The Lakepromo Project Information Package on Lake Management and Restoration Practices in Finland

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Foreword

This information package is part of the European Lakepromo project, which aims to promote co-operation and information exchange regarding water basin management and restoration projects. The project concentrates especially on the planning of lake management and restoration as well as the prevention and management of the effects of eutrophication. The partners of the project are from Finland, Denmark, Great Britain, Spain, Estonia, Germany, Hungary and Russia. Lakepromo - Tools for water management and restoration processes, is partly financed by the European Union (Interreg IIIC Programme). The project began in September 2004 and ends in September 2007. It is co-ordinated by the Savonia University of Applied Sciences (Savonia-ammattikorkeakoulu, Tekniikka) in Kuopio.

Experiences and know-how between the Lakepromo countries will be exchanged at management and restoration sites and in seminars arranged in each country in turn. Each partner country has chosen an actual management and restoration site the planning of which is mutually observed and supported during the project.

To promote co-operation and mutual learning, an information package is collected on the basis of a common outline from each partner country. The information package explains e.g. the legislation, methods and interested parties regarding lake management and restoration and illustrates implemented restoration projects. The common structure of the information packages hopefully aids the comparison of different measures and the finding of best practices and solutions. The expertise of each country is central in the information packages and thus the project makes it available to all the partners.

The Lakepromo partners pass the information packages on to the interest groups in their own municipalities, regions and countries:

- authorities and interested parties of restoration projects can get information on the execution of the Water Framework Directive

- universities, polytechnics as well as other education and research institutions can use the information package as educational material, for example

- the information package can give planners, consultants and contractors a general idea of restoration methods and operation models among other things

- local people and users of water resources can get information on operational procedures and participation regarding lake management and restoration

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A warm thank you to all who have taken part in the writing and editing of this information package!

8th May 2006, in Kuopio

Satu Tiilikainen

Glossary

Algal bloom	The mass occurrence of plankton algal population in a body of water.
Association for joint ownership	The body of administration and management regarding waters in joint ownership.
Biomass	The total mass of all or some specific living organisms in a given area or volume.
Bioturbation	The activity of fish and zoobenthos which causes internal loading by stirring up the sediment in a lake.
Buffering capacity	The ability to resist acidification.
Catchment	The area demarcated by the watershed from which water gathers into a certain place or body of water.
Catchment restoration	Measures taken in the catchment in order to reduce external loading.
Diffuse pollution	A load which is non point-specific, coming from surrounding agricultural and sparsely populated areas.
Diffusion	In diffusion molecules tend to move from an area of high concentration to an area of low concentration, e.g. phosphorus dissolves from the sediment into water.
Eutrophication	Intensification of primary production and biomass growth, e.g. the increased growth of aquatic vegetation with the increase of nutrients.
External loading	Load coming from outside the water body, e.g. waste water from the catchment or runoff from fields.
Food chain	A chain of species in which the previous is always the food of the following.
Forestry Centre	The Finnish Regional Forestry Network (Metsäkeskus) is owned by the State of Finland and is responsible for the official duties statutory in the Forest Act. It is also a source of expertise regarding forestry.
Ground water	Water stored in the pores, cavities and clefts of the rocks of the earth’s surface.
GTK	Geological Survey of Finland (Geologian Tutkimuskeskus) owned by the State of Finland.

Humus	Partially decayed organic substance. Rich humus content colours the water a yellowy brown.
Hydrology	The discipline, which studies the circulation, occurrence, movement and distribution of waters on earth.
Internal loading	Loading caused by phosphorus released from the sediment in anoxic conditions, when fish stir up the bottom sediment of a lake or when the wind mixes the mass of water deep down to the sediment.
Lake outlet	The opening of a lake where a river flows out, from which water is discharged.
Lake Protection Association	An organisation of local inhabitants or lake-side residents.
Limnology	The discipline, which primarily studies the physical, chemical and biological aspects of inland waters. It is concerned with the changes and phenomenon occurring in inland waters and their causal connections.
Methane	A combustible and odourless gas which develops when e.g. plants decay in anoxic conditions.
Minimum factor	The factor (amount of nutrients, micronutrients or light) of which lack is greatest and which restricts the production of biomass.
Minimum nutrient	The nutrient which restricts the production of biomass, usually nitrogen and/or phosphorus. Minimum nutrient loading causes eutrophication.
MMM	Ministry of Agriculture and Forestry (Maa- ja metsätalousministeriö).
Morphology	E.g. the structure and form of lakes.
MTT	Agrifood Research Finland (Maa- ja elintarviketalouden tutkimuskeskus). This research institute is owned by the State of Finland.
Natural washout rate	Substances (nutrients and solid substances) washed into a body of water without the effect of human activity.
Nutrients	Elements (except for oxygen, hydrogen and carbon) required in the building and metabolism of biomass.
Oxygen depletion	The removal of oxygen from a body of water or the hypolimnion. It can be caused by eutrophication or emission of pollution which uses up oxygen and can result in fish kill and accelerated eutrophication as phosphorus dissolves from the bottom sediment.

Party	The interested parties of a restoration project are e.g. the local inhabitants, planners, contractor and authorities.
Pelagic region	Open sea. Open water zone.
pH-value	An absolute value indicating the acidity of a solution. The pH-value of a neutral solution is 7 when the temperature is 25 °C.
Phytoplankton	Usually microscopic algae which floats freely in water.
Point load	Pollution, which comes for e.g. discharge points of industrial plants and communities. The discharge point can be specified.
Prioritization procedure	Prioritization procedure sets matters into an order of importance
Resuspension	The return of nutrients from the sediment into the water phase e.g. as a consequence of surging.
Retention period	Period of time taken for the whole amount of water to retain in a particular area or system.
River basin district	The area determined in the Act on Water Resources Management (1299/2004), which consists of one or more river basins. There are 7 river basin districts in Finland.
River basin management plan	The management plan for a river basin district presents e.g. the status of the water, measures taken in the area and an.
RKTL	Finnish Game and Fisheries Research Institute (Riista- ja kalatalouden tutkimuslaitos). A research institute which provides data about fish and game, and helps to maintain biodiversity through research and aquaculture. It is owned by the State of Finland.
Sediment	The layer formed by substances which have descended to the bottom of a water body.
Storm water	Water from rain and melting snow led into the water bodies from impermeable surfaces (e.g. asphalt). Storm water runoff forms mainly in population centres. It contains nutrients and pollutants.
Surface water	Area covered by water, coastal area or regional waters.
SYKE	Finnish Environment Institute **(**Suomen ympäristökeskus).
TM	Ministry of Labour (Työministeriö).
Water phase	A state of water. In this information package, it means the fluid form/state of water.

VSY	A local lake protection association. The association promotes the protection of water in the area (11 associations in Finland). It carries out e.g. monitoring of water body status and loading.
YM	Ministry of the Environment (Ympäristöministeriö).
Zoobenthos	Invertebrate animals living in the bottom of lakes and rivers. Most of them are larval stages of insects.

1 Background

(Satu Tiilikainen)

Finland's northern location has a considerable influence on the life of people and wildlife. The alternation of four distinct seasons is a typical feature of the environment. Winters are cold and summers warm. The climate has features of both maritime and continental climates. For the most part, Finland belongs to the coniferous forest zone. Finland's climate is significantly different from the climate elsewhere in Europe. (Ilmatieteenlaitos 2005.)

About 10 % of the total area of Finland is water. Finland has approximately 188 000 lakes with an area exceeding 0.05 ha (485.6 m²); the total area covered by lakes is 33 700 km^2. Therefore, Finland is often called the land of thousands of lakes. Most lakes are situated in central Finland in an area called Järvi-Suomi (Raatikainen & Kuusisto 1990; Niemi *et al.* 2004). Typically, Finnish lakes are small in size and volume, and they are naturally shallow (the mean depth being 7.2 metres). They also have lots of islands and a complex outline. (Eloranta 1997, 2005.) Further, they are typically linked together and have a high humus concentration. Table 1 presents the size distribution of Finland's lakes.

Table 1. Area of lakes in Finland (Raatikainen & Kuusisto 1990).

Area (km²)	Size of Lake	Number of Lakes
< 0,01	Very small lakes	131 876
0,01-0,1	Small lakes	40 309
0,1-1	Quite small lakes	13 114
1-10	Middle-sized lakes	2 263
10-100	Quite large lakes	279
100-1000	Large lakes	44
>1000	Very large lakes	3
Total		187 888

See below pictures of two summer scenes from two different types of lake (a eutrophic and an oligotrophic) as well as a winter view from a lakeside.

The majority of Finland's water bodies are in joint ownership. The partners have ownership and the right to speak on matters concerning lake management. However, water bodies are also owned by the State of Finland, municipalities, parishes and private owners. Like in other Nordic countries, Finland's concept of everyman's right gives everyone the right to enjoy the countryside without charge irrespective of who owns the area. Where lakes and rivers are concerned, the right of common use is usually the term used. It includes the right to use the water bodies for travelling, anchoring and swimming. Angling and ice fishing are also public rights free of charge unless fishing is prohibited for protective reasons in the area (Salminen&Böhling 2002; Ympäristöhallinto 2005).

Human activity affects the status of water bodies. Throughout the centuries, the water environment has been used for various purposes. To begin with, water bodies were used for travelling and fishing. Later, they were harnessed to produce energy and provide raw water for waterworks (Kuusisto, 2004). Presently, the recreational use of lakes has grown with the strengthening of the cottage culture in Finland; there are at about 0.5 million summer-cottages in the country. Finns are interested in the lake environment where their own cottage exists (Lehtoranta, 2005). Lately, public interest in lake restoration has grown. This is due to better availability of information on restoration (Keto *et al.* 2004).

The Finnish Environmental Institute and Regional Environment Centres continuously observe the status of lakes, rivers and coastal waters. It has been monitored systematically since the 1960s, and the quality of water has been monitored since the 1970s. In the classification determined by the Environmental Administration in Finland, waters are divided into five categories (excellent, good, satisfactory, passable and poor) on the basis of various qualities of the water. In the follow-up period of 2002-2003, 82 % of all lakes with an area bigger than 1 km^2 were studied. Water quality in 80 % of lakes surveyed was good or excellent (Ympäristöhallinto 2005a).

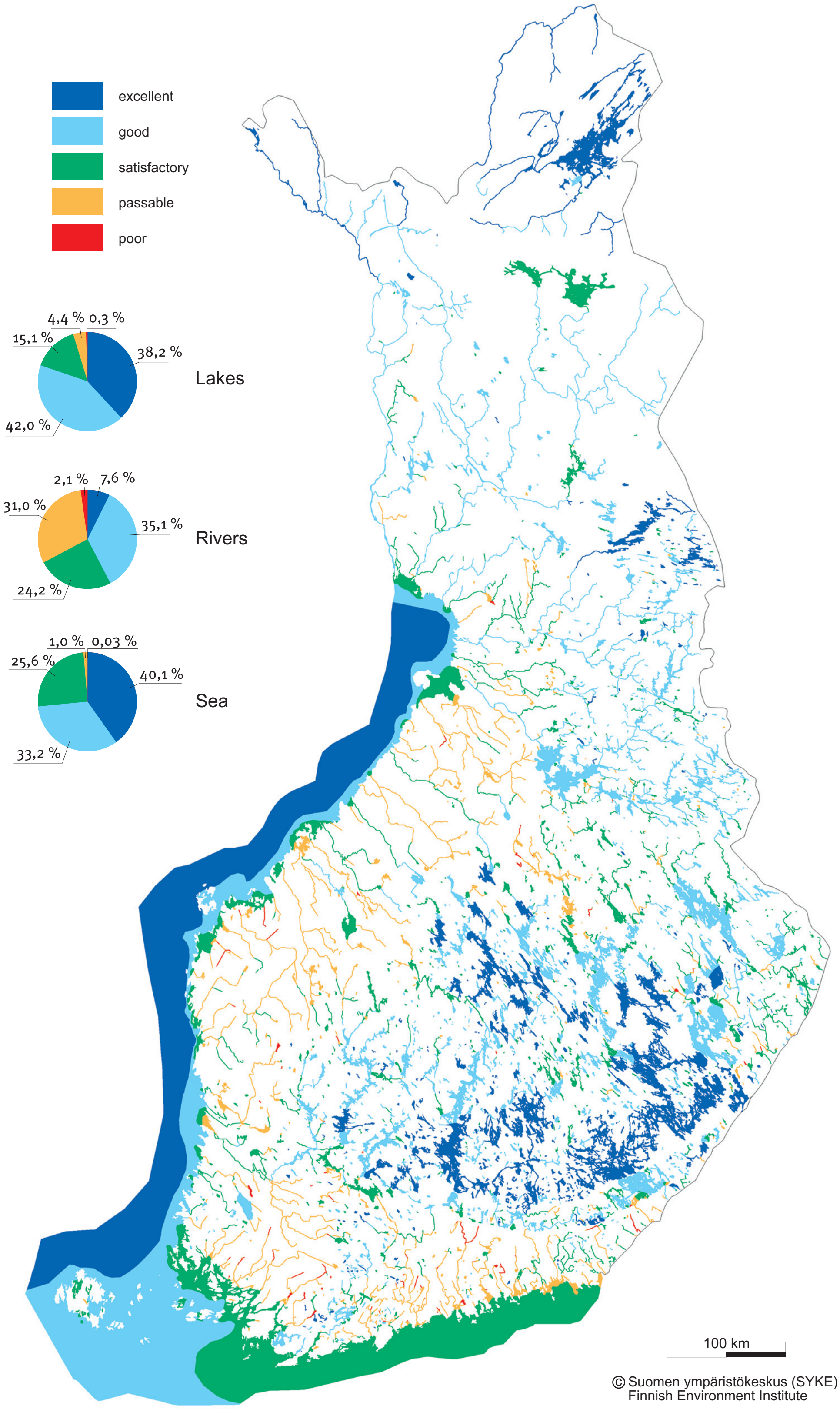


Figure 1. The quality of the surface waters in Finland in 2000-2003 (Ympäristöhallinto 2005b).

1.1 Features of eutrophic lakes in Finland

Lakes in Finland, as in northern areas elsewhere, are sensitive to the pernicious effects of human activity. Sensitivity is caused by facts like the low buffering capacity, naturally low nutrient content, small volume and shallowness of lakes. Also the ice-covering during winter adds to the sensitivity towards changes. (Niemi *et al*. 2004.)

In the general water quality grading, the Environmental Administration in Finland has defined the limiting values for chlorophyll-a and total phosphorus when determining the trophic status. Nowadays trophic status is determined on the basis of chemical (phosphorus and nitrogen) and biological (chlorophyll-a or phytoplankton biomass) variables. In practice, however, the phosphorus content is the decisive factor. Inland lakes are restricted in phosphorus and the phosphorus content usually determines the trophic status of the lake, but sometimes a big phosphorus load can cause restriction in nitrogen. (Eloranta 2005.) Other trophic status classifications also exist. Their limiting values for the different stages of trophic status vary. See Table 2 for the limiting values set by the Environmental Administration in Finland for the overall phosphorus and chlorophyll-a.

Table 2. The limiting values for assessing eutrophication determined by the Finnish Environmental Administration in the Usability Classification of Water Bodies (Ympäristöhallinto 2005c).

Usability Classification / Eutrophication Indicator	Excellent	Good	Satisfactory	Passable	Poor
Chlorophyll-*a* (µg/l) (lakes)	< 4	<10	<20	20-50	> 50
Chlorophyll-*a* (µg/l) (sea)	< 2	2-4	4-12	12-30	> 30
Total phosphorus (µg/l) (lakes)	< 12	< 30	< 50	50-100	> 100
Total phosphorus (µg/l) (sea)	< 12	13-20	20-40	40-80	> 80

Typically, lakes in Finland have indented shores and a large amount of islands. This prevents water from changing and can therefore cause problems locally. Small capacity, shallowness and long lag weaken the natural ability of lakes to cope with load. Headwater lakes are most sensitive towards changes. (Eloranta 1997, 2005)

The long winter in Finland puts the ecosystem of a lake to a test. Lakes in Finland have an ice covering on average for 5-7 months which has its effects on the life and state of lakes. The layer of ice prevents gas exchange which can cause oxygen depletion. The maximum thickness of the ice layer is on average 50-90 centimetres. (Korhonen 2005.)

1.2 The development of the status of lakes

Lakes are naturally in a state of slow change, but it is accelerated by human activity. Usually the change is towards a more eutrophic stage. Restoration aims at slowing down the natural change of lakes or even bringing the lake as close as possible to its natural state. (Lehtoranta 2005.)

The loading caused by human activity became notable when new areas were cleared and drained for agricultural use in the eighteenth century (Mattila 2005). The water level of lakes was lowered from the eighteenth century till the 1950s. The water level of some 3000 lakes has been lowered or the lake has been dried up completely during that period (Lakso 2005). The development of agriculture has been rapid since the 1950s. Tractors replaced horses in farm work and cultivation techniques became more intensive. Trenching was done more effectively and fields were fertilized abundantly. (Markkola 2004.) These actions caused nutrients to wash into bodies of water. In addition to this, the character of the load changed over the years due to stock husbandry. At the end of the nineteenth century, the focus of agriculture changed from growing cereal to stock rearing (Peltonen 2004). Nowadays, cattle farms have specialized to certain products, the sizes of the farms have grown and there are fewer farms (Mattila 2005).

The discharges of industry which loaded water bodies increased notably in the 1950s. Industry grew and population centres grew around the industrial plants. Waste water load grew. The sewage treatment techniques began to become more efficient in the 1970s, and today, sewage treatment is very efficient. The load caused by waste water has decreased so that the waters downstream have begun to recover. (Mattila 2005.)

The load caused by forestry increased with the trenching of forests in the 1960s, and since the 1970s, forests were fertilized abundantly. In the 1980s, however, the use of fertilizer was reduced. The reason for more effective forestry lay in industry's need for raw material. (Marttila 2005.)

Twenty percent of Finns, that is about 1 million persons, live in areas that are out of reach of the water supply and sewerage network services. In Finland, there are 30 000 - 50 000 free-time dwellings equipped with modern appliances. The decree of the Council of State which came into force in 2004, aims to decrease the load on waters from sparsely populated areas. (Ympäristöministeriö 2003.)

During the last 20 years, population centres have grown rapidly. Meanwhile, storm water runoff into water bodies has increased as well (Kesäniemi 2004). Nowadays, 80 % of Finns live in population centres. The building of urban areas has changed the water circulation and caused hydrological problems. Storm waters contain nutrients and pollutants which generally feed bodies of water through storm water sewers. The effect of storm water runoff is seen particularly in bodies of water near small population centres. The importance of storm water treatment has been recognised only during the last few years. (Jormola *et al.* 2003.)

Fish farming began in Finland in the 1950s. In the mid 1960s, it developed into a commercial business. The production of fish farming was at its greatest in the 1990s and has now begun to decline. In 2002, there were 585 fish farms in Finland. Of them 70 % were in inland areas. (Suomen kalankasvatusliitto ry. 2005.) The load caused by fish farming has dropped to half of the amounts detected in 1980 (Ympäristöministeriö 2004).

Fur farming is also an industry that affects bodies of water. Nationally, the load caused by fur farming is only small, but locally it can cause significant loading. Modern fur farming began in Finland at the beginning of the 20th century. 90 % of Finland's 1600 fur farms are situated in Western Finland. (STKL 2005.)

The sources of nutrient loading are presented in Table 3 and their distribution in Figure 2.

Table 3. Total loading in Finland's water bodies in 2003 (Ympäristöhallinto 2005d).

Source of Loading	Phosphorus t/y	Nitrogen t/y
Agriculture	2600	39500
Separately populated areas	355	2500
Forestry	350	4100
Atmospheric deposition	280	13000
Industry	230	3558
Community	224	12347
Fish farming	80	646
Fur farming	45	430
Peat production	45	1000
Total loading	**4209**	**77081**
Natural runoff	**2700**	**70000**

*Table 3 includes the load led into the lakes as well as the sea. The figures for atmospheric deposition and natural runoff have been determined by the Environmental Administration in Finland.

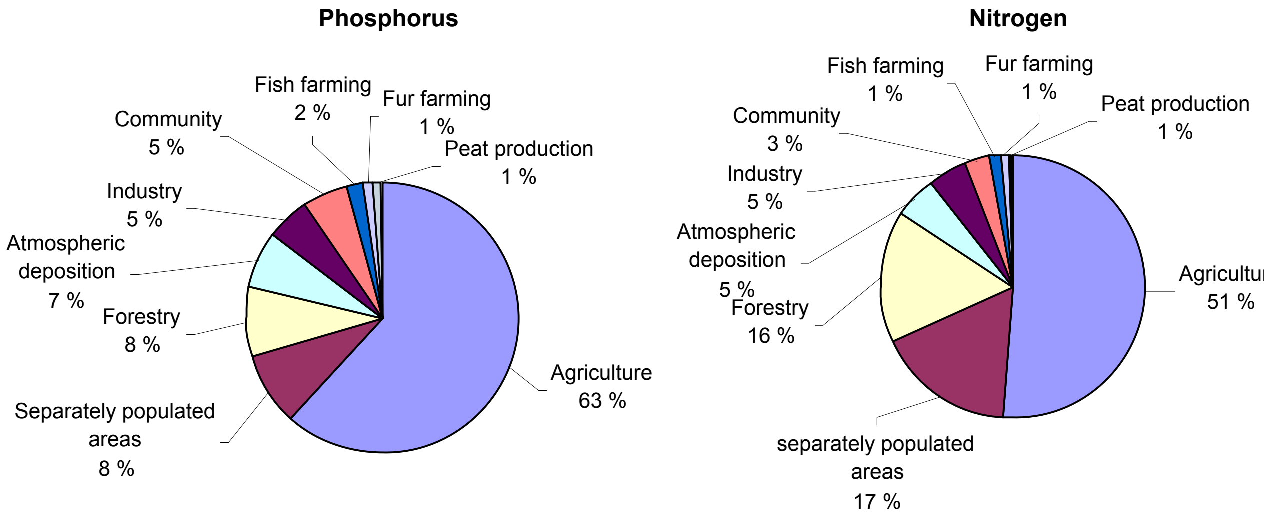


Figure 2. The proportional division of sources of phosphorus and nitrogen in Finland in 2003. The figure shows only the load caused by human activity. Storm waters are included in the load values (Ympäristöhallinto 2005d).

In addition to the external sources of loading, eutrophication is caused also by the internal nutrient load. Even though the external load diminishes or finishes, the eutrophication of a lake can continue due to internal load. The nutrients settled at the bottom of the lake can return to the water phase by means of diffusion, mixing waters or bioturbation. (Eloranta 2005.)

The eutrophication of lakes has accelerated because of excessive (external or internal) nutrient load. Due to eutrophication e.g. the recreational utility value (fishing, swimming and boating) can lessen. The scenic value erodes as well when e.g. vegetation multiplies a lot. Table 4 presents the most common consequences of eutrophication.

Table 4. Effects of eutrophication (Äystö 1997).

Consequences of Eutrophication
Increase of algal blooms
Dominance of cyprinids in fish population
Oxygen depletion
Increase of macrophyte/aquatic vegetation and changes in the species
Diminishing of transparency of water
Darkening of colour of water
Strengthening of odour of water

1.3 History of lake restoration and present state in Finland

Systematic lake restoration in Finland began in the 1960s. However, the Mäyhäjärvi Lake was aerated as early as the 1950s to prevent fish deaths. In the 1960s and 70s the most common restoration measures were oxidation and raising water level. In those years, dredging and leading out the hypolimnion were also tried. Restoration of the food chain was tried only later at the end of the 1980s (Case Vesijärvi, see Chapter 6.3.1). (Lehtoranta 2005)

In the years 1970-1995, 553 restoration projects were implemented, and in 1998-2002 the corresponding figure was 223 (Lehtinen et al 2002). In 1970-1995 the main restoration methods were oxidation, removal of hydrophytes and the raising of water level. The focus of restoration has slightly changed during the recent years, and now the most common methods are removal of hydrophytes, dredging and the restoration of the food chain (see Figure 3). (Keto et al. 2004.) By 2002, approximately 800 lakes had undergone restoration (Lehtoranta 2005).

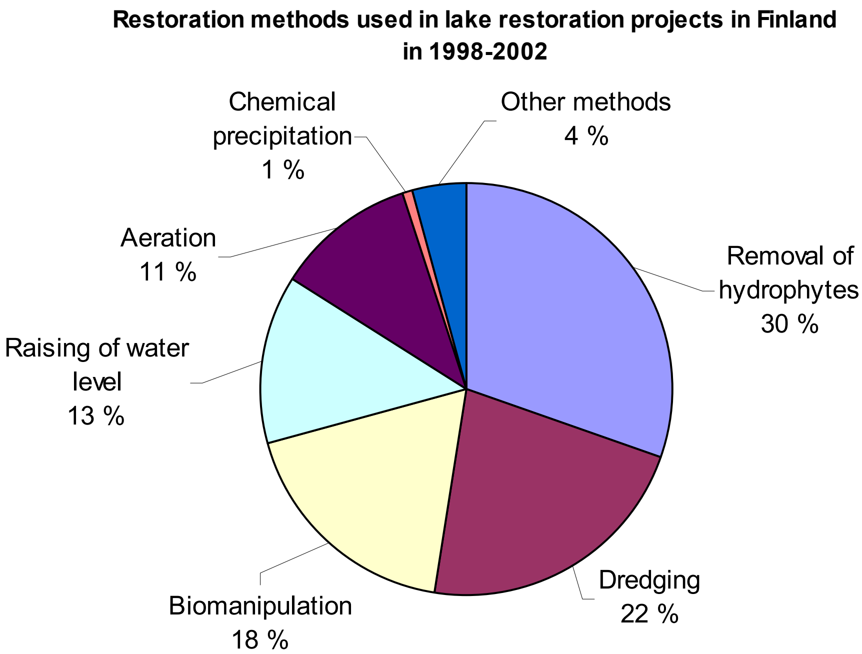


Figure 3. Restoration methods used in the years 1998-2002 (Lehtinen *et al.* 2002).

In Finland, 45 new restoration projects are registered annually. The Regional Environmental Centres and the Employment and Economic Development Centres receive every year a total of about 350 written and 900 oral initiatives concerning restoration. (Turunen & Äystö 2000.)

According to the restoration needs survey done in 1999, there are about 1500 lakes which should be restored. The problems of 1329 lakes have been identified. Eutrophication is the problem in 945 lakes. Most of the lakes which are in need of restoration have an area of 0.1-10 km^2 and the total area of all these lakes is estimated to 6 700 km^2. There are an estimate of 37 000 lodgings and 240 swimming areas on the shores of these lakes. The total restoration expenses would be about 228.7 million euros. Presently, the funding and planning capacity of restoration procedures does not correspond to the initiatives brought up annually. The Ministry of Environment and the Ministry of Agriculture and Forestry allocate 4.32 million euros per year to restoration of water bodies, while the need would be 13.6 million euros per year in 1999-2009. (The state subsidy for restoration projects has been taken into account; it is 50 % at the most.). (Turunen & Äystö 2000.) The Regional Environmental Centres use prioritisation procedures for annually selecting the lakes to which restoration plans are made. The unification of the prioritisation procedures in Finland is in progress.

1.4 Present-day methods for lake restoration and management

Restoration consists of improvement measures in the lake as well as preventive and/or improvement measures in the catchment (Seppänen 1973; Keto *et. al.* 2004). In normal language use, restoration and management concerning lakes have meant almost the same thing. Lake management means actions taken to maintain the good condition of a lake. Management is also needed to maintain improved restoration results. Lake management measures are, therefore, used to prevent the lake from declining to the state where it was prior to restoration (see Figure 4). (Ympäristöhallinto 2005e.)

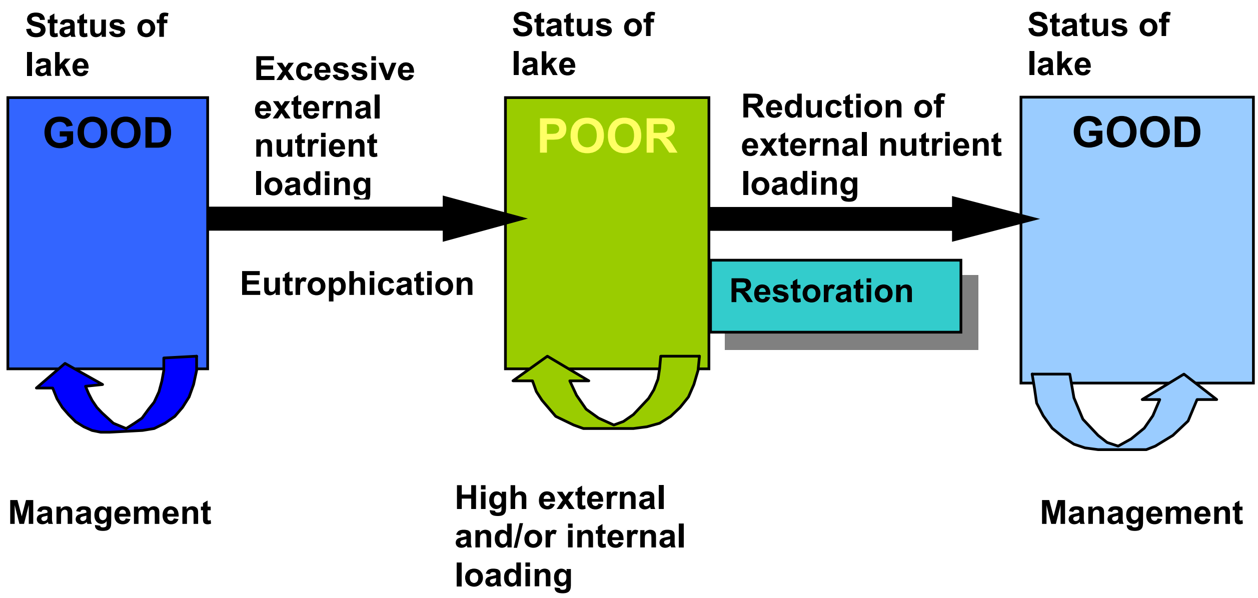


Figure 4. Restoration and management of lakes (adaptation, Sammalkorpi & Horppila 2005).

The restoration method(s) for a lake are chosen during the planning phase of a restoration project. The restoration plan is discussed in more detail in Chapter 5. The best results are usually attained by a combination of various restoration methods, which decrease external and internal loading. Specialists choose appropriate restoration methods on the basis of the characteristics and problems of the lake, the set objectives and the existing resources. The use of most restoration methods requires the approval or permission of the owner of the waters. For larger projects a permit from an authority is usually needed. (Väisänen & Lakso 2005.) Table 5 presents the restoration methods used today.

Table 5. Lake restoration methods used since 1950 (Airaksinen 2004; Keto *et al.* 2004; Lappalainen 2005).

Objective	Method	Number of restoration sites	Costs	Efficiency	Repetitions needed during the next 10 years
Eutrophication control	Aeration	200	40-200 €/ ha y	Proven efficiency	3-10
	Biomanipulation	100	33-750 €/ ha y	Proven efficiency	2-4
	Chemical precipitation of phosphorus	20	50-170 €/ ha	Short term effect	3
	Hypolimnetic water withdrawal	10	Depends on the restoration site	Not adequate alone	
Multiple benefit lake treatment	Removal of hydrophytes	210	85-500 € / ha (harvesting)	Clear immediate effects	1-3
	Raising water level	170	8500-50000 €	Effects clear and long-lasting	1
	Dredging	110	6700-20200 €/ha	Effects clear and long-lasting	1

Aeration aims at increasing the oxygen content of a mass of water by dissolving oxygen into the water or by leading oxygenous water into the water with reduced oxygen concentration. Some of the main methods used in Finland are: aeration of hypolimnion by adding oxygen into the water, mixing the epilimnion into the hypolimnion, horizontal circulation of water, destratification or the prevention of stratification by leading small air bubbles into the water.

Pros and cons: The method ensures oxygen for organisms and reduces release of phosphorus from the sediment, but the treatment usually must be renewed every year which causes continuous expenses. (Lappalainen 2005; Väisänen & Lakso 2005.)

Biomanipulation aims at improving the water quality by mass removal of fish populations with a dominance of cyprinids followed by management fishing which aims at preventing the condition of the lake from declining. In addition to the removal of fishes, the population of predatory fish is strengthened by fish stocking.

Pros and cons: Decreases internal loading and can be done partly as voluntary work, but the job is laborious, time consuming and must often be renewed. (Sammalkorpi & Horppila 2005; Väisänen & Lakso 2005.)

Chemical precipitation of phosphorus is a restoration method, wherein the soluble phosphorus in a mass of water is bound by iron or aluminium compounds to the sediment.

Pros and cons: The method is easy to carry out and the results are seen immediately, but it has only a short term effect (about 3 years). Chemical over-dosage can cause fish deaths. (Keto *et al*. 2004, Oravainen 2005.)

Dredging aims at increasing the depth of water and the usability of shores by removing decaying matter or reducing nutrient return from the sediment to the water phase (resuspension). Dredging is done as excavation work from the shore, a working raft or the ice. Suction dredging is also possible. Usually less than one metre of sediment is removed.

Pros and cons: Reduces internal loading and increases depth of water, but the expenses are high. (Viinikkala *et al.* 2005; Väisänen & Lakso 2005.)

Removal of hydrophytes aims predominantly at improving the recreational use of lakes and their scenic value. Vegetation can be reduced using mechanical, physical, chemical and biological methods. In Finland, the greater part of the removal of aquatic vegetation is done mechanically (harvesting and seine-netting).

Pros and cons: Can be done as voluntary work and the results are seen immediately, but the procedure is laborious, time-consuming and it must be repeated many times. Abundant removal of aquatic vegetation can cause mass-occurrences of blue-green algae. (Kääriäinen & Rajala 2005; Väisänen & Lakso 2005.)

Raising water level aims at preventing the vegetal invasion of the lake. It also promotes the recreational use of the lake and improves the lakeside scenery. Raising water level is an inexpensive restoration method, if the lake has previously undergone the procedure of lowering water level. The water level of a lake is raised usually by building a dam at the outlet of the lake.

Pros and cons: Raising water level improves the lake scenery, raises the value of lakeside properties and improves swimming, fishing and boating conditions. Raising water level causes waterlogging which is compensated financially to the lakeside inhabitants. (Lakso 2005.) The method of raising water level is often difficult to carry out because it requires unanimity towards the restoration measures from the owners of the lakeside properties.

Hypolimnetic water withdrawal aims at replacing the hypolimnion enriched with nutrients and low in oxygen with more oxygen-rich water from the epilimnion above. The hypolimnion is led to a body of water downstream by means of gravitation or pumping. The removal of hypolimnion lends itself well to lakes with temperature stratification.

Pros and cons: Low using expenses, if gravitation is used. Usually the method is not an adequate measure of restoration on its own. (Ulvi 2005; Väisänen & Lakso 2005.)

The effect of the measure is more permanent, if external loading from the catchment is reduced to a level which the lake tolerates. Table 6 presents means of diminishing external loading.

Table 6. Ways of diminishing external loading (Savolainen *et al*. 1996; Kesäniemi 2004; Pakkanen 2003; Hiltunen 2005; Mattila 2005; Saariston tietopankki 2005; SKTL 2005).

Source of loading	Ways of decreasing loading in the extraction area	Ways of decreasing loading outside the extraction area
Agriculture	- Cultivation techniques (green fallow, precise farming, direct drilling as a sowing method, winter cereals, sowing across tillage direction, minimum tillage) - Buffer zones - Intensified use of manure	- Wetlands - Sedimentation ponds - Chemical treatment
Sparsely-populated rural areas	- Separating grey and black waters (dry closets) - Phosphate-free detergents - Development plans for water supply and sewage (extension of the waste water network)	- Buried sand filter or absorption into soil - Small sewage treatment plants
Forestry	- Planning of logging - Planning of tilling - Buffer zones	- Breaks in the digging and clearing of ditches - Sludge pits - Sedimentation ponds - Overland flow fields
Storm runoff	- Reducing the amount of impervious surfaces - Absorption into soil	- Absorption ponds and hollows - Wetlands - Sedimentation ponds
Peat production	- Planning the drainage of peatland and peat production on the grounds of sufficient field investigations	- Headland pipes and barriers for field ditches - Sedimentation ponds - Overland flow fields - Chemical treatment - Controlling run-off peaks - Filtering through soil
Fish farming	- Improving the qualities of fish feed - More efficient feeding/feeding methods	- Bag pens and sludge funnels (on trial) - Microsieving and filtration
Fur farming	- Collecting faeces and urine away - Keeping the production area dry	- Chemical treatment

The industrial and community waste water load has decreased substantially and is, therefore, not mentioned in the table above. Likewise, Table 6 does not mention deposition as a means of reducing external loading.

Agriculture receives subsidies for reducing external loading according to the special measure under the agri-environmental support scheme. It is also possible to receive financial support for water pollution control regarding forestry and sewage systems in sparsely-populated areas. (Mattila 2005.)

2 Administrative organisation and legislation

(Tomi Puustinen, Eila Pulkkinen, Veli-Matti Vallinkoski)

2.1 The administrative organisation of lake restoration in Finland

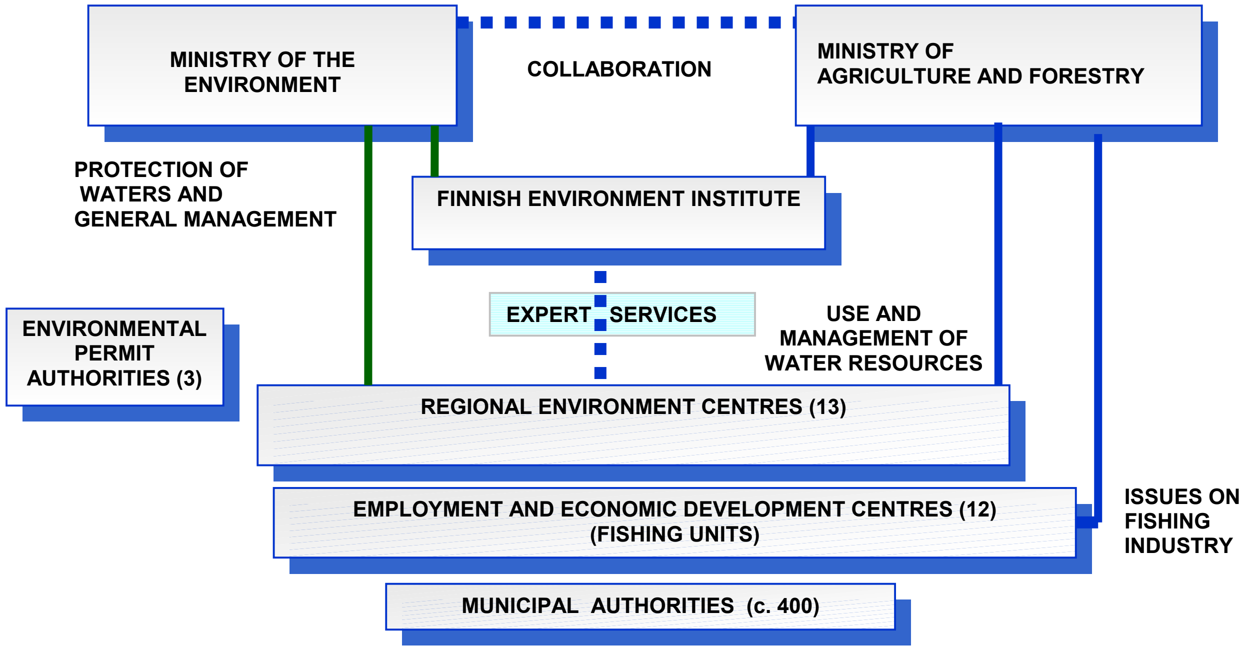


Figure 5. The administrative organisation of lake restoration (Maunula 25.11.2004).

Ministry of the Environment promotes sustainable development. The Ministry is responsible for environmental policies, strategic planning and management as well as international co-operation in its area of interest. It also prepares the legislation and draws up its own budget. It directs funds to the planning and implementation of restoration projects. (Ympäristöhallinto 2005f.)

Ministry of Agriculture and Forestry directs the Regional Environment Centres in the use and maintenance of water resources mainly by means of a performance agreement. The Ministry annually enters into an Agreement of Perfomance Guidance with each of the Regional Environment Centres and grants funds for the implementation of its objectives. (MMM 2005.)

The Finnish Environment Institute is a centre for environmental research and development. It provides information on the environment, environmental trends and factors behind these trends. The Finnish Environment Institute also assesses alternative trends and developing solutions which can be used to influence future development. The Finnish Environment Institute functions as a national information centre, which collects, processes and provides environmental data for the use of various interest groups. It also takes care of the various reporting obligations related to EU environmental legislation and other international agreements. In addition to this, the Finnish Environmental Institute takes care of some duties of authorities. (Ympäristöhallinto 2005f.)

Regional Environment Centres promote environmental protection and function as an environmental supervisory and licensing authority. The regional environmental centres issue environmental permits for activities with significant environmental impacts, grant subsidies, compile and disseminate environmental information and carry out management and restoration work related to the environment, including waterways and water supply. The regional environmental centres work in close co-operation with municipalities, other local administrative authorities, provincial federations as well as the residents and enterprises in the area. The environmental centres also attend to harmful effects caused by the maintenance and repair of older waterways and hydraulic engineering structures. (Ympäristöhallinto-esite.)

Fishing Units of Employment and Economic Development Centres take care of interests of fishing industry in issues concerning water rights legislation in the area, commercial fishing registers and promotion funds, restoration of fishing waters, developing recreational fishing, and management of fish stocks. (TE-keskus 2005.)

Environmental Permit Authorities decide on environmental permits for activities which have the most important major environmental impact and which take place under the Water Act or which have been initiated or promoted by a regional environment centre. (Ympäristöhallinto 2005f.)

Municipalities have different statutory tasks in the field of environmental protection. Legislation regulating the administration of environmental protection requires municipalities to monitor, promote and follow up the state of the environment. Some environmental permits are also granted by the municipality. These tasks are usually looked after by environmental boards which are appointed on political basis.

2.2 The main national legislation

The legislation concerning hydraulic engineering has been reviewed by Kuusiniemi *et al*. 2001 and Majuri 2005 among others. These sources have been used in the following.

In Finland, there is no special legislation concerning restoration of lakes. Restoration is governed mainly by the Water Act, Environmental Protection Act, Nature Conservation Act as well as Land Use and Building Act. The Water Act is presently being reformed, and the reform may bring some changes into the legislation related to restoration of water bodies as well. The Act on Water Resources Management (unofficial translation) which executes the EU Framework Directive in the field of water policy came into force at the turn of 2005. It will most likely have an effect on restoration projects in the future.

On the basis of the Water Act or the Environmental Protection Act, all major restoration projects usually require a permit. The need for the permit depends first and foremost on what harmful effects the project causes. According to the Water Act, a permit is needed, if the project causes harm for public or private interest. The harm can be towards the property of others, the functioning of the water environment, the aesthetic character of nature, the attractiveness of surroundings or the use of a public waterway. A permit is needed also, if the project causes a threat to the habitat types included in the Water Act (coastal lagoons, small water channels and springs). According to the Environmental Protection Act, a permit is needed, if the project can cause pollution (or contamination) of the water systems.

When deciding on permits or implementing restoration projects, the statutes of the Nature Conservation Act and the Antiquities Act must always be taken into consideration. The Nature Conservation Act takes effect also in projects within the Natura 2000 Network or the nearby areas. The effects of restoration projects on the nature values must be identified. If the project is likely to weaken the nature values because of which the site has been taken into the Network, the implementer of the project must make an assessment of the effects. The environmental effects of big projects may also have to be assessed on the basis of the Environmental Impact Assessment Act. The list of projects which according to the Environmental Impact Decree must be systematically assessed does not include water management sites. However, if the project may have a major negative impact on the environment, the discretionary assessment can be applied.

The Land Use and Building Act can affect restoration projects especially in urban areas, where the town and master plans must be taken into account when considering the preconditions of project implementation. If the restoration area has a building restriction, the implementation of the project may require a permit on the basis of the Act.

In Finland, the EU Directives regarding water management have been executed by special legislation or by including them in the existing legislation. The Integrated Pollution Prevention and Control Directive has been included in the Environmental Protection Act which came into force in 2000. The Environmental Impact Assessment Directive has also been executed with special legislation. On the other hand, Habitats and Birds Directives have been included in the Nature Conservation Act. The Act on Arranging Water Resources Management (unofficial translation) has been enacted in order to execute the Water Framework Directive. This Directive is considered in more detail in Chapter 2.3.

2.3 The present state of the Water Framework Directive in Finland

The central contents of the Framework Directive in the field of water policy

The objective of the Framework Directive in the field of water policy which entered into force in 2000 (Directive 2000/60/EC of the European Parliament and of the Council, hereafter the 'Water Framework Directive') is to secure sustainable use and management of the water environment as well as to standardise the assessment, monitoring and management planning of water bodies. The directive sets clear environmental objectives for water management in the member states. The general aim of water management organisation is to protect, improve and restore water basins so that the quality of surface and ground waters will not weaken and that the status would be at least good. Concerning surface waters, the aim is that the ecological status of water bodies could be graded good by the year 2015. Water bodies with a heavily modified hydrology and structure should aim at achieving a so called good ecological potential. According to the directive, the status classification evaluation and monitoring criteria should use variables reflecting the species composition and abundance of the central biological – phytoplankton, aquatic vegetation, zoobenthos and fish fauna. In addition, variables illustrating the physico-chemical and hydromorphological conditions must be monitored to support the biological factors mentioned above.

In Finland, the classification of surface water status has mainly been determined on the basis of physico-chemical qualities of the water and the criterion have been based on the usability of water for the needs of humans, such as abstraction of water for human consumption, recreational use and fishing. The classification has not taken into consideration the natural characteristics of the lake. Instead, all lakes have been assessed with uniform criteria. According to the Water Framework Directive, the assessment of the ecological state of water bodies must take into account the characteristics of the lakes. Lakes are to be categorized into types according to their natural characteristics. The status of a lake is determined by comparing the biotic community composition of the lake to that of a lake of the same type in natural state. If needed, the point of comparison can be created by modelling or evaluated by an expert.

The typology and classification of lakes in Finland

In Finland, the preparations for the execution of the Water Framework Directive began in 1999 when the Ministry of Environment set up a group of experts in order to develop a classification for an ecological status evaluation of water bodies. Experts from the Regional Environmental Centres and the Finnish Game and Fisheries Research Institute took part in the work which was co-ordinated by the Finnish Environment Institute. In addition, experts from various universities and research institutes have participated in the implementation of the directive.

The first proposal concerning the typology of surface waters in Finland was completed in March 2002 (Pilke et al. 2002). The typology proposal was based on the B System of Annex II of the Water Framework Directive, and the compulsory typology factors used were geographical location, geology of the catchment and surface area of the lake. The lakes of Southern Finland were divided into groups according to size and humus content.

Beside this, lakes that are naturally rich in nutrients and those rich in calcium were divided into separate groups. The mean depth was used as an additional factor in the classification because it has a central significance in the thermal stratification of lakes and at the same time in the entire function of the ecological systems of the water.

In Finland, knowledge of the natural alternation of biological quality factors with relation to the typology factors mentioned above has been insufficient. For this reason, the typology proposal was tested in several different projects (e.g. Tammi et al. 2001, 2002, Lepistö 2004, Tolonen 2005). On the basis of these tests, the general outline of the typology proposal of 2002 was found to be well-designed, and the changes suggested in the reviewed typology, which was completed at the end of 2004, were relatively minor. The main change was the separation of lakes with a short retention time (so-called chain of lakes) into a type of their own, and joining all dark-watered humus lakes into the same type irrespective of size. Further, the naturally eutrophic and calciferous lakes were combined to form one type. After these changes, the number of lake types reduced to twelve.

The Finnish Environment Institute co-ordinated the classification projects and has taken part in the intercalibration work among the Member States. Selecting the measurable variables, defining the reference conditions and setting the class boundaries concerning the biological quality factors have been central questions in the development of the classification system. The directions for the typology of Finland’s surface waters and the grounds for ecological classification will be completed in the near future (manuscript, Vuori et al. 19.5. 2005).

Changes needed in the monitoring of water body status

According to the Framework Directive in the field of water policy basic monitoring should monitor all four biological quality elements. Traditionally, the Finnish monitoring system for water bodies has been based mainly on monitoring physico-chemical conditions. In some of the water bodies in more precise monitoring, however, the status of the water body has been monitored for a relatively long time also on the basis of aquatic organisms; e.g. the zoobenthos has been a parameter which has been generally used in obligatory monitoring to measure the state of the ecosystem. We have also used some indicator species of phytoplankton as well as various eutrophication gradings for a relatively long period of time. On the other hand, the systematic monitoring of aquatic vegetation has been minor, and the use of fish as an indicator of the ecological status of the water body has concentrated on running waters. These studies have concentrated on finding out the environmental requirements of salmonoids.

As a whole, the Finnish monitoring system for the status of water bodies has been comparatively extensive even prior to the implementation of the Framework Directive in the field of water policy. In the future, the biggest challenge and change will be the development of monitoring methods and standards for the biological indicators, and increasing the amount of biological monitoring to the amount required by the directive.

Presently, we are going through the analysis of the characteristics of the water bodies in the river basin districts and the formulating of monitoring programmes. The collected data and plans will be annexed to the river basin management plan which will be finished in 2009. If needed, defining operational programmes will be written out in order to achieve the set environmental objectives.

The changes in the national legislation

The reforms required by the Framework Directive in the field of water policy came into force in Finland's national legislation at the turn of year 2005 along with a new act and a decree to supplement it (Act on Arranging Water Resources Management and Decree on River Basin Districts (both unofficial translations)). In addition to the objectives for water use and management, the decree defines how water management administration, co-operation and involvement will be arranged. Also the decrees concerning the typology and classification of water bodies and the monitoring of hazardous (priority) substances is under preparation.

3 Parties

(Satu Tiilikainen, Ville Matikka)

3.1 Interested parties and networking

The interested parties of a lake management and restoration project often take care of various tasks. The tasks and the scale on which they function (local, regional or national) depend on the project. Table 7 presents the tasks of the various parties.

Table 7. The main tasks of the interested parties in a restoration project (Äystö 1998).

Interested Parties		Tasks
Beneficiaries	Local inhabitants	- initiate new restoration projects - establish lake management and protection associations - monitor the status of lake (before and after restoration)
	Lake management and protection associations	- civil activity/voluntary activities (voluntary work and campaigns) - produce information and arranges training - take responsibility of restoration projects locally - arrange funding
	Associations for joint ownership	- arrange permits from the owners of the water area for restoration measures - measure concerning improvement of fish habitat - voluntary work and knowledge of local matters
	Regional advisory council for fishing/fisheries	- regional partner in issues concerning improvement of fish habitat and fishing - prepares and implements plans for use and management of fish habitat - takes part in funding
Actual doers	Consultants and contractors	- planning, monitoring and research - implementing restoration measures (e.g. dredging, removal of aquatic vegetation, chemicalization)
Administrative and supervisory authorities	Municipality	- local authority in issues concerning water and environment - applies for funding and permits - finances restoration measures and monitoring
	Regional Environmental Centre	- regional authority in issues concerning water and environment - advisory body in issues concerning restoration - planning and funding - monitoring the status of water bodies
	Employment and Economic Development Centre (Fishing Unit)	- regional authority in issues concerning fishing industry and agriculture - guidance, information and funding - gives information on EU agricultural support and funding
	Environmental Permit Authority	- licensing authority in big projects and in projects where a regional environment centre applies for the permit and acts as planner or financier
	Ministry of the Environment and Ministry of Agriculture and Forestry	- financial guidance for restoration projects
	EU	- directives - funding
Experts	Finnish Environment Institute	- advise in planning, monitoring and research, when needed - general monitoring of the environmental status
	Finnish Game and Fisheries Research Institute	- statistics on fish populations
	Research and education institutes (universities etc.)	- advise in planning, monitoring and research, when needed
	VSY, MTT, GTK	- environmental research, occasionally funding

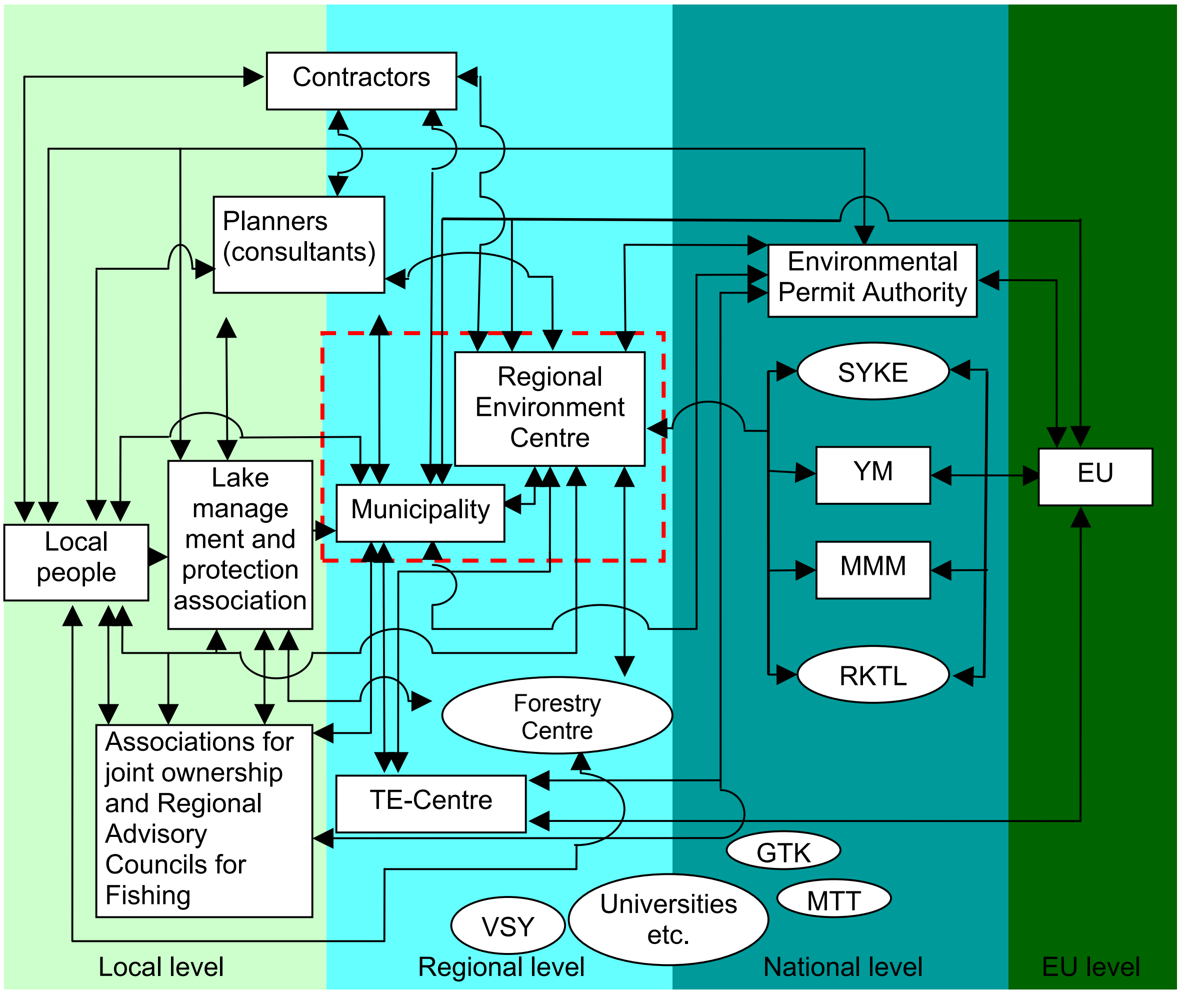


Figure 6. The co-operation network of various interested parties in Finland
(In the figure, the ellipses represent specialists).

Key

SYKE	Finnish Environment Institute
YM	Ministry of the Environment
MMM	Ministry of Agriculture and Forestry
RKTL	Finnish Game and Fisheries Research Institute
TE-Centre	Employment and Economic Development Centre
VSY	Local lake protection association
GTK	Geological Survey of Finland
MTT	Agrifood Research Finland

Figure 6 illustrates how the application procedure of a restoration project progresses from left to right. All interested parties do not necessarily work in close co-operation with all other parties; instead, they come into contact only when necessary. Also the roles of the parties can vary depending on the location and project. For example, the lake management and protection association is not needed in all projects. In some cases, its tasks are taken care of by the municipality or association of joint ownership, for example. Neither do all projects need EU financing; the lake can be restored using voluntary work or funding from the municipality. As the figure indicates, the municipality and regional environmental centre play a central role in restoration projects.

3.2 Research and educational institutions in Finland

Lake management and restoration requires expertise from various fields. For this reason, research and education concerning water basins is dispersed and specialized. Table 8 presents nationally significant research and educational institutions the expertise of which will be used in the management and restoration of water bodies. Table 8 is not exhaustive; there may be also other institutions in Finland, which work in the field of lake management and restoration.

Table 8. Nationally significant research and education institutions.

Research and Educational Organisations	Special Area of Expertise	Contact Information
Finnish Environment Institute (SYKE)	All lake management and restoration matters	www.ymparisto.fi Researcher Ilkka Sammalkorpi ilkka.sammalkorpi@ymparisto.fi
Finnish Game and Fisheries Research Institute (RKTL)	Fish research	www.rktl.fi Researcher Jukka Ruuhijärvi jukka.ruuhijarvi@rktl.fi
Geological Survey of Finland (GTK)	Sediment research	http://www.gtk.fi/ Senior Research Scientist Tommi Kauppila tommi.kauppila@gtk.fi
Agrifood Research Finland (MTT)	Agricultural engineering research	http://www.mtt.fi/tutkimus/ymparisto/vesistokuormitus.html Principal Research Scientist Eila Turtola eila.turtola@mtt.fi
University of Helsinki Department of Biological and Environmental Sciences	Hydrobiology, limnology and fisheries sciences	http://www.helsinki.fi/biosci/akva/limnoyl.htm
University of Jyväskylä Aquatic Resources, Faculty of Mathematics and Science	Expertise in the aquatic ecosystem, biological research	http://www.jyu.fi/bio/hyb/ Professor Juha Karjalainen juhakar@bytl.jyu.fi Professor Roger Jones rjones@cc.jyu.fi
University of Oulu Department of Biology	Assessment of watercourse restoration impact	http://cc.oulu.fi/~biolwww/index.html Professor Timo Muotka timo.muotka@oulu.fi
University of Oulu Water Resources and Environmental Engineering Laboratory	Assessment of lake restoration impact; hydraulic modelling	http://www.oulu.fi/poves/ Professor Esko Lakso esko.lakso@oulu.fi
Tampere University of Technology Environmental Engineering and Biotechnology	Polluted dredging mass; reducing external loading	http://www.tut.fi/units/ymp/bio/' Professor Tuula Tuhkanen tuula.tuhkanen@tut.fi
Helsinki University of Technology Water Resources Engineering	Urban hydrology; ecohydraulics; modelling	http://www.water.tkk.fi/wr/index.html Professor Pertti Vakkilainen pertti.vakkilainen@tkk.fi
University of Turku Department of Biology, Section of Ecology	Aquatic food chain research	http://www.sci.utu.fi/biologia/ekologia/index.html Professor Jouko Sarvala jousar@utu.fi
Academic field stations	Environmental research	http://honeybee.helsinki.fi/hyytiala/fs/asemat.htm
Lake Pyhäjärvi Protection Fund	Comprehensive lake restoration	http://www.pyhajarvensuojelu.net/ Project Manager Anne-Mari Ventelä anne-mari.ventelä@pyhajarvi-instituutti.fi

Research and Educational Organisations	Special Area of Expertise	Contact Information
Häme University of Applied Sciences Environmental Technology	Water use and management plans; loading assessments in catchment areas, restoration plans, lake restoration training	http://www2.hamk.fi/ymparistoteknologia Training Programme Director Markku Raimovaara markku.raimovaara@hamk.fi
Lahti University of Applied Sciences	Education regarding lake management and restoration	http://www.lamk.fi/tl Head Teacher of Environmental Bioengineering silja.kostia@lamk.fi
Laurea University of Applied Sciences	Education and projects regarding lake restoration	http://www.laurea.fi/net/fi/ Senior Lecturer Eila Pulkkinen-Härkönen eila.pulkkinen-harkonen@laurea.fi
Oulu University of Applied Sciences	Field survey and impact assessments of lake restoration	http://www.oamk.fi/tekniikka/index.php Head Teacher Jyrki Röpelinen jyrki.ropelinen@oamk.fi
North Karelia University of Applied Sciences	Extensive education regarding lake restoration (research and projects)	http://www.ncp.fi Full-time Teacher Tarmo Tossavainen tarmo.tossavainen@pkky.fi
Savonia University of Applied Sciences	Lakepromo, Järvipooli and Vesivelho projects, education regarding lake management and restoration	http://www.savonia-amk.fi/teku/projtutk/rakeympa/ Research Superior Eero Antikainen Eero.Antikainen@savonia-amk.fi
Turku University of Applied Sciences	Education and projects regarding lake restoration	http://www.turkuamk.fi/ Training Superior Sirpa Halonen sirpa.halonen@turkuamk.fi
Vaasa University of Applied SciencesPolytechnic	Education regarding lake management and restoration	http://www.puv.fi/fi/ Senior Lecturer Riitta Niemelä riitta.niemela@puv.fi

4 Sources of funding for restoration projects

(Tomi Puustinen)

The choice of funding source for restoration projects depends on the total cost, the location of the restoration site and the implementing bodies (sources for funding in Table 9). Small projects can be implemented solely on private funding (e.g. removal of aquatic vegetation), but bigger projects need public funding (EU, the State and municipalities). (Mattila & Kirkkala 2005)

The European Union is the most important financier of lake restorations in Finland. The money for lake restoration projects comes from the EU structural funds such as the European Regional Development Fund ERDF, the European Social Fund ESF, the European Agricultural Guidance and Guarantee Fund EAGGF and Financial Instrument for Fisheries Guidance FIFG. In practice, funding for lake restoration is allocated through target programmes (1, 2, 3 and ALMA) and community initiatives (Interreg and Leader programmes). EU funding for restoration projects is applied from the Regional Environment Centres or the Employment and Economic Development Centres. A prerequisite for EU funding is the existence of local funding. Voluntary work can be included into the local funding. The percentage which can be covered with EU funding varies according to the location and the project.

The involvement of the State of Finland in lake restoration is directed by the Government resolution on restoration of water bodies (3rd May 1990). According to this resolution the State can take part in projects which have a substantial public significance in promoting the use, management and protection of a water body. A lake restoration project in which the State of Finland is a partaker can be planned and implemented partly or as a whole as Government work within the limits of the State budget. If the restoration is done totally as Government work, the municipality pays its share of the restoration to the State. The prerequisite for receiving State funding is that the other parties underwrite at least 50 percent of the total expenses.

Municipalities plan and implement their own restoration projects. In addition to these, municipalities give funding to projects which receive partial funding from the EU and the State. Private persons and communities take part in lake restoration mainly through voluntary work, which is calculated as part of the local funding. Actual private funding plays usually only a small part in restoration projects. Restorations of small lakes are sometimes implemented totally with private funding and voluntary work.

Table 9. Sources of funding in Finland for restoration of water bodies (Elinvoimaa EU-ohjelmista).

Financier		**Share of the total costs of a project (%)**	**Purpose**	**Prerequisites**
EU	- ERDF - ESF - EAGGF - FIFG	50–75	Planning Implementation	- Local funding
State of Finland	- Ministry of the Environment - Ministry of Agriculture and Forestry - Ministry of Labour	- max. 50 - max. 50 - max.100	Planning Implementation	- Project has an outstanding public significance - Municipality takes part in the funding
Municipality/ Town/City	- Own projects - Local funding	- 100 - 1–50	Planning Implementation	- Project has an outstanding public significance
Private	- Associations for joint ownership - Lake protection Associations - Local inhabitants - Enterprises	1–100	Implementation	

5 Planning and implementation process of lake restoration

(Satu Tiilikainen)

A lake restoration project consists of many stages (see Figure 7). The stages illustrated in the diagram below can be applied to most projects. The number of stages, however, can vary according to project, extensiveness of project and method of implementation. Planning is done at several restoration phases and is revised as the project proceeds. The monitoring of the lake is begun prior to the restoration project and it continues after the project as well. Restoration projects can be implemented on one's own initiative, partly spontaneously or professionally. (Vääriskoski ja Ulvi 2005.)

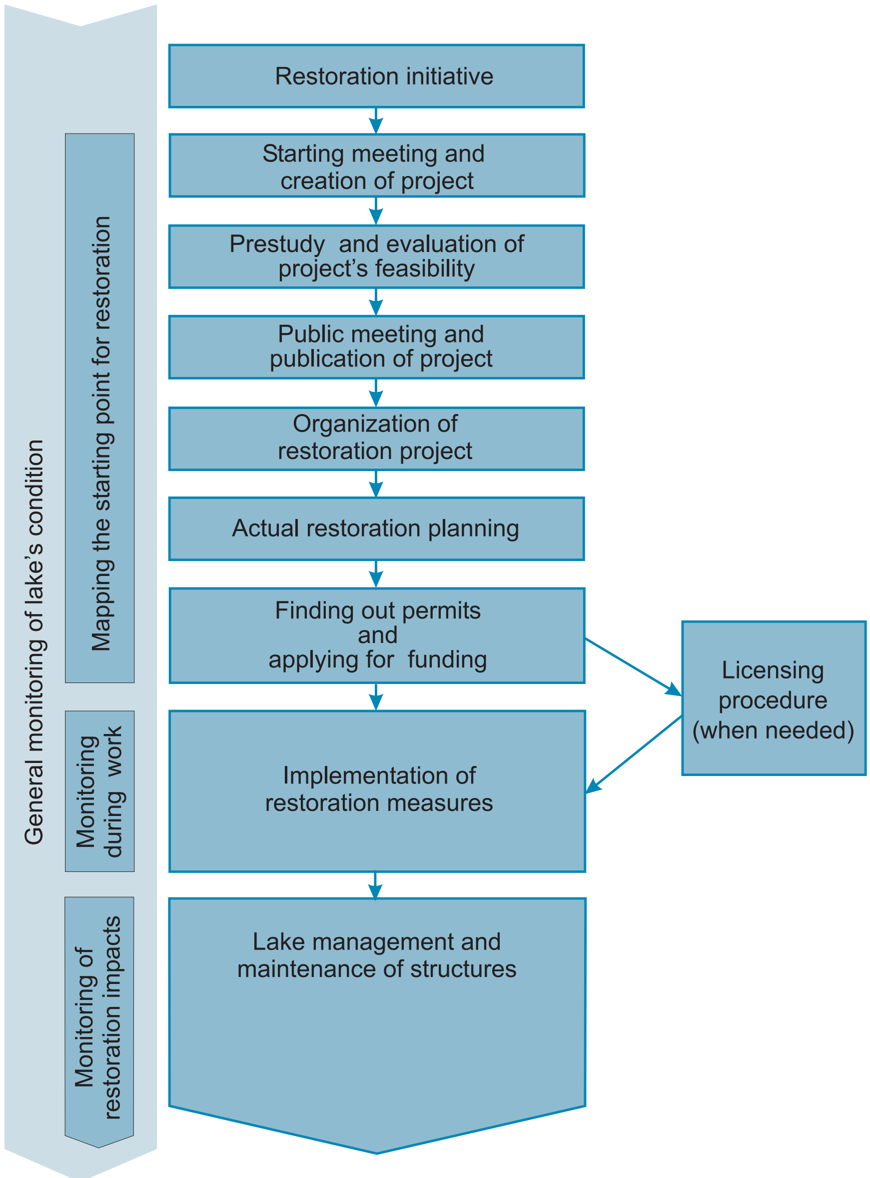


Figure 7. The stages of a restoration project (Vääriskoski & Ulvi 2005).

A project is begun by a **restoration initiative**. The initiative can be taken by a private person or a community. Usually the initiative is brought forward through some beneficiary society. Such beneficiaries can be for example an association for joint ownership or a village committee. If the project is a small one, the initiative is taken orally or in writing to the municipality, and if it is a larger one, the initiative is taken to the regional government officials. The purpose of the initiative is to inform about the restoration project, and begin a public discussion and evaluation over the matter. (Vääriskoski & Ulvi 2005.)

At the **initial meeting** the initiators, the representatives of the main groups and partners concerned, and possibly also a lake restoration specialist make a tentative examination of the needs and objectives of the restoration project. The meeting aims telling the various parties what is presently known of the lake and what is required to build up the project. It is recommended to reserve enough time for the creation of the project and include all interested parties, because innovativeness and various developmental aspects are among the criteria when financiers decide on their support. (Vääriskoski & Ulvi 2005.)

A **pre-study** gives a general view of the condition of the lake and the depth of the problems concerned. The purpose of the pre-study is to make a preliminary evaluation of the project, possible restoration methods and how realistic and compatible the objectives are. The pre-study also investigates the possible need for additional research. Often, the information for the pre-study must be collected from several sources, e.g. environmental secretaries of the municipalities, Regional Environment Centres, lake management and protection associations, Employment and Economic Development Centres and universities. The pre-study consists of e.g. information concerning the lake, catchment and loading. (Vääriskoski & Ulvi 2005.)

The lake users are then heard at a **public meeting.** The purpose is to find out their opinions on the condition of the lake and the objectives of the restoration project. The present stage of the restoration project and information on the lake are presented to all parties. Usually, the instigator of the project or a promoting party such as an association for joint ownership or the municipality set an invitation for the public meeting. The invitation can be presented in a local paper or personally. The owners of the lakeside properties, a representative of the municipality and possibly a lake restoration specialist are invited to the meeting. (Vääriskoski & Ulvi 2005.)

Creating an organisation for the project is part of the restoration process. It is required to keep contact with the parties of the project and to apply for the funding and possible permits needed. Associations for joint ownership, municipalities and – in large projects – Regional Environment Centres have functioned as project organisers. A project plan is formulated at the beginning of the project. Depending on the extensiveness of the project, the project plan consists of information on e.g. the background, objectives, schedule, estimated funding and how the responsibilities are divided of the project. (Vääriskoski & Ulvi 2005.)

The actual **planning of the restoration** begins by making a general plan on the basis of the pre-study. The general plan presents the different restoration options and the preliminary assessments of their effects as well as the cost estimate of the project. After the restoration methods have been chosen, the structural and implementational plans are formulated. In addition to these technical solutions, a plan consisting of the financial programme and a plan for reducing the external loading needs to be made. The final restoration plan is reviewed after the project is approved, and the funding and permits are confirmed. The project plan can be done by the parties of the project or a planner can be employed for this purpose. A project plan can also be ordered from a consultant. The contents of the restoration plan depend on the project. The restoration plans of big projects should usually present the following information: e.g. basic information of the lake and its catchment, ways in which the water body is used, status of the water body and its problems, objectives of the project and measures planned to be taken, assessment of the effects (pros and cons), matters concerning permits, cost estimate and funding, the surveillance of the work, and lake management monitoring plan. (Vääriskoski & Ulvi 2005.)

Settling the permits and applying for the funding is the next phase in the planning of a restoration project. All restoration projects need at least the approval of the owner of the waters, but in many cases a permit from an authority is also needed. Regarding lake restoration, the need for a permit is based largely in the Water Act, but sometimes also on the Environmental Protection Act. The need for a permit is estimated by the Regional Environment Centre. Matters concerning permits are dealt with in more detail in Chapter 2.2. Restoration projects can be financed in various ways. Besides the external funding, most projects have a self-financing part, which can in some cases be partly voluntary work. The choice of the source of funding depends o the expenses, implementing parties and location of the project. Chapter 4 deals with matters concerning funding in more detail. (Mattila & Kirkkala 2005; Vääriskoski & Ulvi 2005.)

Restoration measures can begin when the restoration plans have been approved and permits and funding are in order. They can be contracted out or done as voluntary work partly or as a whole. The restoration measures are to be carried out in a season when they cause as little inconvenience as possible for lake users and the owners of the water and lakeside areas. The effects of the measures are monitored. The monitoring is the responsibility of the implementer of the project and the supervision of the work is the responsibility of the project organiser. The project organiser inspects and approves the work. All tasks done during the project are documented and the information is filed away for at least the duration of the project. (Vääriskoski & Ulvi 2005.)

Lake management and maintenance of constructions ensures that the good status achieved by the restoration measures will endure. The impact of the restoration measures is monitored in order to determine the efficacy of the measures. The management procedures following the restoration measures can also be directed by the monitoring. Monitoring is reported at regular intervals. All installations and technical equipment such as dams, banks and dykes, channels and oxidizers are to be included in the project. The implementer of the project or the owner of the installations is responsible for their maintenance. (Vääriskoski & Ulvi 2005.)

6 Best practices and expertise concerning methods and projects

(Ilkka Sammalkorpi, Erkki Saarijärvi, Satu Tiilikainen, Tomi Puustinen)

6.1 National expertise

Finland has developed expertise in two methods which are not as common in other countries: oxidation and biomanipulation. The first oxidation trials took place in the beginning of the 1970s, and already in the 1980s, oxidation was widely in use (Seppänen 1973; Lappalainen 1982; Äystö 1997; Lappalainen & Lakso 2005). Oxidation was used to reduce internal loading but also to prevent fish deaths (also in fish traps during winter). The primary aim of biomanipulation has usually been to improve water quality. Since the Vesijärvi Project (see Chapter 6.3.1), an important supplementary aim has been to improve the utility and commercial value of the lake. To maintain the status achieved by restoration a combination of management fishing and stocking of predatory fish is used in many lakes.

Oxidation and aeration to reduce internal loading

Finland's lakes are susceptible to oxygen depletion during winter due to their shallowness and ice cover during the winter months. During some winters, last 1995/1996 and 2002/2003, the lakes froze early in the autumn the temperature of the water being still 2-3 °C. As a result of this early freezing, high average temperature and long period of ice cover preventing contact with air, the lake developed large oxygen depleted areas resulting in fish deaths. Various methods have successfully been used to prevent oxygen depletion during normal winters (Lappalainen & Lakso 2005).

Circulation oxidation (where oxygen or air bubbles are not led into the water) is common in Finland. It has proven to be a cost efficient way of reducing the internal loading of basin areas in the summer. This method is suitable for lakes of average depth and periodical stratification during summer in which an internal phosphorus load pulse caused by temporary stratification and oxygen depletion occurs 2-3 times (for example Saarijärvi & Lappalainen 2005). In order to prevent these pulses, the oxygen concentration is not to sink below 3 - 4 mg/l. For example, in Lake Tuusulanjärvi (mean depth 3.2 m) and Lake Pitkäjärvi in Espoo (mean depth 2.3 m) it has been possible to regulate the stratification. Oxygen concentration has been kept adequate when the amount of water corresponding to the water volume of the lake is pumped through a circulating oxidizer in 40 days, or the discharge is 0.025 times the volume of the lake in 24 hours (Lappalainen & Lakso 2005). The result is interesting in as much as normally the prevention of stratification and especially the closely related destratification has been considered an expensive and/or harmful measure. It is possible to improve the oxygen concentration of lakes that have a non-specific stratification pattern also with other methods, but the costs of these methods which bring oxygen into the water in various ways are often rather high. The impression that prevention of stratification would have a negative effect on the lake is possibly due to the fact that the measure has been implemented inadequately. For example, in 1998-2004 adequate circulation oxidation has, apart from small exceptions, clearly reduced the internal loading of the hypolimnion. During previous summers, however, when the oxidation capacity was smaller, internal loading was a continuous problem. As a secondary effect, the smelt population of Lake Tuusulanjärvi weakened when the temperature of the basin area rose. Oxidation together with extremely strong mass removal of fish was a prerequisite for a clear reduction in the amount of blue-green algae blooms in Lake Tuusulanjärvi in the 2000s (Lepistö *et al.* 2003). The fact that the environmental administration had monitored Lake Tuusulanjärvi intensively since the 1970s was a great help in finding the right amount of oxidation needed (Pekkarinen 1990; Lepistö *et al.* 1998).

Biomanipulation to reduce internal loading and improve the structure of fish fauna

In Finland, biomanipulation rose quickly into public awareness after the mass removal of fish quickly reduced blue-green algae blooms from Lake Vesijärvi in Lahti after more than 12 years of waste water loading had caused continuous problems with the algae (Keto & Sammalkorpi 1988; Kairesalo *et al*. 1990; Sammalkorpi *et al.* 1995; Horppila *et al.* 1998). In the beginning, there were some administrational difficulties with the implementation of these measures because the objective was in the field of environmental administration while the measure itself belonged to the field of fishing industry administration. However, when the biomanipulation measures proved to give good results the administrational problems seemed to be solved quickly.

The methods used presently in Finland were developed for the Vesijärvi Project from techniques used for professional fishing of vendace (*Coregonus albula*) in inland waters (Sammalkorpi *et al*. 1995, Turunen *et al.* 1997). The main development was to decrease the size of mesh in the netting of fish traps. Nowadays the length of mesh side in fyke and seine nets used for mass removal of cyprinids is 6-8 mm in the finer parts of the net and 10-15 mm at the parts with bigger mesh size. All net traps with small mesh size have also been used to remove cyprinids. The most common length of the seine nets has been about 300 m. The cod-end of a fyke net is usually 3-5 m wide and 10-15 m long.

Success in biomanipulation requires usually a good knowledge of the lake's fish fauna. The preliminary mapping of the species is usually done by experimental gillnetting (Olin *et al.* 2002, 2005). If the fish fauna is predominantly cyprinid and the catch with the Nordic experimental gill net exceeds 2 kg and 100 fish/experimental gill net, reducing algal blooms by removal of cyprinids can be considered. Because reliable fish population estimates, of larger lakes especially, are time-consuming and expensive to carry out, an estimation based on the average phosphorus concentration during the growth period is used to make a preliminary judgement of the intended catch: removal requirement kg/ha = $16.2 * TP^{0,52}$ (Jeppesen & Sammalkorpi 2002). In big projects, population analysis has also been used for fish population follow-up (VPA; Horppila & Peltonen 1994; Horppila *et al.* 1996). Echo sounding has been used in deep lakes to estimate the density of pelagic fish – smelt in particular (Malinen *et al.* 2005).

The effective removal of cyprinids requires knowledge of the ecological behaviour of the target species and understanding of the prevailing conditions. It is also necessary to have the right equipment and adequate fishing effort (Table 10). When the change has been achieved by means of mass removal of fish, maintaining the result requires management fishing at a smaller capacity and/or management of predatory fish with e.g. fish stocking and the regulations concerning pikeperch gillnetting. Often shore management in order to strengthen pike populations is also part of the biomanipulation measures. Most commonly, shore management is harvesting reeds (*Phragmites* australis) because the natural reproduction of pike in the invaded shores of eutrophic lakes has been found to be weak

(Korhonen & Nyberg 2001). Minimizing the external loading is a prerequisite for cost efficient biomanipulation (Sammalkorpi & Horppila 2005). For example, the external loading at Lake Vesijärvi in Lahti was less than 50 % of the critical level after the waste water load had ended. However, biomanipulation procedures have had effects on water quality even in Lake Tuusulanjärvi although the loading is double the critical level (Lepistö *et al.* 2003). The effect of the loading can be seen in the cyprinid population. It is very large (e.g. on the basis of the catch done by an experimental gill net) despite the effective mass removals carried out (Rask *et al*. 2005).

Professional fishers implement the mass removals of fish from large lakes. From small lakes removals can be contracted out by professionals, done as instructed voluntary work or as a combination of both. Where small lakes are concerned, the work done by on a voluntary basis often has a significant importance because the hours of voluntary work can be counted as self-financing in the project budget.

Table 10. The suitability of various fishing methods used in biomanipulation for different target species, age groups and lake types (Sammalkorpi *et al.* 1999).

Method	General features of use					Species and age groups of cyprinids							
	Efficiency	Expenses	Voluntary work	Small lakes	Large lakes	Roach	Bream	White bream	Bleak	Smelt	Ruffe	Old	Young
Pound net	X (orange) X (blue)	X (blue)	X (blue)	X (blue)	X (grey) X (orange)	O (blue)	O (grey) O (blue)	O (grey)	O (grey)	O (orange)	O (grey)	O (blue)	O (orange)
Fyke net (height > 1,5 m)	X (grey) X (blue)	X (blue)	X (blue)	X (blue)	X (blue)	O (blue)	O (grey) O (blue)	O (grey)	O (blue)	O (grey)	O (grey)	O (blue)	O (grey)
Autumn seine netting	X (blue)	X (grey)	X (grey)	X (blue)	X (blue)	O (blue)	O (grey) O (blue)	O (grey)	O (blue)	O (blue)	O (orange)	O (grey)	O (blue)
Winter seine netting	X (grey) X (blue)	X (grey)	X (grey)	X (grey)	X (blue)	O (grey) O (blue)	O (grey) O (blue)	O (grey)	O (grey) O (blue)	O (blue)	O (blue)	O (grey)	O (blue)
Net trap	X (orange) X (grey)	X (blue)	X (blue)	X (blue)	X (grey) X (orange)	O (grey)	O (grey)	O (grey)	O (orange)	O (orange)	O (grey)	O (blue)	O (orange)
Gillnets	X (orange) X (grey)	X (blue)	X (blue)	X (blue)	X (orange)	O (grey) O (blue)	O (orange)	O (orange)	O (grey)	O (orange)	O (orange)	O (grey)	O (grey)
Ditch fishing at spawning time	X (orange) X (grey)	X (blue)	X (blue)	X (grey)	X (grey)	O (grey) O (blue)	O (grey)	?	O (grey)	O (grey)	O (grey)	O (grey)	O (grey)
Trawling	X (blue)	X (orange) X (grey)	X (orange)	X (orange)	X (blue)	O (blue)	O (grey)	?	O (grey) O (blue)	O (blue)	O (orange)	O (grey)	O (grey)
Stocking of predatory fish	X (orange) X (grey)	X (blue)	X (blue)	X (blue)	X (blue)	O (grey)	O (orange)	O (orange)	O (grey)	O (blue)	O (grey)	O (orange)	O (blue)

XO (orange) Suitability poor or uncertain, costly, ineffective
XO (grey) Suitability, cost level or efficiency fairly good
XO (blue) Suitability good, affordable, effective

In successful biomanipulation projects, the amount of fish removed from eutrophic lakes per year has been as big as c. 200 kg/ha; in lakes with less nutrients about 50 kg/ha has been adequate (Table 11). Biomanipulation has succeeded in small and large lakes as well as shallow and deep ones.

Table 11. Information on the area, catch and phosphorus concentration of some biomanipulation sites in Finland before mass removal of fish. (Sarvala *et al.* 2000.)

Lake	Area (ha)	Mean depth (metre)	Total phosphorus (µg/l)	Biggest catch per year (kg/ha)	Removed fish (kg/ha) (years)
Vesijärvi Enonselkä	2600	5,8	48	102	423 (5)
Vesijärvi Paimelanlahti	390	4,0	50	165	355 (3)
Pieksänjärvi	1950	2,0	19	65	200 (4)
Espoon Lippajärvi	58	3,0	55	164	200 (3)
Kärkölän Valkjärvi	145	3,5	65	180	360 (3)
Hattulan Armijärvi	9	5	25	90	?
Tuusulanjärvi	592	3,2	100	189	702 (7)

6.2 New innovations and methods on trial

The history of development of lake management and restoration methods in Finland is fairly long. The main types of restoration methods were described as early as at the end of the 1970s, but due to the dispersion of knowledge and lack of resources there still remains a lot to develop concerning restoration method. The mixing and covering of the sediment as well as temporary drying up of a lake have once more taken their place in the list of methods to be studied and tried. These restoration methods have been tested during the last few years and the results have been mainly positive. These methods, however, are not suitable for all restoration sites and there are no monitoring results yet.

Sediment mixing has been tested in four small lakes. The aim of sediment mixing has been e.g. to diminish the effect of the methane bubbling up from the sediment, to compress the sediment and to mix good sediment from under the anthropogenic surface into the poor surface sediment (so-called sediment dilution). The sediment is mixed with an apparatus resembling the brush of a car washing machine attached to a raft. Sediment mixing is done according to the condition of the lake. In satisfactory lakes, mixing is done in aerobic conditions. During this aerobic manipulation the mixing brings oxygen into the sediment. In lakes of poor condition, mixing is done in anaerobic conditions. In this anaerobic manipulation, decomposition is accelerated by mixing the sediment. The mixing of sediment has been tested in very eutrophic lakes. According to the present knowledge, the mixing of sediment lends itself well to restoration of small and shallow lakes with no toxic substances in the sediment. Following the sediment mixing treatment, the management/restoration of the lake is continued with other methods. (Saarijärvi 2005.) Figure 8 presents the function of the sediment mixing device.

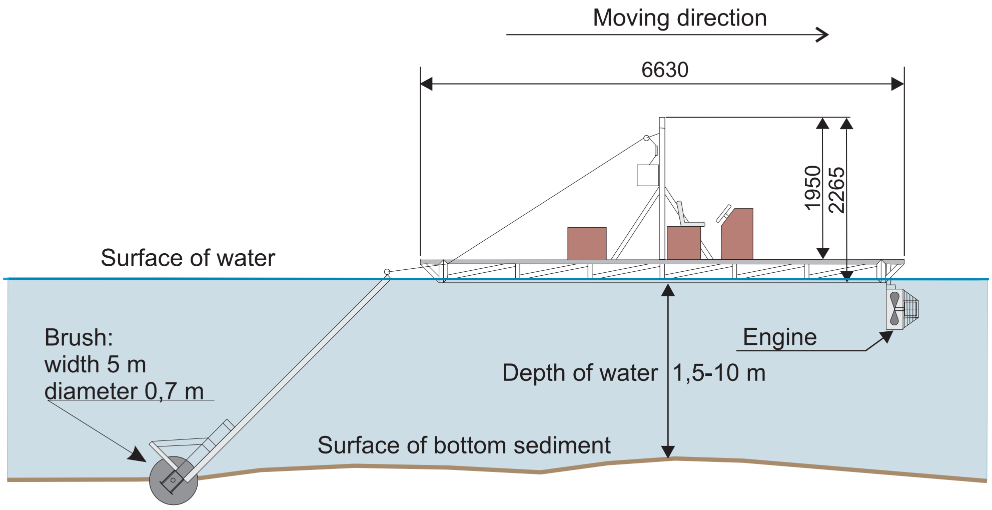


Figure 8. Sediment mixing apparatus/device (Saarijärvi 2005).

The ferrous plaster cover method has been tested at two restoration sites. With the ferrous plaster treatment the sediment is compressed, the resuspension of phosphorus and organic substances from the sediment is diminished, methane bubbling is restricted and the oxygen erosion in the sediment is reduced. The plaster treatment changes the microbe strains so that sulphate reduction bacteria function as decomposers of organic substances instead of methane bacteria (see Figure 9). Ferrous plaster is spread into the lake as granule, powder or mixture (with water) from a tanker lorry or a boat. The method is suitable for lakes of sufficient depth with a lake bottom which is oxygen-free and in a very bad condition. Only the areas which are in poor condition are treated. The action makes the water non-transparent for some hours and powdered plaster causes dust in the air during the spreading procedure. Before the treatment, the quality of the sediment in the basin area (nutrient content, pH, oxygen concentration, redox-potential and the mechanisms of internal loading) as well as the fish fauna and zoobenthos must be defined. On the basis of performed tests, it is possible to state that the phosphorus loading of the bottom sediment reduces significantly and water becomes transparent after the treatment. An estimate is that the effect of the treatment lasts 4-6 years. The ferrous plaster cover supplements other restoration methods. (Varjo & Salonen 2005.)

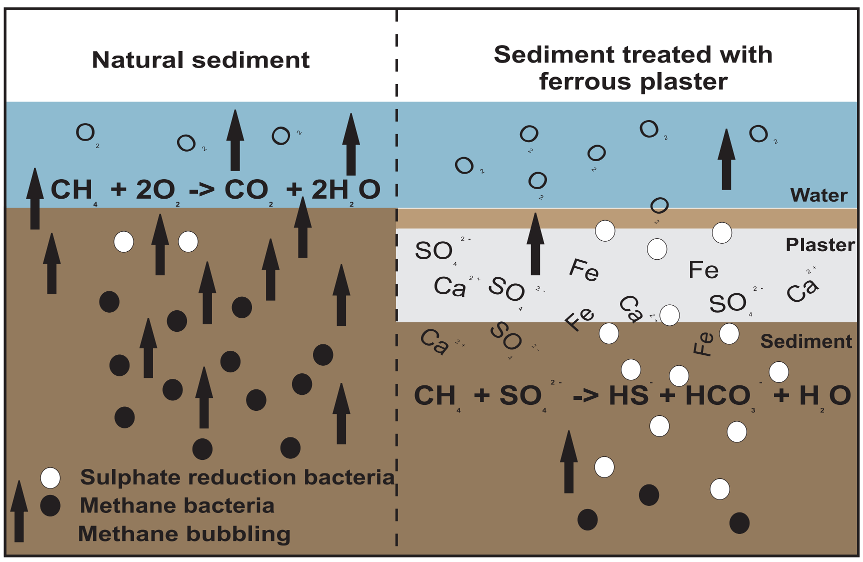


Figure 9. A principal diagram of the function of the ferrous plaster cover. (Varjo & Salonen 2005).

Clay cover is another covering method under development for sediment in poor condition. During the treatment the bottom sediment is sealed off from the water phase with a 5-10 cm layer of clay. The effectiveness of the method can be improved by treating the surface sediment with ferrous sulphate. Organic substances decay under the clay cover and the decomposition product is comprised mainly of methane. Big methane bubbles penetrate the clay layer and are released into the atmosphere without using oxygen from the sediment (Figure 10). By adding ferrous sulphate it is possible to reduce the formation of methane. The clay substance is spread onto the bottom of the lake by pumping it with suction dredgers or stuff pumps (Figure 11). The treatment makes the water temporarily non-transparent. Before the treatment the internal loading of the lake must be defined by defining the nutrient level, sedimentation and condition of bottom sediment. In order to determine the thickness of the clay cover required the amount of methane bubbling must be defined. (Pekkarinen 2005.) In the basin tests carried out at Lake Tuusulanjärvi the clay cover and adding of ferrous sulphate reduced the release of phosphorus from the sediment 75-80% (Sommarlund *et al*. 1998).

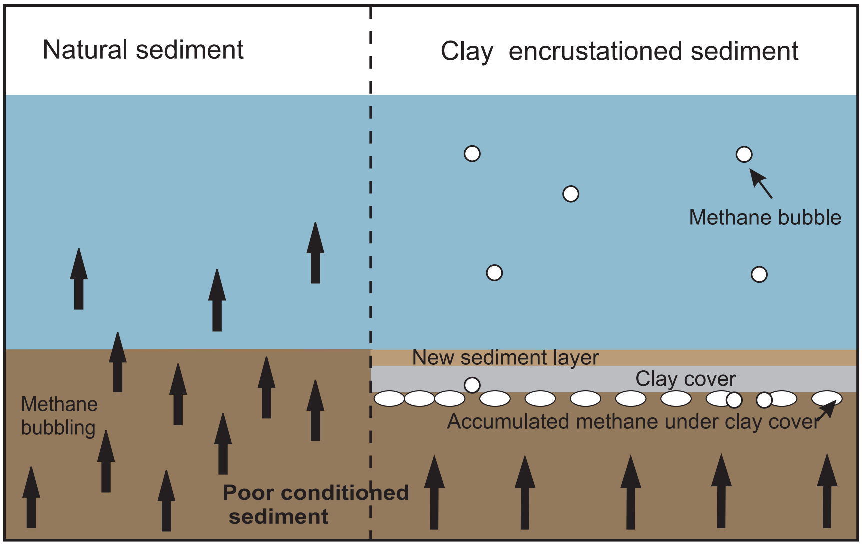


Figure 10. A principal diagram of the mechanism of the clay cover (Pekkarinen 2005).

Figure 11. Nozzle for spreading clay

The temporary drainage of a lake is a restoration method under development, which reduces the internal loading and the effects of eutrophication. Two temporary drainages of lakes have been implemented in Finland. During the treatment the surface of the lake is lowered substantially or the lake basin is drained for one or two years. During the drainage the bottom sediment of the lake sinks down and becomes compact and the water volume grows, dominance of cyprinids in the fish fauna changes and the vegetation lessens. During the drainage, it is possible to dry dredge the shores of the lake and the sediment to be dredged is easier to treat. Before implementing the treatment the morphology of the lake, discharges, water quality, features of sediment, features of catchment and typography of outlet of the lake must be defined. Also the owners of the lake and shores must be defined. The method suits best lakes which have a fine and soft sediment. The immediate effects have been according to the expectations, but information on the long term effects is received in the coming years. (Lehmikangas 2005.)

Table 12 is a summary of the pilot cases and expenses of the above mentioned restoration methods.

Table 12. Methods at research and development stage (Lehmikangas 2005; Saarijärvi 2005; Varjo & Salonen 2005; Väisänen & Lakso 2005).

Restoration method	Pilot cases	Surface area (ha)	Max. depth (m)	Expenses based on the pilot cases	Need to renew treatment during 10 years
Sediment mixing	Heinälampi	9,7	5,5	- *anaerobic treatment* 1200-1500 € / ha a - *aerobic treatment* 1400-2400 € / ha	3 times (anaerobic) 1 time (aerobic)
	Postilampi	3	4,5		
	Likolampi	5	5,8		
	Laitilanlahti	7,5	3,5		
Clay cover	Tuusulanjärvi*	595	10	7000-14000 € / ha	1 time
Ferrous plaster cover	Laikkalammi	0,7	14	3500 € / ha (0,5 cm layer)	1 time
	Kaukjärvi	10,5	4,6		
Temporary drainage	Särkijärvi	123	1,8	Särkijärvi 387 000 € (total expenses including dredging)	1 time
	Lahdenlampi	9,5	2,0		

*Tested in an area of 0.5 hectares. The whole lake was not covered with clay instead oxidation of the hypolimnion and mass removal of fish were chosen as additional treatments in the lake.

6.3 Examples of implemented projects

6.3.1 Case Vesijärvi

Vesijärvi Project is one of the first, largest and most successful biomanipulation restoration projects carried out in Finland. It was implemented in 1987–1994 after which the management and restoration of Lake Vesijärvi has been continued by several follow-up projects. Examples of these follow-up projects have been:

- Life for Lake Vesijärvi (1995 - 1998)
- Big Lakes – Sustainable recreational use of lakes (1999 - 2001)
- Vesijärvi II -projekti (Vesijärvi Project II) (2002 - 2006).

The total cost of the restoration and management of Lake Vesijärvi has been 5 million euros of which about 3.4 million euros has been external funding and the rest (1.6 million euros) has been self-funding and voluntary work. At present, some 2000 hours of voluntary work is used annually for the management and restoration of Lake Vesijärvi. The provisioning and compensation for expenses of the voluntary workers are about 11 000 €/year. (Keto 2005.) A timeline showing development in the status and restoration of Lake Vesijärvi is presented in Figure 14 at the end of this chapter.

The situation at the beginning of the project

Vesijärvi is a large, shallowish lake – surface area 109 km^2 – in Central Finland. Figure 12 presents a map of Lake Vesijärvi. Vesijärvi is a naturally eutrophic lake and in some areas there have been blue-green algae blooms as early as the 1920s.

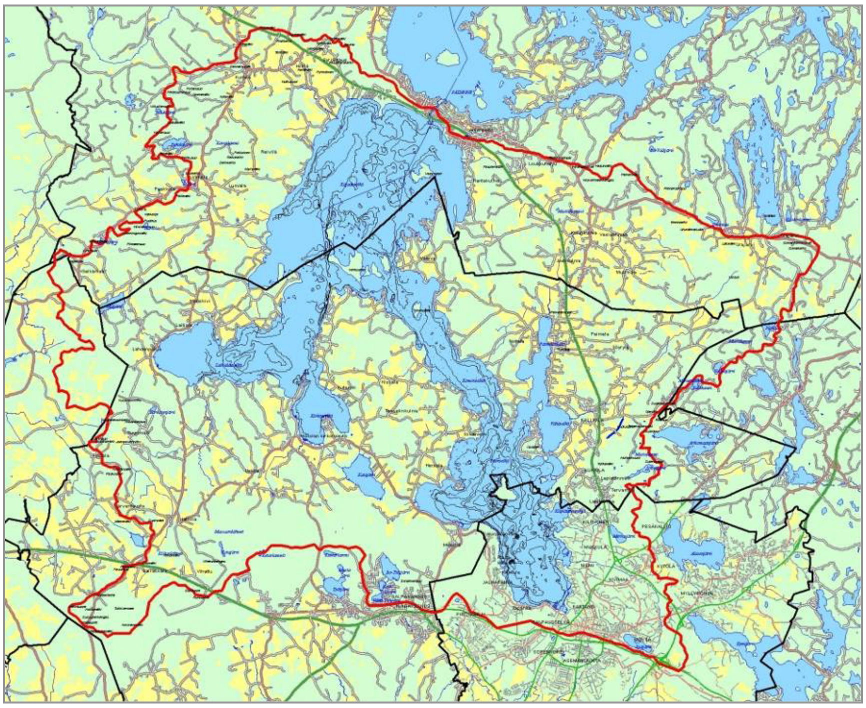


Figure 12. The catchment of the Vesijärvi Lake (Keto 2005).

In Lake Vesijärvi, blue-green algae blooms became a continuous problem in the 1960s and a decade later blooms existed also during winter (Keto 2005). The eutrophication of Lake Vesijärvi was caused mainly by waste water loading from the industry and community. The loading was at its greatest in the 1970s, when it was seven times higher than the critical loading levels determined by Vollenweider. Waste water loading ended in 1976, but blue-green algae continued to exist despite the fact that the nutrient content of the water clearly dropped. The Enonselkä basin (Enonselän syvänne) of Lake Vesijärvi was oxidised in 1979-1984 in order to reduce internal loading, but no clear connection between oxygen deletion and blue-green algae blooms was detected. So, the oxidisation of the hypolimnion was stopped in 1984. The results of statutory monitoring carried out by the City of Lahti showed that the phosphorus concentration on average doubled during the summer. According to test fishing related to the statutory monitoring, the roach population was big. Besides, the results from an echo sounding test showed that there was a very large smelt population at Enonselkä. (Sammalkorpi *et al.* 1995; Sammalkorpi & Horppila 2005.)

Implementing the project

The Vesijärvi Project began in 1987. The objective of the project was to improve the recreational use of the lake and its value in sustainable fishery by means of biomanipulation. First, the pikeperch population which had been declining was brought back by extensive fish stocking. The validity of the starting information was also assessed and the objectives were defined with the aid of results from basin tests. The first two years were needed to find fishing methods which were sufficiently effective. During 1989-1993, mainly roach and smelt totalling up to 1 100 tonnes were predominantly trawled from the Enonselkä area of 2,600 ha. The total catch was 423 kg/ha, the average annual catch was 84 kg/ha and the maximum annual catch was 102 kg/ha. Furthermore, during the same years, birds caught a total of about 90 kg of fish per hectare. Therefore, the average removal of fish at Enonselkä was annually over 100 kg/ha. (Sammalkorpi *et al*. 1995; Sammalkorpi & Horppila 2005.)

Also the testing of the suitability of seine and fyke nets for mass removal of fish was activated during the project. The results were positive and since then seine and fyke nets have been used in the management fishing of other lakes as well. In 1993, voluntary workers began to make big fyke nets (height more than 1.5 m) for the management of Lake Vesijärvi. Annually, 40-60 persons still take part in this voluntary work of making these fish traps (Sammalkorpi *et al.* 1995; Keto 2005).

After the mass removal of fish, management fishing was continued at Enonselkä. According to calculations based on the trawling catch, the intended catch had to be about 30 kg/ha per year. The figures of the intended catch were reached during most years and the water quality at Enonselkä remained good for the rest of the 1990s. According to models of fish population growth, the roach population at Enonselkä would have grown to its former size in three years without management fishing. Blue-green algae blooms did not appear until in 2002, apparently due to the increase in lakeside construction work and the contributory effect of several warm summers. Because of biomanipulation measures, the water quality of Lake Vesijärvi was restored substantially (see Table 13). In the beginning of the 1990s the amount of blue-green algae blooms decreased. However, as the transparency of water became better the amount of aquatic plants increased.

(Sammalkorpi *et al.* 1995; Sammalkorpi & Horppila 2005.) See a view from Lake Vesijärvi today in Figure 13.

Table 13. Some indicators of improvement in the water quality of Lake Vesijärvi as the management measures advanced.

Area	In the beginning of the 1990s			In 1995		
	Phosphorus (µg/l)	chlorophyll-a (µg/l)	Transparency (m)	Phosphorus (µg/l)	chlorophyll-a (µg/l)	Transparency (m)
Paimelanlahti	50	24	1	31	11	2
Enonselkä	48	>20	1,5	< 30	< 10	2,5

The status of Lake Vesijärvi and the restoration of the lake have continuously been important topics in the local media. In the 1980s, the plentiful information on the status of the lake worked in favour of the Vesijärvi Project e.g. in fundraising. The measures and research carried out by the project received a lot of publicity so the local people and authorities knew about the situation at Lake Vesijärvi. (Sammalkorpi *et al.* 1995)

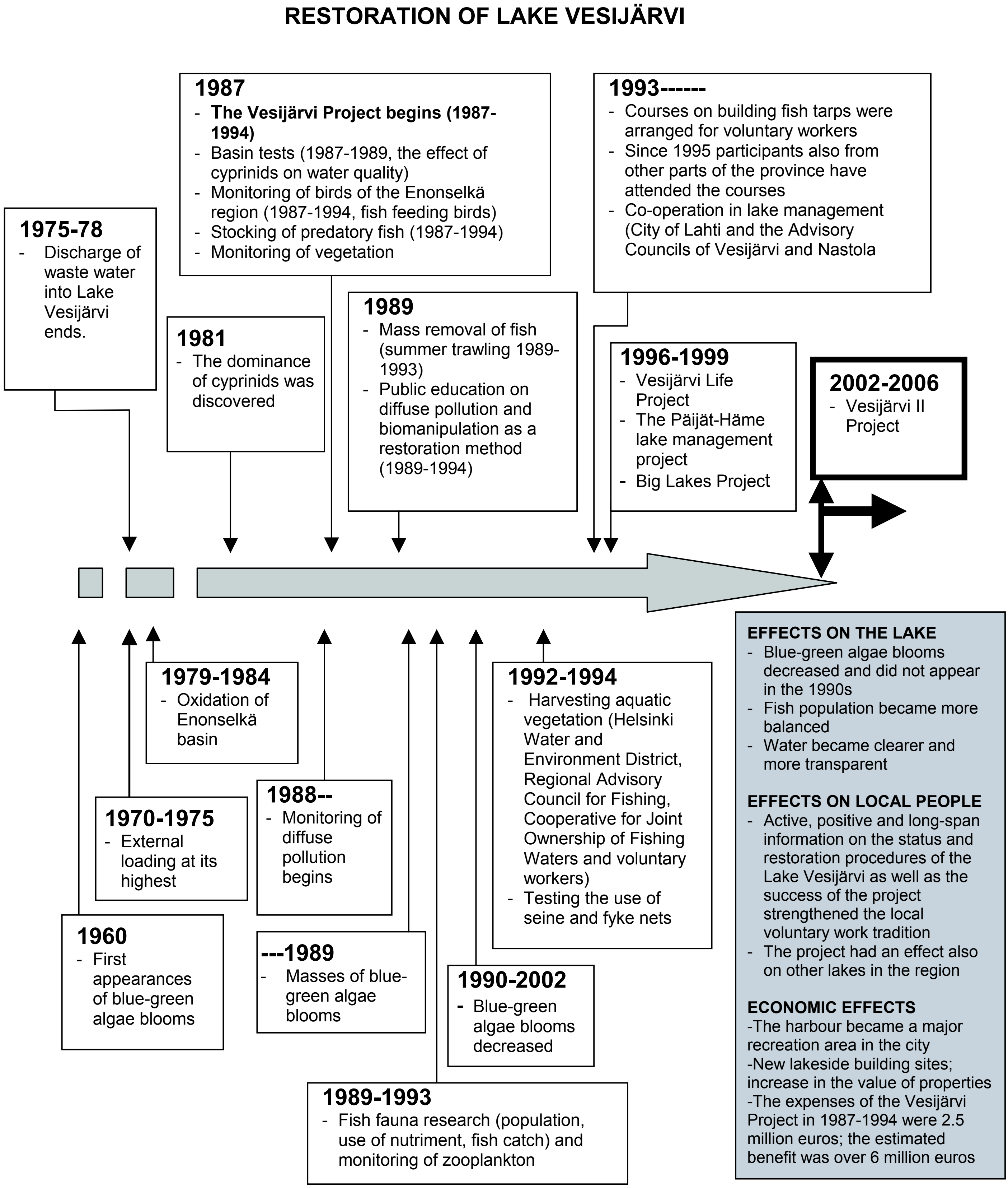
Administration and funding

In 1987, the environmental protection authority of the City of Lahti made a notice of the meeting of the Vesijärvi Project. The project supervisory body consisted of the City of Lahti, the Municipalities of Hollola and Asikkala, the Helsinki Water and Environment District, the Finnish Game and Fisheries Research Institute and the University of Helsinki. The Vesijärvi Project also had a project management group. The members of this group prepared for example the implementation of the plan of action (reduction of external loading, harvesting and fishing as voluntary work). During 1992-1994, more than 60 people took part in the meetings of the management group and an even bigger amount of local people took part in the voluntary work. The project's sources of funding are presented in Table 14.

Table 14. Division of expenses among the parties of the Vesijärvi Project in 1987-1994.

	Expenses (€)
City of Lahti	1 688 600
Municipality of Hollola	136 600
Municipality of Asikkala	51700
Helsinki Water and Environment District	259000
Academy of Finland Ministry of Agriculture and Forestry Foundation for Research of Natural Resources in Finland Tor and Maj Nessling Foundation	308100
Voluntary work	Expenses not counted (hundreds of hours)
Total expenses	2 444 000

Figure 13. Lake Vesijärvi today (Photo taken 6.9.2005).



Since 1976, information on the physico-chemical status of the water of Vesijärvi, the phytoplankton and the fish fauna has been received from the obligatory monitoring done at the sewage treatment plant. Other sources of loading also had to carry out smaller-scale obligatory monitoring. In 1989–1994, the municipalities of Hollola and Asikkala also funded the monitoring of water quality in their part.

Figure 14. The restoration timeline of Lake Vesijärvi (Sammalkorpi *et al.* 1995).

6.3.2 Case Heiniöjärvi

THE RESTORATION OF HEINIÖJÄRVI LAKE AS VOLUNTARY WORK

The situation at the beginning of the project

Heiniöjärvi is a lake of 1.65 km^2 at Pieksänmaa in the South Savo region. The problem of Lake Heiniöjärvi was heavy eutrophication in the 1960s. From time to time the status of the lake was polluted. In the 1950s, the water level of Lake Heiniöjärvi was lowered. The loading came mainly from animal husbandry and agriculture. A few fish deaths occurred. Coming into the 1990s, the status of the lake recovered. Part of the lake had filled in with aquatic vegetation.

Implementing the project

Heiniöjärvi is a relatively small lake, and it is not of great importance regionally. The South Savo Regional Environment Centre was not able to provide direct financial support for the planning of the restoration of the lake. However, the project was supported with guidance and training. In this way the project also received indirect financial support e.g. wages and reimbursement of travelling expenses for employees of the environment centre.

A committee of local inhabitants compiled the restoration plan. Local teams collected background information. For example, the following matters were clarified: the number of properties in the area and how the waste water is treated, the present state of the farming and the environmental management as well as what forestry measures had been taken in the catchment during the past decade. Also information regarding the use of the lake and fish fauna was collected, and the vegetation of the lake was mapped and water samples were taken on behalf of authorities.

The ultimate responsibility for the planning of the restoration project belonged to the South Savo Regional Environment Centre, which functioned also as an advisory body and partly as supplier of equipment. The funding and implementing of the plan was carried out as far as possible at a local level. Lake Heiniöjärvi was restored in 1997-2000 (see Figure 15). The following restoration measures were carried out: removal of moss, cutting cane-grass, dredging (small areas), mass removal of fish and management fishing. Additionally, the quality of run-off was improved by building a sedimentation pool and treating the agricultural run-off chemically. The Heiniöjärvi restoration and management project was a long-lasting and demanding project which required a lot of co-operation. Action was emphasized in this project rather than research. The status of the lake has been improved and the process still continues. The timeline regarding the Heiniöjärvi Project is presented in Figure 17.

Funding

The restoration requires about 700 man-hours and some 100 machine work hours. The total expenses were nearly 47 000 euros. Table 15 shows how the expenses divided between the different parties.

Table 15. Division of expenses among the different parties in the Heiniöjärvi restoration project.

	Planning (€)	Implementing (€)	Water pollution control (€)
South Savo Regional Environment Centre	3 000	2 000	70
Voluntary work	5 500	11 700	5 500
Self-funding	500	1 200	
MTT			1 200
Municipality of Pieksämaa			1 000
Leader		12 100	2 900

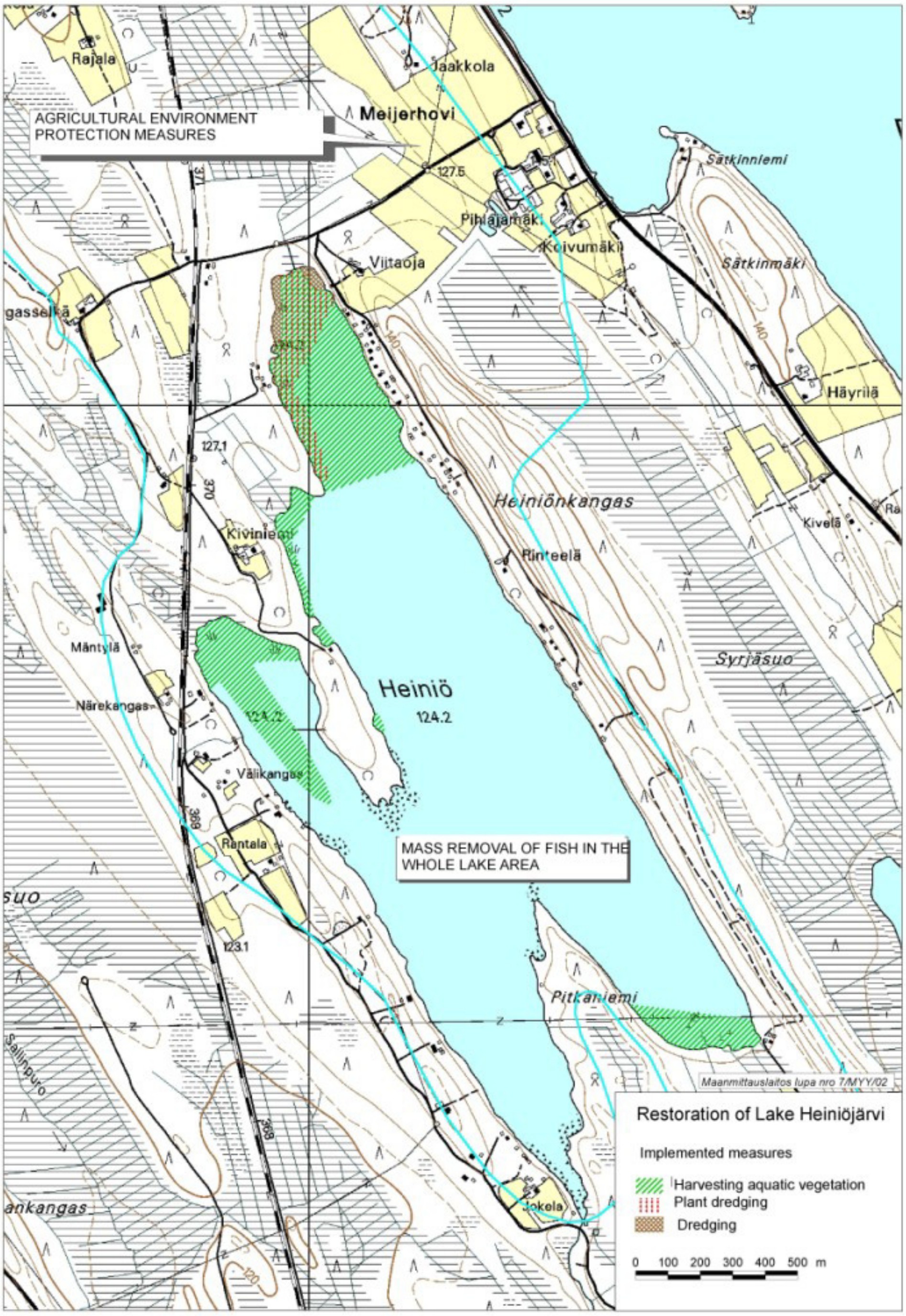


Figure 15. The areas where restoration measures were taken in the Heiniöjärvi project.

Figure 16. Lake Heiniöjärvi after the restoration. Photo taken on 6th September 2005.

RESTORATION OF LAKE HEINIÖJÄRVI BY VOLUNTARY WORK

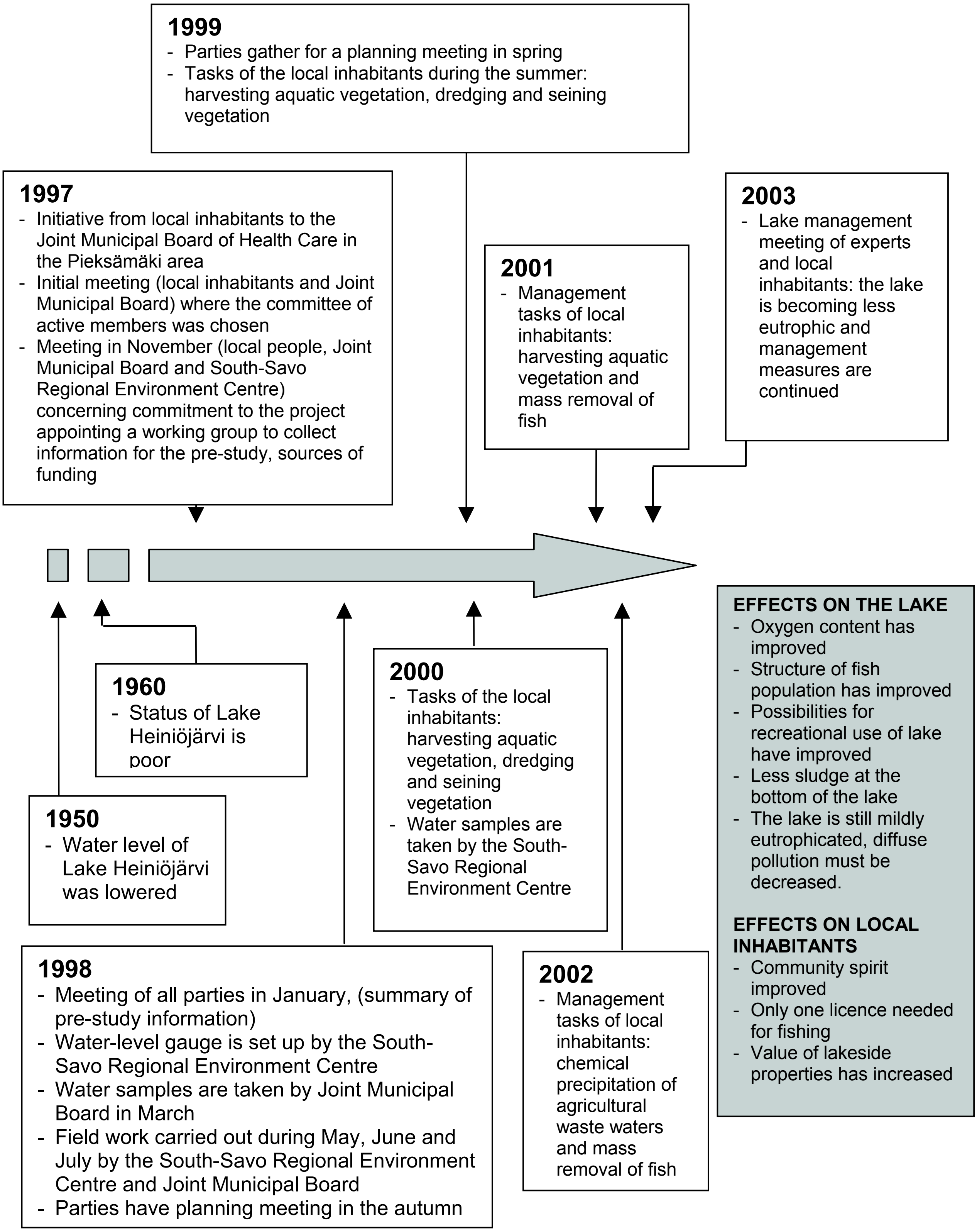


Figure 17. The restoration timeline of Lake Heiniöjärvi.

7 Conclusion and development needs

Most of Finland's medium sized and large lakes are in good condition. However, in Finland there are many small lakes which are eutrophic or could easily become eutrophic. The poor status of water bodies reduces the environmental diversity and restricts the use of lakes. The climate and the characteristics of lakes in Finland have a significant effect on the status of Finland's lakes.

Throughout the centuries, water bodies have been used for various purposes. The focus is changing from using the lake for economic gain to recreational use. Human activity (agriculture, forestry, industry, inhabitation, fishing industry and fur farming) cause discharges which cause eutrophication in the bodies of water. At present the loading caused to the water bodies in Finland by human activity is 4209 t P/year and 77081 t N/year. Nationwide, the biggest sources of loading are agriculture and diffuse source input.

In Finland, about 800 restoration projects have been implemented during the years 1970-2000. The restoration methods used most during the last few years have been removal of macrophyte, dredging and biomanipulation. The idea of non-recurrent restoration measures is being replaced by an idea of continuous lake management. In addition, the focus has moved from reducing point source pollution to the reduction of diffuse source input because point source pollution is mainly in control. In the future, more attention concerning lake restoration will be paid to monitoring of results in order to develop restoration methods. Restoration projects can be very different in type. Typically, a restoration project is a long process consisting of several phases. The research and planning regarding the restoration project alone may take 1-2 years.

In Finland, there is no special legislation concerning lake restoration. Restoration is enacted primarily all by the Water Act, Environmental Protection Act, Nature Conservation Act as well as Land Use and Building Act. All major restoration projects usually require a permit on the basis of the Water Act or the Environmental Protection Act.

The Water Framework Directive sets clear environmental objectives for water management in the EU member states. The general objective of water management is to protect, improve and restore water bodies so that the status of surface waters and ground waters will not weaken and that their status would be at least good. Concerning surface waters, the aim is that a good ecological status and a good ecological potential will be reached by the year 2015. In Finland, the status of water bodies has been assessed mainly on the basis of the physical-chemical quality of water, but along with the Water Framework Directive the use of biological monitoring and its follow-up data in assessment of the status of water bodies will be substantially increased. In the future, the natural characteristics of a lake will be taken into account when assessing its ecological status. These have not been taken into account in previous assessments. Presently, the implementation of the Water Framework Directive in Finland is in the stage of formulating programmes for analysing and monitoring water body features. The guiding principles for the typological and ecological classification of Finland's surface waters will be completed in the near future.

The tasks, role and co-operation of the parties vary according to location and project. The local inhabitants play an important role as they often instigate the restoration projects and take part in the voluntary work. The municipality and Regional Environment Centre are also important participants in a restoration project.

In Finland the management and restoration of lakes has been hindered by e.g. the insufficiency of funding. Funding and planning resources allocated to restoration projects do not correspond to the amount of restoration initiatives made. Projects must be prioritized in order to improve at least the status of the most important water bodies. Restoration projects have been funded mainly by the EU, the state of Finland and municipalities. Private funding has played a minor part.

The development of restoration methods has been ad-hoc and has therefore been tardy. Some restoration methods which have already been tested before have been developed and tested again (sediment mixing, use of covers and temporary drainage of the lake). The exploitation of information and measuring technology in the development of restoration measures has also been studied. Besides developing individual restoration methods, the pros and cons of the combined use of various methods have lately been studied and tested. For example the combination of oxidation and mass removal of fish has proved to be rather effective.

Vesijärvi and Heiniöjärvi were typical lakes that suffered from eutrophication. The problems in both cases have been similar and, therefore, also the restoration measures have been to a large extent similar. These cases differed in the history of loading and volume of restoration and management measures. Many local persons and voluntary workers have taken part in the Vesijärvi and Heiniöjärvi restoration projects. Table 16 consists of an analysis of the present state of lake management and restoration in Finland.

Table 16. SWOT analysis of lake restoration and management in Finland.

Strengths	**Weaknesses**
+ Opinions of lakeside inhabitants are heard and local people are encouraged to take part in restoration projects in various ways + Regional prioritization of projects + Existing training and education on lake restoration and management + Existing general knowledge on lake restoration thanks to the increased amount of information published by the Finnish Environment Centre / EU projects	- Divergent views of concerned parties on the state of the lake → difficulties in setting objectives for the restoration - Co-operation of parties not assured - Joint ownership of water areas hinders some projects because receiving the approval of owners can be difficult - Restoration process progresses slowly - Reducing diffuse pollution / control still very basic - Research and reduction of storm water loading still very basic - Short-term and insufficient funding → makes the continuous arranging of lake management and monitoring difficult - Quality of research and monitoring information/data varies and assessment of effects of restoration is scarce

Potentials	Risks
+ More funding and new work places along with the Water Framework? + Development of restoration methods + National prioritization of projects + Financial benefits: rise in the value of land and commercial value of the lake	- Decrease in budgetary appropriations hinders lake restoration - Diffuse pollution (agriculture, storm waters of population centres) - Ageing of voluntary workers

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