ACID DEPOSITION FROM THE RUSSIAN KOLA PENINSULA: ARE SENSITIVE FISH POPULATIONS IN NORTH-EASTERN FINNISH LAPLAND AFFECTED?

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Abstract. Sulphur emissions from Russian Kola Peninsula smelters are known to cause surface water acidification in the border areas between Norway and Russia. The sulphur deposition is also high in the eastern part of Finnish Lapland. In 1990, a monitoring programme was started to survey the effects of acid deposition on sensitive fish populations in north-eastern Finnish Lapland. Altogether 103 sites in three areas were electrofished and autumn water samples were taken. Besides the brown trout (*Salmo trutta*), special attention was paid to the occurrence of minnow (*Phoxinus phoxinus*) since it is a common species in small waters and is highly sensitive to acidification. During the first three years of monitoring no signs of acidification were recorded. The alkalinity values of brooks generally exceeded 0.1 mmol/l. Brown trout, minnow and burbot (*Lota lota*) were caught frequently in the study sites. Later the study was focused on the uninhabited Vätsäri area which is receiving the highest sulphur deposition in Finnish Lapland. The alkalinity values of the sampled brooks were in most cases below 0.05 mmol/l, indicating a decreased buffer capacity. However, the electrofishing of the brooks showed no acid-induced damage. The lowest alkalinity values were detected from a group of small upland ponds. In four such ponds the alkalinity was zero or negative. No minnows were caught from these four ponds apart from one, where the minnows were exceptionally large. The results show that the waters near the eastern border of northern Finnish Lapland are threatened by acidification. No damage to fish populations subject to fishing was observed. The absence of minnows in some small waters is possibly the first sign of acid-induced fish population damage.

1. Introduction

The environmental effects of the industrial activities of the Kola Peninsula became widely known in the late 1980s. Recent studies on water quality in the border areas between Norway and Russia indicate extensive acidification of small lakes (see e.g. Traaen *et al.*, 1992), and there is also possible evidence of fish population damage in Norway (Nøst *et al.*, 1991, Hesthagen *et al.*, 1992). Severe fish population damage has been reported from the Russian side, especially near factories, but has been attributed mainly to heavy metal pollution (Nøst *et al.*, 1991).

The estimated total sulphur deposition is also high (0.5-1.5 g S /m^2/yr) in the eastern part of Finnish Lapland (Tuovinen *et al.*, 1993). As large areas of Finnish Lapland are sensitive to acidification due to geological conditions (Kähkönen and Mähönen, 1993), it is realistic to suppose that acidification can threaten the most sensitive fish populations. In 1990 the Finnish Game and Fisheries Reseach Institute started a monitoring programme on the effects of acid precipitation on fish populations in north-eastern Lapland. The programme was focused on small running waters, where the first signs of acid-induced fish population damages are assumed to appear.

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The aim of this paper is to summarize the results since 1990. Special attention has been paid to the occurrence of the minnow (*Phoxinus phoxinus* L.), since it is a common species in the small waters of northern Finland and is highly sensitive to acidification (Muniz, 1984, Magnuson *et al.*, 1984, Bergquist, 1991). Another interesting species is the brown trout (*Salmo trutta* L.), which is also sensitive to acidification and an important species from the perspective of fisheries.

2. Materials and methods

In the initial stage of the monitoring programme, study areas were located near the eastern border of Finland south of Lake Inari. From 1990-1991, 82 sites in two areas (Fig.1, areas 1-2) were electrofished (for more details see Erkinaro *et al.*, 1992). Study sites were selected to represent typical stream habitats of young brown trout. Electrofishing was carried out quantitatively at most of the sites by successive removals of fish. Water samples were taken in September 1991 and analyzed in the laboratory of the Finnish Game and Fisheries Research Institute according to SFS-standards.

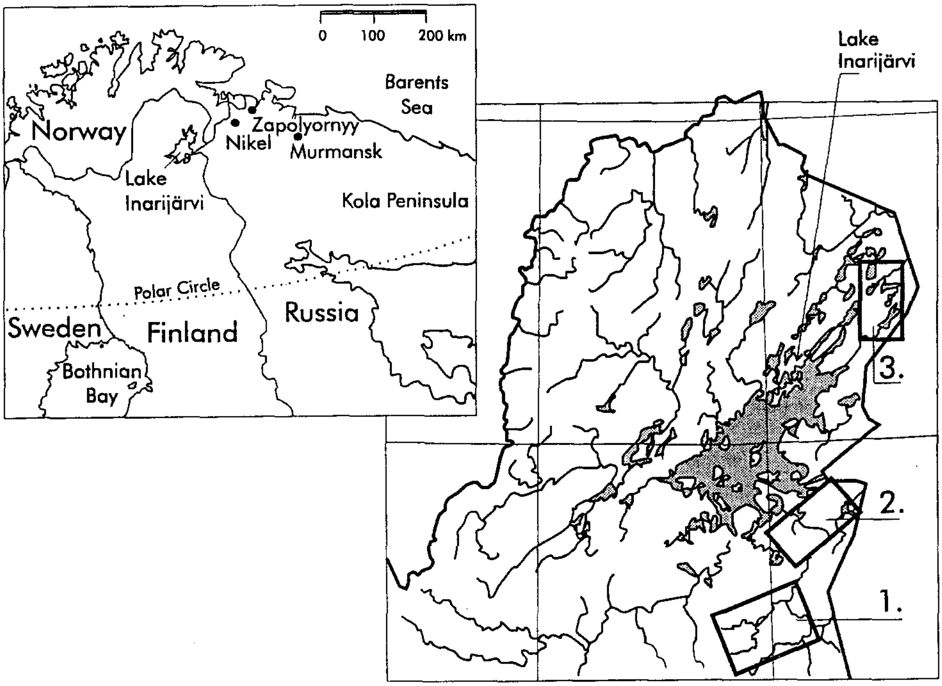

Fig 1. The location of the study areas. 1. Luttojoki River area, 2. Nellimöjoki and Sarmijoki River area, 3. Vätsäri area.

In 1993, the study was focused on the uninhabited Vätsäri area (Fig. 1, area 3), where no test fishing had been done earlier. This area receives the highest sulphur deposition in Finnish Lapland (Tuovinen *et al.*, 1993). The distance to the nearest Russian industrial centre, the Nikel kombinat, is only 40 km. The annual sulfur deposition (over 1.0 g $S/m^2/yr$) is of the same magnitude as that of southern Finland (Tuovinen *et al.*, 1993), where fish population losses have been observed (Rask and Tuunainen, 1990). The Vätsäri area is a watershed for three large water systems running into the Barents Sea. The surface waters of the area are sensitive to acidification due to the geochemistry of the soil in the area (Kähkönen and Mähönen, 1993) and the exceptionally high number of small headwater lakes and brooks. Due to the relatively high altitude differences within a short range, natural migration obstacles are the norm and many fish populations in lakes and brooks are isolated from each other.

In September 1993, small brooks and the stony shorelines of small ponds were electrofished in the Vätsäri area. Eight of the brooks were situated around a group of small lakes named Lake Joulujärvet. The remaining five brooks were situated approximately 10 kilometres north running into Lake Vuontisjärvi. The brooks fished in both subareas were typical for the Vätsäri area. They were short brooks (50-400 metres) between small (5-70 ha) headwater lakes at 89-167 metres above sea level. Some of the brooks were nearly dry at that time. The eight small ponds (3-6 ha) fished in the Vätsäri area were situated in a local upland area near Lake Äälisjärvi. This third subarea is only a little over 200 metres above sea level, but unlike the other two subareas, it is above the local coniferous tree line. The ponds were isolated from each other even though the distances between them were only a few hundred metres. The electrofishing survey in the brooks and ponds was qualitative and the sites were fished only once. Water samples were taken in September 1993 from each site and were analyzed in the laboratory of the Lapland Regional Environment Centre. Total aluminium concentrations were analyzed by AAS-method and concentrations of different fractions were not analyzed.

3. Results

In study areas 1 and 2, no signs of acidification were recorded. The rivers and brooks were not acidic and alkalinity values were > 0.1 mmol/l (Table 1). Total aluminium (Al_{tot}) concentrations were usually below 50 µg/l. The results of electrofishing showed no symptoms of acid-induced damage on fish populations either. Brown trout was the most common fish species in the rivers and brooks examined and the mean densities varied from 2.4 to 29.0 fish 100 m^{-2}. Minnow and burbot (*Lota lota* L.) were also common species in most of the brooks and rivers. The mean densities of minnow varied from 0.8 to 13.6 100 m^{-2}.

The measured pH values of small brooks in the eastern Vätsäri area were quite similar to other areas (Table 1). However, alkalinity was clearly lower, in most cases below 0.05 mmol/l. Al_{tot} concentrations were below 50 ug/l. Despite low alkalinity, the results of electrofishing survey showed no signs of acid-induced damage on fish populations. Minnow was the most common fish species in most small brooks and even at the mouths of temporarily nearly dry brooks. Young brown trout were common in brooks with greater discharge and suitable habitats. Burbot were also present at many fishing sites. The length distributions of minnow and brown trout showed the presence of several age classes and thus indicated no signs of failure in reproduction.

TABLE I

Ranges of some chemical properties of the autumn water samples from the study areas.

Area	Sampling sites (n)	pH	Alkalinity mmol/l	Ca mg/l	Colour Pt mg/l	Al_{tot} µg/l	SO_4^- mg/l
Luttojoki River area (1)	29	6.7-7.2	0.115-0.294	0.8-5.2	5-40	11-77	-
Nellimöjoki and Sarmijoki River areas (2)	17	6.6-7.2	0.184-0.295	2.6-4.3	5-30	12-113	-
Vätsäri (3)							
Brooks in the Lake Joulujärvi area	3	6.5-6.7	0.024-0.040	0.9-1.1	5-10	24-33	2.7
Brooks in the Lake Vuontisjärvi area	5	6.0-6.9	0.045-0.073	1.4-1.7	15-20	24-35	2.2-2.6
Ponds in the Lake Äälisjärvi area	8	5.9-6.9	0.004-0.047	0.6-1.0	5-20	13-49	2.3-3.0

The lowest alkalinity values were taken from eight small ponds at a higher elevation near Lake Äälisjärvi in Vätsäri (Table I). Measured pH values were not especially low, but alkalinity was below 0.05 mmol/l in all ponds. In four ponds, alkalinity was even zero or negative. Al_{tot} concentrations were at the same level as in other areas. Local reindeer owners and frontier guards have considered the isolated group of ponds fishless. However, electrofishing of the stony shorelines produced minnows from five of the ponds and a few burbots from three ponds. Of the four ponds without any buffering capacity, minnows were caught in just one. The six individuals caught were exceptionally large. Their average length was 9.4 cm (SE 0.6 cm), about 3 cm more than was recorded in the other four ponds containing minnows and with slightly higher alkalinity.

4. Discussion

Alkalinity values below 0.05 mmol/l in the Vätsäri area indicated a decreased buffer capacity in small waters. Acid peaks have been recorded during the spring snowmelt in even better buffered brooks in north-eastern Lapland (Tuunainen *et al.*, 1991). Levels for sulphate (SO_4^-) in the Vätsäri area were higher than the median value (1,7 mg/l) of 190 randomly sampled lakes in northern Finland (Forsius, 1992), indicating the effects of deposition and thus the potential for acid peaks.

The alkalinity value of 0,02 mmol/l is used for the evaluation of critical loads for the most sensitive freshwater fish species (Henriksen *et al.*, 1992). The measured values in the brooks of the eastern Vätsäri area were nevetheless slightly above that value. Thus, it was not surprising that no damages to fish was found, particularly when Al_{tot} concentrations were low. Aluminium occurring as inorganic ions (labile aluminium) is most harmful to fish. In Norwegian lakes, concentrations of inorganic aluminium exceeding 60 μg/l can produce toxic conditions to sensitive fish species at low pH (Skogheim and Rosseland, 1986). In our samples, the concentrations of inorganic aluminium were not analyzed. However, even Al_{tot} concentrations, including all fractions of aluminium, were clearly less than 60 μg/l in the brooks. Al_{tot} concentrations of at least 150 μg/l and at pH 5 and 6 have been reported to cause high mortality to minnows (Norrgren *et al.*, 1991).

We suggest that the absence of minnows in the catch of small ponds with no buffering capacity is a symptom of acidification. This seems to be the only plausible explanation since in the same group of similar small ponds, minnows were present in all those with little higher buffering capacity. The presence of only large minnows in the catch of one pond with no buffering capacity in particular might be a symptom of recruitment failure. According to the growth data from northern regions (Mills, 1988) minnows of 10 cm in length caught from that pond may be over ten years of age. The oldest minnows in Mill's data from the Utsjoki river in northern Finland were 13 years old yet still smaller than 8 cm.

In conclusion, the results show that small waters near the eastern border of northern Finnish Lapland are threatened by acid deposition from the Kola Peninsula. However, no damage to fish populations subject to fishing were observed. In Finnish Lapland, the absence of minnows in the catches of some waters without buffering capacity can be the first sign of acid-induced fish population damages. The minnow seems to be a suitable indicator species for acidification in northern conditions. It is distributed widely and can be the only fish species present in the smallest and most acid sensitive watercourses.

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