LOSSES AND RECOVERIES OF FISH POPULATIONS IN ACIDIFIED LAKES OF SOUTHERN FINLAND IN THE LAST DECADE

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Abstract. Acid-induced fish damage in small lakes in southern Finland was studied in a fish status survey of eighty lakes from 1985-1987. Later, twenty of these lakes were selected for further monitoring. A sampling of these lakes from 1988-1989 showed that the decrease in some perch (*Perca fluviatilis* L.) and roach (*Rutilus rutilus* L.) populations still continued. The results from the same lakes in 1992 showed that successful reproduction had taken place with many of the perch populations that had been close to extinction in 1985. In contrast, no signs of recovery in the roach populations were detected. The explanation for the appearance of new cohorts of perch could have been the decrease in acid deposition but the exceptional hydrological conditions of winters in the early 1990s may also have affected them. The different responses of the perch and roach populations were interpreted as a consequence of the different sensitivity of these two species to acidification. Even a slight improvement in the water quality has resulted in the appearance of strong new year-classes of perch, but not of roach. Therefore, more improvement in water quality is needed until a sensitive species like roach can reproduce again.

Key words: Fish populations, perch, roach, growth, reproduction, water chemistry, acidification, recovery

1. Introduction

The fish status survey of the Finnish Research Programme on Acidification (HAPRO), made in the acid sensitive areas of southern Finland from 1985-1987, showed that a considerable number of small lakes suffered from damage to fish due to acidification. Out of the eighty lakes we found twenty-five affected fish populations, mostly roach and perch that are, together with pike, *Esox lucius* L., and ruffe, *Gymnocephalus cernuus* L., the most common fish species in small lakes in southern Finland (Rask and Tuunainen, 1990). According to information from local fishers, several fish populations, mostly roach, disappeared in recent years or decades. Some unexpected fish kills had also taken place that could be related to nothing else but acidity.

At the same time as the fish status survey, a statistical survey on lake water chemistry was conducted in order to determine the regional patterns of lake acidification in Finland (Kämäri *et al.* 1991). After combining the data on fish status and water chemistry, we estimated that 1000 to 2000 fish populations, mainly acid-sensitive roach, were extinct due to acid precipitation and in addition that 1200-2400 populations had been affected (Rask *et al.*, 1995).

Sulfate deposition has decreased in southern Finland since the late 1970s (Laurila, 1990; Leinonen, 1993). Correspondingly, sulfate concentrations showed a general decline in dilute lakes in south-western Finland during the 80s. This was accompanied, as in the deposition, with a decrease in base cation concentrations and, therefore, lake acidification did not cease (Roila, 1992). To answer the question of the possible recovery of affected fish populations up till now, we present in this paper examples of the responses of some perch and roach populations in our monitored lakes and relate these observations to the changes in water quality.

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2. Material and methods

The twenty fish monitoring lakes of this study were selected from the material of the fish satus survey of eighty lakes. They are small (3-200 hectares) dilute headwater lakes in acid sensitive upland areas with thin soils. The fish samples were taken by test fishing the lakes with a standard Finnish series of eight 1.8 x 30 m gill nets of mesh sizes 12 to 60 mm. For details of sampling, see Raitaniemi *et al.* (1988). Attention was paid to the length frequency distributions of perch and roach in the gill net catches and to the growth of the fish, determined from scales for roach and from opercular bones for perch.

Ten out of the twenty fish monitoring lakes have been sampled for water quality during the autumn turnover since 1987. The water analyses (twenty-four variables altogether) included all major cations and anions, pH and alkalinity as well as total organic carbon and aluminium fractions (See Forsius *et al.*1990), carried out by laboratories in the Water and Environment Administration. In addition, water quality data for five of these lakes has been collected since the early 1980s.

3. Results and discussion

In the fish status survey of eighty lakes in 1985-1987, we found nine perch populations that were affected by acid precipitation. Four of them were close to extinction. Roach catches from fifteen lakes of pH levels 5-6 consisted of a low amount of mainly larger roach, suggesting acidification effects. Out of these fifteen roach populations, eleven were considered affected and four were close to extinction. For details of the criteria of this classification, see Rask *et al.*, 1995. In addition, based on the information from local residents, five of the acidic lakes of the eighty lake survey had already lost their roach population, some of them as early as during the 1960s.

According to the sampling of twenty acidification monitoring lakes in 1988, little change was recorded in the status of perch or roach (Figure 1). In one lake, the perch catch was numerically more abundant than three years earlier. The perch that recruited to a catchable size since 1985 have clearly shown slower growth than the fish that were caught in 1985 (Figure 2), suggesting an increase in population density and intraspecific food competition. The decrease in roach populations still continued (Rask, 1990) and some of the sparse populations were virtually extinct.

In the 1992 sampling, a positive development in perch populations was recorded. Apart from two acidified high aluminium lakes that became fishless during the late 1980s, perch in all other affected populations reproduced successfully resulting in higher catches, a more normal population structure (Figure 1) and decreased growth (Figure 2).

However, despite the start of the recovery of perch populations, no positive signs were recorded among roach populations. The different responses of perch and roach populations were interpreted as a consequence of the different sensitivity of these two species to acidification. Perch is tolerant and roach sensitive and therefore even a slight improvement in water quality would have resulted in the appearance of new strong year-classes of perch, but not however of roach. Hultberg (1988) gave critical pH values 5.3 for perch and 5.8 for roach. Based on the Finnish data, critical pH values for

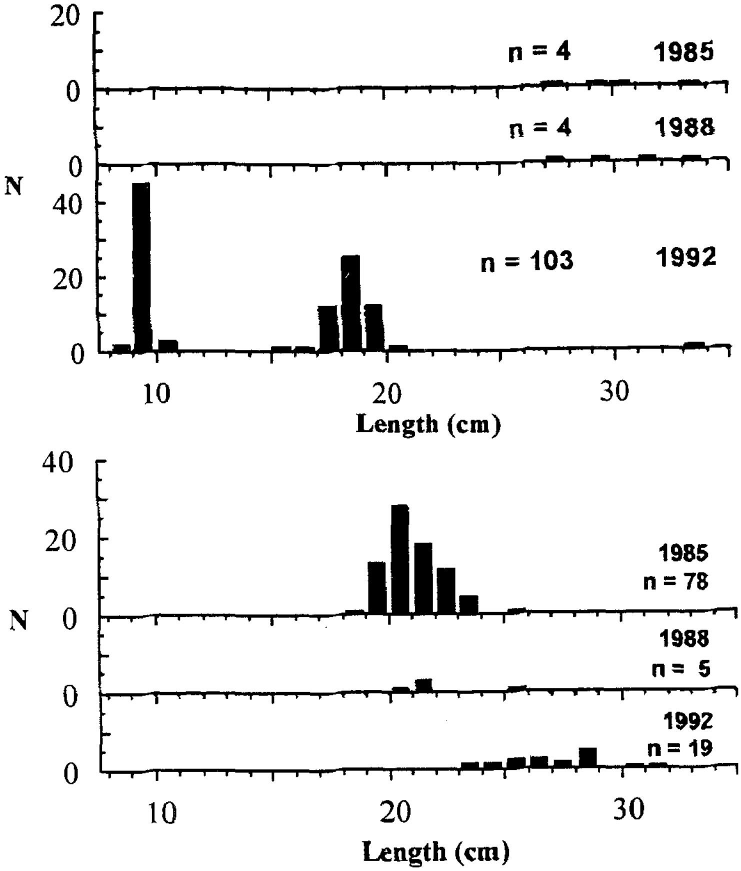

Fig. 1. The perch population (top) of L. Munajärvi (pH 4.5-4.9; Al_{lab} 80-110 µg/l) was very sparse after a fish kill in 1981 but after 1988 two new year-classes have appeared. The roach population (bottom) of L. Isojärvi (pH 5.6-5.8; Al_{lab} 10-30) is still decreasing; the last year-class of roach in that lake was born in 1980.

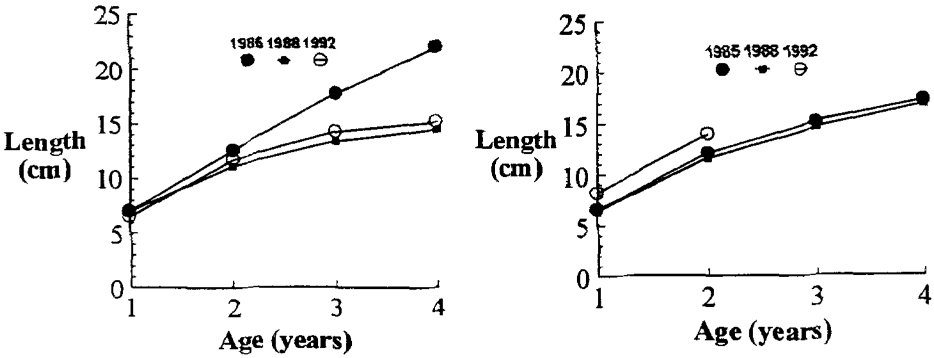

Fig. 2. The growth of perch (left) in L. Saaren Musta (pH 4.9-5.2; Al_{lab} 70-120 µg/l) slowed when strong year-classes appeared after 1985. The number of perch in the gill net catches in 1985, 1988 and 1992 were 45, 224 and 127. The growth of young roach (right) caught in L. Vitsjön (pH 6.1-6.4; Al_{lab} <10 µg/l) in 1992 was somewhat higher than earlier, suggesting a lower food competition between fish in the decreasing population. The number of roach in the gill net catches in 1985, 1988 and 1992 were 144, 175 and 105.

perch are 4.8-5.5 and for roach 5.3-6.0 depending on other water quality parameters like aluminium (Rask *et al.*, 1995).

Our data support the conclusion of improved water quality. In some lakes a decrease in sulfate and a corresponding increase in alkalinity can be seen (Figure 3) and lake alkalinities in general also show an increasing trend (Figure 4) probably reflecting the apparent decrease in the ratio of sulfate to neutralizing base cations (Nyberg *et al.*, 1996, Mannio and Vuorenmaa, 1996). In a set of fifty monitoring lakes of the Finnish Environment Agency in southern Finland the increase of pH and alkalinity and the decrease of sulfate were statistically significant from 1987 to 1993 (Mannio, 1994). Still, the mean acidity of the deposition, although lower than the critical levels for perch, may be critical for roach (See Rask *et al.*, 1995). If this is the case, further decrease is needed in the acid load until any roach population can recover.

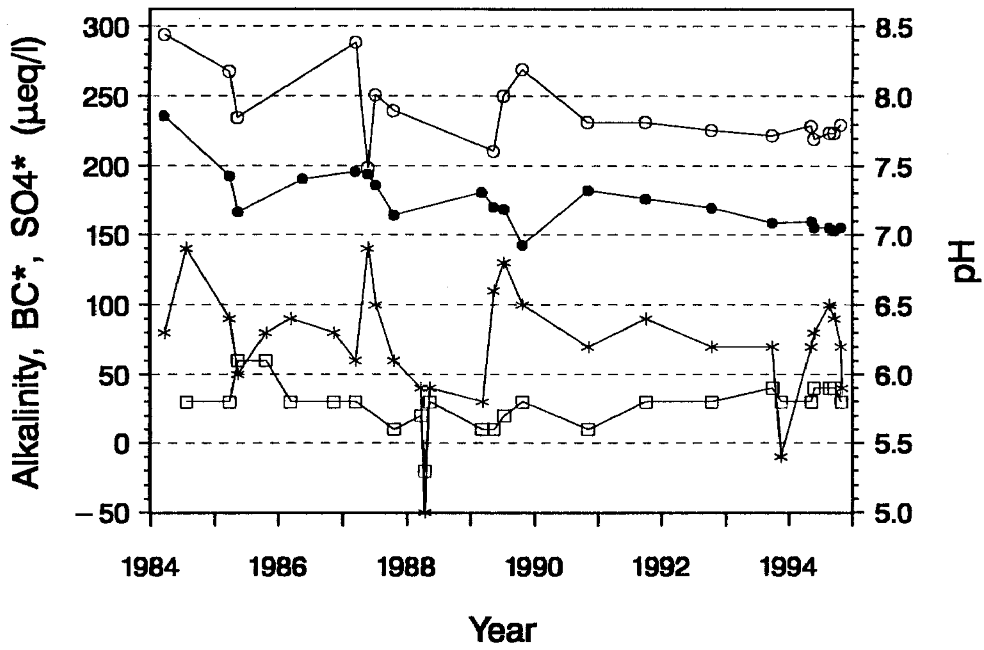

Fig. 3. Water quality of Lake Vitsjön between 1984 and 1994, SW Finland. Alkalinity =square; pH =cross; base cations (BC*) =circle; sulfate =dot. The pH 5.0 in 1988 is a spring value but in 1993 a pH of 5.5 was recorded in the autumn sampling. This kind of wide, short-term variation indicates that water quality conditions in the lake are still critical for the roach population.

Other factors than a decreasing acid load may also have affected the occurrence of suitable conditions for the reproduction of perch during the 1990s. The hydrologically extremely dry latter part of 1989 formed a basis for a low water table in the spring melting period of 1990. Permafrost was weak in the winter of 1989/90, and thus could allow melting waters to percolate through soils with more exchangeable base cations than normal, resulting in less acid input to the lake in spring. This kind of base cation peak in the spring melt was observed in 1990 in one of the national catchment monitoring sites, 10-15 km NW of some of our study lakes (Finnish Environment Agency, unpubl.). Spring runoff peaks in 1991 and 1992 from that catchment were also lower than normal due to mild winters and low amounts of snow. Most likely no spring acidity peaks occurred which may have positively affected the conditions for successful perch reproduction.

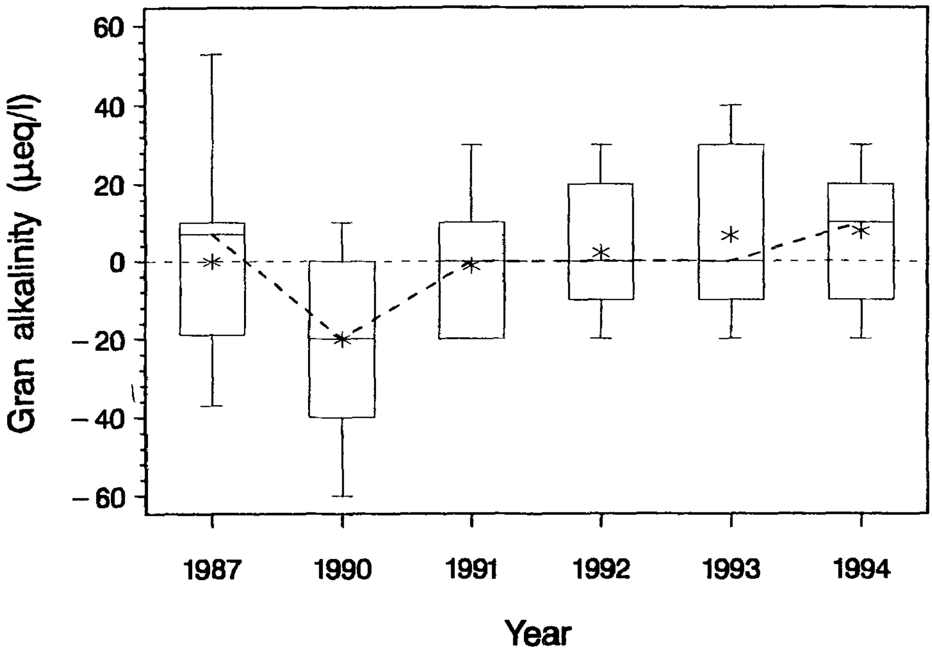

Fig. 4. Box-plots of autumn alkalinity in ten lakes in 1987 and 1990-94. Upper and lower ends of the boxes = 75th and 25th percentiles; line across the box = median; star = mean; vertical whisker lines = 1.5 x (75th-25th percentiles).

During the late 1980s and early 1990s there were several warm years, which also may have played a role in the recent reproductive success of perch in the monitored lakes. Good thermal conditions, e.g., increased temperatures during the growing season, are known to be beneficial to percid fishes in boreal waters, resulting in both strong year-classes and increased growth of perch (Hokanson, 1977, Koli *et al.*, 1985). In a study of liming responses to perch and roach, we showed that temperature affected the first year growth of perch more significantly than did the liming. However, for older perch the effect of temperature was not as clear (Raitaniemi and Rask, 1994). In the case of our monitoring lakes, we believe that the changes in the growth of perch were mostly due to dramatic acidification-induced changes in population density. This is also supported by the decreased growth in the new year-classes during the warm years of the early 1990s.

4. Conclusions

Our study suggests that many populations of acid tolerant perch in small lakes in southern Finland are now recovering from acidification but that populations of the more sensitive roach are still decreasing. This is because the most sensitive lakes in southern Finland experienced severe acidification, down to pH levels of 4.5-5.0, during the 1960s and 1970s. This is far too acidic for roach and rising the pH levels again to 5.5-6.5 takes a lot of time and also demands more decreases in acid precipitation.Finally, when interpreting the signs of recovery in perch populations, the potential effects of the favourable climate and the exceptional hydrological conditions of the last few years must not be forgotten.

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