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Biomass, growth, and diet of fish in forest lakes affected by alkaline mining water in NW Russia

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Abstract. Waste water from the mining industry has altered the water chemistry of naturally oligotrophic lakes in the Kostomuksha area of NW Russia, resulting in high alkalinity and high concentrations of certain anions. Two such lakes, Poppalijärvi and Kento, and one reference lake, Upper Kuito, were sampled for fish using multimesh gillnets in three successive years, 2000–2002. The total CPUE (g gillnet^{-1} night^{-1}) was 2.5 times higher in the affected lakes than in the reference lake. Perch and roach, the predominant species, grew well in all the lakes presumably due to an abundant supply of high quality macroinvertebrate food in their benthic habitats. The proportion of large piscivorous perch was notably high, especially in Lake Kento, probably as a result of low fishing pressure and the abundance of fish prey. Although detailed studies have revealed differences in the structure and function of fish gills and liver between the affected lakes and the reference lake, the environment in Lake Poppalijärvi and Lake Kento enables fast growth of the fish and promotes the existence of a high fish biomass.

Key words: fish biomass, fish growth, perch, roach, waste water, water chemistry, zoobenthos.

INTRODUCTION

Industrial waste water often causes harmful changes in the water chemistry and food webs in the recipient lake basins. The large mining company JSC Karelsky Okatysh, or Karelian Pellet, operates in Karelia, NW Russia, ca. 30 km east of the Finnish border extracting magnetite ore and processing it into iron pellets (ca. 6 mill. t a^{-1}) which are sold to steel plants all over the world. The main effects on the environment take the form of air pollution (SO_2 and dust) and waste water emissions. Since the construction of the factory as a joint Finnish–Russian project in 1984, its waste water has been discharged into a dammed basin, formerly a natural lake. Having filled the basin, the waste water has been allowed to flow into the natural Kenti lake–river system and finally via the Kem River to the White Sea.

Several lakes downstream of the factory show a clear increase in the mineral content of their water. The pH and concentrations of potassium, lithium, calcium, and magnesium are one to two orders of magnitude higher in the lakes close to the waste basin than in the natural lakes further downstream, whereas total phosphorus has been at the same low level as in local oligotrophic lakes that are in a natural state (Table 1). No drastic differences in diversity and abundance of zoobenthos have been observed between the reference and affected lakes, although the high pH and calcium contents have probably favoured molluscs with hard shells in the latter ones (Aroviita et al., 2006). Nevertheless, planktonic communities have obviously been harmed by the altered water chemistry in the affected lakes (Holopainen et al., 2008).

In general, lakes with alkaline water are eutrophic, and their fish community is dominated by cyprinids (Rask et al., 2002). In addition, a high pH favours roach *Rutilus rutilus* (L.) more than perch *Perca fluviatilis* (L.) (Rask et al., 1995) and associates with a high fish biomass in lakes (Holmgren & Appelberg, 2000). Although factors that have major effects on the fish community (high alkalinity, low productivity, and low fishing pressure) are combined in an extraordinary way in the waste water affected lakes of the Kenti lake–river system, the water chemistry and a high biomass of molluscs, suitable food for cyprinids, should favour especially cyprinids, such as roach. However, lakes in the area are oligotrophic, which in turn favours salmonids and percids instead of cyprinids (Persson et al., 1991).

This paper presents results regarding various aspects of fish biology in the two affected lakes by comparison with a reference lake. Factors underlying the apparently similar fish fauna but twice as high catch per unit effort in the lakes with drastically altered water chemistry and plankton communities are discussed. Descriptions and data on the water chemistry, plankton, and zoobenthos of this

Table 1. Characteristics of the lakes studied

Characteristic	Affected lakes in the Kenti river system						Reference lake Upper Kuito		
	Poppalijärvi			Kento					
	2000	2001	2002	2000	2001	2002	2000	2001	2002
Surface area, km^2	1.7[a]			27.1[a]			198[a]		
Mean depth, m	4.3[a]			3.8[a]			–		
Max depth, m	11[a]			24[a]			44[a]		
pH	8.3[b]	8.0	8.0	7.7[b]	7.7	8.0	6.8[b]	6.7	6.6
Conductivity, mS m^{-1}	39.1[b]	39.4	39.0	4.9[b]	14.0	14.5	2.5[b]	2.4	2.8
Secchi depth, m	2.1	2.6	2.9	2.7	3.2	3.0	2.8	2.8	3.0
Total phosphorus, µg L^{-1}	6[b]	9	7	8[b]	8	8	14[b]	11	9
K^+, mg L^{-1}	60[b]	60	51	20[b]	20	17	0.5[b]	0.4	0.6
Li^+, µg L^{-1}	20[b]	–	20.0	7[b]	–	4.0	0.2[b]	–	0
Ca^{2+}, mg L^{-1}	21[b]	23	21	7.9[b]	8.4	8.7	1.9[b]	1.9	2.1
Mg^{2+}, mg L^{-1}	8.3[b]	7.7	8.0	3.1[b]	3.2	3.1	0.8[b]	0.6	0.9

[a] Data from Lozovik et al. (2001).
[b] Data from Tkatcheva et al. (2002).
– No data.

watercourse have been published previously by Kukharev et al. (1995), Virtanen & Markkanen (2000), Lozovik et al. (2001), and Kalinkina et al. (2003), for example. Studies concerning the effects of the alteration in water quality on fish health have revealed changes in the histological structure of liver (Tkatcheva et al., 2000) and gill (Tkatcheva et al., 2004) tissue from perch and roach in the affected lakes. High lithium concentration in water has been shown to alter the gill membrane fluidity in fish (Tkatcheva et al., 2007a, b). The consequences for the food web have been discussed by Tkatcheva et al. (2002), Holopainen et al. (2003, 2008), and Aroviita et al. (2006).

SITES, MATERIAL, AND METHODS

The Kenti lake–river system in the Kostomuksha area (64°43′ N, 30°58′ E) of Karelia, NW Russia, receives alkaline waste water from an iron mine and its processing plant. Since 1994, waste water from a dammed basin (ca. 10–20 mill. m^3 a^{-1}, Lozovik et al., 2001) and from open mining pits (2–3 mill. m^3 a^{-1}) has been allowed to flow a distance of 75 km to the larger lake Middle Kuito through a number of small lakes and along the Kento River (Fig. 1). This waste flow represents ca. 8% of the mean discharge (8.21 m^3 s^{-1}, Kukharev et al., 1995)

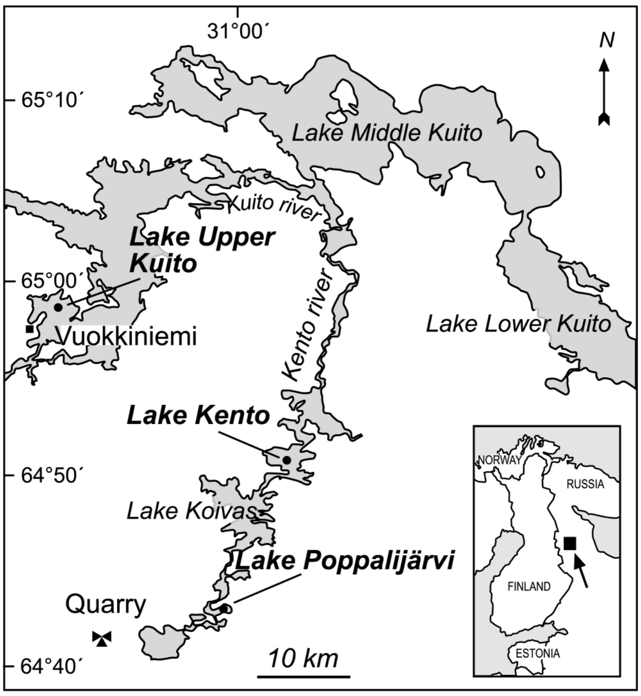

Fig. 1. Map of the Kostomuksha area in NW Russia.

at the river outlet. The two affected lakes studied here – Poppalijärvi, 1.7 km^2, ca. 4 km downstream from the waste basin, and Kento, 27.1 km^2, ca. 20 km downstream – are oligotrophic humic forest lakes unaffected by any source of pollution other than the mining water (Table 1). A partly isolated basin of Lake Upper Kuito, flowing into Lake Middle Kuito like the affected lakes, was used as a reference as it is only slightly affected by discharges from the local village of ca. 500 inhabitants, Vuokkiniemi. The fishing pressure on all these lakes is low and no commercial or effective regular fishing is known to take place in them.

The Kostomuksha region is part of the middle boreal zone and the ancient Baltic or Scandinavian shield area, consisting of Precambrian silicate rocks below a thin cover of glacial deposits. The area was deglaciated only ca. 8000 years ago, and the resulting variable topography explains its high number of small lakes. It is part of the widespread northern coniferous zone with Scots pine (*Pinus sylvestris* L.) and Norway spruce (*Picea abies* (L.) H. Karst.) as the dominant trees. In addition to natural forest (70%), wetlands (with a marsh or peat bog vegetation) cover ca. 20% of the area and lakes ca. 10%. The climate is continental, with relatively warm summers but cold winters; all the lakes are covered by ice and snow for ca. 200 days each year.

Fish were sampled in all three lakes in early August in three successive years (2000–2002) using multimesh gillnets (1.5 m × 30 m) of nine mesh sizes (10, 12, 15, 20, 25, 30, 35, 45, and 55 mm from knot to knot) in order to study the abundance, biomass, and structure of the fish fauna (see Kurkilahti & Rask, 1996). Stratified random sampling with three inshore nets at a depth of 0–3 m and six offshore nets, three pelagic and three on the bottom, at 10–12 m was carried out simultaneously in all three lakes for 12 h, at the same sites in all years. The fish in each net were identified to species, counted, and weighed and their stomachs, scales, opercula, and cleithra were subsampled for diet and growth analyses. The subsampled fish were individually weighed (fresh mass, *FM*) and their total lengths (*TL*) measured. For the purposes of the calculations and comparisons, the gillnet catch data were transformed to correspond to the NORDIC gillnet catch (SFS-EN, 2005; Voutilainen & Huuskonen, 2006) and expressed as catch per unit effort (CPUE, g gillnet^{-1} night^{-1}). The two predominant species, roach and perch, were routinely aged from scales. Condition factors (Bolger & Connolly, 1989) were calculated for them employing the formula:

$$K = 100 * \frac{FM}{TL^b},$$

where K is the condition factor, FM is fresh mass (g), TL is total length (cm), and b is the slope of the linear regression between $\log_{10}FM$ and $\log_{10}TL$ fitted to the data pooled over the lakes and the years of sampling. Univariate Analysis of Variance (ANOVA in SPSS 14.0 for Windows) was used to test differences in total CPUE and the condition factor in the perch and roach between the lakes, taking the lake of origin as a fixed factor in both the analyses and the year of sampling as a random factor in the condition factor analysis. The condition factors for perch and roach were analysed separately for each age group from 1+ to 6+ years. If the effect of lake on CPUE or the condition factor was significant ($p < 0.05$), a post hoc test (LSD) was conducted. Univariate Analysis of Covariance (ANCOVA) was used to test differences in the back-calculated length at age in the perch and roach between the lakes, taking the lake of origin as a fixed factor and the age of the fish as a covariate. The back-calculated length at age was analysed separately for each year from 1995 to 2001. When necessary, the variables were log-transformed to meet the assumptions of analysis of variance.

The diet of a total of 100 perch and 86 roach was examined. The fish were picked out from the gillnet catch, except for 2002, when a hook and line were used to obtain a fresh catch. The stomachs of the perch and digestive tracts of the roach were removed in the field and preserved in 70% ethanol. After exclusion of those with empty stomachs and perch with a fish diet, the number of perch in further analyses was 51 and that of roach 64. In the laboratory, the percentage fullness of the stomach and gut in each case was estimated as 0% (empty), 25%, 50%, 75%, and 100% (full). The food items were identified under a dissecting microscope to the lowest taxonomic level possible, whether family, genus, or species. The frequency of occurrence (%) of each food item in the stomach or gut was calculated and its importance (relative volume) in each stomach or gut was estimated by the Points method (Hynes, 1950), after which the points were scaled down to percentages to give a volume-based indication of the composition of the food. The relation of the food of the perch and roach to the food available in the lakes was assessed by calculating the Jacobs index D (Jacobs, 1974):

$$D = \frac{(r-p)}{[(r+p)-2rp]},$$

where r is the proportion of the food item in the stomach or gut, and p the proportion of the same food in the environment. As the fish that had been caught were found to feed mainly from the bottom, the macrozoobenthos biomass in the corresponding year (Aroviita et al., 2006) was used to reflect the amount of food in the environment. Both the littoral and profundal zones were regarded as possible environments because no information was available on the areas where the fish had been feeding.

RESULTS

The gillnet catch in the reference lake, Upper Kuito, consisted of eight fish species: pike *Esox lucius* (L.), perch, ruffe *Gymnocephalus cernuus* (L.), roach, dace *Leuciscus leuciscus* (L.), bleak *Alburnus alburnus* (L.), whitefish *Coregonus* *lavaretus* s.l. (L.), and vendace *Coregonus albula* (L.). Dace was not found in the catch from the two affected lakes, Poppalijärvi and Kento. Roach and perch were the predominant species in all three lakes, roach having a higher CPUE than perch in the reference lake, whereas the opposite was observed in the affected lakes (Fig. 2). The proportion of small perch ($TL < 15$ cm) in the catch was highest in the reference lake (ca. 70%), where that of large perch ($TL > 25$ cm) was lowest (<1%), whereas the proportion of large perch was highest in the catch from Lake Kento (4%). Young perch and roach ($TL < 10$ cm) were present in the catches from all the lakes suggesting a normal pattern of reproduction for the species.

The CPUE for the fish differed between the lakes but not between the sampling years (ANOVA and LSD, $p < 0.05$ for the lake, and $p > 0.05$ for the year and for the interaction between lake and year), being lower in the reference lake, Upper Kuito (402 ± 42 g, mean ± SE), than in the affected lakes, Poppalijärvi (814 ± 92 g) and Kento (1006 ± 118 g) (Fig. 2). The back-calculated length at age of perch did not differ between the lakes in any year (1995–2001) (ANCOVA, $p < 0.01$ for age and $p > 0.05$ for the lake and for the interaction between lake and age in each year). The same was true of the length at age of roach ($p < 0.01$ for age and $p > 0.05$ for the lake and for the interaction between lake and age), except in 1998, when the roach were longer in the two affected lakes than in the reference lake (ANCOVA Contrast, $p < 0.05$).

The condition factors of perch in the age group 3+ and roach in the age group 5+ were lower in Lake Poppalijärvi than in Lake Kento and Lake Upper Kuito (ANOVA and LSD, $p < 0.05$ for the lake and $p > 0.05$ for the year of sampling

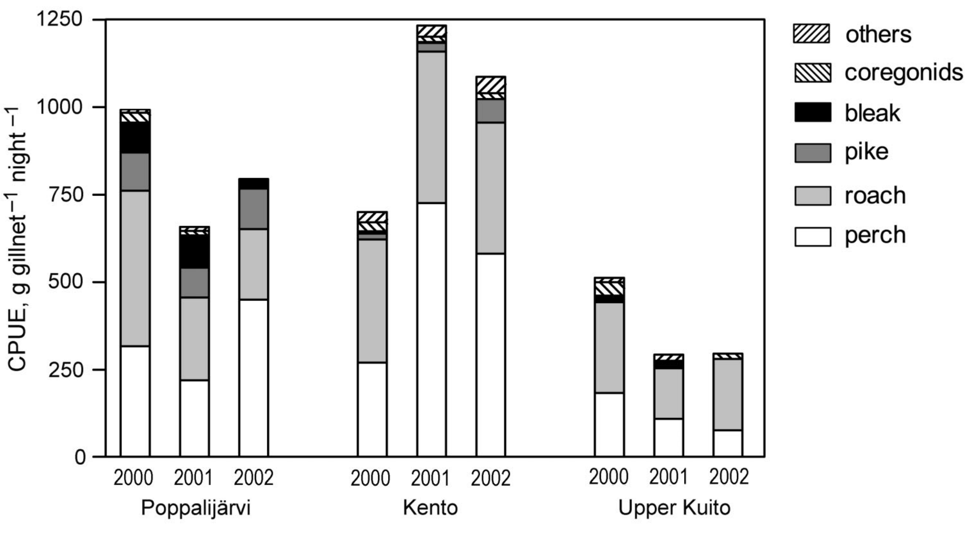

Fig. 2. Fish CPUE in 2000–2002.

and for the interaction between lake and year). In the all other age groups (from 1+ to 6+ years), the condition factors of perch and roach did not vary between the lakes (ANOVA, $p > 0.05$ for the lake and for the year of sampling, but $p < 0.01$ for the interaction between lake and year in the roach age groups from 1+ to 4+).

Out of the 100 perch and 86 roach examined, 12% of the perch stomachs and 24% of the roach digestive tracts were totally empty and could not be used in the diet analysis. The perch stomachs were evaluated as being fuller on average than the roach guts. In the most seriously affected lake, Poppalijärvi, >30% of the perch stomachs and >40% of the roach guts were full (75–100% fullness), as compared with <20% of perch and 24% of roach in the reference lake, Upper Kuito.

Larvae of Ephemeroptera (mostly *Ephemera vulgata* L.) formed a major part of the diet of the smaller perch ($TL < 20$ cm) when evaluated as a percentage of the stomach content by volume (Fig. 3). The proportion of Ephemeroptera in the diet was largest (Fig. 3) and the selectivity index (D) of perch for *E. vulgata* highest in the reference lake, Upper Kuito (Table 2). The second most abundant group of taxa in the diet of perch was Cladocera (mostly *Eurycercus lamellatus* (Chydoridae)), followed by Chironomidae (Fig. 3). The proportion of Chironomidae in the stomach content was slightly larger in the affected lakes than in the reference lake (Fig. 3), while conversely, the perch in Lake Upper Kuito, unlike those in the affected lakes, had eaten some *Bosmina* (Cladocera) and Copepoda. Insect larvae other than Ephemeroptera, notably Trichoptera (e.g. *Molanna angustata*), were common in the perch diet in the affected lakes. The diet of the large perch ($TL > 20$ cm) consisted of fish.

Sphaeridae (*Pisidium* spp.) (Bivalvia) were the most common food items in the diet of the roach in the most seriously affected lake, Poppalijärvi (Fig. 3), while *E. lamellatus* (Cladocera) was the most abundant item in both Lake Kento

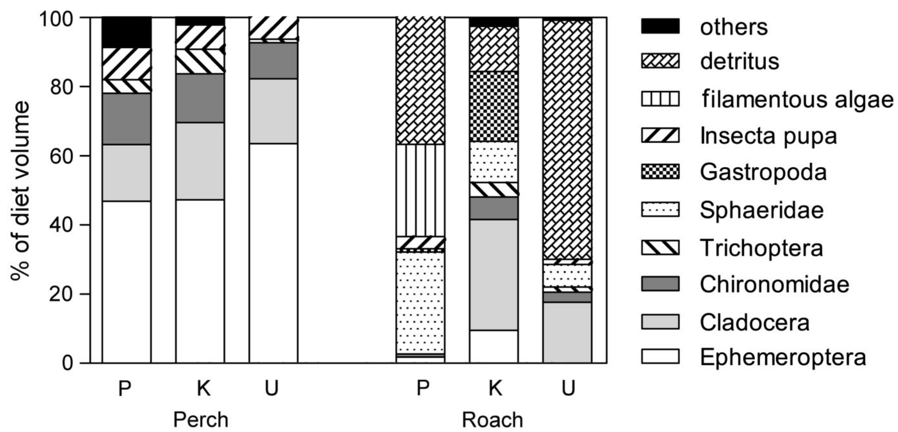

Fig. 3. Composition (per cent by volume) of the diet of perch ($TL < 20$ cm) and roach in Lake Poppalijärvi (P), Lake Kento (K), and Lake Upper Kuito (U).

Table 2. The Jacobs index (mean, the number of fish that had eaten the specific food item in brackets) for the main taxonomic groups in the diet of perch (*TL* < 20 cm) and roach in the affected lakes, Poppalijärvi and Kento, and in the reference lake, Upper Kuito

Food taxon	Poppalijärvi				Kento				Upper Kuito			
	Perch		Roach		Perch		Roach		Perch		Roach	
Cladocera	1.0	(6)	–	(0)	1.0	(8)	1.0	(14)	1.0	(4)	0.9	(11)
Diptera												
Chironomidae	–0.3	(13)	–0.5	(1)	0.0	(12)	0.1	(4)	–0.4	(5)	–0.7	(4)
Ephemeroptera												
E. vulgata	0.6	(11)	0.5	(1)	0.7	(12)	0.6	(3)	0.9	(9)	–	(0)
Caenis horaria	0.8	(2)	–	(0)	1.0	(2)	–	(0)	0.9	(1)	–	(0)
Megaloptera												
Sialidae	0.7	(3)	–	(0)	–	(0)	–	(0)	–	(0)	–	(0)
Trichoptera	1.0	(4)	–	(0)	1.0	(5)	1.0	(1)	0.9	(1)	0.8	(2)
Insecta pupa	0.8	(8)	0.9	(2)	1.0	(6)	–	(0)	0.9	(3)	1.0	(2)
Bivalvia												
Sphaeridae	–	(0)	0.4	(8)	–	(0)	0	(7)	–	(0)	0.6	(4)
Gastropoda	–	(0)	0.6	(1)	–	(0)	0.9	(8)	–	(0)	–	(0)

and Lake Upper Kuito and Cladocera other than *E. lamellatus* were common, especially in the diet of the roach in Upper Kuito. The number of Cladocera in the guts of the roach from Lake Poppalijärvi was negligible, but the proportion of filamentous algae was high, ca. 25% (Fig. 3). In contrast to Poppalijärvi and Upper Kuito, the roach in Kento had eaten a large amount of Gastropoda (Fig. 3). The selectivity (*D*) of roach for Gastropoda was positive and high in Kento, and that for Cladocera both in Kento and Upper Kuito (Table 2). In general, and especially in Upper Kuito, the high abundance of detritus in the roach guts made it difficult to identify the food items and to estimate the taxa as proportions of the total gut content by volume.

DISCUSSION

The number of fish species (seven) in the gillnet catches from the two NW Russian lakes affected by waste water from the mining industry, Poppalijärvi and Kento, exceeded that to be found in unaffected Finnish (Rask et al., 1999; Helminen et al., 2000) or Swedish (Holmgren, 1999) oligotrophic lakes (total phosphorus <10 $\mu g\ L^{-1}$) of the same size. Also their CPUE was higher than in many unaffected Scandinavian lakes (Holmgren, 1999; Helminen et al., 2000). The number of species (eight) in the catch from the reference lake, Upper Kuito, corresponded to that for Finnish lakes (Helminen et al., 2000), although the CPUE was lower than in Scandinavian lakes of a similar character (Holmgren, 1999; Helminen et al., 2000).

Perch and roach were the predominant fish species in the gillnet catch from all three lakes, and both had grown well between 1995 and 2001, although the age-specific length of the roach was somewhat shorter in Upper Kuito than in Poppalijärvi and Kento, probably due to slow growth in 1998. The overall growth of perch in the Kostomuksha lakes was faster than that observed in two Finnish oligotrophic lakes at the same latitudes, the slightly acidic Lake Suomunjärvi (Viljanen & Holopainen, 1982) and the alkaline Lake Pesosjärvi (Rask et al., 1998), but corresponded to that in the slightly acidic oligotrophic Lake Iso Hietajärvi (Rask et al., 1998). Especially in the affected lakes, Poppalijärvi and Kento, the roach had grown fast compared with cases observed in several slightly acidic lakes in Finland (Rask & Tuunainen, 1990) and in the eutrophic Lake Vesijärvi (Horppila, 1994). The cyprinids to percids biomass ratio was highest (1.7) in the catch from the reference lake and lowest (0.7) in the catch from Lake Kento, a high proportion of which consisted of large piscivorous perch. Cyprinids generally dominate gillnet catches in nutrient-rich lakes (Olin et al., 2002), while salmonids (e.g. vendace, whitefish, and smelt *Osmerus eperlanus* (L.)) are more abundant than other fish in an oligotrophic environment (Persson et al., 1991). Percid dominance is typical of moderately productive systems (Persson et al., 1991).

Acidification has been shown to be severely harmful to fish communities (see Rask & Tuunainen, 1990), but a high pH is associated with a high fish biomass in lakes (Holmgren & Appelberg, 2000). On the other hand, a high pH favours roach more than perch, due to the higher tolerance of the latter to acidified water (Rask et al., 1995). Lakes with alkaline water are usually eutrophic, and their fish biomass is dominated by cyprinids (Rask et al., 2002). Despite the calcium-rich alkaline water, which should favour cyprinids, the biomass of percids in the gillnet catches from Lake Poppalijärvi and Lake Kento was higher than that of cyprinids. A probable reason for the percid dominance in those lakes is the shortage of nutrients, which is in turn related to a low chlorophyll-*a* content (Holopainen et al., 2008) and to a low biomass of cyprinids (see Persson et al., 1991). Moreover, fish communities in the Kostomuksha lakes are not affected by commercial or domestic fishing, which usually hits piscivorous fish such as large perch harder than smaller cyprinids such as roach (see Auvinen, 1987).

The CPUE for the fish caught from the affected lakes was about 2.5 times higher than that in the reference lake, mainly because of the great abundance of perch in the former. The main differences in water chemistry between the affected lakes and the reference lake were the considerably higher pH and conductivity and the higher concentrations of certain anions in the former. However, although both conductivity and anion concentrations were higher in the most seriously affected lake, Poppalijärvi, than in Lake Kento, no evident differences in the fish community were observed between these lakes. Most fish were caught from benthic habitats in all three lakes. Both the total biomass of zoobenthos (Aroviita et al., 2006) and the benthic CPUEs for perch and roach were highest in Lake Kento and lowest in Lake Upper Kuito (Fig. 4). The environment in Poppalijärvi and Kento obviously favours the growth of zoobenthos (Aroviita et al., 2006), which is used as food by both perch and roach (Fig. 3). The density of chironomids

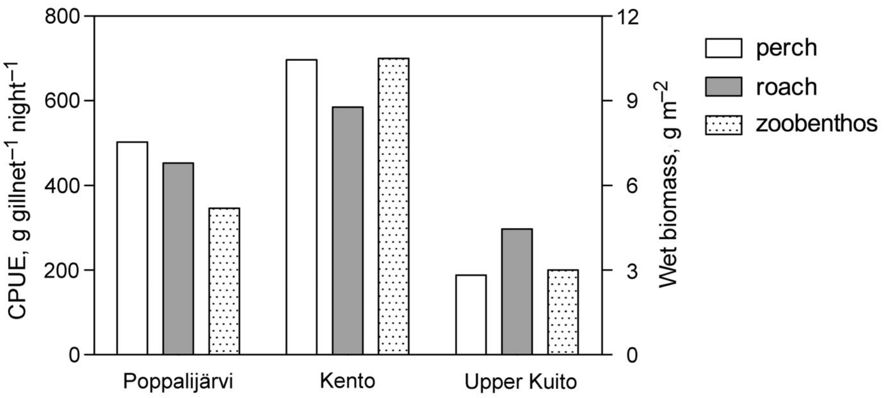

Fig. 4. Perch and roach CPUE and invertebrate biomass in benthic habitats (littoral and profundal data combined).

is high in all three lakes, but the density and biomass of molluscs, as well as the biomass of all zoobenthos, are greater in the affected lakes, especially in Kento, than in the reference lake (Aroviita et al., 2006). Moreover, large insect larvae, such as *E. vulgata*, are abundant in the littoral zone of the affected lakes, whereas oligochaetes are numerous in the reference lake (Aroviita et al., 2006).

The lower condition factor of the perch in the age group 3+ and roach in the age group 5+ in Poppalijärvi than in Kento or Upper Kuito is probably the result of the denser perch and roach populations consuming macroinvertebrate food. Perch feed mainly on zooplankton in early life and then switch to zoobenthos and eventually to fish (see e.g. Hjelm et al., 2000). The switch from planktonic to benthic food takes place gradually, but the biggest 'leap' usually occurs when the fish exceed 13–15 cm in length (Rask, 1986; Rask et al., 1998; Horppila et al., 2000), corresponding to the age group 3+ in Poppalijärvi, Kento, and Upper Kuito. Roach of all sizes except for one-summer-old fish are omnivorous, but the proportion of zooplankton in their diet when of size $TL < 15$–18 cm is generally higher than that of zoobenthos, and vice versa in the diet of roach of size $TL > 15$–18 cm (Horppila et al., 2000; Vinni et al., 2000). The selectivity (D) of perch ($TL < 20$ cm) for *E. vulgata*, the most numerous food item in the stomach content of the present samples, was nevertheless higher in Lake Upper Kuito than in the affected lakes. The roach in the same lake, Upper Kuito, fed mainly on detritus and zooplankton but less on zoobenthos, including *E. vulgata*. Consequently, the results suggest a more severe state of competition for food between perch and roach and between the age groups of perch (see Persson, 1986, 1987; Persson & Greenberg, 1990) in Lake Upper Kuito than in the affected lakes, due to a shortage of macroinvertebrate food. As a general rule, the diet of perch and roach in all three lakes reflected the structure of the zoobenthos and zooplankton communities and the abundance of invertebrates in the lake (Holopainen et al., 2003, 2008; Aroviita et al., 2006). The proportion of Cladocera in the diet of perch and especially in the diet of roach was lower in Poppalijärvi than in Kento and Upper Kuito (Fig. 3), where the biomass of Cladocera is in turn higher than in Poppalijärvi (Holopainen et al., 2008). Furthermore, the proportion of Gastropoda was high in the diet of roach in Kento (Fig. 3), where both the density and biomass of gastropods are higher than in Poppalijärvi or Upper Kuito (Aroviita et al., 2006). Chironomidae, which were common food items in the diet of perch (Fig. 3), are abundant in the benthic habitats in all three lakes (Aroviita et al., 2006).

To conclude, waste water from the mining industry has caused considerable alterations in water chemistry, especially in Lake Poppalijärvi but also in Lake Kento, and the environment in these lakes is more favourable to the growth of the macroinvertebrate fauna (Aroviita et al., 2006), which in turn reduces intra-specific and inter-specific competition for food between fish such as perch and roach, and hence enables fast growth of the fish and promotes the existence of a high fish biomass. Furthermore, the abundance of fish prey and the low fishing pressure favour the growth of piscivorous fish, e.g. large perch. Although detailed histological and physiological examinations have revealed differences in the structure and function of fish gills and liver between Lake Poppalijärvi, Lake Kento, and Lake Upper Kuito (Tkatcheva et al., 2000, 2004), the ecological importance of these differences appears to us to be negligible.

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Kalade biomass, kasvukiirus ja toiduratsioon aluseliste kaevandusvete poolt mõjutatud Loode-Venemaa metsajärvedes

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Kaevanduse heitveed on muutnud Loode-Venemaa Kostomukša piirkonna oligotroofsete järvede vee aluselisemaks ja suurendanud mitmete anioonide kontsentratsiooni. Kahes kaevandusvetest mõjutatud järves (Poppalijärvi ja Kento) ning ühes referentsjärves (Ülem-Kuito) uuriti aastatel 2000–2002 multisektsioonsete nakkevõrkude abil kalastiku olukorda. Mõjutatud järvedes oli kalastiku biomass CPUE alusel (ühe võrguga öö jooksul püütud kala hulk) 2,5 korda suurem kui referentsjärves. Domineerivad kalaliigid ahven ja särg kasvasid hästi kõigis järvedes: eelkõige tänu küllaldasele ning kvaliteetsele toiduvarule bentiliste suurselgrootute näol. Suurte röövtoiduliste ahvenate osakaal oli märkimisväärselt suur Kento järves: ilmselt väikese püügisurve ja arvuka toiduvaru tõttu. Ehkki detailsed uuringud näitasid, et mõjutatud järvedes erinesid kalade lõpuste ja maksa funktsionaalsed parameetrid referentsjärve omadest, võimaldab kaevandusvetest mõjutatud elukeskkond siiski kalade kiiret kasvu ning suure biomassi kujunemist.