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An introduction to the limnology of the Finnish Integrated Monitoring lakes

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The limnological monitoring of the lakes in the Finnish Integrated Monitoring catchment areas was started in 1990 in order to study the effects of airborne pollutants on ecosystems. The four pristine headwater lakes made up a wide gradient in terms of location, pH, alkalinity, water colour and total phosphorus concentration. The productivity of the lakes decreased from south to north, as was implied by data on phytoplankton biomass, chlorophyll concentration, primary production of phytoplankton and abundance of rotiferan zooplankton. However, the test fishing catches were not related to the productivity of the lakes. Perch, *Perca fluviatilis*, was the only fish species present in all four lakes. The appearance of new year-classes of roach, *Rutilus rutilus*, in one lake was interpreted to be a consequence of the slight decrease in the water acidity during 1988–1996.

Introduction

The Integrated Monitoring Programme of Air Pollution Effects on Ecosystems (IM Programme) is one of the five International Co-operative Programmes of the United Nations Economic Commission of Europe (UN ECE) commenced since 1993. The IM Programme in Finland was started already in 1987 and the subprogramme 'Hydrobiology of Lakes' has been carried out since 1990 as a cooperation of several institutions, including Regional Environment Centres, Universities and the Finnish Environment Institute and the Finnish Game and Fisheries Research Institute.

Several monitoring programmes on the impacts of air pollution have been carried out in Finland during the last two decades. These include programmes on wet deposition (Soveri and Peltonen 1995), on lake water quality (Mannio and Vuorenmaa 1995), on forests (Lumme *et al.* 1995), and on fish (Rask *et al.* 1995b). The goal of the Integrated Monitoring Programme is to carry out different types of monitoring activities in the atmosphere and terrestrial and aquatic ecosystems in the same catchments. Within the subprogramme 'Hydrobiology of Lakes' this means the inclusion of several water quality and biological parameters (phytoplankton, primary production and respiration of plankton, macrophytes, zooplankton, zoobenthos and fish) in the sampling programme. The sampling frequency for the biological parameters was chosen in accordance with the life cycles of the organisms in question. The aim of this monitoring is to study the effects of airborne pollutants on ecosystems, and, in addition, to increase the knowledge of natural variability of lake ecosystems in relation to environmental changes. The aim of this paper is to describe and compare the hydrochemical and hydrobiological characteristics of the lakes of the Finnish IM catchment areas.

Material and methods

Three catchment areas of the Finnish Integrated Monitoring Project with the lakes Valkea-Kotinen, Iso Hietajärvi and Pesosjärvi are located in boreal coniferous forest areas. The fourth catchment with the Vuoskojärvi is situated in the northermost part of Finland (Fig. 1, Table 1), in the area of subalpine birch and scots pine forests. A detailed description of the IM catchment areas and their lakes can be found in Bergström *et al.* (1995).

The monitoring of water properties was started in Iso Hietajärvi in 1988, in Valkea-Kotinen in 1989, and in the two other lakes in 1990. The continuous monitoring of plankton communities in Valkea-Kotinen started in 1990. In the other lakes a two-year monitoring of plankton was conducted as follows: Iso Hietajärvi 1990–1991, Pesosjärvi 1992–1993 and Vuoskojärvi 1994–1995.

Samples for physical and chemical water quality parameters and plankton were taken with tube samplers (Ruttner, Limnos, Sormunen types). Sampling was always carried out before noon at weekly or biweekly interval throughout the ice-free period. In Valkea-Kotinen and Pesosjärvi, samples were also taken once a month in winter. The analyses were made according to the Finnish standard methods for water analysis (SFS-standards). Phytoplankton samples were fixed with acid Lugol solution. Biomass and species composition of phytoplankton was determined with an inverted microscope using the settling chamber technique (Utermöhl 1958). Primary production was determined with the acidification and bubbling modification of the ^{14}C method (Schindler *et al.* 1972, Niemi *et al.* 1983) with incubation time of 24 h *in situ*. Zooplankton samples had been sieved through a 50 µm plankton net and fixed in 4% formaldehyde solution. Details on hydrobiological sampling and analyses can be found in Keskitalo and Salonen (1994).

Fish samples were taken during two periods: first in 1988–1990 and then in 1993–1994. Test fishings (1 to 3 fishing efforts per lake per year) were conducted in August (in Vuoskojärvi in October) with a series of eight 1.8 × 30 m gill nets, mesh sizes from knot to knot being 12, 15, 20, 25, 30, 35, 45 and 60 mm. Samples were taken from Valkea-Kotinen with the gill net series in 1990 and from 1991 onwards with wire traps (1 cm square mesh). The sampling was carried out once a month from May to September. The population size of perch was determined in Valkea-Kotinen with marking and recapturing technique (Krebs 1989) from 1991 onwards. When possible

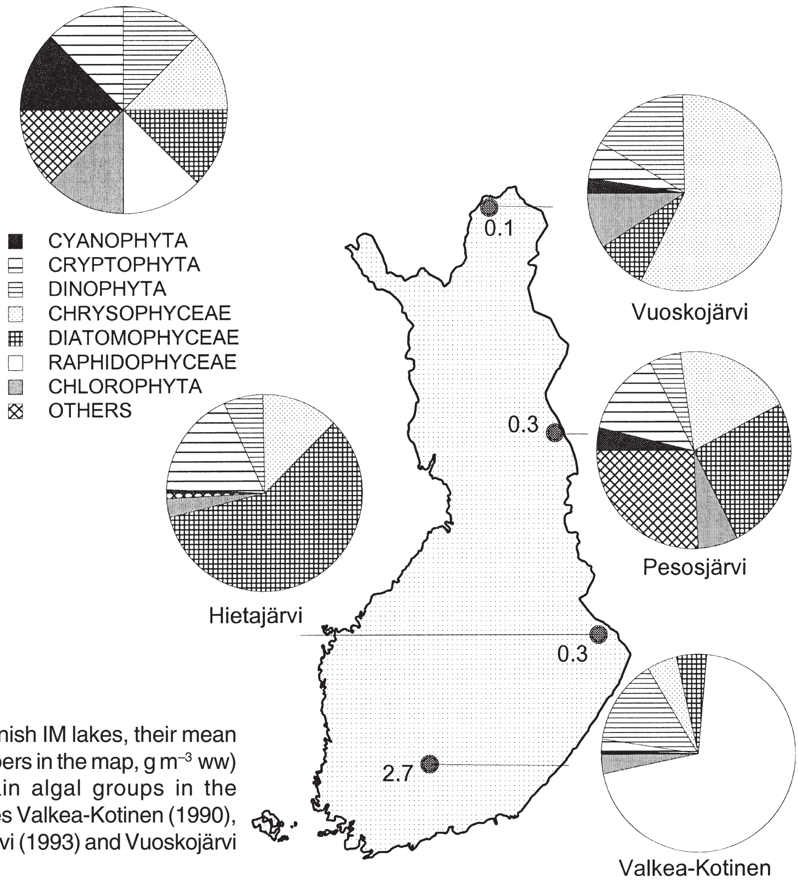

Fig. 1. The location of the Finnish IM lakes, their mean phytoplankton biomass (numbers in the map, g m^{-3} ww) and the proportions of main algal groups in the phytoplankton biomass in lakes Valkea-Kotinen (1990), Iso Hietajärvi (1990), Pesosjärvi (1993) and Vuoskojärvi (1994).

from the fish catches of all the lakes, a sample of 50 individuals of each species was taken for age, growth and diet analyses and for the determination of mercury concentrations. For perch, opercular bones were used for the determination of age and growth (Monastyrsky procedure, Bagenal and Tesch 1978). The age and growth of roach was determined from scales (Fraser-Lee method, Bagenal and Tesch 1978). The diet of perch was determined from 1993 and 1994 samples with a volumetric points method (Windell 1971). Samples for mercury concentrations were taken from the dorsal axial muscle of perch, pike and whitefish and determined as total mercury using the cold vapor atomic absorption technique (Armstrong and Uthe 1971).

Table 1. Size and location of the Integrated Monitoring Programme catchment areas in Finland (Bergström *et al.* 1995).

	Catchment area (ha)	Lake area (ha)	Mean depth (m)	Coordinates	Altitutde (m a.s.l)
Valkea-Kotinen	30	3.6	3.0	61°14´N, 25°04´E	156
Iso Hietajärvi	464	83	3.6	63°10´N, 30°43´E	165
Pesosjärvi	628	44	4.7	66°17´N, 29°31´E	256
Vuoskojärvi	178	17	3.0	69°44´N, 26°57´E	145

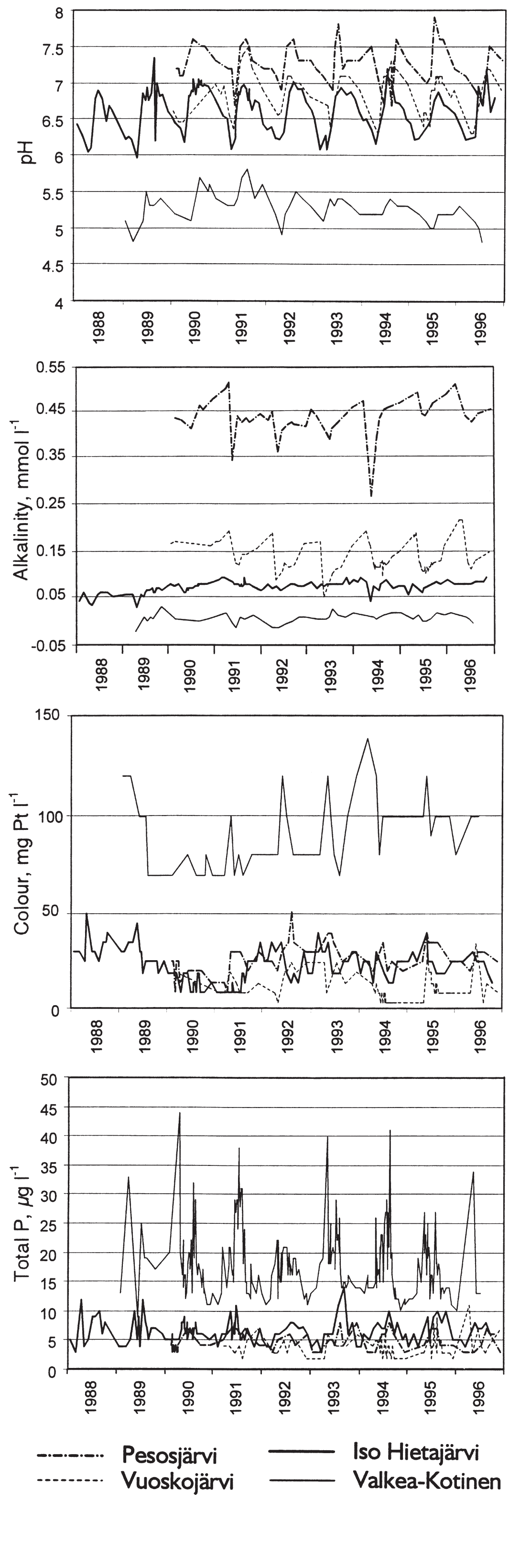

Fig. 2. The pH, alkalinity, water colour and total phosphorus concentrations in the Finnish IM lakes during 1988–1996, sampling depth 1 m.

Results

Water chemistry

Valkea-Kotinen was the most acidic of the Finnish IM lakes with pH-values varying from 4.8 to 5.8 in 1989–1996 and alkalinity being temporarily negative (Fig. 2). There was in Iso Hietajärvi a slightly increasing trend in pH, which rose from 6–6.5 to 6.5–7 during the study period. At the same time, the alkalinity in Iso Hietajärvi increased from 0.05 mmol l^{-1} to a level of 0.07 mmol l^{-1} (Fig. 2). Pesosjärvi and Vuoskojärvi with their annual mean alkalinities of 0.15 and 0.45 mmol l^{-1} were better buffered than the other two lakes.

Valkea-Kotinen was clearly more humic than the other lakes, with the mean epilimnetic water colour varying around 100 mg Pt l^{-1} (Fig. 2), and total organic carbon (TOC) between 7 and 13 mg l^{-1}. Iso Hietajärvi and also Vuoskojärvi and Pesosjärvi were clear-water lakes with water colour usually below 40 mg Pt l^{-1} (Fig. 2) and TOC concentration around 4–5 mg l^{-1} (range 2–8 mg l^{-1}). Correspondingly, the transparency of water in these three lakes was 4–5 m but in Valkea-Kotinen only around 1.5 m.

The total phosphorus concentration in epilimnion of Valkea-Kotinen varied generally from 15 to 22 µg l^{-1} during the growing seasons 1990–1996 but peaks up to 40 µg l^{-1} were also recorded (Fig. 2). During anoxic periods the hypolimnetic total phosphorus concentrations in Valkea-Kotinen were up to 90 µg l^{-1}. The mean total phosphorus concentrations of lakes Iso Hietajärvi, Pesosjärvi and Vuoskojärvi varied around 5 µg l^{-1} (Fig. 2) indicating oligotrophic conditions.

The mean epilimnetic chlorophyll *a* concentration during the growing season was clearly highest in Valkea-Kotinen, where it varied between 13 and 35 mg m^{-3} in 1990–1996. Concentrations up to 100 mg m^{-3} were recorded in the surface water. In other IM lakes the mean chlorophyll *a* concentrations varied between 0.6–3.4 mg m^{-3} (Table 2).

Phytoplankton

The highest epilimnetic phytoplankton biomass was measured in Valkea-Kotinen, where the mean biomass in May–September 1990 was 2.7 g m^{-3}. The lowest mean biomass, 0.1 g m^{-3} in 1994, was recorded in Vuoskojärvi. Phytoplankton biomass was also low in lakes Hietajärvi and Pesosjärvi where the mean biomass in May–September was 0.3 g m^{-3} (Fig. 1).

In Valkea-Kotinen, *Gonyostomum semen* (Raphidophyceae) was the dominant species in summer. In Hietajärvi, the diatoms and cryptophytes composed most of the biomass during the growing season. Cryptophytes and chrysophytes were abundant in Pesosjärvi in spring and at the beginning of summer and diatoms during the late summer. Vuoskojärvi was a typical chrysophyte lake (Fig. 1).

The annual primary production of the lakes varied from 6–8 g C m^{-2} in Vuoskojärvi to 25–38 g C m^{-2} in Valkea-Kotinen (Table 3).

Zooplankton

In Valkea-Kotinen, the zooplankton community in 1992 and 1993 was dominated by rotifers (Fig. 3). *Kellicottia bostoniensis* appeared in 1990 and on the basis of densities dominated the zooplankton community during the whole growing season 1993 as well as the following years (Keskitalo *et al.* 1998). The most abundant cladocerans were *Holopedium gibberum, Bosmina longirostris* and *Ceriodaphnia quadrangula* (Fig. 4), and copepods *Mesocyclops leucarti* and *Thermocyclops* spp. A comparison of the mean densities of the main zooplankton groups in the four IM lakes during the growing season is presented table 4.

In Iso Hietajärvi, rotifers were dominant, especially *Conochilus unicornis*, throughout the growing season 1990. The most numerous cladoceran was *Bosmina longispina*. In 1991, rotifers were dominant throughout the season but only in early summer were their numbers high (Fig. 3). In 1991, Cladocerans, mainly *Daphnia* species, were more abundant in mid summer than in the previous year and declined again in late summer. Copepods were abundant after the peak of cladocerans in July, but mainly because of high numbers of both Calanoida and Cyclopoida nauplii.

In Pesosjärvi, rotifers were dominant throughout the growing season of 1992 except in early summer when copepods were most abundant (Fig. 3) due to high numbers of *Eudiaptomus graciloides* and Cyclopoid nauplii. The rotifer peak in mid summer was mainly due to high numbers of *Conochilus unicornis, Polyarthra vulgaris* and *Kellicottia longispina*. The number of cladocerans increased towards the end of the season. *Bosmina longispina* was abundant in early summer and *Daphnia* species (*D. cristata* and *D. galeata*) in late summer. In 1993, the relative abun-

Table 2. Mean chlorophyll *a* concentrations (mg m^{-3}) in the surface water (0–2 m) of the Finnish IM lakes during the open water periods in 1988–1996 (data from Keskitalo *et al.* 1998).

	1988	1989	1990	1991	1992	1993	1994	1995	1996
Valkea-Kotinen			27	31	15	16	35	13	15
Iso Hietajärvi	2.6	3.4	2.6	2.5	2.9	2.4	2.1	1.9	1.9
Pesosjärvi		1.5	1.1	1.4	1.4	1.1	1.2	1.5	1.3
Vuoskojärvi			1.9	0.7	0.6	0.8	0.7	0.9	0.6

Table 3. Annual primary production of phytoplankton (g C m^{-2}) in the Finnish IM lakes.

	1990	1991	1992	1993	1994	1995	1996
Valkea-Kotinen	36	33	28	28	38	25	28
Iso Hietajärvi	17	13					
Pesosjärvi			22				
Vuoskojärvi					8	6	

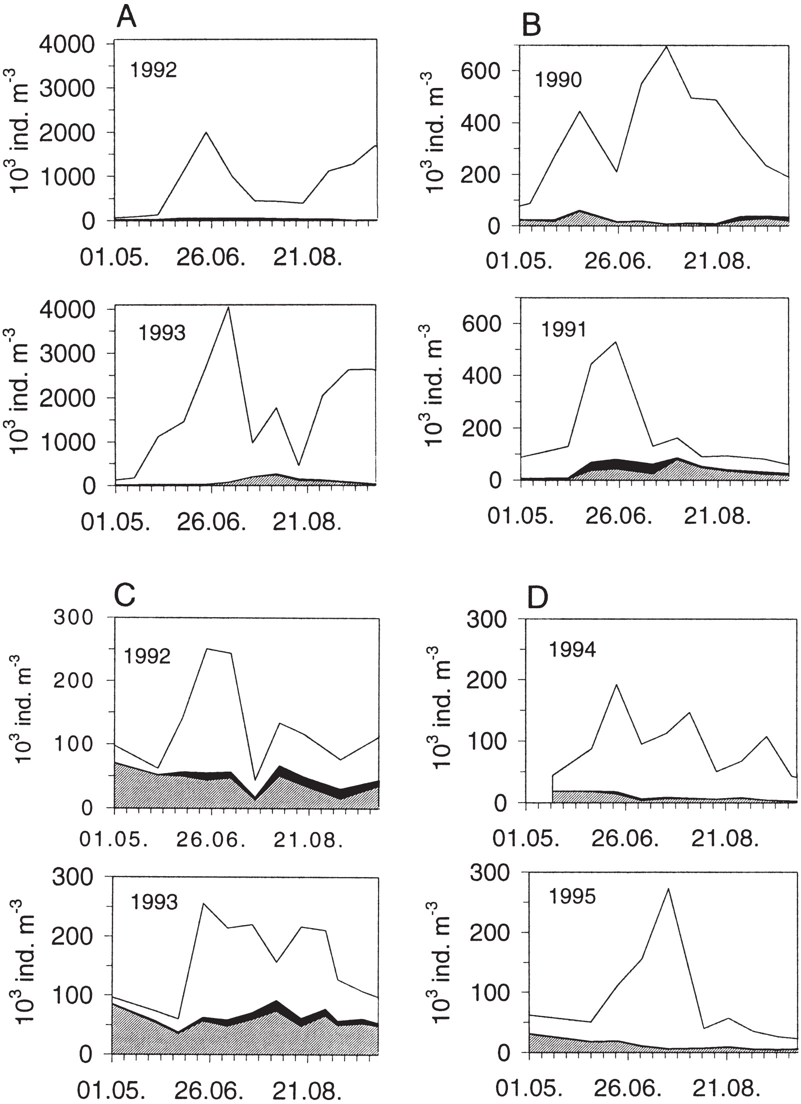

Fig. 3. The densities of main zooplankton groups (rotifers white, cladocerans black, copepods grey) during the growing season in Valkea-Kotinen 1992–1993 (A), Iso Hietajärvi 1990–1991 (B), Pesosjärvi 1992–1993 (C) and Vuoskojärvi 1994–1995 (D).

dances were similar to those in 1992.

In Vuoskojärvi, rotifers had three peaks during the growing season 1994 (Fig. 3). The number of clacocerans was at the maximum in late July, when *Bosmina longispina* and *Holopedium gibberum* were most abundant The number of copepods was highest in early summer due to Calanoid nauplii (*Eudiaptomus graciloides*). In 1995 rotifers still dominated the zooplankton community but there was now only one peak in July followed by a rapid decline. The crustacean zooplankton was small in number as it was during the previous year (Table 4).

Fish

The mean catches of one gill net series varied from 3.1 to 13.8 kg in 1988–1990 and from 0.8 to 16.1 kg in 1993–1994 (Fig. 5). In contrast to the abundance of phytoplankton and zooplankton in the lakes, the gillnet catches of fish were not related to the lake productivity. Perch (*Perca fluviatilis*) was the only fish species in the catches of Valkea-Kotinen, although the lake is known to be inhabited also by pike (*Esox lucius*). In the catches of Vuoskojärvi in 1990, perch was accompanied by whitefish (*Coregonus lavaretus*). In Pesosjärvi,

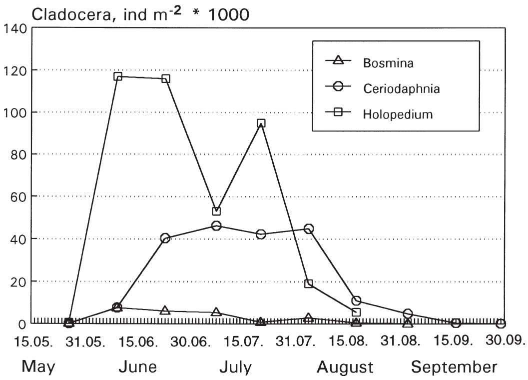

Fig. 4. The density of most abundant cladocerans in zooplankton of Valkea-Kotinen during May–September 1992.

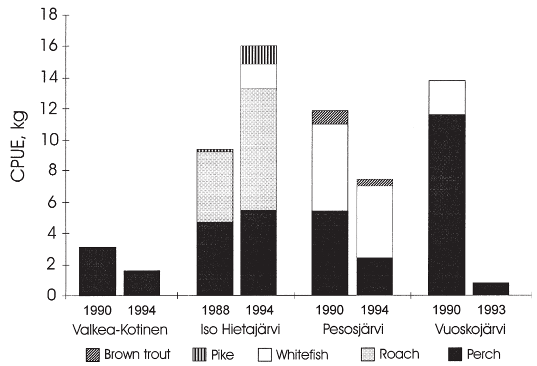

Fig. 5. The mean catches of fish per gillnet series in lakes Valkea-Kotinen, Iso Hietajärvi, Pesosjärvi and Vuoskojärvi during the sampling periods.

there were three species, namely perch, whitefish and brown trout (*Salmo trutta*). In Iso Hietajärvi, perch and roach (*Rutilus rutilus*) were most abundant, but also some whitefish, pike, bleak (*Alburnus alburnus*) and ruffe (*Gymnocephalus cernuus*) were caught. Whitefish is not a native species in the IM lakes, but it has been stocked and probably cannot reproduce in the lakes. The population size of perch in Valkea-Kotinen in 1991–1996 varied between 2 500 and 5 000 individuals larger than 9 cm in total length. The population density was thus 680 to 1 370 perch ha^{-1} and the corresponding biomass 23 to 37 kg ha^{-1} (Table 5).

The length frequency distributions of perch from the two sampling periods differed from each other in lakes Iso Hietajärvi and Pesosjärvi (Fig. 6). In Valkea-Kotinen, the population data of perch showed that a new strong year-class appeared about every third year. In 1988, the roach population of Iso Hietajärvi was dominated by 8–10 year old individuals with 20–25 cm total length, while in 1994 roach of 12–14 cm in total length and 4–5 years in age were most abundant (Fig. 7). In 1990, the brown trout catch of Pesosjärvi con-

Table 4. Mean densities of zooplankton (10^3 ind. m^{-3}) in the water column (0–5 m) in May–September in the Finnish IM lakes.

	Rotifera	Cladocera	Copepoda
Valkea-Kotinen			
1992	755	13	27
1993	1727	8	84
Iso Hietajärvi			
1990	358	6	20
1991	154	17	37
Pesosjärvi			
1992	83	9	38
1993	101	9	54
Vuoskojärvi			
1994	85	1	9
1995	83	1	10

Table 5. Population estimate, population density (ind. ha^{-1}) and biomass (kg ha^{-1}, ww) of perch of > 9 cm total length in Valkea Kotinen during 1991–1996.

Year	Population estimate	95% c.l.	Population density (ind. ha^{-1})	Biomass (kg ha^{-1})
1991	3 130	2 675–3 585	870	23
1992	2 723	2 527–2 951	760	23
1993	4 930	4 352–5 686	1 370	37
1994	4 500	3 960–5 210	1 250	36
1995	3 194	2 744–3 821	890	30
1996	2 455	2 162–2 814	680	31

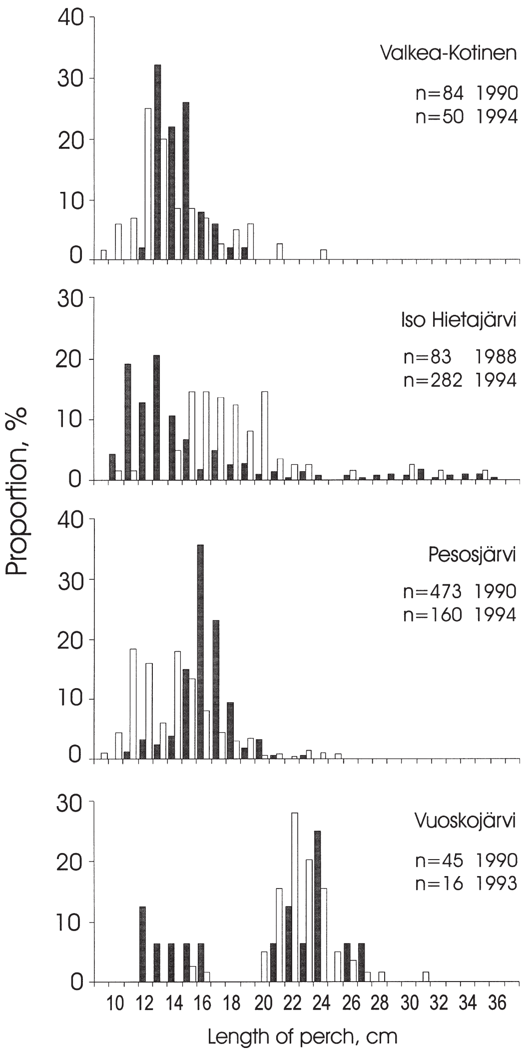

Fig. 6. Length frequency distributions of perch in the study lakes during the first (white columns) and the second (shaded columns) sampling period.

sisted of 20 individuals with total lengths of 17–28 cm, whereas seven specimen of 25–27 cm were caught in 1994.

The growth of perch was slow in all lakes except in Iso Hietajärvi (Fig. 8). In Iso Hietajärvi, the total length of 20 cm was exceeded at the age of 5–6 years, while in other lakes it took 8–10 years to reach that length. There were no changes in the growth of perch between the two sampling periods. This was also the case with roach in Iso Hietajärvi, where the total length of 20 cm was exceeded after the age of eight years both in 1988 and 1994.

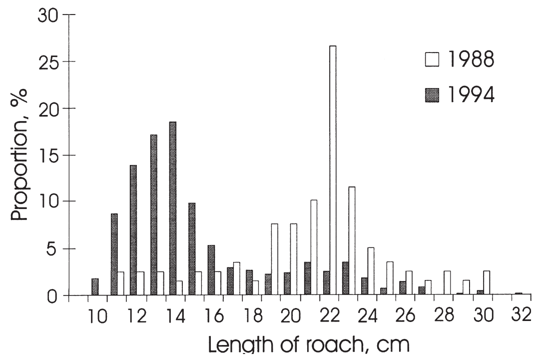

Fig. 7. Length frequency distribution of roach in Iso Hietajärvi in 1988 and in 1994.

In Valkea-Kotinen, the diet of perch < 15 cm in total length was dominated by *Chaoborus* larvae, in Iso Hietajärvi and Pesosjärvi by crustacean zooplankton and in Vuoskojärvi by Ephemeroptera larvae (Fig. 9). In larger perch (≥ 15 cm total length) the most important food items were Trichoptera larvae in Valkea-Kotinen, fish in Iso Hietajärvi, zooplankton and Ephemeroptera larvae in Pesosjärvi and Neuroptera larvae in Vuoskojärvi (Fig. 9).

The availability of suitable food organisms in zooplankton and zoobenthos changed in the course of the growing season. For example, in 1992 in Valkea-Kotinen the diet of perch < 15 cm total length was dominated by Ephemeroptera larvae in May, by *Chaoborus* larvae in June and July, by crustacean zooplankton in August and by *Asellus aquaticus* in September (Fig. 10). Smaller perch of < 15 cm preferred small cladocerans *Bosmina* sp. and *Ceriodaphnia quadrangula* whereas larger perch of > 15 cm fed more on large *Holopedium gibberum* (Fig. 10). These three species were most abundant in lake plankton in June and July (Fig. 4) whereas their proportion in the diet of perch was highest in August (Fig. 10).

In August 1994 in Pesosjärvi, 80% of the stomach contents of whitefish consisted of crustacean zooplankton. Cladocerans *Bosmina* sp., *Daphnia* sp., *Holopedium gibberum* and the copepod *Eudiaptomus* sp. were the most important food items.

Mercury concentrations of perch in all four lakes varied between 0.1 and 0.3 µg g^{-1} (Fig. 11). The mean mercury concentration of 1 kg pike in Iso Hietajärvi (n = 4) was 0.40 µg g^{-1} while for whitefish in Pesosjärvi (n = 5) it was 0.20 µg g^{-1}.

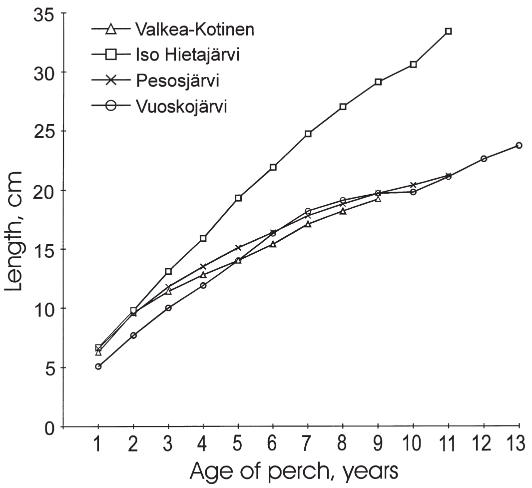

Fig. 8. Back-calculated growth of perch in the study lakes in the sampling period 1993–1994.

Discussion

Compared to the data of Nordic national lake surveys in 1995 (Henriksen *et al*. 1997), the pH and alkalinity of lakes Iso Hietajärvi and Vuoskojärvi were around the median values (pH 6.58 and alkalinity 0.111 mmol l^{-1}) of the Finnish lakes larger than four hectare in area, whereas Valkea-Kotinen was clearly acidic and Pesosjärvi extremely well buffered. Thus, the four Finnish IM lakes cover the acidity gradient from non-buffered to well buffered systems. Valkea-Kotinen can be considered as a mesotrophic lake with total phosphorus concentration mostly above the Finnish median (13 μg l^{-1}). The other three lakes were oligotrophic with the total phosphorus concentration about 50% lower than the median of Finnish lakes. The concentration of total organic carbon in Valkea-Kotinen was 1.5 times higher than the Finnish median 7.64 mg l^{-1}, whereas the TOC concentrations in the other lakes were 50% lower than the Finnish median. Despite these lake to lake differences in water quality, the Finnish IM lakes were regionally quite representative and therefore they were suitable sites for monitoring the effects of changes in atmospheric load on their surroundings.

According to a sediment diatom analysis (Liukkonen 1989) the pH of Valkea-Kotinen was around 6.0 for 150 years until the 1970s. After that the lake has acidified and the pH has dropped by ca. one unit, although during the IM programme no clear trend could be detected. The increasing trend in the pH and alkalinity of Iso Hietajärvi is probably due to the decrease in acidifying load, as recorded in 1988–1995 in most IM sites in Nordic countries (Vuorenmaa 1997) and suggests a recovery from a slight acidification that was earlier shown in a paleolimnological study (Simola *et al*. 1991).

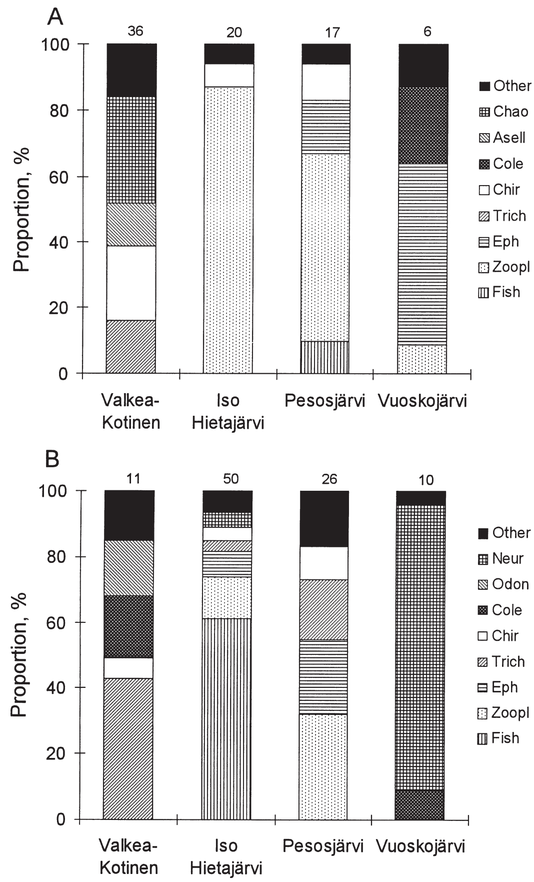

Fig. 9. The diet of perch < 15 cm (a) and ≥ 15 cm (b) in the study lakes in August 1994 (for Vuoskojärvi October 1993). The number of examined individuals is indicated at the top of the columns. Chao = *Chaoborus*, Asell = *Asellus aquaticus*, Cole = Coleoptera, Chir = Chironomidae, Trich = Trichoptera, Eph = Ephemeroptera, Neur = Neuroptera, Zoopl = zooplankton.

The average phytoplankton biomass in Valkea-Kotinen was ca. 10 times higher than in the other IM lakes. The higher productivity of the lake also resulted in higher abundance of zooplankton. Keskitalo *et al*. (1998) suggest that the high production in Valkea-Kotinen is linked to vertical migrations of a flagellated alga *Gonyo-*

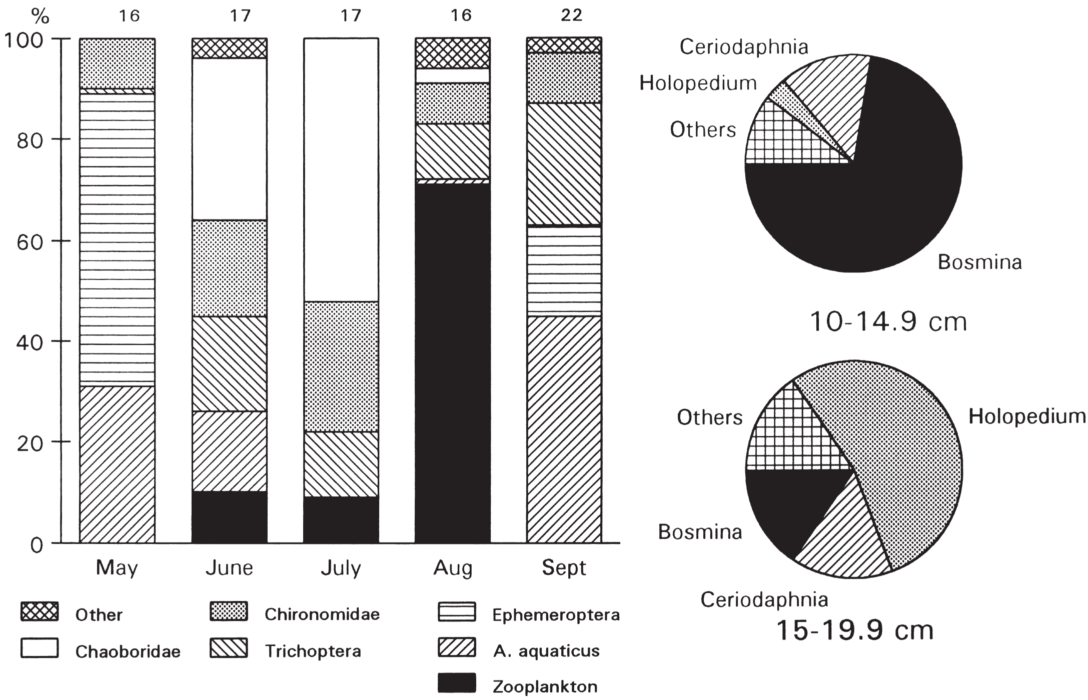

Fig. 10. The diet composition of perch < 15 cm in Valkea-Kotinen in May–September 1992 (left) and the composition of zooplankton diet of perch < 15 cm (n = 16) and > 15 cm (n = 18) in August 1992 (right). The number of examined fish at the top of columns.

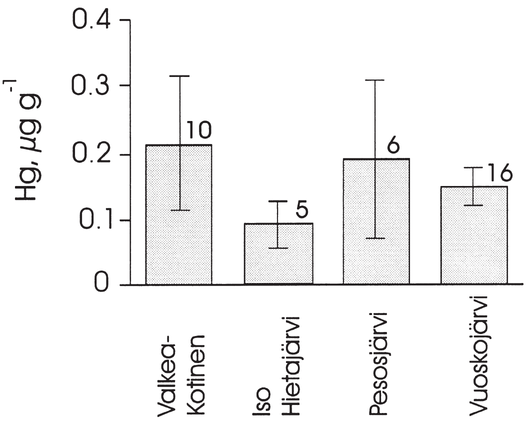

Fig. 11. Mercury concentrations in perch (µg g^{-1}, ww) in the study lakes. The number of analysed fishes is indicated at the top of the columns.

stomum semen. This species migrates vertically to the anaerobic hypolimnion at night time, takes nutrients and migrates back to epilimnion in the morning (Salonen *et al.* 1993). The perch feeding on zooplankton and *Chaoborus* larvae then effectively distribute the nutrients taken from the hypolimnion by the algae. No drastic changes in the zooplankton community were recorded within any lake from year to year, except the sudden dominance of the rotifer *Kellicottia bostoniensis* in Valkea-Kotinen since 1993 (Keskitalo *et al.* 1998). The occurrence of the same cladoceran species *Bosmina longispina* and *Holopedium gibberum* in all four lakes indicates the wide environmental tolerance of the species.

No systematic changes were recorded in species composition, population structure, or growth of fish in the IM lakes. The test fishing catches were neither related to the phosphorus concentration nor the primary production of the water although such relations have been shown in other studies (Jones and Lee 1986, Downing *et al.* 1990). The appearance of new strong year-classes of perch in lakes Iso Hietajärvi and Pesosjärvi was striking but is a part of the normal population dynamics of this species (Sumari 1971). It was earlier suggested by Rask and Järvinen (1995) that roach in Iso Hietajärvi might suffer from acidification. Among the common fish species in Finland roach is the most sensitive to acidification.

The roach population in 1988 was dominated by large and old individuals which could be an indication of reproductive failures (Rask *et al.* 1995a). The increasing trend in pH and alkalinity of Iso Hietajärvi and the dominance of small and young individuals in the roach catch in 1994 suggest that the species has reproduced regularly during the latest years.

New year-classes of perch appeared also in Vuoskojärvi. In this lake the population dynamics of perch may be affected by climatic factors. Perch is a warm water fish species with an optimal physiological temperature of 22–24 °C (Kitchell *et al.* 1977). Consequently, the occurrence of strong year classes of perch in boreal regions is closely related to summer temperatures (Craig 1987, Sarvala and Helminen 1995). In Lapland, perch lives in extreme thermal conditions and during cold summers the young-of-the year perch cannot reach the required minimum size to survive over their first winter. Therefore, the general warming of the climate would favour perch in the northernmost waters and it might result in increased abundance and distribution of the species (Hill and Magnuson 1990, Lehtonen 1996).

The mercury concentrations of perch in IM lakes and also those of pike from Iso Hietajärvi were relatively low in comparison to small lakes in southern Finland (Metsälä and Rask 1989, Rask and Metsälä 1991) but also when compared to small lakes in more remote areas (Rask *et al.* 1998). These results, although based on a small number of samples, indicate a representative pattern in mercury enrichment from the planktivorous whitefish (0.2 $\mu g\ g^{-1}$) to the mostly benthivorous perch (0.3 $\mu g\ g^{-1}$) and to the piscivorous pike (0.4 $\mu g\ g^{-1}$). No decreasing trend from south to north in perch mercury concentrations was recorded despite the corresponding trend in the Hg deposition. This can be due to the various catchment area, water and ecosystem characteristics affecting the enrichment of mercury in aquatic food chains (*see* Verta 1990).

Because fish commonly have life cycles of several years, applicable information on their relative abundance, population structure, growth, and concentrations of bioaccumulating substances can be drawn from samples taken once a year or even at intervals of three to five years (Appelberg *et al.* 1995, Rask *et al.* 1995b). When interactions between fish and other biota like zooplankton and zoobenthos are to be monitored, more frequent sampling for fish population structure and density, diets and the population dynamics and availability of food organisms is needed during the growing season.

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