %	IRI
Ruffe	18.5	1399	20.11	543
Smelt	4.9	612	20.0	2648
Perch	7.9	277	7.02	141
Pikeperch	56.8	246	40.14	107
Vendace	2.6	24	0	0
Roach	16.6	81	7.0	26
Bream	0	0	5.73	4
Pike	0.6	0	0	0

Size-related changes

The stomach content of pike changed with the growth of fish. Smelt was the commonest fish species in the diet of small pike (Sl < 40 cm) (Fig. 3). The stomach content of small pike did not vary significantly in different years. In the diet of pike of Sl 30–39 cm smelt predominated both with respect to FO and numerically, with only slight differences in the diet in different years (Fig. 4).

The proportion of smelt decreased numerically in the food of larger pike, whereas that of ruffe increased gradually (Fig. 3). Ruffe occupied the first place in the food of pike of length groups 40–79 cm, constituting about half of all fishes consumed by the predator with Sl of 40–69 cm. Pikeperch appeared in the food of larger pike and was the most abundant prey species (31% in number) for the largest (Sl > 80 cm) specimens. Perch was also mostly consumed by larger pike. The proportion of other fishes (roach, vendace, and pike) was modest.

The mean length of prey increased with the growth of the predator. As a rule, larger specimens of pike had consumed larger prey items; the correlation between the length of the predator and the length of the prey fish ($r = 0.39$, $n = 234$, $p < 0.001$) was highly significant.

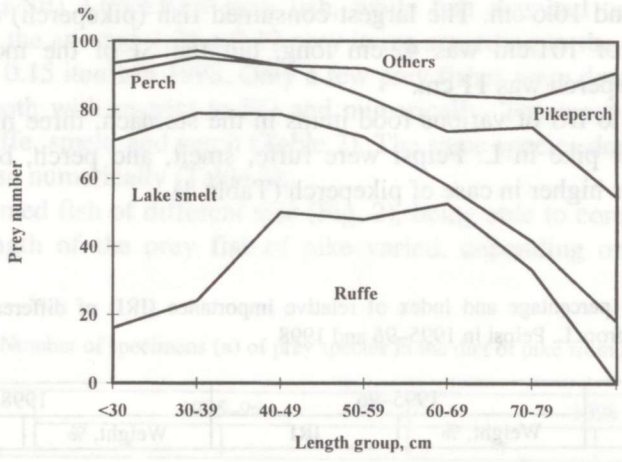

Fig. 3. Size-related variation in the number of prey fishes in the diet of pike from L. Peipsi.

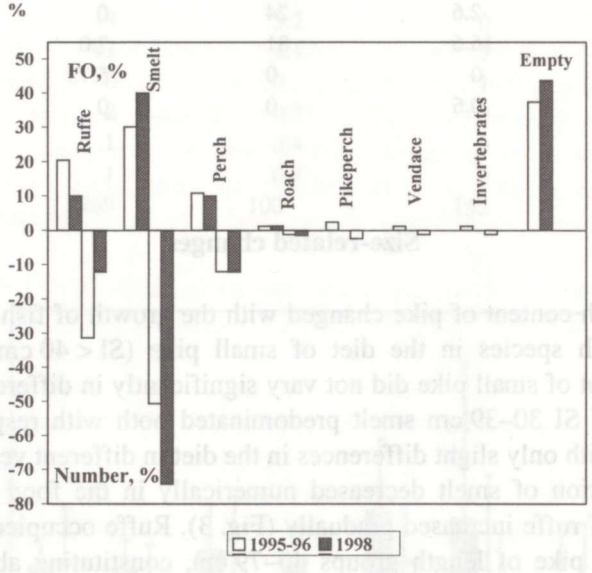

Fig. 4. Frequency of occurrence (FO, %) and number of prey species in the diet of pike (Sl 30–39 cm) from L. Peipsi in 1995–96 and 1998.

DISCUSSION

Pike is a specialized fish-eater (Varley, 1967; Winfield, 1992). In L. Peipsi, fish appear in the food of pike at a body length of 3–5 cm (Pihu & Pihu, 1974). According to Mann (1982) pike aged one year and older are predominantly

piscivorous with less than 1% of their prey with respect to weight being invertebrate animals. Fish serve generally as the main prey of pike over 20 cm in length (Treasurer & Owen, 1991). Many studies have shown cannibalism to be important in the diet when other prey were not available (Raat, 1988; Treasurer & Owen, 1991). Under controlled conditions larval pike attacked each other at high densities, although the fish were fed *ad libitum,* while the first cannibalistic attacks were observed on the 5th–7th days of rearing (Kucharczuk et al., 1998). In L. Peipsi, cannibalism did not play an important role in the recent diet of pike because alternative fish species (such as smelt, ruffe, perch) were abundantly available and the population density of pike was low.

In L. Peipsi with abundant suitable prey fishes pike did not need to feed on invertebrates after their first year of life, which is often the case in small lakes in Finland (Rask & Arvola, 1985). In lakes of Scotland with few prey fishes, larger pike also eat small items such as invertebrates (Treasurer & Owen, 1991; Treasurer, 1998). *Gammarus* is the main food of pike in Loch Choin (Munro, 1957) and *Procambarus clarkii* serves as a common food item in L. Ruidera, Spain (Elvira et al., 1994).

A large number of pike's stomachs (42–45%) sampled from L. Peipsi were empty. It is charateristic of carnivores to swallow their prey whole and to feed to repletion and then rest before feeding again; so there are periods when their stomachs are empty when caught (Varley, 1967, Adams et al., 1994). For example, in two oligotrophic lakes in northeastern Finland the proportion of empty pike stomachs was 43–50% (Heikinheimo & Korhonen, 1996). In hyper-eutrophic Loch of Skene (Scotland) the proportion of empty stomachs was 37% (Treasurer & Owen, 1991).

According to the present study, one of the most important prey species for pike in L. Peipsi was ruffe. Ruffe were found to dominate in the recent diet of pike in Loch Lomond (UK) as well, where this fish has now been introduced (Winfield, 1992). Ruffe are relatively poor swimmers, which makes them an easily accessible food source for piscivorous predators (Adams, 1991).

Detailed studies on the ecology of pike and pikeperch in the waters of the UK have shown that in both still and flowing waters, small cyprinids such as young roach are a major component of the diet of pikeperch, in contrast to relatively larger and hence older individuals typically taken by pike (Winfield, 1992). In L. Peipsi, both smaller pike (< 40 cm) and pikeperch fed mainly on smelt. In comparison with pikeperch, larger pike fed more on ruffe (Kangur & Kangur, 1998), although smelt, ruffe, and perch were the main prey items of both top predators.

In the other large eutrophic lake of Estonia, L. Võrtsjärv, smelt is not the main prey of pike, because the abundance of smelt is low in this lake. The other main prey fishes of pike in both lakes are the same: perch, roach, and ruffe (Kangur, 1969). In the Baltic Sea pike feed mainly on roach, perch, and herring, *Clupea harengus membras* L. (Erm et al., 1970).

Pike are opportunistic in their feeding habits. It has been suggested that they can change their prey selection relatively rapidly in response to changes in the abundance and vulnerability of prey species (Mann, 1982; Adams, 1991). Comparison of the diet of pike from L. Peipsi in 1995–96 and 1998 with respective data from 1960–63 (Pihu, 1966) demonstrates a slight shift in the choice of prey (Table 5). The average number of swallowed fish was approximately the same whilst the composition of prey had changed. In 1960–63, the diet of pike (Sl 10–80 cm) included at least 16 prey fish species; among them smelt, perch, ruffe, and roach dominated in the FO and number of prey. Smelt formed a major part in the diet of pike in 1960–63 and was permanently found to dominate in the recent diet of smaller pike. The role of roach, as well as that of bleak and burbot, has decreased in recent decades. At the same time, the share of pikeperch in the food of pike has increased, probably in connection with the growing abundance of the pikeperch population in the lake (Kangur & Kangur, 1996; Pihu, 1996). During the 1960s pike consumed only a very small amount of pikeperch fry (Pihu, 1966), whereas in 1995–96 this prey species dominated in the food of large (Sl > 80 cm) pike. At the same time, the abundance of the pike population has decreased in the lake. The catch of pike on the Estonian side of L. Peipsi was about 190 t (5–6% of total annual catch according to Pihu, 1966) in 1958–68, but only 29–98 t (1.4–3.2% of total annual catch) in 1995–98.

Table 5. Mean and maximum number of prey species per stomach (fish with empty stomachs were excluded) of pike sampled from L. Peipsi in 1960–63 (Pihu, 1966), 1995–96, and 1998

Prey species	1960–63	1995–96		1998	
	Mean	Mean ± SE	Max	Mean ± SE	Max
Ruffe	0.24	0.73 ± 0.10	6	0.41 ± 0.11	7
Smelt	1.06	0.55 ± 0.09	7	1.03 ± 0.16	11
Perch	0.24	0.25 ± 0.04	2	0.16 ± 0.04	1
Vendace	0.08	0.10 ± 0.05	6	0	0
Roach	0.21	0.08 ± 0.02	2	0.06 ± 0.03	2
Pikeperch	0	0.12 ± 0.04	4	0.05 ± 0.02	1
Pike	0	0.01 ± 0.01	1	0	0
Unidentified	0.01	0.01 ± 0.01	1	0	0
Others	0.09	0	1	0	1
Invertebrates	0	0.01 ± 0.01	1	0	0
Total	1.93	1.84 ± 0.12	9	1.72 ± 0.15	11

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HAUGI (*Esox lucius* L.) TOIDU KOOSSEIS PEIPSI JÄRVES

Peeter KANGUR

Haug on eelistatumaid püügikalu Peipsi järves, ehkki tema osa kalade väljapüügis pole kunagi olnud eriti suur. Töö eesmärk oli kindlaks teha üksikute saakkalaliikide vahekord haugi toidus, selgitada selle röövkala toidu koosseisu sõltuvust kala pikkusest ja uurida, kas haugi toidu koosseis on viimastel aastakümnetel muutunud. Aastatel 1995–1996 ja 1998 lahati 415 haugi (standardpikkusega 21,5–105 cm) ja analüüsiti nende mao sisu. 42–45% uuritud magudest olid tühjad. Haugi ratsioon koosneb vähemalt kaheksast saakkalaliigist, kõige sagedamad neist olid kiisk, tint ja ahven. Samad liigid domineerisid haugi toidus ka arvuliselt. Tint oli kõige tavalisem kala väiksemate haugide (Sl < 40 cm) toidus. Suuremate isendite toidus tindi osatähtsus kahanes, kuna kiisa oma tõusis. Kannibalismi täheldati harva. Võrreldes 1960.–1963. aasta andmetega (Pihu, 1966) on praeguseks ajaks suurenenud koha osa haugi toidus.