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Monitoring and Assessment of the Ecological Status of Lakes

A pilot procedure developed and tested in the Life Vuoksi project

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Foreword

This publication is the outcome of one part of the Life Vuoksi Project. The Project, titled as "Role of the littoral area as a part of an optimal model for environmental monitoring and the involvement of local people", has been a wide co-operation project involving three regional environmental authorities in eastern Finland on the Vuoksi River Basin, namely the South Savo (SSREC), North Savo (NSREC) and North Karelia Regional Environment Centres (NKREC). The Finnish Environment Institute (SYKE) has also participated in the project and the University of Oulu has been the fifth project partner.

In the Vuoksi River Basin, as elsewhere in Finland, there are many actors and stakeholders actively related to the monitoring and management of water bodies. Effective data handling and information flow is needed for successful decision-making. Due to the large area of the Vuoksi River Basin, varying river basin characteristics and the number of interest groups concerned, a cost-effective integrated monitoring and assessment procedure is obviously needed. The assessment of the ecological status of lakes is a basic issue for the monitoring activities. This work provides a concrete example how to approach challenging monitoring and assessment issues in practise. The project provides a good basis for the further development of the monitoring and assessment procedures in the future.

In addition to the presentation and testing of the proposed monitoring and assessment procedure some limnological aspects and main elements concerning monitoring and assessment issues have been described in this report to provide some necessary and useful background information about the matter as a whole.

The Life Vuoksi Project was started in April 2001 and completed in March 2004. The EU Life Environment Fund has financially supported the project. This report, in which the pilot monitoring and assessment procedure is outlined, has been mainly carried out during the last half of the project. The results from the other parts of the project have been published earlier and used as one important source of information for this work.

SYKE has been responsible for the elaboration of the pilot monitoring and assessment procedure presented in this report. The regional organisations have had different responsibilities according to their expertise as well as their geographical location. The South Savo and North Savo Regional Environment Centres have been responsible especially for the aquatic macrophyte studies and the North Karelia Regional Environment Centre especially for the benthic macroinvertebrates studies. The South Savo Regional Environment Centre has been responsible fort the management of the project as a whole. The University of Oulu has provided expertise in aerial photography for monitoring purposes. The international exchange of knowledge has been ensured by co-operation with the subcontractors from Northern Ireland.

The compilation of this report would not have been possible without co-operation of a number of experts representing all Project Partners. From SYKE Monitoring Coordinator Pertti Heinonen, Research Scientists Olli-Pekka Pietiläinen, Krister Karttunen, Heikki Mäkinen, Ansa Pilke, Heidi Vuoristo, Jouko Rissanen and Johanna Issakainen and Hydrobiologist Liisa Lepistö have participated in the work. From the South Savo Regional Environment Centre the participants are Project Coordinator Outi Airaksinen, Research Scientist Olavi Sandman, Hydrobiologists Pertti Manninen and Pekka Sojakka, Biologists Jarkko Leka and Arto Ustinov. Research Scientists Antti Kanninen, Antti Haapala and Veli-Matti Vallinkoski, Limnologist Taina Hammar and Research Professor Kristina Servomaa represented the North Savo Regional Environment Centre. Head of Research Hannu Luotonen, Limnologists Riitta Niinioja and Paula Mononen and Research Scientists Anna-Liisa Holopainen, Heikki Hämäläinen and Kimmo Tolonen have represented the North Karelia Environment Centre. Research Scientist Kirsi Valta-Hulkkonen from the University of Oulu has participated in the work.

The authors would like to thank Principal Biologist Peter Hale and Victoria Crone from the Environment Heritage Service, Northern Ireland, and Professor Brian Rippey from the University of Ulster, Northern Ireland, for commenting the manuscript. The authors also thank Docent Markku Viljanen and Dr. Seppo Rekolainen for the audition of the publication and Mr. Tim Whale for revising the English of the manuscript.

Contents

Introduction

1.1 Background

The management of water quality in lakes and rivers has been an important environmental issue in Europe during the past decades. Although remarkable improvements have been made, the topic is still current. The European Community is steadily working to improve water quality and to guarantee good status of all waters. Monitoring and assessment of water quality is one important tool for water management. Monitoring and assessment activities produce information on, for example, trends in water quality and help us to focus protection measures to right targets. Monitoring and assessment procedures also give information about the success of protection activities.

Implementation of the EU Water Framework Directive (WFD, Directive 2000/60/EC), which came into force in December 2000, is a current and challenging environmental issue in Europe. According to the Directive, all waters should be in good status by 2015. The WFD brings some new aspects to the monitoring and assessment issues. According to the Directive the assessment of ecological status of rivers and lakes should be mainly based on biological elements, such as aquatic macrophytes, phytobenthos, benthic macroinvertebrates, phytoplankton and fish. Traditionally, these elements have not all been included in all monitoring schemes.

As the biological elements are not very often included in routine monitoring, experience is needed to be able to use these elements properly. Information is needed on the suitability of different elements and parameters for monitoring purposes, responses of the elements/parameters to different pressures, how sampling should be carried out, what would be the costs of monitoring, etc. According to the WFD the assessment of ecological status should be based on the Ecological Quality Ratios (EQR). Currently, there is a strong pan-European need to clarify how to use different biological elements and how to combine the scorings of these elements. The development of ecological assessment and classification system is not a simple issue but "*one of the most important and technically challenging parts of the implementation of the Water Framework Directive*" as stated by the Water Directors at the European level (Overall Approach to the classification of Ecological Status and Ecological Potential, 2003). Furthermore, the Water Directors stated that "*the development and improvement of appropriate* (ecological assessment and classification) *systems will involve a learning process*". These statements clearly indicate that the implementation of the WFD is not an easy and rapid issue to solve but a challenging and time-consuming learning process for years to come.

1.2 Life Vuoksi Project

The Life Vuoksi Project can be considered as part of the above-mentioned pan-European learning process. The project is supporting the implementation of the WFD by producing information and practical examples upon issues related to the monitoring and assessment of the biological elements of lakes, especially of the littoral zone, and upon the role of local inhabitants.

This publication is the outcome of one of the work packages of the Life Vuoksi Project. The key aim for this work was to compile an assessment and monitoring system especially taking into account the littoral zone of lakes. A harmonized monitoring and assessment procedure has not been available for defining the ecological status of water bodies. Only numerous separate, biological and water quality practices exist. This work is a pilot towards an integrated single ecological assessment procedure as required by the WFD. More information about the subject is provided in the publications "Overall Approach to the classification of Ecological Status and Ecological Potential" (2003) and "Guidance on establishing reference conditions and ecological class boundaries for inland surface waters (2003)", produced by the Water Framework Directive Common Implementation Strategy Working Groups.

The results from the other work packages of the Life Vuoksi Project have been published earlier in separate volumes and have been important sources of information for preparing this report. As the previous project publications have been mainly published in Finnish, some of the key results, especially concerning the parameter testing, have been summarised in this report.

The testing phase of the biological parameters has been a very important part of the project with the aim to compare the suitability and cost-efficiency of different methods and parameters in the littoral zone. The monitoring methods to be tested were selected based on the experts' opinions and the gathered information and data. The studied biological elements were aquatic macrophyte vegetation (Leka et al. 2003), benthic macroinvertebartes (Tolonen et al. 2003), as well as periphyton and phytoplankton (Sojakka et al. 2003a, b). Chapter 4 in this report summarises these works.

One of the tasks of the project was to collect and evaluate the existing biological and water quality data on lakes in the Vuoksi River Basin to give a summary of the quality of the available data (Airaksinen 2004). The target areas for further project activities were selected on the basis of the existing information to represent typical lake and land use types in the Vuoksi River Basin. The evaluation of the loading pressures and present water quality was carried out on the target lakes (Manninen et al. 2003).

As there are many interest groups and stakeholders closely related to the monitoring, assessment and management of water bodies, the Life Vuoksi Project has also dealt with public participation issues and studied the role of local people in water management (Sandman et al. 2004).

Major aspects concerning monitoring and assessment of the ecological status of lakes

2

2.1 General aspects

Generally, any environmental monitoring programme shall never be kept as a totally independent piece of activity. In contrast, it should always be considered as an important element of a larger environmental context, first in the assessment of the status and trends of the environment in the past, and secondly as a basic operational precondition for preparing and implementing sustainable solutions in environmental protection and management (Fig. 1).

This cycle of monitoring activities should be considered as a continuous iterative process, which shall be checked and possibly renewed at certain intervals. A very suitable moment to check and renew any monitoring programme is bound with the reporting phase.

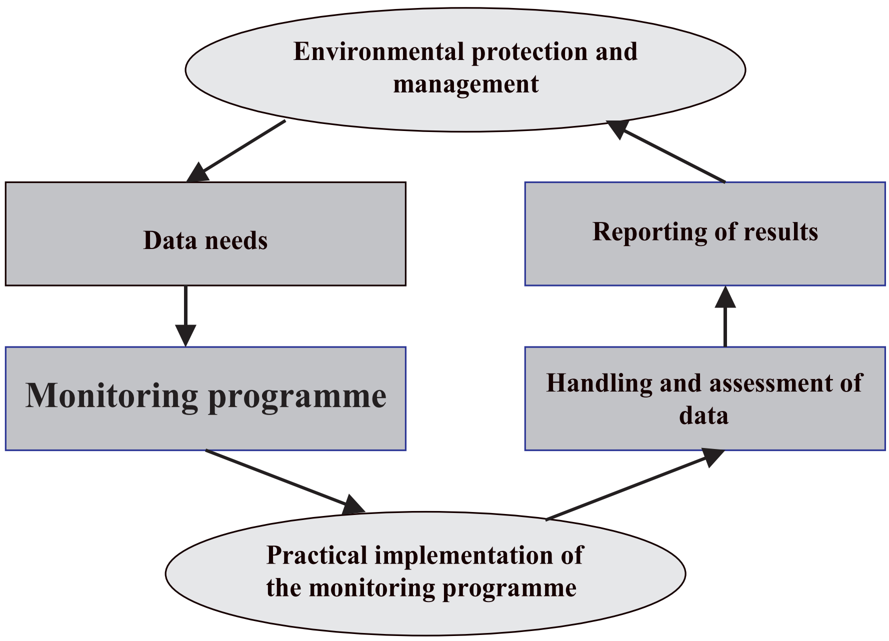


Figure 1.The cycle of monitoring activities.

At the start of planning a monitoring programme – or a monitoring and assessment procedure – available knowledge e.g. from other monitoring programmes should be utilized and activities of the monitoring cycle should be planned as far as possible.

At the first stages of planning a lake monitoring programme it is necessary to carefully identify all the relevant needs for monitoring activities to obtain reasonable and economic solutions. In Finland this identification has mostly been achieved by regional or national water authorities, which are responsible for planning water protection measures at regional and national level. In the case of statutory monitoring of point source discharges (so-called local pollution control monitoring), the programmes are planned by polluters or consulting firms and accepted by regional authorities. People living close to lakes, or who are using the lakes, or even being the owners of the water areas should be provided with an opportunity to present their views and demands concerning monitoring programmes. The general guidelines used in the monitoring planning processes are usually established at national level. However, the planning of any lake monitoring programme should always be kept as open a process as possible.

Besides local, regional and national needs, there are also many important international demands, especially European, usually issued by different EU Directives, which should be taken into account in the monitoring and assessment planning process. EU Member States have to monitor and report e.g. the quality of bathing water (Council Directive 76/160/EEC of 8 December 1975) and water intended for human consumption (Council Directive 98/83/EC of 3 November 1998). Furthermore, the EU demands continuous monitoring of urban waste waters (Council Directive 91/271/EEC of 21 May 1991), industrial sewages (Council Directive 96/61/EC of 24 September 1996), and fish waters (Freshwater Fish Directive 78/659/EEC). The pollution caused by nitrates from agriculture is also controlled by the EU (Council Directive 91/676/EEC of 12 December 1991).

In addition to the other directives related to freshwaters, the key directive concerning lake monitoring is, however, the EU Water Framework Directive (WFD). The WFD sets many-sided monitoring obligations for water bodies (presented in the Annex V).

One important issue regarding monitoring programmes is to define the actual sites and components (elements/parameters), that have to be monitored, as well as monitoring frequencies. Different guidelines and handbooks offer many good "recipes" for lake monitoring. In Finland various national demands, and the demands derived from EU directives and their obligations should be followed. At present, the requirements of the WFD are very basic and the Directive necessitates a monitoring of ecological status and monitoring of chemical status in different water bodies. Therefore, the WFD itself and several guidelines produced to help the implementation of the Directive (e.g. Water Framework Directive, Common Implementation Strategy, Working Group 2.7 Monitoring, 2003) are controlling the basic set of monitoring requirements widely in Europe.

Generally, monitoring programmes are presumed to be stable for a longer period of time with the same sampling seasons, sampling sites and sampling depths and especially with the same monitoring methods. In sampling ISO-, CEN- or national standards or at least other well documented and validated methods are used. Quality assurance is also needed in the sampling phase as well as in data handling and reporting procedures. Quality assurance systems are used to ensure the comparability of the results originating from different periods and different lakes.

Finally, we have to identify needs deriving from the assessment and reporting procedures. In most cases, any reports delivered to the EU regarding the implementation of different directives have to be in a prefixed format. For national purposes the demands are often more variable depending, for example, on the administrative level (national, regional, local) where the data is produced and utilised. The needs of the general public have to be kept in mind also in this context.

2.2 Limnological aspects

When preparing a monitoring and assessment procedure for a lake, we have to keep in mind, that each lake is only one element of a larger hydrological system/cycle of the river basin. Accordingly, lake monitoring is only one part of an entire river basin monitoring. Different water bodies in the watershed are in many cases more or less closely connected to each other. As shown in Figure 2, lake NN is situated in the lower reaches of a river basin. In this case the number and location of other lakes in the upper reaches of the basin can have significant impact on the nutrient flow discharged into the lake NN and thus also on the state of the lake. A good knowledge of the hydrological properties is essential to understand the ecology of the lake concerned.

In Case 1 (Fig. 2), there is only Lake NN in the whole river basin. Consequently, in Case 1, Lake NN is more dependent on, for example, heavy summer rain showers than in Cases 2 and 3, where other lakes of the river basin effectively smooth water flows. As a result, the relative phosphorus load into the lake (NN) is significantly different in three cases, especially in those river basins with extensive agricultural or forestry areas, i.e. potential sources of non-point loading.

The location of different types of loading factors compared to the location of the lake itself is for the same reasons a very important aspect (Fig. 3). The number and spatial distribution of lakes and different loading factors, as well as different temporal scales, should therefore be carefully taken into account early in planning a monitoring programme. In many cases the nutrient load from an urban wastewater treatment plant is very constant, whereas the load from industrial sources varies e.g. according to different production processes. The load from non-point sources, such as agriculture, often varies significantly on a daily, seasonal and inter-annual basis.

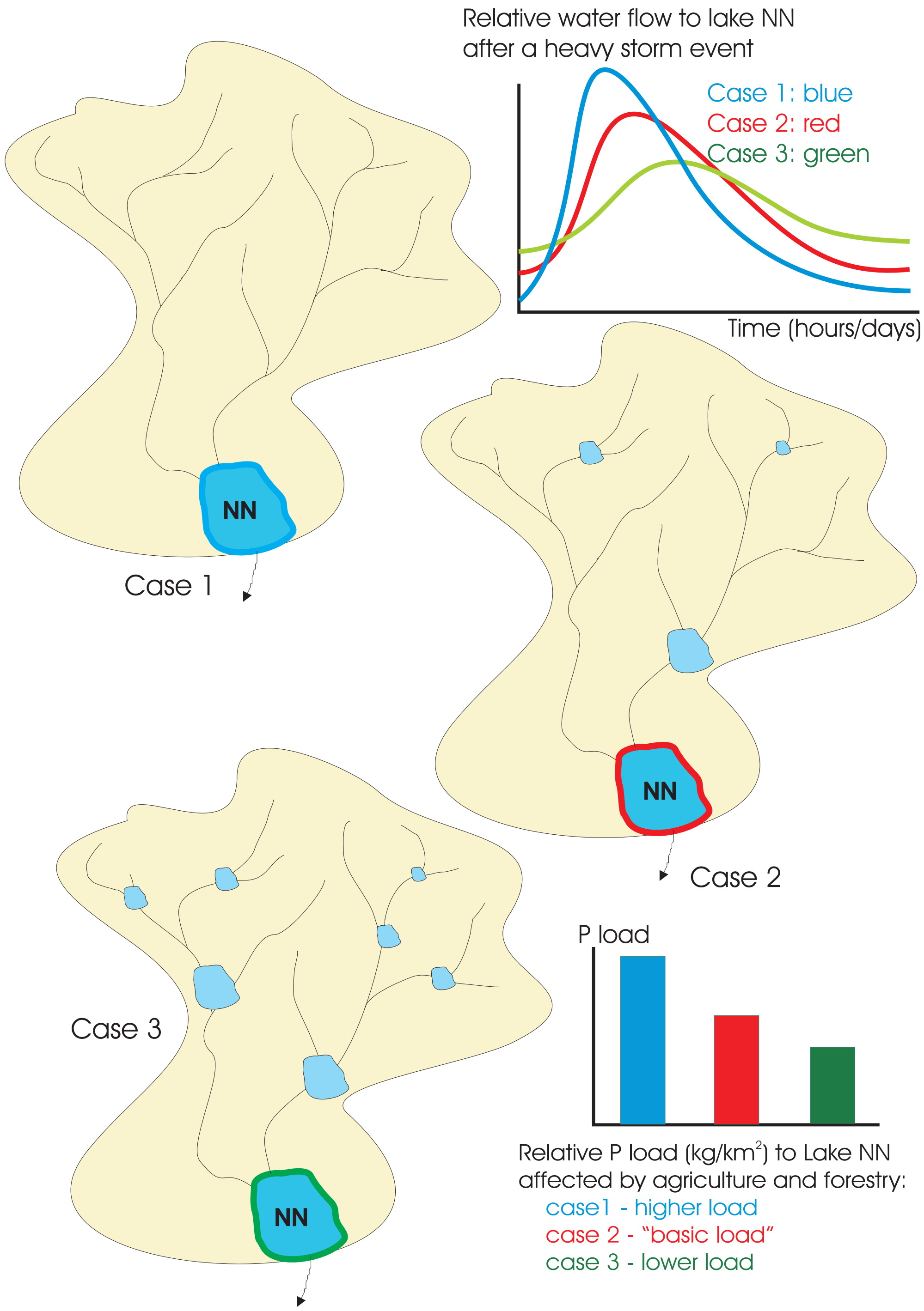


Figure 2. A schematic representation of the potential effect of upstream lakes on the relative water flow and relative P load into Lake NN.

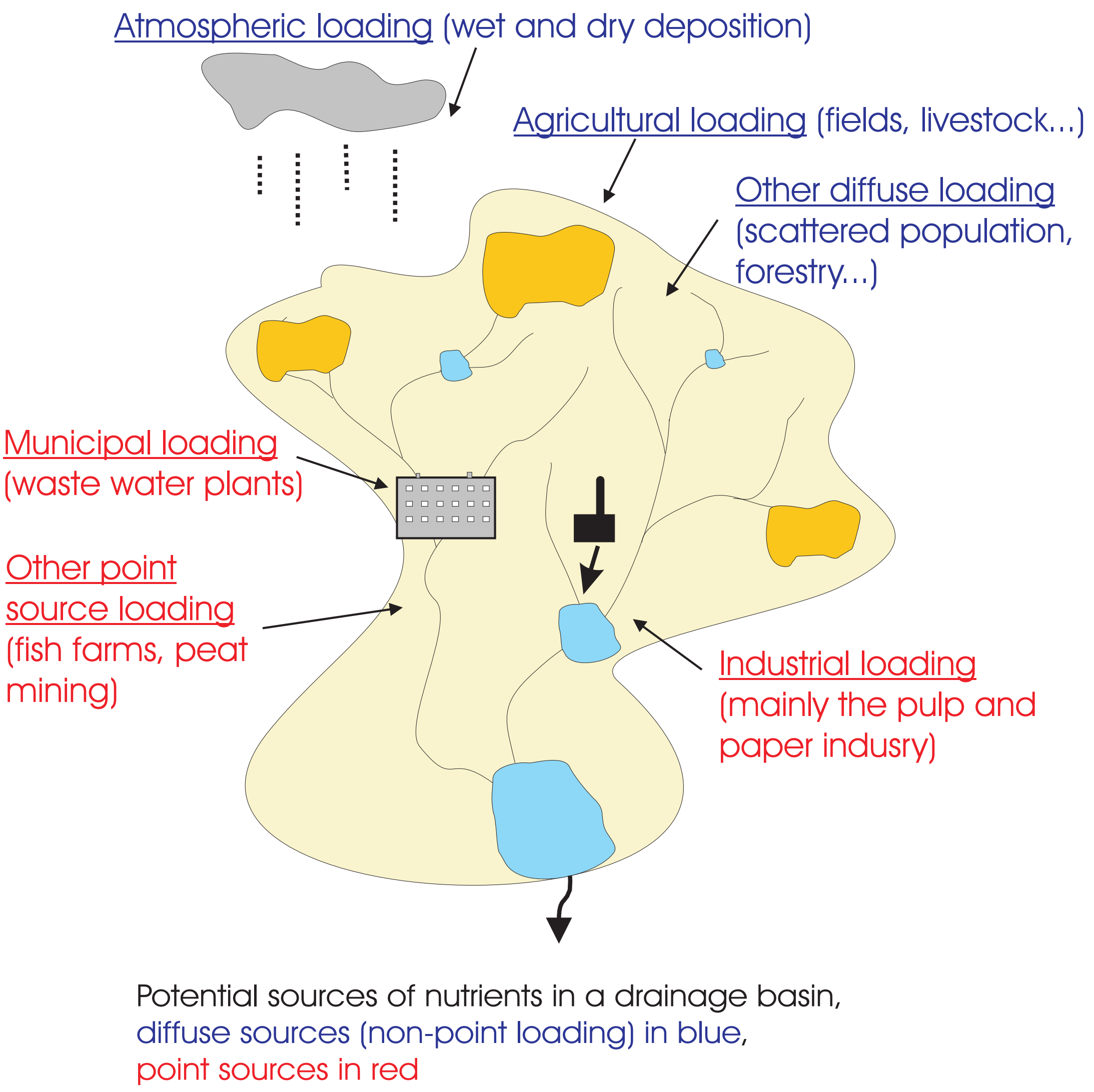


Figure 3. Major loading factors affecting the state of lakes in the Nordic countries.

The preparation of a monitoring and assessment procedure for a single lake also requires that we take into account morphological characteristics of the lake (Fig. 4).

Deep lakes with a relatively narrow littoral zone differ markedly from shallow lakes that can proportionally have a much wider littoral zone. The effect of wind during an ice-free season, re-suspension of organic and inorganic material and retention time are quite different in these two morphologically different lake types. Therefore, the abundances and relationships concerning different biological elements of the biocoenosis are usually significantly different in these two basic types of lakes.

Monitoring programmes should be organized in such a way that relevant information can be gained from all important areas and depths to enable a reliable assessment and classification procedure for defining ecological status of hydromorphologically different lakes.

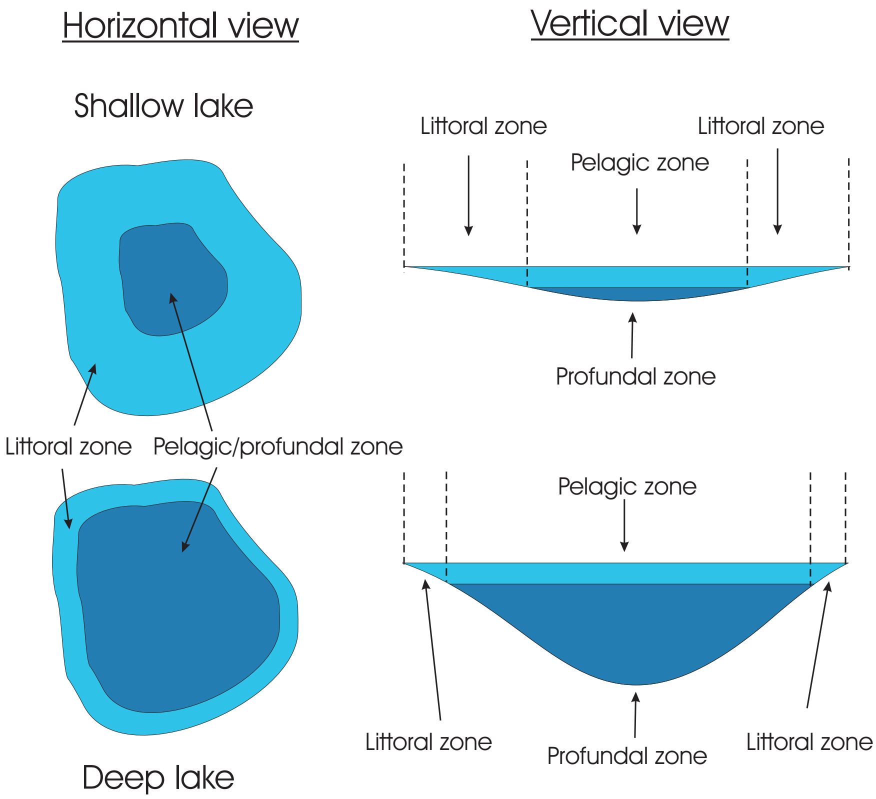


Figure 4. Two hydro-morphologically different lakes showing the proportional area and significance of littoral and pelagic/profundal zones.

From the limnological point of view, it is extremely important that monitoring sites are placed in an appropriate and representative way. In Finland and many other European countries, monitoring and assessment of the status of deep lakes has traditionally been focused on the deepest parts of lakes. The basis for this common practice has arisen from the following limnological realities:

- During the summer stratification period, stratified water layers of a stratified lake can usually be found in the deepest parts of the lake,

- oxygen deficiency can first be found in the hypolimnion (deep water column) of a lake affected by anthropogenic pressures,
- the oxygen content of the hypolimnetic area is crucial for the development of internal loading of nutrients, especially that of phosphorus,
- many large or otherwise important lakes have bathymetric maps or other relevant data. These sources enable some volumetric estimations and calculations (e.g. the total amounts of nutrients), which are valuable information in the long-term monitoring of lakes. Calculations can easily be made from samples taken vertically from the deepest part of lakes,
- the pelagic areas are good for monitoring phytoplankton, the most important group of primary producers in deeper lakes,
- the bottom fauna of the profundal zone is a good indicator of lake trophic status and eutrophication and
- in many lakes, the pelagic area (open water area) is the most important part of the lake for commercial fishing.

Despite the traditional emphasis of the role of the pelagic area of a lake, the littoral zone, i.e. the shallow-water zone of a lake, has also an important role not only in the assessment of the general status of lakes, but also as a subject of general public discussions. Amongst many others, the following main aspects have increased the interest in the littoral area:

- The significance of biological quality elements in the implementation of the WFD, especially the need to monitor macrophytes and phytobenthos, and also benthic macroinvertebrates in the littoral zone,
- the sensitivity of periphytic growth to indicate early phases of eutrophication, especially the harmful sliming of shorelines, fishing nets and piers,
- the role of macrophytes as an indicator of long-term changes in the water ecosystem,
- the importance of the littoral zone as a fundamental breeding and feeding area for many groups and species of animals and
- the interest and concern of local people about the state of their nearest water area is mainly directed to the shoreline, i.e. the littoral area.

People living in the vicinity of lakes, or people who are regularly using lakes for swimming, fishing or other recreational purposes are more interested in knowing about the part of water body they are mainly using, i.e. the littoral zone. In many cases, they have even found disparity between monitoring reports (especially classification maps based on monitoring data from the pelagic and profundal zones of lakes) and their own impression of the status, based on their own understanding and every day visual observations.

To focus monitoring activities on the lake itself is, however, not adequate. Besides the hydrological and limnological monitoring of water resources, it is also important to obtain simultaneously a lot of other information. For example, it is important to know the natural conditions of the watershed area, and actual pressure factors affecting water bodies.

The most important background information and data of the watershed area are as follows:

- Climate (seasons, temperature, precipitation, prevailing wind directions),
- land use (agriculture and forestry, built environment),
- population density in the river basin area (inhabitants/km^2),
- wastewater load (urban and industrial waste water, fish farming etc.) and
- non-point loading (agriculture, forestry, storm water etc.).

Data from other monitoring programmes covering other relevant elements of nature and the environment should be used especially in the assessment of hydrological and limnological data of the lake concerned.

Taking into account all the relevant aspects concerning lake monitoring described above, one possible solution in placing sampling sites in a lake is presented in Figure 5. For example, the deepest parts of the lake ecosystem could be monitored by using two different methods complementary to each other. First, by traditional vertical sampling regarding different chemical and physico-chemical elements, and secondly, the pelagic areas of the system could be monitored by e.g. the phytoplankton and the profundal areas by the benthic fauna.

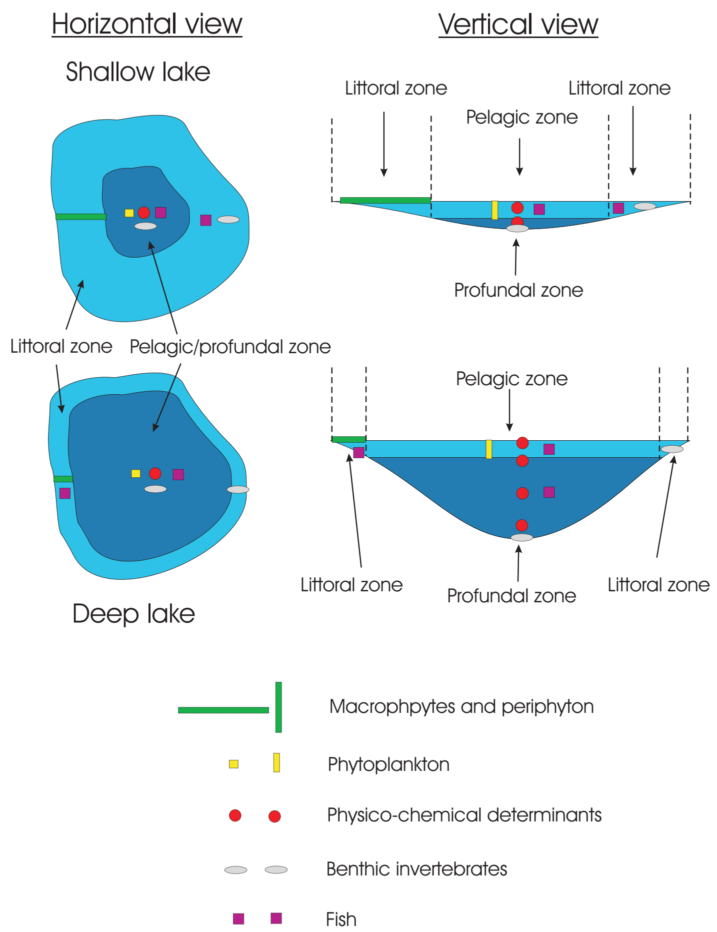


Figure 5. A schematic presentation of how to choose sampling points for two morphologically different lakes.

2.3 Water Framework Directive versus lake monitoring and assessment issues

For surface waters the main objective of the WFD is to reach a good status or to maintain a good or high status where it already prevails. The status of surface waters will be determined based on the ecological status and chemical status. The lower of these two will be decisive. Chemical status is established using the environmental quality standards (EQSs) of priority substances. These are the hazardous substances (specific priority pollutants / Annex V of the Directive) agreed at EU level. Ecological status is based on biological quality elements and supporting physico-chemical and hydro-morphological quality elements. Reference conditions will be defined for various types of waters and they form the basis for classification of waters. The status classes should indicate the deviation from reference conditions, which is of anthropogenic origin. There are five status classes from high to bad.

In the normative definitions of ecological status in Annex V of the WFD the following is written concerning the general description of good ecological status:

> *"The values of the biological quality elements for the surface water body type show low levels of distortion resulting from human activity, but deviate only slightly from those normally associated with the surface water body type under undisturbed conditions."*

For biological elements the status classes will be defined using ecological quality ratios (EQRs), which compare the results of monitoring of a water body with reference values. For physico-chemical quality elements various ranges will help the defining of status classes. For pollutants, in other words for hazardous substances used e.g. in a river basin or a country, also the environmental quality standards should be used in defining a good ecological status.

According to the WFD, the role of water body typology is essential. The classification system should use typology in order to indicate the most suitable reference conditions and status class boundaries for a specific water body. It is certainly a very demanding task to establish typology that would fulfil this and be also practical in monitoring and status assessment.

In the Annex II of the WFD principles of two systems for lake typology have been established using geographical, physical and chemical factors. System A is a categorical system of a few obligatory factors called descriptors, for which class boundaries have been given. The requirements of System B provide more freedom. It should be based on a somewhat higher number of abiotic factors. Some of the factors are optional and no class boundaries have been given for them.

In a proposal for the surface water typology of Finnish lakes (Pilke et al. 2002), lake types were based on System B (Fig. 6). The following obligatory factors were used: altitude or latitude for differentiating lakes of northernmost Finland from others in Finland, geology (nutrient richness, calcium, organic soil), and area of the lake. Most lakes will be differentiated according to the size and humic content of lakes or organic geology of the catchment area, since humic waters are typical of Finland. The following additional factors have been proposed to be examined during the development of the classification procedure: water depth or summer stratification characteristics, residence time and water level fluctuation.

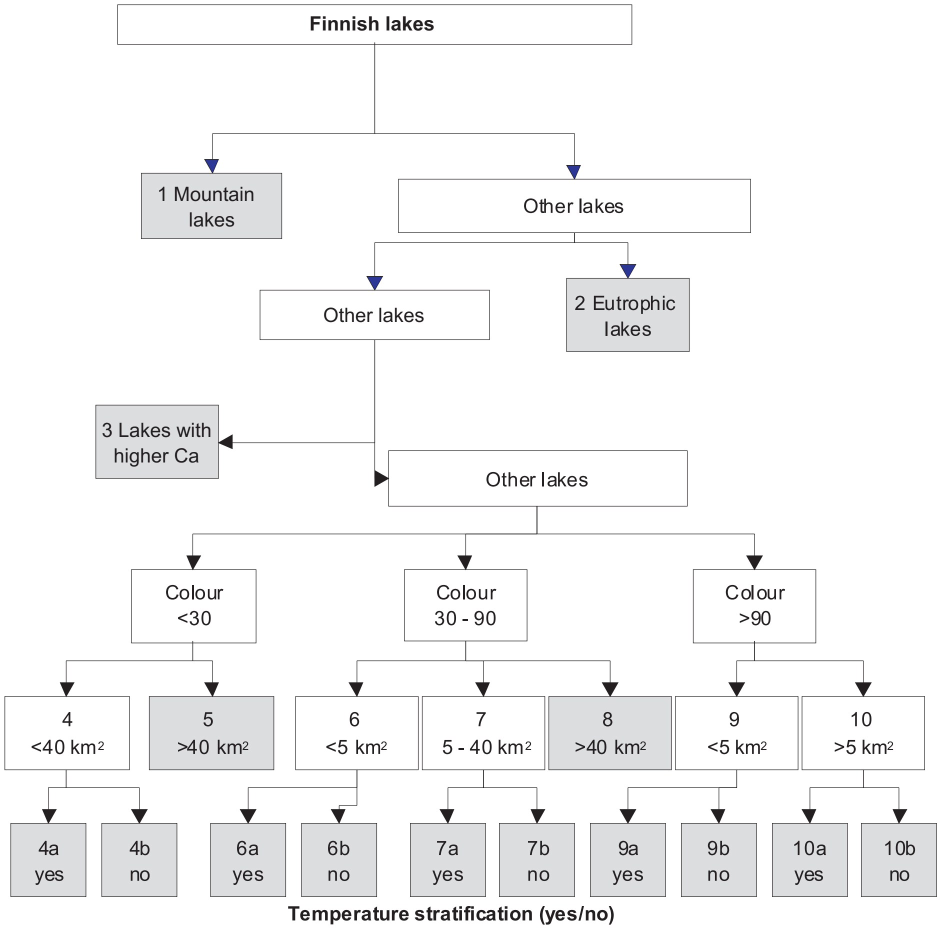


Figure 6. Draft proposal for the typology of Finnish lakes, using stratification as an optional factor (Pilke et al. 2002).

Existing biological and limnological typologies were used as a starting point for the work. However, further evaluation of the biological relevance of lake types will be performed during the development of the monitoring and classification procedure and in the testing phase. In this context also the work of the Life Vuoksi Project has been very fruitful, since the monitoring and status assessment of several types of the proposal have been in focus.

For each lake type reference conditions shall be determined. They must be in accordance with the pristine or nearly pristine conditions of a lake. These conditions can be spatially based or based on modelling, or may be derived using a combination of these methods (the WFD, Annex II). Expert judgement alone can be used if other procedures are not possible. In the Life Vuoksi Project also the reference conditions have been inspected for those lake types that have been included in the programme.

The major phases of the implementation of the WFD related to the monitoring and assessment of surface waters are summarised in Figure 7. The first major step is the identification of surface water bodies (location, boundaries), in this case lakes or parts of lakes. Progress is ongoing and there are still many open questions at European level, such as aggregation/grouping of water bodies, merging and splitting of water bodies etc. (Gendebien and Whalley 2003).

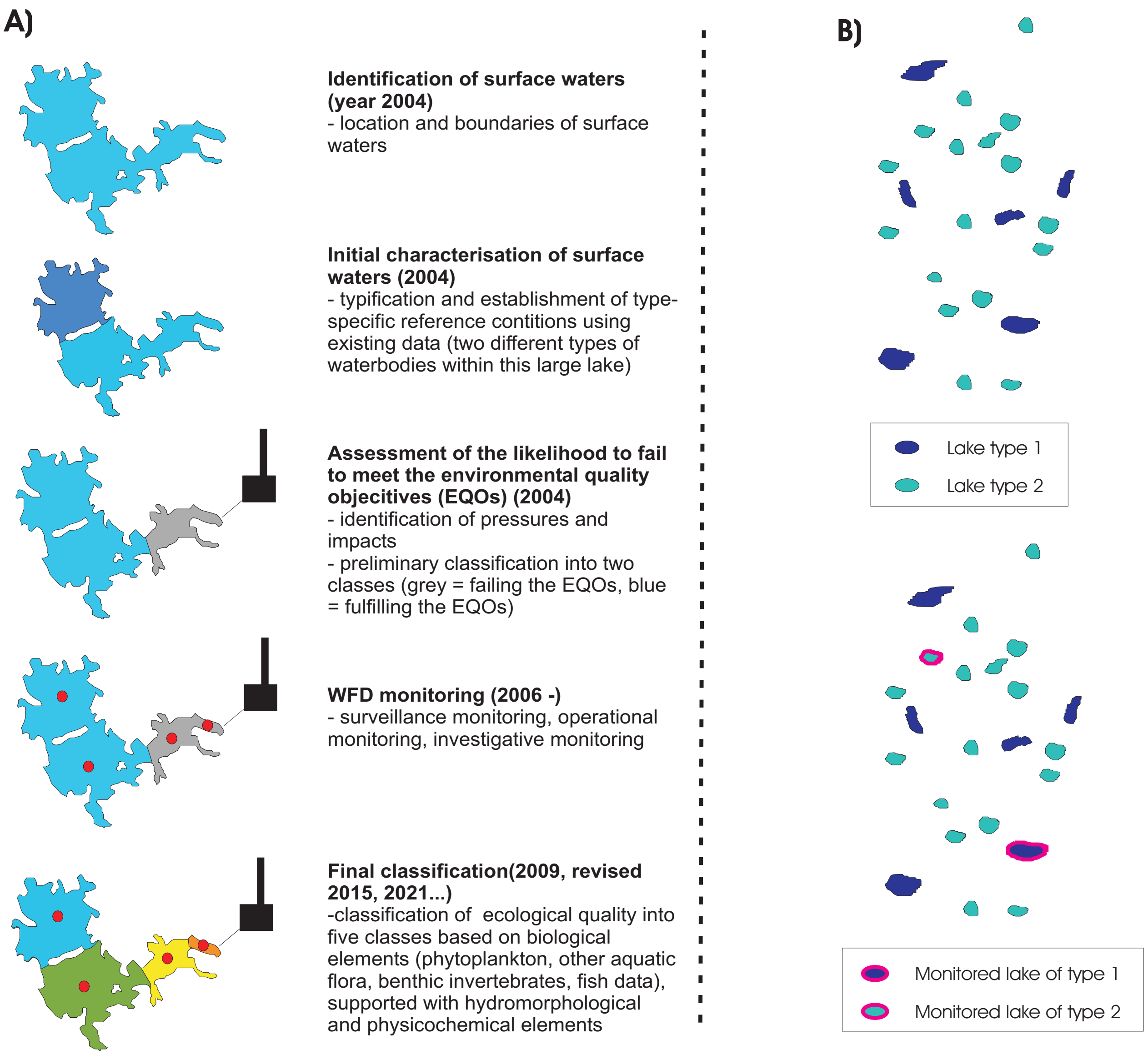


Figure 7. Major phases in the implementation of WFD related to monitoring and assessment (a), and an example of how to aggregate/group smaller lakes for various WFD actions, such as monitoring and reporting (b).

In the case of smaller lakes (Fig. 7b), a great number of small water bodies in the same river basin can be aggregated/grouped, for example, to enable feasible and simplified pressure/impact assessment, monitoring and reporting of lakes without handling every lake as a separate unit. This basic delineation will be carried out in the early stages of the implementation of the WFD. In the case of a large lake (Fig. 7a) the lake may be split into smaller units (water bodies) according to different types, and in the later phases also according to different ecological status (classes). This detailed delineation of water bodies will be an iterative process that can be checked every six years simultaneously with the renewal and updating of River Basin Management Plans. One of the basic questions related to the classification certainly is what kind of spatial scale is needed and used in the monitoring and assessment phase and how detailed maps do we want to produce.

According to the WFD the monitoring programmes should be commenced before the end of 2006. There are three different types of monitoring: (i) Surveillance monitoring – especially for water bodies, which are in high or good ecological status. (ii) Operational monitoring – for water bodies in which good ecological status may not be met because of anthropogenic pressures or where actions have been taken to improve water status. (iii) Investigative monitoring in surface waters where, for example, the reason for (accidental) deterioration is unknown. A schematic representation of how different pressure factors can affect a larger lake and thus also contribute to monitoring procedures is illustrated in Figure 8.

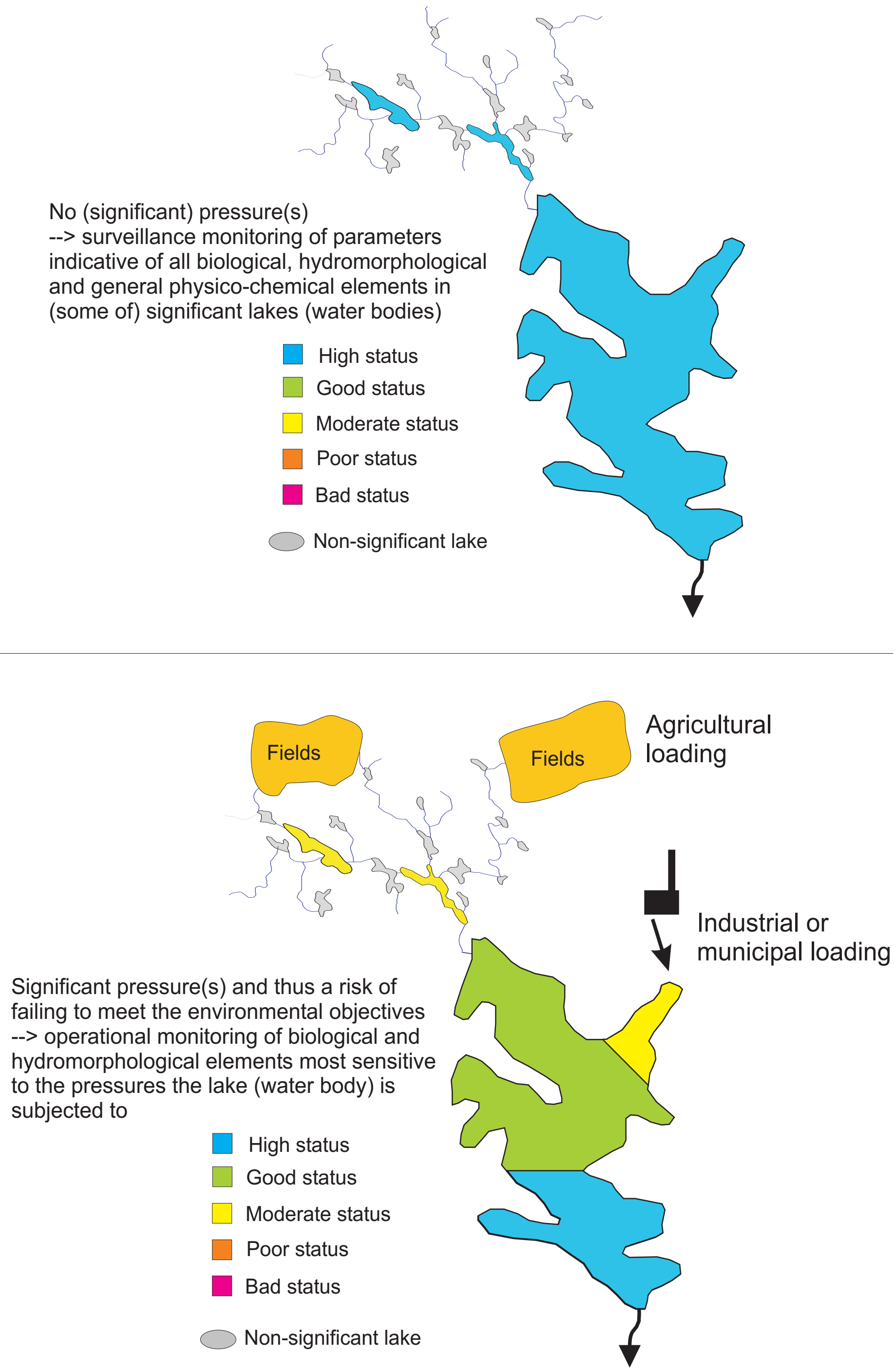


Figure 8. The relationships between different pressures and different types of monitoring activities according to the WFD.

These types of monitoring programmes will be created for lakes during the coming years. The present EUROWATERNET monitoring network for lakes (cf. Niemi et al. 2001a, Mitikka and Ekholm 2003, Räike et al. 2003) will offer a good and practical basis for the WFD monitoring programmes in Finland. In many cases, technical details are already solved, but the requirement for biological information is obvious for both surveillance and operational monitoring to make the assessment procedure and ecological classification possible and reliable in the future.

3 General description of the monitoring and assessment procedure

3.1 The structure of the monitoring and assessment procedure

In this chapter the theoretical basis of the monitoring and assessment procedure is presented. Chapter 4 provides basic information on the main elements required in the monitoring and assessment procedure to obtain a reliable picture of the ecological status of lakes. The testing of the monitoring and assessment procedure is presented in Chapters 5 and 6. Chapter 7 provides overall conclusions from the procedure.

There are many ways to assess the ecological status of a lake. According to the WFD the official procedure seems to be straightforward. According to Annex V of the Directive it is necessary to monitor certain biological, hydro-morphological, chemical and physico-chemical characteristics of a given lake and then calculate special ecological quality ratios (EQR) for each of the biological quality elements. From these values (theoretically between 0–1) the actual ecological status of the lake can be concluded. The status can be in one of the five classes ranging from Class I (high status, EQR close to 1) to Class V (bad status, EQR close to 0).

However, any natural spatial and temporal (long-term, annual and seasonal) variations of biological characteristics (mentioned in the WFD) render this method liable to misclassification. A more sophisticated procedure will take into account and process all available long-term monitoring data from the lake concerned and other lakes of the same lake type (reference lakes). Principally, the assessment of the ecological status of a lake will be composed of several logically successive expert judgements. Even using this method the classification task is a difficult and challenging one. In the long run, expert judgement will, however, be replaced by the EQR values, which will be calculated on a widely accepted and internationally comparable manner in the future.

All the lake zones are included in the development of monitoring and assessment procedure for lakes. The procedure will combine monitoring possibilities and results of the pelagic and profundal areas with those of the littoral zones. The procedure will also provide some common guidelines for the use of supporting chemical and physico-chemical characteristics and hydromorphological elements, mentioned in the WFD. The basic reason to develop this procedure is simply to enable the combination of information from two important areas of the lake, i.e. the littoral and pelagic zones, together with all other relevant information of the lake (Fig. 9).

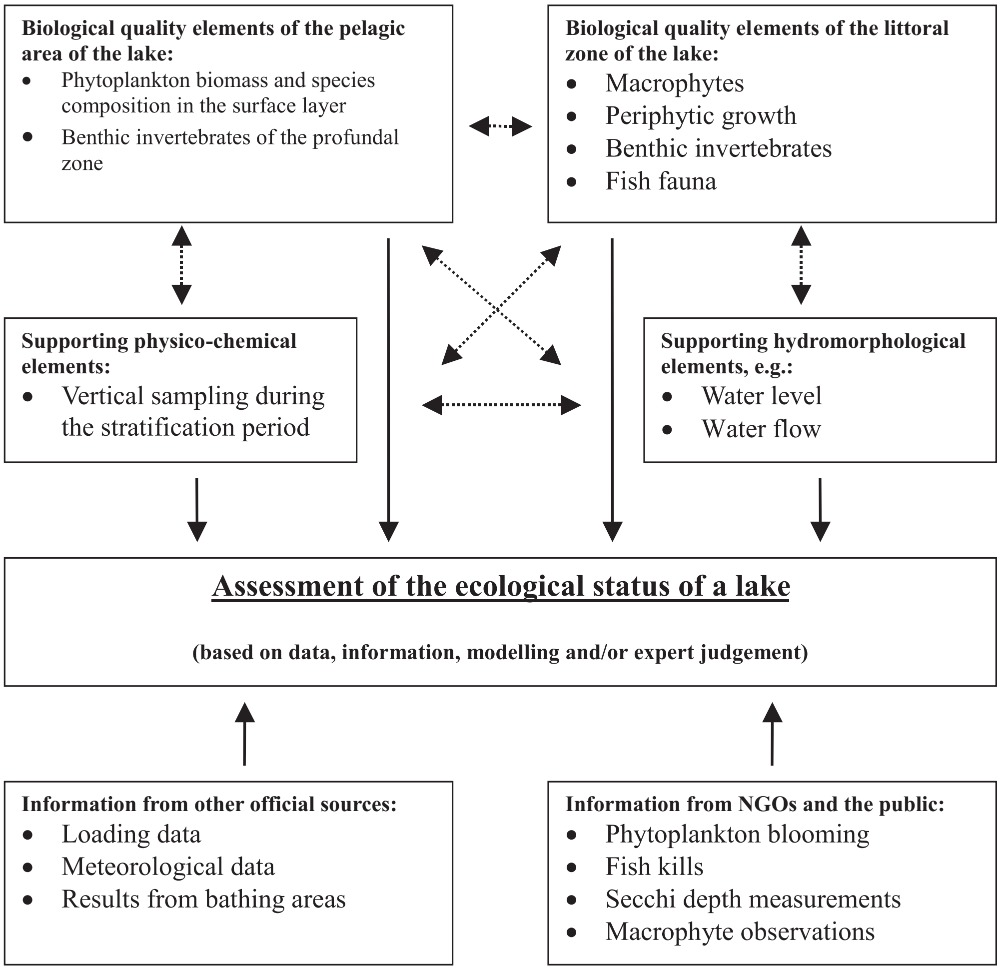


Figure 9. Main components of the monitoring and assessment procedure for lakes.

In this context many subjects such as different needs for information on the monitoring and assessment procedure, the role of monitoring in different parts and areas of lakes, and the relevancy of different environmental variables both in the pelagic and littoral areas will be discussed in more detail.

A reliable assessment of the overall status of a given lake should always be based on diverse monitoring data from several relevant areas. The object to be assessed is neither a certain sampling point or site nor a certain larger limnological zone or area of the lake, but the entire lake. In case a given lake is large and complex enough, it is possible to characterise and define different parts of the lake and consider them as separate lake systems.

The timescale of monitoring is also an important detail. Data from one year only is often not a good basis for a reliable assessment procedure. Normally, a much longer period is justified. There are good reasons to assume that data covering at least six years period (which is the normal reporting period of the WFD) is required. Besides the important assessment of the current status of a lake one has to be aware of water quality trends (biological, chemical, hydrological) in the longer term. In this work especially biological data is available from one year only. Therefore, the preliminary results obtained in this work must be complemented later to obtain a more reliable picture of the ecological status of the target lakes.

3.2 Information needs of the monitoring and assessment procedure

The principle of any monitoring practice should be to combine the production of data and especially the handling of biological, physico-chemical, hydrological and meteorological characteristics from different parts (areas) of lakes, as well as from different periods in a certain order. The structure of a monitoring procedure for lakes consists of the following main compartments:

- General and more specific information on the entire river basin and the lake concerned,
- data from the biological quality elements from the pelagic area,
- data from the biological quality elements from the littoral zone
- supporting chemical and physico-chemical data from the lake concerned,
- supporting hydrological monitoring and meteorological data from the river basin area,
- data from the pressures of different origins (point, non-point, other anthropogenic activities etc.) and
- the use of other specific monitoring programmes (bathing waters etc.).

Data production as well as the use of data in this type of monitoring and assessment procedure is a developing process, which will be improved during a longer monitoring period. One key principle is that all the data collected in different monitoring sub-programmes should be effectively used in the assessment process. Irrelevant data should be excluded from the monitoring programmes.

The lack of important components and data should be recognised and corrected during the implementation of a monitoring programme. The re-checking of monitoring programmes must be carried out at least once in every reporting period.

3.3 The role of public participation

The need for stronger interaction between regional and local authorities and civil society has become more obvious during the last decades. The Sixth Community Environment Action Programme of the European Parliament and of the Council expects extensive dialogue with stakeholders, raising environmental awareness and public participation. This kind of statement is widely included in the new EU environmental legislation, (e.g. in the WFD) in national legislation and governance practices. In a complex and diversified world people have divergent interests and expectations, which can not be met with traditional methods of governing. The spirit of the time calls for people-sensitive models of governance, communicative planning and public participation. As an integral component of planning and management processes monitoring is not an exception to this demand.

Public participation can be defined as a chance for people to influence the outcome of plans and working processes. Participation not only guarantees a social basis as broad as possible for planning, but also provides a source of knowledge and experience that can be considered as an input leading to the best possible plan. Knowledge and value do not merely have objective existence in the external world to be discovered by scientific inquiry but are rather actively constituted through social interactive processes such as planning through which ways of thinking, valuing and acting are constructed by participants. The new way to act may lead to social learning and attitudes of better environmental awareness.

The key word in public participation is information. In the context of monitoring, the public can be seen as both subject and object of a two-way information flow: On the one hand public participation can itself be seen as a valuable source of information and can contribute ideas to the decision-making process (= public as a subject). From this point of view the role of the public can be related to creation of monitoring programmes and to layman observations if not actual monitoring as well. The administration is up to a certain level willing to consider public participation as a complementary element of monitoring activities made by environmental authorities i.e. filling gaps, which exists between government resources, and actions needed to be done. On the other hand information supply to the public is necessary for any form of public participation (= public as an object). Monitoring is a crucial part of producing information in order to enable the public participation and interactive policy development. It is therefore essential that monitoring programmes are set up in such a fashion that relevant information reaches not only researchers and institutional experts but also local people and various interest groups in an understandable and usable form.

The timing and scale plays a major role when organizing public participation. The only way of achieving maximum mutual benefit from it is to involve stakeholders in the process before decisions are taken – consultation afterwards is only a whitewash. The degree of participation may vary during the process and case by case. Certain limitations usually exist concerning the participation procedure, which can be carried out, and the range of results achieved. In order to avoid false expectations the role of the stakeholder should be clarified. It should be explained to the participants how and when their involvement will be used.

The scale of issue in public participation can determine the issues to be dealt with at specific levels. On a local scale, issues can be discussed in more details than participation at a regional or national level. Also on a local scale direct response can be obtained more easily as well as engagement of people and grass root organizations in the process. So there are good reasons for arranging participation on a lower scale, but that is not the entire truth. Firstly, the existing institutional structure needs to be taken into account in order to obtain sufficient institutional power, substance competence and funding for the process. More institutional resources, which are required in an administrative decision making process, may be available at a higher institutional level. Secondly, arbitration between competing claims and priorities and development of longer term policy may be easier at a higher level. Finally, many stakeholders are nowadays represented by larger national or international organizations, which may be the key players instead of local actors when discussing and deciding main milestones and principles of the process.

Participation can play an important role in planning and decision-making if the messages of participants and their arguments are taken into account. The main issue is to find the right scale – local, regional, national or international – for participation in each case.

3.4 Use of the monitoring and assessment procedure

This chapter presents the basic principles for the elaboration of the monitoring and assessment procedure for lakes. The procedure takes carefully into account the requirements set by the WFD. This kind of procedure is required to ensure that an inaccurate or imprecise assessment of the ecological status of surface waters is unlikely to occur. The overall purpose of the monitoring and assessment procedure is to collect, evaluate and combine all possible data that could facilitate the elaboration of a reliable picture of the condition of a given lake in a transparent way.

Data production as well as the use of data in this type of monitoring and assessment procedure is a developing process, which will be improved over a longer time period. The basic components, mentioned in Figure 9, have to be put into a logical chronological order to facilitate a flexible assessment procedure (Fig. 10).

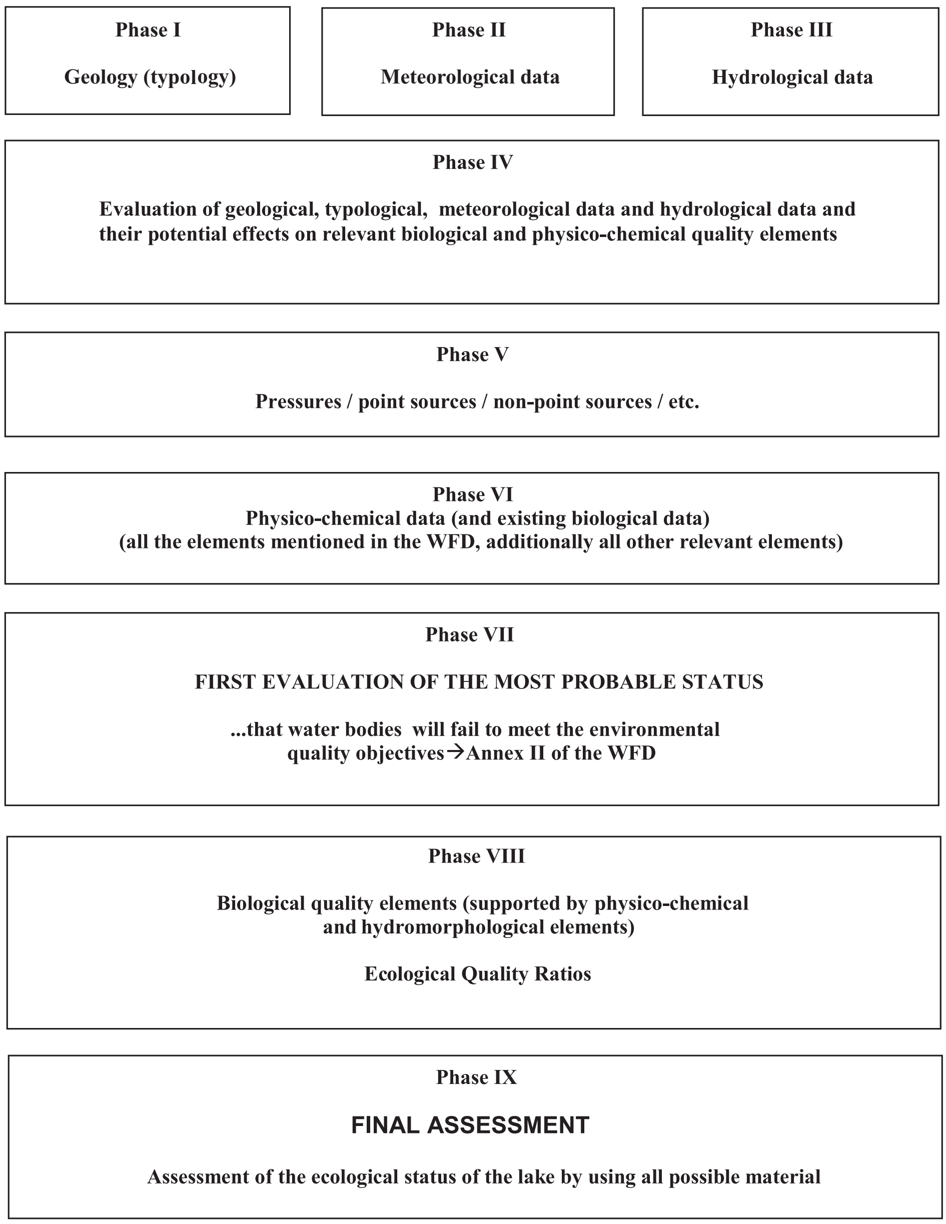


Figure 10. Flow chart of the monitoring and assessment procedure.

In this monitoring and assessment procedure, the data from one lake should be discussed, evaluated and assessed simultaneously with other water bodies of the entire river basin. In this way, relevant meteorological and hydrological data can be taken better into account, and for example natural variations in biological quality elements, which have originated solely as a function of exceptional weather circumstances, are more likely detected.

The very first, basic phase (Phase I) of the assessment process is to describe relevant geological information, i.e. data on the bedrock and soil conditions of the river basin concerned. Furthermore, some basic hydro-morphological features (Annex V of the Directive) of the lake itself are required. These geological and hydro-morphological data are necessary to describe and differentiate water bodies into different types according to the WFD. This information is often ready in GIS-format. From the ecological classification point of view, it is also important to know certain characteristics of the lake (flow-through-lake, headwater lake, etc.), and the theoretical retention time, because of the different environmental assimilative capacity of lakes. These characteristics are also very permanent, and as a rule there is no need to update this part of assessment procedure later. However, one must be aware of any possible restoration projects or their equivalent that may alter the water level and, thus, also affect the water ecosystem.

After describing the geology of the drainage basin and the typology of the lake itself, it is logical to continue with the meteorological data (Phase II). Long-term seasonal data, as well as data on the reporting period (e.g. 1997–2002), for temperature, precipitation, winds and light conditions are required. Usually there are well organised monitoring programmes on meteorological characteristics with a relatively dense observation network in all European countries.

Hydrological data (Phase III) has close connections with the previous phase of meteorology. This is a very important phase, because hydrological factors can significantly affect lake biology through several different ways. At least long-term series of water discharges to and from the lake, as well as the height of water level in the lake, and their seasonal variations are required.

Usually there are well organised hydrological monitoring programmes and practices in all EU Member States. Hydrological observations should be examined and compared with the meteorological data. Meteorological and hydrological data are some of the most important supporting information for the evaluation of biological phenomena and their variations in the water courses, rivers and lakes.

The next phase (Phase IV) is an overall estimation and assessment of how Phases I – III can affect biological and physico-chemical quality elements. It is obvious that rainy summers are characterised by high discharges and thus also by high non-point nutrient loads to lakes. If a lake is affected almost only by point-source load, high water discharges can dilute nutrient concentrations in the lake. If summers are warm and sunny, the conditions are more optimal to provide algal blooms.

In the next phase of the assessment procedure the base level and possible changes in the pressure factors (Phase V) in the entire river basin should be considered. The data from point sources should be compared with the results of data over the previous couple of years. Estimations of non-point loading should be compared with meteorological and hydrological data. Guidelines for the analysis of pressures and impacts (list of pressures) could be of great help in this context. Trends for the relevant variables (phosphorus, nitrogen, harmful substances, etc.) should be examined.

In the next phase, all physico-chemical and chemical data should be gathered and evaluated (Phase VI). These values should be compared with the hydrological data. All the general physico-chemical and chemical characteristics mentioned in the WFD should be thoroughly evaluated. Special attention should be focused on nutrient concentrations, their seasonal and inter-annual variations and possible trends.

On the basis of all of the previous phases a preliminary expert judgement procedure (Phase VII) should be performed to produce the first evaluation of the most probable status of the lake concerned. This phase should, however, be understood as an intermediate phase in the whole assessment process. The total lack or shortage of reliable and comparative data on the biological elements increases the value of this phase. In the long-run the classification of surface water quality will be mainly/only based on the value of the ecological quality ratio (EQR) and chemical status. However, this will take time because the preliminary classification will be done in 2004, monitoring will take place in 2006 and the first real classification will be finalised in 2009 and rechecked and renewed then every six years from the year 2015 onwards (Fig. 7).

One of the most challenging and important phases of the entire assessment procedure is to examine the results of biological characteristics (Phase VIII). Most likely this can be initiated most easily with phytoplankton data, because there is usually quite good information on several previous years to make more precise calculations e.g. of the most indicative quotients in Finland and in many other European countries. The EQRs should be determined according to the principles presented in the WFD i.e. by comparison with the representative reference data e.g. from the sufficient number of lakes near pristine state representing the same lake type of the proposal for national lake typology (Pilke et al. 2002).

The next step is to compare the results of the biological characteristics with those of the physico-chemical supporting elements. If there are any inconsistencies between the different quality elements, we have to compare the meteorological and hydrological information as well as the data of the pressures with the biological characteristics.

The next and the final step is the assessment of the most probable ecological status (Phase IX). This phase should always be performed as a summary of all the monitoring data and other relevant material. The use of the monitoring and assessment procedure can be described as a continuous monitoring, data collecting and data handling process. The phases in this process are combined with each other, and they continuously need mutual checking. It is important to note that the final surface water status determination will not only rely on the ecological status but also on the chemical status (priority and priority hazardous substances). The final status of body of water will be determined by the poorer state of these two fundamental components.

Description of the main elements of the monitoring and assessment procedure

4

4.1 Biological quality elements

To understand better the methodology used in different areas of a lake in assessing the overall ecological status of the lake, and to use the proposed monitoring and assessment procedure in practice, some general and national information has been gathered and will be presented and discussed in the following sub-chapters (cf. e.g. Heinonen et al. 2000).

4.1.1 Phytoplankton

Studies on phytoplankton assemblages in Finnish lakes were initiated in the late 1890s by e.g. Levander (1900) and Blomqvist et al. (1917). In the early 1910s, Järnefelt (e.g. 1932, 1934) started his fundamental studies on phytoplankton, covering lakes from southern Finland up to Lapland. He classified the trophic status of lakes according to their phytoplankton assemblages (Järnefelt 1952, 1956, 1958). On the basis of Järnefelt's studies, surface water monitoring was started in the early 1960s by water authorities. The first national monitoring network covered the quantity and quality of some 150 lakes in Finland (Heinonen 1980).

In addition to the monitoring data collected by water authorities (e.g. Lepistö et al. 2003), several authors have published articles on phytoplankton from Finnish lakes. For instance, Ilmavirta (1980), Arvola (1983) and Salonen et al. (1992) have studied humic lakes and focused on the influence of water colour on the phytoplankton assemblages. Eloranta (1995) examined the phytoplankton of lakes situated in the national parks. These lakes could easily be regarded as reference lakes. Furthermore, Granberg (1973) studied the influence of paper mill waste waters on phytoplankton in Lake Päijänne. The horizontal distribution of phytoplankton and relationships between phytoplankton, zooplankton and water quality in Lake Saimaa have been examined by Holopainen et al. (1993).

Phytoplankton is known to react quickly to many environmental changes. The composition of a phytoplankton assemblage does not depend only on nutrients but also on physical factors (e.g. temperature, illumination and turbulence), other chemical factors (e.g. vitamins and antibiotics) and biological factors, such as specific growth and loss rates among the algae, parasitism, predation, and competition (Hutchinson 1967, Reynolds 1986, Willén 1992). These factors should be taken into account when considering the reasons for the fluctuation of phytoplankton (Jacobsen and Simonsen 1993), and due to their complex interactions and rapid changes, no absolute standards for biological quality can be set.

In most cases, plankton communities are not spatially or temporally constant. Besides the seasonal variability, phytoplankton usually show marked inter-annual variations in respect of abundance (Lepistö 1999). The species assemblage from year to year has no exact timing, and hence the occurrence of individual species may vary widely so that the dominant species at any given successive stage will not always be the same. Seasonally the mean population densities may vary within 6–9 orders of magnitude (Reynolds 1986).

A discrete group among algae are the cyanophytes, also referred to as Cyanophyceae, Cyanobacteria, Cyanoprokaryota or simply "blue-green algae" (Anagnostidis and Komárek 1985). This group is best known by its ability to compose extensive and in many cases also poisonous algal blooms.

There is also a mixture of other algal groups (Round 1981, Tikkanen and Willén 1992). Phytoplankton encompasses a great range of cell size and cell volume from the largest forms visible to the naked eye, to algae less than 1 µm in diameter. The assessment of ecological status using phytoplankton is usually based on the following parameters: the taxonomic composition, the average phytoplankton abundance, and the frequency and intensity of planctonic blooms.

Phytoplankton sampling should cover at least spring and autumn mixing periods and summer stagnation period with 5–9 samples (Olrik et al. 1998). However, in the Finnish nationwide monitoring programme phytoplankton monitoring is generally minimized to only one summertime sample per year per lake (July, according to the results by Heinonen 1982) on a three years sampling rotation principle. This network covers about 255 lakes. Only 15 of these lakes are intensively monitored and sampled five times a summer (growing season) each year.

4.1.2 Periphyton

The term periphyton is used for microfloral growth and organic material attached upon underwater solid substrates, like stones and stems of macrophytes, in aquatic ecosystems (Wetzel and Westlake 1969, Sládecková and Sládecek 1978). Periphyton community can consist of different types of organisms, like algae, autotrophic and heterotrophic bacteria, ciliata, spongides and flagellata (Sládecková 1960, Weitzel 1979, Round 1981). The term phytobenthos mentioned in the WFD can also be considered to include communities growing on soft substrates like sand and mud.

The growth of periphytic algae has proved to be a sensitive method for monitoring changes in the eutrophication status of water. Finland has a long tradition in the use of periphyton methodology in routine lake monitoring, mostly using artificial substrates, mainly polycarbonate plates or glassfibre filters (e.g. Eloranta and Kunnas 1979, Heinonen 1981, Leskinen 1984, Sojakka 1996). The studies have been mainly quantitative, including laboratory measurements of total solids, organic/inorganic fractions and chlorophyll *a*. The artificial substrate method is mostly used in pelagial areas for operational monitoring of point source loading.

The taxonomic composition of periphytic algal communities is not so commonly used for monitoring purposes and the method can be mainly characterized as applied research. In Finland the taxonomy and diatom indices of perifyton have been mainly used for the indication of trophic status of rivers (e.g. Eloranta and Kwandrans 1996, Eloranta and Andersson 1998, Eloranta 1999). Several diatom indices, such as PSI (Pollution Sensitivity index, CEMAGREF, 1982), TDI (Trophic Diatom Index, e.g. Kelly and Whitton 1995, Kelly et al. 1996) and GDI (Generic Diatom Index, e.g. Prygiel et al. 1996), are commonly used in Europe.

In the monitoring of the littoral zone, perifyton can be studied by using natural substrates, such as stones and aquatic macrophytes. However, in many cases different artificial substrate methods are also used in the littoral zone.

4.1.3 Aquatic macrophytes

Aquatic macrophytes are an essential part of the productive zone in many northern lakes. Aquatic vegetation has been studied and classified in Finland quite actively since the 1930s (Linkola 1933, Vaarama 1938, Maristo 1941). For example Maristo (1941) classified Finnish lakes as botanical lake types according to dominant macrophyte species and their relative abundances.

Usually examined metrics in field surveys have been: 1) species composition, 2) estimation of species abundances (frequency and coverage) and 3) biomass measurements. In Finland aquatic macrophyte surveys have been done for many purposes and in various lake types. Since the 1950s aquatic macrophytes have been used as bioindicators of forest industry wastewaters (e.g. Perttula 1953). The effects of water level regulation on the littoral vegetation have been studied since the 1980s (Granberg and Hakkari 1980, Hellsten and Joronen 1986). Aquatic macrophyte mappings have been done for many lake rehabilitation projects and for the protection of bird species around lakes (e.g. Nybom 1988, Venetvaara et al. 1993). So far aquatic macrophytes have not been included in nationwide monitoring programmes in Finland.

The aquatic vegetation reflects conditions of its habitat. Aquatic macrophytes are suitable for long-term studies of the littoral area especially in small and medium-sized shallow lakes, which are quite typical of Finland. In the Nordic countries indicator values (four to six categories) are given to macrophyte species according to their requirements regarding the nutrient level of their site (Linkola 1933, Jensén 1994, Toivonen and Huttunen 1995, Toivonen 2000). For example according to Toivonen (1988) *Isoëtes* spp. and *Lobelia dortmanna* are considered as indicators for oligotrophy and *Butomus umbellatus* and *Ceratophyllum emersum* for eutrophy.

In Finland the most suitable time for the aquatic macrophyte survey is usually from the middle of July to the end of August. Because aquatic macrophytes respond quite slowly to environmental changes, the monitoring interval should be several years. A suitable survey interval could be 5–10 years, which fits well with the reporting requirements of the WFD (6-years monitoring cycle). The parameters to be used in the ecological quality assessment according to the WFD are e.g. the taxonomic composition and abundance of macrophytes.

4.1.4 Benthic invertebrates

Suitability of profundal macroinvertebrates as indicators of the lake trophic status is well documented (e.g. Wiederholm 1980, Kansanen et al. 1990, Rosenberg and Resh 1993, Brodersen and Lindegaard 1999). Compared to profundal zoobenthos, research activity in the littoral zone and the use of littoral benthic invertebrates in monitoring have been low (see, however, Holopainen et al. 2001, Irvine et al. 2001). Reasons for that may be the difficulties in sampling a patchy and structurally complex environments, and higher costs of sample processing e.g. due to the high amount of coarse organic particulate matter and high number of individuals and species in the samples.

However, the composition of the littoral communities has also been found to change along the nutrient gradient (Tolonen et al. 2001). On the other hand, profundal and littoral benthic communities may respond differently to various types of anthropogenic stresses. Impacts of some stresses like water level regulation, acidification, recreational activities and shoreline alteration e.g. by summer cottages and other constructions may be mainly defined by the littoral zone. Furthermore, non-point load of nutrients and suspended material (agriculture, forestry) may first affect the littoral zone. Thus, littoral communities would respond more rapidly to the anthropogenic impacts compared to profundal invertebrate communities.

In contrast, profundal communities may reflect long-term changes in environmental conditions of the lake. The prevailing environmental conditions in the vicinity of deep bottom areas are fairly constant despite alterations of water level etc. In the littoral zone, each habitat type often supports fairly characteristic fauna. Thus, samples from different habitat types are not comparable to each other and stratification of the sampling by habitat type is obviously necessary (Tolonen et al. 2001).

In Finnish biomonitoring programmes, sampling has typically been conducted in autumn (September, partly October during the autumn overturn) based on the standards of different sampling methods (e.g. SFS-EN ISO 9391, SFS 5076 1989, SFS 5730 1992). In the stony littoral areas, Johnson et al. (1993) found that late summer sampling (August) provided the best measure of the lake type compared to spring, early summer and autumn (October) samples. Despite the inter-annual variations in benthic communities (Hämäläinen et al. 2003), the samples of different monitoring programmes are usually taken at three years intervals. In some special and intensive monitoring programmes, the samples are taken every year.

A combined examination of profundal and littoral benthic invertebrates provides a useful and competent tool for assessing impacts of various stresses and the ecological status of lakes. In general, benthic invertebrates are fairly sessile with relatively long life-cycles and they include a large number of sensitive species having responses to various short-term and long-term impacts caused by anthropogenic activity. Thus, benthic invertebrates are widely used and applied as a tool for bioassessment at small- and large-scales. For example, mouthpart malformations are good tools for studying the effects of harmful substances and they were used in this context during the last decade.

For the assessment of ecological state using benthic invertebrates, the parameters nominated as variables of ecological quality (EQ) by the WFD are abundance, diversity, presence of sensitive taxa and taxonomic composition of the community. The zones (littoral, sublittoral or profundal) or habitat types to be included in the assessment of EQ are not defined in the WFD.

4.2 Supporting chemical and physico-chemical quality elements

4.2.1 Nutrients

Besides the biological elements, chemical and physico-chemical elements "supporting the biological elements" are also used in the ecological classification of the WFD. These elements are listed in the Annex V of the WFD. The list of physico-chemical elements consists of fairly general limnological determinands. One very important category in the Annex list is "Nutrient conditions". In practice, it means phosphorus and nitrogen compounds.

Nitrogen and phosphorus are the major nutrients causing eutrophication of surface waters. These nutrients partially originate from natural sources but mainly from anthropogenic sources in areas affected by various human activities. Nitrogen loading is mainly due to diffuse sources such as agriculture and forestry, while phosphorus loading can be dominated by point sources such as municipal sewage waters or industrial effluents (in Ecoregion 17 diffuse agrigulture is a major source of P).

Excessive loading of nitrogen and phosphorus may drastically change the biological structure of a water body leading to undesirable phenomena such as blue-green algal blooms, pronounced overgrowth of macrophytes, or even fish kills caused by intensive decomposition of organic material and subsequent oxygen deficiency in the water. In most cases phosphorus is the limiting nutrient for algal growth in lakes, especially in oligotrophic-mesotrophic conditions. The regulating role of nitrogen becomes more important in eutrophic or hypertrophic lakes and marine waters.

Most primary producers (e.g. phytoplankton, periphyton, macrophytes) can only utilize dissolved forms of nutrients such as ammonium, nitrite, nitrate, urea, and phosphate. Therefore, the total concentrations of nitrogen and phosphorus do not necessarily reveal the limiting nutrient of the lake ecosystem. In many temperate lakes a great proportion of nitrogen is bound to humus, which cannot be directly utilized by most primary producers. The actual bioavailability of nutrients is also affected by varying levels of alkalinity, ionic balances, and particulate matter content in the water column.

More information about the current eutrophication situation can be achieved by monitoring an easy chemical variable demonstrating phytoplankton biomass, i.e. chlorophyll *a*, together with nutrients. The correlation between different nutrients and chlorophyll *a* can give a very good basis for further discussions of the relevant minimum factor of primary production in Nordic lakes. In some other European regions the possibility of chlorophyll *a* suppression by zebra mussel should be considered.

4.2.2 Other elements

The other chemical and physico-chemical quality elements (except nutrients) for lakes mentioned in the Annex V of the WFD are listed as follows:

- General
  - Transparency
  - Thermal conditions
  - Oxygenation conditions
  - Salinity
  - Acidification status
- Specific pollutants
  - Pollution by all priority substances identified as being discharged into the body of water
  - Pollution by other substances identified as being discharged in significant quantities into the body of water

In Nordic humic lakes, transparency and oxygenation conditions are usually important monitoring elements, because humic substances have significant effects on primary production and eutrophication processes. The amount of humic substances can be estimated using e.g. water colour, COD, TOC and Secchi disc values.

Besides eutrophication, acidification of lakes can in some areas be of great importance (cf. Forsius et al. 2003). Different types of alkalinity analyses, as well as pH-value measurements are useful tools to estimate acidification status.

A special category of quality elements are the priority substances (e.g. benzene, pentachlorophenol), or generally all the anthropogenic harmful substances (e.g. PCBs), which are discharged to watercourses with the industrial or urban waste waters, or in some cases from polluted soils. These elements have, however, not been analyzed in the target lakes of the project. The probability to find any of them in these lakes has also been most unlikely.

4.3 Other supporting monitoring material

Meteorological and hydrological data are very basic issues in understanding different biological phenomena in the nature. These issues will be dealt in more detail in Chapters 5.3.1 and 5.3.2.

All results from any other monitoring activity concerning the lake, e.g. if the usability of common bathing areas has been checked by hygienic analyses, analyses of raw water for drinking water, etc., should be presented and assessed together with the other material. Also, if there are any other on-going projects, which are focused into different compartments of the lake (e.g. sediments, fishes etc.), into water protection management, any planning activity on the river basin, all data should be considered.

The principle should always be to check all possible sources of information to get a reliable and transparent basis for the overall assessment.

4.4 Observations made by the public

The citizens have a role in gathering monitoring information and in evaluating the changes in the status of the lake. The local people should also be seen as important co-players in setting the targets for the water protection and in planning and delivery of lake restoration.

The monitoring network in Finland is well organized and gives a good overall view of water status but due to the huge number of lakes and rivers it can never catch all water bodies. Local people often face the unwanted changes in water status in their daily life far before any "official" alarm bells start ringing. Changes in the water environment often give rise to direct and indirect conflicts of interest among individuals and groups and therefore local people may feel unfair if excluded from the planning process. Above and beyond they consider themselves as best experts in respect with the areas they have been living and working maybe for tens of years.

Observations made by the public can come from different sources. In many cases, e.g. if a local lake management project is going on, authority is co-operating with local groups or people and actively gathering information from the public. The information may be observations or measurements of certain features, like transparency. On the other hand the information may be on more general level, e.g. opinions or overviews of the quality status of the nearby lake. Questionnaires and discussions with local people produce a lot of this type of information. Their knowledge is not necessarily universal or expressed in a scientific form but contextual and more layman style. However, it must not be disregarded by professionals and authorities. The challenge may be how to reach all the available information and how to validate it.

Concerning the public observations of harmful algae data is collected and registered by environmental authorities in Finland. A nationwide algal monitoring programme using permanent sites and voluntary observers is running successfully (Lepistö et al. 1998). The abundance of algae is observed weekly during the summer and classified roughly into classes 0–3.

Description of the target lakes and material used in the testing of the monitoring and assessment procedure

5

5.1 Target lakes

The target lakes for the project activities are located across the Vuoksi River Basin in the eastern part of Finland, which is exceptionally rich in lakes. In some regions approximately 25% of the total area is covered by water. In general, the Vuoksi River basin is characterised by a rather nutrient poor siliceous bedrock. As a result, most of the lakes in the basin are naturally oligotrophic or oligo-mesotrophic of their nature.

Altogether 21 lakes were chosen as target lakes for the project activities, such as testing the field methods for measuring the biological quality elements and carrying out public participation tasks. All the target lakes were not used for all parameter testing, but a reasonable set of lakes was chosen for each purpose. For testing the monitoring and assessment procedure altogether 8 lakes and their data were chosen (Figure 11, Table 1). However, one of the lakes, Lake Keskimmäinen-Alimmainen has in some connections been treated as two lakes, Lake Keskimmäinen and Lake Alimmainen. Also the watershed areas of the lakes have been considered in the project for evaluating loading pressures on the lakes (Annex 1).

The project target areas (lakes) were chosen by using regional expertise of the project partners. The main selection criteria used were:

1) The natural lake type
2) The type of human impact on the site
3) The existing biological data and other ongoing activities

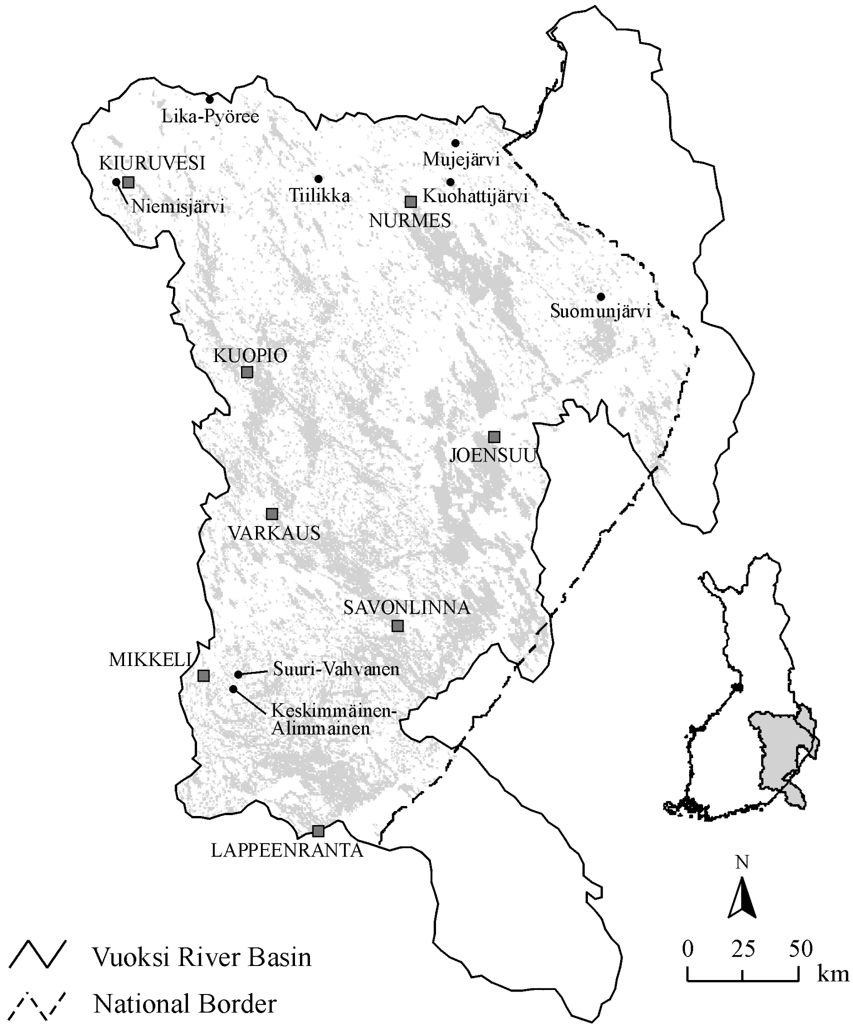


Figure 11. Location of the target lakes included in the testing of the monitoring and assessment procedure.

The idea was to select examples of the main natural lake types typical of the Vuoksi River basin, such as small slightly humic lakes, medium-sized moderately humic lakes, small very humic lakes and naturally eutrophic lakes. The most current national information concerning the typology of lakes (c.f. Pilke et al. 2002) according to the WFD was crucial for the selection and it was taken into account during the work. Existing paleolimnological information was used to help in typification of lakes presumed to be naturally eutrophic.

Table 1. The target lakes of the Life Vuoksi Project used for the testing of the monitoring and assessment procedure. The total phosphorus and colour values are given as annual means from the surface water layer samples. The types are according to Pilke et al. (2002)

Target lake	Municipality	Character of the watershed area	Area (km^2)	Total P ($\mu g/l$)	Colour (mg Pt/l)
Naturally eutrophic lakes (type 2, located in clay soils or soils rich in nutrients)					
Lika-Pyöree	Sonkajärvi	reference area	1.95	30	160
Niemisjärvi	Kiuruvesi	agriculture	4.18	63	200
Small and middle sized slightly humic lakes (type 4, colour < 30 and area < 40 km^2)					
Suuri-Vahvanen	Mikkeli	reference area	1.32	5	16
Keskimmäinen	Mikkeli	diverse non-point loading	0.80	14	51
Alimmainen	Mikkeli	diverse non-point loading	0.74	25	70
Middle-sized moderately humic lakes (type 7, colour 30-90 and area 5-40 km^2)					
Suomunjärvi	Lieksa	reference area	6.63	6	70
Kuohattijärvi	Nurmes	forestry	10.81	12	70
Small very humic lakes (type 9, colour > 90 and area < 5 km^2)					
Tiilikka	Rautavaara	reference area	4.20	13	100
Mujejärvi	Nurmes	forestry	3.51	29	150

Note: Lake Keskimmäinen-Alimmainen consists of two basins, which are connected to each other by a narrow strait. Sometimes the system is considered as a single lake and sometimes as two separate lakes.

5.2 Testing of biological elements

One of the main tasks of the Life Vuoksi Project was to test different methods for monitoring biological quality elements. The testing was focused especially on aquatic macrophytes, periphyton and benthic macroinvertebrates. Also phytoplankton was studied. The special aims for the method testing varied slightly from one biological element to another, because of their different nature and different traditions. Accordingly, the specific study requirements also varied between the elements. For each biological element, calculation of the ecological quality ratios was tested. It was nearer to the testing of the calculation procedures, because the datasets were insufficiently large enough for proper status estimations.

The results of the other work packages are used here as one important source for outlining the monitoring and assessment procedure, which is the major aim of this report. The relevant results of the method testing are briefly referred here. The results have been reported in full detail in Finnish. The Finnish references are given below in corresponding context as well as the existing English references.

5.2.1 Phytoplankton

In the Life Vuoksi project phytoplankton was sampled from 12 lakes in August 2002 as composite samples from surface to 2 meters. Phytoplankton biomass was estimated by microscopy using the Utermöhl (1958) technique from the composite samples taken from the pelagial part of the lakes, as recommended by Olrik et al. (1998). Furthermore, to identify five dominating taxa, composite samples were taken close to shorelines simultaneously with fluorometric measurement, and concentrated with a net.

The results of this study supported, in general, the proposed Finnish typification of the lakes (Pilke et al. 2002). The degree of loading varies in different lakes, and thus may be reflected in the phytoplankton assemblage and further in the EQR-value. Phytoplankton quantity and quality discriminated lakes that were not affected by human activities from the impacted ones, especially naturally eutrophic lakes affected by loads from agricultural sources.

The samples from the littoral area represent generally a different phytoplankton assemblage with a dominance of large taxa compared to that dominating in the pelagial area. Furthermore, the quick but very robust analysis by microscope provides information on the taxa, which mainly form the chlorophyll *a* concentration estimated by fluorometric measurement. The estimation of phytoplankton abundance only by fluorometric measurements is risky, as especially abundant *Gonyostomum semen* increase chlorophyll *a* concentration whereas *Hyalotheca dissiliensis* with a large biovolume does not. This is why at least a robust microscopical investigation is needed to describe the phytoplankton assemblage behind the concentrations. However, these simple methods do not provide accurate information concerning the phytoplankton quantity.

The net sampling method presented here is easily adapted to the monitoring of the littoral area of a lake carried out by individuals who are able to use a simple field microscope. The estimation of the ecological state of lakes, if based on phytoplankton, has to be based on samples taken from the pelagial part of a lake and on more laborious phytoplankton analyses. These are especially t required for estimating the EQR-values.

The phytoplankton results are given in full detail in Finnish by Sojakka et al. (2003a). A brief summary in English is presented by Sojakka et al. (2003b).

5.2.2 Periphyton

The study was directed towards the diatom communities of the periphytic growth and the aim of the work was to test periphyton methods and the usefulness of periphytic diatom species composition as well as sampling strategies in order to test the method for the classification purposes in the implementation of the WFD.

Periphyton diatom samples were collected in August 2002 from 6 lakes and different substrates in the littoral area: water macrophytes (*Carex, Phragmites and Scirpus*-species) and natural bottom stones. In addition, samples were collected from artificial substrata (clear polycarbonate plastic plates), which were incubated three weeks in the littoral zone.

When comparing water quality and the lake type, the values of different diatom indices displayed quite similar view. Basically, these results were logically correct, which was seen from index values according to the water quality change. However, from the compared lake pairs only type 2 lakes differed statistically significantly from each other. Most promising results to separate reference sites and the impacted sites using diatom indices came from stone samples, where the taxa richness was 15–20% higher than macrophytes or polycarbonate plates.

The results in full detail are given in Finnish by Sojakka et al. (2003a). A brief summary in English is presented by Sojakka et al. (2003b).

5.2.3 Aquatic macrophytes

The field method broadly tested is called the main belt transect method. The main belt transect is a 5 m wide area located perpendicular to the shoreline. It starts from the upper eulittoral and continues up to the outer borderline of submersed macrophytes. The main belt transect is partitioned into zones based on the life forms of aquatic macrophytes, which are defined according to the dominant species. Field surveys were made in July–August 2002. This field survey method provides quite accurate information on species composition, abundance and also some supporting data (e.g. water depth, bottom quality) was reported.

Two main metrics were considered: species richness and relative abundance. Besides this, relative abundances of life forms were considered. The data produced was also used for preliminary calculations of Ecological Quality Ratios using the similarity of the species composition as a parameter.

The results supported the outcome of previous studies that aquatic macrophytes could be suitable for monitoring the effects of the pulp and paper industry and agriculture/diffuse loading. The effects of forestry on the ecological status of the target lakes as indicated by aquatic macrophytes were not inconclusive.

In the remote sensing study digital colour infrared (CIR) aerial photography data was acquired in July–August 2002. Reference data from the field was collected using the main belt transects and reference plots, which were planned to correspond with the remote sensing surveys. The reference plots were at least 3 x 3 m wide areas, selected from differing densities of each life form and dominant species of the lake. Species composition, coverage, water depth and bottom quality were measured for five randomly chosen quadrants in each reference plot.

With the aid of field information the aerial photography data was numerically classified using the maximum likelihood classifier. The remote sensing method provides spatially representative information on species abundance. Taxonomical accuracy is mainly coarse, since the phenotype and coverage of species has a great effect on the classification. The observation of the species density enables, on the other hand, the biomass assessment of species. In addition the method is useful for detecting temporal changes in macrophyte stands.

Aerial photograph interpretation was shown to be a useful monitoring method of helophytes and nymphaeids, while it is was less useful for discriminating submerged vegetation. Abundance information about nymphaeid and helophytic vegetation, calculated as a percentage of the possible colonisation area of colonisation actually covered by vegetation, and the relative long-term change were in accordance with the concentrations of total phosphorus and nitrogen of the lakes. This indicates that the abundance of helophytes and nymphaeids measured using the method concerned is changed along the lake nutrient gradient and, therefore, could also be used as a measure of ecological status.

The results of the field methods in full detail are reported in Finnish by Leka et al. (2003). A summary in English is presented by Leka and Kanninen (2003). The results of testing the numerical interpretation of aerial photography are published by Valta-Hulkkonen et al. (2003a, 2003b).

5.2.4 Benthic invertebrates

In the Life Vuoksi project, the parameters for benthic invertebrate studies were abundance (density), diversity (taxa richness, Shannon's H and evenness), presence of sensitive taxa (profundal) and taxonomic composition by using three methods: ordination, Jaccard index and method analogous to predictive modelling by RIVPACS (e.g. Wright 2000) described in Hämäläinen et al. (2002).

In the study lakes of the Life Vuoksi project, the profundal zone and three littoral habitat types, stony, sandy and vegetated (silty and muddy) bottoms were sampled. Each studied lake type included one or two reference lakes and one to four lakes stressed by different anthropogenic activities.

The testing of different sampling methods in the littoral zone (four sub-basins of a large lake, Lake Haukivesi along the gradient of nutrient loading) was conducted in early July 2002. Smaller lakes representing four different lake types were sampled during September and the first week of October. All the lakes were sampled once.

The aims of the project were to compare the suitability of different lake zones and habitat types to the assessment of ecological quality and to compare different sampling methods in discriminating stressed and reference communities. Cost-effectiveness of the methods and the effect of taxonomic resolution on separating stressed vs. reference conditions were also studied. In the Life Vuoksi project, the low number of reference lakes in each type may restrict the reliable estimation of the ecological status of lakes. Thus, further studies with a higher number of reference lakes are needed.

The results in full detail are given in Finnish in Tolonen et al. (2003).

5.2.5 The costs of monitoring

The cost of the lake monitoring and assessment activity can be roughly divided into five sectors: planning (including general preparation), fieldwork (including mainly sampling and pre-treatment), sample analysis, data recording and reporting. Each of these sectors can be furthermore separated into general (fixed) costs and unit dependent costs. Units can be for example the size of the study area, the number of monitored lakes, the number of sampling sites, the number of replicate samples. The costs should include staff expenses, travelling costs, vessels, equipment and reagents and outsourcing services. Also overheads and other general costs should be included.

Costs for monitoring the different biological elements are presented in the original Finnish reports mentioned in the chapters above. Costs for the fieldwork were in these cases easier to determine while the planning cost were mainly underestimated to be used in various conditions. In this kind of pilot studies the planning period takes a relatively long time. The reporting costs were left out in these calculations because the time used for the reporting of these studies were quite unique and can not be generalized for future monitoring work. Neither general cost, overheads, vessels or cost of office, sampling and laboratory equipment were included. Thus the calculations presented in these reports are focused on the costs mostly originating from the fieldwork, sampling, data analyses and basic recording only and can not be used as a base of future monitoring resource calculations or competitive biddings. All these cost calculations are based on the average values without any information on the variation between lakes and habitats. The handling costs of samples taken from different lake types and habitats may differ greatly.

5.3 Other material

5.3.1 Meteorological data

Meteorological data is of great importance in the evaluation of different biological phenomena in the nature.

In this project, most of the biological observations were performed during summer 2002. According to the Finnish Meteorological Institute (2003) the weather in summer 2002 was as follows:

"June was at first very warm and sunny, but the end of the month was rainy and cool. Except for Lapland, July was very hot. On July 5th, powerful thunder and lightning accompanied by gusts of stormy weather and heavy showers caused major material damage and hazardous situations especially in the eastern part of the country. This stormy weather was followed by a quite dry period, which persisted until the end of summer.

August was dry and record warm. The southern and western parts of the country enjoyed a record number of hot days for August; between 10 and 17 depending on the locality. August provided a new national record for the average monthly temperature when 20.9 °C was measured in the south-western Archipelago on Utö island. The period from June to August was the second warmest period on average in most parts of the country since the beginning of the 1900s. The southern and central parts of the country enjoyed a record number of hot days, between 20 and 35. The end of the summer was characterised by severe drought; this was especially so in the coastal regions".

5.3.2 Hydrological data

The overall hydrological situation of previous years is reported by the Finnish Environment Institute. The monthly report from August 2002 (Finnish Environment Institute, Hydrological reports 2001 – 2002) informs the hydrological situation as follows:

"Both the dry weather during August in Finland and its surrounding areas, and the heavy rainfall and floods which occurred in central Europe resulted from a belt of high pressure which remained stationary for a long period over Finland, the Baltic States and Northern Russia. Precipitation in Southern and Central Finland was very low, evaporation from watercourses was high and both surface water and groundwater levels decreased rapidly. The effects of the drought were seen in areas with low rainfall as parching of grass and hay and even as the death of bushes and trees. In the north of the country, hydrological conditions were approximately normal. Water temperatures remained at record-breaking high levels.

Precipitation during August in Southern Finland was very low, in many areas only 10–20 mm. The rainfall came mainly as local showers and in many parts of the country the overall rainfall was only half the long-term seasonal mean. The high regional variation in precipitation was reflected in a corresponding high variation in watercourse resources.

The very warm weather caused a considerable increase in water temperatures and in evaporation from water surfaces. High soil temperatures caused an increase in evaporation from the ground, although parching of grass and hay actually limited overall evaporation. Evaporation from trees caused a drying out of deeper soil layers.

Water levels and discharges of watercourses with few lakes decreased sharply from the beginning of August in Southern and Central Finland. In the Lake District of central Finland, water levels decreased to 10–40 cm below the seasonal mean by the end of the month.

The deviation of Lake Saimaa from the seasonal mean at the end of August was –38 cm. The mean August discharge of River Pielisjoki (discharging to Lake Saimaa) was 78% of the mean August discharge during the reference period 1961–1990 and the corresponding figure in River Vuoksi (outflow from Lake Saimaa) was 94%.

Groundwater levels decreased rapidly in a large part of the country and approached critically low levels in some areas with very low rainfall. The groundwater table was typically 30–50 cm below the seasonal mean at the end of the month, but regional variation was high. Soil layers above the groundwater level were so dry in a large part of Southern and Central Finland that the soil water deficit reached or even exceeded 100 mm. The exceptionally high soil heat reserves caused rapid evaporation of precipitation reaching the surface layers in many areas.

Water temperatures were unpredictably high until the very end of August. Surface water temperatures of 20–22 °C were still generally recorded on August 28th in Southern and Central Finland, about 5 or even 6 °C above the seasonal mean. For instance, in southern Lake Saimaa the mean surface water temperature in August 2002 was 22.2 ^{o}C, when the mean value for 1961–1990 is 18.3 ^{o}C."

5.4 Co-operation with local inhabitants

One of the objectives of the Life Vuoksi Project was to activate local citizens both by encouraging them to become more familiar with lake ecology and also to start voluntary lake monitoring. Getting to know better the environment motivates also to actively manage the lake and improve the quality of the environment. Previous experience also indicated that people would be eager to learn more about the ecology of their nearby lakes. Project activities were focused on areas where water quality problems, especially eutrophication, have already been identified and carried out in close co-operation with local restoration projects. The fishery and its economic benefits are very important for the people in the Vuoksi River Basin, too, which were taken into account when planning the activities.

In the Life Vuoksi Project the tools used were enquiries, village events, training and an information package. Also material for a nature trail was produced on one project area. On each target area the tools were chosen on the basis of local needs and traditions.

Opinions and attitudes of local people and information about the changes in lake and lake water quality were gathered by enquiries, which were carried out on three watershed areas. Two of which were watershed areas including several small lakes. An enquiry form was posted to all households. The answering activity varied between ca. 30–50%.

In village events laymen were informed and motivated in lake monitoring. The use of a Secchi disk for assessing the transparency of the water was promoted. Also the monitoring of littoral macrophytes was actively promoted. The methods were developed and the people were informed and guided in a new information package, made in the project, served this aim, too. There was co-operation with some schools also.

Results from the enquiries were descriptively compared with expert results concerning the ecological status of the lakes. Monitoring results made by the local inhabitants were not so plentiful and they were not used directly for the status assessment of the lakes.

A report of the works has been compiled in Finnish (Sandman et al. 2004).

6 Practical testing of the monitoring and assessment procedure

6.1 Pilot testing of the integrated monitoring and assessment procedure

This chapter presents the results of the testing phase of the monitoring and assessment procedure of all together 8 (or 9, cf. Chapter 5) target lakes (Figure 11, Table 1). The remainder of the 21 study lakes were only used for other project activities, such as testing the field methods for measuring the biological quality elements and carrying out public participation tasks. More detailed research results of other purposes of the Life Vuoksi project are presented in separate publications (Leka et al. 2003, Manninen et al. 2003, Sojakka et al. 2003a,b, Tolonen et al. 2003).

The testing phase of the target lakes and major sources of pollution to them are:

- Lake Keskimmäinen-Alimmainen (non-point loading: agriculture, scattered population, forestry).
- Lake Suuri-Vahvanen (reference lake for Lake Keskimmäinen-Alimmainen).

- Lake Niemisjärvi (non-point loading, agriculture)
- Lake Lika-Pyöreä (reference lake for Lake Niemisjärvi).

- Lake Kuohattijärvi (non-point loading, forestry)
- Lake Suomunjärvi (reference lake for Lake Kuohattijärvi).

- Lake Mujejärvi (non-point loading, forestry)
- Lake Tiilikka (reference lake for lake Mujejärvi).

A general procedure on how to use the results of the different quality elements of the testing lakes will be discussed using the flow chart for the monitoring and assessment procedure (see Fig. 10). The aim has been to use and evaluate the applicability of the most important factors/phases of the assessment procedure.

It is quite obvious that the assessment procedure has to be organized in the future by a team of experts. One additional important issue is how to resolve and connect public participation to this important assessment phase.

6.2 Lakes affected by non-point loading from various sources

Authors: SYKE/Heinonen, P. SSREC/Leka, J., Manninen, P. and Sojakka, P.

Many lakes in Finland are affected by non-point loading from different sources, such as a scattered population without organised public water services, agriculture, forestry, airborne pollution. Further, in most cases there is more than one source. In this project Lake Keskimmäinen-Alimmainen (non-point loading: agriculture, scattered population, forestry) and Lake Suuri-Vahvanen (reference lake, nearly natural condition) were tested to represent this group following the flow chart of the monitoring and assessment procedure (Fig. 10). This pair of lakes was case study number 1.

Phase I – geological and hydro-morphological information on the lake and its catchment

Lake Keskimmäinen-Alimmainen consists, actually, of two separate lakes, which are connected to each other by a narrow strait (Appendix 1). However, in many cases the water area is considered as a single lake. The main characteristics of the watershed (catchment) area of the lake and the hydrological and morphological features of the lake are presented in Tables 1 and 2.

The surface area of almost pristine Lake Suuri-Vahvanen is of the same size as that of Lake Keskimmäinen-Alimmainen but it has clearly a smaller drainage area and thus also significantly longer water retention time than in Lake Keskimmäinen-Alimmainen (Appendix 1, Tables 1 and 2).

The share of peat land in the catchment of Lake Keskimmäinen-Alimmainen is of the same degree than in the catchment of Lake Suuri-Vahvanen. Lake Keskimmäinen-Alimmainen can be estimated to have been in natural status an oligohumic and oligotrophic lake. Following the Pilke et al. 2002 proposal for the typology of Finnish lakes (see chapter 2.3), these lakes have been estimated to belong to type 4. More details of the location and the soil properties of Lakes Keskimmäinen-Alimmainen and Suuri-Vahvanen can be found in the publication by Manninen et al. 2003.

Table 2. Basic information on the lakes and their watersheds.

Lake	Watershed area (km^2)	Altitude (m a.s.l.)	Proportion of peatland (% of ws)	Surface area (km^2)	Mean discharge (m^3/s)	Depth (m) mean	Depth (m) max	Volume (10^6 m^3)	Retention time (months)
Keskimmäinen-Alimmainen	69.1	88.9	5.9	1.53	0.62	3.2	15	7.65	4.7
Suuri-Vahvanen	6.8	78.9	5.4	1.32	0.06	4*	15	7.60	48.4

a.s.l. = above sea level
ws = watershed
* = 0.1921 x maximum depth + 1.1518

Original lake type has been determined by using the geological data of the local ground and soil, as well as the morphological data on the lakes. All the material has been available, and the handling of material was not time consuming. However, the original lake type is an assumption, based mainly on the proportion of peat land in the catchment area. Lakes are situated geographically close to each other in the same drainage basin (in the same lake system). Paleolimnological data from these lakes does not exist.

In this context no attention has been paid to the thermal stratification of lakes although thermal stratification is mentioned as a secondary factor in the typification of certain lakes in the proposal for the typology of Finnish lakes (Pilke et al. 2002). In general, it is probable that biological elements could be quite different in shallow lakes compared to deep lakes although the other factors (area, water quality, catchment area) are similar. Habitat types in shallow and deep lakes differ. But the question is also what part of the water volume should be stratified when lakes are divided as shallow or deep ones. In the case of Lakes Keskimmäinen-Alimmainen and Suuri-Vahvanen it seems to be relevant to compare these lakes because the estimated mean depths do not differ much.

Phase II – meteorological data

The nearest meteorological observation station to Lakes Keskimmäinen-Alimmainen and Suuri-Vahvanen is situated at the Mikkeli airport, only some 17 kilometres from the lakes. This meteorological station measures temperature, humidity, wind direction and speed, air pressure, and cloud continuously.

From the meteorological observations, the summer period (1.6.–31.8.) of the year 2002 at Mikkeli airport was 1.9 °C warmer than the long-term average for 1971–2000 (Finnish Meteorological Institute). This should have increased the aquatic primary production, even in a natural reference lake.

Precipitation at the Mikkeli airport in the year 2002 was 8.5% lower than the mean annual value for 1971–2000 (Finnish Meteorological Institute). The difference was caused by the exceptionally dry period from August to December although in November the precipitation was above normal (Fig. 12). In the first half of the year the precipitation was above normal.

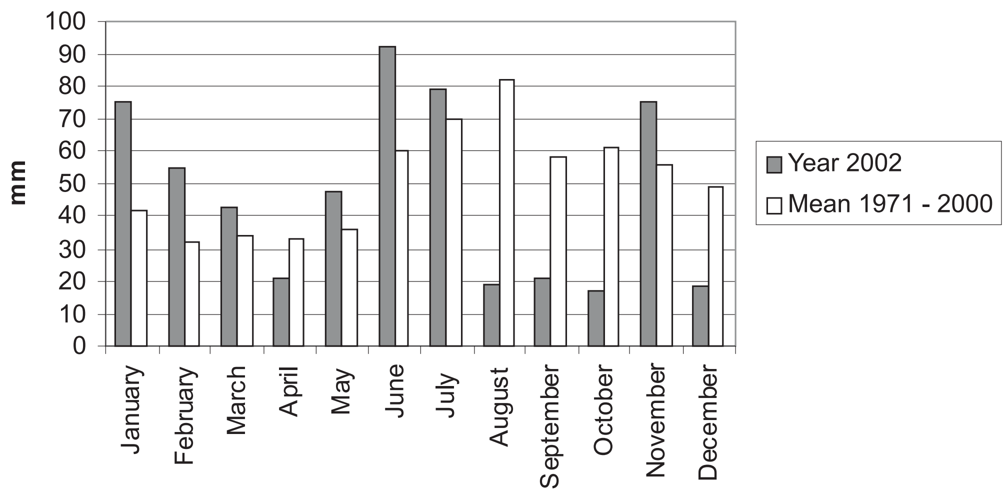


Figure 12. Monthly precipitation at the Mikkeli airport during the year 2002 compared to the mean monthly precipitation during 1971–2000.

Phase III – hydrological data

The estimated mean discharge (MQ) from the outlet of the Lake Keskimmäinen-Alimmainen is some 0.6 m^3/s. Based on expert judgement using the meteorological data the mean discharge during summer 2002 was 2/3 of the normal values. In the outlet of Lake Suuri-Vahvanen it was estimated to be 0.06 m^3/s. A rough estimate suggests that the mean discharge could have been over half of the normal value in summer 2002.

The water levels in Lake Keskimmäinen-Alimmainen and Lake Suuri-Vahvanen were not measured, but it was estimated that water level in the lakes was in summer 2002 roughly 10 cm lower than normally.

Phase IV – evaluation of geological, typological, hydro-morphological, meteorological and hydrological data and their potential effects on biological and physico-chemical quality elements

The river discharges were very low in 2002 because of the very dry summer. Nevertheless, the hydrological data is in good accord with the meteorological observations. The low discharges could have decreased the non-point loading from e.g. agricultural areas, as well as the natural leaching of nutrients. On the other hand, the retention time in lakes during the warmest season was longer than usual, which could have increased the primary production potential.

Phase V – pressures on the lakes

The nutrient load on Lake Keskimmäinen-Alimmainen is from non-point sources, of which agriculture is the most significant. It should be also mentioned that the inflow of the lake empties into the Alimmainen sub-basin and the major nutrient loading from the agriculture is concentrated to that part of the lake. On the other hand 70% of summer cottages are situated on the shores of the Keskimmäinen sub-basin. The nutrient loading has been calculated using discharge and corresponding concentration values, or estimated from the land use data (in details see Manninen et al. 2003). Both phosphorus and nitrogen loadings have been presented on an annual basis. Different sources of loadings have been discussed separately.

The phosphorus loading has been estimated to be approximately 700 kg/a over the whole lake (153 ha), which means some 0.46 $g/m^2/a$. Using the values critical for eutrophication according to Vollenweider (1968), this means a clear dangerous loading for such a shallow lake as Lake Keskimmäinen-Alimmainen. The highest acceptable annual phosphorus load could be 0.07 g/m^2, and the critical values are more than 0.13 $g/m^2/a$ (Table 3).

Table 3. Estimated phosphorus and nitrogen loadings to the study lakes (Manninen et al. 2003) and calculated critical loading values according to [1)]Vollenweider (1968).

Lake	Area (ha)	Mean depth(m)	Loading from the whole watershed		Loading from the nearest watershed		*Calculated annual loading values for the whole ws; the nearest ws.		[1)] **Permissible and dangerous values of P ($g/m^2/a$); mean depth		[1)] **Permissible and dangerous values of N ($g/m^2/a$); mean depth	
			P kg/a	N kg/a	P kg/a	N g/a	P g/m^2	N g/m^2	5 m	5-10 m	5 m	5-10 m
Keskimmäinen-Alimmainen	153	3.2	705	18990	428	9450	0.46; 0.27	12.4; 6.18	0.07; 0.13		1.0; 2.0	
Suuri-Vahvanen	90	4	139	3623	139	3623	0.073; ”	1.91; ”	0.07; 0.13		1.0; 2.0	

* Calculated annual loading values: The first figures refer to the whole watershed and the second ones to the nearest watershed, e.g. 0.46; 0.27. ws = watershed.
** The first figures refer to the permissible values and the second ones to the dangerous values

Nitrogen loading has been estimated to be 19 000 kg/a, which is an annual loading of 12.4 g/m^2. Also this value is according to Vollenweider (1968) clearly too high, the acceptable value could be for a shallow lake only 1.0 $g/m^2/a$ and the dangerous nitrogen value is more than 2.0 $g/m^2/a$. However it is to be remembered, that in Finland total nitrogen, which consists of mineral nitrogen compounds and also organic compounds has been analysed, whereas Wollenweider (1968) refers to inorganic nitrogen. In humic waters the share of organic nitrogen compounds, considered not so important for primary production, is usually high.

The reference lake, Lake Suuri-Vahvanen, is in nearly natural condition. According to Manninen et al. (2003) only slight non-point loading can be traced. The acceptable values (Vollenweider 1968) for phosphorus and nitrogen have been 0.07 $g/m^2/a$ and 1.0 $g/m^2/a$, respectively. For Lake Suuri-Vahvanen the calculated values were 0.073 $g/m^2/a$ for phophorus and 1.9 $g/m^2/a$ for nitrogen.

As a summary, nutrient loading has significantly increased in Lake Keskimmäinen-Alimmainen, and the loading pressure is clearly too high for this type of lake.

Phase VI – physico-chemical data

There has not been a permanent monitoring programme for Lakes Keskimmäinen-Alimmainen and Suuri-Vahvanen. The physico-chemical data is therefore very sparse. The only significant results from the assessment point of view are some chlorophyll *a* analyses, measured during summer time (Table 4). Chlorophyll values are clearly indicative for meso-eutrophy in Lake Alimmainen and indicative for mesotrophy in Lake Keskimmäinen. It must be pointed out that a massive occurrence of *Gonyostomum semen* was observed in Alimmainen in summer 2002. This will most probably cause difficulties when comparing these chlorophyll *a* results to the results from the other sites. The corresponding values from Lake Suuri-Vahvanen are, on the contrary, very low and indicative of oligotrophy.

Table 4. Water quality data of the surface water (0–1 m) during summer (1.6.–15.9.) in years 1985–2002.

Lake	area (km^2)	tot P ($\mu g/l$)	tot N ($\mu g/l$)	colour (mg Pt/l)	chlorophyll *a* ($\mu g/l$)
Keskimmäinen	0.84	14	520	48	16
Alimmainen	0.69	24	570	56	31
Suuri-Vahvanen	1.32	5	310	16	2.6

According to recent total phosphorus concentration Lake Keskimmäinen-Alimmainen is estimated as mesotrophic and Lake Suuri-Vahvanen as oligotrophic. Water colour values are relatively high in Lake Keskimmäinen-Alimmainen compared to Lake Suuri-Vahvanen (Table 1). Therefore it has been debated that Lake Keskimmäinen-Alimmainen could originally have been a moderately humic lake (type 6, water colour 30–90 mg Pt/l).

As a summary of the relatively minor physico-chemical data it can, however, be evaluated, that Lake Keskimmäinen-Alimmainen is clearly eutrophied, and the production of algae is so high that it can be detected visually.

Phase VII – first evaluation of the most probable status

According to all the information presented in the previous phases, Lake Keskimmäinen-Alimmainen seems to be a lake with relatively great changes from the natural status. Eutrophication is very clear in Lake Keskimmäinen-Alimmainen.

One of the first obligations of the WFD, which should be reported at the end of 2004, is that Member States shall carry out an assessment of the likelihood that surface water bodies will fail to meet the environmental quality objectives set for the bodies under Article 4. Member States may utilise modelling techniques to assist in such an assessment (Annex II of the WFD).

This first evaluation of the most probable status provides in the case of Lake Keskimmäinen-Alimmainen the result that the lake fails to meet the objectives of the WFD, i.e. "good ecological status". This assessment is based especially on pressure information and few physico-chemical data (chlorophyll).

Phase VIII – biological quality elements and Ecological Quality Ratios (EQR)

Aquatic macrophytes

The taxonomic composition and relative abundances of aquatic macrophytes of Lake Keskimmäinen-Alimmainen differed spatially to such an extent that it was reasonable to separate Lake Keskimmäinen and Lake Alimmainen as different water bodies. According to the aquatic macrophyte metrics the ecological status of Lake Keskimmäinen could be good and the ecological status of Lake Alimmainen could be moderate (Table 5). The expected values for these metrics were calculated from data for the two reference lakes: Lake Suuri-Vahvanen and Lake Sylkky, not described in detail in this report. The similarity of the species composition between the reference lakes was quite low (natural variation, field methods). Therefore, it appears that the calculated EQR values would not underestimate the ecological status of these lakes.

Periphyton

The number of diatom taxa found from natural surfaces does not differ between Lakes Suuri-Vahvanen (43) and Keskimmäinen-Alimmainen (42). Taxon diversity was lower (3.07) in Lake Keskimmäinen-Alimmainen than in Lake Suuri-Vahvanen (3.90) and the calculated EQR of Lake Keskimmäinen-Alimmainen was approximately 0.78 suggesting good condition. The trophic state (production potential) calculated from diatom taxa (Van Dam et al. 1994) showed Lake Keskimmäinen-Alimmainen to be clearly mesotrophic and Lake Suuri-Vahvanen to be oligo-mesotrophic.

The diatom indices (PSI, Descy, GDI and TDI) which estimate the trophic state, organic pollution (PSI, Descy, GDI) and nutrient conditions (TDI) (Sojakka et al. 2003a,b), all showed that the trophic status of Lake Keskimmäinen-Alimmainen was higher compared to the reference Lake Suuri-Vahvanen (Table 5). Quantitative periphyton analyses showed that the chlorophyll *a* content of periphyton varied a lot (artificial surfaces, arithmetic means 1.10 mg/m^2 in Lake Keskimmäinen-Alimmainen and 0.66 mg/m^2 in Lake Suuri-Vahvanen). The amount on total solids (0.80 and 0.19 g/m^2, means of three different stations) deviated much for these two lakes. There were no periphyton samples from Lake Sylkky, the other reference lake.

Table 5. Assessment of the ecological status of Lake Keskimmäinen-Alimmainen based on expert judgement and results of the biological elements during summer 2002. Class boundaries between the ecological status classes have not been defined for these metrics.

Biological element	Common aspects	Expert judgement of the ecological status	Ecological Quality Ratio
Aquatic macrophytes:	The lake was separated into two water bodies, because of different aquatic macrophyte communities.	Keskimmäinen good Alimmainen moderate	
Number of taxa	Suuri-Vahvanen 17 species Kesk.-Alimm. 34 species		Kesk. 0.64 Alimm. 0.50
Species composition			Kesk. 0.88 Alimm. 0.63
Species frequency			Kesk. 0.95 Alimm. 0.68
Benthic invertebrates:		good-moderate	
Hämäläinen			0.77
Jaccard Similarity			0.49
Periphyton:		good-moderate	
Jaccard's Similarity			0.41
Sørensen's Similarity£			0.58
Number of taxa			0.71
Diatom biotic index (PSI and TDI)			0.83
Phytoplankton:			
Total biomass			
ref. national databank			0.50-0.60
ref. S-V ja Sylkky			0.1*

* dense population of taxon *Gonyostomum semen*

Phytoplankton

According to previous physico-chemical data and data collected during the Life Vuoksi Project in the summer of 2002 the chlorophyll *a* content of Lake Keskimmäinen-Alimmainen is quite high and the trophic status is mesotrophic. EQR-values of Lake Keskimmäinen-Alimmainen varied between 0.5–0.6, when based on a larger dataset from national reference lakes. When based on the reference lakes of the Life Vuoksi Project, Lakes Suuri-Vahvanen and Sylkky, the EQR was low, 0.1.

The reason for this extremely low value was probably the dense *Gonyostomum semen* (*Raphidophyceae*) population during summer 2002 in the lake. According to the fluorometer measurements and microscopic analyses, Lake Keskimmäinen-Alimmainen has occasionally spatially dense *G. semen* populations. *G. semen* is a big alga, which contains a lot of chlorophyll. It is the main reason for the very high chlorophyll content in the lake. *G. semen* is quite common in mesotrophic brown-water lakes in Finland and is a problematic alga because it can move up and down in the water column and benefit from higher nutrient contents near the lake bottom. At the same time it can have some influence on the species composition and biomass of other algae. All the other brown water target lakes examined included *G. semen*, too.

The rod-shaped alga *Hyalotheca dissiliens* (*Conjucatophyceae*) was also quite common in Lake Keskimmäinen-Alimmainen and in the other lakes studied. *H. dissiliens* has caused intense sliming of fishermen´s gill nets and other traps in Finland.

Benthic invertebrates
In general, animal density was usually higher in loaded lakes than in the reference lakes, but the EQRs calculated by using the species diversity and evenness-index were not unambiguous. EQR-values calculated from the species composition (Jaccard-similarity index and similarity according to Hämäläinen et al. 2002) showed a better response between the loaded and reference lakes. The calculated EQR values (Table 5) for Lake Keskimmäinen-Alimmainen were 0.77 (Hämäläinen et al.) and 0.49 (Jaccard). According to the EQR values the state of Lake Keskimmäinen-Alimmainen is in the area of good or moderate status.

Phase IX – final assessment of the ecological status

As a conclusion, based on all available data, the ecological status of Lake Keskimmäinen-Alimmainen deviates moderately from the reference condition. The ecological status of Alimmainen might be moderate. The ecological status of Lake Keskimmäinen seems to be somewhat higher and reflects a good status.

6.3 Lakes affected by non-point loading from agriculture

Authors: NSREC/Kanninen, A., Hammar, T., Haapala, A. and Vallinkoski, V.-M.

Agriculture is at present the highest single source of nutrients to surface waters in Finland. In this project Lake Niemisjärvi (non-point source loading: agriculture) and Lake Lika-Pyöree (as reference lake) were tested from this group following the flow chart of the monitoring and assessment procedure (Fig. 10). This pair of lakes was case study number 2.

Phase I – geological and hydro-morphological information on the lake and its catchment

Lake Niemisjärvi is a relatively small, shallow lake with a short retention time (Tables 1 and 6). The lake is situated in a catchment area with a great proportion of soils sensitive to erosion, e.g. clay. The proportion of peat land in the catchment area is 22% and, as a result, the humic content of the water is high (mean colour 200 mg Pt/l). Naturally high trophic status, due to e.g. the high proportion of clay soils, in combination with a high humic content is typical of lakes situated in the Iisalmen reitti watercourse in the northern part of the Vuoksi River basin. Most of the lakes in the Iisalmen reitti belong to the naturally eutrophic lake type (type 2 of the typification system proposed by Pilke et al. 2002).

The reference lake, Lake Lika-Pyöree is very shallow, small (Tables 1 and 6) and situated in the northernmost part of the Iisalmen reitti watercourse. The proportion of peat land in the catchment area of Lake Lika-Pyöree is very high (53%). The soils are not nutrient rich (e.g. no clay soils). Information on the bedrock is not available. Some nutrient rich bogs are situated near the lake, which indicates that the peat land of the catchment area may be naturally nutrient rich. However, the high trophic status of the lake is probably more clearly a consequence of the shallowness and nutrients attached to humic substances originating from the catchment area. The typification of Lake Lika-Pyöree is, therefore, somewhat problematic, as it could also be categorised as belonging to the small, humic lake type (type 9). On the other hand, available paleolimnological data (personal communication by Juha Miettinen, University of Joensuu) supports the typification used, as it indicates that the lake has most probably been eutrophic since its formation after the last glacial ice period. The data on diatom remains even suggests that the lake has undergone some oligotrophication process.

Table 6. Basic information on the lakes and their watersheds.

Lake	Watershed area (km^2)	Altitude (m a.s.l.)	Proportion of peatland (% of ws)	Surface area (km^2)	Mean discharge (m^3/s)	Depth (m) mean	max	Volume (10^6 m^3)	Retention time (months)
Niemisjärvi	177	99	22	4.18	1.6	1.5	5	6.50	1.52
Lika-Pyöree	24.7	154	53	1.96	0.3	0.6	0.9	1.18	2.14

a.s.l. = above sea level
ws = watershed

Phase II – meteorological data

The meteorological data should be treated as indicative only, because the observation stations concerned are quite far from Lakes Niemisjärvi and Lika-Pyöree. The meteorological station Kuopio Airport is 95 km south-east of Lake Niemisjärvi and 110 km south of Lake Lika-Pyöree. The distance between the lakes and the hydrological observation station at Lake Kallavesi for measuring water temperature and freezing/break up dates is 10 km further away.

The average temperature for the year 2002 at the Kuopio airport was 3.6 °C, being 0.5 °C higher than the average for the reference period of 1971–2000 (Finnish Meteorological Institute). The year 2002 began with very mild weather. Warm weather in March–April caused a rapid melting of the snow 1–3 weeks ahead of the normal annual schedule (Finnish Environment Institute, Hydrological reports 2001–2002). Break-up of ice in the Lake Kallavesi (7.5.) occurred nearly a week ahead of the median in 1971–2000 (12.5.). The earliest break-up date in the reference period is 29.4 (in 1989) and the latest is 25.5. (1996). The summer was warm and the surface water temperatures were above the seasonal mean almost throughout the summer (Fig. 13). During the summer of 2002 the average surface water temperature was 2 °C higher than the long term average. In the shallow brownwater target lakes the absolute difference of year 2002 water temperature to the long-term average may be higher than in deep Lake Kallavesi.

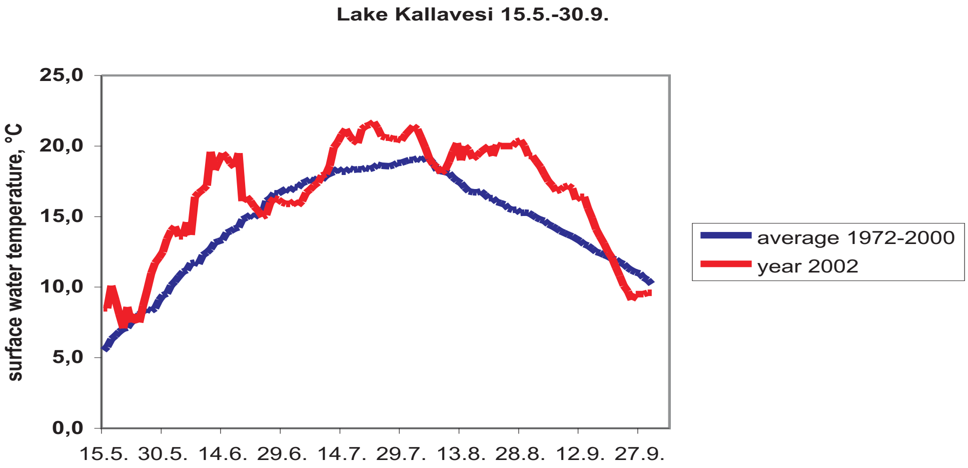


Figure 13. Surface water temperatures in Lake Kallavesi during the summer of 2002.

During the autumn 2002, water temperatures decreased rapidly and the freezing over of Lake Kallavesi occurred 16.11. as much as two weeks earlier than normal. During 1970–2002 the earliest freezing date of Lake Kallavesi was 9.11. (1992), the latest 29.12. (1974) and the median 1.12. Lakes Lika-Pyöree and Niemisjärvi are small and shallow lakes and situated over 100 kilometres north of Lake Kallavesi and the freezing over obviously occurred at the end of October.

Precipitation during the year 2002 was low. At the Kuopio Airport it was ca 7% below the mean annual precipitation during 1971–2000. Normal or above-normal precipitation was recorded only in January–March, in June–July and in November (Fig. 14). Particularly low precipitation occurred during the latter half of the year as a result of the almost unbroken period of high pressure (Finnish Environment Institute, Hydrological reports 2001–2002).

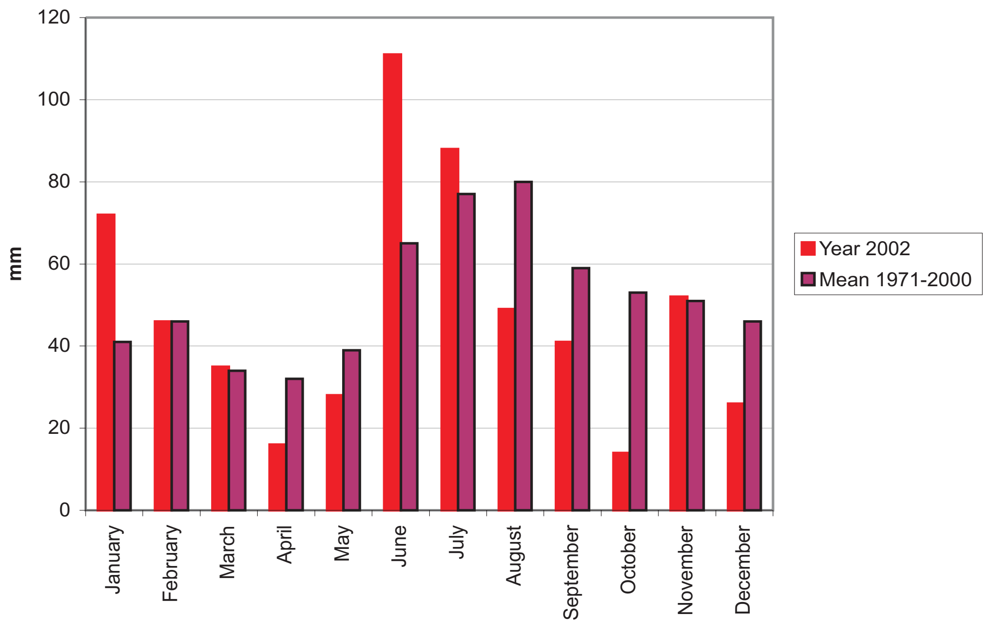


Figure 14. Monthly precipitation at the Kuopio airport in 2002.

The weather in autumn is important to the oxygen regime and water quality during winter stratification. Precipitation was low in summer and autumn 2001 and lake water levels were below the seasonal mean values (Finnish Environment Institute, Hydrological reports 2001–2002). Freezing over of watercourses progressed approximately normally but due to the warm autumn the turnover was inefficient. Thus the hypolimnetic water did not cool down as normally before the lake froze over.

Phase III – hydrological data

The water level in 2002 (MW N43 + 99.20) did not differ significantly from long-term average values (MW N43 + 99.16). The water level fluctuation of 2002 was characterized by a rise of the water level after the storms in the beginning of July (Fig. 15; see also 5.3.1 and 5.3.2). This is most likely due to regulation, not meteorological effects, since a regulation dam constructed by the locals is situated in the outlet of the lake and was likely used in summer 2002 to raise the lowest water levels.

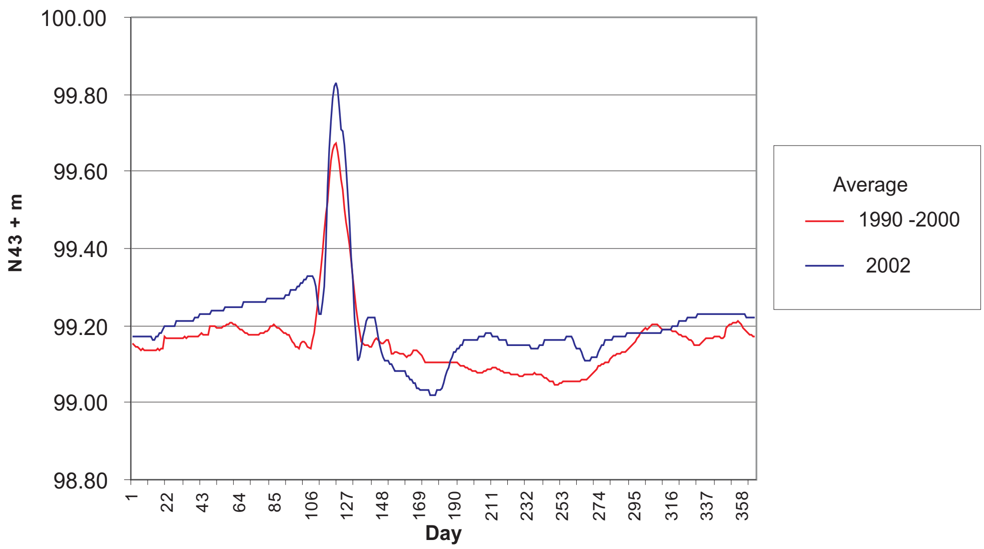


Figure 15. Water level fluctuation of Lake Niemisjärvi during 1990–2001 and in 2002.

The mean discharge from Lake Niemisjärvi is calculated based on the hydrological models of the Finnish Environment Institute. The mean discharge from Lake Niemisjärvi was 0.95 m^3/s in 2002 while it has been on average 1.82 m^3/s in 1991–2001. Measured discharges from the nearest continuous measurement station support the conclusion that discharge from lakes in this region have been significantly lower in 2002 than on average. However, the 2002 discharge from Lake Niemisjärvi contains some probable errors and underestimates the actual mean discharge (Fig. 16).

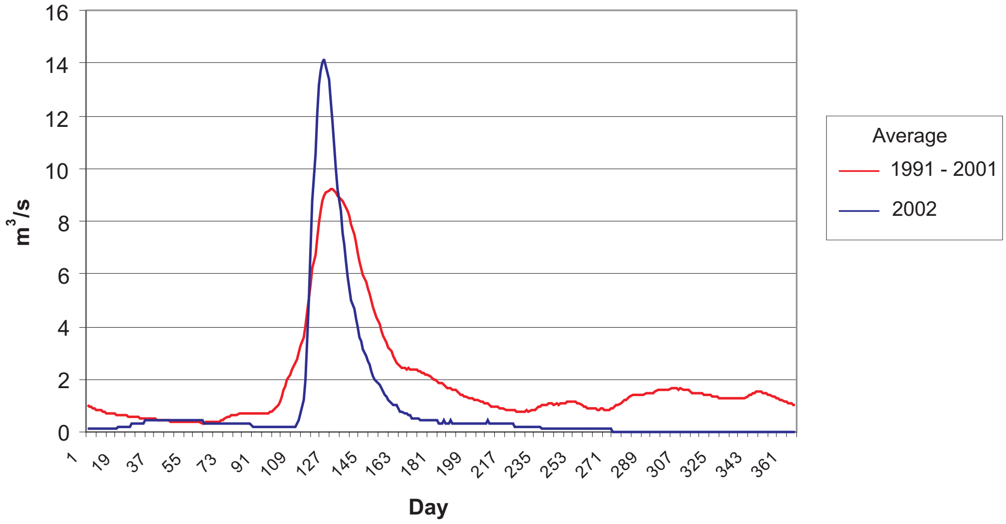


Figure 16. Mean discharge from Lake Niemisjärvi during 1991–2001 and in 2002.

There is no measured data on water level fluctuation from Lake Lika-Pyöree. The calculated discharge from the water basin where the lake is situated was 0.53 m^3/s in 2002 which is clearly lower than the average 1.21 m^3/s in 1991–2001.

Phase IV – evaluation of geological, typological, hydro-morphological, meteorological and hydrological data and their potential effects on biological and physico-chemical quality elements

An evaluation of the typical phosphorus concentration of the naturally eutrophic lakes in the Iisalmen reitti was based on a paleolimnological study (Miettinen et al. 2001) conducted at one sampling point in Lake Onkivesi, the central lake of the river basin. The effect of anthropogenic loading was evaluated in the study to have increased the phosphorous concentration by approximately 9 µg/l. Compared to the present day observed values at the same sampling point, an estimate of the natural concentration of phosphorus is approximately 35 µg/l. Using the Dillon and Rigler (1974) equation for the relationship between phosphorous and chlorophyll *a* concentration, the corresponding, typical values of chlorophyll *a* can be estimated to be 12–14 µg/l.

Due to the dry and warm autumn of 2001 the concentrations of nutrients and humic substances tended to be below normal values during the winter stratification period of 2001–2002. Inefficient autumn turnover resulted in lower oxygen concentrations than on average, but meltwaters during the mild weather in March–April improved the oxygen regime in epilimnion. As a consequence of low precipitation during winter and spring the spring runoff of nutrients were low. This obviously limited the profusion of algae which on the other hand was favoured by high surface water temperatures. Heavy rainfall in June and July possibly resulted in new supplies of nutrients in headwater lakes. In shallow lakes without permanent summer stratification nutrients also return from the sediment into the surface water during circulation in stormy weather.

Phase V – pressures on the lakes

Lake Niemisjärvi is mostly affected by diffuse loading from agriculture and, to a lesser extent, by forestry and scattered population. The discharge into the lake is dominated by discharge from the River Vaaksjoki, which also brings in the main portion of the nutrient loading. The calculation of nutrient loading is presented in the report of Life Vuoksi WP3 (Manninen et al. 2003).

The phosphorus load into the lake has been calculated to be on average 6 098 kg/a. Related to the surface area of the lake, this equals to 1.46 g/m^2/a. The dangerous load according to Vollenweider (1968) in shallow lakes is 0.20 g/m^2/a, which is clearly exceeded in this case (Table 7).

The nitrogen load to Lake Niemisjärvi has been on average 83 272 kg/a. This equals to 19.9 g/m^2/a, which clearly exceeds the dangerous load (Table 7). However, the Vollenweider method is not considered to be very suitable for shallow lakes.

In Lake Lika-Pyöree the calculated phosphorus load into the lake is only 0.106 g/m^2/a and for nitrogen 3.27 g/m^2/a. Most of the loading originates from forests in the catchment area and a small amount of loading originates from a peat production area in the upper reaches of the catchment area. In Lake Lika-Pyöree, the phosphorus load is under the theoretical dangerous load, although it exceeds the permissible load (Table 7). The loading of nitrogen clearly exceeds the dangerous level (Table 7). The calculations of permissible and dangerous loads according to Vollenweider (1968) are not very applicable for the naturally eutrophic lake type, as the background natural loading alone may exceed the dangerous level of loading.

Table 7. Estimated phosphorus and nitrogen loadings to the study lakes (Manninen et al. 2003) and calculated critical loading values according to [1)]Vollenweider (1968)

Lake	Area (ha)	Mean depth(m)	Loading from the whole watershed		Loading from the nearest watershed		*Calculated annual loading values for whole ws; nearest ws.		[1)] **Permissible and dangerous values of P (g/m^2/a); mean depth		[1)] **Permissible and dangerous values of N (g/m^2/a); mean depth	
			P kg/a	N kg/a	P kg/a	N g/a	P g/m^2	N g/m^2	5 m	5-10 m	5 m	5-10 m
Niemisjärvi	418	1.5	6098	83272	1527	24994	1.46;	19.9;	0.10;		1.0;	
							0.365	5.98	0.20		2.0	
Lika-Pyöree	196	0.6	208	6415	same as whole ws	same as whole ws	0.106	3.27;	0.07;		1.0	
								0.13	2.0			

* Calculated annual loading values: The first figures refer to the whole watershed and the second ones to the nearest watershed, e.g. 1.46; 0.365. ws = watershed.

** The first figures refer to the permissible values and the second ones to the dangerous values

Both lakes have undergone water level alterations. In Lake Niemisjärvi the water level has been lowered several times, but is at present regulated by an unauthorized dam which has raised the MW since the last lowering in the 1950s. From Lake Lika-Pyöree there is unofficial information about a water level lowering conducted in the 1930s by a forestry company.

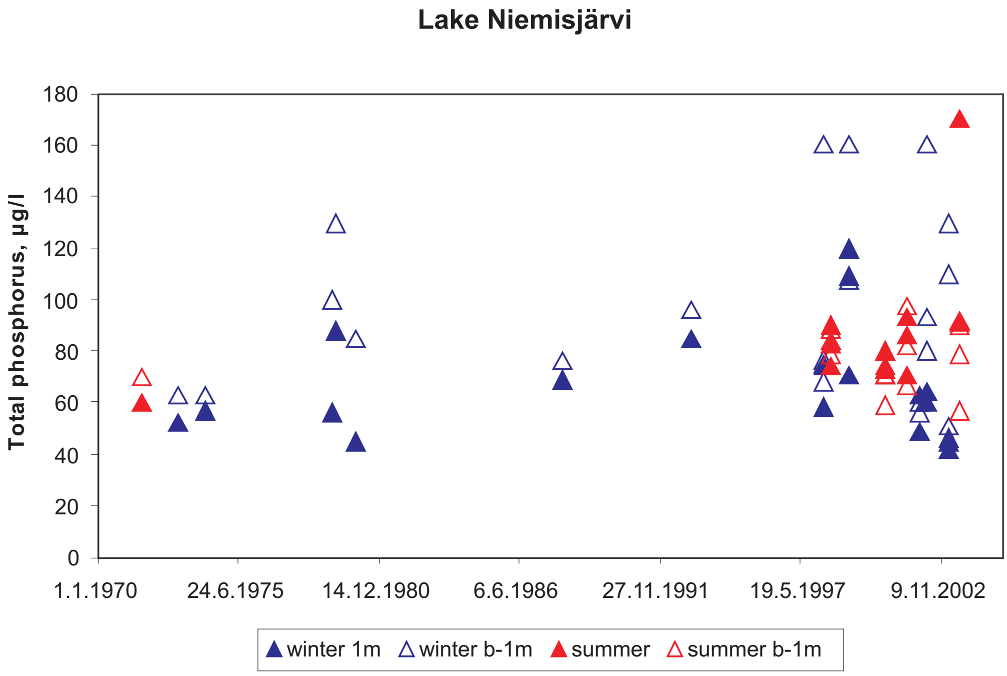
Phase VI – physico-chemical data

Samples for the physico-chemical analyses were collected during the winter stratification period from the deepest sites of the lake basins. At Lake Niemisjärvi there were three different sampling sites. The sampling date at Lake Lika-Pyöree was significantly earlier than in Lake Niemisjärvi (26.2.2002 vs. 8.4.2002) which has to be taken into account when drawing conclusions about e.g. oxygen regime. Lake Lika-Pyöree was also sampled at the end of July.

Table 8. Water quality data (mean values) of the surface water (1 m, 0–2 m for chlorophyll-*a*) in the primary production period (1.6.–15.9.) during the last decades. N = number of observations.

Lake	Colour (mg Pt/l)	tot N, (µg/l)	tot P, (µg/l)	Chlorophyll *a* (µg/l)	Transparency (m)	Years; n
Niemisjärvi	160	1325	90	67	0.7	1993-2003;12
Lika-Pyöree	150	635	28	14.5	0.9 (bottom)	2001-2002;2

Lake Niemisjärvi is a humic lake with a water colour value of ca 160 mg Pt/l (table 8). Despite a plenitude of organic acids the alkalinity was as high as 0.35 mmol/l (average of 3 sites), which is an indication of the fertile soil. Also the pH-value (6.5) was quite high for a humic lake in winter. The total phosphorus concentration in surface water was on the average 63 µg/l (3 sites). The Secchi disk transparency was on average 0.96 m. Due to meteorological factors (low runoff of nutrients during previous autumn, meltwaters during late winter) the epilimnion values for water colour, phosphorus concentration and especially oxygen were better than previously during corresponding periods (Fig. 17).



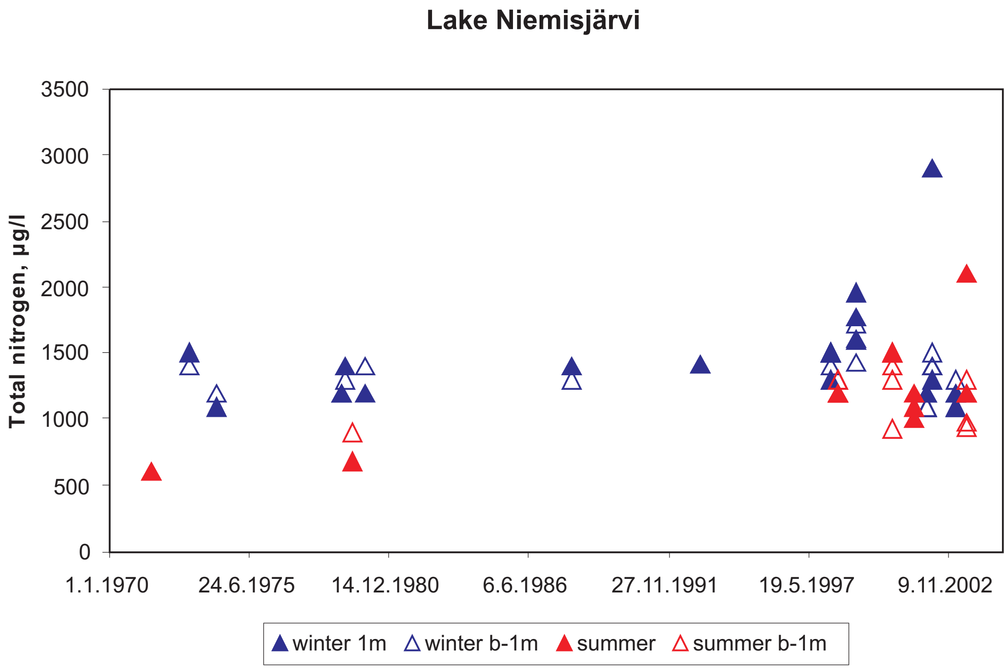


Figure 17. Total phosphorus and nitrogen concentrations in Lake Niemisjärvi during 1971–2002.

During the summer of 2002 there were extremely high chlorophyll *a* concentrations of 67 µg/l (the mean of 1993–2003; Table 8) in Lake Niemisjärvi and total phosphorus concentrations are higher than in winter (a mean concentration of 90 µg/l; Table 8).

Lake Lika-Pyöree is as humic as Lake Niemisjärvi, but the alkalinity is significantly lower (0.12 mmol/l and the pH-value is lower as well (5.8). In the lake there is a tendency for severe oxygen depletion in winter because of its shallowness. The total phosphorus concentration has been ca. 25–30 µg/l (summer) and the chlorophyll *a* concentration 12–17 µg/l. In 2002 the concentrations of phosphorus and chlorophyll *a* might have been somewhat lower but the oxygen regime in winter worse than normal.

Phase VII – first evaluation of the most probable status

According to available pressure information and water quality, Lake Niemisjärvi probably fails to meet the objective of good ecological quality. The concentrations of nutrients and chlorophyll *a* deviate clearly from the estimated type-specific values (estimated as in phase IV and based on values of the reference Lake Lika-Pyöree) and the deviations can not be explained by meteorological or hydrological conditions.

Phase VIII – biological quality elements and Ecological Quality Ratios (EQR)

Aquatic macrophytes

Lake Niemisjärvi differs clearly from the reference Lake Lika-Pyöree with respect to the taxonomic composition of macrophytes (Table 9). Taking into account only the species present, the similarity of the two lakes is somewhat lower (0.27) than when taking into account also the abundance of species (0.41). Lake Niemisjärvi has species indicative of high trophic status (*Hydrocharis morsus-ranae, Lemna minor, Potamogeton obtusifolius*), while these species are missing from Lake Lika-Pyöree. On the other hand, aquatic mosses and isoetids are abundant in Lake Lika-Pyöree while both life-forms are sparse or absent in Lake Niemisjärvi.

Table 9. Ecological quality ratios of Lake Niemisjärvi calculated from the different macrophyte metrics. The calculations are based on a comparison with Lake Lika-Pyöree.

	Number of taxa	Species composition	Species frequencies	Abundance based on % in transects of vegetated area	average
Niemisjärvi	0.79	0.27	0.41	0.46	0.48

The abundance of macrophytes, as estimated by the aerial photograph interpretation, is higher in Lake Niemisjärvi than in Lake Lika-Pyöree and the ecological quality of Lake Niemijärvi based on this metric is evidently weakened. On basis of the field survey data, also, nymphaeids and helophytes are more abundant in Lake Niemisjärvi. In both lakes, however, the abundance of vegetation interpreted from aerial photographs has markedly increased from the 1950s, even more in the reference lake than in the loaded lake. The water level of both lakes has been altered, which has probably led to increased overgrowth of the littoral areas.

The difference in aquatic vegetation is so apparent that it clearly indicates a weakened ecological state of Lake Niemisjärvi. It must be taken into account though, that the species composition of the reference Lake Lika-Pyöree resembles that of other small, humic lakes (Tiilikka, Mujejärvi). Therefore, the macrophyte data also indicates that Lake Lika-Pyöree might be more accurately typified as belonging to the small, humic lake type and the comparison between Lakes Niemisjärvi and Lika-Pyöree is affected to some extent by the inherent difference in the natural state of the lakes.

Periphyton

In Lake Niemisjärvi the investigation included epilithic and epiphytic algae (5 sites) and in Lake Lika-Pyöree only epiphytic algae (3 sites). In addition artificial substrates were also used: polycarbonate plates were incubated in August–September 2002 for three weeks. In Lake Niemisjärvi observations and impressions of sliming made and judged by the public were tested by incubating nettings stretched on frames in the lake outlet twice in August 2002 (incubation time 4 hours).

The periphyton results including both quantitative and qualitative analyses indicated clearly that the trophic status of Lake Niemisjärvi was higher than that of the reference Lake Lika-Pyöree (Table 10).

Table 10. Some figures showing the characteristics of periphyton and phytoplankton communities in Lakes Niemisjärvi and Lika-Pyöree.

	Lake Niemisjärvi	Lake Lika-Pyöree
Proportion of detritus on natural surfaces	70-95%	20-90%
Proportion of diatoms	<1-20%	<1-10%
Proportion of filamentous green algae	generally1-2%, one site 28%	5-10%
Proportion of filamentous 'Conjugatophycean algae'	generally <1%, one site 10%	<1-10%
Proportion of filamentous blue-green algae	<1-2 %	5-70%
Number of Diatomophyceae taxa	42	49
Evenness index of diatoms	0.60	0.73
Diversity index of diatoms	3.26	4.53
Indication of pH	mainly taxons favouring neutral water, quite many alkaliphilic taxa, some alkalibionts	plenty of acidophilic taxons, also acidobiont taxa
Indication of trophy	plenty of eutrophic and meso-eutrophic taxons	oligotrophic species dominant
Chlorophyll *a*	4.34 +-0.9 mg/m^2	0.50 +-0.07 mg/m^2
Suspended solids	3.02 mg/m^2	0.3 mg/m^2

Phytoplankton

During the Life Vuoksi project Lake Niemisjärvi and Lake Lika-Pyöree were sampled twice in August 2002 for phytoplankton. Samples were taken from 8 sites in Lake Niemisjärvi and from 4 sites in Lake Lika-Pyöree. The phytoplankton biomass was estimated by microscopy using the Utermöhl technique from the pelagial samples of the lakes (one site/lake) and dominating taxa were identified from samples taken from all sampling sites and concentrated with a net.

The phytoplankton biomass in the 'pelagial' of Lake Lika-Pyöree was at the beginning of August 0.6 mg/l and three weeks later 0.3 mg/l. In Lake Niemisjärvi the phytoplankton biomasses were over ten-fold greater: 7.9 mg/l and 4.3 mg/l respectively.

The taxonomic composition of phytoplankton samples also differed significantly in the two lakes. In Lake Niemisjärvi the most common taxa were cyanophytes: *Aphanizomenon sp* and *Synechococcus sp* (*Cyanotheca sp*). In Lake Lika-Pyöree the most common taxon was *Chroococcus sp (Cyanophyceae)* and the dominating taxon was *Gonyostomum semen (Raphidophyceae).* There were also plenty of *Dinobryon sociale* and *Dinobryon divergens (Chrysophyceae).* In Lake Niemisjärvi substantial blue-green algal blooms have also been frequent, unlike Lake Lika-Pyöree.

In Lake Lika-Pyöree there were 2 indicator species of oligotrophy (O-species) and none of eutrophy (E-species) whereas in Lake Niemisjärvi the number of E-species was 5 and the number of O-species was 1.

Benthic invertebrates

According to the results from the work on littoral macrozoobenthos (benthic invertebrates), metrics based on species composition showed on average the clearest distinction between the impacted and the reference lakes. In the case of Lake Niemisjärvi, the calculation of ecological quality ratios based on the two species composition metrics used show ambiguous results, as the EQR of Lake Niemisjärvi based on Jaccard similarity was 0.16 and the EQR based on the method of Hämäläinen et al. (2002) was 0.94 (Table 11). In contrast, in the loaded Lake Niemisjärvi, the density (3-fold) and species richness (2-fold) of animals were clearly higher than in the reference lake Lika-Pyöree. However, the evenness was higher in Lake Lika-Pyöree (1.00 vs. 0.66).

There is no data on profundal macrozoobenthos from Lake Niemisjärvi. With regard to profundal zoobenthos Lake Lika-Pyöree was compared to another eutrophic lake, Lake Luupuvesi, situated in the Iisalmen reitti river basin. The calculated benthic quality index (BQI) was clearly higher in lake Lika-Pyöree (2.0–3.2) than in the loaded Lake Luupuvesi (1.0). (Tolonen et al. 2003).

Inconsistent results were obtained by calculating EQRs by different community metrics. Even two metrics related to the species composition gave contrasting results. Thus and due to the lack of extensive reference data, the estimation of ecological status of Lake Niemisjärvi is difficult. However, based on the metrics used, the most probable status of the lake could be good to moderate.

Phase IX – final assessment of the ecological status

In the final assessment the views of local inhabitants can be also used. In the case of Lake Niemisjärvi an inquiry on the opinions of the public on the status of the lake was conducted in 2002 as a part of the Life Vuoksi project. The opinions of the people supported the conclusion that significant changes have taken place in the status of the lake. The changes are not unambiguously regarded as decreasing the value of the lake, but many of them are considered undesirable.

Based on all available data, the ecological status of Lake Niemisjärvi has to be regarded as deviating from the reference condition at least moderately (Table 11). Although all biological elements (e.g. benthic invertebrates) do not show a clear deviation, at least the composition of phytoplankton and macrophyte communities clearly deviate from the reference condition clearly. Also the general conditions as indicated by the physico-chemical data suggest a clearly altered ecological status of Lake Niemisjärvi. However, the role of Lake Lika-Pyöree as a reference lake to Lake Niemisjärvi is not clear because the natural conditions are possibly not very similar.

Table 11. Assessment of the ecological status of Lake Niemisjärvi based on expert judgement and results of the biological elements in the summer 2002. Class boundaries between the ecological status classes have not been defined for these metrics.

Biological element	Common aspects	Expert judgement of the ecological status	Ecological Quality Ratio
Aquatic macrophytes:		moderate	
Number of taxons	Lika-Pyöree 27 Niemisjärvi 34		0.79
Species composition			0.27
Species frequency			0.41
Percentage of vegetated area			0.48
Benthic invertebrates:		good-moderate	
Hämäläinen			0.94
Jaccard Similarity			0.16
Evenness			0.66
Periphyton:		moderate	
Jaccard's Similarity			0.35
Sørensen's Similarity			0.52
Number of taxons			1.07
Diatom biotic index (PSI and TDI)			
Phytoplankton:		moderate-poor	
Total biomass			
ref. national databank			0.1
ref. Lika-Pyöree			0.1

6.4 Lakes affected by non-point loading from forestry

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Case study 3: Lakes Kuohattijärvi and Suomunjärvi

Case study 4: Lakes Mujejärvi and Tiilikka

Forestry is a very important sector of economic life in Finland, because some 70% of the land area is covered by forests (about 85% in North Karelia). Many lakes in Finland are therefore affected by non-point loading from forestry. In this project two pairs of lakes from this group were tested following the flow chart of the monitoring and assessment procedure (Fig.10). In the Life Vuoksi project Lake Mujejärvi (non-point loading: forestry) and Lake Tiilikka (as reference lake) were tested, and the other pair of pilot lakes in this group were Lake Kuohattijärvi (non-point loading: forestry) and Lake Suomunjärvi (as reference lake). Three of these lakes are situated in North Karelia, and one, Lake Tiilikka, in North Savo.

Phase I – geological and hydro-morphological information on the lake and its catchment

Basic information on the study lakes affected by loading from forestry is presented in Tables 1 and 12. The data is collected from Manninen et al. (2003) and from the North Karelia Regional Environment Centre / Veijo Puustinen (mean discharge data from Kuohatti-, Suomun- and Mujejärvi).

Table 12. Basic information on the lakes and their watersheds.

Lake	Watershed area (km^2)	Altitude (m a.s.l.)	Proportion of peatland (% of ws)	Surface area (km^2)	Mean discharge (m^3/s)	Depth (m) mean	Depth (m) max	Volume (10^6 m^3)	Retention time (months)
Kuohattijärvi	56.1	162	31	10.8	0.6	6.1	18.0	66	50.3
Suomunjärvi	116.7	152	36	6.6	1.2	5.5	23.6	37	13.5
Mujejärvi	108.8	197	38	3.5	1.1	5.0	21.3	17	7.0
Tiilikka	20.0*	187	57*	4.2	1.8	2.4	8.1	10	2.1

a.s.l. = above sea level
ws = watershed
* nearest watershed area

Case 3: Lakes Kuohattijärvi and Suomunjärvi

Lake Kuohattijärvi cover an area of 10.8 km^2, and has a quite small watershed, of which nearly 1/3 is peat land (Table 12). The retention time is one of the longest among the target lakes in the Life Vuoksi Project (Manninen et al. 2003). About 36% of the catchment area of Lake Kuohattijärvi was drained for forestry and about 55% fertilised during 1950–1994 (Tossavainen 1997, Niinioja et al. 2001a, 2001b).

Lake Suomunjärvi, the assumed reference lake, has peat land in its watershed of nearly 36%. Lake Suomunjärvi is situated in the Patvinsuo National Park. The theoretical retention time is much shorter than that of L. Kuohattijärvi (Table 12).

Available palaeolimnological data shows that the total phosphorus concentration of Lake Kuohattijärvi has been below 10 µg/l in its natural state (Niinioja et al. 2001a, 2001b), and that of Lake Suomunjärvi about 6 µg/l (preliminary results, unpublished data, Juha Miettinen, University of Joensuu). These results suggest that both lakes have been in their natural status oligohumic and oligotrophic lakes.

Following the proposal for the typology of Finnish lakes (Pilke et al. 2002) both lakes belong to type 7 (surface area 5–40 km^2, colour 30–90 mg/l).

Summarising phase I / case 3: Lakes Kuohattijärvi and Suomunjärvi: There were problems in determining reliably of the original lake type. The lake type might be better to determine at a later stage, immediately after dealing with the physicochemical data.

The land use data and available soil data must be used with care. The Slam3 data seems to be more reliable concerning the share of peatlands than the Slices data. The geological data (soil, bedrock) are not very easily available. There should be data base or maps (electronic forms preferred) of the geology on a scale of e.g. 1:50 000 at least. The morphological data of the lakes has been easy to collect. When all the material is available, even if in several data bases, the handling of the material is not time consuming.

Case 4: Lakes Mujejärvi and Tiilikka

Lake Mujejärvi in North Karelia has an area of 3.5 km^2, and has quite a large watershed area of which about 40% is peat land (Table 12). The lake is shallow even though the maximum depth is 21.3 m. The retention time has been estimated to be as short as 7.0 months.

Lake Tiilikka is situated in Tiilikka National Park in North Savo. The lake covers an area of 4.2 km^2, and its watershed is quite large of which nearly 60% is peat land. Lake Tiilikka is very shallow (Table 12).

There is no palaeolimnological data of these lakes.

Following the proposal for the typology of Finnish lakes (Pilke et al. 2002) both lakes belong to type 9 (surface area <5 km^2, colour >90 mg/l).

Summarising phase I / case 4: Lakes Mujejärvi and Tiilikka: see phase I, Case 3.

Phase II – meteorological data

Case 3: Lakes Kuohattijärvi and Suomunjärvi

In North Karelia the climate is continental with cool summers and long winters. The year 2002 was warm, especially in the summer. The yearly mean temperature was 3.0 °C in Joensuu (the main city in North Karelia near to the study lakes), the long-term mean was 3.2 °C in 1961–1990 and 2.6 °C in 1971–2000, respectively. In 2002 the precipitation was quite low (547 mm) in Joensuu compared to the long-term mean (612 mm in 1971–1990 and 643 mm in 1971–2000, Finnish Meteorological Institute, 2003). In 2002, the areal precipitation near Lakes Tiilikka, Kuohattijärvi and Mujejärvi was somewhat greater (601–700 mm/a) than near Lake Suomunjärvi situated in the east (501–600 mm/a) in 2002 (http://www.fmi.fi/saa/tilastot_23.html#1).

As a summary, the year 2002 was some 0.8 °C warmer than the long-term mean in 1961–1990, and 0.4 °C warmer than in 1971–2000. Precipitation was small during the year 2002. Summer 2002 was exceptionally dry and warm. These circumstances should have potentially increased aquatic primary production. This situation has also affected the lakes by lowering their water levels and simultaneously decreasing water volumes, so increasing the nutrient concentrations at least in some lakes. Also the oxygen situation might have been quite poor, or very poor especially during winter stratification.

Summarising phase II / case 3: Lakes Kuohattijärvi and Suomunjärvi: The meteorological data can easily be delivered from the data base and from the monthly information of the Finnish Meteorological Institute. The time series are quite long and offer a very good basis for comparisons. However, the nearest meteorological observation station to Lake Kuohattijärvi is situated quite far in Sotkamo Vuokatti and that of Lake Suomunjärvi in Lieksa. Near Lieksa the meteorological conditions are observed at the Hietajärvi Integrated Monitoring area about 10 km from Lake Suomunjärvi. The observations of these stations might be more useful than the data from Joensuu (about 100 –150 km from the lakes) for the estimation of the weather conditions of these lakes. The problem is that the data of Vuokatti and Lieksa should be requested and paid separately for the Finnish Meteorological Institute. These data should be collected more easily and free of charge between authorities and research institutes, e.g. on the basis of a joint agreement.

Case 4: Lakes Mujejärvi and Tiilikka
Lake Mujejärvi and Lake Tiilikka are situated quite near to Lake Kuohattijärvi. The distances are about 10 km, and about 50 km, respectively. One can assume that the meteorological data used for Lake Kuohattijärvi should be relevant for these lakes.

<u>Summarising phase II / case 4: Lakes Mujejärvi and Tiilikka:</u> see phase II, Case 3.

Phase III – hydrological data

Case 3: Lakes Kuohattijärvi and Suomunjärvi
Hydrological data for Lake Kuohattijärvi has been estimated from the values of the observation site at Roukkajankoski. The estimated mean discharge (MQ) from the outlet of Lake Kuohattijärvi is some 0.6 m^3/s (Table 12) and the corresponding value was roughly 0.3 m^3/s in 2002. The mean summer discharge is approximately 0.8 m^3/s, in summer 2002 only 0.4 m^3/s. The yearly mean water level is approximately +162.15 m (N_{60}) and the long term summer mean +162.20 m (N_{60}). In 2002 the water level in the lake was approx. +162.07 m (N_{60}) and the summer mean level was approx. +162.10 m (N_{60}).

Hydrological data for Lake Suomunjärvi has been estimated using the data of the observation site at Putkulankoski. The mean discharge in the outlet of Lake Suomunjärvi was estimated to be 1.2 m^3/s (Table 12) and the corresponding value was approximately 1.3 m^3/s in 2002. However, the summer discharge in 2002 was approximately 1.4 m^3/s and the long term mean was 1.5 m^3/s. The yearly mean water level is approximated to be +152.10 m (N_{60}) and the long term summer mean +152.15 m (N_{60}). In 2002 the water level in the lake was about +152.10–152.12 m (N_{60}) and the summer mean level was approximately +152.13 m (N_{60}).

The discharges have been low in summer 2002 because of the very dry summer. The discharge and water level of Lake Kuohattijärvi were clearly lower than the long term values. This situation is mainly due to the quite small watershed area of this lake. Concerning Lake Suomunjärvi, the hydrological situation seems to differ only slightly in 2002 from the normal values. The large watershed area of this lake might have balanced the hydrological circumstances.

<u>Summarising phase III / case 3: Lakes Kuohattijärvi and Suomunjärvi:</u> Hydrological data is easily collected from the the national environmental database (Hertta) of the Finnish Environmental Administration. The problem is a lack of regionally adequate hydrological data in some cases. E.g. there is water level data from Lake Kuohattijärvi only in January 1990, when the water level was +161.85 m(N_{60}) and the water level on the map 1:20000 is +161.9 m (N_{60}). From Lake Suomunjärvi there are 13 water level observations from the spring 1993 during high discharges. The water level value on the map 1:20000 is +152.0 m (N_{60}). However, the water levels and discharges can be estimated roughly using hydrological models developed at the Finnish Environment Institute and data from the nearest long term observation sites.

Case 4: Lakes Mujejärvi and Tiilikka
Hydrological data of Lake Mujejärvi has been estimated using data from the observation site at Roukkajankoski. The mean discharge at the outlet of Lake Mujejärvi was estimated to be 1.1 m^3/s (Table 12) and the corresponding value was approximately only 0.5 m^3/s in 2002. The summer discharge was approximately 0.7 m^3/s in 2002 and the long term mean 1.0 m^3/s. The yearly mean water level is approximated to be +197.15 m (N_{60}) and the long term summer mean +197.05 m

(N_{60}). In 2002 the water level in the lake was about +196.90 m (N_{60}) and the summer mean level was approximately +196.95 m (N_{60}). The estimated values for Lake Tiilikka in 2002 are also low compared to the long term means.

The discharges were low in summer 2002 because of the very dry summer.

Summarising phase III / case 4: Lakes Mujejärvi and Tiilikka: see phase III Case 3. There are no permanent observations of Lake Mujejärvi and Lake Tiilikka. The hydrological values for Lake Mujejärvi are estimated using the hydrological models and data from the observation site at Roukkajankoski, situated quite near Lake Mujejärvi. There are no water level observations from Lake Mujejärvi. Its water level value on the map 1:20000 is +197.1 m (N_{60}).

Phase IV – evaluation of geological, typological, hydro-morphological, meteorological and hydrological data and their potential effects on biological and physico-chemical quality elements

Cases 3 and 4: Lakes Kuohattijärvi and Suomunjärvi, Lakes Mujejärvi and Tiilikka
The hydrological data is in good relation with the meteorological observations. As a summary it can be established that low discharges in 2002 could have decreased the non-point loading from e.g. forestry areas, as well as also natural leaching of nutrients. On the other hand, the retention time in lakes during the warmest season has been longer in 2002 than usual, which could have slightly increased the primary production potential.

The weather was dry and warm in autumn 2001 as well as in summer and autumn 2002. This might have caused that some decreases in the concentrations of nutrients and humic substances during the winter stratifications in 2001–2002 and in 2002–2003. In 2002, winter started about 2 weeks earlier than normally, and the autumn overturn in many smaller lakes was inefficient in autumn 2002. All these circumstances resulted in a poor oxygen situation, resulting in even oxygen deficiency in many lakes during winter 2002–2003.

Precipitation was low during winter and spring of 2001 and 2002, and it caused lower leaching of nutrients during the spring than normal. These factors have probably limited the growth of algae, which on the other hand was favoured by high surface water temperatures (see also phase VI) The heavy rainfalls in June and July 2001 might have caused an increase of nutrient leaching also from forested watersheds.

Phase V – pressures on the lakes
Nutrient loading has been calculated using discharge and corresponding concentration values or values estimated from land use data (in details, see Manninen et al. 2003). Both phosphorus and nitrogen loadings have been presented on an annual level and loadings from different sources have been discussed separately by Manninen et al. (2003). Here the annual loadings are calculated for the lake surface area, and these figures have been compared to the permissible and dangerous loading values according to Vollenweider (1968, see also Wetzel 2001). These figures are different for shallow (mean depth 5m or below) and deeper lakes (here the category from 5 m to 10 m used). The data of study lakes is presented in Table 13. The data is used in this phase and in the preliminary evaluation of the state of the lakes in phase VI.

Table 13. Estimated phosphorus and nitrogen loadings to the study lakes (Manninen et al. 2003) and calculated critical loading values according to [1)]Vollenweider (1968)

Lake	Area (ha)	Mean depth(m)	Loading from the whole watershed		Loading from the nearest watershed		*Calculated annual loading values for whole ws; nearest ws.		[1)] **Permissible and dangerous values of P ($g/m^2/a$); mean depth		[1)] **Permissible and dangerous values of N ($g/m^2/a$); mean depth	
			P kg/a	N kg/a	P kg/a	N g/a	P g/m^2	N g/m^2	5 m	5-10 m	5 m	5-10 m
Kuohattijärvi	1080	6.1	966	15970	same as	same as	0.09	1.5		0.10;		1.5
					whole ws.	whole ws.				0.20		3.0
Suomunjärvi	660	5.5	1434	26363	674	9763	0.22;	4.0;		0.10;		1.5;
							0.10	1.5		0.20		3.0
Mujejärvi	350	5.0	1306	18128	576	7328	0.27;	5.2;		0.10;		1.5;
							0.17	2.1		0.20		3.0
Tiilikka	420	2.4	928	15752	183	5935	0.22;	3.8;	0.07;		1.0;	
							0.04	1.4	0.13		2.0	

* Calculated annual loading values: The first figures refer to the whole watershed and the second ones to the nearest watershed, e.g. 0.22; 0.10. ws = watershed.

** The first figures refer to the permissible values and the second ones to the dangerous values

Case 3: Lakes Kuohattijärvi and Suomunjärvi

Lake Kuohattijärvi is loaded by different non-point sources, of which forestry is the most significant.

The phosphorus and nitrogen loadings to Lake Kuohattijärvi are permissible according to Vollenweider (1968) (Table 13). It is to be remembered that total nitrogen, which consists of mineral nitrogen compounds and also organic compounds, is analysed in Finland. In humic waters such as Lake Kuohattijärvi the share of the organic nitrogen compounds, which is not so important for primary production, is usually high.

The reference lake, Lake Suomunjärvi has only slight non-point loading (Manninen et al. 2003, Table 13). The annual loading values for phosphorus and nitrogen were calculated for the whole watershed (Table 13). According to the Vollenweider's (1968) values these levels are dangerous. However, phosphorus and nitrogen loadings from the nearest watershed of Lake Suomunjärvi and the corresponding annual loading values for phosphorus and nitrogen are 0.10 g/m^2 and 1.48 g/m^2, respectively. These values are permissible values for Lake Suomunjärvi (Table 13) according to Vollenweider (1968).

<u>Summarising phase V / case 3: Lakes Kuohattijärvi and Suomunjärvi:</u> Phosphorus and nitrogen loadings are today low concerning Lake Kuohattijärvi, but they are too high for the reference lake, L. Suomunjärvi. The nearest watershed area of Lake Suomunjärvi is entirely a nature conservation area. This means that the loading of this lake is mainly background loading from near-natural areas. It seems that the used loading calculation methods (see Manninen et al. 2003) overestimate the loadings of these type of areas. One can also assume that the critical loading calculations according to Vollenweider (1968) are not very suitable, if suitable at all, for Finnish lakes. The data of Vollenweider (1968) is not very comprehensive, and the amount of Nordic lakes etc is minimal. Using the estimated loading and critical loadings, the most relevant data seems to use loadings of the nearest watershed as opposed to loadings of the entire watershed.

Case 4: Lakes Mujejärvi and Tiilikka

Phosphorus loading estimated over the entire Lake Mujejärvi (Manninen et al. 2003, Table 13) provides the value of 0.27 $g/m^2/a$, which according to Vollenweider (1968) is a dangerous value for the lakes with a mean depth of 5m and also that of 5–10 m (Table 13). Using only the estimated phosphorus loading for the nearest watershed of Lake Mujejärvi the value is 0.17 $g/m^2/a$, which is between the permissible and dangerous loadings for deeper lakes (mean depth 5–10 m).

Nitrogen loading of the entire watershed of Lake Mujejärvi means an annual value of 5.2 g/m^2 (Table 13). According to Vollenweider (1968), this is a dangerous nitrogen value. The corresponding annual value for the nearest watershed is 2.1 g/m^2. This is between permissible and dangerous values.

For Lake Tiilikka the phosphorus value is 0.22 $g/m^2/a$ (Table 13), which exceeds the dangerous value of 0.13 $g/m^2/a$ according to Vollenweider (1968). Using the estimated loading for the nearest watershed of Lake Mujejärvi (Manninen et al. 2003, Table 13), the value is 0.04 g/m^2, which is below the permissible value.

Nitrogen loading to Lake Tiilikka has an annual value of 3.8 g/m^2 (Table 13), which exceeds the dangerous value of Vollenweider (1968) for shallow lakes with a mean depth of 5 m. The corresponding figure for the nearest watershed is 1.4 $g/m^2/a$. This is between the above mentioned permissible and dangerous values (Table 13).

Summarising phase V / case 4: Lakes Mujejärvi and Tiilikka: see phase V Case 3. The Lake Mujejärvi watershed area is mainly intensively used forestry land. The used loading calculation methods (see Manninen et al. 2003) can underestimate the loading of this kind of intensively used areas. Lake Mujejärvi has a mean depth of 5.0 m. Because there are also quite deep parts in the lake, Vollenweider's (1968) figures for deeper lakes with the mean depth from 5 m to 10 m were used here.

Phase VI – physico-chemical data

Some water quality data of the study lakes are presented in Table 14. The data is collected from the common database of the Finnish Environment Institute and Regional Environmental Centres. Some information of lake water temperatures in North Karelia (in general) is also shown here.

Table 14. Water quality data (mean values) of the surface water (1 m, 0–2 m for chlorophyll-*a*) in the primary production period (1.6.–15.9.) during the last decades. N = number of observations.

Lake	Colour (mg Pt/l)	tot N (µg/l)	tot P (µg/l)	Chlorophyll-*a* (µg/l)	Transparency (m)	Years; n
Kuohattijärvi	62	310	14	4.7	3.1	1988-2003; 15-19
Suomunjärvi	50	250	7	3.5	3.1	1985-2003; 16
Mujejärvi	no data	380	22	no data	1.7	1998-00; 3
Tiilikka	97	300	13	5.7	1.6	1996-2002; 6

The freezing and break-up dates of Lake Pielinen are 21.11. and 15.5. (means in 1961–1989, 1961–1990; Leppäjärvi 1995). This data is from Lieksa, less than 100 km from the study lakes Lake Kuohattijärvi and Lake Suomunjärvi. Continuous surface water temperature data from Lake Pielinen (surface area about 900 km^2), quite close to the test lakes of this chapter, were available. The temperatures during May–October 2002 with the reference of the long term means for every 10^{th} day in 1981–1990 are presented in Figure 18.

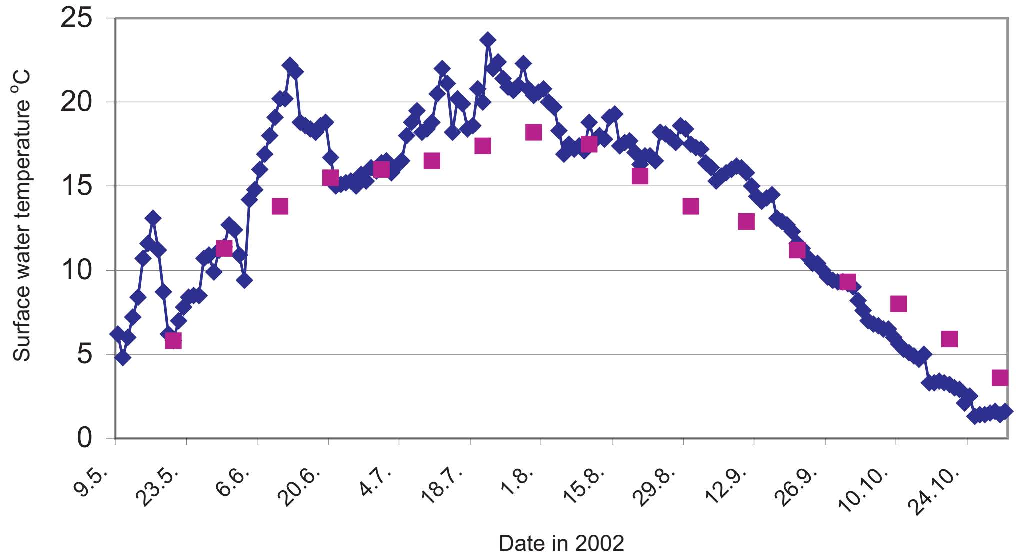

Figure 18. Surface water temperatures (°C) of Lake Pielinen (observation station in Nurmes about 20 km south-west from Lake Kuohattijärvi) in May–October 2002 (solid line) with the reference of long-term 10-day means in 1981–1990 (squares) (Data: Finnish environmental administration 2003, Leppäjärvi 1995).

One can assume that the temperatures of Lake Suomunjärvi are quite similar to those of Lake Iso Hietajärvi (surface area 83 ha), situated about 10 km from Lake Suomunjärvi. The surface water temperatures of the intensively studied Lake Hietajärvi varied seasonally between the minimum of 0.3.°C in winter and maximum of 22.5 °C in the summers of 1988–2002. The temperature of the epilimnion was above the average in 1994, 1999, 2001 and 2002. Lake Iso Hietajärvi stratified weakly during the open water season in 1988–2001 (Holopainen et al. 2003), and in winter, also.

Lake Kuohattijärvi stratifies during summers and winters. There is not enough summer time data to assess the stability of the stratification in these lakes or in Lakes Mujejärvi and Tiilikka.

Case 3: Lakes Kuohattijärvi and Suomunjärvi

Lake Kuohattijärvi and Lake Suomunjärvi have been monitored permanently according to the regional and nationwide monitoring programmes (Niinioja 2000, 2003; Niemi & Heinonen 2000, 2003). Unfortunately, both programmes of this lake were ended in 1999. Since 2000 the lake has been again in the regional programme. Lake Kuohattijärvi is a target lake in regional research (e.g. Tossavainen 1997, Lyytikäinen et al. 2003a, 2003b) and monitoring programmes of the North Karelia Regional Environment Centre. The lake is also one of the impact lakes monitored in the Finnish Eurowaternet since 2000 (Niemi et al. 2001b). For these reasons the physico-chemical data is quite suitable.

The colour values of Lakes Kuohattijärvi and Suomunjärvi are between 50–62 mg Pt/l (Table 14). The colour was 40 mg Pt/l in both lakes in 2003 (March and August values, 1 m). In 1999, the colour values were 75 mg Pt/l in Lake Suomunjärvi and 55 mg Pt/l in Lake Kuohattijärvi (March and August values, 1 m). There proportion of peatlands in the watershed is somewhat greater in Lake Suomunjärvi, and the colour figures in 1999 might reflect the greater leaching of humic substances during the 1999 rainy year – or at least more rainy than in 2003. Both lakes, with their colour (between 30–90 mg Pt/l) and the size (between 5–40 km^2), seem to belong to preliminary lake type 7 of the Finnish lake typification scheme (Pilke et al. 2002).

The August results 1991–2001 of the phosphorus concentration (1 m) were 11 µg/l for median (n=5) and 11.2 µg/l for mean in Lake Kuohattijärvi and those of Lake Suomunjärvi were 7.5 µg/l and 7.8 µg/l, respectively (n=5; see also Manninen et al. 2003, annex 1). The long-term figures for the production period are presented in Table 13. The quite high total phosphorus value of Lake Kuohattijärvi (14 µg/l) is mainly due to one high result, 37 µg/l from the 2nd of June, 1993.

There is also palaeolimnological data available from these lakes. The calculated total phosphorus concentrations based on sediment diatom assemblages were below 10 µg/l in the early history of Lake Kuohattijärvi but increased to about 17 µg/l in 1996 which was close to the total phosphorus concentration of the lake water, 14–20 µg/l, observed in the epilimnion in 1995–1996 (Niinioja et al. 2001a, 2001b). According to total phosphorus concentrations Lake Kuohattijärvi is now mesotrophic (tot P 10–35 µg/l) and Lake Suomunjärvi oligotrophic (tot P < 10 µg/l, see OECD 1982, Table 1).

<u>Summarising phase VI / case 3: Lakes Kuohattijärvi and Suomunjärvi:</u> The physico-chemical data was easily collected from the common database of the environmental authorities.

It could be asked if Lake Suomunjärvi is a suitable reference of Lake Kuohattijärvi. The basic hydro-morphological data is very different (see Table 12), e.g. the retention time differs greatly.

Case 4: Lakes Mujejärvi and Tiilikka

Lake Mujejärvi is monitored from time to time, and it has been a target lake of a watershed restoration project (Tossavainen, report under preparation). The physico-chemical data is not comprehensive for this lake, for instance there is no chlorophyll data during 1991–2001 (Manninen et al. 2003) and other important properties are available only from the 1980s from the common database Hertta of the Finnish environmental administration.

Lake Tiilikka has been monitored permanently according to the nationwide programmes (Niemi & Heinonen 2000, 2003; Servomaa 2002). The lake is also one of the reference lakes monitored in the Finnish Eurowaternet since 2000 (Niemi et al. 2001b). For these reasons the physico-chemical data is quite suitable.

Colour data is available only from 1987–1988 for Lake Mujejärvi, and the figures are high, about 150 mg Pt/l. The mean colour of Lake Tiilikka is nearly 100 mg Pt/l (Table 14). Both lakes with their high colour (over 90 mg Pt/l) and their size (below 5 km^2) seem to belong to the preliminary lake type 9 of Finnish lakes (Pilke et al. 2002).

The August results of 1991–2001 of the phosphorus concentration (1 m) is 19 µg/l (mean value, n=2) in Lake Mujejärvi and those of Lake Tiilikka 13 µg/l (mean) and 12 µg/l (median; n=11; see also Manninen et al. 2003, annex 1). The long-term figures are presented in Table 13. According to the classification of OECD (1982) it can be evaluated, that both Lake Mujejärvi and Lake Tiilikka are slightly eutrophied (mesotrophic).

<u>Summarising phase VI / case 4: Lakes Mujejärvi and Tiilikka:</u> The physico-chemical data are easily collected from the common database of the environmental authorities.

It could be asked if Lake Mujejärvi is a suitable reference of Lake Tiilikka. The basic hydro-morphological data is very different (see Table 12), e.g. the retention time and the watershed areas differ greatly.

Phase VII – first evaluation of the most probable status

Case 3: Lakes Kuohattijärvi and Suomunjärvi

One of the obligations of the Water Framework Directive, which should be reported at the end of 2004, is that Member States shall carry out an assessment of the likelihood that surface waters bodies will fail to meet the environmental quality objectives set for the bodies under Article 4. Member States may utilise modelling techniques to assist in such an assessment (Annex II of the WFD).

According to all the information presented in the previous phases, Lake Kuohattijärvi seems to be a lake with some changes from its natural status. This first evaluation of the most probable status suggests that Lake Kuohattijärvi meets the objectives of the WFD, i.e. "good ecological status". This assessment is based especially on the pressure information, the physico-chemical data and the fact that the state of the lake water has improved during very recent years. Nutrient loading has decreased due to the restoration measures in the watershed (and partly in the lake, also; Tossavainen, report under preparation, Lyytikäinen et al. 2003a, 2003b).

Case 4: Lakes Mujejärvi and Tiilikka

According to all the information presented in the previous phases, Lake Mujejärvi seems to be a lake with clear changes from its natural status. This first evaluation of the most probably status suggests that Lake Mujejärvi might fail to meet the objectives of the WFD, i.e. "good ecological status". This assessment is based on the physico-chemical data, mainly total phosphorus. However, there is very little water quality data. The calculated annual loadings according to Vollenweider (1968) for deeper lakes with a mean depth from 5 m to 10 m were used here, and they are permissible values. As a conclusion, one can assume that Lake Mujejärvi is near "the good status".

Phase VIII – biological quality elements and Ecological Quality Ratios (EQR)

Case 3: Lakes Kuohattijärvi and Suomunjärvi

Phytoplankton (Anna-Liisa Holopainen)

In 2001 both the phytoplankton biomass (0.25 mg/l^{-1}) and chlorophyll *a* values (4.7 µg/l) were low in Lake Kuohattijärvi indicating an oligotrophic state of the lake. The biomass mainly consisted of Cryptophyceae, Chrysophyceae and Bacillariophyceae. Altogether 40 phytoplankton taxa were found and numerically the most abundant crysophyceans were *Dinobryon divergens* Imhof, *Uroglena* sp. and small Chrysomonadineae. According to Lepistö & Rosenström (1998) the dominant Chrysophyceae from the genera *Dinobryon* and *Uroglena* are typical for oligotrophic clear water lakes. The cryptophycean *Rhodomonas lacustris* Pascher & Ruttner, and the diatoms *Asterionella formosa* Hassall *and Tabellaria flocculosa* (Roth) Kützing were abundant in this lake. The biomass of green algae was small and *Monomastix* sp. was typical for Lake Kuohattijärvi. The blue-green flora was scarce, typical species were *Merismopedia warmingiana* Lagerheim (Chroococcales) and *Anabaena lemmermannii* P. Richter (Nostocales).

In Lake Suomunjärvi, the reference lake of the Life Vuoksi Project, the phytoplankton biomass (0.21 mg l^{-1}) was low and mainly composed of Cryptophyceae and Bacillariophyceae. Altogether 32 taxa (species and genera) were identified from one sample. The Cryptophyceae species *Cryptomonas spp*. and *Rhodomonas lacustris* were numerically most abundant (38% of total numbers). Typical diatoms in this lake were *Rhizosolenia longiseta* Zacharias *and Tabellaria flocculosa* (Roth) Kützing. The blue-green *Merismopedia warmingiana* (Chroococcales) was abundant also in this lake.

In Lake Kuohattijärvi the EQR-value of phytoplankton biomass was 4.7 thus belonging to the high status (>0.8). EQR value is calculated here as a ratio of expected and observed value of phytoplankton biomass. For this lake type the mean value of phytoplankton biomass in the dataset from national reference lakes (1.17 mg/l in 2002, Lepistö *et al*. 2003) was used as the expected biomass. The mean of two measurements in 2002 was used as the observed value. When calculated against Lake Suomunjärvi, the reference lake of the Life Vuoksi Project, the EQR was 0.8. According to this material Lake Kuohattijärvi seems to have the same trophic state than the national reference lake of this type and also the reference Lake Suomunjärvi. The number of samples for such calculations is, however, very small.

Aquatic macrophytes (Hannu Luotonen)
There are three main factors controlling the emergency of aquatic macrophytes in lakes: The trophic status of lake, the quality of habitat and the shelterness of the habitat. The impacts of forestry (clear cuttings, ditching, fertilization) on lakes can be divided in two main categories: changes in nutrient and trophic status and changes in the characters of habitats.

According to the results of field surveys in 2002 (Leka et al. 2003), Lake Suomunjärvi and Lake Kuohattijärvi have almost the same number of macrophyte species, 33 in Lake Suomunjärvi and 28 in Lake Kuohattijärvi. In both lakes the macrophyte species composition is quite similar. In practice the most common species are the same. The only exception is the species *Juncus supinus* in Lake Suomunjärvi (having the line frequency of 83.7), which is lacking in Lake Kuohattijärvi. The Jaccards similarity index (based on the species frequencies of the results in 2002) was quite high 0.61, as also the similarities of the other indexes (Leka et al. 2003):

Line frequency	0.65
Average coverage	0.42
Longitudinal frequency	0.43
Area coverage	0.21
Vegetation index	0.57
Average observed value	0.46

The Jaccards index between the results of Lake Kuohattijärvi in 2002 and Lake Suomunjärvi in 1976–1978 (Toivonen & Lappalainen 1980) was 0.68. The ecological quality ratio (EQR) for Lake Kuohattijärvi was 0.75 (0.61/0.81).

The assessment of the ecological state of Lake Kuohattijärvi and Lake Suomunjärvi is difficult on the basis of aquatic macrophytes. Lake Kuohattijärvi (especially the water quality) has been heavily changed from its pristine condition, mainly by the loading of nutrients and suspended material caused by forestry activities. However, the anthropogenic impacts on the macrophytes are not easy to observe in this material. The small differences of the macrophyte species composition and assemblages and between the different similarity indexes calculated from the material are most easily explained by differences of the morphological characteristics between lakes, especially the littoral areas. In Lake Suomunjärvi sandy shores are typical while Lake Kuohatti is characterised by stony shores. More information on the characteristics of habitats in Lake Kuohattijärvi is required. These information include e.g. questions on how heterogenic the littoral habitats are, and sandy areas between stone and cobble areas (important e.g. for the isoetids). There have also been some impacts of forestry on Lake Suomunjärvi before establishing the Patvinsuo National Park.

Based on aquatic macrophytes, the ecological state of Lake Kuohattijärvi can likely be classified as good or very near the good status. However, more information is needed for further assessment of the ecological status of Lake Kuohattijärvi: such as whether the lake is classified accurately according to the proposal for the typology of Finnish lakes (Pilke et al. 2002), and whether Lake Suomunjärvi is an appropriate reference site for Lake Kuohattijärvi etc. Also more information is required to separate the natural changes in the macrophyte assemblages (especially in reference sites) and also the anthropogenic impacts on the moderate humic lakes.

Benthic invertebrates (H. Luotonen)

In Lakes Kuohattijärvi and Suomunjärvi, the data from the littoral and profundal zones was used in the assessment of the ecological state by the benthic macroinvertebrates from the littoral and profundal areas. The results are provided in more detail in Tolonen et al. (2003).

The quality of the bottom material, the habitat structure (heterogeneity of the habitats), trophic status and also the amount of oxygen in the profundal areas are the main factors explaining the structure of macrozoobenthos assemblages in the lakes. In assessing the ecological state of benthic invertebrates, the parameters nominated as the indicators of ecological quality (EQ) by the WFD are abundance, diversity, presence of sensitive taxa and taxonomic composition of the community.

The impacts of forestry are focused on the macrozoobenthos assemblages in two ways. First, the increasing nutrient load amount increase the productivity of phytoplankton and the sedimentation of organic matter. Increased decomposition of the organic matter can cause oxygen deficiency, especially in the profundal zone. Second, the loading of suspended solids can cover and change the original bottom surfaces, and further change the habitat structure.

In the stony littoral habitat, the number of species and individuals sampled was much higher in Lake Kuohattijärvi (52 taxa and 6882 individuals) than in Lake Suomunjärvi (32 taxa and 1019 individuals). The sampling effort in the lakes was similar. The evenness index was higher in Lake Suomunjärvi than in Lake Kuohattijärvi. In the DCA-ordination, the littoral assemblages of two lakes separated from each other. Although density and species richness were higher in Lake Kuohattijärvi than in Lake Suomunjärvi, the EQR-values calculated for the evenness and species composition were lower in Lake Kuohattijärvi (Tolonen et al. 2003).

As in the littoral zone, the numbers of species and individuals in the profundal zone were higher in Lake Kuohattijärvi (17 species and 653 ind./m^2) compared to Lake Suomunjärvi (12 species and 102 ind./m^2). The values of benthic quality index (BQI, Wiederholm 1980) were approximately the same in the two lakes.

When assessing the ecological state by the macroinvertebrate assemblages, the same difficulties were met as with the aquatic macrophytes. In the stony littoral area, the differences in the species richness could be explained by the differences in structural features of the habitat or the trophic status of the lake. Higher animal densities in Lake Kuohattijärvi (also in the profundal areas) could be due to higher productivity and eutrophication caused by forestry and other anthropogenic load.

Assessing the ecological state of Lake Kuohattijärvi by benthic invertebrates is difficult. Based on the present data, the lake could be classified to represent good or even high status. However, more information is required to separate the impacts of forestry and the inter-annual variation and to establish reference conditions using benthic macroinvertebrates in this type of moderately humic lake (i.e. more reference lakes are required).

Case 4: Lakes Mujejärvi and Tiilikka

Phytoplankton (A.-L. Holopainen)
Lakes Mujejärvi and Tiilikka were sampled for pelagial phytoplankton two times during August 2002. The early August biomass of phytoplankton in Lake Tiilikka was 0.4 mg/l, but three weeks later the biomass was only 0.1 mg/l. In Lake Mujejärvi the phytoplankton biomass varied from 0.8 to 0.9 mg/l.

In August the net samples from Lake Tiilikka were dominated first by the chrysophyte *Mallomonas caudata* and later by *Dinobryon bavaricum* and *Peridiniales* dinophytes. *Gonyostomum semen* (Raphidophyta) was also abundant in August 2002. Typical phytoplankton species in the net samples from Lake Mujejärvi were the diatoms *Tabellaria spp*, and the desmid *Closterium; Gonyostomum semen* (Raphidophyta) was also quite abundant at the beginning of August. The biomass was dominated by *Hyalotheca dissiliensis* (Desmidiales) at the end of August.

In Lake Mujejärvi the ecological quality ratio (EQR-value) of phytoplankton biomass was 3.2 thus suggesting the lake belonging to the high status (>0.8) class. EQR value is calculated here as a ratio of the expected and the observed value of phytoplankton biomass. For this lake type the mean value of phytoplankton biomass in the dataset from national reference lakes (2.68 mg/l in 2002, Lepistö *et al*. 2003) was used as the expected biomass. The observed value was a mean of two measurements in 2002. According to this material Lake Mujejärvi seems to have the same or better trophic state than the national reference lake of this type. However, when calculated against Lake Tiilikka, the reference lake of the Life Vuoksi Project, the EQR varied from 0.1 to 0.5 (0.3) indicating bad or poor status of the lake. The number of samples for such calculations is, however, very small.

Aquatic macrophytes (H. Luotonen)
According to the results of field surveys carried out in 2002 (Leka et al. 2003), in Lake Tiilikka (the reference lake) there were 27 aquatic macrophyte species and 29 in Lake Mujejärvi. The most abundant species in Lake Tiilikka were *Equisetum fluviatile* having a line frequency of 70.6 and the isoetids *Isoetes echinospora* (61.8), *Nuphar lutea* (50.0) and *Utricularia vulgaris* (50.0). In Lake Mujejärvi with the anthropogenic impact by forestry, the species *Nuphar lutea* had the highest line frequency (78.6). Other dominating species were *Equisetum fluviatile* (50.0), *Isoetes lacustris* (32.1) and *Utricularia vulgaris* (32.1). Based on aquatic macrophyte species the lakes are quite similar.

In general, the amount and line frequencies of the isoetids were higher and there were some species (e.g. *Subularia aquatica*) typical of the reference Lake Tiilikka, which were not found in Lake Mujejärvi or had a very low or lower line frequency in Lake Mujejärvi than in Lake Tiilikka (*Eleocharis acicularis, Lobelia dortmanna*). In Lake Mujejärvi the number of aquatic bryophyta species was higher than in Lake Tiilikka.

The Jaccards similarity index (based on the species frequencies of the results in 2002) was 0.51 and also the similarities of the other indexes (Leka et al. 2003):

Line frequency	0.58
Average coverage	0.49
Longitudinal frequency	0.45
Area coverage	0.43
Vegetation index	0.47
Average observed value	0.49

According to Leka et al. (2003) the excepted value for the ecological quality ratio for Lake Mujejärvi was 0.75 and the observed 0.51. Based on aquatic macrophytes the ecological status of Lake Mujejärvi is good. The observed differences between lakes are quite small, and partly explained by the morphological or hydro-morphological characters of the lakes. In Lake Mujejärvi some changes can be detected, which are possibly due to minor anthropogenic impacts.

Benthic invertebrates (H. Luotonen)
For assessing the ecological state of Lake Tiilikka and Lake Mujejärvi based on macrozoobenthos there were material only from the littoral stony areas from both lakes and profundal samples were taken only from Lake Mujejärvi. The ecological state of macrozoobenthos assemblages in Lake Tiilikka and Lake Mujejärvi are described in more detail in Tolonen et al. (2003).

In the littoral areas (stony habitats) the number of species was a bit higher in Lake Mujejärvi (36 species/taxons) as opposed to Lake Tiilikka (30 species/taxons). The number of individuals was higher in Lake Tiilikka (2197 individuals) as opposed to Lake Mujejärvi (1262 individuals). The ecological quality ratio calculated (based on the index of evenness and number of species/taxons) was lower in Lake Tiilikka than in Lake Mujejärvi and higher when comparing the density values. In the DCA-ordination the littoral macrozoobenthos assemblages were situated quite separately. The differences in the number of species in the stony littoral areas between lakes are mostly explained by the structural and morphological differences in the habitat structures. The higher number of species in Lake Mujejärvi can be a response to the higher nutrient load and a higher level of eutrophication caused by forestry and other anthropogenic load.

The number of species and individuals in the profundal area of Lake Mujejärvi consisted of nine species and 905 individuals/m^2. The benthic quality index (Wiederholm 1980) was in Lake Mujejärvi quite high. The species *Chironomus antrachinus-t*. indicate a mesotrophic nutrient level and *Chaoborus flavicans* a lack of oxygen in the profundal area in Lake Mujejärvi.

Based on macrozoobenthos the ecological status of Lake Mujejärvi can be classified as good. There are some changes to observe, which indicate the anthropogenic impacts, but mostly the differences between the lakes also in this case are explained by the other, morphological factors.

Phase IX – Final assessment of the ecological status

Case 3: Lakes Kuohattijärvi and Suomunjärvi

Based on the present biological data Lake Kuohattijärvi can be classified as good in status. Using both the biological data and the physico-chemical data presented in the earlier phases and all other available data, we suggest that Lake Kuohattijärvi now meets the requirements of the good ecological status even though more data is required for a more reliable assessment.

Case 4: Lakes Mujejärvi and Tiilikka

Based on the present biological data Lake Mujejärvi can be classified to have a good status. Using both the biological data and the physico-chemical data presented in the earlier phases and all other available data, we suggest that Lake Mujejärvi now meets the requirements of the good ecological status even though more data is required to confirm the solution. The reference lake, Lake Tiilikka has some hydro-morphological differences with Lake Mujejärvi (e.g. water retention time, water currency, habitat quality of the littoral zone). It is also possible, that Lake Tiilikka is relatively unsuitable as a reference lake for Lake Mujejärvi.

Conclusions of the usability of the monitoring and assessment procedure

7

7.1 Usability of the monitoring and assessment procedure

The integrated monitoring and assessment procedure was tested using data from the summer of 2002 from altogether eight lakes. The amount and quality of data used in the procedure varied slightly from lake to lake. However, the proposed procedure was able to go successfully through in all the study lakes.

The assessment procedure started with gathering and evaluation of meteorological information. In Finland, it is easy to get enough reliable data on different meteorological variables. However, data collection on a yearly and site-specific basis is relatively laborious, especially in starting a new praxis in data use.

Hydrological information showing adequate accuracy can also be arrived very easily in Finland. The hydrological monitoring programmes cover quite satisfactorily all the major river basins in Finland. If there are no monitoring results available from a certain lake, hydrological modelling based on precipitation measurements can be used for estimating these.

Information on different loading factors is quite easily accessible and adequate in Finland. Point source loaders and their loadings are registered well and the estimates of non-point loading entering Finnish lakes can be obtained with a special model called VEPS. However, this model should be developed further in order to give more accurate estimations.

The weakest point in this status assessment procedure is insufficiency or total lack of (easily accessible and/or good quality) biological data in many Finnish lakes. If any biological data exists, in most cases it is phytoplankton, measured as chlorophyll *a* content. The other appropriate biological elements have been monitored in only few sites and in low or very low intensities.

The relationship between the method-specific values concerning e.g. the abundance of macrophytes or macroinvertebrates and the background variables (e.g. hydrological variables) is insufficiently known. In the future, the development of the monitoring and assessment procedure might include the collection of "background database" where any relevant background information needed for drawing conclusions about the values of biological elements/survey results would be in a more easy-to-use format.

This kind of extra data would allow a quick screening of possible exceptional conditions. If the conditions are such as in average, no separate background data collection would be needed. The data could be organised e.g. to include a dataset for certain area and different years of the relevant background variables. Research is also needed to produce information about the relationship of inter-annual variation (caused by the environmental variable other than changing human impact) to the calculated ecological quality ratios.

The assessment of ecological status of lakes will be a continuous process that will be repeated once every six years in connection with an official reporting procedure. It is obvious that in many lakes the actual monitoring has to be more frequent than once every six years. It is notable, that the data collected through this process is not only needed for the classification purposes of the WFD but also for various other national or local needs. If and when future plans for monitoring and assessment are done on a soundly basis, the classification work will be much easier in the future compared to the very first trial presented in this paper.

7.2 Role of the littoral zone in the monitoring and assessment procedure

Aquatic macrophytes

Macrophytes are an important part of the lake ecosystem as primary producers and habitats for other organisms, especially in shallow lakes. Macrophytes are relatively persistent in their site and respond to long term changes in anthropogenic pressures, like eutrophication caused by agriculture and diffuse loading from scattered population. Macrophytes also respond to acidification, water level regulation and physical alterations in the littoral zone.

The macrophyte monitoring methods used in this project are cost-effective and reveal differences in the present status of plant communities of lakes. However, due to the variation in the subjective assessment methods of the field surveys and to the variation caused by e.g. atmospheric factors in the remote sensing methods, the changes in the abundance of macrophytes have to be relatively considerable for the methods to detect them. Therefore, more sensitive methods (like biomass measurements) may be needed to detect the slight, early changes caused by eutrophication, like the densification of helophyte stands. When monitoring programmes are designed, also site-specific factors related to variation in macrophyte communities (e.g. bottom substrate, exposure of sites) have to be considered more carefully to create optimal monitoring programmes.

Periphyton (attached microalgae)

Attached algal communities 'periphyton' have an important role as primary producers in many aquatic systems, particularly in lotic environments and also in shallow lakes together with phytoplankton and macrophytes. The species composition and number of organisms in the natural periphyton communities are directly related to water quality. Diatoms have become widely accepted as monitors or 'indicators' of water quality and environmental change (Weitzel 1979).

Based on the species composition including some other metrics the general typification of lakes showed great promise in this project. The community structure approach seemed to be relevant to define type-specific algae reference condition for the lake littoral system. However, the evaluation of human impacts using diatom indicator species list was problematic in most lakes because of narrow range and low tolerance of used indices. Most of the used diatom indices are developed in Central Europe and reflect the degree of high eutrophication or sabrobity. Typically, humic substances cause a lot of the variation of diatom indices values in Finnish surface waters thus making the interpretation of current results difficult. Some standardization, calibration and more data sets would be required to ensure that the methods were consistant (Eloranta 1999). With appropriate modifications the diatom method can be applied to the study of benthic diatoms in the lake littoral.

Even though the comparison of the results between different water bodies is difficult because of environmental dissimilarities, the level of impact was detected using simple and robust productivity measurements of periphyton communities e.g biomass and chlorophyll *a* content. The factors that regulate the development and growth of periphyton should be considered when monitoring periphyton communities, especially on artificial substrates.

Benthic macroinvertebrates

Benthic invertebrates of the littoral zone have an important role in the functioning of lake ecosystems. As with most other groups of aquatic organisms, the diversity is highest in the littoral zone. As a food source of fish, benthic invertebrates are an important link between the aquatic primary producers and fish. Furthermore, the functional importance of benthic invertebrates is increased by their ability to use decaying organic matter (detritus) of autochtonous (aquatic) as well as allochtonous (terrestrial) origin. Due to their linkage with terrestrial carbon, the littoral benthic macroinvertebrates may be better indicators of the disturbances related to the forestry practices and land use than profundal communities. Impacts of many other disturbances on macroinvertebrates e.g. water level regulation, acidification, shoreline alteration, recreational activities and local small-scale point-loading of nutrients could be mainly confined to the littoral zone.

The importance of profundal zoobenthos as an indicator of lake productivity and oxygen conditions in the hypolimnion is well documented. However, suitability of the profundal macroinvertebrates for monitoring purposes may be lower in small lake. The decomposition of accumulated organic matter of terrestrial and aquatic origin in areally small profundal zone may cause oxygen deficiency, which can also be a common phenomenon in oligotrophic lakes with reference status. Thus, the profundal fauna typical of eutrophic lakes may also thrive in small oligotrophic lakes. This was evident in small mesohumic lakes of this project. Similarly to the profundal communities, the littoral macroinvertebrates have been found to respond to the lake nutrient status. Consequently, in a comparison with the profundal communities of small mesohumic lakes, the littoral fauna was observed to be more sensitive to separate reference lakes from the disturbed ones.

Phytoplankton

Phytoplankton reacts quickly to environmental changes, especially to the increase of nutrient loading, but depends also on physical and biological factors. Phytoplankton assemblages with short renewal times are not constant, as there is seasonal variability and marked inter-annual variation in the abundance. The dominant species at any given successional stage will not always be the same.

In the Life Vuoksi project, phytoplankton was sampled from twelve lakes in August 2002 as composite samples from surface to the depth of two metres. The phytoplankton biomass and species composition were estimated quantitatively by microscopy from ten composite samples taken from the pelagial part of the lakes. Furthermore, 103 samples were taken from the pelagial area and close to the shorelines simultaneously with fluorometric measuring for estimating five dominating taxa. These composite samples were concentrated with a net.

Phytoplankton quantity and quality can be applied when discriminating the lakes not affected by human activities from the impacted ones. The determination of the ecological status of impacted lakes is based on the EQR-ratios calculated from the biomass values in reference conditions.

The robust phytoplankton analysis by microscope gives information about the taxa which mainly form the chlorophyll *a* concentration estimated by fluorometric measurements. However, the simplified method does not give accurate information concerning the phytoplankton quantity. The method used is easily adapted to the monitoring of littoral area of the lake by private persons capable of using a field microscope.

7.3 Role of different biological elements in the monitoring and assessment procedure

In this project the focus was largely oriented towards the development of monitoring methods, especially in specifying and clarifying the role of the littoral area in lake monitoring. Indeed, much interesting and valuable information of methods was caught up.

Several conclusions on the role of various biological elements can be drawn. The target lakes, which represented the natural lake types and loading levels typical of the area, could be distinguished on the basis of their periphyton populations, but the interpretation was not unambiguous. The loaded lakes and reference lakes also had distinctive quantitative perifyton parameters. The periphytic indices of water quality, although not pointing out significant changes in these impacted lakes, worked logically compared to the pressures. It could be assumed that periphyton studies are more useful in monitoring the effects of somewhat higher point source loading.

Regarding the phytoplankton studies the focus was on collecting net plankton samples to support the method testing of fluorometer measurements in the methodology report. The net plankton sampling was concluded to be more of an informative nature and not suitable in routine determination of lake status. The number of phytoplankton samples from the pelagial area was not high. The crucial role of phytoplankton studies is otherwise well documented. Although this was not the main issue in this study, the pelagial phytoplankton data supported other information in general. The biomasses were typical of oligotrophic status in reference lakes, but also in some less impacted lakes.

Littoral benthic macroinvertebrates may be good indicators of the disturbances related to the forestry practices and land use but also to many other disturbances e.g. water level regulation and acidification. The amount of work per site was estimated to be higher for processing the littoral samples compared to that of the profundal ones. However, the costs of sample processing could be considered to diminish e.g. by fixed-count sub-sampling procedure, where a targeted number of individuals is sorted and identified. This method could be expected to reduce the handling times of littoral samples, since the costs of sample processing were observed to be largely depended on the number of individuals per sample (59% of the variation in processing time). According to the methodology studies of benthic macroinvertebrates in the Project, the taxonomic composition of littoral invertebrates was characteristic of each habitat type. This should be taken into account in planning the monitoring of the littoral area. Of the studied habitat types, the effects of nutrient loading were most pronounced on stony shores. However, in some cases the use of this habitat in monitoring may be problematic. Although stony bottoms typically comprise the main habitat in large lakes, stony shores may completely be lacking from small lakes with gently sloping shores.

For various biological elements EQRs were preliminarily determined. However, it should not be forgotten, that this was done at a very early stage of classification development. There was no opportunity to define reliably reference conditions based on data of a sufficient number of lakes in a certain type. Neither any nationally suggested class boundaries existed. The calculated EQRs were appointed to classes based on expert judgement. Therefore, the analysis of EQRs cannot be very profound.

The exercises with EQRs, presented in more detail in Chapter 6, are summarized in Table 15. It is obvious that the preliminary estimates of EQRs for different biological quality elements in a given lake differ significantly. The estimates for preliminary EQR values differed most in the case of phytoplankton, which is not surprising compared to the focus of the plankton sampling in this project. These EQR values are only preliminary and uncertain estimates based on too restricted data in respect of both spatial and temporal scales. Most of the study lakes show a variation in the preliminary status estimate obtained using different quality elements. However, the overall information is parallel. But since no actual type-specific reference conditions or class boundaries were not available at the time, both columns (3 and 4) in the table 15 reflect the judgement of the experts in the Project, from slightly varying approaches.

Table 15. Preliminary estimates of the ecological status of five of the study lakes based on different quality elements/metrics/methods and an expert judgement procedure.

Lake	Biological element	EQR/Status	Expert judgement
Keskimmäinen	Aquatic macrophytes:	G[1)]	Good (Weakened)
	Littoral and profundal benthic invertebrates:	G/M[2)]	
	Periphyton:	G/M[2)]	
	Phytoplankton:	G/M/P[2)]	
Alimmainen	Aquatic macrophytes:	M[1)]	Moderate
	Littoral and profundal benthic invertebrates:	G/M[2)]	
	Periphyton:	G/M[2)]	
	Phytoplankton:	G/M/P[2)]	
Niemisjärvi	Aquatic macrophytes:	M	Moderate
	Littoral and profundal benthic invertebrates:	G/M	
	Periphyton:	M	
	Phytoplankton:	M/P	
Kuohattijärvi	Aquatic macrophytes:	G	Good
	Littoral and profundal benthic invertebrates:	G/H	
	Periphyton:	-	
	Phytoplankton:	H	
Mujejärvi	Aquatic macrophytes:	G	Good
	Littoral and profundal benthic invertebrates:	G	
	Periphyton:	-	
	Phytoplankton:	H(B/P)	

- = no data; Status: H = high, G = good, M = moderate, P = poor, B = bad.

Lake Keskimmäinen-Alimmainen treated as 1) two separate lake basins (Lake Keskimmäinen and Lake Alimmainen) 2) one combined lake (Lake Keskimmäinen-Alimmainen)

It is evident, that a lot of work and further investigations are urgently needed to improve the estimates of the ecological status of lakes. The integrated use of various parameters of one biological element needs much emphasis, as well as the integrated use of several biological elements in the classification of waters. The suggestions for further research are represented in Chapter 7.5.

Cost-efficiency

In the monitoring and status assessment procedure cost-efficiency is best reached based on objective-oriented and comprehensive work plans. In selecting the monitoring means, a holistic approach to the status of a lake ecosystem should be the starting point. The planning of monitoring should be based on thorough-going analysis of present status information and data as well as long-term scheduling.

The monitoring and assessment procedure deals with these main principles in a systematic and preindicating way. The available data and information is analysed in phases I–VII. These interim results and conclusions should be used after phase VII, or even previously, for future steps in the status assessment and for gathering extra monitoring data when needed.

In the LifeVuoksi Project it has not been possible to test the monitoring and assessment procedure for a period of several years. Many specific features in the monitoring and assessment procedure will be found out only when implementing it in practice. However, it can be presumed, that the early-phase information collection and analysis during the first phases will lead to benefits as saved working hours in the final status assessment phase. On a rough scale these savings of costs could be forecasted to range from one to several working days as a minimum for a small or medium-sized lake. This is very important in countries where water bodies are numerous. On the other hand, a systematic procedure is specifically needed in regions where much new monitoring and assessment work e.g. in the implementation of the WFD is going on. A systematic storage of data and information is a requirement in order to reach these benefits.

However, the most important benefits from the cost-efficiency view are in the right targeting of monitoring and in the positive effects on the quality of monitoring and status assessment. These results are furthermore benefited from a comprehensive monitoring and reporting of a river basin, which is a requirement of the WFD as well.

The cost-efficiency in monitoring and status assessment can thus be divided into several parts:

1) Actual costs in sampling, analysing and reporting.
2) Reaching the targets of status assessment. That is to say, getting the information needed for setting the goals of water protection and maintaining good awareness of the state of the environment.
3) Quality in monitoring: in addition to the technical quality assurance in sampling and analysing, also the quality of monitoring as an entity, in understanding the ecological status of a whole lake. In this respect also the littoral zone will have a more decisive role in the future.

The Life Vuoksi Project has produced tools for parts 1, 2 and 3. Focusing on the littoral zone has produced especially knowledge on its monitoring methods. The main conclusions on the methodology are:

- In diverse lake environments the most effective monitoring may be to concentrate on monitoring of a specific habitat type. The idea is not new, but the project has produced concrete new information on habitat type monitoring for macrophytes and benthic macroinvertebrates. In macroinvertebrate studies it was concluded that stratification of (littoral) habitat types is advisable in order to make among-lake comparisons. Also the amount of work is somewhat different for different habitats (see an example on benthic invertebrates, Figure 19).

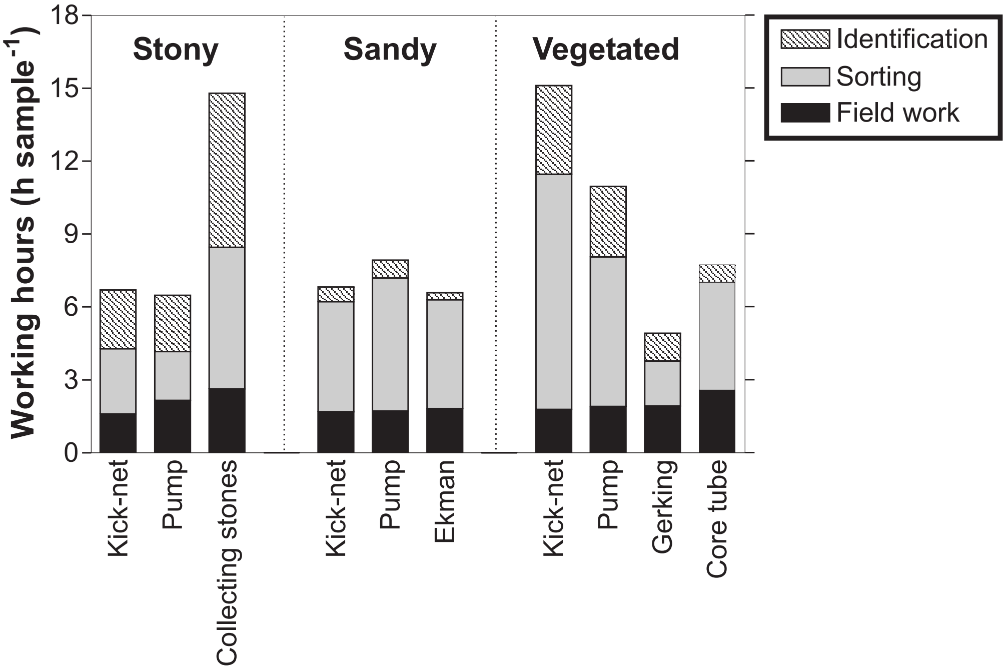

Figure 19. Working time in various steps of sample handling using different sampling methods in stony, sandy and vegetated habitats of the study lakes (Tolonen et al. 2003).

- In diverse lake environments at least occasional surveys are needed, in large lakes even regional surveys. Surveying is needed e.g. for understanding the impacts of various polluters and even the spatial variation, which occurs also naturally. The use of a field fluorometer is a method tested in the Life Vuoksi project for assessing eutrophication of waters.
- In macrophyte monitoring the combination of air photography and field studies may produce cost-efficient results. Available aerial photographs can also be used, in digitised format as well (Valta-Hulkkonen et al. 2003 a,b).
- Several detailed results of the project can be used in monitoring. E.g. the sensitivity of biota in different lake habitats to various pressures, the resolution in taxa analyses (family level or genus/species level). These results of the methodology testing of the project form a sound basis in the procedure after phase VII. The detailed results of the methodology testing give information and comparisons of the methods (Leka et al. 2003, Sojakka et al. 2003 a, b, Tolonen et al. 2003, Valta-Hulkkonen et al. 2003 a, b). Further development of the procedure is also needed, as stated in 7.5.

7.4 Possibilities of public participation

Local inhabitants and stakeholder groups have valuable information about local waters and therefore their role can be very important in the management of water bodies and watershed areas. People have different relations and contradictory viewpoints to the waters according to e.g. if they use the water body for their source of livelihood or if they use it for recreation purposes. Questionaires, working groups and discussions can be used for gathering and sharing information between local people and authorities or other experts. The big but is to get all key partners to participate and also to commit to the decisions and activities. Possible economical consequences play a key role there.

Concerning the public participation in monitoring, the identification of suitable monitoring methods and organisation of the activity are crucial. The experience from different sources shows that continuous motivation and training by experts is needed for successful and continuous work. The criteria for suitable characteristics for voluntary monitoring are demanding: measurement should be objective, easy, not needing expensive equipment, clearly related to the observed nuisance, enough sensitive to detect changes but not too noisy to avoid confusing results. These can be achieved best when making observations of transparency and observation of the algal blooms. Observation of aquatic macrophytes is considered very interesting by public but in practise it needs much expertise and training. Observations related to fishing activities are also possible. The reporting of the results of the voluntary monitoring is related to the question of the organisation. If authorities are involved and are aiming to use the produced information they should take responsibility of the reporting phase at least at national level.

In the Life Vuoksi Project the activities were carried out at the level of a certain local lake and it´s inhabitants. The activities were planned in co-operation with local lake management projects in order to get the most practical touch to the matter. In the WFD context the challenge for the public participation is to choose the right scale. On the one hand operating extensively at local level may bee too laborious and too detailed but on the other hand water management without local dimension is nothing but an abstraction.

7.5 Need for further studies

The Life Vuoksi project ended up in a list of some important topics, which should be investigated more precisely in the future. The topics are the following:

- to estimate natural variations of different biological elements in different types of lakes
- to establish experimental pilots to understand better the fate and effects of anthropogenic pollution in different type of lakes
- to estimate the role of fishes and fishing
- to estimate the costs of getting sufficient amount of data on different biological elements for statistically reliable EQRs in different types of lakes and pollution cases.

The assessment of the ecological status of lakes is a long learning process that is inevitably needed in the implementation of the WFD.

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Suomenkielinen lyhennelmä (abstract in Finnish)

Järvien ekologisen tilan arviointi- ja seurantamenetelmä

Yhteenveto Life Vuoksi -hankkeen osakokonaisuuden raportista

Life Vuoksi -hankkeessa kehitettiin ja testattiin järvien ekologisen tilan arviointi- ja seurantamenetelmä

Vuoksen vesistöalueella toteutetun 3-vuotisen Life Vuoksi -hankkeen yksi keskeinen osakokonaisuus oli järvien ekologisen tilan seuranta- ja arviointimenetelmän kehittäminen ja testaus. Seuranta- ja arviointimenetelmän kehittäminen perustui hankkeen muiden osioiden tulosten yhdistämiseen, tulkintaan ja hyödyntämiseen. Näissä osioissa mm. testattiin ja arvioitiin biologisten laatutekijöiden (kasviplankton, päällyslevät, vesikasvit ja pohjaeläimet) tutkimusmenetelmiä, joiden tarkka tuntemus on yksi luotettavan seuranta- ja arviointimenetelmän kehittämisen välttämättömistä perusedellytyksistä.

Hankkeen kohdejärvet valittiin kattamaan mahdollisimman hyvin Vuoksen vesistöalueen tärkeimmät luontaiset järvityypit. Valuma-alueeltaan, pinta-alaltaan, veden väriltään ja muilta tärkeiltä perusominaisuuksiltaan erityyppisille järville valittiin sekä selvästi kuormitettu että mahdollisimman kuormittamaton kohdejärvi seuranta- ja arviointimenetelmän testaamista varten. Järvien ekologisen tilan seuranta- ja arviointimenetelmää testattiin neljässä järviparissa.

Tässä yhteenvedossa kuvataan seuranta- ja arviointimenetelmän kehittelyssä ja testauksessa tarvittavat taustatiedot ja menettelytavat sekä kuvataan lyhyesti menetelmän käyttö ja tulevaisuuden haasteet. Hankkeessa kehitettyä seuranta- ja arviointimenetelmää voidaan hyödyntää EU:n vesipolitiikan puitedirektiivin mukaisessa ekologisen tilan luokittelussa, vaikka menetelmä vaatiikin lisäkehittelyä.

Järvien ekologisen tilan arviointi- ja seurantamenetelmän kehittämisestä hankkeessa vastasi Suomen ympäristökeskus ja siihen osallistuivat kaikki hankekumppanit. Hanke kokonaisuudessaan toteutettiin Etelä-Savon ympäristökeskuksen johdolla. Lisäksi siihen osallistuivat Pohjois-Savon ja Pohjois-Karjalan ympäristökeskukset sekä Oulun yliopisto.

Vesipolitiikan puitedirektiivi ohjaa seuranta- ja arviointijärjestelmien kehitystä

Vuonna 2000 voimaan tullut vesipolitiikan puitedirektiivi (VPD) määrittelee EU:n vesiensuojelun suuntaviivat vuosikymmenien päähän. Direktiivi vaatii, että järvet ja muut pintavedet on pystyttävä luokittelemaan ekologisen tilan perusteella viiteen laatuluokkaan. Perustavoite on, että vesien tila ei heikkene missään. Mikäli järven ekologinen tila on erinomainen tai hyvä, lisätoimiin ei tarvitse ryhtyä. Mikäli järven tila on tyydyttävä tai sitä heikompi, on tehtävä toimenpiteitä, jotta vähintään hyvä ekologinen tila saavutetaan. Järven hyvän ekologisen tilan saavuttamisen keinot on esiteltävä vesienhoitoalueen (esim. Vuoksen vesistö) hoitosuunnitelmiin kuuluvissa toimenpideohjelmissa. Suomessa vesiensuojelulla on jo pitkät ja hyvät perinteet, joten monin paikoin direktiivi ei tuone merkittäviä muutoksia vesiensuojeluun.

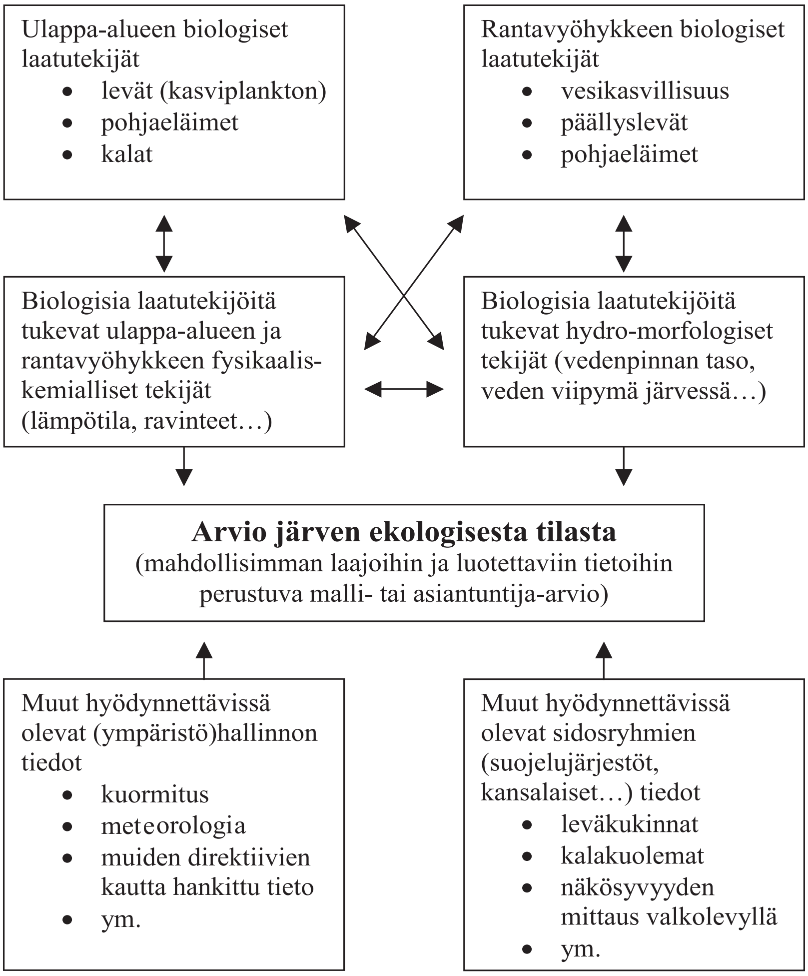
Vesien tila-arvioinnin yksi keskeisistä osista on ekologisen tilan luokittelu. Tällä hetkellä Suomessa tai muualla Euroopassa ei ole valmiina biologisiin laatutekijöihin perustuvia luokitusjärjestelmiä. Life Vuoksi -hankkeessa kehitelty seuranta- ja arviointimenetelmä palvelee osaltaan tätä eri maissa tehtävää kehittämistyötä. Tietämys lisääntyy vähitellen, kun biologisten muuttujien seurantaa kehitetään jäsenmaissa lähivuosina ja muokatut seurantaohjelmat käynnistetään vuoden 2006 loppuun mennessä.

Järven eri laatutekijät ja osa-alueet seuranta- ja arviointijärjestelmän osina

Suomessa järvien tilan seuranta on perinteisesti keskittynyt fysikaalis-kemiallisten muuttujien (mm. happi, fosfori, typpi) ja kasviplanktonin (lajikoostumus, runsaussuhteet, *a*-klorofyllipitoisuus) seurantaan ulappa-alueella. Perusajatus on ollut, että syvännepisteestä eri syvyyksiltä otetut vesinäytteet todennäköisimmin kuvastavat järven keskimääräistä vedenlaatua. Esimerkiksi happikato seurausvaikutuksineen, kuten syvänteen pohjaeläimistön häiriintyminen, havaitaan useimmiten järven syvännealueella.

Nykyisin järvien tilaa halutaan seurata myös rantavyöhykkeellä (litoraali) useastakin syystä. Ravinteet kulkeutuvat valuma-alueelta jokia ja pienempiä vesiuomia pitkin ensimmäiseksi rantavyöhykkeelle ja aiheuttavat vesikasvien runsastumista sekä rantojen limoittumista. Toisaalta rantavyöhyke on se osa järveä, jonka läheisyydessä ihmiset viettävät usein vapaa-aikaansa. Yksi rantavyöhykkeen merkityksen korostamisen selkeistä perussyistä on vesipuitedirektiivin vaatimukset mm. rantakasvillisuuden selvittämiseksi.

Oheisessa kuvassa on esitetty Life Vuoksi -hankkeen seuranta- ja arviointimenetelmän kehittämisessä käytettyjä laatutekijöitä, järven eri osa-alueita ja tärkeitä tietolähteitä.



Järven ekologisen tilan määrityksessä pitää ottaa huomioon järven ulappa- ja ranta-alue sekä eri biologiset eliöryhmät. Näiden biologisten tekijöiden tueksi tarkastellaan veden laatua sekä mm. hydrologisia tekijöitä, jotta saadaan kokonaiskuva veden tilasta. Tärkeää myös ottaa huomioon paikallisten asukkaiden, teollisuuden, kuntien, kansalaisjärjestöjen ja muiden tahojen näkemykset ja mielipiteet järven ja sen valuma-alueen ympäristötavoitteiden määrittelystä ja keinoista niiden saavuttamiseen.

Ekologisen tilan seuranta- ja arviointimenetelmän käyttö

Kun yllä esitellyt seuranta- ja arviointijärjestelmän päätekijät on määritelty tapauskohtaisesti, tekijät on käsiteltävä järjestelmällisesti, jotta ekologisen tilan arviointi olisi mahdollisimman monipuolista. Life Vuoksi -projektissa ekologisen tilan arviointi jaettiin seuraaviin yhdeksään vaiheeseen:

Vaihe 1:
Järven ja valuma-alueen perustiedot

Vaihe 2:
Meteorologiset tiedot

Vaihe 3:
Hydrologiset tiedot

Vaihe 4:
Arvio vaiheiden 1 – 3 potentiaalisista yhteisvaikutuksista suhteessa järven biologiseen ja fysikaalis-kemialliseen tilaan (esim. miten kuiva ja lämmin kesä tai kylmä ja sateinen kesä vaikuttavat välillisesti maaperältään erityyppisten alueiden kooltaan/muodoltaan/syvyydeltään erilaisiin järviin)

Vaihe 5:
Koko valuma-alueen piste- ja hajakuormituksen suuruuden ja vaihteluiden kartoitus (erityisesti fosfori- ja typpikuormitus)

Vaihe 6:
Järven fysikaalis-kemiallisen tilan kartoitus (fysikaalis-kemialliset laatutekijät: erityisesti fosfori- ja typpipitoisuudet sekä niiden ajalliset vaihtelut/muutokset – vuoden sisäiset, vuosien väliset, vuosikymmenien aikasarjat)

Vaihe 7:
ALUSTAVA ARVIO JÄRVEN EKOLOGISESTA TILASTA
(saavuttaako järvi tavoitetilan?)

Vaihe 8:
Järven biologisen tilan kartoitus (biologiset laatutekijät: kasviplankton, muu vesikasvillisuus, päällyslevät, pohjaeläimet, kalat → ekologisen laatusuhteen laskeminen laatutekijöittäin)

Vaihe 9:
LOPULLINEN ARVIO JÄRVEN EKOLOGISESTA TILASTA
Järven ekologisen tilan arviointi kaikkiin saatavilla olevien luotettaviin tietoihin perustuen

Vaiheessa 1 kartoitetaan järven ja sen valuma-alueen perustiedot kuten järven pinta-ala, syvyys ja syvyyssuhteet sekä valuma-alueen maaperän ominaisuudet (esim. turvemaiden osuus). Vaiheissa 2 ja 3 kerätään ja arvioidaan meteorologiset ja hydrologiset tiedot sekä verrataan niitä pidemmän aikavälin keskimääräisiin arvoihin.

Vaiheessa 4 arvioidaan, miten kolmen ensimmäisen vaiheen tekijät voivat potentiaalisesti vaikuttaa järven tilaan tarkasteluaikana. Esimerkiksi lämpimänä kesänä on odotettavissa keskimääräistä voimakkaampia leväkukintoja ja kylmänä kesänä levähaitat jäävät todennäköisesti keskimääräistä pienemmiksi.

Vaiheessa 5 arvioidaan valuma-alueen piste- ja hajakuormituksen määrä tarkasteluaikana ja verrataan sitä aiempien vuosien keskimääräisiin arvoihin ja kehityssuuntiin. Vaiheen 4 päätelmiä käytetään, kun arvioidaan kuormituslukujen ajallista edustavuutta mm. hajakuormituksen osalta.

Vaiheessa 6 selvitetään järven fysikaalis-kemiallisia laatutekijöitä, erityisesti rehevöitymisen kannalta merkittävien ravinteiden, fosforin ja typen, pitoisuuksia ja ajallisia muutoksia. Mahdollisten pitkäaikaismuutosten suunnan ja voimakkuuden havaitseminen ja tulkinta ovat kuudennen vaiheen yksi oleellinen osa.

Vaiheessa 7 arvioidaan alustavasti järven ekologinen tila vaiheiden 1–6 tietojen perusteella. Koska Suomen järvistä ei vielä ole saatavissa riittävän kattavasti biologista tietoa, järvien ekologinen tila on lähivuosina arvioitava tällä tavalla.

Pidemmän aikavälin tavoitteena on saada tietoa myös biologisista laatutekijöistä järvien ekologisen tilan arvioinnin pohjaksi. Vaihe 8 liittyy siten enemmän tulevien vuosien tarkasteluihin. Tavoitteena on kerätä järjestelmällisesti ja vertailukelpoisella tavalla tietoja pintavesien biologiasta, jotta kunkin vesistöalueen vesien ekologisesta tilasta voidaan muodostaa yhtenäinen ja monipuolinen kokonaiskuva. Tällaisen kuvan muodostaminen vaatii laatutekijäkohtaisten (kasviplankton, muu vesikasvillisuus, pohjaeläimet, kalat) vertailulukujen (= ekologinen laatusuhde) kehittelyn ja laskemisen.

Kun ekologiset laatusuhteet voidaan laskea riittävän luotettavasti, järvien ekologisen tilan arviointi tapahtuu vaiheen 9 mukaisesti. Lopullinen arvio järven ekologisesta tilasta, jonka paikkansapitävyys luonnollisesti tarkistetaan säännöllisin väliajoin, perustuu siten pitkälti järvien biologisten muuttujien varaan. Vuoden 2009 jälkeen pintavesien ekologinen tila tulisi arvioida EU-maissa lähinnä biologisten muuttujien avulla.

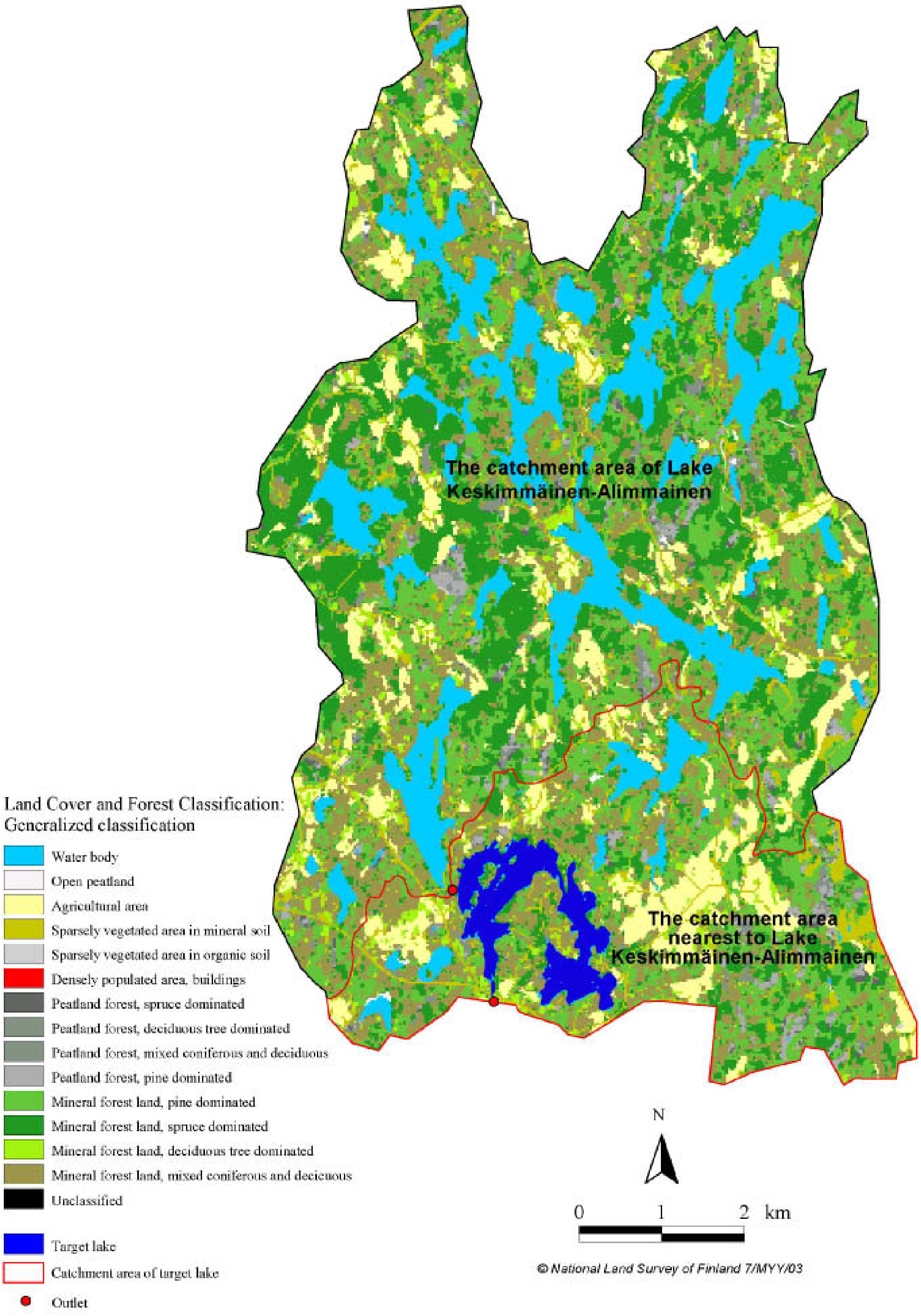
Lisätietoja kaivataan erityisesti järvien biologisista muuttujista

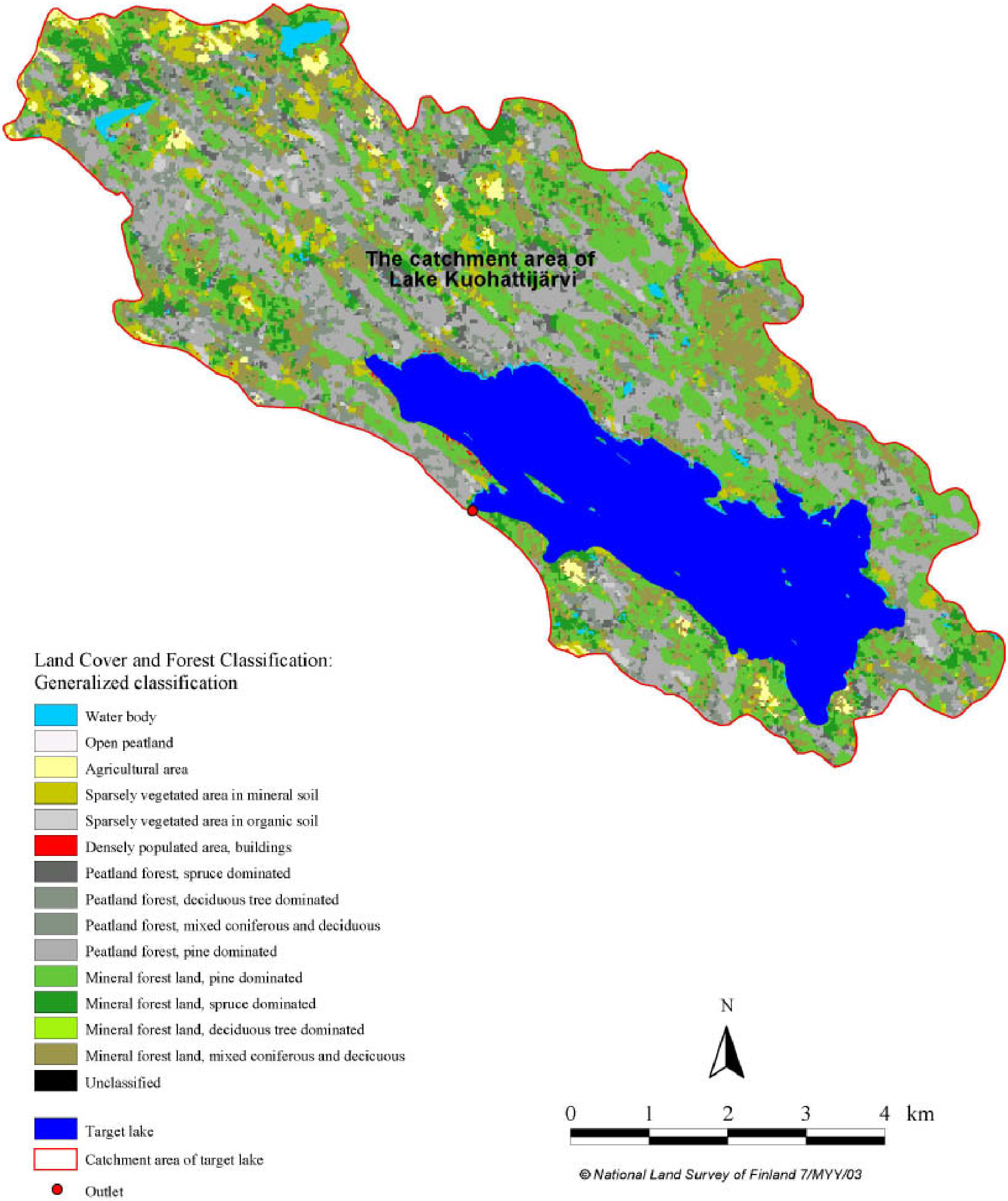
Life Vuoksi -hankkeessa kehitetty seuranta- ja arviointimenetelmä antaa hyvän pohjan tulevaisuuden seuranta-, arviointi- ja luokittelutöille. Suurin ongelma on se, että Suomen järvien biologista laatutekijöistä ei ole riittävästi tietoa. Toisaalta emme tiedä, miten paljon biologiset tekijät vaihtelevat järvityypeittäin tai järvien osa-alueittain. Yksi tulevaisuuden haasteista on, miten ranta-asukkaiden ja muiden sidosryhmien näkemykset saadaan kattavasti ja luotettavasti mukaan seuranta- ja arviointijärjestelmän osaksi.

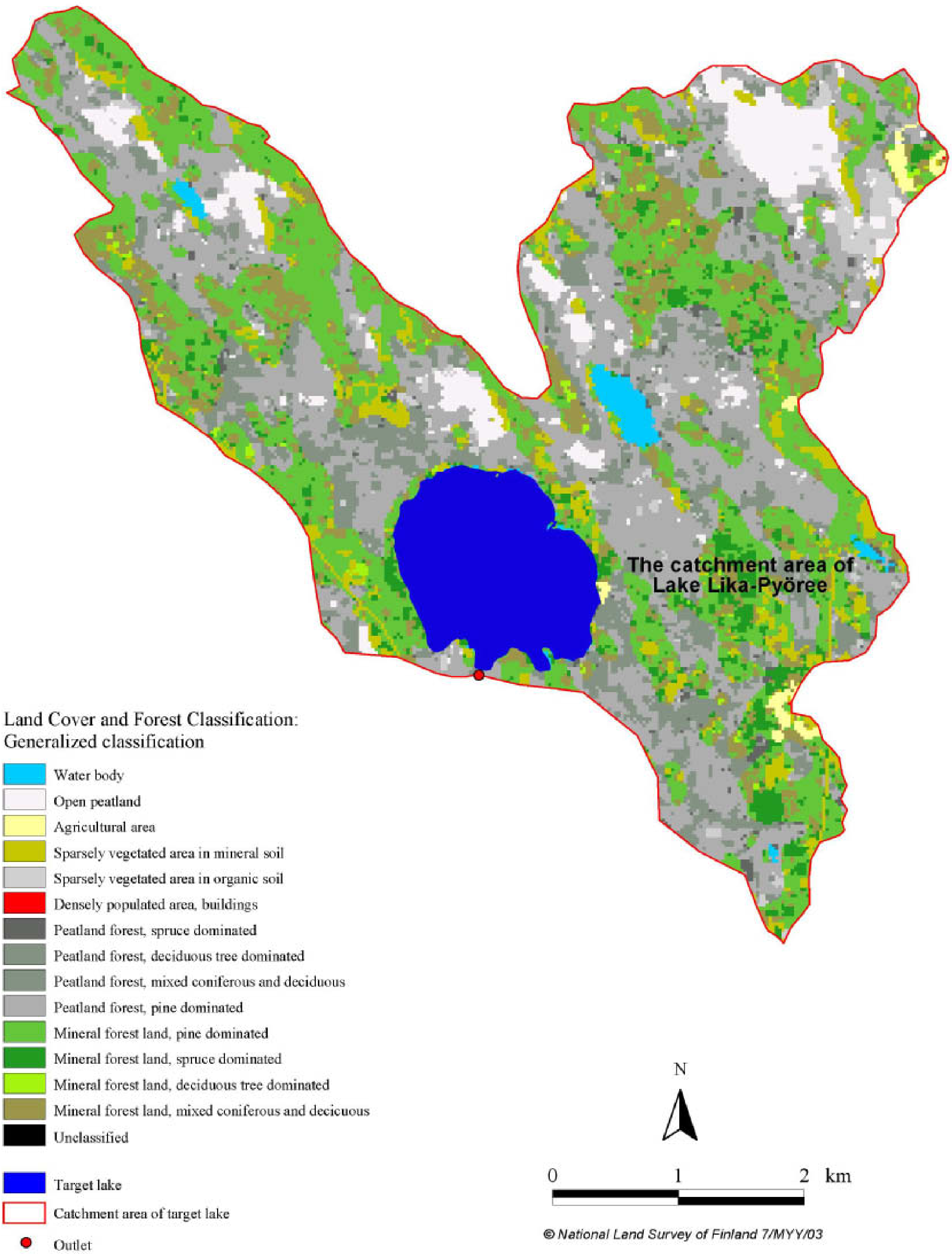
Annexes

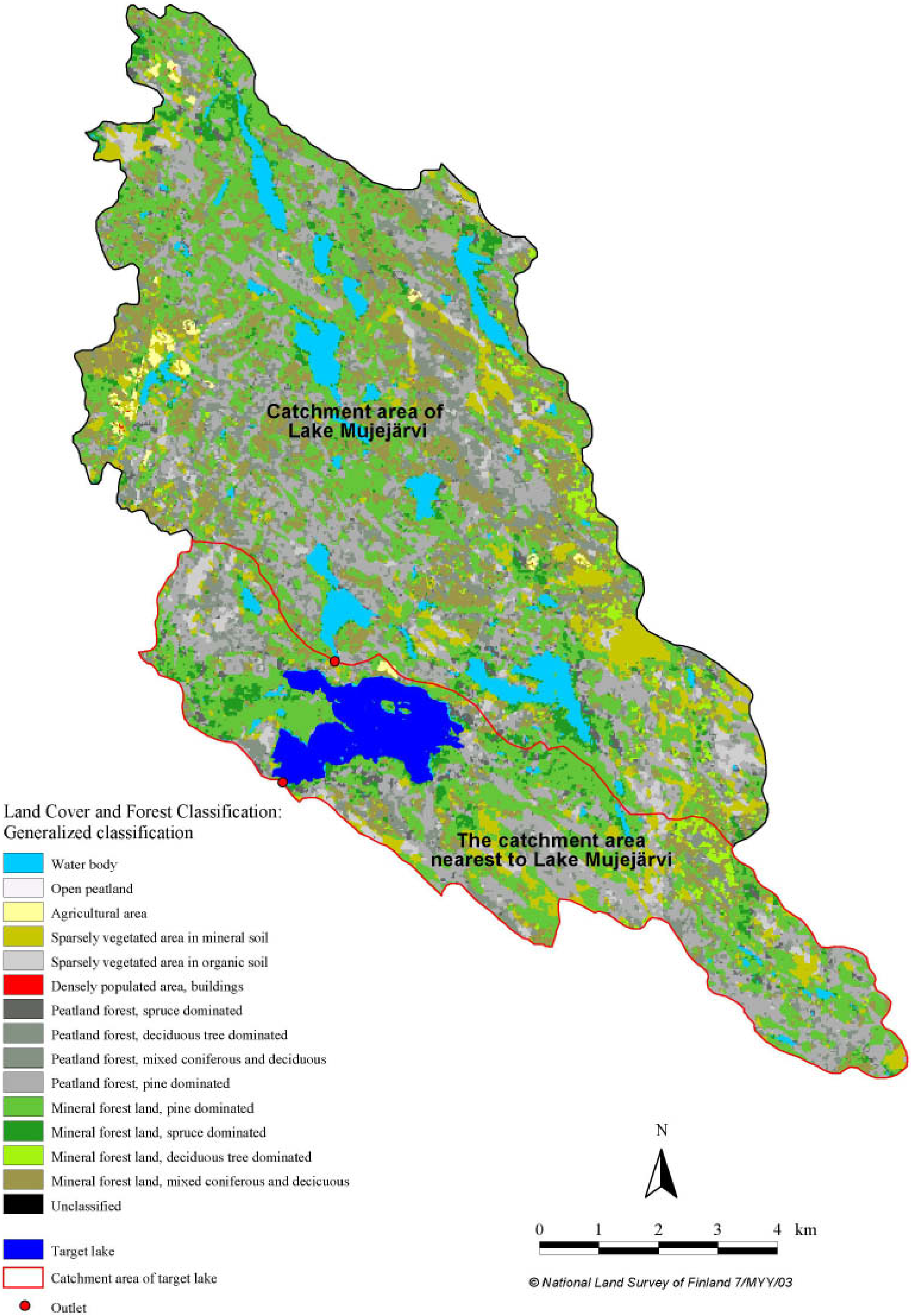
Land cover and forest classification maps over the catchment areas of the study lakes

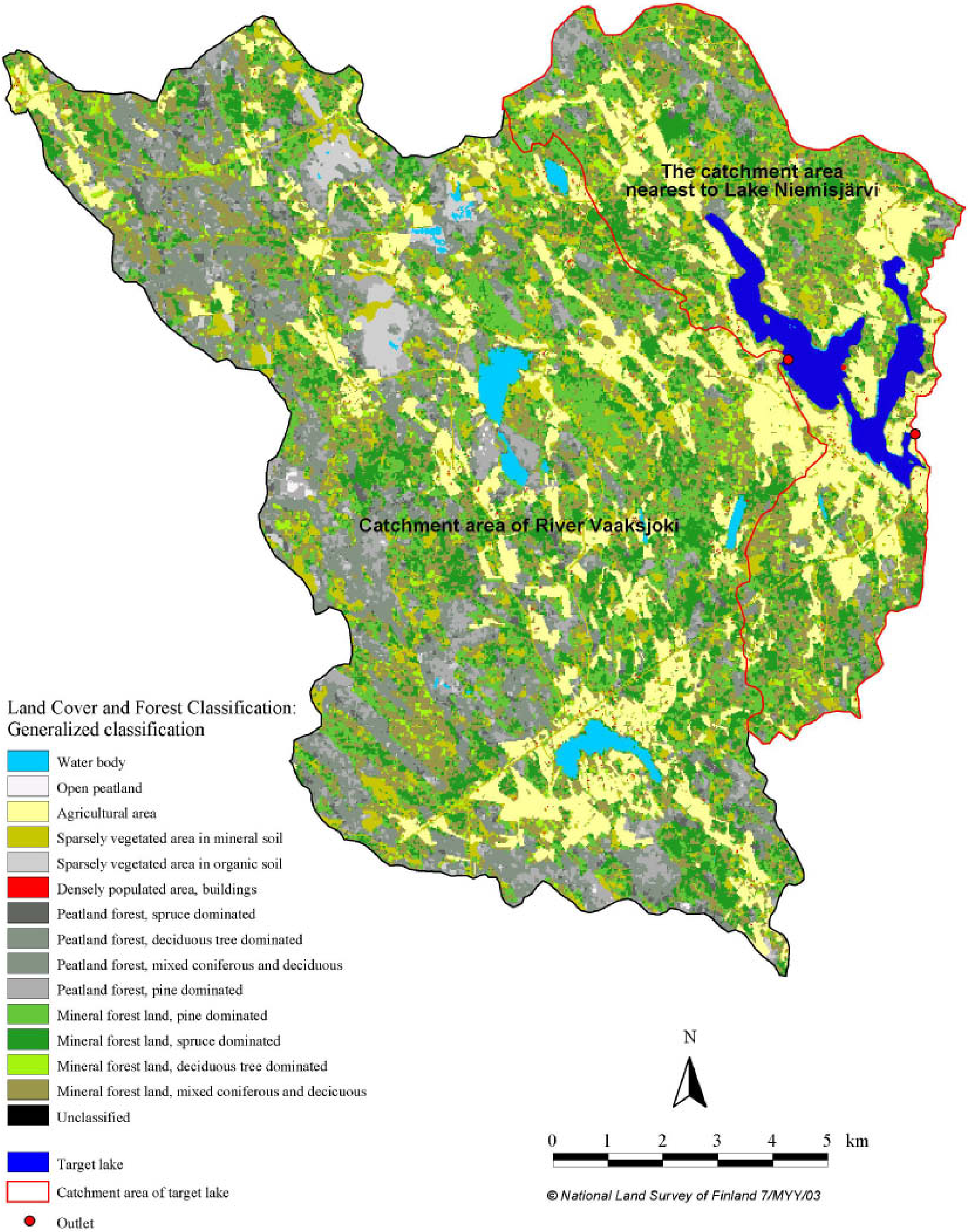
For more details, see Chapter 5.1.

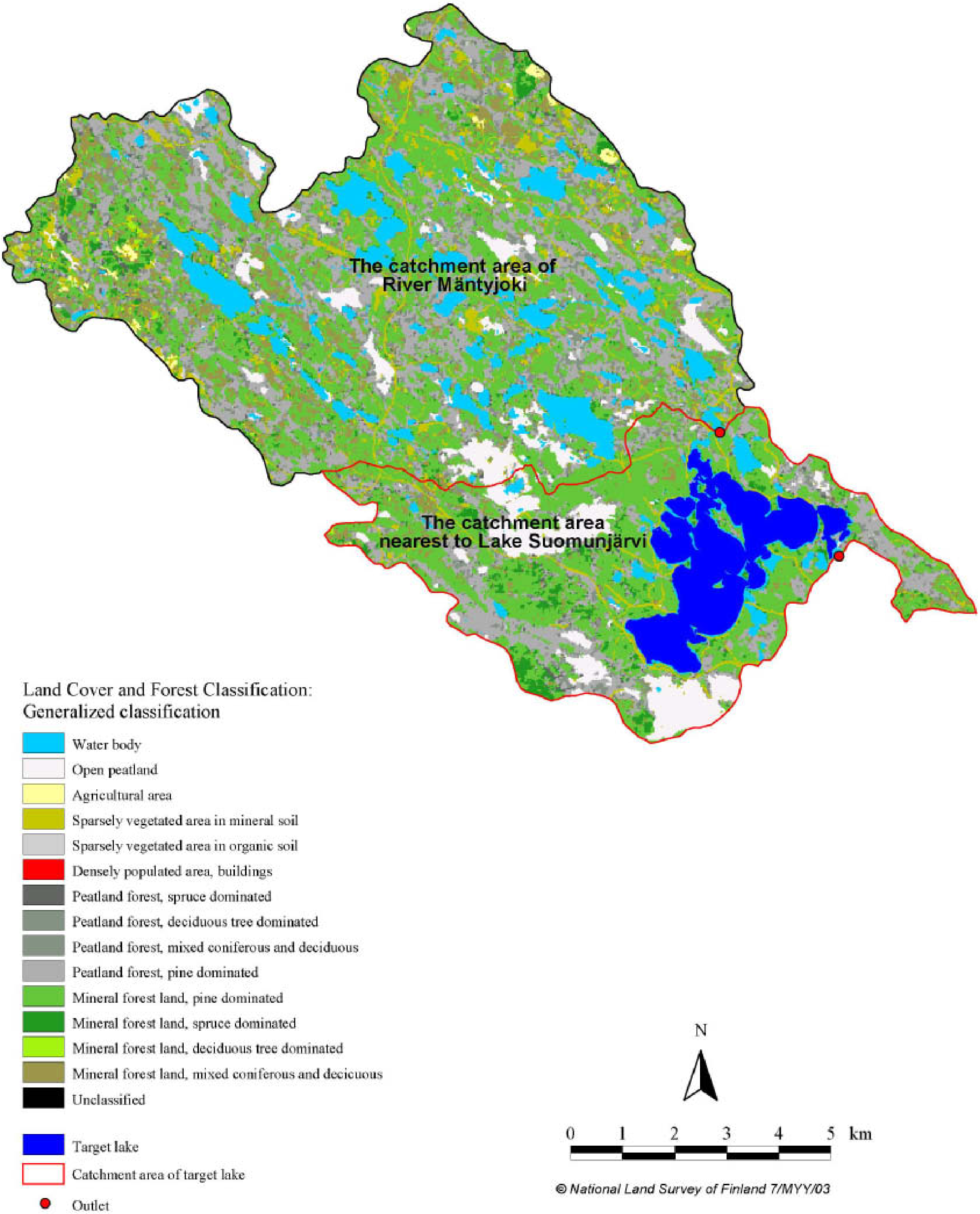


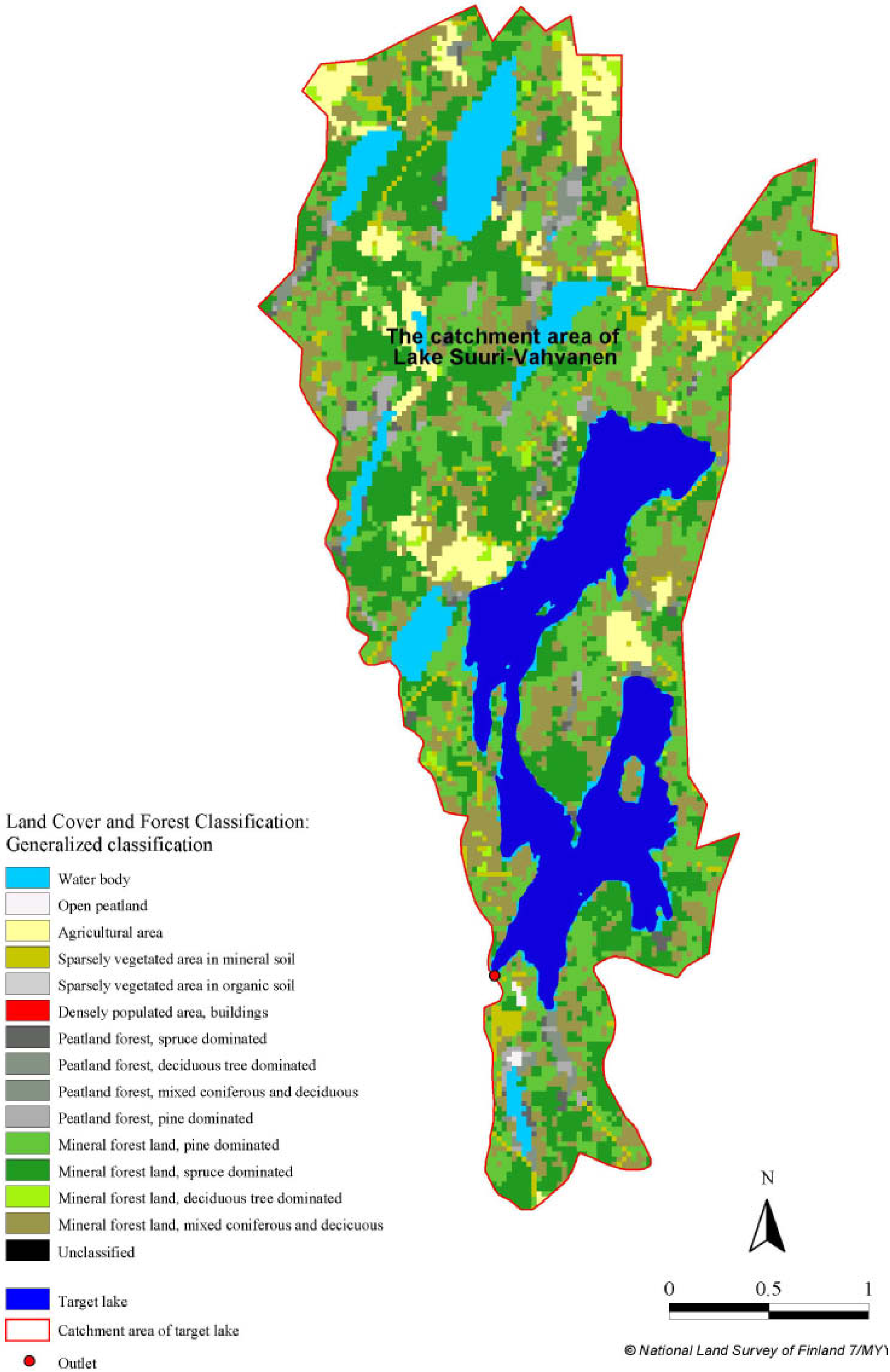

The catchment area of
Lake Kuohattijärvi
Land Cover and Forest Classification:
Generalized classification
Water body
Open peatland
Agricultural area
Sparsely vegetated area in mineral soil
Sparsely vegetated area in organic soil
Densely populated area, buildings
Peatland forest, spruce dominated
Peatland forest, deciduous tree dominated
Peatland forest, mixed coniferous and deciduous
Peatland forest, pine dominated
Mineral forest land, pine dominated
Mineral forest land, spruce dominated
Mineral forest land, deciduous tree dominated
Mineral forest land, mixed coniferous and decicuous
Unclassified
Target lake
Catchment area of target lake
Outlet
N
0 1 2 3 4 km
© National Land Survey of Finland 7/MYY/03

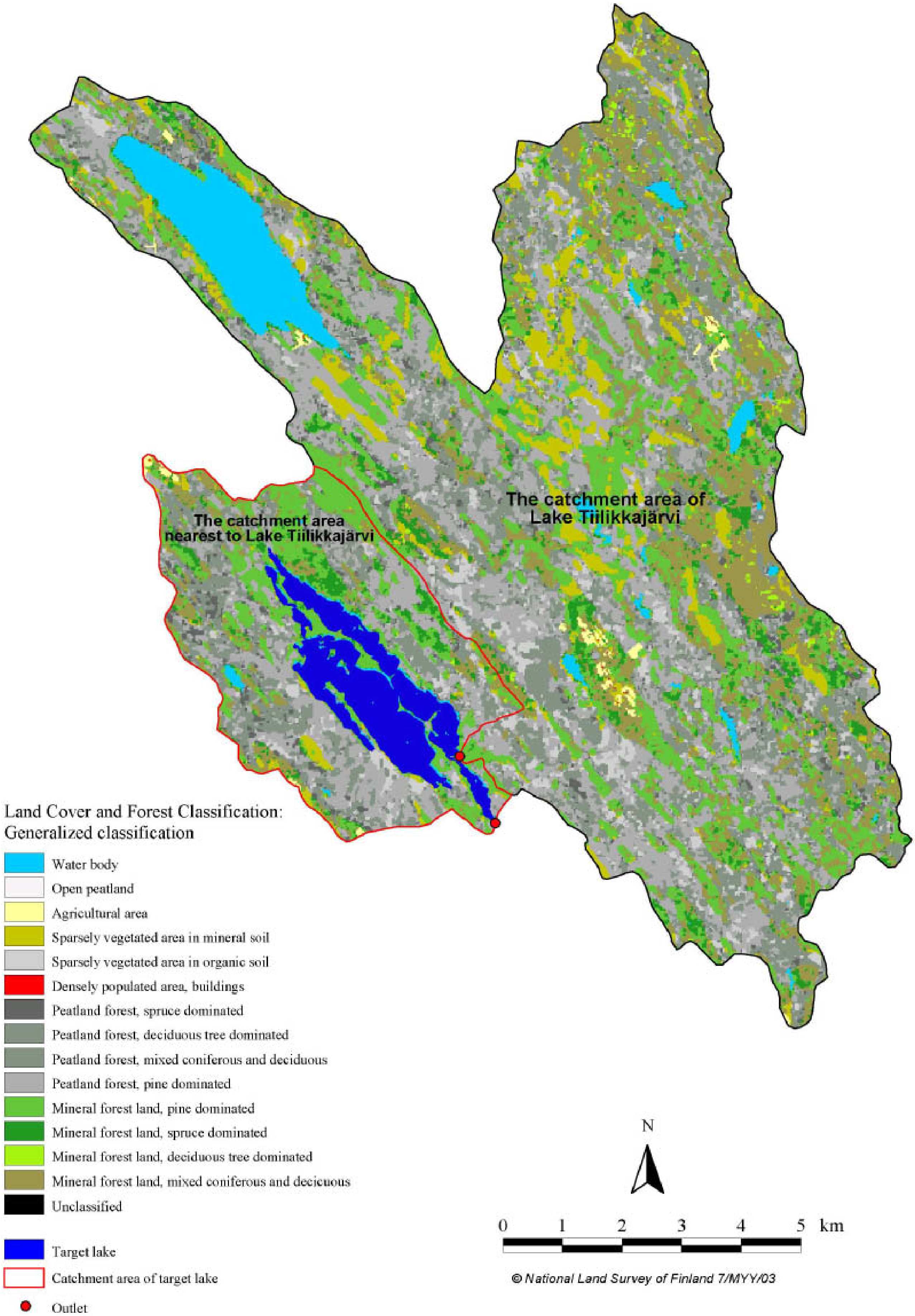

The catchment area of
Lake Lika-Pyöree
Land Cover and Forest Classification:
Generalized classification
Water body
Open peatland
Agricultural area
Sparsely vegetated area in mineral soil
Sparsely vegetated area in organic soil
Densely populated area, buildings
Peatland forest, spruce dominated
Peatland forest, deciduous tree dominated
Peatland forest, mixed coniferous and deciduous
Peatland forest, pine dominated
Mineral forest land, pine dominated
Mineral forest land, spruce dominated
Mineral forest land, deciduous tree dominated
Mineral forest land, mixed coniferous and decicuous
Unclassified
Target lake
Catchment area of target lake
Outlet
N
0
1
2 km
© National Land Survey of Finland 7/MYY/03


Catchment area of
Lake Mujejärvi
The catchment area
nearest to Lake Mujejärvi
Land Cover and Forest Classification:
Generalized classification
Water body
Open peatland
Agricultural area
Sparsely vegetated area in mineral soil
Sparsely vegetated area in organic soil
Densely populated area, buildings
Peatland forest, spruce dominated
Peatland forest, deciduous tree dominated
Peatland forest, mixed coniferous and deciduous
Peatland forest, pine dominated
Mineral forest land, pine dominated
Mineral forest land, spruce dominated
Mineral forest land, deciduous tree dominated
Mineral forest land, mixed coniferous and decicuous
Unclassified
Target lake
Catchment area of target lake
Outlet
N
0 1 2 3 4 km
© National Land Survey of Finland 7/MYY/03


The catchment area nearest to Lake Niemisjärvi
Catchment area of River Vaaksjoki
Land Cover and Forest Classification: Generalized classification
Water body
Open peatland
Agricultural area
Sparsely vegetated area in mineral soil
Sparsely vegetated area in organic soil
Densely populated area, buildings
Peatland forest, spruce dominated
Peatland forest, deciduous tree dominated
Peatland forest, mixed coniferous and deciduous
Peatland forest, pine dominated
Mineral forest land, pine dominated
Mineral forest land, spruce dominated
Mineral forest land, deciduous tree dominated
Mineral forest land, mixed coniferous and decicuous
Unclassified
Target lake
Catchment area of target lake
Outlet
N
0 1 2 3 4 5 km
© National Land Survey of Finland 7/MYY/03


The catchment area of River Mäntyjoki
The catchment area nearest to Lake Suomunjärvi
Land Cover and Forest Classification:
Generalized classification
Water body
Open peatland
Agricultural area
Sparsely vegetated area in mineral soil
Sparsely vegetated area in organic soil
Densely populated area, buildings
Peatland forest, spruce dominated
Peatland forest, deciduous tree dominated
Peatland forest, mixed coniferous and deciduous
Peatland forest, pine dominated
Mineral forest land, pine dominated
Mineral forest land, spruce dominated
Mineral forest land, deciduous tree dominated
Mineral forest land, mixed coniferous and decicuous
Unclassified
Target lake
Catchment area of target lake
Outlet
N
0 1 2 3 4 5 km
© National Land Survey of Finland 7/MYY/03


The catchment area of
Lake Suuri-Vahvanen
Land Cover and Forest Classification:
Generalized classification
Water body
Open peatland
Agricultural area
Sparsely vegetated area in mineral soil
Sparsely vegetated area in organic soil
Densely populated area, buildings
Peatland forest, spruce dominated
Peatland forest, deciduous tree dominated
Peatland forest, mixed coniferous and deciduous
Peatland forest, pine dominated
Mineral forest land, pine dominated
Mineral forest land, spruce dominated
Mineral forest land, deciduous tree dominated
Mineral forest land, mixed coniferous and decicuous
Unclassified
Target lake
Catchment area of target lake
Outlet
N
0
0.5
1
© National Land Survey of Finland 7/MYY



The catchment area nearest to Lake Tiilikkajärvi
The catchment area of Lake Tiilikkajärvi
Land Cover and Forest Classification:
Generalized classification
Water body
Open peatland
Agricultural area
Sparsely vegetated area in mineral soil
Sparsely vegetated area in organic soil
Densely populated area, buildings
Peatland forest, spruce dominated
Peatland forest, deciduous tree dominated
Peatland forest, mixed coniferous and deciduous
Peatland forest, pine dominated
Mineral forest land, pine dominated
Mineral forest land, spruce dominated
Mineral forest land, deciduous tree dominated
Mineral forest land, mixed coniferous and decicuous
Unclassified
Target lake
Catchment area of target lake
Outlet
N
0 1 2 3 4 5 km
© National Land Survey of Finland 7/MYY/03

Kuvailulehti

Julkaisija	Suomen ympäristökeskus — Julkaisuaika: Marraskuu 2004
Tekijä(t)	Heinonen, P., Pietiläinen, O.-P., Airaksinen, O., Haapala, A., Hammar, T., Holopainen, A.-L., Hämäläinen, H., Issakainen, J., Kanninen, A., Karttunen, K., Leka, J., Lepistö, L., Luotonen, H., Manninen, P., Mononen, P., Mäkinen, H., Niinioja, R., Pilke, A., Rissanen, J., Sandman, O., Servomaa, K., Sojakka, P., Tolonen, K.T., Ustinov, A., Vallinkoski, V.-M., Valta-Hulkkonen, K., Vuoristo, H.
Julkaisun nimi	Monitoring and Assessment of the Ecological Status of Lakes – a pilot procedure developed and tested in the Life Vuoksi project (Järvien ekologisen tilan arviointi- ja seurantamenetelmän kehittely ja testaus Life Vuoksi -hankkeessa)
Julkaisun osat/ muut saman projektin tuottamat julkaisut	Julkaisu on saatavana myös internetistä: www.environment.fi/publications
Tiivistelmä	Tämä julkaisu on Vuoksen vesistöalueella toteutetun kolmivuotisen Life Vuoksi -hankkeen yksi osio. Julkaisussa esitellään järvien ekologisen tilan seuranta- ja arviointimenetelmä. Menetelmä pohjautuu Life Vuoksi -hankkeen muihin osioihin, joissa testattiin ja arvioitiin biologisten laatutekijöiden (kasviplankton, päällyslevät, vesikasvit ja pohjaeläimet) tutkimusmenetelmiä erityisesti rantavyöhykkeessä (litoraali). Seuranta- ja arviointimenetelmän testaukseen valitut kahdeksan järveä (kuormitettu ja kuormittamaton -parit) kattoivat hyvin Vuoksen vesistöalueen tärkeimmät luontaiset järvityypit. Hankkeessa kehitetty vaiheittain etenevä yhdeksänportainen seuranta- ja arviointimenetelmä sisältää sekä ranta-alueen että ulappa-alueen tärkeimmät hydrologis-morfologiset, fysikaalis-kemialliset ja biologiset tekijät. Menetelmässä huomioidaan myös valuma-alueen perusominaisuuksien (esim. geologia ja maankäyttö) ja meteorologian vaikutus sekä arvioidaan piste- ja hajakuormituksen suuruus ja vaihtelut. Menetelmän viimeissä vaiheessa arvioidaan järven ekologinen tila kaiken saatavilla olevan käyttökelpoisen tiedon perusteella. Menetelmä luo hyvän pohjan vesipolitiikan puitedirektiivin mukaiselle järvien ekologisen tilan arvioinnille. Menetelmän käyttökelpoisuutta heikentää eniten se, että Suomen järvien biologiset tiedot ovat usein riittämättömät. Järvien ekologisen tilan luotettava arviointi vaatiikin biologisten tekijöiden seurannan selkeää lisäämistä.
Asiasanat	Vesipolitiikan puitedirektiivi, luokittelu, ekologinen tila, vedenlaatu, järvi, seuranta, Vuoksen vesistö
Julkaisusarjan nimi ja numero	The Finnish Environment 719
Julkaisun teema	Ympäristönsuojelu
Projektihankkeen nimi ja projektinumero	LIFE VUOKSI: Rantavyöhykkeen merkitys seurantaohjelman osana ja paikalliset asukkaat ympäristönsä hoitajina. LIFE00 ENV/FIN/649
Rahoittaja/ toimeksiantaja	EU:n LifeYmpäristö -rahasto, Suomen ympäristökeskus, Etelä-Savon ympäristökeskus, Pohjois-Savon ympäristökeskus, Pohjois-Karjalan ympäristökeskus, Oulun yliopisto
Projektiryhmään kuuluvat organisaatiot	Suomen ympäristökeskus, Etelä-Savon ympäristökeskus, Pohjois-Savon ympäristökeskus, Pohjois-Karjalan ympäristökeskus, Oulun yliopisto
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Publikationens titel	Monitoring and Assessment of the Ecological Status of Lakes – a pilot procedure developed and tested in the Life Vuoksi project (Utveckling och testning av värderings- och övervakningsmetoder för sjöars ekologiska tillstånd i Life Vuoksi -projektet)
Publikationens delar/ andra publikationer inom samma projekt	Publikationen finns tillgänglig på internet: www.environment.fi/publications
Sammandrag	Denna publikation är en del av det treåriga Life Vuoksi -projektet, som förverkligades på Vuoksi flodområde. I publikationen förevisas en värderings- och övervakningsmetod för sjöars ekologiska tillstånd. Metoden grundar sig på Life Vuoksi -projektets andra delområden, var de biologiska kvalitetsfaktorernas (växtplankton, påväxt, makrofyter och bottenfauna) undersökningsmetoder testades och värderades, speciellt på strandbältet (litoral zon). De åtta sjöar som valts för testning av övervaknings- och värderingsmetoden (parvis belastad och icke-belastad), omfattade väl de viktigaste naturliga sjötyperna i Vuoksi flodområde. Övervaknings- och värderingsmetoden, som utvecklats inom projektet, framskrider etappvis i nio steg och innehåller de viktigaste hydrologis-morfologiska, fysikalisk-kemiska samt biologiska faktorer för både strandbältet och i öppet vatten. Metoden registrerar också avrinningsområdets grundegenskaper (t.ex. geologi och markanvändning) samt meteorologisk inverkan och kan värdera punkt- samt diffusbelastningens storlek och fluktuation. Under metodens sista steg värderas sjöns ekologiska tillstånd på basen av all tillgänglig, användbar information. Metoden lägger en bra grund för värdering av sjöars ekologiska tillstånd enligt ramdirektivet för vattenpolitik. Det som mest minskar metodens användbarhet är att det finns otillräckligt med biologisk information över finska sjöar. För att åstadkomma en tillförlitlig värdering av ekologiska tillståndet i sjöar behövs en klar ökning i övervakningen av biologiska faktorer.
Nyckelord	Ramdirektivet för vattenpolitik, klassificering, ekologiskt tillstånd, vattenkvalitet, sjö, övervakning, Vuoksi vattendrag
Publikationsserie och nummer	The Finnish Environment 719
Publikationens tema	Miljövård
Projektets namn och nummer	LIFE VUOKSI: Strandbältets betydelse som en del av övervakningsprogrammet och de lokala invånarna som miljövårdare. LIFE00 ENV/FIN/649
Finansiär/ uppdragsgivare	EU:s miljöfond Life, Finlands miljöcentral, Södra Savolax miljöcentral, Norra Savolax miljöcentral, Norra Karelens miljöcentral, Uleåborgs universitet
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Title of publication	Monitoring and Assessment of the Ecological Status of Lakes – a pilot procedure developed and tested in the Life Vuoksi project
Parts of publication/ other project publications	The publication is available in the internet: www.environment.fi/publications
Abstract	This document provides the results of one part of a three-year project called Life Vuoksi. The project studied and evaluated the usefulness and cost-effectiveness of different biological monitoring methods for the littoral zone of lakes in eastern Finland. The following biological quality elements were included in the study: aquatic macrophytes, benthic invertebrates, periphyton/sliming and phytoplankton. The monitoring and assessment procedure, presented in this document, is mainly based on the results of the above mentioned biological elements produced by the other parts of the Life Vuoksi project. Additionally, all other relevant environmental information was used in the elaboration of the new procedure. The monitoring and assessment procedure is a nine-phased step by step process to assess the ecological status of lakes. The procedure takes into account both the littoral zone and the pelagic area of lakes. The phases include various environmental issues/variables, such as geology of the drainage basin, metorological data, hydro-morphological data, physico-chemical data, and finally biological data. After going through eight phases covering all the above-mentioned variables and a good variety of others, the last ninth phase of the procedure is to draw up the final conclusion of the ecological status of a given lake, based on all available information. The monitoring and assessment procedure was considered as a good basic tool for the assessment of the ecological status of lakes. However, the lack of relevant data, especially on biological variables, reduced the applicability of the monitoring and assessment procedure. Currently, the assessment of ecological status of lakes is often composed of several logically successive expert judgements. In the future, the judgement will be mainly based on commonly accepted internationally comparable systems which will be based on the use of ecological quality ratios, according to the Water Framework Directive.
Keywords	Water framework directive, classification, ecological status, water quality, lake, monitoring, Vuoksi River Basin
Publication series and number	The Finnish Environment 719
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ENVIRONMENTAL PROTECTION

Monitoring and Assessment of the Ecological Status of Lakes

A pilot procedure developed and tested in the Life Vuoksi project

This document presents a procedure for monitoring and assessing the ecological status of lakes. The nine-phase procedure takes into account available data on both the shoreline area and the open water area to facilitate an integrated assessment of the ecological status of lakes. The assessment of the ecological status is an important issue in the implementation phase of the EU Water Framework Directive. It is also a long learning process that covers varying natural conditions and different countries in Europe.

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