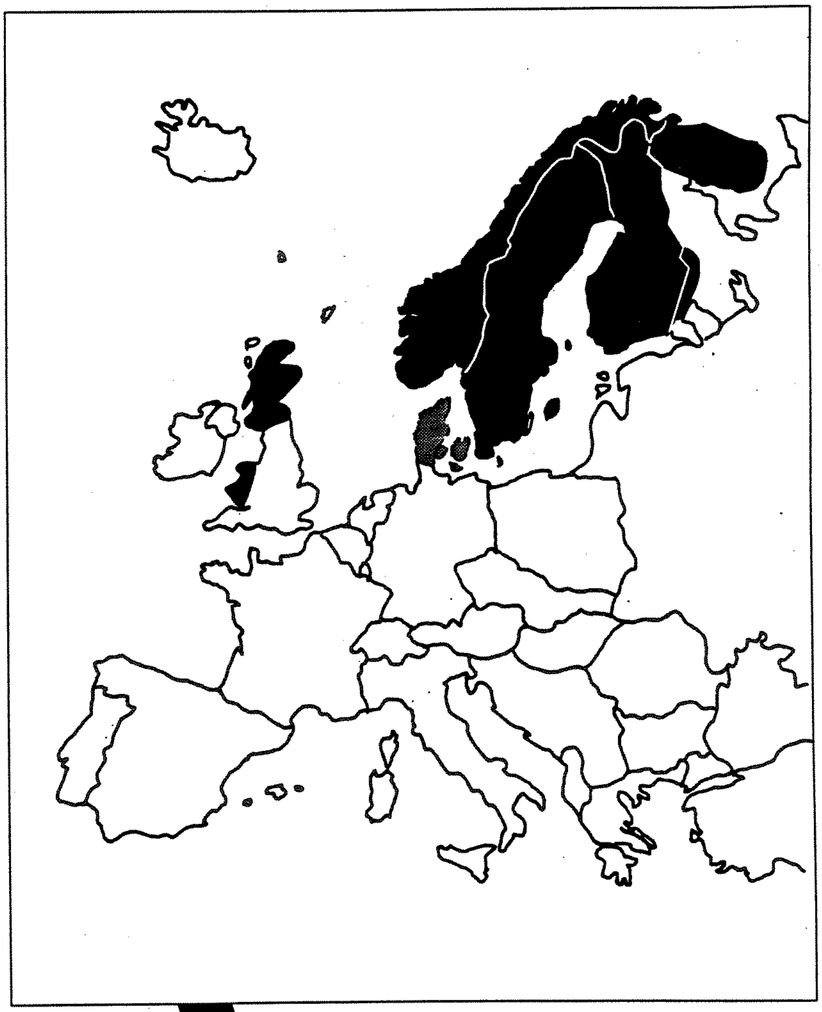
Acid Rain Research

REPORT 40/1996

Regional Lake Surveys in Finland - Norway - Sweden - Northern Kola - Russian Karelia - Scotland - Wales 1995

Coordination and Design



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Abstract: The three Nordic countries Finland, Norway and Sweden decided to carry out a joint Nordic Lake Survey in the fall of 1995. A working group, supported financially by the Nordic Council of Ministers (NMR), prepared a common manual for this purpose. It was decided to use similar lake selection criteria and harmonized analytical procedures. Generally, lakes in Denmark are not sensitive to acidification, but most lakes are strongly affected by nutrients. Thus, lake surveys like those carried out in the other Nordic countries have not been undertaken in this country. NMR has asked for a common evaluation of the properties of the lake populations in the four countries. As a result of Norwegian-Finnish-Swedish-Russian initiatives lake surveys were also carried out concurrently in Northern Kola and the Russian Karelia with financial support from Finland, Norway and Sweden. The working group also asked the United Kingdom to join in a common lake survey. As a result a lake survey was concurrently carried out in Scotland and Wales using similar lake selection criterias as those used for the surveys in Finland, Norway and Sweden. This report presents the coordination and the design of the surveys. A second report will present and discuss the results.

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Regional Lake Surveys
in
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Northern Kola - Russian Karelia
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1995

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Content

Summary

Previously, the most extensive lake surveys have been carried out in Finland in 1987, Norway in 1986 and Sweden in 1990. The data from these surveys formed a common ground for calculating critical loads for surface waters used in the negotiations for the second sulphur protocol signed in Oslo in June 1994. The Finnish and Swedish latest surveys were based on statistical selection of lakes from their national lake registers, while the Norwegian survey was based on subjectively selected lakes within areas with geology giving lakes sensitive to acidification.

Based upon the co-operative experience gained from these surveys as well as subsequent evaluation of the data, it was decided to carry out a joint Nordic Lake Survey in the fall of 1995. A working group, supported financially by the Nordic Council of Ministers (NMR), prepared a common manual for this purpose. It was decided to use similar lake selection criteria and harmonized analytical procedures. Each country will report their survey to the national authorities in their own selected way. Generally, lakes in Denmark are not sensitive to acidification, but most lakes are strongly affected by nutrients. Thus, lake surveys like those carried out in the other Nordic countries have not been undertaken in this country.

Since 1985 the Nordic Council of Ministers (NMR) has supported projects dealing with critical loads of air pollutants. NMR has asked for a common evaluation of the properties of the lake populations in the four countries and a working group from these countries was established to prepare such a report. As a result of Norwegian-Finnish-Swedish-Russian initiatives lake surveys were also carried out concurrently in Northern Kola and the Russian Karelia with financial support from Finland, Norway and Sweden. The working group of the NMR-project also asked the United Kingdom to join in a common lake survey. As a result of this initiative a lake survey was concurrently carried out in Scotland and Wales. Similar lake selection criterias were used for the surveys in Finland, Norway, Sweden, Northern Kola and Scotland and Wales.

The purpose of the Nordic Lake Survey in 1995 is to assess the status of the Nordic lakes with respect to:

1. the general water quality,
2. the occurrence and large scale regional variation in acidification,
3. establishing a new baseline of chemical data to follow up the future effects of the new sulphur protocol that was signed in Oslo in June 1994,
4. establishing the effects of nitrogen deposition on lake water chemistry in connection with the development of critical loads for nitrogen under the Working Group on Effects established by the United Nations Economic Commission for Europe's (UN/ECE) Excecutive Body on Long Range Transboundary Air Pollution (LRTAP) and
5. the eutrophication status and levels of heavy metals.

1. Introduction

Since 1985 the Nordic Council of Ministers (NMR) has supported projects dealing with critical loads of air pollutants. Three project dealt with critical loads for surface waters in the Fennoscandian countries. In 1990 a project on inter- and intra-regional variability of critical loads was carried out (Henriksen et al. 1990). In 1992 this project was followed by a project aimed at deriving critical loads of nitrogen and sulphur and providing the means for assessing target loads on the basis of these critical loads (Henriksen et al. 1993). Further, the working group on Air Pollution in the Northern Fennoscandia ("Luftforurensninger på Nordkalotten") asked the Norwegian Institute for Water Research (NIVA) to organize and carry out a cooperative research project on the status of critical loads of atmospheric sulphur for surface waters in this area, with participation of specialists from Sweden, Norway and Finland (Henriksen et al. 1994).

Regional lake surveys have previously been carried out in Finland, Norway and Sweden in order to assess the extent and magnitude of acidification in the three countries. A joint lake survey was carried out in the fall of 1995. NMR has asked for a common evaluation of the properties of the lake populations in the four countries and a working group from the four countries was established to prepare such a report. Each country will report their survey to the national authorities in their own selected way. These reports will be in the national language of each country.

As a result of Norwegian-Finnish-Swedish-Russian initiatives lake surveys were also carried out concurrently in Northern Kola and the Russian Karelia.

Generally, lakes in Denmark are not sensitive to acidification, but most lakes are polluted by nutrients. Thus, lake surveys like those carried out in the other Nordic counties have not been and will most likely not be undertaken. The Nordic Council of Ministers (NMR) has, however, asked for a common evaluation of the properties of the lake populations in the four countries. Thus, a description of the lakes in Denmark and the monitoring programs for Danish lakes are included in this report.

The working group of the NMR-project has also asked the United Kingdom to join in a common lake survey so that a common assessment of the lake populations and the lake water quality in Finland, Sweden, Norway, Denmark, Kola North, Russian Karelia and the UK can be made. As a concequence of this initiative, lake surveys were carried out in Scotland and Wales, the parts of UK where lakes are most sensitive to acidification.

Two reports in English will be produced: This report (Report 1) presents information on the lake populations in Finland, Norway, Sweden, Denmark, Northern Kola, Russian Karelia and Scotland and Wales. Background information on the present lake surveys and also an overview of previous lake surveys are given. One Annex contains the manual presenting the agreed procedures applied in the selection of lakes as well as sampling procedures and the analytical programme including quality assurance and control. Two additional annexes contain results from intercalibrations of chemical and physical methods used by the participating laboratories.

The contents of Report 2 is outlined below in the chapter Presentation of results.

2. Previous lake surveys

Regional lake surveys have been carried out in Finland, Norway and Sweden several times (see below). The most extensive surveys were carried out in Finland in 1987, Norway in 1986 and Sweden in 1990. The data from these surveys formed the basis for calculating critical loads for surface waters used in the negotiations for the second sulphur protocol signed in Oslo in June 1994.

2.1. Denmark

Data from earlier surveys were collected in the eighties and stored in the national lake database at the National Environmental Research Institute, Ministry of Environment and Energy (NERI). The results have been reported in Kristensen et al. (1990). Rebsdorf and Nygaard (1991) have made a summary of surveys and unpublished data concerning Danish acidified and potentially acidified lakes.

2.2. Finland

Several local/regional acidification oriented surveys with 50-150 lakes have been carried out since early 1980s, mostly in southern Finland (Isotalo 1984, Pätilä 1986, Oravainen 1985, Puomio and Braunschweiler 1993, Peura 1990, Peura & Sevola 1992, Oikari & Markkanen 1995).

The first and only extensive lake survey in Finland was carried out in fall 1987 by statistically selecting

Table 1 National lake surveys in Finland

Network	No of lakes	Samples/yr	Starting year
Large lakes	71	3	1962
ICP Waters			
(seasonal)	5	4	
(regional)	175	1-4	1978, 1988
Finland	970	1	1987
Lapland	200	1/2-3 yr	1989

970 lakes (Forsius et al. 1990). During the years 1987 - 1989 a total of 480 additional lakes were surveyed by the Lapland Water and Environment District. These 1450 lakes form the basis for assessing critical loads for Finnish surface waters. The spatial distribution of the lake data set reflects the actual lake density in different regions, and therefore no data were available for a few grids having very low number of lakes. The lakes for the 1987 lake survey were selected from two separate subregions, Subregion 1 (southern and central Finland) and Subregion 2 (northern Finland) The statistical sampling "frame" in each subregion consisted of a series of 1:50,000-scale topographic maps (20 x 30 km^2). Due to the uncertainty of the size distributions included in the lake frame population and the large variations in lake density in the different regions, a two-stage cluster sampling was used. All basins considered as lakes with a surface area within the pre-defined size range were numbered, and 8 lakes were randomly sampled from each map. If the number of lakes on the map was 8 or less, all lakes were sampled. The lakes sampled represents ca. 2% of the total number of lakes in the size range 0.01 - 10 km^2 in Subregion 1, and 5% of the lakes with surface areas 0.1 - 10 km^2 in Subregion 2.

2.3. Norway

Regional lake surveys have been carried out several times in Norway. Most of them have been restricted to Southern Norway, because this area is most heavily impacted by acid deposition. These surveys are summarized in Table 2.

In 1974 and 1975 samples were taken from 719 lakes in southernmost (Wright et al. 1977). Fish status for 600 of the lakes was established by interviews with local residents and evaluation of written records. An additional regional survey was conducted as part of the SNSF-project (Acid precipitation - effects on forest and fish). The sampling of lakes began in the fall of 1974 after the lakes had circulated. The lakes in this survey and also those sampled in 1975-1977 (table 2) were all selected from a statistical grid net. The later regional surveys conducted as part of the SNSF-project were carried out during the winter season.

In the 1000 Lake survey in 1986 water samples were collected during fall overturn from 1005 lakes throughout Norway during fall. The lakes were not selected statistically, but chosen from areas underlain by types of bedrock expected to give runoff waters having low buffering capacities, such as granites, gneisses and migmatites. 305 of the lakes located in southern Norway had been sampled in the fall of 1974 and 1975 (table 2). Most of the lakes sampled were larger than 0.2 km^2. The lakes had no appreciable direct human influence, were located in headwater areas and were not affected by local sources of pollution. Almost half of the lakes were selected from counties most affected by acidification. Samples were collected from the outlet of the lakes. A total of 14 chemical variables were measured on each lakewater sample.

2.4. Sweden

Sweden has carried out extensive lake surveys since 1972 (Table 3). They were made during various seasons and with different objectives. The first survey focussed on the trophic state of the lakes, even though indicators for acidification were included. This study also included an extensive study of phytoplankton (Rosén, 1981). Each county administration selected about 50 lakes in order to give a reasonably good geographical distribution. The survey in the spring of 1975 covered most of the lakes in the previous survey, but focused on acidification. Most ambitious was the 1990 survey, where the selection of lakes could be made from a national lake register covering nearly all Swedish lakes with an area >0.01 km^2 (Bernes, 1991). Three types of lakes were excluded: (a) overgrown or very

Table 2 Previous regional lake surveys in Norway

Date	Number of lakes	Area of coverage	Reference
October 1974	155	Southern Norway	Wright et al. 1977 Wright and Henriksen 1978
March 1975	153	Norway	Wright et al. 1977
March 1978	112	Norway	Wright et al. 1977
Fall 1974 and fall 1975	719	Southernmost Norway	Wright and Snekvik 1978
March 1977	38	Southern Norway	Henriksen 1979
March 1978	49	Southern Norway	Henriksen 1979
March 1981	49	Southern Norway	SFT 1982
October 1983	623	Southern Norway	Sevaldrud and Skogheim 1986
Fall 1986 (1000-Lake Survey)	1005	Norway	Henriksen et al. 1988
1988 (4 times)	355	Norway	Faafeng et al. 1990

Table 3. Previous national lake surveys in Sweden

Time	Number of lakes	Area of coverage	Reference
August 1972	1250	Sweden	Johansson and Karlgren 1974, Dietrichson 1975
Spring 1975	1000	Sweden	Dietrichson 1975
1977-80	8000	Counties	Johansson and Nyberg 1981, Bernes 1981
Winter 1985	6900	Sweden	Bernes 1986
Winter 1990	4018	Sweden	Bernes 1991

shallow lakes (water depth less than 1 m), (b) certain reservoirs used for industries or as receiving bodies for sewage water, and (c) certain reservoirs used for the generation of hydroelectric power (short-term regulation). In order to obtain a reasonable geographic distribution the lake register was stratified with respect to counties, and within each county the lakes were classified according to area into size classes 0.01 - 0.1 km^2, 0.1 - 1 km^2, 1 - 10 km^2, 10 - 100 km^2, and > 100 km^2. From each size class a pre-defined percentage of the number of lakes was randomly selected for sampling. If there were less than 40 lakes in a size class, all lakes were sampled. In addition an extra set of 40 lakes was selected randomly. For the latter group the decision for sampling was left to the county authorities. A total of 4018 lakes were sampled between the end of January and beginning of May 1990. Samples were normally taken through the ice at 2 m depth with a Ruttner sampler and a total of 12 chemical variables were determined.

2.5. Northern Kola

Northern Kola (Murmansk Region) is the northeastern part of Fennoscandia. Precipitation falling in this area is severely polluted by strong acids and heavy metals due to emissions from large nickel smelters "Pechenganickel" and "Severonickel". Large areas in the region are sensitive to acid precipitation due to the climatological and geological conditions. Before 1990 information of acidification of freshwaters in this area, as well as for Russia as a whole, was limited. During the period 1990-1992 a survey of 370 lakes was conducted in the Northern Kola, based on the selection criterias and sampling and analytical methods used in the Nordic countries (Henriksen et al. 1990). Headwater lakes were sampled at the outlet in late autumn and winter and analysed by the same chemical and physical methods as those used in Finland and Norway. Laboratory performance and data quality were ensured by participation in the intercalibration routines conducted by the UN/ECE International Co-operative Program on Acidification of Rivers and Lakes (ICP-Waters).

2.6. Russian Karelia

Regional lake surveys have been carried out several times in Russian Karelia. Most of them have been restricted to southern Karelia and to the north-eastern part of Karelia. The southern part is heavily impacted by acidic deposition, the north-eastern part by the significant fluoride deposition. During the years 1989-1991 samples were taken from 345 lakes including the river basins Shuya (109 lakes; Lozovik and Freidling 1991), Suna (93), and Vyg (143). Most of the surveyed lakes were larger than 1.0 km^2. Samples were taken during the autumn overturn from the surface water layer using helicopter. More than 25 chemical variables were measured in each water sample.

2.7. Scotland and Wales

Before 1950 the only systematic survey of lakes in the UK was done by Murray and Pullar (1910) for Scottish lochs. 562 of the largest lochs were included in the bathymetrical survey, but unfortunately no chemical analysis was done.

No systematic chemical sampling of UK lakes has been attempted. However, regional surveys of upland lakes in Wales, northern England and Scotland have been done from as early as the 1950's in the lake district of England and the Cairngorms of Scotland (Gorham, 1957). In the 1970's more extensive regional surveys were initiated, especially in Wales and Scotland, to assess the extent of surface water acidification in the UK (eg Acidification in Scotland, 1989: Acid Waters in Wales, 1990). The first systematic survey of UK lakes was done in the early 1990's as part of Department of Environments critical load programme. Over 1,500 lakes were sampled in the most sensitive UK regions using the criteria of one lake per 10 km square. Analytical procedures were similar to those of the Nordic surveys. (Critical Loads Advisory Group on Freshwaters, 1995).

3. Assessment of regional lake chemistry

3.1. Fennoscandian lakes

In recent years large areas of Europe and eastern regions of North America have suffered from acid precipitation resulting in the acidification of surface waters, increased fish mortality and other ecological changes. The regional lake surveys previously carried out in Finland, Norway and Sweden have been used to assess the extent and magnitude of acidification in the three countries. The Finnish and Swedish latest surveys were based on statistical selection of lakes from their national lake registers, while the Norwegian survey was based on subjectively selected lakes within areas with a geology giving lakes sensitive to acidification. The chemistry data bases for these Nordic surveys have been used for the assessment of critical loads and critical load exceedances of surface waters within each of the three Nordic countries (Henriksen et al. 1990, Posch et al. 1995). For the joint lake survey in 1995 it was, however, decided to use similar lake selection criteria for the three Nordic countries.

3.2. Lakes in Denmark

Denmark has 709 lakes with an surface area greater than 0.04 km^2 (4 ha). The typical Danish lake is small, shallow and has a short water residence time, and "the typical lake" is quite heavily loaded with nutrients.

Table 4. Danish national surface water monitoring programme - lakes (NERI).

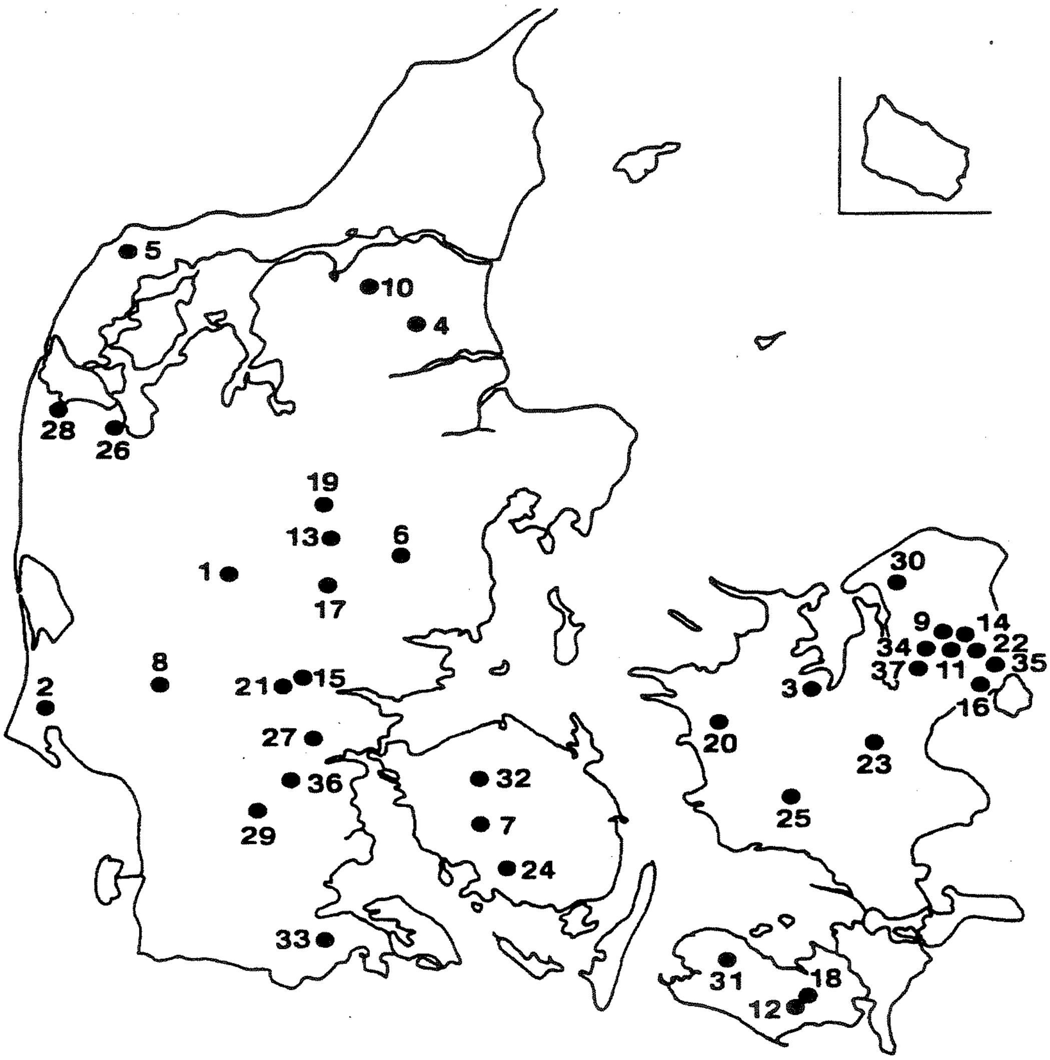
Variables	Period of operation & Sampling Frequency (SF)	Geographical coverage	Data& national reporting
Chemical and physical variables in lake water and tributaries.	Since 1989 SF: Lake water 19/yr Tributaries 12-26/yr	Nationwide 37 lakes	Database: NERI Reporting: NERI
Phyto- & zooplankton, fish and macrophytes.		Plankton 19/yr	
Sediment composition	Fish, macrophytes & sediment 1/5 yr		

NERI: National Environmental Research Institute, Ministry of Environment and Energy

Table 5. List of parameters measured in the lake monitoring programme

Parameter	Epilimnion	Hypolimnion	Tributaries
		Field measurements	
Water level	*		
Continuous measurement of discharge			*
Water temperature (incl. profile)	*	*	
Oxygen (incl. profile)	*	*	
pH	*	*	*
		Laboratory measurements	
pH (at 25 °C)	*	*	*
Alkalinity	*	*	*§
NO_2 +NO_3-N	*	*	*§
NH_4-N	*	*	*§
Total Nitrogen	*	*	*
Dissolved PO_4-P	*	*	*
Total Phosphorus	*	*	*
Suspended matter (SS)	*		
Loss on ignition of SS	*		
Particulate COD	*		
Chlorophyll a	*		
Phytoplankton (Species comp., numbers and biomasses)	*	*§	
Zooplankton (Species comp., numbers and biomasses)	*	*§	

§ in some cases optional or otherwise restricted. Obs. Conductivity is measured in a number of the lakes.



1 Søby Sø
2 Holm Sø
3 Maglesø
4 Madum Sø
5 Nors Sø
6 Ravn Sø
7 Søholm Sø
8 Kvie Sø
9 Bastrup Sø
10 Hornum Sø
11 Sønderso
12 Røgbølle Sø
13 Ørn Sø
14 Fureso
15 Fårup Sø
16 Damhussøen
17 Bryrup Langsø
18 Hejrede Sø
19 Hinge Sø
20 Tissø
21 Engelsholm Sø
22 Bagsværd Sø
23 Borup Sø
24 Arreskov Sø
25 Tystrup Sø
26 Kilen
27 Dons Nørresø
28 Lemvig Sø
29 Jels Oversø
30 Arresø
31 Vesterborg Sø
32 Langesø
33 St. Søgård Sø
34 Fuglesø
35 Utterslev Mos
36 Søgård Sø
37 Gundsømagle Sø

Figure 1. Geographic location and name of the 37 Danish lakes included in the Nationwide Monitoring Programme.

Due to intensive farming and high population density the discharge of phosphorus and nitrogen has been quite high in the past decades.
Acidification is a potential problem in a number of low-alkaline (<0.4 mmol l-1) lakes, mostly situated in the western, northern and central part of Jutland. The National part of the monitoring of lakes in Denmark is, however, still focusing on the main problem: eutrophication, and the monitoring programme is especially designed to fulfill this purpose. Since no lake survey will be carried out in Denmark, we instead present the Danish monitoring programme in some detail. The data from this programmme will be used in the next report to compare the lake water chemistry in Denmark with the chemistry of the lakes in the other participating countries.

3.2.1. Surface water monitoring
Surface water monitoring in Denmark has been undertaken since the early 1970's. The 14 Danish counties have been responsible for inland surface water and coastal water monitoring and management, while the Ministry of Environment and Energy is responsible for monitoring the marine areas. During

the 1970's and 1980's much information on the environmental state of surface waters was collected and reported by the counties. A nationwide monitoring programme was established in 1988.

In order to obtain this information, monitoring sites have been established at locations all over Denmark plus a comprehensive sampling programme. The regional authorities (the 14 Danish counties) are responsible for monitoring groundwater, rivers, lakes and coastal waters, while the National Environmental Research Institute (NERI) is responsible for monitoring the open sea and the atmospheric deposition. NERI and Geological Survey of Denmark have the responsibility of national planning, coordination, and national annual reporting of the environmental state of the aquatic environment.

3.2.2. Lakes

The objectives of the lake monitoring programme L1 are to record the magnitude of nutrient loading and to elucidate trends in lake nutrient loading and its effects on physical, chemical and biological conditions. Of a total of 468 Danish lakes larger than 5 ha, 37 representatives, concerning morphometrics and eutrophication level, are included in the monitoring programme (Fig. 1). These lakes are studied intensively each year (Table 4). A specific list of standard parameters which are measured/analyzed for is given in Table 5.

3.3. Lakes in the Northern Kola

The impacts of acid precipitation in Northern Kola is considerably higher than in the northern parts of the other Nordic countries. There is clear evidence of lake acidification in the Kola region, where 5% of the 370 lakes studied in 1990-1992 had pH < 5, and in 10.5% of the lakes pH was less than 6. Further, 30% of the lakes are threatened by acidification (ANC < 50 μeq/l). Acidified lakes are found throughout Northern Kola (Moiseenko 1994). For almost 50% of the lakes the critical load of sulphur was exceeded (ANC_{limit} = 20 μeq/L). These data are, however, considered to be preliminary, since the selected lakes were not regularly distributed over the area. The new survey was designed to give a better representation of the lake population in Northern Kola.

3.4. Lakes in the Russian Karelia

Precipitation falling on Russian Karelia is severely polluted by strong acids due to transboundary air pollution and sulphate and nitrogen emissions from local industrial centers in Kostamuksha, Segeza, Kondopoga and Petrozavodsk. Deposition of fluoride compounds are significant near Nadvoitsy. Surface waters in Russian Karelia are highly sensitive to acidic deposition. The most acidic lakes occur in the southwestern part of Russian Karelia.

3.5. Lakes in the UK

Of the total UK area of about 230,000 km^2 approximately 1% (2,404 km^2) has been estimated to be inland surface water. Smith and Lyle (1979) estimated 1,445 river systems and 5,505 lakes of >4 ha, of which 66% of rivers and 69% of lakes are found in Scotland.

Most of the river systems are routinely sampled by the National Rivers Authority in England and Wales and by the River Purification Boards or Island councils in Scotland. Pollutant levels are controlled by UK Acts of Parliament and more recently European Community Directives, mainly by limiting discharges from point sources. In lowland waters the major pollutant sources are associated with agricultural practices and sewage disposal while upland lakes, the effects of atmosphere deposition and land use changes have caused the greatest concern.

4. Description of the coordinated lake surveys 1995

4.1. The Nordic lake survey

In February 1994 representatives of the environmental authorities and scientists from Finland, Norway and Sweden met in Stockholm to discuss the coordination of planned regional lake surveys in their respective countries. The planning and coordination were further elucidated at two successive meetings in Uppsala (May 1994) and Helsinki (October 1994). It was agreed that a manual for the Nordic Lake Survey 1995 should be worked out. This manual was discussed in Oslo in February 1995 and accepted at a meeting in Visby, Gotland, in August 1995. This manual is included as an Appendix in this report.

The purpose of the Nordic Lake Survey is to assess the status of the Nordic lakes with respect to

- general water quality
- occurrence and large scale regional variation in acidification
- baseline chemical data for following up future effects of the new sulphur protocol that was signed in Oslo in June 1994
- effects of nitrogen deposition on lake water chemistry in connection with the development of critical loads for nitrogen under the Working Group on effects established by the United Nations Economic Commission for Europe's (UN/ECE) Excecutive Body on Long Range Transboundary Air Pollution (LRTAP).
- eutrophication status and levels of heavy metals

4.2. Lake surveys in UK

The main purpose of the Scottish survey was to provide the Scottish Office with the first statistical assessment of the acidification and nutrient status of Scottish lochs. The data will provide the basis of a GIS based Scottish Freshwater Database. The Welsh and Scottish data will also be used to supplement the UK critical loads database for Freshwaters and allow a comparison of the FAB, SSWC- and diatom- critical load models for freshwaters.

5. Lake registers and lake size distributions

5.1. Lake registers

Finland, Norway and Sweden have official lake registers covering lakes with areas down to 1 ha in Sweden and Finland and 4 ha in Norway, and lakes were statistically selected from these databases (see below). In Scotland, estimates of lake size and density were made from 1:50,000 digitised Ordnance Survey data while the Welsh lakes were selected from 1:25,000 maps by manual procedures. For the Kola North and Russian Karelia no official lake databases are available. In the eastern part of Kola the lakes were selected from 1:200,000 maps and the size distribution was sought to be similar to the Nordic lake selection.

5.1.1. Finland

A lake register database based on the 1:20,000 topographic map information is maintained by the Finnish Environment Agency. All lakes above 1 ha are included in this database. Basic information is given in table 6.

5.1.2. Norway

Based on the digitized 1:250,000 maps from Statens kartverk (the Norwegian Mapping Agency), the Norwegian Water and Energy Works (NVE) has created a database with information about all "visual" lakes. For this purpose the GIS-software Arc/Info has been used. This database contains information about 64597 lakes (Table 6). Since the lake register is derived from 1:250,000 scale maps there is a lower limit to the size of the lakes included. The register has been found to be reliable for lakes above 0.04 km^2 in surface area, giving a total of 38845 lakes larger than 0.04 km^2. Only a fraction of lakes smaller than 0.04 km^2 is registered. Comparing lakes registered with lakes present on 1:50,000 maps we have estimated the number of lakes > 0.01 km2 (1 ha) to be about 146,000 for Norway.

5.1.3. Sweden

The selection was based on the Swedish Lake Register (Swedish Meteorological and Hydrological Institute, updated version May 1994). The register identifies the lake by coordinates and name and contains information about the size class and map reference (table 6). The size class for the smallest lakes includes 0.01-0.1 km^2. Therefore the number of lakes in the class 0.04-0.1 km^2 has been estimated from the relation found for the lakes sampled in 1990 for which the actual lake size has been measured.

Table 6 . Information contained in the lake registers of Finland, Norway and Sweden

	Finland	Norway	Sweden
Lake number	x	x	x
Name	x	x	x
Lake area, km^2	x	x	x
Circumference, km	x	x	
Height above sea level, m	x	x	
Municipality number	x	x	x
Map reference	1:20,000 maps	1:50,000 maps	1:50,000 maps
Watercourse number		x	x
Geographical coordinates	UTM for a point within lake area	UTM for a point within lake area	UTM for lake outlet

Table 7. Lake size distributions in Finland, Sweden, Norway, Denmark, Russian Karelia, Northern Kola and Scotland and Wales

Size classes	1	2	3	4	5		
Size (km^2)	0.04-0.1	0.1-1	1-10	10-100	>100	Total > 0.04	Total > 0.01
Finland	14716	12308	2164	290	47	29525	[1]55317
Norway	21218	16417	2139	164	7	38845	[2]146000
Sweden	[3]35802	20484	3599	379	24	602883	[3] 94687
Denmark	365	269	69	6	0		709
Russian Karelia	ca. 12000	8355	1370	156	21	ca.37700	[4]49746
Northern Kola	12129	7283	830	78	0	20320	
Scotland	[5]3517	1369	147	21	0	[6]5054	8387
Wales	160	79	16	0	0	255	

1) Number of lakes 0.01-0.039 km^2: 25792
2) Estimated number
3) Estimated values (actual numbers 0.01 - 0.1 km^2 = 70201)
4) Including size class 0.01-0.1.
5) 0.02-0.1 km^2
6 Lakes larger than 0.02 km^2

5.2. Lake size distributions

The working group has decided to divide the lakes into 5 size classes : 0.04-1 km^2, 0.1-1 km^2, 1-10 km^2, 10-100 km^2 and >100 km^2. From the Finnish, Norwegian and Swedish lake registers Table 7 can be derived. The figures for Russian Karelia are from Grigoriew and Gritsevskaja (1959). The figures for Northern Kola is from personal communication (T. Moiseenko).

6. Lake selection criteria

6.1. Finland, Norway and Sweden

For Finland, Norway and Sweden the lakes were selected at random from the national registers with the common requirements that:

- a minimum of 1% of the lakes within any county/region shall be included
- the proportion of lakes in size classes 0.04-0.1, 0,1-1, 1-10 and 10-100 km² shall be 1-1-4-8; all lakes >100 km² shall be included.

The final number of lakes from different counties/regions has been made in slightly different ways, but with a common goal of achieving a larger proportion of lakes in areas with a high degree of acidification or critical load exceedance, few lakes and/or more variable lake chemistry (as estimated from previous surveys). Thus the proportion of lakes in the two smallest size classes was selected as follows:

NORWAY:
1.2 % in northern Norway, 2.1 % in middle Norway and 3.0 % in southern and eastern Norway.

FINLAND:
1.5 % in northeastern Lapland, 2 % in inland and remaining parts of northern Finland, 4 % in coastal counties/regions.

SWEDEN:
2 % in northern and 8 % in southern Sweden; percentage in areas in between depending on the variability in alkalinity as measured in the previous survey and modified so that a similar number of lakes per NILU-grid (50 x 50 km) would be achieved.

The number of lakes in the larger size classes was arrived at by multiplying the basic percentages by the factors 4 or 8 for these size classes on a county or region basis; all lakes >100 km² were included. The number of lakes selected in each country is shown in Table 8 and the location of the lakes are shown in Figure 2.

6.1.1. Exclusion criteria

The following types of lakes were excluded.

1. Hydro-electric power reservoirs with > 5 m regulation
2. Catchment area/lake area > 100/1 (Norway and Sweden only)
3. Maximum lake depth < 1 m
4. Extended rivers
5. Treatment ponds and similar water bodies
6. Limed lakes (Finland and Norway)

If such lakes were drawn they were substituted as follows:

FINLAND:
The selection procedure included ca. 40 percent oversampling. If a lake was excluded the lake was replaced with the first lake from the spare list of the same size category and watershed number. If these types are absent on the list, then the nearest one on the list (within the size category) was selected. The criterium lake/watershed ratio 1:100 was not used because chain-type lakes are common in Finland, but short retention time river extensions were removed.

NORWAY:
The random selection programme selected twice the required number of lakes for each class and region. If a lake was exluded, the first on the "spare" list was selected. If a lake was excluded because of liming a similar lake nearby in the same size class was selected. The latter was done to ensure that areas with many limed lakes (these are the most acidified areas) also were represented in the lake populations.

Table 8. Number of lakes selected in each country

Size classes Size (km²)	1 0.04-0.1	2 0.1-1	3 1-10	4 10-100	5 >100	Total >0.04
NORWAY						
Selected	433	359	181	30	7	1010
Percentage	2.2	2.2	8.9	18.3	100	2.6
SWEDEN						
Selected	1373	900	640	139	23	3075
Percentage	3.8	4	17.7	36.6	96	3.2
FINLAND						
Selected	315	272	200	61	45	893
Percentage	2.2	2.3	9.2	17.8	100	2.9

Table 9. Number of lakes selected for the regional lake surveys in Russian Karelia and Northern Kola

Size classes Size (km²)	1 0.04-0.1	2 0.1-1	3 1-10	4 10-100	5 >100	Total > 0.04
Northern Kola						
Selected	227	188	73	10	2	500
Percentage	2	2.4	8.3	15		2.5
Russian Karelia						
Selected	0	6	14	7	2	29

Table 10. Number of lakes selected in Scotland and Wales

Scotland **Size classes** **Size (km²)**	1 0.02-0.1	2 0.1-1.0	3 1.0-10	4 10-100	5 >100	Total >0.02
Selected	76	35	20	5	0	136
Percentage	2.2	2.6	13.6	23.8	0	2.7
Wales **Size classes** **Size (km²)**	**1** **0.04-0.1**	**2** **0.1-1.0**	**3** **1.0-10**	**4** **10-100**	**5** **>100**	**Total** **>0.02**
Selected	30	15	7	0	0	52
Percentage	18.8	19.0	43.8	0	0	20.4

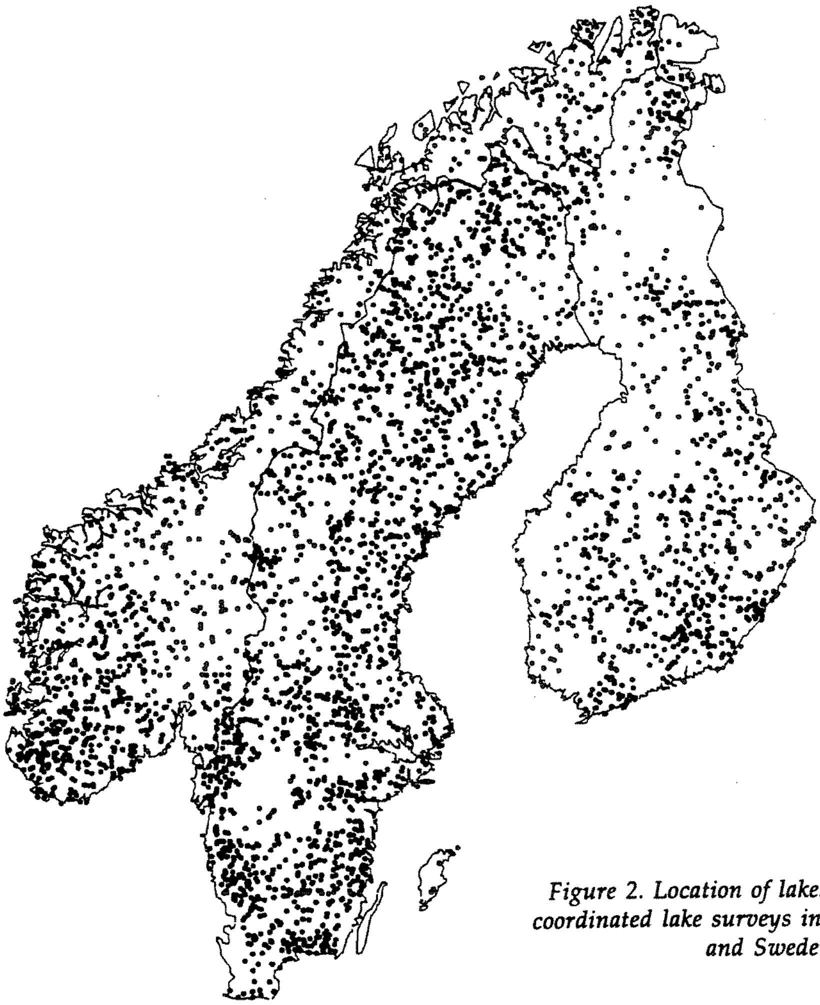


Figure 2. Location of lakes selected for the coordinated lake surveys in Finland, Norway and Sweden.

SWEDEN:
An excluded lake was replaced by the next, randomly chosen lake within the same size class and county.

6.2. Northern Kola

In order to obtain lake samples coordinated in time and space with the Nordic survey two lake surveys in Northern Kola have been intiated.

In the first survey the selection of lakes was made on the basis of the same size classes used in the Nordic countries for the whole area. In lack of a complete data register for lakes in Northern Kola, the random selection used in the Nordic countries could not be directly applied. The lake selection in was made by INEP based on geographical maps (1:100,000). An important criterium for lake selection was to obtain a good geographical coverage and more dense sampling was carried out in areas affected by acid deposition and in acidification sensitve areas.

The Institute of North Industrial Ecology Problems (INEP) sampled 500 lakes all over Northern Kola, 230 from the eastern part (66.30,29.30 - 69.30,41.00) and 270 lakes from the western part (66.30,29.00 - 69.30,35.00). The samples were collected in September and October and analysed at INEP. TOC and aluminium fractions were analysed at NIVA for a subset of samples. This part of the project is financed by the Norwegian Department of Environment (MD), the Swedish Environmental Protection Agency (SNV), NIVA and INEP.

In addition approximately 130 lakes in the western part of the Kola peninsula (west of 35°30') were sampled by a geological expedition with participation from the Norwegian Geological Survey (NGU) and Central Kola Expedition (CKE) during the summer. The water samples were analysed by NGU and NIVA. This part of the project is financed by NGU and NIVA.

6.3. Russian Karelia

Lake selection in Russian Karelia was made by the Northern Water Problems Institute. In lack of a complete data register for lakes, the random selection used in the Nordic countries could not be applied. The selection of lakes was made by the Northern Water Problems Institute in Petrozavodsk. The selection was restricted to lakes situated near the Finnish border and accessable by car. Investigations of lakes in the western part of Russian Karelia was coordinated by the North Karelia Regional Environment Centre, which is partly financed by the Ministry of the Environment in Finland. 28 lakes near the Finnish border were sampled as a joint survey with North Karelia Regional Environment Centre, Joensuu, Finland and the Karelian Academy of Sciences, Northern Water Problems Institute, Petrozavodsk, Russia.

6.4. UK

There is no inventory of UK lakes. Therefore for reasons of data availability and logistics the 1995 survey has been limited to Scotland and Wales. All lakes down to 2 ha are available from the Ordnance Survey in digitised form in Scotland. For Wales a cut off at 4 ha was made. The statistical selection has been made on the basis of 100 km^2 blocks in Scotland, with no weighting for acidification status, but using the agreed size range weighting of 1:1:4:8: all of the five size classes. For Wales, the country was taken as a singleunit with no acidification weighting applied. Because of the small number of lakes involved a weighting of 1:1:2 was used.

7. Sampling

The samples were collected shortly after the autumn overturn in all countries, following the procedures given in the annexed Manual.

7.1. Finland

Seven percent of the total lakes was sampled by helicopter, all in N. Lapland. The remaining lakes were all accessable by foot. The samples were transported by car to the resp. Regional Environment Centre, where they were analysed.

7.2. Norway

The samples were collected during the period September-November by foot or by helicopter, depending on the access to the lake. For practical and time saving reasons about 96% of the were sampled by helicopter. The samples were collected either at the outlet by filling the bottles directly underneath the surface, or from the lake near the outlet with Ruttner-type sampler operated from the helicopter. At the end of each day of sampling the water bottles were sent by car or mail to the NIVA's laboratory in Oslo for analyses.

7.3. Sweden

The sampling started in the middle of September in the northern parts of Sweden. Most samples were collected from the middle of the lake from a helicopter with a teflon tube submerged into the water and connected through a peristaltic pump to the sampling bottles. Samples were sent daily to the laboratory for analyses.

7.4 Northern Kola

The sampling in Northern Kola was carried out by

INEP during the period August - October 1995. The sampling requiring helicopter took place in the period 20 September - 10 October. Samples from lakes accessible by car were collected all throughout the period. The sampling procedure was as given in the Manual.

7.5. Russian Karelia

The sampling in Russian Karelia was conducted as a joint work by the North Karelia Environment Regional Centre and Northern Water Problems Institute. The samples were collected during the autumn overturn during the first two weeks of October 1995 (2-5 October and 9 - 11 October). The sampling procedure was similar to the one used in Finland.

7.6. Scotland and Wales

Sampling in Scotland did not commence until December because surface water temperatures remained >6 °C in the autumn due to exceptionally mild weather. All sampling was done by road and foot and completed by end of January 1996. All 188 samples from Scotland and Wales were analysed at the Freshwater Fisheries Laboratory in Scotland.

8. Variables

All analytical work has been centralized in national laboratories with extensive Quality Assurance/Quality Control routines. No variables have been measured in the field. The laboratories responsible for analyses are:

- Norwegian Institute for Water Research, Oslo, Norway (NIVA),
- Department of Environmental Assessment at the Swedish University of Agricultural Sciences, Uppsala, Sweden (SLU),
- Finnish Environment Agency, Helsinki, Finland (former Water and Environment Research Institute, WERI), Regional Environment Centres in Finland (3-13 depending on the variable)
- Institute of North Industrial Problems (INEP).
- Freshwater Fisheries Laboratory, Faskally, Pitlochry, Pertshire PH16 5LB, United Kingdom.

The following variables were determined

Table 11. Variables analysed for the regional lake surveys. (Denmark is not included. No survey was carried out.)

Variable	Finland			Norway	Sweden	Kola	Russian Karelia			Scotland and Wales
	A	B	C			x	A	B	C	
pH	x			x	x	x	x			x
Conductivity	x			x	x	x	x			x
Temperature	x			x	x	x	x			x
Alkalinity	x			x	x	x	x			x
SO_4		x		x	x	x		x		x
Cl		x		x	x	x		x		x
F		x		x	x	x		x		
Ca, Mg, Na, K		x		x	x	x		x		x
NO_3-N	x			x	x	x	x			x
NH_4-N	x			For eutrophic lakes only	x	x	x			x
Tot-N	x			x	x	x	x			x
Tot-P	x			x	x	x	x			x
TOC		x	x	x	x	COD_{Mn}		x	x	x
Tot. monom. Al			x[1]	x	1/3	x			x[1]	x
Non-labile Al			x[1]	x	1/3	1/3			x[1]	x
"Trace" metals (ICP/MS			x[2]	x[3]	1/3	AAB/FYX	for 8 lakes			x[3]
SiO_2		x		x	x	x		x		x
Absorbance				(x)	x					x
TIC		x	x					x	x	
Colour	x					x	x			
Turbidity	x						x			
Phosphate-P	x					x	x			x

[1] For every second lake in size classes 1+2
[2] For every second lake in all size classes
[3] Depends on funding

A = Regional Laboratories (13)
B = Regional Laboratories (3)
C = Finnish Environment Agency

9. Quality assurance and quality control

The project was carried out according to the individual countries quality assurance and quality control programs. The laboratories in Norway (NIVA), Sweden, (SLU), Finland (FEA, Helsinki and Southeast REC/Kouvola), Denmark (NERI, Silkeborg), Kola (INEP, Apatity) and Scotland (DAFS, Pitlochry) all participate yearly in the intercomparison tests of the UN/ECE/ICP-Waters Programme, carried out by NIVA. The intercalibration covers all major ions, pH, conductivity, aluminium and organic carbon. In 1994 alltogether 26 laboratories participated in the intercalibration and for most parameters only 2-5 laboratories reported results lying outside the general target accuracy of ± 20%. Only in a few cases laboratories analysing samples from the present survey were outside this limit (see also Annex 2).

10. Presentation of results

Each country will, as pointed out above, report the surveys to their respective national authorities in their own selected way and in their own national language, but common ways of presentation will be aimed at.

The NMR working group will work out a report to be completed at the end of 1996 dealing with the results from the lake surveys. The working group is planning as a first step to present the status of the lakes as commented figures:

1. Point maps showing measured/classified values for a selection of variables (pH, Ca, SO_4, NO_3 etc.)
2. NILU- grids showing average (median) values for a selection of variables (pH, Ca, SO_4, NO_3 etc.)
3. Critical load maps
4. Critical exceedance maps with respect to sulphur acidity exceedance and present acidity exceedance (thus including present NO_3 leaching).
5. Potential acidity exceedance (FAB-model)
6. Comparisons with data from previous surveys, when applicable.
7. Whenever possible we will include data from Denmark, Northern Kola, Russian Karelia and Scotland and Wales in the above mentioned evaluations.

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Annex 1

Manual for the Nordic Lake Survey 1995

by

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1. Objectives

The goal of the Nordic Lake Survey is to provide opportunities, through the harmonization and coordination of sampling, laboratory analyses, background information and data bases, for a common assessment of the status of Nordic lakes with respect to:

- the occurrence and large scale regional variation of acidification, eutrophication and, to some extent, elevated levels of trace metals
- critical loads and their exceedance for sulphur and nitrogen.

Each country will be responsible for the field work and data analysis of its own national survey. The sampling design will take into account the countries´ own evaluative demands as well as the requirements of an inter-country comparison (e.g. by ecoregion).

This manual describes the procedures that the countries have agreed on in order to ensure that a common assessment will be possible. The planning and reporting of the common assessment will take place within a Nordic Council of Ministers (NMR) project.

2. Sampling design

Lakes have been selected at random from the national registers with the common requirements that:

- a minimum of 1% of the lakes within any county/region shall be included
- the proportion of lakes in size classes 0.04-0.1, 0,1-1, 1-10 and 10-100 km² shall be 1-1-4-8; all lakes >100 km² shall be included.

The final number of lakes from different counties/regions has been made in slightly different ways, but with a common goal of achieving a larger proportion of lakes in areas with a high degree of acidification or critical load exceedance, few lakes and/or more variable lake chemistry (as estimated from previous surveys). Thus the proportion of lakes in the two smallest size classes was selected as follows:

NORWAY:
1,2% in northern Norway, 2,1% in middle Norway and 3,0% in southern and eastern Norway.

FINLAND:
1,5 % in northeastern Lapland, 2% in inland and remaining parts of northern Finland, 4 % in coastal counties.

SWEDEN:
2% in northern and 8 % in southern Sweden; percentage in areas in between depending on the variability in alkalinity as measured in the previous survey and modified so that a similar number of lakes per NILU-grid would be achieved.

The number of lakes in the larger size classes was arrived at by multiplying the basic percentages by the factors 4 or 8 for these size classes on a county or region basis: all lakes >100 km² were included

Table 2.1. Number of lakes selected in each country

Size classes Size (km²)	1 0.04-0.1	2 0.1-1	3 1-10	4 10-100	5 >100	Total >0.04
NORWAY						
Selected	433	359	181	30	7	1010
Percentage	2.2	2.2	8.9	18.3	100	2.6
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Selected	1373	900	640	139	23	3075
Percentage	3.8	4	17.7	36.6	96	3.2
FINLAND						
Selected	315	272	200	61	45	893
Percentage	2.2	2.3	9.2	17.8	100	2.9

The number of lakes selected in each country is shown in Table 2.1.

The following lake categories have not been included:

- regulated lakes (amplitude >5 m);
- very shallow lakes (maximum depth <1 m);
- lakes with a very short retention time (river extensions)
- treatment ponds and other similar water bodies; and
- limed lakes (Norway and Finland).

Special interest lakes, e.g. lakes from previous surveys but not randomly selected, may be included but should be treated separately (Norway includes 500 of the lakes surveyed in 1986).

3. Sampling

3.1. General

Sampling shall be undertaken by trained personnel.

Most of the lakes will be accessed on foot or by car and sampled from the outlet (straight to bottles) or by boat with Ruttner-type samplers. If the lakes are located more than 1-2 km from the nearest road or require more than one hours walk to reach, effective sampling will need access by helicopter.

Descriptions of sampling routines exist in each country (e.g. Mäkelä et al. 1992, Naturvårdsverket 1995). The routines may differ in some details. These differences are judged as being of little significance. More important is that the field personnel are familiar with their own sampling methods, which therefore should not be changed without particular reason. The most important is, that the single sample from each lake is as representative as possible at the time of the sampling.

3.2. Time of sampling

The lakes should be sampled during or shortly after the period of autumn overturn in 1995. In this period, a water sample from the outlet or from the central part of the lake should be representative for the whole lake. Samples taken during this period should also give values close to annual mean values for most of the examined parameters. Logistic reasons may cause changes in the sampling schedule, but the sampling should not start before the surface temperature of the lakes is below 6°C.

The time when autumn overturn occurs varies considerably with north-south latitude, with altitude above sea level and from one year to another due to climatic variations. Proposed sampling regions and sampling periods for the various regions of Fennoscandia are shown below. The borders between the sampling regions are roughly drawn, and the proposed sampling periods are adjustable to local conditions and climate variations.

3.3. Sampling technique and location

The local conditions (morphometry, hydrology,

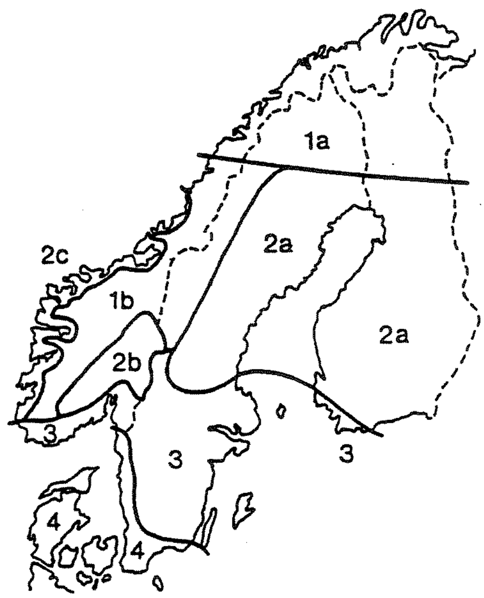

Diagram of the Nordic countries showing ecoregion delineations.

Region	Location of the lakes	Sampling period
1a	North of Polar circle (Arctic, Alpine and Northern boreal zone)	1 Sept. - 1 Oct.
1b	Mountains above timber line (Alpine zone)	15 Sept. - 1 Oct.
2a	Coniferous forest (Northern, Middle and Southern boreal zone)	1 Oct. - 1 Nov.
2b	Premountain region (Northern-Southern complex boreal zone)	1 Oct. - 1 Nov.
2c	Coastal area of deciduous and pine forest (Oceanic southern boreal zone)	1 Oct. - 1 Nov.
3	Boreo-Nemoral zone	15 Oct. - 15 Nov.
4	Nemoral zone	15 Nov. - 1 Dec.

vegetation) determine the place of the sampling. Lakes with high runoff (large lakes, high precipitation) or in surroundings of steep topography are suitable for outlet sampling. Lakes with flat surroundings and littoral vegetation need sampling from the open water area. In shallow water outlets, the samples may be taken directly in the bottles below the surface. In larger outlets, samplers should be used to get samples from the depth of 0.5-1 m.

In lake environments, samplers should be used to get samples from the depth of 1 meter in the open area, preferably near the outlet. If the sampling location is less than 1.5 m deep, a sample free of debris should be taken from the depth of 0.5 m. This should be indicated on the field data form.

The weather conditions during sampling and temperature on the sampling depth should be recorded in the field form in all cases.

In very small drainage lakes (and seepage and closed lakes) there might not be any outlet. In such conditions, the sample must be taken from the open area, reached e.g. by an inflatable boat. The sampling should be done sufficiently far from shores and littoral vegetation (minimum distance ca. 30 meters).

Samples for heavy metal determination, if included in the national surveys, should be taken below the surface film directly into a specieally treated bottle bottle, either by hand, wearing plastic gloves, or the bottle attached to a stick.

All sampling bottles will be prepared for field personnel by national laboratories (cf below) with standard cleaning procedures for each deteminand type. Therefore there is no apparent need to unify the routinely used bottles in different countries. Intercalibration and field blanks will reveal arising problems. For most inorganic measurements, properly cleaned (synthetic detergent or acid wash followed by rinsing several times with deionized water) polyethene bottles are suitable.

Regarding heavy metal sampling and bottle (HDPE) cleaning, a common Nordic standard exists (SS 028194, NS 4784, SFS 5503).

3.5 Sample handling and transport

After sampling, all samples should be kept cool (ca. + 4 °C) in dark containers. At the end of each day of sampling the water bottles should be sent by mail to the appointed laboratory for analyses. The samples will be delivered to the laboratories between 4 hours to 3 days after sampling. The transportation is organized by car (field sampling personnel) or mailed with prepaid postage. The analyzes will be carried out within 1 day - 3 months, depending on the variable (Table 4.1). Sample preservation for certain analyses is carried out at the laboratory.

3.6. Field observations

All abnormal conditions (watershed characteristics which are not displayed on map) observed when sampling the lake should be noted in the field form. These include new roads, buildings, ditching and logging operations in the watershed and dense macrophyte vegetation, turbidity of the lake etc.

4. Analyses

All analytical work will be centralized in governmental laboratories with extensive internal QA/QC routines. No chemical field measurements are included. The laboratories responsible for analyses are:

- Norwegian Institute for Water Research (NIVA), Oslo, Norway
- Department of Environmental Assessment at the Swedish University of Agricultural Sciences (SLU), Uppsala, Sweden
- Finnish Environment Centre, Helsinki, Finland (former Water and Environment Research Institute, WERI), Regional Environment Centres in Finland (3-13 depending on the variable)

Mandatory analytical variables are listed in table 4.1. Additional, optional variables are listed in table 4.2. Several variables relate to the acid/base status of lakes: pH, alkalinity, sulfate, nitrate and organic carbon.

Table 4.1. Analytical method, preservation, detection limit (DL) and holding time for mandatory variables.

Variable	Analytical method	DL	Holding time (d
pH	combination electrode		1
Conductivity	conductometric determination		1
Temperature	field measurement with thermometer	0.1 C	0
Alkalinity	acid titration1)	1 µeq/l	1
SO_4	ion chromatograph	0.1 mg/l	<30
Cl	ion chromatograph	0.5 mg/l	<30
NO_3-N	ion chromatograph/ colorimetry after reduction to N_{NO2}	10 µg/l	1[2] or 7[3]
F	ion selective electrode/ion chromatograph	0.1 mg/l	<30
Ca, Mg, Na, K	flame atomic absorption /ICP-MS	0.1 mg/l	<30
NH_4-N	colorimetry (hypochlorite and phenol)	10 µg/l	1[2] or 7[3]
N_{tot}	oxidation to N_{NO3} followed by colorimetry	50 µg/l	1[2] or 7[3]
P_{tot}	oxidation followed by colorimetry (phosphomolybdate)	2 µg /l	1[2] or 7[3]*
TOC	oxidation to CO_2, IR-measurement	0.5 mg/l	<30[4]
Total monom. Al	autoanalyzer with pyrocathecol violet	10 µg /l	1-14[3]
Non-labile Al	autoanalyzer after ion exchange column	10 µg /l	1-14[5]

[1] Fill the bottle so that no air remains inside
[2] Non-preserved samples
[3] Preservation with H_2SO_4 (pH <2)
[4] Preservation with H_3PO_4 or HCl (pH <2)
[5] Samples for non-labile Al must not be preserved.

Cations such as calcium and magnesium describe chemically the acid-sensitivity of lakes and serve along with other ions as quality assurance check on the methods (the sum of cations theoretically equals that of anions). A number of variables important to the biota are also included in the analyses (total P, NH_4 and silica). Fluoride and dissolved organic carbon can reduce the concentrations of toxic forms of aluminum and other metals that can be detrimental to organisms.

Temperature will be measured at the time of sampling. pH, conductivity and alkalinity should be measured as soon as possible after the arrival to the laboratory. Remaining variables may be analysed at a later date as indicated in the tables.

All water samples should have been analysed by February 15 1996. Quality control of the analyses (intercalibration, ionic balance and conductivity control) should be completed by 1 April 1996.

Table 4.2. Analytical method, preservation, detection limit (DL) and holding time for optional variables.

Variable	DL	Holding time (d)
DIC	0,5 mg/l	11)
Fe	10 µg/l	<30[2]
Mn	10 µg/l	<30[2]
SiO_2	0.1 mg/l	<30
P_{PO4}	2 µg/l	1
colour	0 mg Pt/l	1
absorbance	0.001 units	1
COD_{Mn}	-	1
turbidity		
heavy metals	0.005-0.1 µg/l	<60[3]

[1] Fill the bottle so that no air remains inside. pH and DIC have to be measured closely together in time
[2] Preservation with H_2SO_4 (pH<2)
[3] Preservation with ultrapure HNO_3 (pH <2)

5. Background data

5.1. General

Certain background information on the lakes and their catchment areas is needed for the assessment of the empirical data and the calculation of critical loads. The minimum list of required background data is given in Table 5.1.

Table 5.1. Background data needed for each site (minimum list)

Catchment
Map number
Watershed number
Area
Catchment characteristics
- area of lakes upstreams
- coniferous forest area
- deciduous forest area
- peatland area
- agricultural area
- open area
- municipalities

Point sources (categories, load)
Liming (yes, no)
Runoff (long term annual mean value)
Ecoregion
Forests: Net growth uptake of N by forests (annual mean value)
Deposition: S, NO_3, NH_4, Ca, Mg, Na, K (annual value)

Lake
Coordinates (lat-long)
Elevation
Area
Hydrologic type (drainage, seepage)
Position of lake in the watershed (0=headwater, 1 .... etc)
Point sources (categories, load)
Influence of liming (unaffected, affected by upstream liming, affected by liming of the lake)

A list of additional valuable (volontary) information is given in Table 5.2. The information on catchment characteristics should be derived from maps with the highest possible resolution.

Table 5.2. Additional background information (optional)

Catchment
Area of different soil types
Slope
Buildings
Lake
Depth
Volum Shoreline length
Fish status (and its changes)

6. Data handling and access to data base

Data handling should start no later than 15 February 1996.

The data collected in each country will first be stored in national databases. A common Nordic assessment obviously requires that a joint data base, containing the information on both water quality and catchment characteristics, is formed. The structure and format of this database will be decided when the availability and resolution of the background information for each country is known.

A complete data base for all lakes should be accessible to all participating countries by 1 May. The "minimum demand" of background information of all localities should also be available to all participants by 1 May 1996.

7. Quality assurance

7.1. General

To achieve relevant and reliable data during the Nordic lake survey it is essential that the samples are properly collected and stored prior to analysis and the laboratory work is carried out under a quality assurance programme. This chapter focuses on the main quality assurance aspects of sampling procedure and laboratory work. It is recommended,that each laboratory participating in the lake survey has implemented a quality system based on the EN 45001 and the laboratory uses systematic quality assurance procedures described in their quality manual.

Quality assurance in the lake survey study can be summarised as follows:

1) Well trained staff on all field and laboratory work and good supervision of all operations by senior scientists;
2) Well documented instructions and programmes, for all field and laboratory operations;
3) Appropriate collection, preservation, storage and transport of samples from field to a laboratory;
4) Vessels, labware and reagents of proper quality needed for sampling and analytical operations;
5) Suitable field and laboratory facilities and equipments with proper maintenance and servicing;
6) Suitable procedures for cleaning of sampling facilities and labware to prevent contamination;
7) Quality system based on the EN 45001 and described in a quality manual, which is used by all staff involved in analytical measurements;
8) Systematic quality control procedures to check the accuracy and precision of analytical measurements and documentation of the results on control charts;
9) Participation in interlaboratory comparison test to provide the laboratory`s capability to produce reliable data;
10) The review of the sample data after analyses to check possible errors prior to final documentation.

Several of the above points are dealt with in the previous section of this manual. Further comments on certain aspects are given below.

7.2. Field work

Contamination is one of the most general and serious sources of errors in collecting samples of natural waters. Therefore, avoiding contamination during sampling, transport and storage is essential. Sampling vessels and sample containers have to be cleaned and stored according to documented instructions. Reagents used in preservation have to be prepared and stored properly and be renewed when necessary.

To check contamination during field operations blank determinations are essential. These are of two kinds: 1) Bottle blanks, consisting of deionized water and reagents filled into randomly selected sampling bottles and analyzed as real samples. This kind of blank is used to test contamination originating from sample bottles. 2) Field blanks, consisting of deionized water, bottles, carried to a sampling site, processed and preserved as a routine sample and returned with the routine samples to the laboratory. This kind of sample is especially necessary for metal samples. For every batch of bottle preparation one bottle blank should be prepared and analyzed. Field blanks are recommended for 1 % of the samples.

In order to estimate overall random error for the sampling and analysis process and to check the contribution of sampling field duplicates are necessary. A field duplicate is a second sample collected by the same site immediately after the real sample is collected. It is recommended that field dublicates are taken along with 1 % of the real samples.

7.3. Analyses

Samples have to be kept refrigerated and in the dark after sampling and while not in use. When an analysis is to be performed, the sample has to be returned to the refrigerator (4°C) as soon as possible and it should remain in a refrigerator in case re-analysis is necessary.

All analyses for each determinand have to be performed within the specified time given in chapter 4 of this manual.

7.4. Interlaboratory comparison test

An interlaboratory comparison will be conducted among participating laboratories. Samples will be distributed by the Laboratory of the Finnish Environment Agency in May 1995. Samples will be distributed for analysis of at least each obligatory determinand.

The results will be reported to the participating laboratories as soon as possible after the laboratories have submitted their results (see Annex 2).

8. References

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Annex 2

Intercalibration test

by

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Before the lake survey was carried out, the laboratory of the Finnish Environment Agency conducted a comparison test among the laboratories producing data from the survey. The samples were distributed to thirteen laboratories in Finland, to one laboratory in Norway, Sweden and in the Kola Peninsula. The results are summarized in Table A2.1 and a summary of the laboratories performance is given in TableA2.2.

In the statistical treatment of the data Grubb's test was used for detecting outliers in the original data. For the evaluation of the laboratory performance, the Z-score test was used. The Z-scores for each laboratory were obtained using the equation $Z = (xi - X)/s$, where xi is the reported result, X is the mean value obtained from the laboratories and s is the standard deviation. The results are considered satisfactory, if [Z] is smaller than 2 (Table A2.2).

The data shows that several results were rejected as outliers. The number of outliers was highest (2-3 results) for conductivity, alkalinity, total phosphorus and sodium. Some laboratories have used automated systems for determination of pH and conductivity, and because of this some of them have obtained tailed values, especially for conductivity. The methods used for determination of alkalinity are slightly different in the participating countries, which can explain the higher number of outliers..

The relative standard deviations for the results were lower than generally obtained in national comparison tests (Finland). For 80 percent of the data the relative standard deviation was lower than 5 percent (Table A2.1).

The performance (Table A2.2) is in most cases lying under the target value, [Z] < 2. About 12 percent of data can be regarded to be unsatisfactory. This can be partly explained by the problems and reasons associated with the determination of conductivity and alkalinity. Generally the qualityof data was good. After the laboratories have made their corrections in routines, it can be expected that the laboratories will produce comparable data from the regional lake surveys.

Table A2.1. Summary of the results of the comparison test in May 1995.

Parameter	Sample	Theoretical conc.	Mean value	Standard deviation	Relative standard deviation, %	No. of labs[1)]
pH	A1	4.30	4.31	0.05	1.2	14/3
	AB2		4.92	0.04	0.8	17/0
	AB3		5.74	0.07	1.2	17/0
	AB4		6.25	0.08	1.3	17/0
f_{25}mS/m	A1	2.60	2.36	0.15	6.4	14/3
	B1		97.42	3.35	3.4	17/0
	AB2		2.20	0.14	6.4	14/3
	AB3		3.04	0.08	2.6	14/3
	AB4		2.94	0.12	4.1	
Alkalinty, mmol/l	C1	0.29	0.29	0.00	0	14/3
	C2		0.06	0.00	0	16/1
	C3		0.02	0.00	0	15/2
	C4		0.11	0.01	9.1	16/1

Table A2.1 continued.

Parameter	Sample	Theoretical conc.	Mean value	Standard deviation	Relative standard deviation, %	No. of labs[1]
P_{tot}, mg/l	D1	111.4	110.4	2.14	1.9	15/2
	D2		14.28	0.85	6.0	16/1
	D3		27.20	0.78	2.9	14/2
	D4		73.45	1.40	1.9	15/2
N_{NH4}, mg/l	E1	61.50	66.23	5.31	8.0	16/1
	EH2		65.19	3.54	5.4	16/1
	EH3		52.08	2.46	4.7	15/2
	EH4		27.81	3.86	13.9	17/0
$N_{NO3+NO2}$	E1	308	305.81	4.13	1.4	16/1
	EH2		100.89	1.96	1.9	15/2
	EH3		54.33	1.39	2.6	16/1
	EH4		167.99	4.84	2.9	16/1
N_{tot}, mg/l	E1	638.5	638.50	30.43	4.8	16/1
mg/l	EH2		340.76	15.42	4.5	17/0
	EH3		249.06	9.47	3.8	16/1
	EH4		429.94	22.82	53	17/0
SO_4-IC[2]	F1	2.67	2.65	0.04	1.5	6/0
mg/l	EH2		3.89	0.08	2.1	6/0
	EH3		6.75	0.14	2.1	6/0
	EH4		5.40	0.13	2.4	6/0
Cl-IC2), mg/l	F1	3.33	3.22	0.15	4.7	6/0
	EH2		4.27	0.18	4.2	6/0
	EH3		1.76	0.03	1.7	5/1
	EH4		1.14	0.05	4.4	6/0
Na, mg/l	H1	2.20	2.19	0.03	1.4	8/2
	EH2		0.99	0.02	2.0	8/2
	EH3		1.44	0.03	2.1	8/2
	EH4		1.10	0.02	1.8	9/1
K, mg/l	H1	1.20	1.17	0.03	2.6	10/0
	EH2		0.31	0.02	6.5	10/0
	EH3	0.59	0.02	3.4	10/0	
	EH4	0.73	0.03	4.1	10/0	
Ca, mg/l	H1	3.60	3.60	0.15	4.2	10/0
	EH2		0.94	0.03	3.2	10/0
	EH3		2.02	0.04	2.0	9/1
	EH4		1.33	0.03	2.3	10/0
Mg, mg/l	H1	1.10	1.10	0.02	1.8	8/2
	EH2		0.82	0.02	2.4	10/0
	EH3		0.65	0.01	1.5	10/0
	EH4		0.39	0.01	2.6	10/0
TOC, mg/l	I1	15.00	15.18	0.26	1.7	4/1
	I2		4.12	0.14	3.4	5/0
	I3		3.66	0.11	3.0	4/1
	I4		9.65	0.87	9.0	5/0
F, mg/l	61	0.40	0.39	0.02	5.1	6/0
	EH2		0.12	0.01	8.3	5/1
	EH3		0.07	0.01	14.3	4/0
	EH4		0.05	0.00	0	4/0

[1] Grubbs test: Laboratories passed/failed
[2] IC = Ion cromatographic method

Table A2.2

SUMMARY ON THE SUCCESS OF THE INTER-LABORATORY COMPARISON 2/1995

a = Result accepted
Z = Result passed Grubbs test but failed Z-score test (|z| >2)
g = Result failed Grubbs test but had to be accepted (at most 2 of 9 results may be rejected)
G = Result failed Grubbs test
- = Result missing

Parameter	Test	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	48
pH	A1	a	G	a	Z	G	a	a	a	a	a	a	a	a	a	G	a	a
pH	AB2	a	Z	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a
pH	AB3	a	a	a	a	a	a	a	a	a	a	a	a	a	a	Z	a	a
pH	AB4	a	Z	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a
Conductivit	A1	a	G	G	a	G	a	a	a	a	a	a	a	Z	a	g	a	g
Conductivit	B1	a	a	Z	a	a	a	a	a	a	a	a	a	a	a	a	a	a
Conductivit	AB2	a	G	a	G	g	a	a	a	G	a	a	a	a	a	a	a	a
Conductivit	AB3	a	G	G	a	G	a	a	a	a	a	a	a	a	a	a	a	g
Conductivit	AB4	a	G	Z	a	G	a	a	a	a	a	a	a	a	a	a	a	Z
Alkalinity	C1	a	G	a	g	a	G	a	a	a	g	a	a	a	a	G	a	a
Alkalinity	C2	a	a	Z	a	a	Z	a	a	a	a	a	a	a	a	G	a	a
Alkalinity	C3	a	a	Z	a	a	G	a	a	a	a	a	a	a	a	G	a	a
Alkalinity	C4	a	a	a	a	a	a	a	a	a	a	a	a	a	a	G	a	a
P-tot	D1	a	a	a	a	a	a	Z	a	a	a	a	Z	a	a	Z	G	G
P-tot	D2	a	a	Z	a	a	a	a	a	a	a	a	a	a	a	a	a	G
P-tot	D3	a	a	a	a	a	a	a	a	a	a	a	a	a	a	-	G	G
P-tot	D4	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	G	G
N-NH4	E1	G	a	a	a	a	a	a	a	a	a	a	Z	a	a	a	a	a
N-NH4	EH2	G	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a
N-NH4	EH3	G	a	a	G	a	a	a	a	a	a	a	a	a	a	a	a	a
N-NH4	EH4	a	a	a	Z	a	a	a	a	a	a	a	a	a	a	a	a	a
N-NO3+N	E1	a	a	a	a	a	a	a	a	a	a	a	G	a	a	a	a	a
N-NO3+N	EH2	a	a	a	a	a	a	a	a	a	a	a	G	a	a	a	a	G
N-NO3+N	EH3	a	a	a	a	a	a	a	a	a	a	a	Z	a	a	a	a	G
N-NO3+N	EH4	a	a	a	a	a	a	a	a	a	a	a	G	a	a	a	a	Z
N-tot	E1	a	a	a	a	Z	a	a	a	a	a	a	a	a	a	a	G	Z
N-tot	EH2	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	Z	a
N-tot	EH3	a	a	Z	a	a	a	a	a	a	a	a	a	a	a	a	G	a
N-tot	EH4	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	Z	a
SO4-IC	F1					a		a					a		a	a	a	
SO4-IC	EH2					a		a					a		a	a	a	
SO4-IC	EH3					a		a					a		a	a	a	
SO4-IC	EH4					a		a					a		a	a	a	
Cl-IC	F1					a		a					a		a	a	a	
Cl-IC	EH2					a		a					a		a	a	a	
Cl-IC	EH3					a		a					a		G	a	a	
Cl-IC	EH4					a		a					a		a	a	a	
Na	H1					a		a	a	a			a	a	a	G	a	G
Na	EH2					a		a	a	G			a	a	a	G	a	a
Na	EH3					a		a	a	G			a	a	a	G	a	a
Na	EH4					a		a	a	a			a	a	a	G	a	a
K	H1					a		a	a	a			a	a	a	a	Z	a
K	EH2					a		a	a	a			a	a	a	a	a	a
K	EH3					a		a	a	a			a	a	Z	a	a	a
K	EH4					a		a	a	a			a	a	a	a	Z	a
Ca	H1					a		a	a	a			a	a	a	a	a	a
Ca	EH2					a		a	a	a			a	a	a	a	a	a
Ca	EH3					a		a	a	a			a	a	a	Z	a	G
Ca	EH4					a		a	a	a			a	a	a	a	a	a
Mg	H1					a		a	a	a			a	a	a	a	G	G
Mg	EH2					a		a	a	a			a	a	a	a	Z	a
Mg	EH3					a		a	a	a			a	a	a	a	a	a
Mg	EH4					a		a	a	a			a	a	a	a	a	a
TOC	I1					G							a		a	g	a	
TOC	I2					a							a		a	a	a	
TOC	I3					a							a		G	a	a	
TOC	I4					a							a		g	a	a	
F	G1					a		a					a			g	a	a
F	EH2					a		a					a			a	a	-
F	EH3					a		a					a			-	a	-
F	EH4					a		a					a			-	a	-

Annex 3

Intercalibration of methods for the determination of alkalinity in natural water

by

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Introduction
Several methods and ways for the determination of alkalinity are used at the Nordic laboratories. The equivalence point for this titration depends on the initial concentration of alkalinity (hydrogen carbonate). In the most simple method a fixed end point is used leading to a varying systematic error. This error can be reduced or eliminated using various correction equations (Henriksen, 1982) or alternative methods. In order to evaluate possible differences an intercalibration was made in the spring of 1995. Six samples from each Finland, Norway and Sweden were analysed at the three participating laboratories.

Methods
In Finland the determination was performed as a titration curve evaluated according to the Gran plot technique and using the criteria described by Kortelainen (1995) and as a two-point titration to pH-values 4.5 and 4.2 (Standard Methods, 1985).
Norway used a titration to pH=4.5, which requires that the results have to be corrected according to the equations 1 and 2.
In Sweden the method with simultaneous removal of carbon dioxide during the titration to a fixed end-point was used (ISO 9963-2).

Results
The results of the measurements are presented in Table A3.1 and compared with values using the Gran plot in Figure A3.1. It is obvious that there is a systematic difference between the method used by Norway and the Gran method. However, Henriksen (1982) presented a method for the correction of the bias caused by the various end-point pH-values. The two equations were applied (his equations 2 and 6)

$$\text{Alk-L} = \text{ALK4.5} - 32 \quad (1)$$
$$\text{Alk-E} = \text{Alk-L} + \sqrt{0.646(\text{Alk-L})} \quad (2)$$

The results were compared using paired t-test with the results presented in Table A3.2.

Conclusions
The methods used by Finland (Henriksen 1982) and Sweden do not significantly differ. The method used by Norway as well as the alternative method used in Finland also gives results similar to those by the Gran method, provided that relevant corrections are made.

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Table A3.1.Results from intercalibration of alkalinity.

Sample	Measured value meq/l							Calculated value meq/l		
	Finland Gran	**Finland** Henriksen	**Norway**	**Sweden**	**TOC** mg/l S	**pH**	**IC mg/l** SF	**Norway** Henriksen 2	**Finland** Henriksen 2+6	**Norway** Henriksen 2+6
A	.009	-.016	.046	.022	1.2		.3	.014		.018
B	.056	.089	.092	.067	1.8		.8	.060	.063	.066
C	.010	-.017	.044	.019	1.1		.2	.012		.016
D	.020	.056	.057	.032	1.1		.4	.025	.029	.030
E	.047	.002	.075	.060	1.5		.8	.043	-.029	.049
F	.125	.135	.160	.131	3.9		1.5	.128	.111	.136
G	.151	.162	.184	.158	3.7		1.9	.152	.138	.161
S1	.052	.069	.084	.032	14.1		.6	.052	.042	.058
S2	.178	.214	.205	.171	5.1		2.3	.173	.191	.182
S3	-.001	.069	.035	.012	10.3		.5	.003	.042	.007
S4	.115	.117	.142	.115	.9		.8	.110	.092	.118
S5	.159	.162	.193	.144	13.7		1.6	.161	.138	.170
S6	.138	.142	.177	.132	10.3		1.7	.145	.118	.154
Välipuro	-.180		.000	-.174	30.8	4.10	1.9	-.032		-.032
Liuhapuro	-.041		.000	-.099	27.7	4.41	.8	-.032		-.032
Murtopuro	.026		.056	-.010	21.4	5.38	.5	.024		.029
Koivupuro	.011		.037	-.015	18.0	5.21	.8	.005		.009
Kauheanpuro	-.027		.000	-.074	23.9	4.57	1.4	-.032		-.032
Majalampi	.014		.017	.000	11.3	5.59	.9	-.015		-.012
Iso-Lähmälampi	-.015		.044	-.016	3.9	4.91	.6	.012		.016

Table A3.2. Paired t-test comparing results from different methods.

Paired t-test Hypothesized Difference = 0

	Mean Diff.	DF	t-Value	P-Value
Gran (Finland) Finland (Henriksen)	-.010	12	-1.130	.2806
Gran (Finland) Norway	-.040	19	-5.200	<.0001
Gran (Finland) Sweden	.007	19	1.485	.1540
Gran (Finland) Norway (Henriksen(2)	-.045	19	-6.037	<.0001
Gran (Finland) Norway (Henriksen 1+2)	-.013	19	-1.759	.0946

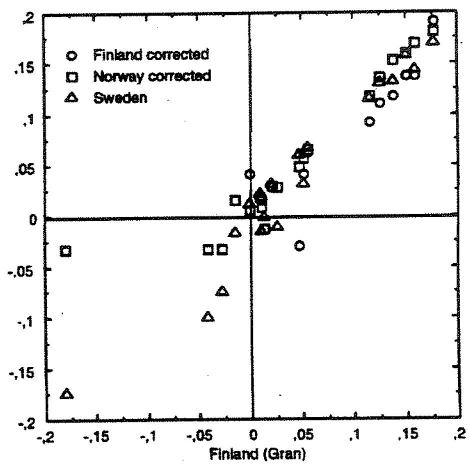

Fig. A3.1. Comparison between the Gran plot evaluation and alternative alkalinity determinations.

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