Integrated Monitoring Programme in Finland

First National Report

UN ECE CONVENTION ON LONG-RANGE TRANSBOUNDARY AIR POLLUTION
International Co-operative Programme on Integrated Monitoring of Air Pollution Effects on Ecosystems
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List of abbreviations used in the text

AC  Air Chemistry subprogramme
AL  Aerial Green Algae subprogramme
AM  Meteorology subprogramme
AR  Forest Stands subprogramme
a.s.l.  above sea level
ATP  adenosine triphosphate
BQI  Benthic Quality Index
BS_e  effective base saturation
BS_p  potential base saturation
CCA  canonical correspondence analysis
CEC_e  effective cation exchange capacity
CEC_p  potential cation exchange capacity
dbh  diameter at breast height
DC  Precipitation Chemistry subprogramme
DIC  dissolved inorganic carbon
DOC  dissolved organic carbon
EA  exchangeable titratable acidity
EA_Ai  exchangeable titratable aluminium acidity
EDC  Environment Data Centre
EI  Expert Institute
EMEP  European Monitoring and Evaluation Programme
EP  Epiphytes subprogramme
FC  filtering correction
IAP  Index of Atmospheric Purity
ICP  inductively coupled plasma emission technique
IM  Integrated Monitoring
LOI  loss on ignition
MC  Moss Chemistry subprogramme
NC  Foliage Chemistry subprogramme
NFP  National Focal Point
PSI  Pollution Sensitivity Index
qCO2  metabolic quotient
SC  Soil Chemistry subprogramme
SF  Stemflow Chemistry subprogramme
SMART  Simulation Model for Acidification’s Regional Trends
SW  Soil Water Chemistry subprogramme
TF  Throughfall Chemistry subprogramme
TOC  total organic carbon
TR  Trees subprogramme
TTA  total titratable acidity
UN ECE  United Nations Economic Commission for Europe
VG  Understorey Vegetation subprogramme
WB  Hydrobiology subprogramme
8-NFI  Eighth National Forest Inventory

The report gives a detailed description of the physicochemical and ecological status and characteristics of the four Finnish IM areas: Valkea-Kotinen (Häme), Hietajärvi (North Karelia), Pesosjärvi (Kainuu) and Vuoskojärvi (Lapland). The report describes intra- and inter-site variation, the deposition of sulphur and nitrogen and air quality in the areas. It also evaluates the present levels of lake and soil acidification and tree vitality. Hydrogen ion budgets have been calculated and the dynamic acidification model, SMART, has been calibrated to two of the IM areas. Owing to the short monitoring period, temporal trends and causal relationships in the functioning of the ecosystems have not yet been clarified. Several recommendations for developing the IM Programme are made.

Key words
Integrated monitoring, small catchments, ecosystem monitoring

Classification


Avainsanat/asiasanat
Yhdennetty seuranta, pienet valuma-alueet, ekosysteemiseuranta

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### Presentationsblad

<table>
<thead>
<tr>
<th>Utgivare</th>
<th>Miljöministeriet</th>
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<tr>
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<td>Språk</td>
<td>Engelska</td>
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<td>Offentlighet och andra villkor</td>
<td>Offentlig</td>
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<tr>
<td>Beställningar/distribution</td>
<td>Miljöministeriet, miljöpolitiska avdelningen</td>
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</tr>
</tbody>
</table>
Contents

PREFACE 11

1 INTRODUCTION 12

1.1 Background and the objectives of the Integrated Monitoring Programme
I. BERGSTROM 12

1.2 The international and national organisation of the Programme
I. BERGSTROM 13

1.3 The Manuals I. BERGSTROM 14

2 MATERIAL AND METHODS 15

2.1 Monitoring areas 15
2.1.1 Location and selection criteria for the monitoring areas I. BERGSTROM 15

2.1.2 Valkea-Kotinen 16
General features of the monitoring area
K. MAKELA
Geology and soils
H. TANSKANEN and M. STARR
Vegetation S. TUOMINEN and K. MAKELA
The lake R. NIINIOJA and L. VILLA

2.1.3 Hietajärvi 20
General features of the monitoring area
K. MAKELA and J. MUURMAN
Geology and soils
H. TANSKANEN and M. STARR
Vegetation S. TUOMINEN and K. MAKELA
The lakes R. NIINIOJA

2.1.4 Pesosjärvi 24
General features of the monitoring area
K. MAKELA and J. MUURMAN
Geology and soils
H. TANSKANEN and M. STARR
Vegetation S. TUOMINEN and K. MAKELA
The lake R. NIINIOJA and A. YLITOLONEN

2.1.5 Vuoskojärvi 28
General features of the monitoring area
K. MAKELA and J. MUURMAN
Geology and soils
H. TANSKANEN and M. STARR
Vegetation S. TUOMINEN and K. MAKELA
The lake R. NIINIOJA and O. MAHONEN

2.2 Permanent sampling plots and location of related terrestrial subprogrammes
M. STARR, A. KOKKO and K. MAKELA 32

2.3 Physicochemical monitoring 35
2.3.1 Climate observations S. SAREKKULA 35
2.3.2 Air quality and deposition T. RUHO-AIROLA 35

2.3.3 Throughfall and stemflow 35
Throughfall L. UKONMAANAHIO and M. STARR
Stemflow L. UKONMAANAHIO and M. STARR

2.3.4 Moss chemistry K. MAKELA 37

2.3.5 Soil and soil water 37
Soil chemistry M. STARR
Soil water chemistry M. STARR and L. UKONMAANAHIO

2.3.6 Catchment runoff and surface waters 39
Catchment runoff P. SELUNA and R. NIINIOJA
Water chemistry R. NIINIOJA, L. VILLA, A. YLITOLONEN and O. MAHONEN
Lake sedimentation
J. KESKITALO and K. SALONEN

2.3.7 Catchment ion mass budgets M. FORSIUS 40

2.3.8 Dynamic model application M. FORSIUS 41

2.4 Biological monitoring 41
2.4.1 Tree stand and forest condition
M. STARR, L. UKONMAANAHIO, K. TAIMI and M. HARTMAN 41

2.4.2 Needles and litterfall 42
Needle chemistry M. STARR and K. TAIMI
Litterfall chemistry M. STARR and L. UKONMAANAHIO

2.4.3 Epiphytes K. MAKELA and S. TUOMINEN 43

2.4.4 Understorey vegetation A. KOKKO, K. MAKELA and S. TUOMINEN 44

2.4.5 Soil microbiology 45
Needle litter decomposition A.-M. KURKA, P. VANHALA, M. KARSISTO and M. STARR
Cellulose decomposition A.-M. KURKA, M. STARR and M. KARSISTO
Soil respiration, ATP concentration, microbial biomass and metabolic quotient P. VANHALA

2.4.6 Hydrobiology 46
Plankton communities J. KESKITALO, K. SALONEN and A.-L. HOLEPAINEN
Benthic fauna E. KOKKINEN
Fish M. RASK and A. JARVINEN

2.4.7 Breeding birds
P. KOSKIMIES and U.-M. LIUKKO 47

2.5 Data storage and handling 48
2.5.1 International data base 48
The data network S. KLEEMOLA
Data reporting formats S. KLEEMOLA

2.5.2 National data bases S. TUOMINEN 49
3 RESULTS AND DISCUSSION 50

3.1 Climate and meteorology S. SARKKUL~O 50
3.2 Air quality T. RUOHO-AIROLA 54
3.3 Bulk deposition 54
3.3.1 Representativeness T. RUOHO-AIROLA 54
3.3.2 Yearly variation of deposition T. RUOHO-AIROLA 56
3.3.3 Deposition of heavy metals T. RUOHO-AIROLA 58
3.4 Throughfall and stemflow 59
3.4.1 Quantity of throughfall and stemflow M. STARR 59
3.4.2 Throughfall chemistry M. STARR AND L. UKONMAANAHO 60
3.4.3 Stemflow chemistry M. STARR AND L. UKONMAANAHO 61
3.4.4 Total forest deposition M. STARR AND L. UKONMAANAHO 63
3.5 Moss chemistry S. TUOMINEN AND K. MAKELA 68
3.6 Soil M. STARR AND L. UKONMAANAHO 71
3.6.1 Comparability of soil chemistry data M. STARR 71
3.6.2 Levels of soil acidity and acidification M. STARR 74
3.6.3 Trace and heavy metals M. STARR 74
3.7 Soil water M. STARR AND L. UKONMAANAHO 74
3.8 Surface waters 76
3.8.1 Water chemistry 76
Lake Valkea-Kotinen J. KESKITALO, K. SALONEN AND A.-L. HOLOPAINEN
Lakes Iso Hietajärvi J. KESKITALO, K. SALONEN AND A.-L. HOLOPAINEN
Lake Pieni Hietajärvi J. KESKITALO, K. SALONEN AND A.-L. HOLOPAINEN
Inlet of Lake Pieni Hietajärvi and outlet of Lake Iso Hietajärvi J. KESKITALO, K. SALONEN AND A.-L. HOLOPAINEN
Comparison between the lakes J. KESKITALO, K. SALONEN AND A.-L. HOLOPAINEN
3.8.2 Lake sedimentation J. KESKITALO AND K. SALONEN 83
3.9 Tree stand 84
3.9.1 Composition and structure 84
Valkea-Kotinen M. STARR
Hietajärvi M. STARR
Pesosjärvi M. STARR
Vuoskojärvi M. STARR
3.9.2 Defoliation, discoloration and fertility L. UKONMAANAHO AND M. STARR 88
3.9.3 Needle chemistry H. RAITIO, M. STARR AND L. UKONMAANAHO 89
3.9.4 Litterfall chemistry M. STARR, L. UKONMAANAHO AND H. RAITIO 92
3.10 Epiphytes S. TUOMINEN AND K. MAKELA 93
3.11 Understorey vegetation K. MAKELA AND S. TUOMINEN 97
3.12 Soil microbiology 101
3.12.1 Needle litter decomposition A.-M. KURKA, M. KARSISTO AND M. STARR 101
3.12.2 Cellulose decomposition A.-M. KURKA, M. KARSISTO AND M. STARR 101
3.12.3 Soil respiration, ATP concentration, microbial biomass and metabolic quotient P. VANHALA 102
3.13 Hydrobiology 102
3.13.1 Plankton 102
Lake Valkea-Kotinen J. KESKITALO, K. SALONEN AND A.-L. HOLOPAINEN
Lake Iso Hietajärvi J. KESKITALO, K. SALONEN AND A.-L. HOLOPAINEN
Lake Pieni Hietajärvi J. KESKITALO, K. SALONEN AND A.-L. HOLOPAINEN
Comparison between the lakes J. KESKITALO, K. SALONEN AND A.-L. HOLOPAINEN
3.13.2 Benthic fauna E. KOSENNIEMI 110
3.13.3 Fish M. RASK AND A. JÄRVINEN 111
3.14 Breeding birds 113
3.14.1 General characteristics of bird communities P. KOSKIMIES, U.-M. LIUKKO AND R. VIRKKALA 113
3.14.2 Detailed description of bird communities in the IM areas 113
Valkea-Kotinen P. KOSKIMIES, U.-M. LIUKKO AND R. VIRKKALA
Hietajärvi P. KOSKIMIES, U.-M. LIUKKO AND R. VIRKKALA
Pesosjärvi P. KOSKIMIES, U.-M. LIUKKO AND R. VIRKKALA
Vuoskojärvi P. KOSKIMIES, U.-M. LIUKKO AND R. VIRKKALA
4 GENERAL DISCUSSION
AND INTEGRATION 115

4.1 Background M. STARR AND M. FORSIUS 115

4.2 Integration of hydrogeochemical
subprogramme results 115

4.2.1 Rationale M. STARR 115

4.2.2 Input-output budgets and concentration
profiles 116

Catchment input-output budgets
M. FORSIUS

Ecosystem water quality profiles
M. STARR

4.2.3 Acid deposition and ecosystem
acidification 118

Soil and lake acidification status
M. FORSIUS AND M. STARR

Catchment hydrogen ion budgets
M. FORSIUS

Calibration of the dynamic SMART
acidification model M. FORSIUS

4.3 Discussion of the biological
subprogrammes 123

4.3.1 Components of the terrestrial
ecosystem 123

Representativeness of the monitoring
areas and permanent plots S. TUOMINEN

Forests and understorey vegetation
M. STARR AND S. TUOMINEN

Epiphytes S. TUOMINEN

Soil microbiology M. STARR

Moss chemistry S. TUOMINEN

Breeding birds R. VIRKKALA

4.3.2 Components of the aquatic ecosystem
126

Plankton J. KESKITALO AND K. SALONEN

Aquatic macrophytes J. KESKITALO

Benthic fauna E. KOSKENHEMI

Fish M. RASK

4.4 Conclusions and recommendations 127

4.4.1 General M. FORSIUS AND M. STARR 127

4.4.2 Summarized recommendations
M. FORSIUS AND M. STARR 128

5 SUMMARY 130

6 REFERENCES 131
Preface

The Integrated Monitoring (IM) Programme started in the mid-1980s as a joint Nordic cooperation programme under the Nordic Council of Ministers. From 1989 to 1991 it was run as the Pilot Programme on Integrated Monitoring by the United Nations Economic Commission of Europe (UN ECE) under the Convention on Long-Range Transboundary Air Pollution. After a favourable evaluation in 1993 IM became a permanent monitoring programme of the UN ECE: the “International Co-operative Programme on Integrated Monitoring of Air Pollution Effects on Ecosystems”. During 1987–1991, the IM Programme was implemented at the first four monitoring areas in Finland.

This report is a summary of the results obtained during the first five years of monitoring (1987–1991) in Finland when the Programme was in its Nordic and UN ECE Pilot Programme phases. Most of the IM subprogrammes have not been running for the whole of this period and some have only been running for a year. We are aware that a five-year period is too short to reveal any significant trends in our relatively unpolluted natural ecosystems. However, comparisons between the IM areas and the assessment of the design and compatibility of subprogrammes and integrability of the results are possible using the data from such a short period.

Most Finnish research institutes and universities involved in environmental research have participated in the IM Programme and several regional authorities have made considerable contributions. In particular, the authors would like to acknowledge the following: the National Board of Waters and the Environment (from 1.3.1995, the Finnish Environment Agency), the Finnish Forest and Park Service, the Finnish Forest Research Institute, the Finnish Game and Fisheries Institute, the Finnish Meteorological Institute, the Geological Survey of Finland, the Helsinki, Oulu, North Karelia, Vaasa and Lapland Water and Environment Districts (from 1.3.1995, the Uusimaa, North Ostrobothnia, North Karelia, West Finland and Lapland Regional Environment Centres), the Evo Institute of Forestry, and the Universities of Helsinki, Joensuu, Oulu and Turku and their field stations. This kind of intensive monitoring would not have been possible without permanent field staff to take care of the routine sampling and field equipment and to provide assistance to visiting specialists. The contributions of the field technicians Seppo Aikio, Ritva Koivunen, Tellervo Kuusela, Matti Lemettinen, Kari Lyytikäinen, Markku Rontti, Väinö Turpeinen and Pekka Vuori are gratefully acknowledged.

The IM Programme is one of the most intensive ecological cooperation programmes ever conducted in Finland. Hence this report has been a challenge to all the participants from various realms of science. The challenge has been to measure and evaluate ecosystems holistically. The authors and editors hope that this first comprehensive report on the Finnish IM Programme will prove that the multidisciplinary approach to the monitoring of ecosystems is worthy of implementation and further development.

The Finnish IM Programme has received a major part of its funding from the Finnish Ministry of the Environment but the participating institutes, universities and local authorities have also contributed financial support. Publication of this report was funded by the Ministry of the Environment.
1 Introduction

1.1 Background and the objectives of the Integrated Monitoring Programme

The fact that very little was known about the effects of acidifying substances and heavy metals on northern coniferous forest ecosystems was the main reason for the initiation of the joint Nordic Programme on Integrated Monitoring in the early 1980s. Such a monitoring programme was first suggested by an expert group of the Nordic Council of Ministers in the early 1980s (Nordiska Ministerrådet 1981). A more detailed plan was presented in 1984 (Nordiska Ministerrådet 1984). The main goal was to monitor air pollution effects over a Nordic network of representative ecosystems in an integrated way (Nordiska Ministerrådet 1984). The Finnish Ministry of the Environment started to implement the Nordic Integrated Monitoring Programme in 1987 (Ympäristöministeriö 1987) according to Nordic guidelines (Nordic Council of Ministers 1988).

Figure 1.1.1. Countries participating in Integrated Monitoring Programme (Canada is not shown).
In 1989, the Nordic Integrated Monitoring Programme was adopted as the Pilot Programme on Integrated Monitoring by the United Nations Economic Commission of Europe (UN ECE) and several continental European countries joined in with the Nordic countries. From 1993 the Integrated Monitoring Programme of Air Pollution Effects on Ecosystems (IM Programme) has been run as a permanent ecosystem monitoring programme under the auspices of the UN ECE. It is now one of five International Co-operative Programmes (also often called ICPs) under the Convention on Long-Range Transboundary Air Pollution. The main aim of the IM Programme is to determine the state of ecosystems/catchments and to predict their changes in a long-term perspective, with respect to regional variation and the impact of air pollutants, especially nitrogen, sulphur and ozone, including their effects on biota (Environment Data Centre 1992). By the end of 1993, 22 countries have joined the IM Programme (Fig. 1.1.1).

The Evaluation Report of the Pilot Programme phase of the IM Programme (Environment Data Centre 1992) set the following short-term objectives:

- To establish a network of IM sites, using comparable methodologies;
- To provide a comprehensive description of within-site and between-site variability;
- To evaluate relationships between atmospheric deposition of sulphur and nitrogen compounds and ecosystem responses. It will be necessary to use information from both the IM network and other long-term datasets;
- To validate existing models and provide preliminary predictions of ecosystem responses to changes in deposition of sulphur and nitrogen compounds;
- To outline future trends and make appropriate recommendations for the long-term Programme.

Two longer-term objectives are:

- To monitor the current and future states of ecosystems and provide an explanation of changes in terms of causative environmental factors in order to provide a scientific basis (e.g. critical loads) for emission controls;
- To develop and validate models for the simulation of ecosystem responses and to use them (a) in conjunction with survey data to make regional assessments, and (b) to estimate responses for actual or predicted changes in pollutant stress.

As stated above, the main aims of the IM Programme are to observe and predict the state and possible changes of the natural ecosystems. To achieve this a large number of ecological variables are monitored simultaneously in the same catchment areas (in this report also referred to as monitoring areas) using the same methods. It is supposed that, using such an approach, will enable the detection and modelling of cause-and-effect relationships in ecosystems and facilitate a more comprehensive understanding of the ecosystems studied.

In relatively unpolluted ecosystems, such as the Finnish IM areas, a five-year period is not really long enough to achieve even the short-term monitoring objectives of the IM Programme. The natural temporal and spatial variation hide small anthropogenic effects on the ecosystem. However, some predictions about the future state of the ecosystems can be made based on accurate multidisciplinary studies of the present state of the monitoring areas.

1.2 The international and national organisation of the Programme

The international organisation of the IM Programme is outlined in Figure 1.2.1. The Expert Institutes (EIs) in each country collect samples, carry out analyses, do the ion balancing and report the data to the National Focal Point (NFP). The EIs also have the primary responsibility for data quality assurance. In principle, the NFPs collect the data from the EIs, run defined models based on primary data (if possible), evaluate the national results and report statistics and conclusions to the international Environment Data Centre (EDC).
EDC is located at the Finnish National Board of Waters and the Environment, Helsinki (from 1.3.1995, the Finnish Environment Agency). The EDC collects and stores national statistics, performs data quality tests prior to storage in the database and provides access to the database. It also evaluates spatial and temporal differences on a continental scale, produces annual synoptic reports, and gives guidance to the NFPs for modelling. *The Programme Task Force* acts as the steering body of the IM Programme. It specifies the timetable for performances and reports the developments to the *Executive Body of the Working Group on Effects*, the Programme control organisation of the UN ECE.

Up until 1992, when the IM Programme was still in the Nordic and Pilot phases, the Finnish Ministry of the Environment had the national coordination responsibility for the Finnish IM Programme. Since 1992 this responsibility has been taken by the Water and Environment Research Institute of the Finnish National Board of Waters and the Environment. The NFP level has not been established in Finland due to close connections between the EIs and the EDC. The EIs and some local authorities are in charge of the relevant subprogrammes, storage of primary data, and evaluation of the data they have collected.

Co-operation between the participants of the IM Programme (the coordinator institute, the EIs, EDC and the Ministry of the Environment) is organised through a National Working Group of Integrated Monitoring.

There is a permanent field technician based in each of the four actively monitored IM areas. The technician takes care of the field equipment, collects the routine samples, delivers them to the EIs for analysis and assists the researchers in the field when necessary.

### 1.3 The Manuals

During the Nordic Programme phase (1987–1988), Nordic guidelines (Nordic Council of Ministers 1988) were used to implement Integrated Monitoring. In the UN ECE Pilot Programme phase, IM was guided by two Manuals (Environment Data Centre 1989a, 1989b). These Manuals described the subprogrammes, the sampling procedures, the variables to be measured, the analytical methods to be used and the data reporting formats. The parameters within the subprogrammes were divided into two categories: “basic” and “optional”. From February 1993, a new revised and combined version of the former UN ECE IM Manuals was adopted (Environment Data Centre 1993). The subprogrammes according to the Pilot Programme phase Manual and those in the revised version of the Manual are given in Appendix 1 for comparison.

The results presented in this report were collected on the basis of the Nordic and UN ECE Pilot Programme phases. Many of the instructions in the Manuals were very general and this has resulted in some problems in carrying out the IM Programme. Several of the subprogrammes were modified and these changes are largely reflected in the new Manual.
2 Material and methods

2.1 Monitoring areas

2.1.1 Location and selection criteria for the monitoring areas

The location of the Finnish IM areas was planned on the basis of the guiding principles laid down by the Nordiska Ministerrådet (1984). The areas recommended for the Integrated Monitoring in Finland by the expert group of the Ministry of the Environment (Ympäristöministeriö 1987) as well as the areas established to date are presented in Figure 2.1.1.1. The IM area codes are those used by the EDC.

The Musta-Kotinen and Storträsket IM areas are not yet actively being monitored but some basic mapping and inventories have been done. Some data from Musta-Kotinen catchment is presented in this report in connection with the adjacent Valka-Kotinen IM area. The Hietajärvi IM area consists of two subcatchments, the larger Iso Hietajärvi catchment and the considerably smaller Pieni Hietajärvi catchment. In this report the latter catchment is usually treated as a part of the former one, but some data are given for the subcatchments separately.

Selection of the IM areas in Finland was made on the basis of the three main Nordic IM Programme site selection criteria and other supplementary criteria were deduced from them (Ympäristöministeriö 1987). The three main site selection criteria were:

- The areas should be representative of the biogeographical province in which it lies. (Finland is responsible for the Integrated Monitoring of the northern boreal vegetation zone in particular);
- The areas had to be primarily forested and in as natural a state as possible;
- The catchment area should be distinct and unambiguous.

The supplementary criteria were as follows:

- To measure runoff, the lake in the area should have a constantly flowing outlet where a permanent dam with a calibrated outflow can be installed;
- If possible, the area should have a lake in which the inflow and outflow can be measured;

- The area may vary in size from a few tens to several hundred ha;
- The areas should be located in different parts of the country, with preference given to those parts where the need for reference areas is greatest;
- No large emission sources should exist close to the area, and no direct impact from local human activities should be allowed;
- At the commencement of monitoring, the area should be under State ownership;
- The area should have a power supply and should be reasonably accessible to facilitate observation tasks and the transport of field research equipment and samples;
- It must be possible to establish a base in the area, and
- The area should be located within a reasonable distance of a research station, so that it is possible to travel there daily.

Figure 2.1.1.1. Codes and names of Finnish Integrated Monitoring areas. Municipalities in which areas are located are mentioned in parentheses. Storträsket and Musta-Kotinen areas are not actively monitored. In the case of planned areas, province is mentioned.
These criteria were derived from the initial objectives of the Nordic Programme outlined by the Working Group of the Nordic Council of Ministers (Nordiska Ministerrådet 1981). Since the Programme became an International Co-operative Programme under the UNECE, these strict criteria have been considerably widened.

The concept of “natural state” can be interpreted in many ways. Therefore, additional criteria were used in selecting the monitoring areas:

- There should have been no clear cutting of timber in the area within a period representing the average forestry rotation period of the area;
- Any thinning operations that may have been carried out in the area should be insignificant and the area affected small;
- The forests should be representative of the region;
- Peatland in the catchment should not have been artificially drained nor large quantities of peat removed;
- There should be no human settlement or industry in the catchment area;
- There should be no agriculture within the catchment area, and
- Pesticides or fertilizers should not have been applied in the catchment area.

While the Finnish IM areas fulfil most of these criteria, no catchment was found that fulfilled all the selection criteria. These shortcomings are mentioned in the area descriptions (Chapters 2.1.2–2.1.5).

Many of the biological and chemical IM subprogrammes are carried out on permanent plots (Tables 2.2.1–2.2.4) within the IM areas. In the text, the permanent plots are referred to by the name of the IM area and plot number (e.g. Valkea-Kotinen Plot 1) but by the IM area code and plot number in the Tables and Figures and sometimes in the text (e.g. FI01_01). In 1990, the permanent plots and associated subprogrammes were reorganised and some new plots established. These changes are described in Chapter 2.2.

### 2.1.2 Valkea-Kotinen

**General features of the monitoring area**

The Valkea-Kotinen catchment is the smallest of the Finnish IM areas, being only about 30 ha. It contains a small headwater lake, Valkea-Kotinen. Upland forests cover about 66% and peatlands 21% of the total area (Fig. 2.1.2.1). The forests are mainly old virgin forests with several canopy layers. The area has a lot of dead standing trees and fallen decaying logs.

The dominant trees are 80–150-year-old Norway spruce (*Picea abies*), Old birch (*Betula spp.*), aspen (*Populus tremula*) and Scots pine (*Pinus sylvestris*) occur among the spruce. The oldest emergent trees are Scots pines over 350 years old. Traces of forest fires can be seen on old tree trunks. Forest fires occurred every 25–30 years in the late 18th and the 19th centuries. The fires usually affected only a small part of the catchment. On the west side of the lake, some of the broad-leaved trees have been felled by beavers. The southern part of the catchment has been subject to forest management, and most of the trees in that section are only 40–50 years old.

The Valkea-Kotinen catchment was protected as a part of Kotinen State Forest Reserve in 1955 by the National Board of Forestry (later the Finnish Forest and Park Service). The protected area was enlarged in 1987, and at the beginning of 1994 the area was made a nature reserve as a part of the protection scheme for primeval forests in Finland.

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**Figure 2.1.2.1. Areas (ha) of biotopes in Valkea-Kotinen Integrated Monitoring area.**

---

The water divide of the catchment is well defined. At some unknown time in the past, the outlet from the lake was clearly modified by digging and the outflow is now more accentuated and confined to the present channel. This modification lowered the water level of the lake and accounts for the observed drainage effect on the peatland vegetation (Vegetation and Fig. 2.1.2.7). There are no inlets to the lake.
Figure 2.1.2.2. Location of permanent plots for different subprogrammes in Valkea-Kotinen Integrated Monitoring area.

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The first IM activities were started in 1987 and have since expanded to include most of the IM subprogrammes (Fig. 2.1.2.2). Due to the thin cover of glacial till, the area lacks suitable sites for groundwater wells. Some leakage from the outflow weir has been observed, but it does not significantly affect the outflow measurements. In 1987–1991 three extra studies were conducted as a result of national interest in Finland: a detailed vegetation mapping, a fish community study and a census of breeding bird fauna. Intensive hydrobiological studies were started in April 1990.

**Geology and soils**

The bedrock at the Valkea-Kotinen catchment (Fig. 2.1.2.3) is part of an old peneplane. The dominant bedrock type is 1.9 billion-year-old mica gneiss which had originally been clay and sand sediments. These sediments were then thoroughly metamorphosed so that their original structures are no longer apparent. The strike of the bedrock is approximately south-north and the dip is to the west, varying 30–80°.

The direction of ice movement during the last Ice Age was 340°. The area is supra-aquatic, i.e. above the highest shoreline of the former stages of the Baltic. The highest coastline of the postglacial Yoldia Sea in the area is about 139 m above sea level (a.s.l.). The area is covered with a 1–3 m-thick silty till (Fig. 2.1.2.4).

Histosols (peat) account about a fifth of the land area of the catchment and are located mainly around the lake. Most of the non-organic soil in the catchment may be classified as dystric cambisols with transitions to podzols, particularly on the upper slopes.

---

**Figure 2.1.2.3. Bedrock of Valkea-Kotinen and Musta-Kotinen Integrated Monitoring areas.** Mapped area does not exactly correspond to catchment borders.

**Figure 2.1.2.4. Surficial deposits of Valkea-Kotinen and Musta-Kotinen Integrated Monitoring areas.** Mapped area does not exactly correspond to catchment borders.
Vegetation

The dominant forest vegetation site types (see Hämet-Ahti 1989, for forest site types) are mesic and rich heaths (Figs. 2.1.2.5 and 2.1.2.6). Both site types are relatively rich in nutrients. The lake is surrounded by a narrow zone of dwarf shrub pine bog, which turns into a treeless fen area to the south of the lake. Beyond the zone of dwarf shrub pine bog, a thin strip of thin-peated spruce heath forest occurs on the east side of the lake. A somewhat more extensive area of peat resembling Vaccinium myrtillus drained peatland forests occurs on the west side of the lake (see Eurola et al. 1984, for mire types).

Figure 2.1.2.5. Areas (ha) of forest site types in Valkea-Kotinen Integrated Monitoring area.

Figure 2.1.2.6. Vegetation of Valkea-Kotinen Integrated Monitoring area.

Figure 2.1.2.7. Areas (ha) of mire types in Valkea-Kotinen Integrated Monitoring area.
The lake

Lake Valkea-Kotinen is a small, humic and acidic headwater lake. It is quite shallow and is usually frozen over between November and May, or for about 170 days of the year (Fig. 2.1.2.8 and Table 2.1.2.1). The acid-neutralizing capacity of the lake water is low. The annual primary production is relatively high, despite the shallow (2 m) epilimnion. The lake is thermally stratified in both summer and winter. At the end of the stratification periods, the entire hypolimnion becomes anaerobic. There is no runoff in very dry summers.

Figure 2.1.2.8. Bathymetric map of Lake Valkea-Kotinen.

| Table 2.1.2.1. Characteristics of Lake Valkea-Kotinen. |
|-----------------|----------|
| Elevation a.s.l., m | 156 |
| Catchment area, ha | 30 |
| Ice period, d | 170 |
| Water surface area, ha | 3.6 |
| Maximum depth, m | 6.5 |
| Mean depth, m | ca. 3.0 |
| Volume, 10^6 m^3 | 0.077 |
| Runoff, Mq 1991, l s^-1 km^-2 | 5.9 |
| pH | 5.3 |
| Gran alkalinity, eq m^-3 | 0.00 |
| Water colour, mg Pt |- | |
| Yearly primary production, g C m^-2 | 34.5 |


2.1.3 Hietajärvi

General features of the monitoring area

The Hietajärvi IM area is about 464 ha (Fig. 2.1.3.1). It consists of two catchment areas with lakes. In this report, the catchment of Pieni Hietajärvi is considered to be part of the main catchment, Iso Hietajärvi, but some results are presented separately. The forests are mainly mature or old, but the northern and eastern parts have young cultivated forest stands. The last major forest fires occurred 130–140 years ago. Up until the beginning of the 20th century, small-scale slash-and-burn clearing and tar-burning was carried out by local peasants. The IM area is a part of Patvinsuo National Park, which was established in 1982.

The relief of the Hietajärvi area is rather low (49 m). Some parts of the northeastern catchment area have been particularly difficult to define. Discharge is monitored at two weirs, one measuring the inflow to Pieni Hietajärvi and the other the outflow from Iso Hietajärvi (Fig. 2.1.3.2). A small brook connects the two lakes.

The first bulk precipitation and lake water samples were collected in 1987. Most of the other IM subprogrammes (Fig. 2.1.3.2) started during the next two years. The groundwater tubes were installed in spring 1993, and intensive hydrobiological studies were conducted during 1990–1991.

Figure 2.1.3.1. Areas (ha) of biotopes in Hietajärvi Integrated Monitoring area.
Precipitation Chemistry (DC) subprogramme
Runoff Water Chemistry (RW) and Hydrobiology (WB; only plankton sampling) subprogrammes at measuring weir.
Runoff Water Chemistry (RW) and Hydrobiology (WB; only plankton sampling) subprogrammes in the lake.
Runoff Water Chemistry (RW) and Hydrobiology (WB; plankton and macrobenthos sampling) subprogrammes in the lake.

Terrestrial permanent plot and number (n). See Table 2.2.2 for list of subprogrammes carried out.
Epiphytes (EP) subprogramme (i.e. lichen sample plot, sample trees are just outside the permanent plot).
Cellulose decomposition measurements. Plot number (n) is indicated.
Catchment border.

Figure 2.1.3.2. Location of permanent plots for different subprogrammes in Hietajärvi Integrated Monitoring area.
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Geology and soils

The bedrock in the Hietajärvi area is only rarely exposed. Hence the bedrock information is based on outcrops that occur along roads in the vicinity, and no bedrock map of the IM area is included here. The dominant rock types are granitoids. Porphyritic granodiorites appear to dominate large areas. The basement of the area is formed of 2 500-million-year-old Archean acidic granitoids. Weathered bedrock (mostly porphyritic types) is observed in a few places.

The Hietajärvi area is supraaquatic. However, during the period when the ice was retreating, the meltwater washed the uppermost layers of loose till, removing the finer material. Some small eskers and esker-like remnants of glaciofluvial deposits occur in the eastern half of the catchment (Fig. 2.1.3.3). Over a third of the area is covered by fibric histosols, with the remaining area being mainly divided between haplic and ferric podzols. Gleyic properties, indicating a shallow fluctuating water table, are quite widespread and give rise to gleyic podzols and gleysols in a few places.

Vegetation

The Hietajärvi area lies in a transition belt between two vegetation zones. In terms of geobotanical zonation (Ahti et al. 1968) it lies in the boundary between the middle boreal and southern boreal zones. In terms of forest vegetation zonation (Kalela 1961), it lies between the zones of southern Finland and southern Ostrobothnia–Kainuu and, according to mire vegetation zonation, between the eccentric bogs and *Sphagnum fuscum* bogs of North Karelia and southern aapa mires (Ruuhiäärvi 1983, Eurola et al. 1984).

The most common forest site types (see Hämet-Ahti 1989, for forest site types) are submesic heaths (Figs. 2.1.3.4 and 2.1.3.5).
Scots pine is the dominant tree species. Norway spruce, birch and aspen occur among the pine. The peatlands are in a natural condition. The larger expanses of mire display features of both main mire complex types, aapa mires and raised bogs. The central parts of the large mire areas are nearly ombrotrophic, but the typical physiognomy of raised bogs has not yet developed. This kind of transitional mire vegetation is common in North Karelia. Ombro-oligotrophic short sedge pine fens and pine fens with flarks, as well as treeless, ombro-oligotrophic short sedge fens and flark fens are typical of large mire areas. *Sphagnum fuscum* bogs are also common (Figs. 2.1.3.5 and 2.1.3.6).

The lakes

Two lakes, Iso Hietajärvi (Fig. 2.1.3.7) and Pieni Hietajärvi, and a number of small ponds are located in the Hietajärvi IM area. The ice period in the region usually lasts about 175 days (Kuusisto 1986, means of 1950–1971). Both IM lakes are quite shallow, the mean depth being only about 3.5 m (Table 2.1.3.1).

The water of Pieni Hietajärvi is humic, whereas that of Iso Hietajärvi is clear. Both lakes have rather low alkalinity (Table 2.1.3.1). During the stratified period, an oxygen shortage has been observed near the lake bottom. The lakes are oligotrophic.

---

**Table 2.1.3.1. Characteristics of Lakes Iso Hietajärvi and Pieni Hietajärvi.**

<table>
<thead>
<tr>
<th></th>
<th>Iso Hietajärvi</th>
<th>Pieni Hietajärvi</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elevation a.s.l., m</td>
<td>165</td>
<td>165</td>
</tr>
<tr>
<td>Catchment area, ha</td>
<td>464</td>
<td>76</td>
</tr>
<tr>
<td>Ice period, d</td>
<td>175</td>
<td>175</td>
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<tr>
<td>Water surface area, ha</td>
<td>83</td>
<td>2.4</td>
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<tr>
<td>Maximum depth, m</td>
<td>8.8</td>
<td>7.0</td>
</tr>
<tr>
<td>Mean depth, m</td>
<td>3.6</td>
<td>3.5</td>
</tr>
<tr>
<td>Volume, 10⁶ m³</td>
<td>2.9</td>
<td>0.086</td>
</tr>
<tr>
<td>Runoff, MQ 1991, 1 s⁻¹ km⁻²</td>
<td>13.2</td>
<td>8.4</td>
</tr>
<tr>
<td>pH</td>
<td>6.6</td>
<td>5.9</td>
</tr>
<tr>
<td>Gran alkalinity, eq m⁻³ ²</td>
<td>0.07</td>
<td>0.09</td>
</tr>
<tr>
<td>Water colour, mg Pt ¹ ²</td>
<td>15</td>
<td>72</td>
</tr>
<tr>
<td>Yearly primary production, g C m⁻² ³</td>
<td>15</td>
<td>14</td>
</tr>
</tbody>
</table>

¹ Kuusisto (1986).
² Epilimnion, growing season averages 1990.
³ Mean of the years 1990–1991.
2.1.4 Pesosjärvi

General features of the monitoring area

The total area of the Pesosjärvi IM area is about 630 ha, making it the largest of the Finnish IM areas (Fig. 2.1.4.1). It is long and narrow in shape. In addition to Lake Pesosjärvi, there are several smaller lakes, ponds, and brooklets in the area. The total water area is about 9% of the entire catchment. Due to the large size of the area, the catchment has been divided into two areas with most of the IM activities concentrated in the eastern part (Fig. 2.1.4.2).

The Pesosjärvi IM area is part of the Kitkanniemi area which was incorporated into Oulanka National Park in 1989. The IM area is largely undisturbed except for the northwestern corner of the catchment, which was clear cut at the end of the 1980s.

The forests are mainly mature or old, and the tree trunks display signs of forest fires that occurred at the turn of this century. Along the banks of brooklets there are meadows which have been harvested in the past for cattle feed.

Geology and soils

The Pesosjärvi IM area is situated in a contact zone with quartzites (Rukatunturi quartzite formation) and basic volcanics (Greenstone formation III; Silvennoinen 1972). Arkosic and sericite quartzites dominate the northeastern half of the catchment, and massive basaltic lavas with thin tuff interlayers dominate in the southwestern half (Fig. 2.1.4.3). In the contact zone, carbonate minerals occur regularly, both in volcanics and in quartzites, especially in the bottom part. The Pesosjärvi catchment follows the above-mentioned contact zone which, due to the presence of carbonate-rich rock types with low abrasion resistance, is eroded deeper than the surrounding area. Consequently the glacial till of the overburden is more calcareous than normal. The strike of the bedrock in the area is roughly from northwest to southeast. The dip of the schistosity is generally 40–70° to the southwest.

The ice flow direction during the last Ice Age was approximately from northwest to

---

Figure 2.1.4.1. Areas (ha) of biotopes in Pesosjärvi Integrated Monitoring area.

Figure 2.1.4.3. Bedrock of Pesosjärvi Integrated Monitoring area. Mapped area does not exactly correspond to catchment borders.
Figure 2.1.4.2. Location of permanent plots for different subprogrammes in Pesosjärvi Integrated Monitoring area.

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southeast. The bedrock is covered by till deposits (Fig. 2.1.4.4). The area is supra-aquatic and little washing of the till has taken place. Weathered bedrock can probably be found in the distal slopes of the hills and in valleys.

The soil types in the Pesosjärvi area have not yet been studied in any detail, but peatlands cover about 123 ha (Fig. 2.1.4.1), histosols can be assumed to account for about a fifth of the soils in the area. All of the permanent plots on mineral soil have been classified as podzols (Table 2.2.3), and most of the nonorganic soils in the area are also expected to be podzols.

**Vegetation**

Like the vegetation in Kuusamo area in general, the vegetation of the Pesosjärvi IM area is diverse and rich. This is due to the presence of calcareous material in the till covering the catchment. There are about 60 different vegetation site types, and most are mires (see Eurola et al. 1984, for mire types). The number of plant species, including some classified as threatened, is very high (Pohjois-Pohjanmaan seutukaavalilitto 1990, Keränen 1993, Keränen & Kokko 1993).

In terms of geobotanical zonation (Ahti et al. 1968), the area belongs to the slightly oceanic subzone of the northern boreal zone. The forest vegetation consists of coniferous forest typical of northern Ostrobothnia. According to the classification of mire vegetation zones, the area lies in the main aapa mire zone (Ruuhiäärvi 1983, Eurola et al. 1984).

The dominant forests are mesic heath forests (Figs. 2.1.4.5 and 2.1.4.6). Several small stands of rich heaths and herb-grass forests also occur in the catchment (see Hämet-Ahti 1989, for forest site types).

Rich mire vegetation is typically concentrated in the valleys along brooksides and around ponds. Poorer mire vegetation occurs especially on the mire margins and on the upper parts of the hills. Spruce mires and thin-peated forests appear as narrow belts in the depressions of hill slopes. Pine mires and bogs occur in the mire areas on hill slopes and in mire margins. Carex globularis pine mires are typical of the Pesosjärvi area. Rich combination types, birch-spruce mires with rich fen features and rich pine fens are also very common. There are many springs and seepage areas in the Pesosjärvi area and most are meso-eutrophic. Their influence on the mire types is apparent. Local variants, e.g. Carex lasiocarpa-Scorpidium flark fens, have been described for these mire types.
Figure 2.1.4.6. Vegetation of Pesosjärvi Integrated Monitoring area. General distribution of mineral soils and peatlands (top) and a detailed vegetation map of southeastern part of the catchment (bottom).
2.1.5 Vuoskojärvi

General features of the monitoring area

The Vuoskojärvi IM area comprises 178 ha, of which Lake Vuoskojärvi covers about 8%. After the water divide had been rechecked in 1992, the area of the catchment was reduced by about 20 ha in the northern part of the area (i.e. from 192 ha to 178 ha). However, in this report the areas of different biotopes are measured according to the old boundary (Figs. 2.1.5.1 and 2.1.5.4). The new boundary is presented in Figure 2.1.5.2.

The Vuoskojärvi IM area has the greatest range in relief of any of the four Finnish IM areas, being 105 m. Subalpine birch forests dominate on the mineral soils. In 1964–1965 the geometrid moth *Epirrita autumnata* (Lepidoptera, Geometridae) caused damage and defoliated large areas of birch forest in the vicinity (Kallio & Lehtonen 1973). Damaged mountain birch (*Betula pubescens* ssp. *tortuosa*) forests cover about 7 ha of the Vuoskojärvi catchment. There are also stands of Scots pine forests in the area, which may be regarded as disjunct fragments of the coniferous zone (Hämet-Ahti 1963). The IM area is situated in the northern part of the Kevo Strict Nature Reserve which was incorporated into the original Kevo Reserve in 1982.

Table 2.1.4.1. Characteristics of Lake Pesosjärvi.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elevation a.s.l., m</td>
<td>256</td>
</tr>
<tr>
<td>Catchment area, ha</td>
<td>628</td>
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<tr>
<td>Ice period, d</td>
<td>197</td>
</tr>
<tr>
<td>Water surface area, ha</td>
<td>44</td>
</tr>
<tr>
<td>Maximum depth, m</td>
<td>12.8</td>
</tr>
<tr>
<td>Mean depth, m</td>
<td>4.7</td>
</tr>
<tr>
<td>Volume, 10⁶ m³</td>
<td>2.08</td>
</tr>
<tr>
<td>Runoff, MQ 1992, l s⁻¹ km⁻²</td>
<td>13.2</td>
</tr>
<tr>
<td>pH</td>
<td>7.3</td>
</tr>
<tr>
<td>Gran alkalinity, eq m⁻³</td>
<td>0.44</td>
</tr>
<tr>
<td>Water colour, mg Pt⁻¹</td>
<td>56</td>
</tr>
<tr>
<td>Yearly primary production, g C m⁻²</td>
<td>22</td>
</tr>
</tbody>
</table>

1 Kuusisto (1986).
2 Mean of June-December.
3 Epiilnimmon, growing season averages 1990.
4 Year 1992.

Vuoskojärvi is a headwater lake which discharges to the south. Discharge from the lake is not, however, confined only to the channel where the weir is located (Fig. 2.1.5.2). Part of the discharge leaves as surface...
Precipitation Chemistry (DC) subprogramme
- Runoff Water Chemistry (RW) subprogramme at measuring weir.
- Runoff Water Chemistry (RW) and Hydrobiology (WB; only macrobenthos sampling) subprogrammes in the lake.
- Terrestrial permanent plot and number (n). See Table 2.2.4 for list of subprogrammes carried out.

Epiphytes (EP) subprogramme (i.e. lichen sample plot, sample trees are just outside the permanent plot).

Cellulose decomposition measurements. Plot number (n) is indicated.

Catchment border.

Figure 2.1.5.2. Location of permanent plots for different subprogrammes in Vuoskojärvi Integrated Monitoring area.

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and shallow subsurface runoff through the surrounding undergrowth and flat stony area surrounding the channel. This discharge is not registered by the automatic recording station at the weir, and therefore the outflow from the catchment is greater than reported. Moreover, ice formation at the weir during the harsh winter months often prevents the measurement of outflow.

The first monitoring activity, i.e. physico-chemical lake water sampling, started in 1988 and most of the other IM subprogrammes soon thereafter (Fig. 2.1.5.2).

**Geology and soils**

The topographic and geophysical maps indicate that the Vuoskojärvi catchment is situated in a strong south-north fracture zone approximately parallel to the Teno River canyon. The Vuoskojärvi IM area is situated in a contact zone between granulite and granitic

![Geological map of Vuoskojärvi IM area](image1)

![Vegetation map of Vuoskojärvi IM area](image2)
gneiss, which is typical of the eastern boundary of the granulite belt in the region. The main bedrock types are gneisses and amphibolites which usually contain small amounts of sulphide minerals (Fig. 2.1.5.3). The strike of the bedrock is roughly south-north and the dip runs at 40–50° to the east.

During the last Ice Age, the main ice flow direction was roughly south-north. The continental ice withdrew from the area about 10 000 years ago and left behind till deposits in the valleys. The hilltops generally lack a cover of loose material except for scattered block fields. The area is supraaquatic.

No inventory of the soils in Vuoskojärvi has yet been made, but given the area of peatland in the catchment (Fig. 2.1.5.1), histosols can be expected to account for about 13% of the soils. Most of the remaining soils can be expected to be podzols. Lithic leptosols are also anticipated. A discontinuous hard iron pan layer in the top of the enriched B (podzol) horizon occurs in the area of mountain birch southeast of the lake.

Vegetation

In terms of geobotanical zonation (Ahti et al. 1968), Vuoskojärvi is situated in the northern boundary of the northern boreal zone. The forest vegetation belongs to the continental subzone of the subalpine mountain birch zone (Hämälä-Ahti 1963, Ahti et al. 1968). The mire vegetation belongs to the palus mire zone (Ruuhijärvi 1983, Eurola et al. 1984).

Subalpine birch forests dominate on mineral soils (Figs. 2.1.5.4 and 2.1.5.5). Mountain birch accounts for almost all of the tree and shrub layers. Lichens and Pleurozium schreberi dominate in the bottom layer. Empetrum hermaphroditum and, on mesic sites, also Vaccinium myrtillus dominate in the field layer. Pine forests classified as “Lichen woodland rich in mosses” and “Lichen woodland poor in mosses” (Hämälä-Ahti 1963) occur especially in the southern part of the catchment. Orohemiartctic heaths dominated by dwarf shrubs and lichens are found on the upper slopes of the catchment.

The boundary between mineral soils and peatlands is not very clear. The vegetation characteristically forms a mosaic of paludified heaths and mire vegetation. The peat layer is usually thin, with a broad influence of groundwater and surface water. The nutrient status of the mire vegetation varies from oligotrophic to eutrophic. Typical mire types are Betula nana pine mires and rich pine fens. Other combination types of mire vegetation are also common (Fig. 2.1.5.5).

### Table 2.1.5.1. Characteristics of Lake Vuoskojärvi.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elevation a.s.l., m</td>
<td>145</td>
</tr>
<tr>
<td>Catchment area, ha</td>
<td>178</td>
</tr>
<tr>
<td>Ice period, d</td>
<td>218</td>
</tr>
<tr>
<td>Water surface area, ha</td>
<td>17</td>
</tr>
<tr>
<td>Maximum depth, m</td>
<td>6.6</td>
</tr>
<tr>
<td>Mean depth, m</td>
<td>3.0</td>
</tr>
<tr>
<td>Volume, $10^6$ m$^3$</td>
<td>0.51</td>
</tr>
<tr>
<td>Runoff, MO 1991, l s$^{-1}$ km$^{-2}$</td>
<td>2.9</td>
</tr>
<tr>
<td>pH</td>
<td>6.9</td>
</tr>
<tr>
<td>Gran alkalinity, eq m$^{-3}$</td>
<td>ca. 0.15</td>
</tr>
<tr>
<td>Water colour, mg Pt l$^{-1}$</td>
<td>10</td>
</tr>
<tr>
<td>Yearly primary production, g C m$^2$</td>
<td>-</td>
</tr>
</tbody>
</table>

1 Kuusisto (1986)
3 Epilimnion, growing season averages 1990.

### The lake

Lake Vuoskojärvi is a clearwater lake, where light penetrates to the bottom. The ice period in the region normally lasts over seven months (from late October to the beginning of June) a year (Kuusisto 1986, means of 1950–1971). Since the lake is quite shallow (Table 2.1.5.1, Fig. 2.1.5.6) and the ice period long, oxygen depletion occurs in the winter. The lake is not thermally stratified. The acid-neutralizing capacity is relatively high.

![Figure 2.1.5.6. Bathymetric map of Lake Vuoskojärvi.](image)
2.2 Permanent sampling plots and location of related terrestrial subprogrammes

In 1987–1989, the Finnish Forest Research Institute established 4–7 permanent plots in each of the four IM catchments (Starr & Ukonmaanaho 1992). These permanent plots are located in stands representative of the main forest types and, if possible, also at high and low elevations in each catchment. Each plot is as homogeneous as possible regarding the soil, ground vegetation and tree stand, and the site is as level as possible. Where the site was not large enough to establish the 40 x 40-m plot, the plot was made as large as possible.

At first, both the Trees (TR) and Soil Chemistry (SC) subprogrammes were carried out on these plots, as was allowed according to IM guidelines at that time (Nordic Council of Ministers 1988). The defoliation and discoloration parts of the Forest Stands (AR) subprogramme were also carried out on these plots, and the Soil Water Chemistry (SW), Throughfall (TF) and Stemflow (SF) subprogrammes were established around some plots. In 1988–1989, the Understorey Vegetation (VG) subprogramme was also carried out on most of the plots. However, in 1990 it was decided that the VG subprogramme would be carried out only on 2–3 of the plots in each catchment (i.e. those plots most representative of the main vegetation type(s) and where the SW, TF, SF, Foliage Chemistry (NC), Litterfall (LF), AR (defoliation and discoloration only), and Epiphytes (EP) subprogrammes were being carried out). Furthermore, due to the disturbance to vegetation caused by soil sampling, it was decided that the SC subprogramme should no longer be carried out on the plots set aside for the VG subprogramme and new soil chemistry plots were established nearby instead.

The pairs of plots thus formed, a vegetation plot and an adjacent soil chemistry plot, are referred to as intensive plot pairs. In some cases, completely new pairs of intensive plots have been established and some of the original plots have been discontinued altogether. The SC, AR (defoliation and discoloration only) and NC subprogrammes and a reduced TR subprogramme are still being carried out on those remaining plots not designated as intensive. Subsequent additional soil water sampling and litterfall sampling has been diverted to the new soil chemistry plots of the intensive plot pairs.

A description of all the plots and a list of the subprogrammes being carried out on them is given in Tables 2.2.1–2.2.4. The sampling design and layout of the subprogrammes on and around the plots is shown in Figure 2.2.1.

![Diagram of subprogrammes](image)

*Sample plot for understorey vegetation (VG) monitoring*

*Sample trees for forest condition (AR) monitoring*

*Sample trees for foliage chemistry (NC) monitoring*

**Figure 2.2.1. Subprogrammes (abbreviations in parentheses; for complete subprogramme title, see Appendix 1).**
Table 2.2.1. Characteristics of intensively monitored permanent plots in Valkea-Kotinen.
Plots 3 & 10 and 8 & 11 are intensive plot pairs (Chapter 2.2).

<table>
<thead>
<tr>
<th>Plot No.</th>
<th>Subprogramme</th>
<th>Date of establishment</th>
<th>Plot size m x m</th>
<th>Elevation m a.s.l.</th>
<th>Site type</th>
<th>Stand Dominant/non-domin. spec.</th>
<th>Soil Group &amp; Unit</th>
<th>Parent material</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>SC, AR⁶, TR, NC</td>
<td>10/87</td>
<td>40 x 30</td>
<td>156</td>
<td>KR</td>
<td>P / S</td>
<td>Fibric Histosol</td>
<td>Organic (peat)</td>
</tr>
<tr>
<td>02</td>
<td>TF, SF, SC, AR⁶, TR, NC</td>
<td>10/87</td>
<td>40 x 40</td>
<td>156</td>
<td>Mtkg</td>
<td>S / P, B</td>
<td>Terric Histosol</td>
<td>Organic (peat)</td>
</tr>
<tr>
<td>03</td>
<td>TF, SF, (SC), SW, AR⁶, TR, VG, NC</td>
<td>10/87</td>
<td>30 x 40</td>
<td>161</td>
<td>OMT</td>
<td>S, B / P</td>
<td>Dystric Cambisol</td>
<td>Glacial (till)</td>
</tr>
<tr>
<td>04</td>
<td>SC, AR⁶, TR, (VG), NC</td>
<td>10/87</td>
<td>30 x 30</td>
<td>157</td>
<td>MT</td>
<td>S / B, P</td>
<td>Dystric Cambisol</td>
<td>Glacial (till)</td>
</tr>
<tr>
<td>05</td>
<td>SC, AR⁶, TR, NC</td>
<td>10/87</td>
<td>25 x 35</td>
<td>172</td>
<td>MT</td>
<td>S / P, B</td>
<td>Dystric Cambisol</td>
<td>Glacial (till)</td>
</tr>
<tr>
<td>07</td>
<td>SC, SW, AR⁶, TR, (VG), NC</td>
<td>10/87</td>
<td>25 x 35</td>
<td>162</td>
<td>MT</td>
<td>S / B, A</td>
<td>Dystric Cambisol</td>
<td>Glacial (till)</td>
</tr>
</tbody>
</table>

1 Plots 5 and 6 have been discontinued. Plot 9 is an intensive lichen plot.
2 For abbreviations of the subprogrammes, see Appendix 1. Subprogrammes in parenthesis have been discontinued.
3 See Eurola et al. (1984) for peatland types and Cajander (1926 and 1949) for mineral soil sites types; KR = Spruce-pine mire, Mtkg = Vaccinium myrtillus drained peatland forest, OMT = Oxalis-Myrtillus type, MT = Myrtillus type.
4 P = Scots pine (Pinus sylvestris), S = Norway spruce (Picea abies), B = Birch (Betula spp.), A = Aspen (Populus tremula), AL = Grey alder (Alnus incana), L = Lime (Tilia cordata).
5 FAO.
6 Defoliation and discoloration on permanent plots.

Table 2.2.2. Characteristics of intensively monitored permanent plots in Hietajärvi.
Plots 1 & 9, 4 & 10 and 7 & 8 are intensive plot pairs (Chapter 2.2).

<table>
<thead>
<tr>
<th>Plot No.</th>
<th>Subprogramme</th>
<th>Date of establishment</th>
<th>Plot size m x m</th>
<th>Elevation m a.s.l.</th>
<th>Site type</th>
<th>Stand Dominant/non-domin. spec.</th>
<th>Soil Group &amp; Unit</th>
<th>Parent material</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>TF, SF, (SC), SW, AR⁶, TR, VG, NC</td>
<td>8/88</td>
<td>40 x 40</td>
<td>168</td>
<td>EVT</td>
<td>P / B, S</td>
<td>Haplic Podzol</td>
<td>Glaciofluvial (sorted)</td>
</tr>
<tr>
<td>02</td>
<td>SC, AR⁶, TR, NC</td>
<td>8/88</td>
<td>40 x 30</td>
<td>211</td>
<td>VMT</td>
<td>P / -</td>
<td>Haplic Podzol</td>
<td>Glacial (till)</td>
</tr>
<tr>
<td>04</td>
<td>TF, SF, (SC), SW, AR⁶, TR, VG, NC</td>
<td>8/88</td>
<td>40 x 40</td>
<td>167</td>
<td>EVT</td>
<td>P / B</td>
<td>Haplic Podzol</td>
<td>Glaciofluvial (sorted)</td>
</tr>
<tr>
<td>05</td>
<td>SC, AR⁶, TR, NC</td>
<td>8/88</td>
<td>30 x 40</td>
<td>168</td>
<td>EVT</td>
<td>P / B</td>
<td>Haplic Podzol</td>
<td>Glaciofluvial (sorted)</td>
</tr>
<tr>
<td>07</td>
<td>TR, VG, NC</td>
<td>6/91</td>
<td>30 x 30</td>
<td>167</td>
<td>TR</td>
<td>P / -</td>
<td>Fibric Histosol</td>
<td>Organic (peat)</td>
</tr>
<tr>
<td>08</td>
<td>SC, TR</td>
<td>6/91</td>
<td>30 x 30</td>
<td>167</td>
<td>TR</td>
<td>P / -</td>
<td>Fibric Histosol</td>
<td>Organic (peat)</td>
</tr>
<tr>
<td>09</td>
<td>SC, SW, AR⁶, TR, LF</td>
<td>6/91</td>
<td>40 x 40</td>
<td>168</td>
<td>EVT</td>
<td>P / B</td>
<td>Haplic Podzol</td>
<td>Glaciofluvial (sorted)</td>
</tr>
<tr>
<td>10</td>
<td>SC, SW, TR, LF</td>
<td>6/91</td>
<td>40 x 40</td>
<td>167</td>
<td>EVT</td>
<td>P / B</td>
<td>Haplic Podzol</td>
<td>Glaciofluvial (sorted)</td>
</tr>
</tbody>
</table>

1 Plots 3 and 6 have been discontinued.
2 For abbreviations of subprogrammes, see Appendix 1. Subprogrammes in parenthesis have been discontinued.
3 See Eurola et al. (1984) for peatland types and Cajander (1926 and 1949) for mineral soil sites types; EVT = Empetrum-Vaccinium type, VMT = Vaccinium-Myrtillus type and TR = Eriophorum vaginatum pine bog.
4 P = Scots pine (Pinus sylvestris), S = Norway spruce (Picea abies), B = Birch (Betula spp.).
5 FAO.
6 Defoliation and discoloration on permanent plots.
Table 2.2.3. Characteristics of intensively monitored permanent plots in Pesosjärvi.
Plots 2 & 7, 5 & 9 and 6 & 10 are intensive plot pairs (Chapter 2.2).

<table>
<thead>
<tr>
<th>Plot No.</th>
<th>Subprogramme</th>
<th>Date of establishment</th>
<th>Plot size m x m</th>
<th>Elevation m a.s.l.</th>
<th>Site type</th>
<th>Stand Dominant/non-domin. spec.</th>
<th>Soil Group &amp; Unit</th>
<th>Parent material</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>TF, SF, (SC), AR, TR, (VG), NC, LF</td>
<td>6/89</td>
<td>30 x 30</td>
<td>263</td>
<td>HMT</td>
<td>S / P, B, A</td>
<td>Carbic Podzol</td>
<td>Glaciofluvial (sorted)</td>
</tr>
<tr>
<td>02</td>
<td>TF, SF, (SC), SW, AR, TR, VG, NC, LF</td>
<td>6/89</td>
<td>30 x 40</td>
<td>270</td>
<td>HMT</td>
<td>P / S, B</td>
<td>Haplic Podzol</td>
<td>Glacial (till)</td>
</tr>
<tr>
<td>03</td>
<td>(SC), SW, AR, TR, (VG), NC</td>
<td>6/89</td>
<td>30 x 30</td>
<td>293</td>
<td>HMT</td>
<td>S / B, P, A</td>
<td>Haplic Podzol</td>
<td>Glacial (till)</td>
</tr>
<tr>
<td>04</td>
<td>(SC), AR, TR, VG, NC</td>
<td>6/89</td>
<td>30 x 30</td>
<td>270</td>
<td>HMT</td>
<td>S / P, B</td>
<td>Carbic Podzol</td>
<td>Glacial (till)</td>
</tr>
<tr>
<td>05</td>
<td>AR, TR, VG, NC</td>
<td>6/91</td>
<td>30 x 30</td>
<td>267</td>
<td>PsR</td>
<td>P / B, S</td>
<td>Terric Histosol</td>
<td>Organic (peat)</td>
</tr>
<tr>
<td>06</td>
<td>SC, SW, TR, LF</td>
<td>8/91</td>
<td>30 x 30</td>
<td>273</td>
<td>HMT</td>
<td>S / B, P</td>
<td>Haplic Podzol</td>
<td>Glacial (till)</td>
</tr>
<tr>
<td>07</td>
<td>SC, SW, TR</td>
<td>8/91</td>
<td>30 x 30</td>
<td>293</td>
<td>HMT</td>
<td>S / B, P, A</td>
<td>Haplic Podzol</td>
<td>Glacial (till)</td>
</tr>
<tr>
<td>08</td>
<td>SC, SW, TR</td>
<td>8/91</td>
<td>30 x 30</td>
<td>293</td>
<td>Lichen</td>
<td>S / B, P, A</td>
<td>Haplic Podzol</td>
<td>Glacial (till)</td>
</tr>
<tr>
<td>09</td>
<td>SC, TR</td>
<td>8/91</td>
<td>30 x 30</td>
<td>271</td>
<td>HMT</td>
<td>S / P, B</td>
<td>Carbic Podzol</td>
<td>Glacial (till)</td>
</tr>
<tr>
<td>10</td>
<td>SC, TR</td>
<td>8/91</td>
<td>30 x 30</td>
<td>267</td>
<td>PsR</td>
<td>P / B, S</td>
<td>Terric Histosol</td>
<td>Organic (peat)</td>
</tr>
</tbody>
</table>

1. Plot 4 has been discontinued.
2. For abbreviations of the subprogrammes, see Appendix 1. Subprogrammes in parenthesis have been discontinued.
4. HMT = Hylocomium-Myrtillus type, PsR = Carex globularis pine mire.
5. FAO.
6. Defoliation and discoloration on permanent plots.

Table 2.2.4. Characteristics of intensively monitored permanent plots in Vuoskojärvi.
Plots 2 & 5, 3 & 6 and 4 & 7 are intensive plot pairs (Chapter 2.2).

<table>
<thead>
<tr>
<th>Plot No.</th>
<th>Subprogramme</th>
<th>Date of establishment</th>
<th>Plot size m x m</th>
<th>Elevation m a.s.l.</th>
<th>Site type</th>
<th>Stand Dominant/non-domin. spec.</th>
<th>Soil Group &amp; Unit</th>
<th>Parent material</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>(SC), SW, AR, TR, (VG), NC</td>
<td>8/88</td>
<td>40 x 40</td>
<td>146</td>
<td>Lichen woodland</td>
<td>P / Bt</td>
<td>Haplic Podzol</td>
<td>Glacial (till)</td>
</tr>
<tr>
<td>02</td>
<td>TF, (SC), TR, VG, LF</td>
<td>8/88</td>
<td>30 x 30</td>
<td>146</td>
<td>Lichen woodland</td>
<td>P / Bt</td>
<td>Haplic Podzol</td>
<td>Glacial (till)</td>
</tr>
<tr>
<td>03</td>
<td>TF, SF, (SC), SW, AR, TR, VG, NC, LF</td>
<td>8/88</td>
<td>40 x 40</td>
<td>158</td>
<td>Lichen woodland</td>
<td>Bt / P</td>
<td>Haplic Podzol</td>
<td>Glacial (till)</td>
</tr>
<tr>
<td>04</td>
<td>(SC), TR, VG</td>
<td>8/88</td>
<td>30 x 30</td>
<td>231</td>
<td>sELIT</td>
<td>Bt / P</td>
<td>Haplic Podzol</td>
<td>Glacial (till)</td>
</tr>
<tr>
<td>05</td>
<td>SC, SW, TR, LF</td>
<td>6/91</td>
<td>30 x 30</td>
<td>146</td>
<td>sELIT</td>
<td>Bt / P</td>
<td>Haplic Podzol</td>
<td>Glacial (till)</td>
</tr>
<tr>
<td>06</td>
<td>SC, SW, TR, LF</td>
<td>6/91</td>
<td>40 x 40</td>
<td>162</td>
<td>Lichen woodland</td>
<td>P / Bt</td>
<td>Haplic Podzol</td>
<td>Glacial (till)</td>
</tr>
<tr>
<td>07</td>
<td>SC</td>
<td>6/91</td>
<td>40 x 20</td>
<td>230</td>
<td>sELIT</td>
<td>Bt / P</td>
<td>Haplic Podzol</td>
<td>Glacial (till)</td>
</tr>
</tbody>
</table>

1. For abbreviations of the subprogrammes, see Appendix 1. Subprogrammes in parenthesis have been discontinued.
2. See Hämet-Ahti (1963) for site types. sELIT = subalpine Empetrum-Lichenes type, sELIPIT = subalpine Empetrum-Lichenes-Pleurozium type.
3. P = Scots pine (Pinus sylvestris), Bt = Mountain birch (Betula pubescens ssp. tortuosa).
4. FAO.
5. Defoliation and discoloration on permanent plots.
7. Lichen woodland rich in mosses.
2.3 Physicochemical monitoring

2.3.1 Climate observations

The climatological data for the IM areas Valkea-Kotinen, Hietajärvi, Pesosjärvi and Vuoskojärvi for the monitoring period January 1, 1987 – December 31, 1991 was obtained from meteorological stations (Table 2.3.1.1) by the Finnish Meteorological Institute according to the Meteorology (AM) subprogramme.

2.3.2 Air quality and deposition

Air quality has been measured since October 21, 1989 according to the EMEP, ECE at the Oulanka EMEP station established by the Finnish Meteorological Institute. The station is situated about 5 km northwest of Pesosjärvi. Table 2.3.2.1 lists the components and methods used according to the Air Chemistry (AC) subprogramme.

The Finnish Meteorological Institute has established deposition measurement stations, which operate according to the Precipitation Chemistry (DC) subprogramme in the IM areas (Figs. 2.1.5.1, 2.1.5.2). Bulk deposition measurements of the acidifying components with three parallel standardized precipitation collectors at each station started first in Valkea-Kotinen on April 1987, then in Hietajärvi and Vuoskojärvi on November 1987. The measurements were started in the Pesosjärvi IM area on July 1988.

For quality assurance purposes, three parallel precipitation collectors are in use in each catchment area. Parallel sampling serves as a method of continuously monitoring the precision of the sampling procedure as well as a checkup of sample contamination. To examine the variation of deposition within the catchment area, two additional samplers with an identical measuring programme were set up in June–July 1990 about 100 m away from the others for about two years.

After visual checking, the weekly samples were combined to form monthly samples, kept cool and analysed in the laboratory of the Finnish Meteorological Institute. For determining heavy metal deposition, all the stations were equipped with an acid-washed bulk deposition collector in June 1990. The heavy metal deposition samples were collected monthly. The analytical programme and the methods used are presented in Table 2.3.2.2.

The quality of the analysis of acidifying components was checked by calculating a cation–anion balance and by comparing the measured and calculated conductivity. If needed, the samples were reanalysed by the checking procedure.

2.3.3 Throughfall and stemflow

Throughfall

Throughfall is that part of the incident precipitation which reaches the forest floor after having passed through the canopy and gaps. At the time of plot establishment (Tables 2.2.1–2.2.4), throughfall collectors were placed systematically at 10-m intervals (Fig. 2.2.1) around 2–3 of the permanent plots in each catchment. Depending on its size, there are 10–16 collectors around each plot.

Each throughfall collector consists of an acid-washed polyethylene funnel (collecting area = 308 cm²) connected to an acid-washed polyethylene bottle (Fig. 2.2.1). The throughfall samples were collected once a week. The volume of throughfall collected by

<table>
<thead>
<tr>
<th>Meteorological station</th>
<th>IM area</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Data collected</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Temperature</td>
</tr>
<tr>
<td>Lammi, Biological Station</td>
<td>Valkea-Kotinen</td>
<td>61°03'N</td>
<td>25°03'E</td>
<td>x</td>
</tr>
<tr>
<td>Lammi, Iso-Evo</td>
<td>Valkea-Kotinen</td>
<td>61°11'N</td>
<td>25°02'E</td>
<td>x</td>
</tr>
<tr>
<td>Lahti, Laune</td>
<td>Valkea-Kotinen</td>
<td>60°58'N</td>
<td>25°35'E</td>
<td>x</td>
</tr>
<tr>
<td>Lieksa, Lampela</td>
<td>Hietajärvi</td>
<td>63°19'N</td>
<td>30°13'E</td>
<td>x</td>
</tr>
<tr>
<td>Joensuu, Church</td>
<td>Hietajärvi</td>
<td>62°41'N</td>
<td>30°57'E</td>
<td>x</td>
</tr>
<tr>
<td>Joensuu, Airport</td>
<td>Hietajärvi</td>
<td>62°40'N</td>
<td>29°38'E</td>
<td>x</td>
</tr>
<tr>
<td>Kuusamo, Kolvanki</td>
<td>Pesosjärvi</td>
<td>65°50'N</td>
<td>29°18'E</td>
<td>x</td>
</tr>
<tr>
<td>Kuusamo, Kiltojavants</td>
<td>Pesosjärvi</td>
<td>66°22'N</td>
<td>29°19'E</td>
<td>x</td>
</tr>
<tr>
<td>Utsjoki, Kevo</td>
<td>Vuoskojärvi</td>
<td>69°45'N</td>
<td>27°02'E</td>
<td>x</td>
</tr>
</tbody>
</table>
Table 2.3.2.1. Air quality measurements and methods used in Air Chemistry (AC) subprogramme.

<table>
<thead>
<tr>
<th>Component</th>
<th>Sampling time</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>SO₂</td>
<td>24 h</td>
<td>NaOH-impregnated Whatman 40 filter, ion chromatography</td>
</tr>
<tr>
<td>SO₂⁴⁻</td>
<td>24 h</td>
<td>Whatman 40 filter, ion chromatography</td>
</tr>
<tr>
<td>NO₃ + NO₂⁻</td>
<td>24 h</td>
<td>Whatman 40 filter + NaOH-impregnated, ion chromatography</td>
</tr>
<tr>
<td>NH₃ + NH₄⁺</td>
<td>24 h</td>
<td>Oxalic acid-impregnated Whatman 40 filter, spectrophotometry</td>
</tr>
<tr>
<td>NO₂</td>
<td>continuous</td>
<td>Spectrophotometry, Salzman</td>
</tr>
<tr>
<td>O₃</td>
<td>continuous</td>
<td>Spectrophotometry</td>
</tr>
</tbody>
</table>

Table 2.3.2.2. Analytical programme and methods used for deposition samples in Precipitation Chemistry (DC) subprogramme.

<table>
<thead>
<tr>
<th>Component</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>Potentiometry, pH-meter</td>
</tr>
<tr>
<td>H⁺</td>
<td>Calculated from pH</td>
</tr>
<tr>
<td>Conductivity</td>
<td>Conductometry</td>
</tr>
<tr>
<td>Cl⁻, NO₃⁻, SO₄²⁻</td>
<td>Ion chromatography</td>
</tr>
<tr>
<td>NH₃⁺</td>
<td>Spectrophotometry, (indophenol blue)</td>
</tr>
<tr>
<td>Mg²⁺, Ca²⁺, Na⁺, K⁺</td>
<td>Atomic absorption spectrophotometry, (flame)</td>
</tr>
<tr>
<td>Zn, Pb, Cu, Cd, Cr, Ni, Fe, V, Mn</td>
<td>Atomic absorption spectrophotometry, (graphite furnace)</td>
</tr>
</tbody>
</table>

Each device was recorded before being poured into a common acid-washed polyethylene canister. A subsample was then taken for analysis. Sampling was carried out during the snow-free period; this was usually May through October/November.

For sample pretreatment and analysis see Chapter 2.3.5 (Soil water chemistry). If concentrations were below detection limits, a value of half the detection limit was given in accordance with the revised IM Manual (Environment Data Centre 1993).

**Stemflow**

The part of the incident precipitation collected by branches and trunks and deposited on the forest floor immediately around the base of the tree is called stemflow. Stemflow collectors in the Stemflow Chemistry (SF) subprogramme (Fig. 2.2.1) have been fitted to 5–10 trees around 1–3 plots in each catchment (Table 2.3.3.1). The plots are the same as those where throughfall is collected. The collectors have been fitted to the dominant tree species. In the case of mixed stands, more than one tree species has been selected.

At the time of plot establishment (Tables 2.2.1–2.2.4), collar-type collectors made of ethylene propane rubber edging (U-shaped in cross section) were used. In 1991, these collectors were replaced with a spiral-type collector made of silicon (Fig. 2.2.1). The sample is collected in an acid-washed...
polyethylene bucket placed inside a plastic sack lined with aluminium foil to protect the sample from direct sunlight.

The volume of stemflow in each bucket was recorded weekly and then emptied into a large acid-washed polyethylene canister; a separate one was used for each tree species at the plot. The canister was shaken and a subsample of this composite poured into an acid-washed polyethylene bottle for analysis. Sampling was carried out during the snow-free period; this was usually May through October/November. Sample pretreatment and analysis was the same as for throughfall.

In 1990 (1991 for the Plot FI01_1; for the codes see Chapter 2.1.1), the position of the stemflow trees was mapped and basic characteristics (species, diameter at breast height (dbh), height and canopy projection; see Chapter 2.4.1 for details) were measured.

### 2.3.4 Moss chemistry

Samples of two carpet-forming moss species, *Hylocomium splendens* and *Pleurozium schreberi*, were collected during summer 1991 in all IM areas for heavy metal analysis according to the Moss Chemistry (MC) subprogramme. In the Hietajärvi catchment, only *Pleurozium schreberi* was collected. Some samples were already taken in 1988 and 1989. *Hylocomium splendens* was collected in the Valkea-Kotinen area in 1988 and in the Hietajärvi and Pesosjärvi areas in 1989.

Composite samples consisting of 5—10 subsamples were collected throughout each area. Sampling sites were open areas, i.e., small gaps in the forest not exposed to throughfall from trees. Sampling was done according to Rühling et al. (1992) and Standard no. 5671 (Suomen Standardisoimisliitto 1990a).

The three youngest fully developed segments of each *Hylocomium splendens* or corresponding shoots of *Pleurozium schreberi* were removed and dried to constant weight at 40° C. After homogenizing, 1 g of dried material was digested in a mixture of concentrated nitric acid and perchloric acid, in a proportion of 4:1. The concentrations of eight heavy metals in moss samples were analysed in the Technical Research Centre of Finland using the inductively coupled plasma emission technique (ICP). The following heavy metals were determined: Cd, Pb, Cr, Ni, Cu, Zn, V and Fe.

In this report, the heavy metal concentrations in moss samples from the IM areas are compared with those from regional background areas. Regional background values, which later will be called “background values”, were taken from Rühling et al. (1987, 1992). The metal concentrations in mosses are also compared with bulk deposition and throughfall.

### 2.3.5 Soil and soil water

#### Soil chemistry

The list of plots on which the Soil Chemistry (SC) subprogramme has been carried out is given in Tables 2.2.1—2.2.4. The location of the plots is indicated in Figures 2.1.2.2, 2.1.3.2, 2.1.4.2 and 2.1.5.2. The classification of the soils into FAO soil units is based on a simple profile description made from a single soil pit dug close to, but outside, each plot.

Data for plots that have since been discontinued (FI01_05 and FI01_06) are included in this report. Both of these plots show signs of having been thinned in the recent past (i.e., stumps present), and Plot FI01_06 is also just outside the catchment.

The first round of soil sampling was carried out in late August—September 1988 for the Hietajärvi and Vuoskojärvi catchments, and in late August—September 1989 for the Pesosjärvi and the Valkea-Kotinen catchments. Sampling was repeated in 1991—1992. Only the data from the first round of sampling is complete at present, and it is this data that is presented in this report.

Three sets of soil samples were taken: 1) samples by fixed depth layers, 2) samples by morphological (pedogenic) horizons, and 3) undisturbed volumetric samples. The “fixed depth” samples were used for the purposes of the SC subprogramme, i.e., soil chemistry monitoring. It is this data that is presented in this report. The “horizon samples” were taken for the purposes of soil classification and for comparison with the “fixed depth samples”; they will probably be taken only once. The undisturbed volumetric samples were taken for the determination of bulk density. Details of the sampling procedures have been described by Starr and Ukonmaanaho (1992).

For the “fixed depth” sampling, four composite samples of each layer (humus layer, 0—5-cm, 5—20-cm and, where possible, also the 20—40-cm) were taken using an auger. The composite subsamples were taken at the intersections of a 10 x 10-m grid laid out over the plot. Thus, depending upon plot size (Tables 2.2.1—2.2.4), the number of subsamples in each composite sample varied from 12 to 25. At each 10-m intersection, the sampling was repeated four times, thus giving four parallel composite samples for each layer and plot. In the case of the peat plots (FI01_01
and FI01_02; Fig. 2.1.2.2), the following layers were sampled: 0—5, 5—10, 10—20 and 20—40 cm, and only one subsample was taken at each 10-m intersection, giving a single composite sample for analysis.

The set of horizon samples was taken from a soil pit dug to make a soil profile description (Appendix 2). The location of the pit was chosen subjectively, being considered representative for the plot. If the soil was not too stony, undisturbed volumetric samples (i.e. 3 x 0.61 dm³ cores from each fixed depth layer or horizon) were also taken from the soil pit.

The soil samples were kept in plastic bags for up to three days in cool (+4°C), dark conditions until they were transported to the laboratory. Upon arrival, the samples were frozen until they could be dried. Drying took place in a large ventilated drying chamber in which the temperature was thermostatically controlled at 40—60°C. After drying, the mass of the sample was recorded. Coarse fragments (stems, roots, cones, etc.) were removed by hand from the surface humus layer and peat samples before being milled into a fine powder. The mineral soil samples were sieved and the <2-mm fraction weighed and retained for analysis.

The samples were analysed for the complete set of basic SC subprogramme properties (Environment Data Centre 1989a, 1989b): pH (measured in water and 1M KCl), exchangeable titratable acidity (EA), exchangeable (extractable) base cations (Na, K, Ca and Mg), base saturation (BS), both total organic carbon (TOC) and loss on ignition (LOI), and total nitrogen. The following optional variables were also determined: exchangeable titratable aluminium acidity (EAₐ), total titratable acidity (TTA), potential cation exchange capacity (CECₐ), total phosphorus and sulphur, and the "slowly available fraction" of Mn, Pb, Cd, Cu and Zn (i.e., for humus layer = total; for mineral soil = organically bound plus the easily weatherable mineral fraction; Bringmark 1989). Selenium and the heavy metals Hg, Cr, As, Ni and V, which are also optional variables, were not determined. Additional variables determined included an estimate of the effective cation exchange capacity (CECₑ), i.e. the CEC at field pH, and its corresponding base saturation value (BSₑ). These variables were calculated according to Bringmark (1989). If concentrations were below detection limits, a value of half the detection limit was given in accordance with the revised IM Manual (Environment Data Centre 1993).

As far as possible, the procedures and methods outlined in the IM Manual were followed (Environment Data Centre 1989a). Full analytical details were described by Ukonmaanaho (1992). In the case of the "slowly available fraction" of heavy metals and total phosphorus, the conventional dry ashing procedure of the Finnish Forest Research Institute for the total analysis of plant material (Halonen et al. 1983) was used. The wet digestion procedures recommended in the IM Manual (Environment Data Centre 1989a) were not routinely used at the Finnish Forest Research Institute laboratory at the time, and there is still disagreement within the IM Programme about which method to use for heavy metal analysis. The dry ashing values for the humus layer and peat samples can be considered comparable to wet digestion values (i.e. totals), but not so in the case of the mineral soil samples. All data (except pH) were calculated on an oven-dry mass basis.

Soil water chemistry

At the time of establishing the permanent plots in the Soil Water Chemistry (SW) subprogramme (Tables 2.2.1—2.2.4), six suction soil water samplers were installed in two of the plots in each catchment. With the exception of Plots FI01_07 and FI05_01, stemflow and throughfall were also collected from the same plots.

The soil water samplers (PRENART teflon samplers) as recommended in the IM Manual (Environment Data Centre 1989a) were installed in pairs at three positions just inside the plots (Fig. 2.2.1). One of each pair was installed to a depth of 15 cm and the other to a depth of 35 cm. A vacuum of about —60 kPa was applied to each sampler and the sample collected after two weeks. The sample volume was recorded and then transferred to an acid-washed polyethylene bottle for transport to the laboratory. The collection bottle was rinsed with distilled deionized water and vacuum was reapplied for the next two-week period. Sampling was carried out during the frost-free period; this was usually May through October/November.

In 1991 and 1992, additional suction soil water samplers (DIAPOR® and Soil Moisture ceramic cups) were installed in some of the plots. Zero-tension lysimeters, which allow the water flux to be measured, were also installed in 1992 in Hietajärvi (Plots FI03_09 and FI03_10). However, the data related to these new samplers are not presented in this report.

The samples were stored in dark and cool (+4°C) conditions until the analysis began. Upon analysis, the samples were filtered using a Schleicher & Schuell 5892 filter paper. The
samples from each sampler were analysed individually.

The chemical properties determined are those listed in the IM Manual (Environment Data Centre 1989a). Details of the analytical methods and procedures used are given by Ukonmaanaho (1992). Acidity (pH) and specific conductivity were determined using a combined electrode/conductivity meter. If the pH of the sample was > 4.2, alkalinity was measured by titration. The concentrations of Ca, Mg, K, Na, P, Al, Mn, Fe, Si, Pb, Cu, Cd and Zn were determined using an ICP analyser (since 1991, concentrated nitric acid was added before analysis; 1:200 v/v). Mercury was not determined as concentrations were expected to be so low as not to justify the cost of the separate analysis which would be required. Labile aluminium concentrations were also not determined. Concentrations of PO$_4^{3-}$, SO$_4^{2-}$, NO$_3^-$ and Cl$^-$ ions were measured using high-pressure ion chromatography (fluoride was found not to be present), and ammonium concentrations were determined by flow-injection analysis and gas diffusion. Since 1991, concentrations of dissolved organic carbon (DOC) have been determined using a Shimadzu TOC-5000 analyser. Samples for the analysis of nitrate and DOC were not conserved with mercuric chloride (Environment Data Centre 1989a). If concentrations were below detection limits, a value of half the detection limit was given in accordance with the revised IM Manual (Environment Data Centre 1993).

### 2.3.6 Catchment runoff and surface waters

**Catchment runoff**

Discharge from the IM areas was measured at a gauging-station located in a suitable section of the outlet channel just below the catchment boundary (Figs. 2.1.2.2, 2.1.3.2, 2.1.4.2 and 2.1.5.2). The gauging station was fitted with a V-notch weir and a continuous water-stage recorder (limniograph). The inflow channels to the lakes in the Hietajärvi and Pesosjärvi areas were also fitted with a gauging-station. The mean daily, monthly and annual runoff (and lake inflow) values were calculated. Monthly runoff values were reported to the EDC. Mean runoff values are presented in the connection with the area descriptions in Tables 2.1.2.1, 2.1.3.1, 2.1.4.1 and 2.1.5.1.

**Water chemistry**

Water samples for physicochemical analysis were taken from lake deeps, inlets and outlets using a Ruttner or Limnos sampler (Environment Data Centre 1989a), except at Valkea-Kotinen where a teflon-coated Limnos-sampler (Keskitalo & Salonen 1994) was used. The sampling stations in each IM area are shown in Figures 2.1.2.2, 2.1.3.2, 2.1.4.2, and 2.1.5.2.

The surface water samples from the inlet and outlet streams were taken weekly during the spring peak runoff period, once a month during the summer and bimonthly during the autumn. Lake deep samples from Lakes Iso Hietajärvi, Pieni Hietajärvi, Pesosjärvi and Vuoskojärvi were taken 2–6 times per year (Nordic Council of Ministers 1988). The samples from the lake deeps were taken at depths of 1, 3 and 5 m and at 1 m above the lake bottom. The lake water samples from Valkea-Kotinen were taken in connection with the phytoplankton programme (Chapter 2.4.6), i.e. weekly during the ice-free period and monthly during winter from the surface and 1, 2, 3 and 5 m depths. Sampling was therefore more intensive at Valkea-Kotinen, with 25–30 samples per year. All the water samples were analysed as described in Table 2.3.6.1.

The runoff values of inlets and outlets and the water chemistry results were stored as monthly means in the IM data base at the EDC. The results of streams (inlets and outlets) are not presented in this report but they are used in catchment ion mass budget calculations (Chapter 2.3.7). However, the results of lake deeps (Figs. 3.8.1.1–3.8.1.16 and Tables 3.8.1.1–3.8.1.4) represent well the water chemistry of the IM areas.

### Table 2.3.6.1. Surface water variables measured and respective analytical methods in Runoff Water Chemistry (RW) subprogramme.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Analytical method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
<td>Mercury thermometer in sampler¹</td>
</tr>
<tr>
<td>pH-value</td>
<td>Potentiometry, pH-meter</td>
</tr>
<tr>
<td>Specific conductivity</td>
<td>Conductometry</td>
</tr>
<tr>
<td>Oxygen</td>
<td>Titrimetry, Winkler method¹</td>
</tr>
<tr>
<td>Alkalinity</td>
<td>Acid titration, Gran-plot</td>
</tr>
<tr>
<td>Colour value</td>
<td>Spectrophotometry at 420 nm</td>
</tr>
<tr>
<td>Total phosphorus</td>
<td>Spectrophotometry, after wet oxidation</td>
</tr>
<tr>
<td>Phosphate phosphorus</td>
<td>Spectrophotometry, molybdate method</td>
</tr>
<tr>
<td>Total nitrogen</td>
<td>Spectrophotometry, after wet oxidation</td>
</tr>
<tr>
<td>Ammonium nitrogen</td>
<td>Spectrophotometry, indophenol method</td>
</tr>
<tr>
<td>Nitrate nitrogen</td>
<td>Spectrophotometry, as nitrite after cadmium reduction</td>
</tr>
<tr>
<td>Dissolved inorganic carbon</td>
<td>Acidification and bubbling method with IR detection²</td>
</tr>
<tr>
<td>Dissolved organic carbon</td>
<td>High temperature combustion²</td>
</tr>
</tbody>
</table>

1. YSI (Yellow Springs Instruments) probe in Valkea-Kotinen.
2. During phytoplankton sampling in Valkea-Kotinen and Hietajärvi.
Lake sedimentation

Sedimented matter was sampled biweekly (once a month in winter) from early June 1991 at Valkea-Kotinen. With the exception of the sedimentation trap construction, the methods followed those described by Keskitalo and Salonen (1994).

Sedimented matter was collected in a trap consisting of a vertical cylinder (0.140 mm), divided into two parts. The lower part was filled with polyurethane foam to make the trap buoyant. The upper part (height 760 mm) was for sediment collection and its mouth was located at 2 m above the bottom (at 4.5 m). A rope was run from the surface buoy to the vertical trap through rollers attached to two bottom weights 2–3 m apart. When the rope was detached from the surface buoy, the buoyancy elevated the trap. The rising velocity was kept smooth by slowly releasing more rope until the trap reached the surface. Water laying above sedimented matter was gradually drained by removing stoppers along the side of the trap. When a suitable water volume was left, the sample was taken into a bottle.

The advantages of this sampling arrangement are: 1) since there are no ropes or floats above the trap, the sample is free from contamination by periphytic growth, and 2) bottom disturbance and resuspension are avoided because the weights remain in place on the bottom.

After removing large animals (copepods, Chaoborus larvae) from the sedimented matter, dry weight (24 h, 60°C) and ignition residue (4 h, 450°C) were determined. Organic matter was calculated by subtracting the weight of the residue from the dry weight. Organic carbon was determined with a carbon analyser (Salonen 1979) and total phosphorus and total nitrogen with an AKEA autoanalyzer using the persulphate oxidation method (Koroleff 1979).

2.3.7 Catchment ion mass budgets

Adequate data for determining ion mass budgets was available for Valkea-Kotinen and the two Hietajärvi catchments, Iso Hietajärvi and Pieni Hietajärvi. The ions included in the input/output calculations were: Na+, K+, Ca++, Mg++, NH4+, H+, NO3-, HCO3-, Cl-, SO42-, and A (organic anions). The annual (water year) budgets are based on 2–5 years of measurements, depending on the catchment. A detailed description of the methods and results of the budget calculations is given in Forsius et al. (1994).

There are a number of methods for estimating total (wet + dry) deposition. In this study, the determination of total deposition to the catchments was based on open-field measurements (bulk deposition) and throughfall studies (Chapters 2.3.2 and 2.3.3). To estimate the filtering effects on the forest stands, a filtering correction was made for the base cations, Cl- and SO42-, based on deposition ratios (DR; i.e. deposition to forest stands divided by deposition in open field). However, since the internal cycling of Ca++, Mg++ and K+ can be considerable, the correction factor for these ions was derived using the filtering correction (FC) of Na+ instead (Ivens 1990).

The specific filtering abilities of different stands (throughfall plots) were taken into account (Kallio & Kauppi 1990):

\[
FC = \frac{\text{DR}_1 A_1 + \text{DR}_2 A_2 + \cdots + \text{DR}_n A_n}{A_{\text{tot}}}
\]

where FC = filtering correction factor for a catchment; DR1, DR2, DRn = deposition ratio for 1...n stands; A1, A2, An = area of stands 1...n; A0 = area of open field; A_{tot} = total area of catchment. Deposition to the basins for the hydrological years was calculated as the sum of monthly values. The total deposition values for months when throughfall was recorded (May–October/November) were obtained by multiplying the open field depositions by the FC factor. For the other months (snow/frost period), bulk deposition measurements were used.

The output fluxes from the catchments were calculated from the quality and quantity of the runoff water. The annual number of samples varied 20–40 (Chapter 2.3.6). The fluxes were estimated by weighting the sample concentrations with the flow at the time of sampling (Rekolainen et al. 1991).

Hydrogen ion budgets were estimated on the basis of deposition, weathering, ion exchange, retention and biological accumulation processes (van Breemen et al. 1984, Kallio & Kauppi 1990). The net hydrogen ion flux due to nitrogen transformations was determined as the difference between the net outputs of ammonium and nitrate (van Breemen et al. 1983). Hydrogen ion production attributed to dissociation of organic anions was estimated using an empirical dissociation equation (Oliver et al. 1983). Average values for the net uptake of base cations due to tree growth were interpolated from a national data base (Johansson & Janssen 1994). The ratio between external (anthropogenic) and internal proton sources was calculated according to van Breemen et al. (1984).
2.3.8 Dynamic model application

The dynamic Simulation Model for Acidification's Regional Trends (SMART acidification model; de Vries et al. 1989, Posch et al. 1993) has been calibrated for seven IM catchments in Europe, including the Valkea-Kotinen (FI01) and Hietajärvi (FI03) catchments in Finland. A detailed description of the modeling exercise is given in Bleeke et al. (1994a, 1994b). The model application had two major objectives:

- To test if SMART can be run using the data as requested and stored in the IM EDC data base, or if additional data are required, and;
- To calibrate SMART within IM data so that it can be used for assessing the environmental consequences of different emission reduction strategies developed under the framework of the UN ECE.

The SMART model was developed to estimate long-term chemical changes in soil, soil water and runoff water in response to changes in atmospheric deposition. The model was originally designed for applications on a regional scale but has since been applied to individual catchments and plots. The output from SMART includes soil base saturation and concentrations of the major anions and cations in soil solution and runoff water.

The model structure is based on the anion mobility concept by incorporating the charge balance principle (Reuss et al. 1986). SMART consists of a set of mass balance equations which describe the soil input output relationships for the major cations and anions, and a set of equilibrium equations which describe the equilibrium soil processes. The soil solution chemistry depends solely on the net element input from the atmosphere and the geochemical interactions (weathering and cation exchange) in the soil.

Apart from the net uptake of nitrogen and base cations in harvested plants and the net nitrogen immobilization in the forest floor, the influence of the nutrient cycle (folian exudation, foliar uptake, litterfall, mineralisation and root uptake) is not taken into account. The various exchange reactions are described by Gaines-Thomas equations. Uptake and reduction of sulphate as well as biological fixation of nitrogen are assumed to be negligible. The weathering rate of base cations from silicates is independent of the soil pH. Lately the soil model has been enhanced by the inclusion of a description of (i) sulphate adsorption/desorption, modeled by a Langmuir isotherm (Cosby et al. 1986), (ii) dissociation of organic anions as a function of pH, (iii) denitrification modeled as a fraction of the net nitrogen input, and (iv) nitrogen immobilization as a function of the C:N ratio (Posch et al. 1993, de Vries et al. 1994).

A lake water module has also been developed recently. This module computes the concentrations of the major ions in the lake water, using the ion fluxes from the catchment soils and direct atmospheric deposition as input. In-lake processes included in the lake module are the retention of sulphate, nitrate and ammonia, the precipitation of aluminium as carbon dioxide degasses, as well as the inorganic carbon equilibria.

The data needed for running the SMART model is a mixture of model parameters, and data for driving variables and initial conditions that should be specified for each catchment. Even though SMART is designed for a lumped-process description to minimize the input data requirements, empirical information for many model variables are generally unavailable or are impossible to determine on a catchment scale. A calibration procedure is therefore necessary to fit the model outputs with the observations. A detailed description of the calibration procedure and model parameters is given in Bleeke et al. (1994a, 1994b).

The historical trend of the sulphur deposition was derived from the report by Mylona (1993), in which the trend of sulphur deposits is based on available historical sulphur emission data. The depositions given in the report by Mylona (1993) were used to scale back the depositions using 1990 as the reference year. The deposition data from 1960 to 2000 were derived by means of the Finnish Integrated Acidification Assessment Model (HAKOMA; Johansson et al. 1989).

The deposition history for nitrate and ammonium deposition was derived according to Wright et al. (1988). For the period 1960–2000, the same approach as for sulphur was used. The base cation historical deposition trend was similar to the sulphur trend, because the nonmarine-base cation deposition was assumed to be caused by industrial emissions only.

2.4 Biological monitoring

2.4.1 Tree stand and forest condition

The first round of the Trees (TR) subprogramme was carried out during August–October in 1987–1989 and repeated in 1991–1992. Only the data collected for the first round are presented in this report (for the location and characteristics of the plots, see Figs. 2.1.2.2, 2.1.3.2, 2.1.4.2, 2.1.5.2 and Tables 2.2.1–2.2.4).
Basic programme parameters were measured as follows. Every standing tree (living and dead) on the plot with a \( dbh > 5 \) cm was permanently numbered. The exact location of each numbered tree, stump, broken stem and corresponding fallen stem and stump was mapped using standard procedures (Finnish Forest Research Institute 1987). The species was recorded and \( dbh \) measured using calipers to an accuracy of \( \pm 1 \) mm in two directions: parallel to the numbered tag and at right angles to it (Finnish Forest Research Institute 1986). The stem diameter at 6 m and height were measured from 30 systematically chosen sample trees per plot, except at Vuoskojärvi, where the height of all trees with a \( dbh > 5 \) cm on the plot was measured. The stem diameter at 6 m was measured from one direction and to an accuracy of \( \pm 1 \) cm using a tree diameter ruler attached to a 5-m pole. Where tree height was \( > 5 \) m, it was measured using a Suunto clinometer (\( \pm 1 \) dm). Where tree height was \( < 5 \) m, it was measured with a 5-m measuring pole. The tree height measurement procedure has an accuracy of \( \pm 2 \) dm. In the case of dead trees where the stem had snapped, the height of the standing stem and the length of the fallen stem on the ground were measured.

For dead trees, the cause of death was identified according to the list of causes given in the IM Manual (Environment Data Centre 1989b). Tree fertility of the forest condition sample trees (see below) was assessed annually according to cone (concurrent year) abundance classes.

Extended programme parameters, canopy projection and crown form of each numbered tree was measured in 1990–1992. The distance from the centre of the stem to the tip of the branches in the four cardinal compass directions was measured to an accuracy of \( \pm 1 \) dm. The form of the crown was classified according to the classes given in the IM Manual (Environment Data Centre 1989a). In 1990, trees with \( dbh < 5 \) cm were also mapped and height and canopy projection measured.

In the Pilot phase of the IM Programme, the monitoring of forest condition (defoliation and discoloration) was part of the Forest Stands (AR) subprogramme, i.e., the catchment-wide forest programme (Environment Data Centre 1989a). However, the Finnish Forest Research Institute has carried out tree condition assessments on each permanent plot. Defoliation, discoloration and diseases have been registered annually using 20 selected dominant or codominant coniferous trees and standard methods (Finnish Forest Research Institute 1986, Müller & Sterlin 1990, Salemaa et al. 1991).

2.4.2 Needles and litterfall

Needle chemistry

Needle sampling according to the Foliage Chemistry (NC) subprogramme has been carried out annually since 1988 (Tables 2.2.1–2.2.4). The needle sample trees are located around the permanent plots (Fig. 2.2.1). They are the healthiest dominant coniferous trees in the stand considered capable of enduring continuous needle sampling, and are similar to those on the tree stand plots. Usually, the same trees were sampled every year. However, on some plots the sample trees in any one year have been selected from a larger number of reserved trees; resting trees in alternative years to minimize possible damage due to sampling.

In October–November, two or three shoots were collected 2–4 m down from the tree top on the south side of the canopy using a tree pruner attached to a pole or, if too high, by climbing the tree. The shoots were placed in paper bags, kept cool and transported to the laboratory.

In the laboratory, shoots of the concurrent (c) and preceding (c+1) years were separated if they had not already been done so in the field, placed in paper bags and dried at 60° C for at least 48 h. The needles were then removed from the shoots and milled into a fine powder and stored in plastic bags. For analysis, subsamples of the milled needles were digested in a mixture of nitric acid and hydrogen peroxide and concentrations of S, Ca, Mg, Na, K, P, Mn, Zn, Cu, Pd and Cd determined using the ICP technique. The list of elements for the NC subprogramme (Environment Data Centre 1989a) also includes boron and molybdenum, but these elements have not been determined because this would have required a separate analysis. Total nitrogen and carbon were determined using a LECO CHN analyser.

Litterfall chemistry

In 1990, litterfall collectors were placed under the canopies of 5–6 dominant trees in accordance with the IM Manual (Environment Data Centre 1989a) around those permanent plots where stemflow and throughfall were being collected (Tables 2.2.1–2.2.4). In 1991, collectors were also placed under the canopies of four trees around the new Plot (FI01_11) in Valkea-Kotinen.

The funnel-shaped collectors (Fig. 2.2.1) have a collecting surface area of 0.5 m² and stands about 1.5 m above the forest floor. The cotton bag containing the litterfall sample was replaced with a clean bag at the beginning of
each month during the frost-free period; this is usually May through October/November.

In 1991, six additional litterfall collectors were set out in a systematic 10 x 10-m grid in the middle of the new soil chemistry plots. The purpose of these additional collectors was to provide litterfall data representative of the plot and not of a tree, as the original collectors did.

In the laboratory, the bags and their contents were left to dry at room temperature and then stored. Before analysis, the samples were dried at 40-60°C for 24 h, weighed, and then milled into a fine powder. For analysis, the samples for May and June, and for July and August were combined; samples for other months were analysed individually. The samples were analysed according to the same procedures as described for the NC subprogramme.

2.4.3 Epiphytes

Monitoring of lichens according to the Epiphytes (EP) subprogramme started in 1988. Since then the sample plot system has been improved and the selection criteria for lichen plots and sample trees have changed. In 1988 the lichen plots were joint plots for lichens, understorey vegetation, trees and soil. This degree of activity caused excessive disturbance to the plots, and since 1989 the lichen plots have been separate plots situated preferably near the vegetation, tree stand and soil measurements (for reorganisation of plots, see also Chapter 2.2). The plots monitored and sample trees measured are listed in Table 2.4.3.1. The location of the plots not discontinued is indicated in Figures 2.1.2.2, 2.1.3.2, 2.1.4.2 and 2.1.5.2.

In Finland, Scots pine is the main tree species monitored in the EP subprogramme. Mountain birch was also selected for monitoring in the Vuoskojärvi area, and Norway spruce in Valkea-Kotinen and Pesosjärvi. The monitoring of spruce was later discontinued due to methodological difficulties especially in the Pesosjärvi area where the spruce branches come down almost to ground level. The spruce monitoring results are not presented here.

Eight sample trees were usually selected for monitoring in each intensive lichen plot. The sample trees belonged to the dominant tree layer and the dbh was 20-40 cm. There were also certain other tree selection criteria concerning health of the tree and shape of the trunk (Mäkelä 1992).

The abundance of different lichen species was measured using the tape method (Environment Data Centre 1989a). An elastic tape was stretched clockwise around the trunk on 4-5 fixed levels (lines). The lines were 60, 90, 120 and 150 cm above the ground in Valkea-Kotinen and Hietajärvi. In the two northernmost areas, Pesosjärvi and Vuoskojärvi, the upper lines were situated higher up due to the presence of reindeer. In Pesosjärvi, the measured lines were 120, 150, 250 and 280 cm and in Vuoskojärvi 60, 90, 120, 150 and 220 cm above the ground. However, the 220-cm line was not high enough to prevent reindeer grazing. On the lines, each lichen thallus was recorded to an accuracy of 1 mm according to a specific species list (Table 2.4.3.2). The presence of other species not included in the species list was also noted as well as species not encountered along the measurement lines, but still existing on the trunk at the heights of 60-150.

Table 2.4.3.1. Information on monitoring years, lichen plots and sample trees in Epiphytes (EP) subprogramme.

<table>
<thead>
<tr>
<th>Area</th>
<th>Year of obs.</th>
<th>Plot number</th>
<th>Sample trees at each plot</th>
<th>Other information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Valkea-Kotinen</td>
<td>1988</td>
<td>3, 4, 5, 6, 7</td>
<td>8 pine (each plot)</td>
<td>Plots 3-6 discontinued¹</td>
</tr>
<tr>
<td></td>
<td>1990</td>
<td>7, 9</td>
<td>+ 7 spruce (Plot 7)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>8 pine</td>
<td></td>
</tr>
<tr>
<td>Hietajärvi</td>
<td>1990</td>
<td>1, 2, 3</td>
<td>8 pine</td>
<td>Plot 9 established</td>
</tr>
<tr>
<td>Pesosjärvi</td>
<td>1989</td>
<td>2, 3, 4, 5</td>
<td>8 pine</td>
<td>plots 3 and 4 discontinued¹</td>
</tr>
<tr>
<td></td>
<td>1991</td>
<td>2, 5, 6</td>
<td>8 pine</td>
<td>Plot 6 established</td>
</tr>
<tr>
<td>Vuoskojärvi</td>
<td>1989</td>
<td>1, 2, 3</td>
<td>8 pine (Plots 1 and 3)</td>
<td>A new method for birches,</td>
</tr>
<tr>
<td></td>
<td>1991</td>
<td>1, 2, 3, 4</td>
<td>8 birch (Plot 2)</td>
<td>Plot 4 established and</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>8 pine (Plots 1 and 3)</td>
<td>new trees selected on Plot 2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>19 birch (Plots 2 and 4)</td>
<td></td>
</tr>
</tbody>
</table>

¹ Results from discontinued plots are not presented in this report.
In addition to the mandatory variables (Environment Data Centre 1989a), the vitality of all lichen species as a whole and of Hypogymnia physodes separately was estimated according to the Finnish Standard for lichen vitality (Suomen Standardisoimisliitto 1990b). The length of every filamentous specimen was also noted at the heights of 120–150 cm, except in the Pesosjärvi area (1989). Of these measurements, only the vitality of Hypogymnia physodes is reported here.

The lichen monitoring of mountain birches in Vuoskojärvi started in 1989. The tape method proved to be poorly suited for use on crooked mountain birches with several stems. Therefore, in the second round of measuring in Vuoskojärvi (1991), only a species list was made at the heights of 50–100 cm, 100–150 cm, 150–200 cm and 200–250 cm.

The Pollution Sensitivity Index (PSI) for each area was calculated using the formula given in the revised IM Manual (Environment Data Centre 1993). Values for the sensitivity factor \( Q_n \) (an empirical sensitivity factor for each lichen species) were according to Hultengren et al. (1991; Table 2.4.3.2).

### Table 2.4.3.2. List of observed species (Nordic Council of Ministers 1988) and their \( Q_n \) values (Hultengren et al. 1991) for Pollution Sensitivity Index (PSI) and \( Q_v \) values (Mikkola, K. pers. comm. 1993) for Index of Atmospheric Purity (IAP) used in Epiphytes (EP) subprogramme.

<table>
<thead>
<tr>
<th>Species</th>
<th>( Q_n )</th>
<th>( Q_v )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alectoridium sarmentosa</td>
<td>7</td>
<td>4.1</td>
</tr>
<tr>
<td>Bryoria spp.</td>
<td>6(^1)</td>
<td>4.1</td>
</tr>
<tr>
<td>Cetraria chlorophylla</td>
<td>4</td>
<td>4.3</td>
</tr>
<tr>
<td>Hypocenomyces chlorophylla</td>
<td>2</td>
<td>3.9</td>
</tr>
<tr>
<td>Hypogymnia farinacea</td>
<td>5</td>
<td>2,(^2)</td>
</tr>
<tr>
<td>Hypogymnia physodes</td>
<td>2</td>
<td>2,(^2)</td>
</tr>
<tr>
<td>Hypogymnia tubulosa</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>Imshaugia aeritdes</td>
<td>7</td>
<td>3.8(^3)</td>
</tr>
<tr>
<td>Lecanora conizaeoides</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Melanelia olivacea</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>Parmelia sulcata</td>
<td>3</td>
<td>5.9</td>
</tr>
<tr>
<td>Parmeliopsis ambigua</td>
<td>2</td>
<td>3.4</td>
</tr>
<tr>
<td>Parmeliopsis hyperopta</td>
<td>3</td>
<td>3.8(^3)</td>
</tr>
<tr>
<td>Platismatia glauca</td>
<td>4</td>
<td>4.3</td>
</tr>
<tr>
<td>Pseudovernia furfuracea</td>
<td>4</td>
<td>4.6</td>
</tr>
<tr>
<td>Usnea spp.</td>
<td>5(^1)</td>
<td>4.3</td>
</tr>
<tr>
<td>Vulpicida pinastri</td>
<td>2</td>
<td>3.4</td>
</tr>
<tr>
<td>Pleurococcus viridis</td>
<td>2</td>
<td>2.9</td>
</tr>
<tr>
<td>Scoliciosporum chlorococcum</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\(^1\) Mean of the values given to Bryoria/Usnea species.

\(^2\) No value given.

\(^3\) Value for Parmeliopsis spp.

The Index of Atmospheric Purity (IAP) was calculated according to the formula (Kuusinen et al. 1990):

\[
IAP = 10^1 \times \sum \frac{Q_v}{f}
\]

where \( Q_v \) = average number of other species growing with the target (= indicator) species (Table 2.4.3.2); \( i = \) indicator species (Table 2.4.3.2); \( f = \) mean cover of the \( i \)th species/area.

Values for \( Q_v \) were taken from data obtained from the Eighth National Forest Inventory (8-NFI) by the Finnish Forest Research Institute (Mikkola, K. pers. comm. 1993). Only indicator species with \( Q_v \) values (a total of 14 species, Table 2.4.3.2) were included.

In Pesosjärvi, aerial green algae growing on spruce needles were observed in 1991 according to the IM Extended Programme (Environment Data Centre 1989a). Three branches of each of the 40 sample trees (height 3–7 m) were examined. Since 1991 the Aerial Green Algae (AL) subprogramme has been included in the IM Programme (Environment Data Centre 1993).

### 2.4.4 Understorey vegetation

The Understorey Vegetation (VG) subprogramme was carried out on 2–3 permanent vegetation plots (Mäkelä 1992). All plots are joint plots with the TR subprogramme (Fig. 2.2.1). At the beginning of monitoring in 1988 and 1989 in Valkkea-Kotinen, Pesosjärvi and Vuoskojärvi, the plots were also shared with the SC subprogramme, but later soil monitoring was discontinued on these plots. New soil chemistry plots were established near these old plots (Chapter 2.2).

In Valkkea-Kotinen the monitoring of understorey vegetation started in 1988 on five permanent plots (Table 2.2.1). Monitoring studies were repeated on one old and one new mineral soil plot in 1990. In Hietajärvi the monitoring started in 1990 on two mineral soil plots and on one peatland plot (Table 2.2.2). These plots were not remeasured until 1992. In Pesosjärvi the monitoring started on five mineral soil plots in 1989 (Table 2.2.3). Monitoring continued on two old mineral soil plots and on one new peatland plot in 1991. In Vuoskojärvi the monitoring started on four mineral soil plots in 1989 and continued on three of these plots (Table 2.2.4) in 1991. Results from discontinued plots are not presented in this report.

Detailed observations of understorey vegetation were performed on smaller sample plots (0.5 x 0.5-m) inside the intensive vegetation plots (Fig. 2.2.1). These sample plots were
established on intensive vegetation plots by using stratified random sampling: 2–3 sample plots for each 10 x 10-m quadrat depending on the heterogeneity of the intensive plot. Earlier in 1988 in Valkea-Kotinen larger (1.0 x 1.0-m) sample plots were used and placed on intensive vegetation plots using systematic sampling. In 1990 these plots were substituted for smaller (0.5 x 0.5-m) sample plots to standardize the methods on the Nordic level. Results of these larger plots are not reported here.

On each permanent sample plot shrub, field and bottom layers were studied. The shrub layer was defined as consisting of shrubs and trees with heights of 0.5–2.0 m. The field layer consists of tree saplings and shrubs with height < 0.5 m and other vascular plants regardless of height. The bottom layer consists of mosses and lichens. The definitions are different from those presented in IM Manual (Environment Data Centre 1989a), but are normally used in Finnish vegetation studies.

The observations were made in July–August, when the majority of the species are fully developed. The cover percentage of each layer, physiognomic group and species was estimated using scale 0.2, 0.5, 1, 2, 3, ...99, 100%. The cover of total litter and different litter types (needle, leaf, herb and twig) as well as the cover of divergent surface was also estimated, as was the cover of bare mineral soil in 1990–1991.

In addition to the mandatory variables (cover and plot frequency of species; Environment Data Centre 1989a, Bråkenhielm 1989), rooted and shoot frequencies of species were also recorded on 10 x 10-cm subplots. These measurements were made as a result of national interest and the results are not included in this report.

For each vegetation sample plot information on forest stand (relation to dominant tree layer and undergrowth, crown cover), soil, topographic position, slope, exposure etc. are reported as background information. Some background information is also reported for intensive vegetation plots (Kokko 1990, Mäkelä 1992).

### 2.4.5 Soil microbiology

Soil microbiology measurements were not included in IM subprogrammes until 1993 (Environment Data Centre 1993). However, some were already recommended in the former version of the Manual (Environment Data Centre 1989a). In Finland, a quite wide soil microbiology programme was conducted already since 1988 due to national interest.

**Needle litter decomposition**

Two-year-old shoots from a young Scots pine stand in the vicinity of the Valkea-Kotinen catchment were taken in June 1988. The shoots were dried at 60° C and the needles removed. Needles (1.0 g) were placed in an 8 x 8-cm nylon bag (mesh size 0.5 mm).

In June 1990, 60 bags were placed on the humus layer at each of five experimental sites in both the Valkea-Kotinen and Hietajärvi catchments. A third of the bags at each site were retrieved after one year (1991) and another third after two years (1992); the remaining bags were retrieved after the third year of exposure (1993). Upon retrieval, the bags were immediately air-dried to halt the decomposition process. The weight of the remaining needle litter was recorded and the weight loss calculated. Only the one-year decomposition results are presented in this report.

**Cellulose decomposition**

Cellulose decomposition was measured in 1989 and 1990. The rate of cellulose decomposition was determined as the weight loss of strips of bleached α-cellulose. Cellulose strips (1 x 30 x 50 mm) were dried at 105° C and then allowed to stabilize to room temperature for two hours before recording their weight. Four cellulose strips were placed lengthwise in a nylon bag (mesh size 1 mm).

In October–November of 1989 and 1990 the cellulose bags were set out in two lines in intensive plots on upland soils: Valkea-Kotinen Plots 3–7; Hietajärvi Plots 1, 2, 4 and 5; Pesosjärvi Plots 1–5; Vuoskójärvi Plots 1–4 (Figs. 2.1.2.2, 2.1.3.2, 2.1.4.2 and 2.1.5.2). In...
each line, five bags were placed on the surface of the humus layer and five inserted into the humus layer at an angle (15°) to a depth of 5 cm (Fig. 2.4.5.1). There were thus a total of 20 cellulose decomposition bags per plot altogether. The bags were left out for one year. The decomposition rate of the cellulose is often so high that little remains after one year.

When the bags were retrieved, roots and mosses were removed and the bags gently washed. The bags were then dried as described above and the remaining cellulose weighed. The cellulose decomposition was then calculated as the weight loss.

Soil respiration, ATP concentration, microbial biomass and metabolic quotient

The soil microbiological measurements were carried out in two of the IM catchments, Valkea-Kotinen and Hietajärvi. Five sampling plots were located in representative forest stands in both catchment areas. A composite sample of the humus layer in each plot was taken in July 1991. Each composite sample consisted of 10 cores of the F + H horizons taken randomly using a stainless steel cylinder (75-mm-diameter). The samples were sieved (mesh size = 4 mm), visible plant material removed and the sample stored at 4°C. The microbiological measurements were completed within two weeks of sample collection.

Soil respiration and the concentration of adenosine triphosphate (ATP) in the humus layer samples, which is related to the amount of active microbial biomass, were measured according to Vanhala and Ahtiainen (1994). The carbon content of the total microbial biomass was determined using the method described by Martikainen and Palojarvi (1990). Extractable organic carbon was determined using an IR-carbon analyser and the content of organic matter was measured as LOI using a temperature of 550°C. The metabolic quotient (qCO₂) was calculated as the ratio of respired carbon and microbial biomass carbon contents.

2.4.6 Hydrobiology

Hydrobiological measurements were carried out more extensively than described in the Hydrobiology (WB) subprogramme (Environment Data Centre 1989a) due to national interest. The complete set of measurements are presented in the optimum programme of Hydrobiology of Lakes as described by Keskitalo and Salonen (1994). Macrophyte and bacteria results will be reported later.

Plankton communities

Plankton studies have been carried out on Lakes Valkea-Kotinen and Iso Hietajärvi since spring 1990. In general plankton samples were taken and processes measured weekly from the ice melt to the end of September. Only zooplankton were sampled biweekly. In October the respective frequencies were biweekly and monthly during ice cover. In Lake Iso Hietajärvi, plankton samples were not taken during winter.

Primary production and other processes were assessed in the middle of the lakes (Figs. 2.1.2.2 and 2.1.3.2) from different depths of the epilimnion. Plankton assemblage samples were taken at two sampling sites and were pooled to obtain one vertical series covering the entire water column. Some processes were also measured at Pieni Hietajärvi and at its inlet brooklet and at the outlet brooklet of Iso Hietajärvi (Fig. 2.1.3.2).

Samples for the determination of primary production, inorganic carbon dark fixation, plankton respiration, and net community production (the latter only in Lake Valkea-Kotinen) were taken with a Limnos sampler (Keskitalo & Salonen 1994). Primary production and dark fixation were determined with the acidification and bubbling modification of the ¹⁴C method (Schindler et al. 1972, Niemi et al. 1983). The samples were incubated for 24 h in situ, after which formaldehyde solution was added to stop the carbon assimilation. Radioactivities were measured with a scintillation counter, and the primary production results calculated as differences between light and dark fixation of carbon.

Respiration of plankton was measured as an increase of dissolved inorganic carbon (DIC) in dark bottles and net community production as a decrease of DIC in light bottles during an incubation time of 24 h in situ. The DIC samples were carried in crushed ice to the laboratory and measured with a carbon analyser (Salonen 1981) usually during the same day after sampling or incubation.

Chlorophyll, phytoplankton and zooplankton samples were taken with a 1.0-m-long, 6.6-dm³ tube sampler from Lake Valkea-Kotinen and with a Limnos sampler from Hietajärvi. When using the Limnos (height 0.3-m), samples were taken stepwise downwards to cover the 1-m (or 2-m) columns. Subsamples from the column sample were taken for chlorophyll, phytoplankton and diatoms, and the rest (usually 11–12 dm³) was concentrated on a 50-μm plankton net to obtain zooplankton.

For the chlorophyll determination algae
were filtered through glass microfibre filters. Chlorophyll was extracted in 94% ethanol, and the absorbances were measured with a spectrophotometer at wavelengths of 665 and 750 nm. In 1990 the extraction time was 18 h at a temperature of +4°C. In 1991 chlorophyll was extracted in hot ethanol (5 min in a 75°C bath) and measured immediately. In four parallel sample series there were no statistically significant differences between the results calculated by these two methods (multifactor ANOVA).

Phytoplankton samples for species determination were fixed with acid Lugol's solution and stored a maximum of one year before microscopy. After settling for 24 h in a 50-cm³ chamber (Utermöhl 1958), the sample was counted with an inverted microscope. For larger species 25% of the cuvette bottom area was counted with a magnification of 390 x, and for smaller species 30 fields of view were counted with a magnification of 625 x.

Zooplankton samples (excluding Protozoa) were preserved in 4% formaldehyde. Small-size (<200 μm) fractions were counted with an inverted microscope using the settling chamber technique while large fractions were counted using a dissecting microscope and a grooved disk. In addition to microscopic counting, the carbon contents of some species were determined by a carbon analyser, and biomasses in 1990–1991 expressed as carbon content will be reported elsewhere. Enumeration of protozoan plankton was done in connection with the phytoplankton study.

Phytoplankton and zooplankton samples were stored in an environmental sample repository and documented with video and photographic techniques (Keskitalo & Salonen 1994).

**Benthic fauna**

Soft profundal and intermediate depth bottoms were sampled with an Ekman grab (sampling area 256–298 cm², 2–5 samples) and the littoral regions by a hand net, respectively. The sampling depths are shown in Table 2.4.6.1.

<table>
<thead>
<tr>
<th>Lake</th>
<th>Profundal</th>
<th>Intermediate</th>
<th>Littoral</th>
</tr>
</thead>
<tbody>
<tr>
<td>Valkea-Kotinen</td>
<td>6.0–6.5</td>
<td>2.5–3.0</td>
<td>0.5–1.0</td>
</tr>
<tr>
<td>Iso Hietajärvi</td>
<td>7.0–7.5</td>
<td>3.0–4.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Pesosjärvi</td>
<td>12.0</td>
<td>5.0–6.0</td>
<td>0.5</td>
</tr>
<tr>
<td>Vuoskojärvi</td>
<td>5.5–6.0</td>
<td></td>
<td>0.5</td>
</tr>
</tbody>
</table>

The littoral sampling site in Lake Vuoskojärvi was stony and covered by benthic algae, while in Lakes Pesosjärvi and Iso Hietajärvi the sites were situated on sandy silty bottoms with emergent vegetation. In Lake Valkea-Kotinen the bottom was soft and muddy with sparse Nuphar vegetation. The profundal regions were sampled in all lakes both in spring and autumn, while other depths were sampled only occasionally. The sieved samples (mesh size 0.5 mm, except 0.6 mm in 1990–1991 in Lake Valkea-Kotinen) were preserved in ethanol in the field and sorting of the animals was performed in the laboratory on a white dish through an illuminated magnification (6x) glass. The biomass values are expressed as organic dry weights converted from wet weight measurements multiplied by a factor of 0.11 and for molluscs 0.055, respectively (Palomäki 1994). A modified Benthic Quality Index (BQI; Paasivirta 1987) was calculated on the profundal data. Index values vary from 1 (ultraoligotrophy) to 5 (eutrophy). When no indicators were found, the index value was zero. Some information is already published in Koskenniemi and Sevola (1992).

**Fish**

The fish communities of the lakes were sampled by using eight-net series of 1.8 x 30m benthic gill nets. The mesh sizes of the nets were 12, 15, 20, 25, 30, 35, 45 and 60 mm, except in Hietajärvi where the 30-mm net was replaced by one with 75-mm mesh size. The nets were kept in the lakes overnight. The intensity of the sampling was approximately one net-series catch per 10 ha of lake area. Hietajärvi was sampled in 1988, the other lakes in 1990.

All fish of each catch were measured for length frequency distribution. Samples of 50 individuals of each fish species were taken for the determination of age and growth. In Valkea-Kotinen the size of the perch (Perca fluviatilis) population was estimated with a mark recapture procedure in 1991. The fish were caught with wire traps (1-cm square mesh) during their spawning time in May, measured for length frequency distribution, marked (fin clipping) and released. No fish were removed from the lake during the marking and recapturing which lasted about three weeks.

**2.4.7 Breeding birds**

From each monitoring area a uniform study plot of 60 ha was chosen which represented the natural habitats of the area as well as possible. The land birds of the study plots were censused by a standard mapping method (Koskimies & Väisänen 1991). Each plot was visited 10 times during a breeding season. The study plot of Valkea-Kotinen also covered parts of the Musta-Kotinen catchment and parts outside both.

The waterfowl (divers, grebes, swans, geese and ducks) and larids (gulls and terns) of the study plots were also censused by the point-count method, i.e. looking for swimming birds from the shore.

The catchment area outside the study plot was visited during the breeding season on several mornings to list the breeding species found in the entire catchment. The catchment of Musta-Kotinen was studied simultaneously with Valkea-Kotinen and the results of these two catchments are presented together. An index of the breeding evidence was used to clarify the breeding status of different bird species.

2.5 Data storage and handling

2.5.1 International data base

The data network

Implementation of the IM Programme in each country is divided between a number of EIs (Chapter 1.2) and laboratories responsible for the performance of subprogrammes within the monitoring areas. In principle, each country has chosen one institute as an NFP, which should serve as the collector of national data and is responsible for communication to the EDC. The NFPs are responsible for the reporting of the national data in the appropriate format to the EDC. However, Finnish EIs have reported their values directly to the EDC. Information and data flow within the Programme are shown in Figure 2.5.1.1.

The EDC is responsible for the storage of data, and the evaluation and reporting of spatial and temporal patterns on a continental scale. During the Pilot phase of the Programme (1989–1991) reporting included fluxes of elements into and out of IM areas (long-term data, if available), ion mass budgets and proton budgets. Biological parameters have also been reported. It is intended to analyse how changes in the biotic components of the ecosystem correlate with changes in the physicochemical state of the IM areas. The use of models for forecasting the response of ecosystems to a reduction of pollutants is one of the main goals for data analysis. So far model runs have been carried out using the SMART acidification model (Bleeker et al. 1994a, 1994b; Chapter 2.3.8).

Data reporting formats

Data reporting formats are structured so as to ease storage and processing at the EDC. The data reporting formats are divided into three types of data subsets: areal description, station identification and variable subsets.

The areal description subset of data comprises data common to the monitoring area. Such data are normally reported only once and
include, e.g., location, climate, vegetation zone, length of growing season, topography and hydrology etc. (see Chapters 2.1.2–2.1.5). The results from animal and plant inventories are reported every five years.

The station identification subset comprises data specifying the stations, i.e. the measuring or observation sites/plots. A station may consist of a number of pooled measuring sites. The station subset of data is of a fixed nature and includes the vegetation and soil types, location within the monitoring area, and codes for identifying subprogramme and the institute performing the measurements.

The variable subset of data contains the actual measured or observed values or calculated statistics (mean, extremes, deviation etc.) of a specific variable at the stations, including information on sampling month, medium (e.g. plant material, soil, lake water etc.) and level (sampling height in the ecosystem). A variable file is identified by its subprogramme, performer institute and station codes.

### 2.5.2 National data bases

In Finland, EIs have reported their data directly to the EDC. Due to close connections between the EIs and the EDC, the NFP level in Finland has not been established and each EI has stored the primary data in its own data bases and reported it to the EDC. However, not all the data are yet properly stored in a data base, which is the case especially with subprogrammes carried out by the universities (Table 2.5.2.1).

Table 2.5.2.1. Storage of data of Integrated Monitoring subprogrammes in Expert Institutes. + = permanent data base. – = no permanent data base.

<table>
<thead>
<tr>
<th>Subprogramme</th>
<th>Expert Institute 1</th>
<th>Data base</th>
</tr>
</thead>
<tbody>
<tr>
<td>AM Meteorology</td>
<td>FMI</td>
<td>+</td>
</tr>
<tr>
<td>AC Air Chemistry</td>
<td>FMI</td>
<td>+</td>
</tr>
<tr>
<td>DC Precipitation Chemistry</td>
<td>FMI</td>
<td>+</td>
</tr>
<tr>
<td>TF Throughfall chemistry</td>
<td>FFRI</td>
<td>+</td>
</tr>
<tr>
<td>SF Stemflow</td>
<td>FFRI</td>
<td>+</td>
</tr>
<tr>
<td>SC Soil chemistry</td>
<td>FFRI</td>
<td>+</td>
</tr>
<tr>
<td>SW Soil water chemistry</td>
<td>FFRI</td>
<td>+</td>
</tr>
<tr>
<td>RW Runoff water chemistry</td>
<td>WERI, WED</td>
<td>+</td>
</tr>
<tr>
<td>WB Hydrobiology</td>
<td>Universities, WERI, WED, FGFRI</td>
<td>-</td>
</tr>
<tr>
<td>AR Forest stand</td>
<td>FFRI</td>
<td>+</td>
</tr>
<tr>
<td>TR Trees</td>
<td>FFRI</td>
<td>+</td>
</tr>
<tr>
<td>VG Understorey vegetation</td>
<td>WERI</td>
<td>+</td>
</tr>
<tr>
<td>EP Epiphytas</td>
<td>WERI, Universities</td>
<td>+</td>
</tr>
<tr>
<td>NC Foliage chemistry</td>
<td>FFRI</td>
<td>+</td>
</tr>
<tr>
<td>LF Litterfall</td>
<td>FFRI</td>
<td>+</td>
</tr>
<tr>
<td>MC Moss chemistry</td>
<td>WERI</td>
<td>-</td>
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1 Institute:
FMI = Finnish Meteorological Institute.
FFRI = Finnish Forest Research Institute.
WERI = Water and Environment Research Institute.
WED = Water and Environment Districts.
FGFRI = Finnish Game and Fisheries Research Institute.
Universities: Universities of Helsinki, Joensuu, Oulu and Turku.
3 Results and discussion

3.1 Climate and meteorology

The temperature, precipitation and wind data at weather stations run by the Finnish Meteorological Institute nearest the Integrated Monitoring (IM) areas are given in Figures 3.1.1–3.1.10. For IM areas Valkea-Kotinen and Pesosjärvi there are temperature and precipitation data from two nearby weather stations. The stations nearest to the IM areas (Iso-Evo

![Image of temperature data](image1)


![Image of precipitation data](image2)