

## FEEDING OF PIKEPERCH, *Stizostedion lucioperca* (L.), IN LAKE PEIPSI

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**Abstract.** The present study examines the composition of the diet and size-related as well as seasonal changes in the prey selection of pikeperch in shallow eutrophic Lake Peipsi. A total of 801 pikeperch with a standard length of 9–73 cm were sampled mostly with a bottom seine and an experimental trawl from August 1994 till October 1998 and their stomach content was analysed. The frequency of occurrence and the number and restored weight of prey fishes per individual were used for the description of diet. Fish with SL < 15 cm had consumed only smelt. With increasing body size the diet of pikeperch was enriched with ruffe, perch, and other small fishes whilst predation pressure on smelt decreased. The main seasonal changes were revealed in the ratio of smelt to percids in the diet of pikeperch.

**Key words:** pikeperch, diet composition, size-related and seasonal changes, Lake Peipsi.

### INTRODUCTION

Pikeperch, *Stizostedion lucioperca* (L.), is the main open-water piscivorous fish in eutrophic waters in Europe (Kitchell et al., 1977). In Estonia pikeperch inhabits eutrophic and hypertrophic lakes that are relatively large and deep, have a rather high pH, and are rich in small fish. As such lakes are mostly located in cultivated areas, they are exposed to agricultural pollution. Pikeperch avoids closed lakes and is quite sensitive to winter anoxia (Pihu, 1993). Preferred biotopes of pikeperch are relatively warm, still or slow flowing productive waters with high turbidity that are rich in small fish (Deelder & Willemssen, 1964; Steffens et al., 1996; Smith et al., 1998). Pikeperch has well-developed eyes, which enhances visual feeding in turbid waters (Ali et al., 1977).

Studies of pikeperch population on L. Peipsi are of great importance, as this species has become one of the economically most important fishes in this lake.

Owing to its high commercial value and vulnerability to fishery, pikeperch is at the same time the most endangered fish species in this lake. Its population is heavily affected by the exploitation in the lake (Kangur & Kangur, 1996a). The stock of pikeperch was strongly suppressed for a long time due to the intensive use of towed fishing gear (trawls and bottom seines). After considerable restriction of bottom seines (= Danish seines) pikeperch could at last realize its reproduction potential and has become one of the most important commercial fishes in the lake (Fig. 1). Increasing eutrophication of the lake supports this process.

According to Windell & Bowen (1978), much of our current understanding of the autecology and ecological role of fish populations is derived from studies of the diet based on analysis of stomach contents. Pikeperch as a top predator can directly affect fish community structure through the effects of predation (Van Densen & Grimm, 1988; Lammens et al., 1992). Adult pikeperch in lakes have the potential to influence the abundance of their prey (Benndorf, 1990; Lehtonen et al., 1996). However, introduction of pikeperch into a waterbody need not affect all fishes equally (Popova, 1978). Large fishes will be less vulnerable to predation and spiny-finned (e.g. perch) or deep-bodied fishes (e.g. bream) may be less influenced compared with more easily caught fishes such as roach (Smith et al., 1996a). The number and type of prey will be affected not only by the total biomass of pikeperch present in a waterbody but also by the predator population's size structure (Popova, 1978). For a given availability of prey, both the size and the species of prey vary as pikeperch increase in size (Willemssen, 1983). In exploited fish populations (like pikeperch in L. Peipsi) large fish are removed in a size-selective manner and the remaining fish population often shows a reduction in mean size. This in turn has implications for the number



Fig. 1. Average annual commercial catches of fishes from the Estonian side of L. Peipsi in 1991–98.



and type of prey fish removed from the fishery by subsequent pikeperch piscivory (Smith et al., 1996b).

The aim of this study was to estimate the composition of the diet and size-related as well as seasonal changes in the prey selection of pikeperch in L. Peipsi. As fish commonly depress prey populations it is necessary to consider how predation pressure is distributed over different prey species. The frequency of occurrence (FO), number, and restored weight of food items per individual as well as the average length of prey fishes are presented.

## STUDY AREA

Lake Peipsi in the broad sense is a large (3555 km<sup>2</sup>) but shallow (up to 15.3 m deep) tripartite waterbody. The biggest, northern part L. Peipsi s.s. (2611 km<sup>2</sup>, maximum depth 12.9 m, average depth 8.3 m at the water level 30.04 m above sea level) is a lowland waterbody on the territories of Estonia and Russia. It is an unstratified eutrophic lake with mesotrophic features (Nõges et al., 1996). The lake is holomictic–dimictic, revealing an unstable summer stratification, but is well aerated down to the bottom by waves and currents (Jaani, 1996). Ice appears usually in November and melts in April. The average temperature of the surface water layer during the ice-free period is about 7.3 °C (Uleksina & Filatova, 1983). Maximum surface temperatures are usually reached in July and measure on an average 21–22 °C in the open region but up to 27–28 °C on shallows in some years. The biological summer (with surface temperature over 10 °C) lasts on average 134 days (Jaani, 1996).

Lake Peipsi belongs to smelt–bream lakes; however, due to eutrophication during recent decades it has obtained features of a pikeperch lake. Both its fish productivity and catches (about 18–20 kg ha<sup>-1</sup> per year in recent time) are high (Kangur & Kangur, 1996b). Considering annual fish catches L. Peipsi surpasses all large lakes in North Europe (Pihu, 1996). The occurrence of fish species typical of oligotrophic waterbodies such as smelt, *Osmerus eperlanus* (L.), and vendace, *Coregonus albula* (L.), is quite high. According to official data the total catch of fish in the Estonian part of L. Peipsi made up 1674–3613 t per year in 1991–98. The main commercial fishes in catches (not considering their cost) are smelt, perch (*Perca fluviatilis* L.), pikeperch, and bream (*Abramis brama* (L.)) (Fig. 1).

## MATERIAL AND METHODS

Pikeperch were sampled from the pelagial on the Estonian part of L. Peipsi s.s. with a commercial bottom seine (mesh size 18–22 mm in the cod-end) and an experimental trawl (mesh size 10–14 mm) from April 1994 to October 1998, mostly in morning hours. In winter fish were caught with gill nets. A total of 801

fish with a standard length (SL) of 9–73 cm (Table 1) were dissected immediately and their stomach content was analysed. Prey fish or their remains were counted, measured, and identified. Some specimens of strongly digested prey fishes, not recognizable by external morphology, were not identified to the species level.

Table 1. Number and measurements of examined pikeperch

Month	Standard length					Total
	< 20	20–29	30–39	40–49	50 <	
February & March	–	–	1	3	7	11
April	–	–	8	18	10	36
May	2	6	16	44	4	72
June	–	1	7	16	3	27
July	13	11	47	27	2	100
August	88	25	24	68	13	218
September	72	48	51	66	10	247
October	2	13	14	29	12	70
November	1	3	1	6	9	20
Total	178	107	169	277	70	801

The following measures were used for the description of the stomach content: frequency of occurrence (the percentage of all fish examined in which that prey species occurred), average number of prey fish and their restored weight per individual as well as the percentage of prey number (the number of each prey species expressed as a percentage of all observed prey). According to the length of prey fish, their total weight in stomachs was restored, using the length–weight relationship of fish sampled from the lake (Kangur, 2000).

In order to analyse seasonal changes in feeding, fish with a length of 35–49 cm, i.e. the most numerous group, were used. Fish caught in August and September were used for describing the diet of different predator size groups. The Pearson correlation analysis was used to measure the relationship between the length of the predator and the length of the prey fish as well as their number and frequency of occurrence.

RESULTS

Composition of the diet

Pikeperch become piscivorous during their first summer. The diet of pikeperch included at least six prey fish species: smelt, ruffe (*Gymnocephalus cernuus* (L.)), perch, vendace, pikeperch, and roach (*Rutilus rutilus* (L.)). In addition, a shell of *Dreissena polymorpha* (Pallas) was found in the stomach of



one pikeperch. About a half (45.9%) of the examined specimens had consumed smelt, followed by ruffe and perch (Table 2). The frequency of occurrence of the other prey fishes (vendace, pikeperch, roach, and unidentified fish remains together) was about 11%. Among the dissected stomachs, about 20% did not contain any food.

Smelt dominated in the diet of pikeperch also numerically. This fish was consumed more than all other prey species combined (Table 3). According to weight, smelt accounted for about 27%. Smelt was followed with respect to both number and weight by ruffe (respectively 21.3% and 24.9%) and perch (10.6% and 22.0%). Thus, smelt dominated by FO, by number, and by weight in the recent diet of pikeperch in L. Peipsi.

Pikeperch stomachs examined in this study contained on the average ( $\pm$  standard error)  $2.16 \pm 0.11$  prey fish whereas individuals that had taken food contained on the average  $2.71 \pm 0.14$  fish (Table 4). The maximum number of engulfed prey fish was 34. Pikeperch swallows rather small prey. The mean length of prey fish varied between species, but did not commonly exceed 12 cm, although the largest consumed fish (pikeperch) had a length of 20 cm (Table 3) and a weight of 123 g.

**Table 2.** Frequency of occurrence (FO) of prey items in the diet of pikeperch from L. Peipsi in 1994–98

Prey	Number of stomachs	FO, %
Smelt	368	45.9
Ruffe	193	24.1
Perch	124	15.5
Vendace	33	4.1
Pikeperch	25	3.1
Unidentified	16	2.0
Roach	14	1.7
Empty	159	19.9

**Table 3.** Number, percentage, and length of consumed fishes in the diet of pikeperch from L. Peipsi in 1994–98

Prey	Number	%	Length, cm	
			Mean $\pm$ SE	Range
Smelt	1059	60.7	$6.4 \pm 0.1$	3–17
Ruffe	372	21.3	$6.4 \pm 0.1$	2–14
Perch	185	10.6	$8.2 \pm 0.2$	2–16
Vendace	71	4.1	$9.2 \pm 0.3$	7–11
Roach	16	0.9	$11.4 \pm 1.0$	6–16
Pikeperch	26	1.5	$12.2 \pm 0.9$	7.7–20
Unidentified	16	0.9	–	–

**Table 4.** Mean number and weight of prey species per stomach (fishes with empty stomachs were included) of pikeperch sampled from L. Peipsi in 1960–63 (Pihu, 1966) and 1994–98

Prey	1960–63	1994–98		
	Mean number	Mean number ± SE	Max number	Mean weight, g
Ruffe	0.06	0.58 ± 0.05	9	3.27
Lake smelt	1.5	1.66 ± 0.13	30	3.52
Perch	0.13	0.29 ± 0.03	6	2.89
Vendace	0.05	0.11 ± 0.02	8	1.52
Roach	0.06	0.03 ± 0.01	2	0.77
Pikeperch	–	0.04 ± 0.01	2	1.52
Bleak	0.04	–	–	–
Others	0.05	–	–	–
Total	1.9	2.71 ± 0.14	34	13.12

**Size-related and seasonal changes**

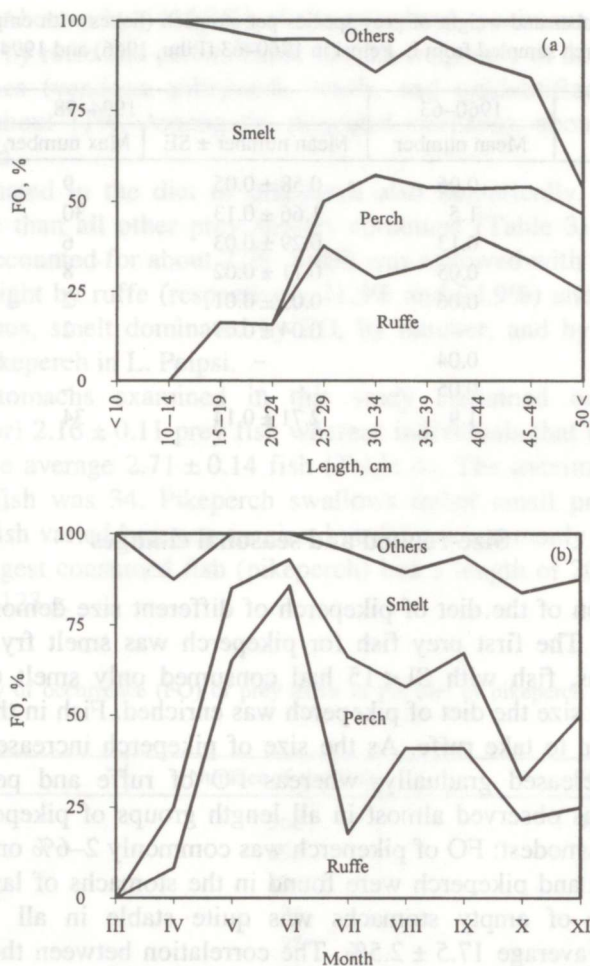
A comparison of the diet of pikeperch of different size demonstrated a shift in prey choice. The first prey fish for pikeperch was smelt fry. According to our observations, fish with  $SL < 15$  had consumed only smelt (Fig. 2a). With increasing body size the diet of pikeperch was enriched. Fish in the length group 15–19 cm began to take ruffe. As the size of pikeperch increased FO of smelt in its food decreased gradually, whereas FO of ruffe and perch increased. Cannibalism was observed almost in all length groups of pikeperch though its importance was modest: FO of pikeperch was commonly 2–6% only. Remains of vendace, roach, and pikeperch were found in the stomachs of larger pikeperch. The proportion of empty stomachs was quite stable in all length groups, constituting on average  $17.5 \pm 2.5\%$ . The correlation between the length of the predator and the proportion of empty stomachs in the length group was insignificant ( $r = 0.19$ ;  $p = 0.6$ ).

The average number of prey fish per one stomach in different predator size groups was different. As a rule, larger specimens had consumed more and larger prey items, the correlations between the length of the predator and the length of the prey fish ( $r = 0.37$ ,  $n = 639$ ,  $p < 0.001$ ) as well as their number ( $r = 0.32$ ,  $n = 639$ ,  $p < 0.001$ ) were significant. The diet of the largest pikeperch was the most diverse.

Main seasonal changes were revealed in the smelt to percids ratio in the diet of pikeperch. The proportion of smelt was large in early spring (Fig. 2b): FO of this fish species was over 80% in April. During summer smelt was quite seldom found in the stomachs, whereas close to autumn its FO increased again.

Percids (ruffe and perch), on the contrary, were common food for pikeperch during summer (Fig. 2b). The number of empty stomachs was the largest in May and June (during the breeding period and immediately after it).





**Fig. 2.** Size-related (a) and seasonal (b) changes in the frequency of occurrence (FO, %) of prey fishes in the diet of pikeperch from L. Peipsi in 1994–98.

## DISCUSSION

Young pikeperch feed initially on zooplankton (Erm, 1961; Pihu & Pihu, 1974; Collette et al., 1977). Pikeperch often become piscivorous during their first summer but fish may constitute a considerable proportion in their diet already when the length of pikeperch is 2–3 cm (Erm, 1976). According to Fickling (1986), pikeperch are usually piscivorous after they reach a length of 6 cm. In L. Peipsi, pikeperch start to prey on the larvae and fry of smelt at a body length of 4 cm (Erm, 1981). Larger pikeperch are known to consume almost all available fish species (Shirkova, 1966; Erm, 1981).

The piscivorous nature of pikeperch has been demonstrated in many studies by the dominance of fish in their diet from their second year of life (Varley, 1967; Erm, 1961, 1981; Lehtonen et al., 1996); however the species composition of the prey varies between areas. Pikeperch are opportunistic in their feeding habits (Salonen et al., 1996). According to our data pikeperch in L. Peipsi fed mainly on smelt, ruffe, and perch, whereas the diet of small specimens (SI < 15 cm) consisted only of smelt. Smelt is the most numerous fish in the pelagic area of L. Peipsi where pikeperch mostly feeds. Studies performed on other lakes also indicate that pikeperch, or at least its youngest age-groups, prefer smelt as a prey species if it is available (Van Densen & Grimm, 1988; Peltonen et al., 1996; Salonen et al., 1996). Smelt may coexist with pikeperch in spite of heavy predation because it compensates for the predation by maturing at a young age (Lammens et al., 1992). At a certain availability of prey in the lake, both the species and size of prey varies as pikeperch increase in size (Popova, 1978; Willemsen, 1983). The diet of larger pikeperch in L. Peipsi diversified mainly with ruffe and the fry of perch being added to smelt. The fractions of other prey fishes (roach, vendace, pikeperch) in the stomachs of predators of SI < 50 cm were small.

Pikeperch eat a limited size range of fish. The average length of prey of pikeperch in L. Peipsi varied, depending on the species, between 6 and 12 cm (Table 3). The diet of pikeperch in the North Oxford Canal (UK) consisted largely of fish less than 8 cm fork length (Fickling, 1986). Pikeperch is known to be a gape-limited predator (Smith et al., 1994; Salonen et al., 1996). Especially, the small pikeperch may not be able to eat large individuals of deep-bodied prey species such as roach and perch but they can forage on the more elongated species like smelt and bleak (*Alburnus alburnus* (L.)). As normally there are only a few large pikeperch in a population, the deep-bodied prey fish may avoid predation by growing to large sizes, i.e. escape to a size refuge (Hambright et al., 1991; Peltonen et al., 1996).

Pikeperch are opportunistic piscivores with the annual feeding patterns closely linked to the seasonal abundance of food (Popova & Sytina, 1977; Popova, 1978). In L. Peipsi seasonal changes in the feeding of pikeperch were revealed mainly in the FO of smelt and percids in stomachs.

A comparison of the diet of pikeperch from L. Peipsi in 1994–98 with data from 1960–63 (Pihu, 1966) showed some minor changes in prey choice (Table 4). The average number of swallowed fish was higher in the 1990s, and the composition of the diet had changed. In 1960–63 the diet of pikeperch (SI 10–70 cm) included at least seven prey fish species; among them smelt, vendace, roach, bleak, ruffe, and perch dominated in occurrence and number of prey. Smelt served continuously as the commonest prey of smaller pikeperch. The proportion of ruffe and perch seems to have increased considerably in recent years. Pihu (1966) did not observe cannibalism whilst FO of pikeperch was about 3% in the recent diet. This is probably connected with the growth of the



pikeperch population in the lake (Pihu, 1996; Kangur & Kangur, 1996a). Pikeperch constituted only 0.2–0.3% (about 19 t) of the total catch in 1960–63 but about 12–27% (261–707 t) in 1994–98 in the Estonian side of the lake.

Detailed studies on the feeding of pikeperch and pike (Kangur & Kangur, 1998) have shown that the recent diets of these top predators in L. Peipsi are not exactly the same, although smelt, ruffe, and perch are the main prey fishes of both. Smelt was the commonest in the diets of pikeperch in contrast to ruffe that was mainly taken by pike. Interspecific competition between these predators is probably not strong, because they inhabit different biotopes: pikeperch live mainly in the open part of the lake, whereas pike prefer the littoral zone.

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## **KOHA (*Stizostedion lucioperca* (L.)) TOIDU KOOSSEIS PEIPSI JÄRVES**

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Koha on praegusel ajal üks olulisemaid töonduskalu Peipsi järves. Töö eesmärk oli kindlaks teha üksikute saakkalaliikide vahekord koha toidus, uurida tema toidu koosseisu sesoonset ja kala pikkusest sõltuvat muutlikkust, samuti selgitada, kas koha toidu koosseisus on viimastel aastakümnetel toimunud muutusi. Kokku uuriti aastatel 1994–1998 järve avaveelisest osast peamiselt mutnikuga (põhjanoodaga) ja katsetraaliga püütud 801 koha (kalade standardpikkus 9–73 cm) mao sisu. Koha toiduratsiooni kirjeldamiseks kasutati järgmisi suurusid: saakkalade esinemissagedus, keskmine neelatud kalade arv ja mass mao kohta, samuti nende pikkus.

Alla 15 cm pikkused kohad olid söönud ainult tinti. Suuremate isendite toit rikastus kiisa, ahvena, räabise, koha ja särjega, kusjuures tindi osa vähenes. Koha sööb suhteliselt väikesi kalu: neelatud isendite keskmine pikkus varieerus liigiti 6–12 cm vahel. Peamised sesoonsed muutused koha toidu koosseisus ilmsesid tindi ning ahvenlaste (peamiselt kiisa ja ahvena) esinemissageduses. Võrreldes 1960.–1963. aasta andmetega (Pihu, 1966) täheldati koha toidu koosseisus mõningaid muutusi, mis ilmselt seonduvad järve kalaliikide vahekorra muutustega.