Chapter 3

Sensitivity Distributions of Finnish Lakes

Martin Forsius

Summary

A regional lake survey of 987 randomly selected lakes was conducted during autumn overturn 1987 as part of the Finnish national research project on acidification (HAPRO). The median pH of the lakes was 6.3, median alkalinity 75 \( \mu \text{eq} \cdot \text{l}^{-1} \), and median base cation concentration 250 \( \mu \text{eq} \cdot \text{l}^{-1} \). About 88 percent of the lakes were humic (TOC > 5 mg l\(^{-1} \)); the median TOC for all lakes was 12 mg l\(^{-1} \). The humic lakes were on an average more acid than the clear-watered lakes. More than 10 percent of the lakes had negative Gran alkalinity. Sulfate concentrations were highest in southern Finland, commonly being more than 100 \( \mu \text{eq} \cdot \text{l}^{-1} \). Several sensitive areas affected by acidic deposition were identified, and acidic and low-ANC lakes were found throughout the country. Inclusion of the organic anion component in the estimation of sensitivity markedly increased the number of lakes potentially susceptible to acidic deposition.

Introduction

There are approximately 56 000 lakes larger than 0.01 km\(^2\) in Finland, about 15 700 of them being larger than 0.1 km\(^2\) (Raatikainen and Kuusisto in press). The lakes are very unevenly distributed throughout the country. Areas with a high number of lakes are found especially in central and eastern Finland, and in the northernmost regions.

Soils in Finland are podzolic, having developed from till or glaciofluvial deposits mostly on granitic bedrock. Peatlands originally covered more than 30 percent of the land area, but to date about half of the peatlands have been drained.

The total deposition of sulfur in Finland is highest along the coastal area of southern Finland (1.5 to 1.8 g S m\(^{-2} \cdot \text{yr}^{-1} \)) and decreases on moving to the north (Nordlund et al. 1985). However, there are elevated levels of deposition also in eastern Lapland due to the extensive smelting industry in the Kola peninsula. The present acidic deposition load over large areas of the country is clearly above the critical load for sensitive ecosystems, estimated to be in the range 15 to 30 keq km\(^{-2} \cdot \text{yr}^{-1} \) (Nilsson and Grennfelt 1988). The

\(^{1}\)Water and Environment Res. Inst., P.O. Box 250, SF-00101 Helsinki, Finland
long term mean pH of precipitation is 4.4 to 5.0 in the southern parts of the country (Järvinen 1987). As a consequence, recent lake acidification is a common phenomenon in small lakes in many areas, especially in southern Finland (e.g. Kämäri 1985; Simola et al. 1985; Tolonen et al. 1986; Forsius et al. 1987). However, high-quality lake water chemistry data have not earlier been available for many regions.

A lake survey was conducted in 1987 in order to evaluate the regional extent of lake acidification in Finland. This survey of 987 randomly selected lakes forms part of the Finnish Research Project on Acidification (HAPRO). The main objectives of the survey were: 1) to collect a representative lake data base for estimating the number and spatial distribution of acidified lakes, 2) to assess the influence of major watershed and soil characteristics on lake water quality, 3) to evaluate the role of organic acidity in the lakes, and 4) to enable regional modelling of aquatic impacts of acidic deposition with varying acid loadings. The survey methodology and chemical characteristics related to sensitivity of the lakes to acidification, as well as the effect of the inclusion of organic anions in the estimation of lake sensitivity, are discussed in this chapter.

Materials and Methods

The lakes for the survey were chosen by two-stage cluster selection from the population of lakes in two subregions covering the whole of Finland. The statistical "frame" in the first stage consisted of the number of lakes in different size classes (Raatikainen and Kuusisto in press) on topographic maps with a scale 1:50 000 (20 - 30 km²). The total number of maps was 472 in subregion 1 (southern and central Finland), and 175 in subregion 2 (northern Finland). All lakes with an area of 0.01 to 10 km² were included in the statistical sampling of subregion 1. In northern Finland (subregion 2) only lakes with an area of 0.1 to 10 km² were included. 100 lake areas (1:50 000 maps) were selected from subregion 1 using the Probability Proportional to Size method (PPS), according to which the selection of the lake areas was weighted by lake density. 25 areas were selected from subregion 2 in the same manner.

In the second selection stage all lakes of a size within the desired size range were numbered, and eight lakes chosen by systematic sampling from each previously selected lake area (1: 50,000 map). If the number of lakes in the area was eight or less, all the lakes were sampled. The total number of lakes was 987. In addition to these lakes, 202 mainly headwater lakes sampled in previous acidification studies were also included. The total lake sample represents ca. two percent of the total number of lakes larger than 0.01 km² in Finland. In this paper only results of the randomly selected lakes are presented.

Water samples were taken from the surface layer (1 m) of the lakes during autumn overturn 1987. All major cations and anions, total organic carbon (TOC), and aluminum fractions were analyzed on all samples. Cadmium, Cu, Ni, Zn and Pb were analyzed from a selected subgroup of headwater lakes. The analysis methods are described by Kortelainen (this volume).