Ann. Zool. Fennici 33: 473–480 ISSN 0003-455X
Helsinki 28 November 1996

Feeding of ruffe *(Gymnocephalus cernuus)* in relation to the abundance of benthic organisms in Lake Vôrtsjärv (Estonia)

Külli Kangur & Andu Kangur

Kangur, K. & Kangur, A., Vôrtsjärv Limnological Station, Institute of Zoology and Botany, Estonian Academy of Sciences, EE-2454 Rannu, Tartu, Estonia

Received 21 August 1995, accepted 10 January 1996

From May till November 1994 the diet of ruffe was investigated in the shallow eutrophic Lake Vôrtsjärv (South Estonia). 187 ruffes of standard length (*SL*) of 4.3–12.0 cm were examined. Ruffe of *SL* over 4.5 cm (age 1+ and older) were typical benthophagous fishes consuming mainly chironomid larvae and pupae (over 95% of the weight of food). *Chironomus plumosus* (91%), *Einfeldia carbonaria* (36%) and *Microchironomus tener* (31%) had the highest frequency of occurrence. The most important food item was *C. plumosus* (about 98% of the chironomid biomass in stomachs). The biomass of *C. plumosus* in the profundal mud bottom corresponded to its proportional amount in stomachs of ruffe. The diet of ruffe was compared with that of eel (*Anguilla anguilla*) and bream (*Abramis brama*). Overlap in their diets appeared mostly in respect of *C. plumosus* larvae and pupae.

1. Introduction

Ruffe is a small bottom-living shoal fish. For many years, it has been considered to have little or no value for commercial or recreational fisheries throughout its natural range in Europe. As a result the species has been relatively neglected by fish biologists and literature data on it are scanty and little reviewed or collated (Winfield & McCulloch 1995).

In Estonia ruffe is found at least in 150 lakes (Mikelsaar 1984). Lake Vôrtsjärv was previously regarded as a ruffe lake because in the 1950s and 1960s the bulk of the fish caught here consisted of ruffe, young perch (*Perca fluviatilis*) and roach (*Rutilus rutilus*). Owing to the rearrangement of the fishing strategy rapid replacement of rough fishes by commercial fishes has taken place (Haberman *et al.* 1996). Bream (*Abramis brama*), eel (*Anguilla anguilla*), pikeperch (*Stizostedion lucioperca*) and pike (*Esox lucius*) are the main commercial fishes in the lake today.

The earliest data on the feeding of fishes in L. Vôrtsjärv were published by Schneider (1920) who found out that ruffe consumed mainly small yellow and green chironomid larvae and pupae. In 1966–1967 Kangur and Tôlp (Kangur 1968, 1969, Kangur & Tôlp 1974) studied seasonal and size related changes in the feeding of ruffe and established that zooplankton predominated in the diet of one-summer-old (0+) ruffe fry. With an increase in the size of ruffe the role of zooplankton decreased, while the share of benthic invertebrates and fishes grew. The authors presented the frequency of occurrence and the number of food objects per individual, as well as the general index of filling. However, none of the papers dealt with the biomass of food animals in the diet of ruffe.

We have studied the diet of ruffe and its relation to the benthic community in L. Vôrtsjärv. This paper describes the composition as well as seasonal changes of the diet of ruffe. An attempt is also made to quantify food consumption. The proportion of the number and biomass of food organisms eaten by ruffe is compared with their abundance and biomass in the bottom substratum. A possible competitive interaction with eel and bream in respect of food organisms is discussed.

2. Material and methods

2.1. Study area

L. Vôrtsjärv is a large (270 km^2) and shallow (mean depth 2.8 m, maximum depth 6 m) lake in Estonia. It is a strongly eutrophic waterbody, characterized by the average concentrations of total N = 2 g/m^3 and total P = 53 mg/m^3. The water is alkaline (pH 7.5–8.5) with a great buffering capacity and a high seston content (Haberman *et al.* 1996). The water is practically homothermic and, due to the wind action, very turbid in summer. In winter there sometimes occurs oxygen deficiency under the ice cover. Macrophytes cover at least 15% of the whole area of the lake while this area is increasing. About 2/3 of the lake bottom is covered with mud lying on marl. The mean (with ± *S.E.*) macrozoobenthos abundance and biomass (870 ± 70 indiv./m^2 and 6.8 ± 1.2 g/m^2 in 1973–1993) are considerably lower than in other neighbouring eutrophic lakes (Kangur *et al.* 1996). The low quantity of zoobenthos in L. Vôrtsjärv is probably caused by its availability to the large number of fishes feeding on benthos (mainly ruffe, bream and eel).

According to the fishery typology L. Vôrtsjärv belongs to the pikeperch lakes, although recently it has acquired some qualities of a bream lake.

2.2. Sampling

In the period from May to November 1994 ruffe samples were collected once or twice a month by experimental bottom trawl with mesh size 12–14 mm in the cod end. Trawling (twelve times) was carried out in the morning hours in the open water of the southern and central parts of the lake.

The collected fishes were weighed with an accuracy of 0.1 g and measured with an accuracy of 1 mm. Thereafter the ruffes were dissected and their sex determined. The stomachs were removed and examined immediately or preserved frozen (– 18°C) till the next day. Before analysis the samples were thawed Slowly. The content of 187 stomachs was analysed in detail (Table 1).

Prey items or their remains were counted, identified under the microscope to the lowest possible taxonomic level and their reconstructed fresh weight was calculated. The mean live weight of chironomid larvae and pupae was calculated according to the data on macrozoobenthos samples collected monthly in 1993 from a profundal sample station of the lake (Kangur & Tuvikene 1996). The reconstructed weight of the stomach content was calculated and expressed as fresh weight (mg) per one ruffe. The larval instars of *C. plumosus* were identified by the width of their head capsules (Kangur & Kangur 1978).

For estimating macrozoobenthos abundance and biomass seasonal bottom samples were taken 3 times a year in 14 stationary stations all over the lake, monthly samples in one station in the profundal and in one station in the littoral. All samples were taken by a Borutski or Zabolotski type of grab sampler with the 225 cm^2 grasp area. Three identical grabhauls were taken in a station at a time (Kangur *et al.* 1996).

3. Results

3.1. The composition of experimental fish catches and abundance of macrozoobenthos

Ruffe made up about 35% by number of fishes in the total experimental catch from May to November 1994 (Fig. 1). The commercial catch of this fish is unknown in recent time because ruffe is recorded together with other small fishes (young bream and roach).

In 1994 the macrozoobenthos of the lake was relatively rich: on an average 1 160 indiv./m^2 and 13.4 g/m^2 (Table 2). In the benthic community of the lake the dominant group was Chironomidae;

Table 1. Measurements of examined ruffe.

Month	Number of fishes	*SL*, cm Mean	*SL*, cm Range	Weight, g Mean	Weight, g Range
May	36	7.9	5–10.5	8.9	2–19
June	30	8.7	6–12	12.2	4–28
July	25	8.0	5.8–11	9.5	3–22
Aug.	31	8.3	6–10.3	10.9	4–21
Sept.	21	8.1	5–11	9.9	2–18.5
Oct.	22	8.4	7–10	10.7	6–17
Nov.	22	7.4	4.3–10.5	8.3	1.4–19.2

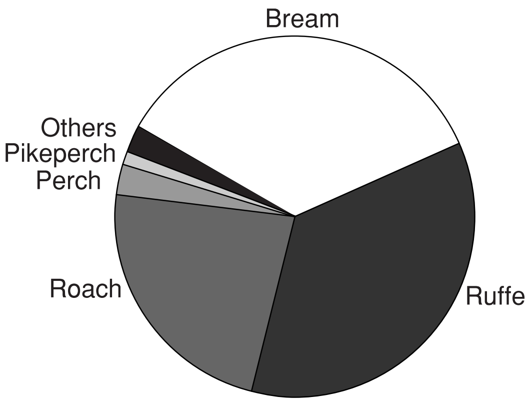

Fig. 1. Composition (in number, %) of experimental fish catches in L. Vôrtsjärv in the period from May to November 1994.

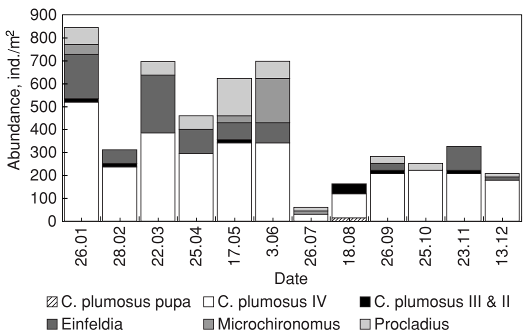

Fig. 2. Abundance of Chironomidae species in the profundal mud bottom of L. Vôrtsjärv in 1994.

among them *C. plumosus* formed over 84% (long-term average 71.5%) of the total biomass of macrozoobenthos (Table 2).

3.2. The composition of the diet

According to the present data young ruffe in L. Vôrtsjärv continue feeding on zooplankton until they are about 4.5 cm long. With increasing size ruffe turn gradually into a benthos feeder.

The diet of bigger ruffe (1+ and older) contained, in addition to zooplankters, chironomids, Oligochaeta cocoons, crustaceans, fish eggs, pieces of macrophytes and algae (Table 3). Detritus was also commonly found in the ruffe's stomach. In particular, ruffe is specialized in feeding on chironomids, the most important benthic food resource in L. Vôrtsjärv. At present the larval instars and pupae of different chironomid species are heavily predated by ruffe but the main food object is still *Chironomus plumosus* (Table 3). The larvae and pupae of this species had the highest frequency of occurrence (91%) in the stomachs. *Einfeldia carbonaria* (36%) and *Microchironomus tener* (33%) were also characterized by a high frequency of occurrence in the food of ruffe.

Ruffe takes mainly large fourth instar larvae and pupae of *C. plumosus* and eat also small third- and second-instar larvae of this species as well as other small-size chironomids.

Other groups of invertebrate food items have rarely been found in the stomach of ruffe (Table 3). Fish eggs (Cyprinidae sp.) were found only in 2% of the stomachs. The share of flora in the food was also insignificant. There was no great difference between the diet of males and females.

3.3. Seasonal changes of feeding

In L. Vôrtsjärv the abundance of macrozoobenthos and its qualitative composition change essentially during the year depending on the life cycles and population dynamics of different species (Fig. 2). These changes are reflected on the feeding conditions of ruffe.

Unlike eel whose intensive feeding period in L. Vôrtsjärv is summer, ruffe continued to take food in late autumn (in October–November) when water temperature decreased to 2–0.2°C.

Changes in the feeding of ruffe during summer were in accordance with the peculiarities of

Table 2. Mean (± *S.E.*) abundance and biomass of macrozoobenthos of L. Vôrtsjärv in 1973–1993 (Kangur *et al.* 1996) and 1994.

Main animal groups	1973–1993 Indiv./m²	1973–1993 g/m²	1994 Indiv./m²	1994 g/m²
Chironomidae (including *C. plumosus*)	576 ± 51	5.68 ± 1.15	646	12.07
C. plumosus	179 ± 40	4.84 ± 1.14	303	11.29
Oligochaeta	242 ± 31	0.45 ± 0.06	468	0.84
Mollusca	13 ± 1	0.41 ± 0.04	10	0.25
Others	39 ± 7	0.23 ± 0.03	36	0.23
Total (excluding large clams)	870 ± 70	6.77 ± 1.20	1160	13.40

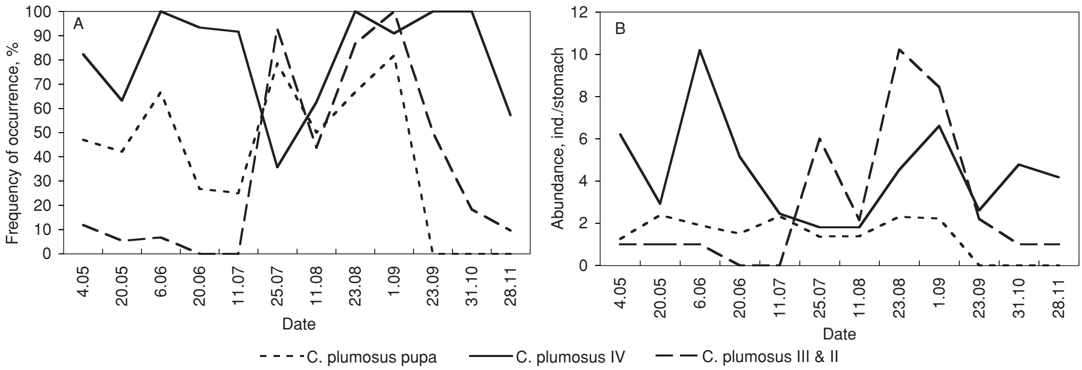

Fig. 3. Frequency of occurrence (A) and mean number (B) of different instars of *Chironomus plumosus* in the food of ruffe in L. Vôrtsjärv during the period from May to November 1994.

the life cycles of chironomids, first of all *C. plumosus*. All larval instars and pupae of chironomids were heavily predated by ruffe. Their proportion in the stomachs depended on larval densities in the bottom substratum at a certain time.

In July, after the spring emergence period and the hatching of a new generation of *C. plumosus*, the frequency of occurrence and mean number of fourth-instar larvae of this species in ruffe stomachs decreased noticeably (Fig. 3). At the same time pupae and third-instar larvae became more frequent as they were the most numerous food items for ruffe at that time. Pupae disappeared from the food of ruffe in late September, at the end of the emergence period; the frequency of occurrence of third-instar larvae, too, decreased in autumn.

Emergence periods were noticeable also in the consumption of other chironomid species (Fig. 4) whose proportions in the stomachs varied during summer too. *Procladius* disappeared from the stomachs in August–September, *Einfeldia* in August, and *Microchironomus* decreased in the autumn months.

Considering weight, the most important food objects for ruffe during the whole vegetation period were the fourth-instar larvae of *C. plumosus*.

3.4. Consumption of the main food items

During the period from May till November 1994 more than 95% of the food of ruffe of *SL* over 4.5 cm was formed, both in number and biomass, by chironomids. The mean total weight of consumed chironomids was about 0.2 g per stomach (Table 4). Estimates of consumption depend on the supposed daily ration

Table 3. Composition of the diet of ruffe (*SL* > 4.5 cm) in L. Vôrtsjärv during the period from May to November 1994.

Taxon	OF*,%	Mean number per stomach
Oligochaeta cocoons (indet.)	5	+
Zooplankton (Cladocera + Copepoda)	26	2.4
Ostracoda (indet.)	5	1.0
Malacostraca		
Asellus aquaticus (L.)	0.5	+
Trichoptera (indet.)	0.5	+
Diptera		
Chironomus plumosus (L.) pupa	38	0.7
IV instar	80	3.8
III instar	29	1.2
II instar	16	0.6
Cladotanytarsus gr. *mancus*	1	+
Cricotopus gr. *sylvestris*	0.5	+
Eifeldia carbonaria (Meig.) pupa	2	+
IV instar	29	0.7
III instar	12	0.2
Endochironomus albipennis (Meig.)		
IV instar	3	+
III instar	1	+
Glyptodendipes glaucus (Meig.)	1	+
G. paripes Edw.	0.5	+
Procladius sp.	20	0.3
Microchironomus tener (Kieff.) pupa	4	+
IV instar	32	0.9
III instar	3	+
Stictochironomus rosenschoeldi Zett.	0.5	+
Chironomidae (indet.)	6	+
Pisces (ovae)	2	+
Plants	4	+
Algae	2	+

* OF – frequency of occurrence; stomachs without food are included. + – Less than 0.1 items per stomach.

per population biomass. Considering the mean weight of the examined ruffe (10.2 g, Table 1) and assuming that their reconstructed stomach content is equal to their daily ration (De Nie 1987), it can be stated that the amount of food taken by ruffe formed on an average at least 2% of the body weight per day. However, consumption estimates may be higher.

According to our calculations on the base of experimental trawl catches, the abundance of ruffe of *SL* over 4.5 cm made up about 950 indiv./ha in 1994. During the period from May till November the stock of ruffe consumed about 40 kg/ha of *C. plumosus* pupae and larvae.

The annual biomass of *C. plumosus* in profundal of L. Vôrtsjärv in 1994 was on an average 13.4 g/m^2 or 134 kg/ha. The coefficient P/B of *C. plumosus* ranges from 2.9 to 4.9 in different years (Kangur 1977). Consequently, the annual production of the *C. plumosus* population can be calculated as 389–657 kg/ha. According to our approximate calculations the stock of ruffe consumes at least 6–10% of the annual production of *C. plumosus*.

The proportion of chironomids (in number and weight) in the stomach of ruffe was compared with their abundance and biomass in the bottom substratum of the lake (Table 4). Larval densities in the profundal mud bottom of the lake did not correspond to the proportional amounts in the food of ruffe. The number of *C. plumosus* third-instar larvae and pupae in the stomach was much larger than it was in bottom samples. Free-living *Procladius* larvae in the stomach of ruffe were scarce in comparison with their occurrence in bottom samples.

The relative weight of *C. plumosus* in the food of ruffe of *SL* over 4.5 cm as well as in the profundal mud bottom of the lake was several times larger than that of all other food items together. *C. plumosus* larvae and pupae made up about 98% of the chironomid biomass in the food of ruffe and about 98% of the chironomid biomass in the profundal mud bottom too. Thus, the biomass of *C. plumosus* in the bottom substratum corresponded to its proportional amount in stomachs of ruffe. More than 80% of the weight of consumed chironomids was constituted by *C. plumosus* fourth-instar larvae.

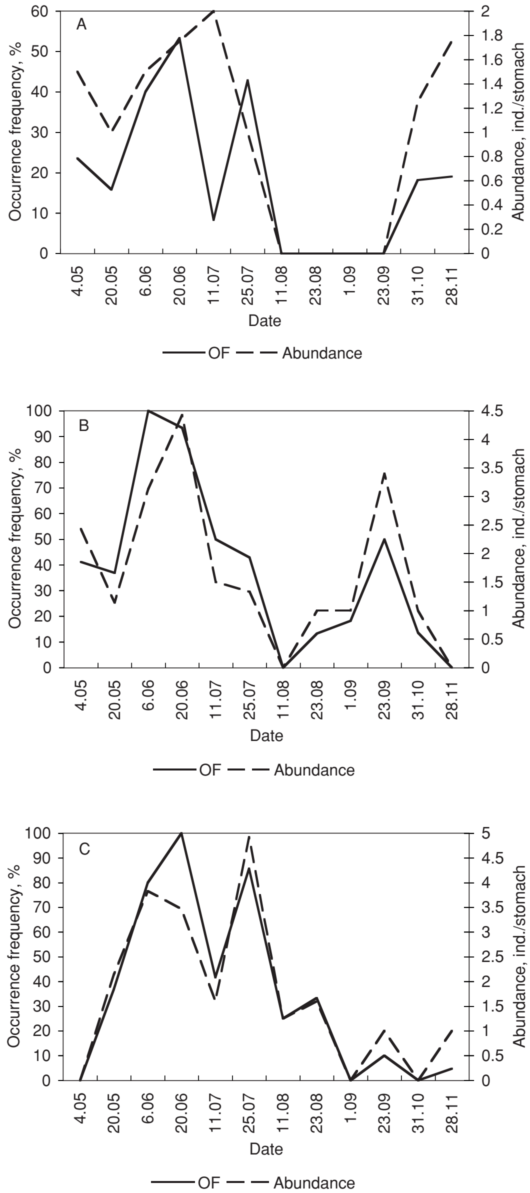

Fig. 4. Frequency of occurrence and mean number of *Procladius* sp. (A), *Einfeldia carbonaria* (B) and *Microchironomus tener* (C) in the food of ruffe in L. Vôrtsjärv during the period from May to November 1994.

4. Discussion

Fry of ruffe feed on zooplankton; in autumn it begins to take also zoobenthos. According to Kangur (1969), the main food for the fry of ruffe in L. Vôrtsjärv was benthopelagic zooplankton (*Cladocera*: *Alona affinis, Chydorus sphaericus, Bosmina coregoni, Daphnia cucullata* and *Cope-*

poda: Cyclopoida, Harpacticoida, Calanoida) as well as *Ostracoda*. The role of zoobenthos in the food of 0+ ruffe was comparatively small.

At present as well as 25–30 years ago the main food objects for 1+ and older ruffe in L. Vôrtsjärv have been chironomids predominating among other macrobenthic invertebrates in all zones of the lake bottom. But these have been different species.

In the 1960s *Procladius, Microchironomus tener* (= *Cryptochironomus* gr. *conjungens*), *Einfeldia carbonaria* were prevailing in the food of ruffe (Kangur & Tôlp 1974). Today (in 1994) the composition of the food of ruffe has considerably changed in L. Vôrtsjärv. All the above mentioned chironomid species are still represented in the food of ruffe but in insignificant amounts. The number of chironomid species in the food of ruffe has also decreased by the present time.

In 1994 the highest frequency of occurrence (91%), mean number (72%) and biomass (98%) in the stomach of ruffe belonged to *C. plumosus* larvae and pupae. But in the 1960s they occurred only in 19% of stomachs (Kangur & Tôlp 1974). Thus, at present the main food of ruffe of *SL* over 4.5 cm in L. Vôrtsjärv is *C. plumosus;* ruffe is tending to be monophagous in the lake, consuming only one type of food organism depending on its availability.

Likewise, *C. plumosus* is the most important food item for ruffe in several other eutrophic lakes in Europe, for example in Lake Peipsi (Antipova 1981, Antipova & Kontsevaya 1988).

Large pupae of *C. plumosus* are heavily predated by ruffe, which indicates that it feeds chiefly in the surface layer of the bottom substratum of the lake. Obviously, ruffe takes pupae also during its ascent to water surface.

In Estonian lakes, ruffe eats the roe of other fishes, if available, on their spawning grounds: lake smelt's (*Osmerus eperlanus eperlanus* m. *spirinchus*) roe in spring (Antipova & Kontsevaya 1988) as well as vendace's (*Coregonus albula*) and whitefish's (*C. lavaretus maraenoides*) roe in late autumn and winter (Pihu & Pihu 1974). In other European lakes, for example in Lake Constance, ruffe is a bottom feeder during the vegetation period, preying mainly on chironomids

Table 4. The proportions of chironomids in the profundal mud bottom and in the food of ruffe in L. Vôrtsjärv in 1994.

Species	Mean values in the profundal				Mean ind. live weight,
	Indiv./m^2	%	g/m^2	%	mg
C. plumosus pupa	1.2 ± 1.2	0.3	0.1 ± 0.1	1.0	42.2 ± 3.8
C. plumosus IV instar	255.6 ± 37.7	62.3	10.2 ± 1.5	97.1	39.7 ± 1.1
C. plumosus III instar	9.9 ± 3.8	2.4	< 0.1	0.1	2.9 ± 0.3
C. plumosus II instar	0	0	0	0	< 0.1
Einfeldia carbonaria	76.7 ± 23.0	18.7	1.0 ± 0.0	1.0	2.7 ± 0.6
Microchironomus tener	23.4 ± 15.9	5.7	< 0.1	0	0.6
Procladius sp.	43.4 ± 13.6	10.6	0.1 ± 0.0	0.8	3.9 ± 2.2
Other chironomids	0	0	0	0	< 1
Total	410.2 ± 71.9	100	10.5 ± 1.5	100	
	Mean values per stomach				
	Indiv.	%	mg	%	
C. plumosus pupa	0.7	8.0	29.5	15.7	
C. plumosus IV instar	3.8	43.7	150.9	80.1	
C. plumosus III instar	1.2	13.8	3.5	1.9	
C. plumosus II instar	0.6	6.9	0.1	0	
Einfeldia carbonaria	0.9	10.3	2.4	1.2	
Microchironomus tener	1.0	11.5	0.6	0.3	
Procladius sp.	0.3	3.5	1.2	0.6	
Other chironomids	0.2	2.3	0.2	0.1	
Total	8.7	100	188.4	100	

and detritus. However, during the coregonid spawning season in December ruffe switch to coregonid eggs as the main prey (Rösch & Smidt 1996). In the present study cyprinids eggs were found only in 2% of ruffe stomachs in May.

According to previous investigations in L. Vôrtsjärv (Kangur 1968), large ruffe take also small fish, mainly lake smelt. In 1994 we did not find any fish in ruffe stomach. Obviously, at present the amount of *C. plumosus* is sufficient for ruffe and other benthophagous fishes in the lake and they do not need other kinds of food.

Fishes may shift their diet and feeding modes from day to day when the availability of food changes (Lammens & Hoogenboezem 1991).

The amount of chironomids available in L. Vôrtsjärv is variable. Especially the abundance of *C. plumosus* varies greatly from year to year (Kangur 1989b). A general tendency to increasing the abundance and biomass of chironomids has been observed in L. Vôrtsjärv during the last 30 years, the increase of *C. plumosus* being the most considerable. This is probably caused by the Slow but continuous eutrophication of the lake (Kangur *et al.* 1996).

C. plumosus is available in the profundal and sublittoral mud and marl bottom of the lake, indicating that ruffe prefers the open water zone as a feeding place.

Chironomid species, first of all *C. plumosus,* are also the main prey items for eel (Kangur 1989a) and bream (Kangur & Kangur 1994, 1995) in L. Vôrtsjärv. Although 11 fish species (chiefly ruffe, roach, young perch, smelt etc.) have been found among the food items of eel of standard length over 30 cm in the lake, the main food objects are still larvae and pupae of *C. plumosus,* which made up about 70% of the restored weight of all food items.

Larval instars and pupae of chironomids are also the main food items for bream of standard length over 15 cm (95% of the diet). *C. plumosus* constituted in average about 97% of the chironomids biomass in bream's food. Consequently, ruffe, bream and eel consume a large proportion of the *C. plumosus* production in the lake, which may lead to a competition between them. However, these fish species can eat different chironomid instars. Unlike eel who takes mainly large fourth-instar larvae and pupae of *C. plumosus* (Kangur 1989a), ruffe and bream eat in addition to them small third- and second-instar larvae of this species as well as other small-size chironomids.

Obviously, even if the overlap was pronounced, serious competitive interactions would arise only in the case of limited food resources. However, in the year 1994 the main food, *C. plumosus* was abundant.

Ruffe is the most important consumer of bottom animals in L. Vôrtsjärv and takes more chironomids than bream and eel together. Ruffe's consumption of food per unit of body weight (2%) is larger than that of bream (1%, Kangur & Kangur 1995) or eel (0.8%, unpublished data of 1994).

Ruffe compensates for the disappearance of one food object by another, abundant item, and always eats the most abundant prey found in the benthos.

Acknowledgements. We thank our colleague Dr. Ervin Pihu for valuable comments on the manuscript. The English text was kindly checked by Mrs. Ester Jaigma.

References

Antipova, L. F. (Антипова, Л. Ф.) 1981: Feeding of benthophagous fish in Pskov-Chud Lake, its quantitative and qualitative characteristics. — Sbornik Nauchnykh Trudov Gosudarstvennogo Nauchno-IsSledovatel'skogo Instituta Ozernogo i Rechnogo Rybnogo Khozyaistva, 162: 181–198. (In Russian with English summary.)

Antipova, L. F. & Kontsevaya, N. Ya. (Антипова, Л. Ф. & Концевая, Н. Я.) 1988: (Population characteristics of ruffe and several peculiarities of its feeding in Pskov Lake.) —Sbornik Nauchnykh Trudov Gosudarstvennogo Nauchno-IsSledovatel'skogo Instituta Ozernogo i Rechnogo Rybnogo Khozyaistva 282: 26–31. (In Russian.)

De Nie, H. W. 1987: Food, feeding periodicity and consumption of the eel Anguilla anguilla (L.) in the shallow eutrophic Tjeukemeer (The Netherlands). — Arch. Hydrobiol. 109: 421–443.

Haberman, J., Nôges, P., Pihu, E., Nôges, T., Kangur, K. & Kisand, V. 1996: Characterization of Lake Vôrtsjärv. — Limnologica. (In print.)

Kangur, A. 1989a: The significance of Chironomus plumosus L. on the feeding of eel in Lake Vôrtsjärv (Estonian SSR, USSR). — Acta Biol. Debr., Oecol. Hung. 3: 177–187.

Kangur, A. & Kangur, K. 1994: The diet of bream (Abramis brama (L.)) and eel (Anguilla anguilla (L.)) in relation to the abundance of benthic organisms in Lake Vôrtsjärv (Estonia). — In: Fishes and their environment: 35–36. Oviedo, Spain.

— 1995: The composition and seasonal changes in the diet of bream (Abramis brama) in relation to the abundance and biomass of its food items in Lake Vôrtsjärv (Estonia). — Proc. Estonian Acad. Sci. Biol. 44: 11–22.

Kangur, K. (Кангур, К.) 1977: (Productivity of Chironomus plumosus L. in the open part of Lake Vôrtsjärv.) — IsSledovaniya po problemam ekologii I ratsional¢nogo ispol'zovaniya prirodnyh resursov: 81–84. Tartu. (In Russian.)

Kangur, K. 1989b: Ecology and population dynamics of Chironomus plumosus L. in Lake Vôrtsjärv, Estonian S.S.R. — Acta Biol. Debr., Oecol. Hung. 3: 189–198.

Kangur, K. & Tuvikene, L. 1996: Live wet weight, dry weight and caloricity of some macrobenthic invertebrates of Lake Vôrtsjärv. — Limnologica. (In print.)

Kangur, K. & Kangur, A. (Кангур, К. & Кангур, А.) 1978: (Length-weight characteristics of Chironomus plumosus L. larvae in Lake Vôrtsjärv.) — Biologiya vnutrennih vod. Informatsionnyj bylleten 37: 51–55. (In Russian.)

Kangur, K., Timm, H., Timm, T. & Timm, V. 1996: Long-term changes in macrozoobenthos of Lake Vôrtsjärv. — Limnologica. (In print.)

Kangur, M. (Кангур, М.) 1968: (On the feeding of ruffe in the Lake Vôrtsjärv.) — Ikhtiol. ozern. rybn. khoz. Mater. XI Konf. vnutr. vod. Pribaltiki: 65–70. Riga. (In Russian.)

Kangur, M. 1969: Feeding and growth of ruff and perch fries in Lake Vôrtsjärv. — Eesti Looduseuurijate Seltsi Aastaraamat 60: 80–91. (In Estonian with English summary.)

Kangur, M. & Tôlp, Ô. (Кангур, М. & Тыл'п, Ы.) 1974: Nutrition of the fish in Lake Vôrtsjärv. — Hydrobiological Researches 6: 138–162. Tartu. (In Russian with English summary.)

Lammens, E. H. R. R. & Hoogenboezem, W. 1991: Diets and Feeding Behaviour. — In: Winfield, I. J. & Nelson, J. (eds.), Cyprinid fishes systematics, biology and exploitation: 353–376. Chapman and Hall, London.

Mikelsaar, N. 1984: Eesti NSV kalad. — Valgus, Tallinn.

Pihu, E. R. & Pihu, E. H. (Пиху, Я. Р. & Пиху, Я. Х.) 1974: The perch and ruffe of Pskovsky-Chudskoy water body. — Izvestiya Gosudarstvennogo Nauchno-IsSledovatel'skogo Instituta Ozernogo i Rechnogo Rybnogo Khozyaistva 83: 111–130. (In Russian with English summary.)

Rösch, R. & Smidt, W. 1996: Ruffe, newly introduced into Lake Constance, population dynamics and possible effects on coregonids. — Ann. Zool. Fennici 33: 467–471.

Schneider, G. 1920: Nahrung, Wachstum und Parasiten der Fische des Wirzjerv. — Arch. Naturk. d. Ostbalt. 2. Ser. 14: 9–117.

Winfield, I. J. & McCulloch, I. D. 1995: An indexed bibliography of the ruffe Gymnocephalus cernuus (L.) (Percidae): a carnivorous freshwater fish threatening rare fishes following recent introductions in Britain, Europe and North America. — Freshwater Biological Association. Occasional Publication No. 31.