Finland
Multiple use and related environmental problems of the Oulujoki River Basin

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Content

Abstract

The Oulujoki catchment is located in the boreal zone of the Fennoscandian eco-region in Northern Finland. It is one of the largest river basins in Finland totalling 22841 km2 with an annual mean flow of 259 m3s-1. The river system in the upper reaches is characterised by chains of short river stretches and lakes. The total number of lakes above a size of 50 ha is 398, the largest one being Lake Oulujärvi. The catchment area is dominated by forests and peatlands. The flow and water level of the Oulujoki river system has been regulated since the 1940s mostly for hydropower production. Most of the river channels are dredged and a series of rapids have been transformed into stable water systems under hydropeaking. Presently, altogether 18 hydropower plants produce more that 2500 GWh, having total power more than 550 MW. In order to facilitate the power production more than 1400 km2 of the lake water levels are regulated.

The case study focused on four major environmental pressures of the drainage area. Effects of peat production were studied in a small tributary of the River Oulujoki. The ecological status of small lakes affected by forestry operations was studied in the upper part of the basin. The Programme of Measures including environmental goals for the heavily modified main channel of the River Oulujoki was dealt with in detail. The Natura 2000 case study provides an approach for setting management objectives for water related protected areas in line with the Water Framework Directive.

In general the effects of peat production were visible, but could not be separated from the effects of loading coming from other diffuse sources. On the other hand, forestry operations were a major determinant for lake status of small lakes. Possibilities to achieve good ecological potential in the heavily modified stretch are limited without having significant effects on the main usage of hydropower production. Water related Natura 2000-areas are also suffering of diffuse loading and need separate management programmes

1 Introduction

The River Oulujoki is situated in Northern Finland and represents a typical northern river basin in Fennoscandia with relatively sparse settlements and low human impacts. The catchment area is rich in waters and the river basin is dominated by forests. The forestry operations, such as clear-cutting, drainage and tillage, may have significant impacts especially on the ecological status of the small upstream lakes and rivers. Locally, peat production may also lead to a deterioration of water quality and ecology.

The flow and water level of the Oulujoki river system has been regulated since the 1940s mostly for hydropower production. Most of the river channels are dredged and a series of rapids have been transformed into stable water systems under hydropeaking. Despite of these human induced effects there are large pristine areas situated in the upper part of the river basin including large Natura 2000 areas. In general, the main pressures are caused by agriculture, forestry and hydropower plants and regulation.

Since 2002 the River Oulujoki has been one of the official pilot river basins under the common implementation strategy (EU/CIS) of the EU Water Framework Directive. Most of the relevant guidance documents have been tested until 2004.

In practice the Oulujoki case study is divided into four separate phases:

a) The sub-study on peat production focuses on creating a planning system, which uses mathematical run-off and loading models to evaluate best possible sites and orders for peat production.

b) The sub-study on forestry focuses on evaluation of harmful effects of forestry on small lakes and ponds to promote sustainable planning of forestry.

c) The hydropower sub-study describes in detail different conflicts and options related to hydrologically and morphologically heavily modified water bodies.

d) The sub-study on protected areas develops criteria for assessing conservation values of Natura 2000 areas in relation to the Water Framework Directive (WFD) and puts these into practice for guiding water managers and spatial planners alike.

2 Background Information

Seppo Hellsten, Teemu Ulvi and Jaana Rintala

2.1 General characteristics of the river basin

The Oulujoki River Basin is located between latitudes 64 and 66 in the province of Oulu in northern Finland (Fig. 1). The main constituents of the river basin are the River Oulujoki, Lake Oulujärvi and the Hyrynsalmi and Sotkamo watercourses. The area of drainage basin covers 22 841 km^2 with a lake percentage of 11.4 %. The Oulujoki watercourse discharges into the Bothnian Bay, which is the northernmost part of the Baltic Sea, with a mean annual discharge of 259 m^{3}s^{-1}. The Bothnian Bay is a shallow basin characterised by oligohaline properties (1-3 ‰) and an ice-covered period of more than 6 months. The sea area is heavily influenced by fresh and humic rich river waters entering from both Finland and Sweden.

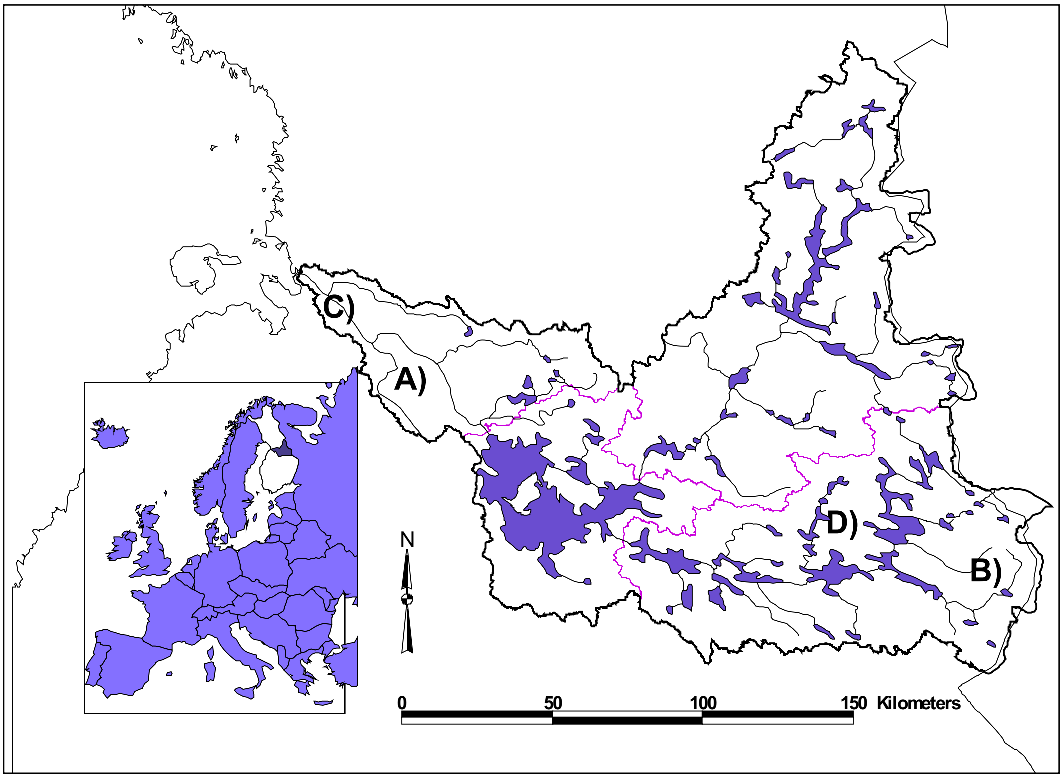

Fig. 1: The location of the Oulujoki River Basin. Main sub-basins are delineated by purple lines. Case study areas A) Peat production, B) Forestry, C) Hydropower, D) Protected areas

According to the Water Framework Directive (WFD), the whole basin belongs to the Fenno-scandian Shield Ecoregion, and the Bothnian Bay is part of the Baltic Sea Ecoregion. Most of the river basin is located in lowlands (altitude <200 m) with only a few hills reaching mid-altitude (200 to 800 m). The river basin is very typical of Finland and also of the northern part of Sweden, with granites and gneisses covered by till formation. The vegetation cover is characterised by pine- and spruce-dominated taiga forests, which start in Sweden and continue eastward across Russia for thousands of kilometres. In addition to forests, there are significant amounts of peatlands covering more than 40 % of the land area. These peatlands are divided into wooded and open ones.

The Oulujoki drainage basin is the sixth largest in Finland, and it is divided into 9 sub-basins. It contains more than 3 000 lakes that are larger than 4 hectares each. The number of lakes larger than 10 km^2 is 24. The biggest lake is Lake Oulujärvi (928 km^2). From the viewpoint of the WFD, there are 398 lakes with a size above 50 hectares. The lakes are mainly very shallow with an average depth of less than 5 metres. The total length of the main river is more than 1000 km. There are very large tributaries consisting of small rivers and brooks providing a network of rich habitats.

The hydrology of the area is characterised by a relatively continental climate with a thick long-term snow cover causing relatively abundant spring floods. The natural water level variation is usually 1-2 metres, reaching 4 metres in some specific river areas.

Most of the lakes and rivers have humic rich waters typical of Finland, but there are also pristine clear-water lakes with very low phosphorus concentrations and low biological production. In the upper reaches of the watercourse the waters are generally rich in humus, and their oxygen content decreases considerably during the ice-bound period.

Closer to the estuary of the River Oulujoki the water is slightly humic, quite brown and relatively eutrophic. The total phosphorus concentration normally varies within 10-20 µg/l and may be as high as 30-50 µg l^{-1} during flood periods. The total nitrogen concentration varies within 250-350 µg l^{-1}, reaching twofold values in the flood period. The pH value varies within 6.4-7.0. In the springtime, pH may be as low as 5.

According to the current Finnish water quality usability classification system, most parts of the Oulujoki River Basin belong to usability class II (good). The high humus content of the water and the significantly lowered oxygen contents in the winter period often result in watercourses in nearly natural state being categorised into class III (satisfactory) even when no point-source pollution is present.

2.2 Descriptions of significant pressures caused by human activities

The whole river basin is sparsely populated; at the beginning of 2000 the total population in the 18 municipalities located in the river basin was approx. 262 000, which means less than 12 inhabitants per km^2. The biggest cities in the area are Oulu (capital of the Northern Ostrobothnia region, 127 000 inhabitants) and Kajaani (capital of the Kainuu region, 36 100 inhabitants).

The natural conditions of the watercourse have been affected mainly by dredging carried out to serve agriculture and forestry, timber floating and hydropower production and by drainage, damming, flow regulation and discharge of wastewaters. The Oulujoki watercourse is the one most heavily developed for hydropower production in Finland with a construction efficiency of more than 80 %. The river stretch from Lake Oulujärvi down to the mouth of the river has several power plants and run-of-river-impoundments. The two lake chains, Sotkamo and Hyrynsalmi, have also been developed, but the uppermost part upstream from the town of Kuhmo is still in a natural state and protected by law. The installed hydropower capacity is 559 MW, i.e. about one fourth of all hydropower capacity installed in Finland. In a hydrologically average year, the power plants in the Oulujoki watercourse produce a total of 2522 GWh. There are altogether 18 hydropower plants in the river basin: 8 in the River Oulujoki and 5 in each of the Hyrynsalmi and Sotkamo watercourses. No new hydropower plants are to be constructed, but the capacity and energy production of the existing power plants can be increased to some extent by renewing the machinery.

Nearly 60 % of the lake area in the Oulujoki drainage basin is regulated for power production purposes. The largest regulated lake is Oulujärvi, whose area at the mean water level is 928 km^2. The total area of the regulated lakes is 1450 km^2 at the mean water level. The tolerances allowed in the operation rules are great, and the allowed water level differences are considerable in the Oulujoki watercourse compared to the other Finnish watercourses.

The total storage capacity of the regulated lakes is 4177 million m^3. The annual flow at the outlet of Lake Oulujärvi, calculated on the basis of the average discharge, is about 7100 million m^3; hence, about 60 % of the annual flow can be stored in the regulation basins.

In addition to hydropower production, water level regulation also serves flood protection purposes. Most of the rivers were also used and modified for timber floating, which was discontinued in the early 1980s, and many rivers have since been restored.

One of the most significant uses of the watercourse is for recreational fishing and for utilisation of shore areas. The number of summer and leisure homes totals 13 000 in the area. In addition to small-scale professional boat traffic, a significant amount of leisure boating is carried out on the lakes.

The municipal water supply primarily draws on groundwater because of its reliability and good quality. The city of Oulu still uses surface water from the river as its main source of drinking water. Especially during the spring flood, the quality of raw water is poor. The water supply from the water distribution network in the area has approx. been 250-300 l/d per capita for decades. This figure also includes the industrial water use from the network. The greatest industrial water users are wood processing, chemical industries, and fish farming.

The usability category has declined at the mouth of the River Oulujoki and in the adjacent sea area due to effluents from pulp and paper, and chemical industries, as well as municipal sewage. In Lake Oulujärvi near the city of Kajaani, usability has been impaired by wastewaters from pulp and paper industry and municipalities. Municipal sewage causes adverse effects downstream of municipal centres, although the effects are often spatially limited. In general, waters in the usability class 'excellent' are found in esker areas, where the humus content of the run-off is low and the proportion of groundwater is high. This situation prevails especially in the northernmost part of the basin.

Wastewater pollution is most abundant in the water areas downstream of the cities of Oulu and Kajaani. Elsewhere, the pollution load is less heavy and originates from non-point sources. For most municipal wastewaters, treatment plants have already been constructed. 69 % of the population of the whole province were connected to the public sewer network in 1990. The pollution load from the pulp and paper industry has been diminished by in-plant measures and by implementing biological treatment of wastewaters in the 1980s.

At the mouth of the River Oulujoki, the chemical industry has substantially reduced the pollution load and thereby diminished the adverse environmental effects. Fish farming increased rapidly in the 1970s and was most common in the 1980s. Most fish farms are located in the eastern part of the river basin.

Non-point source loading in the River Oulujoki is significant (Fig. 2). The proportion of point source loading varies within 4-35 % for phosphorus and within 10-62 % for nitrogen, depending on the size of the studied area. Locally, the effects of point source loading may be very heavy. The biggest non-point sources are agriculture, forestry and rural settlements, as well as some peat production areas. Altogether, the estimated phosphorus flow into the whole river system is 532 kg d^{-1} and nitrogen flow 14 023 kg d^{-1} as a three-year average (2000-2002).

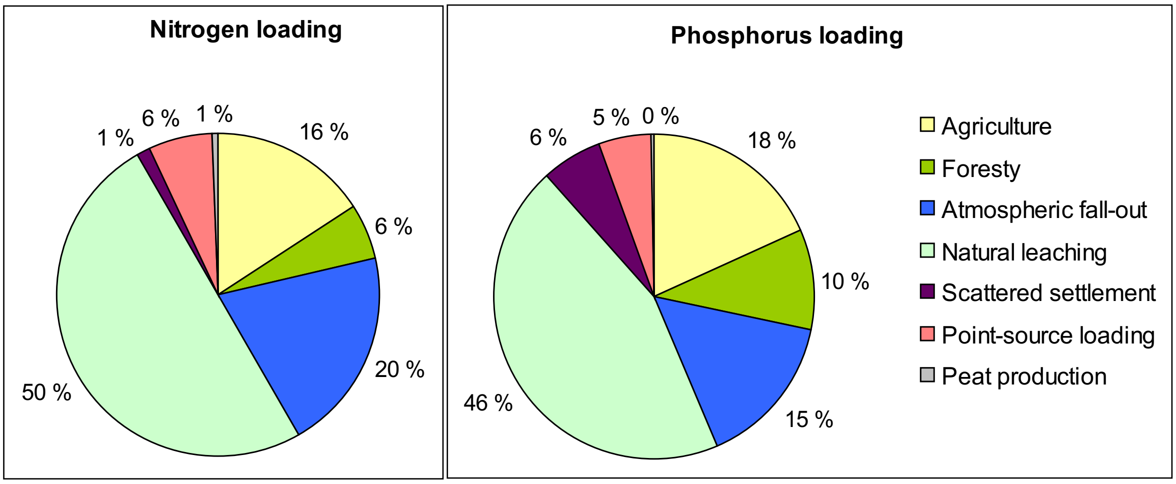

Fig. 2: Phosphorous (right) and nitrogen (left) load distribution of Oulujoki River Basin. (Source Hertta-database, SYKE)

2.3 Risk analysis at national level

The general usability classification of water bodies indicates the average suitability of the water bodies for water supply, fishing and recreation in Finland. The quality class determination is based on the natural quality of the water and human impacts. The water bodies have been classified into five classes: excellent, good, satisfactory, passable and poor.

The main lakes of the Oulujoki River Basin are mainly classified as good or even excellent status, although rivers are suffering of nutrient load from diffuse sources (Fig. 3). On the other hand, this national usability classification does not take into account hydromorphological modifications, and therefore, for example, the main stream of the River Oulujoki is classified as good status although the whole river stretch is fully developed for hydropower production.

Art. 5 on reporting according to EU Water Framework Directive produced the following view of the Oulujoki River Basin (Fig. 4). It should be noted that at this stage Finland only reported rivers with a catchment area larger than 1 000 km^2 and lakes larger than 40 km^2. Almost all large rivers and two large lakes (Lakes Vuokki and Ontojärvi) are significantly altered by water level regulation.

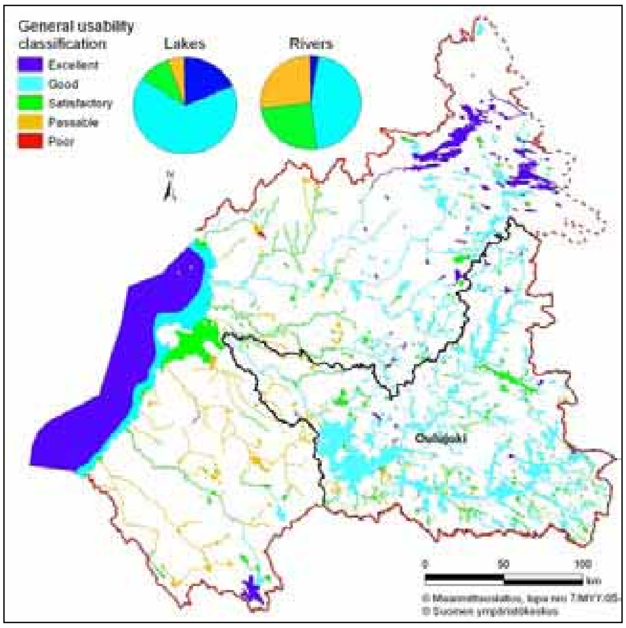

Fig. 3: Distribution of different usability classes of surface water units of the Oulujoki River Basin. Classification is based on results of water quality of 2000 – 2003 and percentage distribution is a summary of total river and lake area. See classification details in http://www.ymparisto.fi/download.asp?contentid=34514&lan=EN

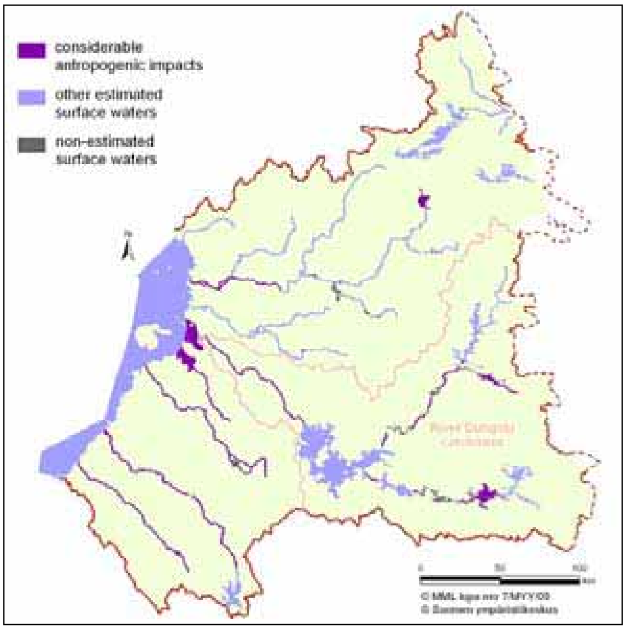

Fig. 4: Significant human impacts on large rivers and lakes of the Oulujoki River Basin based on Art. 5 on reporting in the WFD (modified from Aronsuu and Isid 2006).

3 Environmental and water related problems

3.1 River basin scale

The main environmental problems of the Oulujoki River Basin are relatively limited and focused on heavily modified rivers and lakes. Migratory fish have largely lost their spawning grounds and continuity of rivers has been interrupted by dams and weirs. Natural spring floods have been cut down causing deterioration of flood meadows and further limitations for spring spawning fish. Winter drawdown of lake water levels has also largely changed communities of aquatic macrophytes and benthic invertebrates.

Eutrophication problems, caused by the total loading imposed to the river, have been concentrated in the downstream areas of the river. However, eutrophication can also be observed in some lakes surrounded by agricultural areas. A general description of different problems is presented in the following pressure matrix:

The relative effects of different factors in the pressure matrix are largely related to scale. In tributaries or small brooks effects of separate loading sources, such as forestry and peat production can be significant, whereas in the mainstream of the river the effects can be hardly visible. A more detailed view of impacts is shown in the following chapters 3.2. – 3.5.

	Impacts =>	Physico-chemical quality elements													Biological quality elements						Hydromorphological quality elements			
<= Pressure		Transparency	Temperature	Oxygen conditions	Conductivity	Salinity	Nitrogen	Phosphorous	Suspended solids	Diss. org. matter/Humic subst	Acidification	Priority substances	Other pollutants		Phytoplankton	Planctonic blooms	Macrophytes	Benthic invertebrates	Fish		Hydrological regime	Morphology	River continuity	Tidal regime
Diffuse sources	Scattered settlements sewage	Low		Low			Low	Low							Low		Low	Low						
	Agriculture diffuse	Low		Low	Low		Low	Moderate	Low						Low	Moderate	Low	Low	Low					
	Forestry	Low		Moderate			Moderate	Moderate	Low	Moderate		Moderate			Moderate	Moderate	Low	Moderate	Moderate		Low	Low		
	Urban storm waters																							
	Atmospheric deposition						Low				Low				Low		Low							
Point sources	Industrial wastewaters	Low	Low	Low	Low		Low	Low	Low			Low			Low	Low	Low	Low	Low					
	Municipal wastewaters	Low	Low	Low	Low		Low	Low	Low			Low			Low	Low	Low	Low	Low					
	Mining											Low												
	Contaminated lands											Low												
	Animal husbandry	Low		Low	Low		Low	Low							Low		Low	Low						
	Solid waste management						Low	Low																
	Aquaculture			Low			Low	Low							Low	Low	Low	Low	Low					
	Peat production	Low		Low			Moderate	Moderate	Moderate	Moderate					Low	Low	Low	Low	Low					
Abstraction	Raw water supply																							
	Agriculture																							
	Industry																							
	Fish farming																							
	Hydropower																				Low			
	Open cast coal mining																							
Morphological pressures	Dams (transversal)		Low																High		High		High	
	Weirs (transversal)																		High		Low		Moderate	
	Longitudinal embankments																				Moderate	Low	Moderate	
	Straightening																					Moderate		
	Dredging																				Moderate	High		
	Shore protections																					Moderate		
	Urbanisation																							
Hydrological pressures	Flow regulation (rivers)																				High			
	Hydropeaking																				High			
	Level regulation (lakes)																Low	Moderate	Moderate		High			
	Change in riverprofile		Low	Low					Low	Low					Low		High	High	High		High	High	High	
Other anthropogenic pressure	Recreation																							
	Fishing/angling																							
	Climate changes																				Low			
	Land drainage (forestry)						Low	Low	Low	Low	Low	Low			Low	Low	Low	Moderate	Low		Moderate	Low		
	Overgrazing																							
	Introduced species																Low		Low					
	Introduced diseases																							

Not present

No effect

Low impact

Moderate impact

High impact

3.2 Environmental effects of peat production on the River Muhosjoki

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3.2.1 Introduction

As a result of this case study an example of an environmental impact estimation process in regional planning of land use in a river drainage basin is presented. The main problem relates to the planning of new land use activities in a river basin while ensuring that the environmental effects of the loading on the status of the river are as minor as possible. The most important tool in this work has been the RiverLifeGIS-tool that makes it possible to reach comprehensive, total drainage basin estimations not only of the loading but also of the effects of the loading on river water quality.

Finland is a country of peatlands, which cover wide land areas especially in the drainage basins of the rivers in the northern part of the country. Peat is also an important domestic energy source in Finland. The direct employment effects of peat production are important especially in northern Finland. In 2000, 18 000 hectares of peatland were used in energy peat production in North Ostrobothnia. At present 7-7.5 million m^3 peat are harvested annually producing roughly 7 000 GWh energy. Peat can be produced from the same field for 15–20 years, and it has been estimated that at the present production level 30 000 hectares of new peat production area are needed until 2030.

In this case study a planning system for the assessment of the environmental impacts of new land use activities in a river drainage basin has been presented. Peat production has been used as an example of a new loading source.

3.2.2 General effects of peat production

When establishing a new peat production area the peatland is ditched, its vegetation removed and the fields levelled and shaped. As a result of these actions the runoff from the area, and often also the substance concentrations in the runoff water increase, resulting in an increased transport of suspended solids (SS), organic matter, nitrogen, phosphorus and iron from the area (Sallantaus 1983, 1986, 1988, Stenbeck 1985, Heikkinen 1990a). This causes many kinds of changes in the aquatic environment. Environmental effects of the loading have been reported in bacterioplankton (Heikkinen and Visuri 1990), periphyton algae (Marja-aho and Koskinen 1989), zoobenthos (Stenbeck 1985) and fish (Laine et al. 1996, Laine et al. 2001). Also, increases in the amount of particulate, finegraded organic matter on the riffle beds of boreal streams have been noticed (Laine and Heikkinen 2000).

Loading from peat production areas can nowadays be decreased with many kinds of water pollution control structures, such as field ditch retainers, sedimentation basins and wetlands constructed on peatlands (Ihme et al. 1991a, Ihme et al. 1991b, Savolainen et al. 1996). These methods are widely used in the Finnish peat production areas.

In Finland, peat production is tightly regulated and requires a permit from the environmental permit authorities. The permit is given on the basis of the Environmental Protection Act and the Water Act. An Environmental Impact Assessment (EIA) is carried out, when a new peatland area over 150 hectares is taken into peat production. Environmental permits stipulate the water pollution control of peat production. They also contain maintenance and monitoring obligations and possible additional measures for compensation requirements.

Area reservations for the planned peat production areas over 150 hectares were supposed to be presented in the Master Plan, which guides the amount and locations of peat production. However, environmental permit is also always needed. Peat production was the most problematic issue receiving the largest number of complaints in the preparation of the new Master Plan in North Ostrobothnia, mainly due to its environmental impacts and general nature conservation issues. In the final stage, peat production was left out from the Master Plan.

3.2.3 Environmental impact pattern of the loading in flowing water

The concept of nutrient spiralling (Newbold et al. 1981, Elwood et al. 1981) forms an important basis for the estimation of the extent of influence of the loading in the river channel network. According to this concept nutrients, nitrogen and phosphorus, are transported along a spiral route, as it were, down the river channel, being repeatedly retained and released by the river channel food webs (vegetation, microbes, zoobenthos and fish). Phosphorus is transported mainly as described, but nitrogen can to a certain extent also leave the water through nitrification-denitrification processes.

The concept of nutrient spiralling means that in flowing water ecosystems environmental effects of loading are not confined to one location. For water pollution control in practice, this means that the whole river channel below the loading source should always be seen as the ecological impact area of the loading. It also means that the loading may have detrimental environmental impacts not only on the nearest river channel areas below the loading sources, but often also on the lower river stretches, and eventually even on the river mouths, where the total loading introduced to the river is accumulated.

In applied water pollution control it is important to distinguish the areas of compensable damages from the areas of ecological impacts. The areas of compensable damages are often restricted to the nearest areas below the loading sources, although the ecological impact area of the loading is the whole river channel below the loading source. Possible compensable damages should naturally be checked with regards to the whole area of ecological impacts. A good example of locally compensable damages is the silting of a headwater stream, which is of value to a fishery, due to the suspended solid loading from a peat production area.

3.2.4 Tasks in the integrated planning of new land use activities in a river basin

The main tasks in the integrated planning of new land use activities in a river basin (Fig. 5) include assessment of the present and target ecological status of the river, identification of hydromorphological and pollutant loading pressures affecting the status of the river, assessment of the environmental impacts of the new land use activity, planning effective water pollution control measures and making recommendations for environmental impact monitoring and possibly also for the site selection regarding the activity. After the land use project has been realised, it is important to monitor its environmental impacts. This integrated approach was applied to the Muhosjoki River Basin.

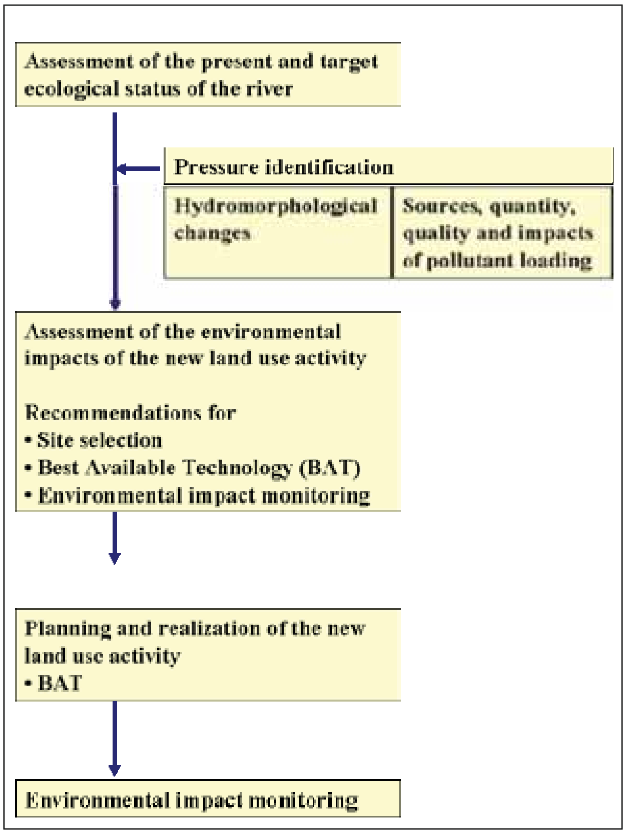


Fig. 5: The main tasks in planning new land use activities in a river basin

3.2.5 Assessment of the present and target ecological status of the river

3.2.5.1 Study area

The Muhosjoki River Basin is one of the main tributaries of the River Oulujoki, with a length of 59 km and a drainage basin area of 537 km². Main tributaries of the river are the Rivers Poikajoki, Kangasjoki and Leppijoki with smaller tributaries, such as the Stream Hanhioja (Fig. 6). The Stream Hanhioja was re-directed in the early 1990s so that it meets the River Muhosjoki 12 km further downstream than before.

The river basin is dominated by forests situated both on mineral and peat soils (Fig. 6). Open peatlands, mainly minerotrophic aapa-mires, account for about one third of the area. Arable land is concentrated at the lower stretch of the river channel, although fields are common near the riverbanks and also in the headwater areas of the river.

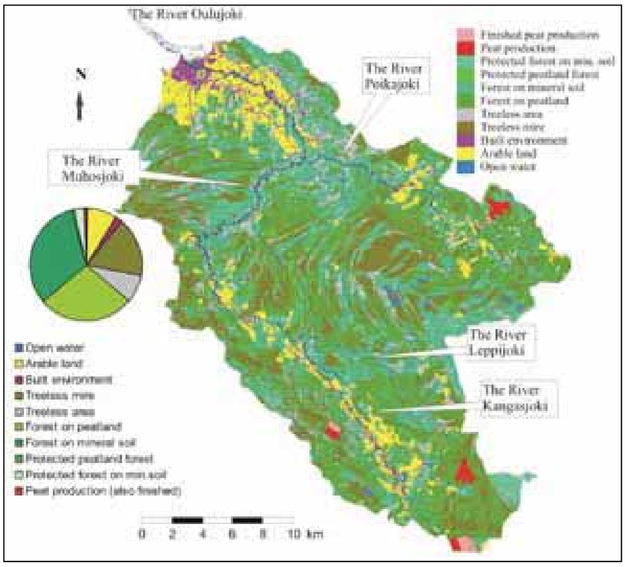


Fig. 6: The main tributaries and land use of the River Muhosjoki drainage basin. Peat production areas from north to south: Keisarinsuo-Timonsuo, Hanhineva, Petäikönsuo and Pelsonsuo. Source: Generalisation of Corine Land Cover 2000 (©SYKE, partly © MMM, MML, VRK), Natura 2000 areas (©SYKE) and peat production areas

There are four peat production areas in the river basin (Fig. 7, Table I). These areas have been drained between 1973-1988, and peat production was carried out during 1975-1991. The drainage waters from Keisarinsuo-Timonsuo and Pelsonsuo are purified with sedimentation basins and those from Hanhineva with an evaporation basin. The most effective water pollution control measures, sedimentation basin, peak runoff control and wetland constructed on peatland, have been constructed in the Petäikönsuo peat production area. Drainage waters from the peat production areas flow via the Vesalankanava Canal, the streams Hanhioja, Mato-oja and Kangasoja and the rivers Kangasjoki and Poikajoki to the River Muhosjoki.

Peat production area	Drained in	Peat production started in	Water pollution control structure	Drainage waters are discharged to
Hanhineva	1982	1985	Evaporation basin	The Stream Hanhioja
Keisarinsuo-Timonsuo	1982	1986	Sedimentation basin	The River Poikajoki
Petäikönsuo	1988	1991	Sedimentation basin Peak runoff control Wetland constructed on peatland	The Stream Mato-oja The Stream Kangasoja The River Kangasjoki
Pelsonsuo	1973	1975	Sedimentation basin	The Vesalankanava Canal

Tab. I: Peat production areas in the Muhosjoki River Basin

Several sampling sites (Fig. 7) were chosen from the river on the basis of existing previous data on water quality and biological quality elements and also on the basis of site location in relation to the peat production areas. The characteristics of the sites were considered on the basis of water quality, benthic diatoms, aquatic macrophytes and fish.

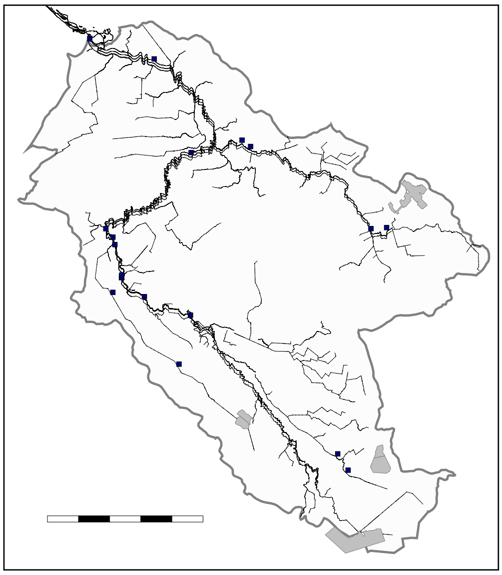


Fig. 7: Sampling sites in the River Muhosjoki and tributaries, peat production areas marked with grey colour

3.2.5.2 Water quality

Material and methods

Most significant water quality parameters of the river drainage basin were selected from the Hertta database of the Finnish environmental administration, and their median values were computed. Median values were selected instead of average values, so that the single extreme values could not have too big an effect on the result where the number of observations is small.

In order to find potential differences between the different sites in the river channel network and potential long-term trends for change in the status of the river, the behaviour of total P concentration was reviewed from the existing databases of the River Poikajoki and the mouth of the river. Total P concentration of the river water was chosen as the target parameter of the study mainly because of its conservative nature. There are no biogeochemical processes that remove P from the river channel, like for instance nitrification-denitrification process in the case of nitrogen. Total P is also largely transported as particulates (suspended solids (SS), living/dead algae) in the riverine environment. Differences could have been created mainly because of the cumulative behaviour of the nutrient and suspended solid loading introduced to the river channel (The Concept of Nutrient Spiralling, Newbold et al. 1981, Elwood et al. 1981). The monitoring programmes of the River Muhosjoki, as generally all monitoring programmes for the rivers in Finland, have so far not included monitoring of the effects of non-point source suspended solid (SS) loading. There has also been no systematic monitoring of biological parameters. For these reasons possible symptoms of deterioration in the rivers have to be sought on the basis of water quality, the monitoring of which has long traditions in all the Finnish river basins.

The water quality of the river was also classified according to the general (Finnish) usability classification of water bodies, using, however, the colours and class names of the ecological status classification developed for the EU Water Framework Directive.

Results

The water in the River Muhosjoki is organically coloured, with high Fe concentrations (Table II), as are most streams and rivers draining peatlands in Finland (Wartiovaara 1978, Heikkinen 1989, 1990a) and in the world (Meybeck 1982). In the northern boreal river waters of the area there is an increase in water colour value with increasing concentrations of dissolved organic matter (DOM) and Fe (Heikkinen 1990b). The DOM consists mainly of humic substances (HS), which effectively absorb light in water and thus affect the growth of biota in rivers and lakes of the area.

In applied water pollution control work it has been generally thought that, because of the HS light absorption, the organically coloured rivers could tolerate more nutrient loading without the same deteriorating effects of eutrophication than the clear water rivers. It is, however, known that the most important algae group in the riverine environment, the periphyton algae, grows at the river bottoms, being concentrated mainly in the rapids of the river channel. In these areas the water depths during the growing season in summer are so low that the effect of light absorption by HS in water probably remains very small. It is thus important to decrease nutrient loading also in the humic river environment to avoid an overgrowth of periphyton algae.

The median concentrations of suspended solids (SS) in the river water are small (Table II). This result does not, however, guarantee that the water quality in this respect is good year-round for example for the fish. It has been noticed that SS loading imposed on the rivers of the area causes siltation even in the rapids of the river channel (Laine and Heikkinen 2000, Laine et al. 2001). This siltation results in a deterioration of the reproduction and feeding habitats of fish (Laine et al. 2001). In Finland SS also carries iron to the river bottoms, which seems to have harmful effects on river biota (Vuori 1995). For many reasons siltation seems thus to be one of the major threats caused by land use in the drainage basin, including agriculture, forestry and peat production, as generally in all northern boreal river ecosystems. It is thus necessary to decrease SS loading imposed on the river.

The waters of the River Muhosjoki are characterised by high nutrient concentrations (Table II). According to the classification of Fedólfy (1976), the trophic state of the River Muhosjoki main channel (M1, M4, M7, M8, M10) ranges from eutrophic to eupolytrophic, that of the River Poikajoki (P1, P3) from eutrophic to polytrophic, and that of the Stream Kangasoja (K1) from eutrophic to eupolytrophic. According to the estimation method of Forsberg et al. (1978), both N and P are nutrients limiting algae growth in the river and can gradually deteriorate the state of the river bottom as the living environment of the river biota.

Site	Tot.P (µg/l)	PO_4-P (µg/l)	Tot.N (µg/l)	NH_4-N (µg/l)	NO_3-N (µg/l)	SS (mg/l)	Fe (µg/l)	Colour (mg Pt/l)
M1	55	32	810	86.5	380	12	4050	170
M4	49	37	810	67	350	6.9	3800	160
M7	46.5	36	720	135	300	7.25	3650	160
M8	49.5	34	795	24	330	8.4	4700	180
M10	85	51	890	142.5	360	6.2	3100	140
P1	132	117	811	94	117	18	3100	350
P3	97	67	755	32	360	4.6	3700	200
K1	63	52.5	718	189	252.5	4.9	4130	250

Tab. II. Median values of water quality in the River Muhosjoki as long term average.

On the basis of the changes in total P concentration symptoms of deterioration can be seen in the River Muhosjoki because of loading. These symptoms are concentrated at the mouth and lower parts of the river channel network, as in rivers generally. In contrast to the upper sampling site of the River Poikajoki, clear momentary intensive increases in total P concentration (Fig. 8) can be observed at the mouth of the river almost regularly during 1997-2004. There is also an increase in total P concentration at the mouth of the river during the 1990s. The increase in total P concentration downstream can, however, at least also partly be a consequence of higher discharge and more easily eroded bottom substrate at the lowermost part of the river. One reason for the increased total P concentration during the 1990s is likely to be the dredging of the river channel.

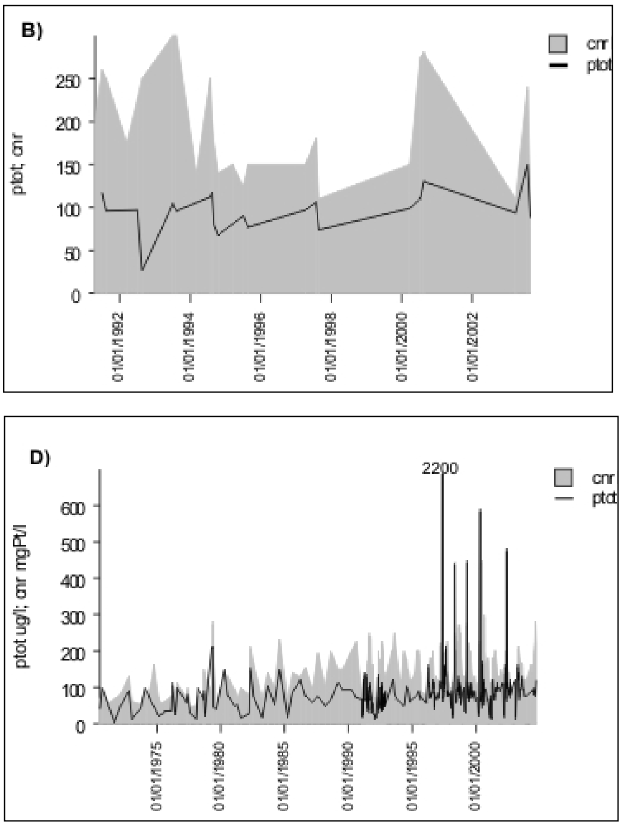


Fig. 8: Total phosphorous concentration (µg l-1) and water colour (cnr, mg Pt l-1) of the River Poikajoki P3 (left) and the River Muhosjoki mouth M10 (right)

According to the current water usability classification, the state of a large part of the River Muhosjoki is poor (passable) and that of the River Poikajoki even bad (poor) (Fig. 9).

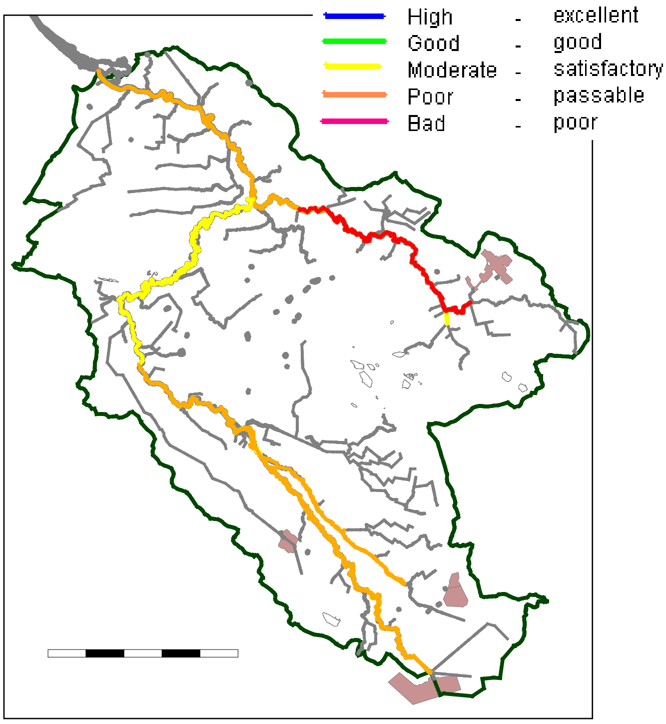


Fig. 9: Water usability classification of the River Muhosjoki based on the median concentrations of total P. Water quality is classified according to the general (Finnish) usability classification of water bodies. The colours and class names are taken from the ecological status classification (WFD).

3.2.5.3 Diatoms

Material and methods

Diatoms in periphyton are widely used for the assessment of water quality as their community structure reflects the water quality over longer period of time than just a single water sample. The sampling of epilithic diatoms was carried out according to the standard SFS-EN 13946 in the River Muhosjoki and its tributaries the Stream Hanhioja and the River Poikajoki (Table III, Fig. 7) in August 1–9, 2005.

The diatom slides were prepared and analysed according to the standards SFS-EN 13946 and SFS-EN 14407. Three diatom indices, IPS, GDI and TDI, were used in the water quality classification. These indices have been found suitable to Finnish rivers, and water quality classifications based on these have been presented by Eloranta and Soininen (2002). Two of the diatom indices used expressed general water quality and especially organic pollution: IPS (based on all species) and GDI (based on all genera). However, Eloranta (1995) noticed that the effects of humic substances on diatoms are not equivalent to those of organic wastes, e.g. sewage. The classification levels in the TDI index relating to nutrient levels range from oligotrophic to eutrophic, even if Hofmann (1996) has criticised the index as being restricted from mesotrophic to hypereutrophic conditions.

In addition to the indices, ecological spectra were also used to distinguish the differences in diatom communities of different sampling points. For this Van Dam's et al. (1994) ecological spectra of trophic state, saprobity (organic pollution), oxygen requirements, nitrogen uptake and pH classes were used.

Site	Phosphorus concentration ug/l: Long term median	Phosphorus concentration ug/l: Diatom sampling date	Diatoms: IPS	Diatoms: GDI	Diatoms: TDI	Real aquatic macro phytes: EQR	Riparian species incl.: EQR	Avg state of the water
MO1						0.00	0.05	MO1
K1	63							K1
H1		21	18.8	18.0	16.3	0.16	0.27	H1
H2		42	18.7	16.8	16.3	0.16	0.21	H2
P1	132					0.16	0.27	P1
P2		160	12.5	15.1				P2
P3	97	110	14.2	15.2	8.9	0.24	0.32	P3
M1	55	36	16.8	16.0		0.32	0.42	M1
M2						0.64	0.64	M2
M3						0.56	0.53	M3
M4	49	36	16.8	16.0	10.8	0.64	0.69	M4
M5		36	17.4	16.3	10.8			M5
M6						0.56	0.53	M6
M7	46.5	37	17.6	16.7	12.3	0.48	0.48	M7
M8	49.5	39	16.7	15.7				M8
M9						0.40	0.42	M9
M10	85					0.40	0.53	M10

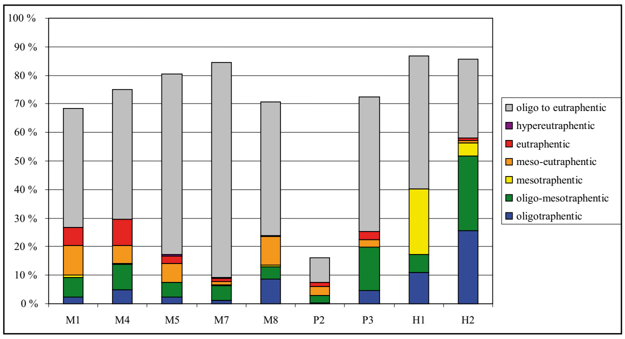
Tab. III: Summary of different indicators and quality classes used in the case study. Sites are pre sented in the Fig. 7 and colour indicators in Fig. 9.

Results

Diatoms formed dense populations on stones in the Stream Hanhioja (H1, H2). According to the diatom community analysis and the indexes used the stream had high water quality according to the IPS index (Table III). Only at the lower sampling point (H2) the generic index (GDI) indicated good water quality. The trophic index TDI indicated high water quality (oligotrophic conditions). In the River Poikajoki (P2, P3), the water quality was moderate according to the IPS index and moderate (mesotrophic) according to the TDI index. The GDI index, however, indicated good water quality, being slightly above the lowest limit of the good water quality class. In the River Muhosjoki the water quality was mainly good according to the IPS and the GDI indexes. In the main channel the TDI index assigned the mesotrophic class to the sampling points above the mouth of the Stream Hanhioja (M1, M4, M5), but the oligo-mesotrophic class below the stream (M7). However, further down from the Stream Hanhioja the water quality of the River Muhosjoki weakened again to mesotrophic on the TDI index.

In all the sampling points of the River Muhosjoki the dominating diatom taxa was beta-mesosaprobic indicating organic pollution of BOD5 level 2–4 mg l-1 (Fig. 10B). The data on the diatoms from the Stream Hanhioja also showed indications of the local effects of a loading source, namely the peat production area. In the sampling point H1, closest to the peat production area, there was more mesotrophic, alpha-mesosaprobic and nitrogen-autotrophic species, and taxa with only moderate (> 50 % oxygen saturation) oxygen requirements than in the sampling point H2 further downstream. Also, the diatoms requiring acid conditions were more abundant. The differences are probably due to an increased nutrient and organic pollution level because of the loading from the peat production area.

A)



B)

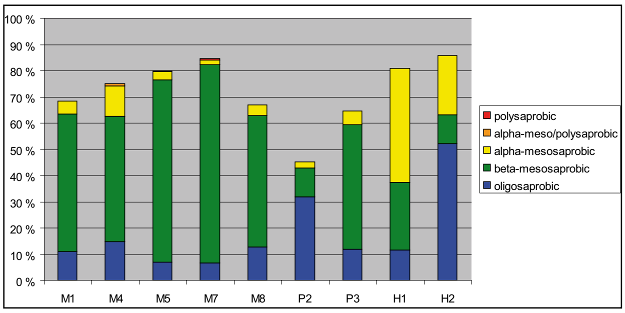


Fig. 10: Distributions of diatom taxa in different classes of trophic state (A) and saprobity (B) in rivers Muhosjoki, Poikajoki and Hanhioja

3.2.5.4 Aquatic macrophytes

Material and methods

Submerged macrophytes are sensitive to changes in water and habitat quality. They integrate pressures over long time periods because they are relatively long-living organisms. Their composition and abundances reflect several factors, for example water quality, catchment and sediment characters, fluctuation of water level and stream velocity. Macrophytes may be, however, unable to detect small changes in the environment of systems with very low species numbers and sparse abundances, such as woodland streams and swiftly flowing rivers (Skriver 2001). In these types of environment their usability as monitoring organisms is limited.

Macrophyte data was collected in the River Muhosjoki on August 5, 2003 (Hellsten et al. 2005) and in its tributaries between August 1-18, 2005. Macrophyte species (vascular plants and braids) growing in the channels and on the river banks were recorded on defined survey lengths (200 m) in the River Muhosjoki (M1 – M10) and the streams Poikajoki (P1, P3), Hanhioja (H1, H2) and Mato-oja (MO1) (Fig. 7). The classification of sites was done according to the number of type-specific macrophyte species. 75 percentile was used as the lower limit of the class 'high' and the EQR (Ecological Quality Ratio) and the values below were divided up equally into four classes. In addition, the EQR values (type-specific species) were calculated. The metrics were calculated separately using data including only aquatic macrophytes and data including both aquatic macrophytes and a determined set of riparian species (helophytes). Data from six rivers situated in Northern Finland, the rivers Jaurujoki, Simojoki, Vuotosjoki, Pärjänjoki, Koutelonjoki and Malisjoki, was used as reference data. Most of these rivers represent the same river type as the River Muhosjoki. The data of reference sites has been collected between 1976-2002 using varying methods and survey lengths.

Results

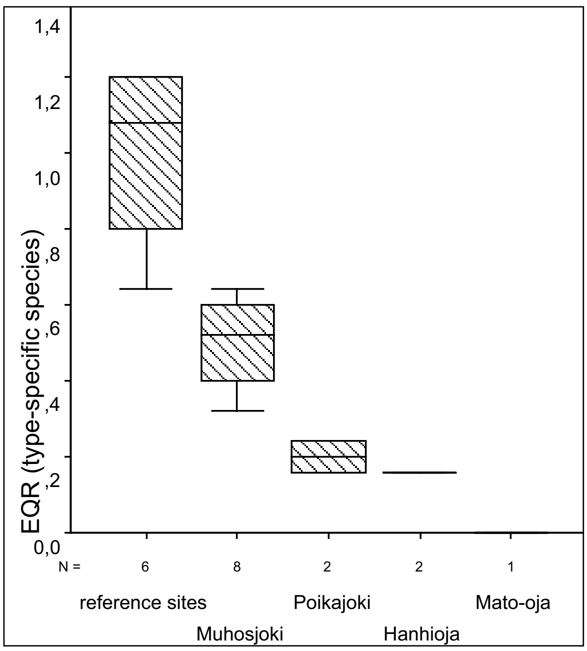
In the River Muhosjoki the number of type-specific submerged macrophyte species ranged between four and eight. The ecological quality (Table III, Fig. 11) of the uppermost stretches of the River Muhosjoki ranged mainly from good to moderate, with an exception of one site (M1, a man-made channel), in spite of the quite high phosphorus concentration of river water in the area. The middle stretches (M6, M7) achieved moderate ecological quality. The two lowest stretches achieved poor quality, and they also showed the highest phosphorus concentrations measured in the river.

The total number of aquatic macrophyte species was very small in the survey lengths of the tributaries. When only the type-specific species are considered, the species number ranged between zero and three. Thus, according to the classification, the lower site of the River Poikajoki was of poor ecological quality, and the upper site of bad ecological quality. In the Stream Hanhioja macrophytes indicated bad ecological quality, as well as in the Stream Mato-oja despite low phosphorus loading.

When riparian species were also included in the consideration, the situation was slightly different in the River Muhosjoki. Only one site reached good quality and most of the sites were of moderate ecological quality. One of the lowest sites and site M1 only achieved bad quality. In the Stream Poikajoki and in the lower site of the Stream Hanhioja macrophytes indicated poor ecological quality. In the upper site of the Stream Hanhioja and Mato-oja the ecological quality was bad.

There are many reasons that limit the suitability of aquatic macrophytes as indicators for loading in the riverine environment studied. The tributaries are narrow woodland streams in which the macrophyte species number is low even in undisturbed reference conditions. On the other hand, reference data of the same river type with tributaries was not available, and the same reference data was used for both the River Muhosjoki and the tributaries, although the tributaries are smaller. Further, the survey lengths are longer in many of the reference sites than in this study. The variation in the survey length and in the width of channel causes variation in the species number. There were also difficulties to find comparable habitats in the tributaries, so the differences for example in stream velocity and sediment characters (grain size) may partly explain the results.

A)



B)

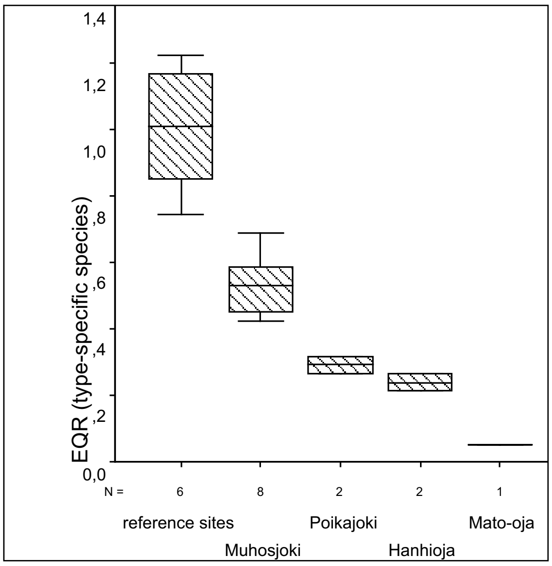


Fig. 11: Aquatic macrophytes in different research areas expressed as ecological quality ratios (EQR) A) Only aquatic macrophytes, B) Riparian species (helophytes) included in aquatic macrophytes

3.2.5.5 Fish

The fish pass past the Merikoski-power station in the lower river Oulujoki was opened in 2003. It allows fish migration from the sea to the next power station (Montta) 35 km upstream from the sea. There are two bigger tributaries in this area, the River Sanginjoki and the River Muhosjoki.

Since the fish pass in Merikoski was opened there has been a wide interest in restoring salmonids (salmon, sea trout and sea whitefish) and a lot of research has been carried out. For example, an extensive research project has been going on in the lower River Oulujoki and in the tributaries, the River Sanginjoki and the River Muhosjoki. This project focusses on estimating the amount of salmon and sea trout breeding grounds and possibilities for an increase in their area (e.g. Tertsunen 2004).

Some habitat restorations in the lower River Oulujoki and in the estuary of the River Muhosjoki have already been carried out. These habitat restorations are very important especially for the River Muhosjoki, because salmonids have not yet found their way to the river. However, poor water quality and the lack of fish being attracted to the estuary of the River Muhosjoki are the biggest problems to be solved, before the sea-based migrating fish species can be restored to the River Muhosjoki.

3.2.5.6 Average state of the river

Materials and methods

The average state of the river main channel and the tributaries was evaluated by giving values 0.1, 0.3, 0.5, 0.7 and 0.9 to state classes bad, poor, moderate, good and high, respectively, calculating mean values for the different state quality indicators (water quality, diatoms and macrophytes), and finally taking the mean values of the different indicator means (Table III, Chapter 3.2.5.3).

Results

On the basis of all the indicators of the study (Table 3) the state of the Stream Hanhioja (H1, H2) is moderate, that of the lowermost River Poikajoki (P3) poor, and of those of the sampling points in the River Muhosjoki (M1, M4, M7) moderate, good and moderate, respectively.

The use of macrophytes as indicators provided the weakest results of status assessment in the headwater streams Mato-oja, Hanhioja and Poikajoki. On the other hand, the use of the GDI index of diatoms presented the highest results of status assessment in almost all the sampling points studied.

The results of the river status assessment indicate that symptoms of deterioration can be seen all over the network of the Muhosjoki River Basin. In order to enable planning for river management and for possible new land use activities in the river basin, reasons for the changes have to be identified.

3.2.6 Pressure identification

3.2.6.1 Hydromorphological changes

The River Kangasjoki is fully dredged and the River Leppijoki was straightened during the 1950s due to flood protection and land drainage purposes (Hellsten et al. 2005). The middle stretch and headwaters of the River Muhosjoki were also dredged during the 1950s and again during the 1990s in order to reduce the harmful effects of spring floods on agricultural fields. Latter activities included the straightening of some meanders and also the building of bottom weirs with artificial rapids in order to decrease the flow of suspended solids. No structural changes in the river channel network have been carried out in the lower stretches of the River Muhosjoki and in the River Poikajoki.

Loading source	Loading kg/ha/yr Total P	Total N	Reference
Agriculture			VEPS[1)], based on model scenarios
- Hanhioja	62.0	1529.9	
- Poikajoki	71.0	1307.0	
- upstream (59.17)	63.3	1327.2	
- avg for Muhosjoki river basin	63.8	1373.6	
Natural leaching			VEPS[1)] - Mattson et al., 2003 and Kortelainen et al., in prep.
- peatland	5	150	
- mineral soil	3.2	70	
Forest			In Northern Finland according to Kortelainen and Saukkonen.
- peatland	11	185	
- mineral soil	10	145	
Scattered settlement (kg/inh./yr)	0.4	2.69	VEPS[1)] - generalised research results, not very accurate in small drainage areas
Holiday residences (kg/resid./yr)	0.145	0.49	
Deposition	10.58	373.26	VEPS[1)]: deposition monitoring stations
Built environment	5.4	145	stormwater (as in VEPS) and natural leaching
Peat production	27	790	VEPS[1)]
- concluded	12	200	Adapted from drained (ditches) peatland forest
- sedimentation basin	41	1200	Monitoring reports
- overland flow field /evaporation basin	23	612	Monitoring reports

[1)]VEPS is a water effluent assessment and management system developed and used in environmental administration in Finland

Tab. IV: Specific loads used in the loading estimations. All the specific loads presented are generalised values, and therefore the results should be considered carefully especially in small drainage areas.

3.2.6.2 Sources, quantity, quality and impacts of pollutants

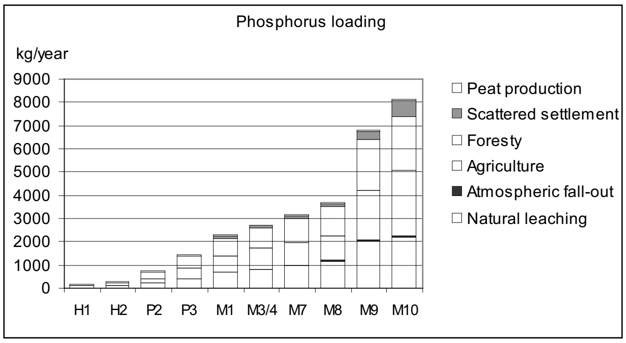
Material and methods

Tot.N and Tot.P loadings above the sampling sites were estimated on the basis of land use GIS data and characteristic loads, i.e. by multiplying the area of the given land use type by its characteristic load (Table IV), and summing up the loads for the different land use types to obtain the total load for the whole basin. The computations were performed using the RiverLifeGIS programme (see Ulvi et al. in this book). The amount of inhabitants and holiday residences of the sampling point's drainage areas was gathered from a GIS-based database of Finnish authorities. In this study a digital elevation model (DEM) at 25 m resolution was used to compute water flow layers needed, and Corine Land Cover 2000 (national data at 25 m resolution) was used as land use data. Local GIS data on peat production areas also includes information on the stage of production and water pollution control measures.

Results

The main sources of anthropogenic nutrient loading in all the sub-drainage basins studied are agriculture and forestry (Fig. 12). Of the total P loading the proportion of peat production ranges from 1.0% to 5.1% and that of the total N loading from 1.4% to 8.8%. The proportions are highest in the upper parts of the River Poikajoki (P2) and the Brook Hanhioja (H1). Besides peat production, there was no point source loading in the area.

There is an increase in the total loading with increasing size of the drainage basin (Fig. 12). This is mainly due to the non-point source character of the loading, which means that the different forms of land use and natural leaching are the main sources of the loading. One reason for the increase is also that the loading estimation was cumulative. Based on the concept of nutrient spiralling (Newbold et al. 1981, Elwood et al. 1981), the whole river channel below the loading source was seen as the ecological impact area of the loading.



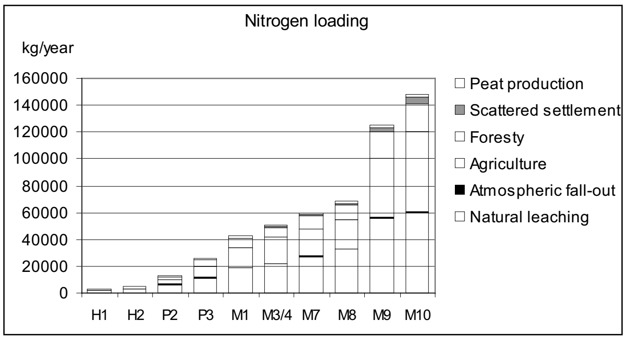


Fig. 12: Amount and distribution of phosphorus and nitrogen loading at different sampling points

3.2.7 Assessment of the environmental impacts of the new land use activity in the drainage basin

The results of the water usability classification and biological classification, based on diatoms and aquatic macrophytes, indicated a weak quality of the River Muhosjoki. The average state of water, based on all the classifications applied, was passable not only in many headwater streams but also at the mouth of the river. This indicates symptoms of deterioration all over the river drainage basin network. There still were, however, also stretches in good ecological quality in the middle stretches of the river.

Local symptoms of deterioration could also be seen on the basis of diatom monitoring. In the upper part of the Stream Hanhioja below the peat production area there was an increase in the diatom taxa indicating mesotrophic conditions and organic pollution. The diatom taxa also tolerate elevated concentrations of organic nitrogen and its oxygen requirements are moderate. The main reason for the change is probably due to an increased nutrient and organic pollution level because of the loading from the peat production area.

The pressure analysis of the river drainage basin showed that the most obvious reason for the weak ecological quality of the river is land use derived non-point source pollution, mainly agriculture and forestry. The proportion of peat production of the total loading is small. The weak ecological quality of the river at the present loading level indicates, however, that the total loading imposed to the river is too high and should be decreased.

Peat production, as all other forms of land use, results in an increased transport of nutrients and suspended solids (SS) to river channels, and thus may weaken the recreational and ecological values of the river further. The results indicate clearly that it is important carefully plan any potential new peat production areas, as well as other forms of land use, taking into account probable environmental impacts. In the first instance this means carrying out local environmental impact assessment and use of effective methods in water pollution control. It is also possible to assess the environmental impacts of the new loading source in advance with hydrological water quality models and estimation tools, e.g. with the RiverLife GIS used in this study.

3.3 Environmental effects of forestry on small lakes

Pekka Korhonen, Sirkka-Liisa Markkanen and Janne Alahuhta

3.3.1 General effects of forestry

Forestry is the major land use activity in Finland - in the upper parts of the Oulujoki catchment almost 85 % of all land areas are used for forestry – giving it an important role in the economy of the Kainuu region. The majority of forested land is owned by the state or private citizens and is actively use for forestry. A section of the Kainuu forests, approx. 7 %, is protected to varying degrees, mainly as strict nature reserves, national parks or old-growth forest protection areas.

Forest management in Finland has changed a lot in 50 years. There was an intensive forest management period between the late 1950s and the beginning of the 1980s. In those days Finnish forestry was characterised by extensive drainage, large scale clear felling and related soil operation, forest fertilising and the construction of a widespread system of forest roads. In the Kainuu region these forest management actions were also very extensive, for instance 67 % (608 000 ha) of the peatland area have been drained for forestry (Tomppo et al. 2003). Since the 1990s ecological, economical, and social sustainability have became a basis for the commercial forest management. To achieve these aims national and regional forestry programmes and forestry planning systems have been developed, which take into account biological and environmental values. New, less harmful methods e.g. for soil preparation and also more effective watercourse protection methods were introduced.

Forestry is estimated to account for 5 % of the nutrient loading on waters in Finland (Ministry of Agriculture and Forestry 2001). In the headwater regions in eastern and northern Finland, where most of the land area is covered by forest, forestry is usually a main loading source beside of agriculture. Forestry operations cause short and long-term effects to watercourses, especially nutrient and suspended solid loadings. Local inhabitants and recreational users have often noticed harmful effects caused by forestry in lakes. These effects appear usually after long periods of constant loading, because environmental changes in lakes are very slow and thus difficult to detect. The most common problem is eutrophication, which can be observed as an increase in the blooming of algae or slight sliming of the shores. These changes also decrease recreation usability of a lake.

The sub-study on forestry focuses on the evaluation of harmful effects of forestry on small lakes situated in the Kainuu region. The sub-study will estimate the ecological status using general methods applied in the WFD, as well as load estimation tools developed in the peat production sub-study to evaluate the effects of forestry. In this study we also examine other useful tools, promote sustainable planning of forestry and evaluate how to apply these measures to regional planning. The usability of databases of local forestry associations (Metsäkeskus, Metsähallitus, UPM-Kymmene) is tested by analysing their data from environmental impact assessments. Other parties involved in this case study were environmental authorities, Kainuu Regional Council and consultants (Environmental. Research Institute etc.)

3.3.2 Description of study area

The research area consists of six different lakes situated in Kainuu in the upper part of Oulujoki river basin (Fig. 13). Four of these lakes (Iso Akonjärvi, Pirttijärvi, Matalanjärvi, Roukajärvi) are surrounded by different forestry activities and two of them (Saari-Kiekki, Itäjärvi) act as reference lakes. Common to the six research areas is, that they are headwater catchments and that there is a high proportion of peatland in the catchment (Table 4). The catchments of impacted lakes are also reserved for forestry in the regional planning. Following the proposal for the typology of Finnish lakes (Pilke et al. 2002) all lakes belong to type 9 (surface area <5 km², colour >90 mg Pt l^{-1}).

The weather in Kainuu is continental with cold, snowy winters, which are also the longest season lasting for from mid-November till mid-April. The thermal growing season begins on average on May 10 and the lakes become ice-free soon after that. The mean annual temperature is approx. +1 °C, the mean summer temperature approx. 14 °C. The mean annual precipitation is about 650 mm, of which about 40 % falls as snow.

The basement of the Kainuu area is formed of 2500-million-year-old Archean acidic granite and gneiss rocks and it is patterned by greenstone belts, where mafic and ultramafic mineralogy prevails (Luukkonen and Lukkarinen 1986). The bedrock is mainly covered by moraine soils, with a mean thickness of 1-5 metres. The Saari-Kiekki, Itäjärvi and Iso Akonjärvi areas are supra-aquatic.

The forests around the reference lakes Saari-Kiekki and Itäjärvi are mostly mature or old coniferous trees (100-200 years), while the northern part of Itäjärvi catchment also has some young cultivated stands. In the catchments of the impacted lakes are mostly regenerated forests with varying age classes. Scots pine (*Pinus sylvestris*) and Norway spruce (*Picea abies*) are the dominant tree species. The Kainuu region is located in the southern aapamire zone (Ruuhijärvi 1988). Mires are typically relatively small, and the landscape is a mosaic of forest, mires and lakes.

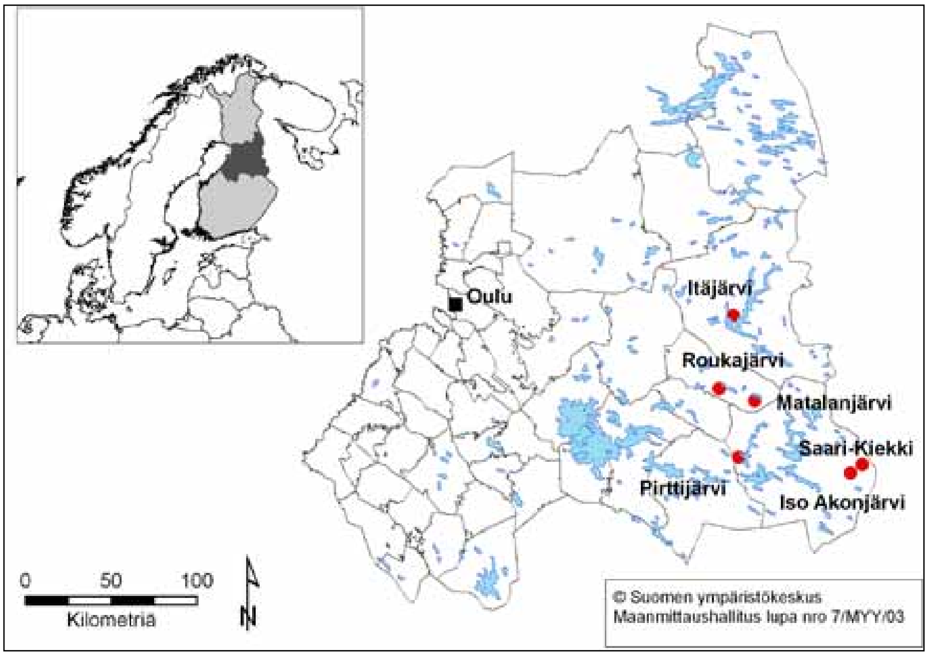


Fig. 13: Forestry case study area in the Oulujoki River basin. Research lakes are marked with red dots.

3.3.3 Determination of environmental effects

3.3.3.1 Loading from forestry

There are many different approaches (mathematical models, assessment and management systems) to estimate loadings to surface waters from land areas (Tattari and Linjama 2004). Common to all approaches is, that they need measured data as background and that they try to simplify complicated natural processes. In this case study the annual loading values for phosphorus were calculated by using land use models with historical data of management (Fig. 14).

The specific load for different forestry operations used varied depending on the time at which the operation had been carried out. These results were compared to P-loading values calculated by the water effluent assessment and management system VEPS, which is an IT-based system providing information on the amount of effluents produced, their distribution among different sources, and temporal changes in the effluent loads. P-loadings from forest areas were also evaluated using specific load values from forests on peatlands (11 kg/a/km) and mineral soils (10 kg/a/km; Saukkonen and Kortelainen 1995).

Status	reference	reference	impacted	impacted	impacted	impacted
lake area, ha	60	55	124	83	36	54
max. depth, m	6.2	10	4	2	7.9	2
Volume, milj. m^3	0.85	1.90	1.78	0.53	0.94	0.38
mean flow, m^3/s	0.16	0.18	0.18	0.10	0.19	0.21
residence time, months	2.9	4.6	3.8	1.9	1.9	0.9
Drainage area, km^2	14.18	13.82	15.56	9.27	16.97	14.89
Peatland %	44	38	48	60	46	55

Tab. V: General characteristics of the research lakes and their watersheds

The main human impact source of loading in the study areas is forestry. There is also some diffuse loading from agriculture and scattered settlement, especially in the Roukajärvi catchment. The reference Lake Itäjärvi also shows some forestry loading (clear cutting, soil preparation) from the outer part of the catchment since the year 2000, as well as previous improvement drainage (1989). The low P-loading values of Lake Matalanjärvi can be explained by the small size of the drainage area (9.3 km^2). In comparison to lake volume, the biggest phosphorus loading is concentrated on Lake Iso Akonjärvi.

Modern, intensive forestry (clear-cutting and artificial regeneration) has caused the forests to become fractioned and monotone. Thus far, at least 65 % of the forest land of the Kainuu region has been regenerated once (Mykrä et al. 2000). In most of the study areas the intensive period in clear-cutting stretched from the 1950s to the 1980s (Table VI.). After cutting the mineral soils were ploughed and either seeded or planted. Peatlands, on the other hand, were drained via ditches and fertilised. In the 1970s hummocking and later also patch scarification became the preferred techniques. Only 5-15 % of peatland habitats in impacted lake catchments have remained untouched by draining. The age of drainage is typically 20-30 years. Improvement draining has been carried out especially in the Matalanjärvi catchment over the past 10 years.

	Clear cutting		Drainage	
	Lake Roukajärvi	Lake Itäjärvi	Lake Roukajärvi	Lake Itäjärvi
1958		13.5		
1959		75		
1962		1.5		
1966		60		
1976-79	35		145	46
1980-84	60		120	
1985-89	2	104		27
1991		19.5	145	
1992		54.9		
1993		11.7	120	

Tab VI: History (1958-2003) of some forestry operations in the catchment areas of Lake Roukajärvi and Lake Itäjärvi indicated as areas (ha) under operation.

Phosphorus loading values using different methods varied between lakes, so that the reference lakes and also Lake Matalanjärvi have lower loading values than the other lakes (Table VII).

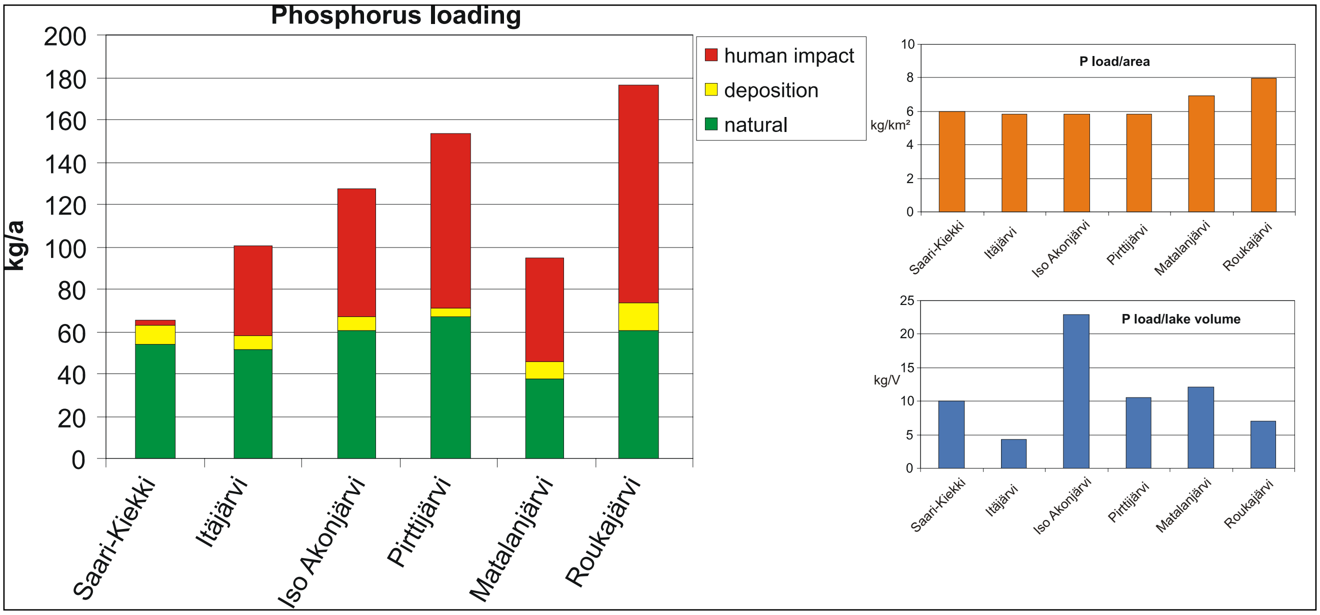


Fig. 14: Phosphorus loading distribution (kg/a) from different sources (human impact (forestry, agriculture, scattered settlement), deposition and natural) and P values based on specific forest load in relation to catchment area (km²) and lake volume of study lakes

The specific load of forests method provided the highest loading value estimates, the management based method shows slightly lower, and the VEPS based method the lowest values. When comparing water sample based phosphorus values with calculated tolerance for phosphorus load of the study lakes (Vollenweider 1968), the phosphorus levels exceed permissible values in the lakes Iso Akonjärvi, Pirttijärvi and Roukajärvi. Also, in the reference Lake Saari-Kiekki the calculated value of phosphorus was higher than the allowed value.

3.3.3.2 Sediments and reference condition

The Water Framework Directive (WFD) identifies three principal approaches for establishing reference conditions: I. paleoecological methods, II. spatial-state schemes and III. mathematical modelling approaches. In this case study paleolimnological samples to identify reference conditions were used. Each sediment core sample was taken from the deepest basin of the lake by using a Limnos core sampler. Average core size was about 30-40 cm. Diatom assemblages were analysed to indicate water quality changes, especially pH and nutrient concentrations. Core-top-and-bottom diatom assemblage analysis was used (Miettinen et al. 2003). In this method, only surface subsample and bottom subsample are analysed.

	Saari-Kiekki	Itäjärvi	Roukajärvi	Matalanjärvi	Pirttijärvi	Iso Akonjärvi
VEPS based P	0.23	0.22	0.34	0.18	0.27	0.24
land use +management P	0.20	0.24	0.40	0.20*	0.29*	0.25*
specific load_forest based P	0.18	0.28	0.48	0.26	0.42	0.35
water sample based P	0.47	0.26	0.82	0.23	0.46	0.43
Allowed P	0.35	0.34	0.49	0.31	0.32	0.35
Dangerous P	0.78	0.74	1.21	0.77	0.64	0.76

Tab.VII: Estimated phosphorus loadings (kg/d; VEPS, land use+management, specific load of forests and water sample based) to study lakes and calculated critical loading values (allowed, dan gerous) according to Vollenweider (1968).
* underestimated values because of insufficient management data

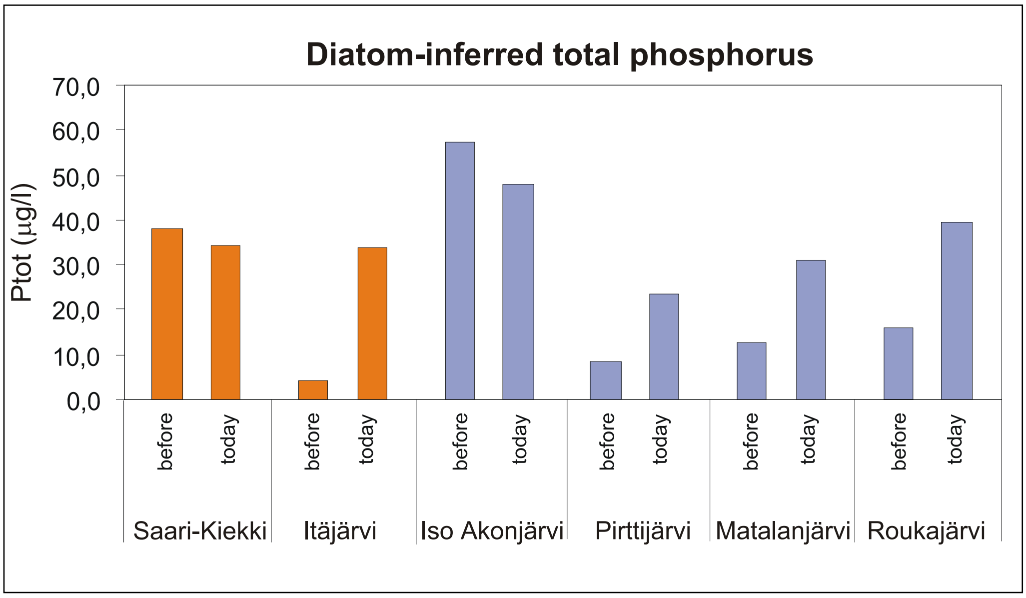


Fig. 15: Total phosphorus content of the study lakes inferred to diatoms during the study period.

quantity reflecting human impacts and dystrophy, and to some degree also eutrophication. In the reference lake Lake Itäjärvi, the low biomass of phytoplankton indicated an oligotrophic state. Average biomass was lower than in the impacted Lake Pirttijärvi. There was also a slight deviation from phytoplankton biomass between the reference lakes and lakes Matalanjärvi and Roukajärvi in June and July. In August, there was a tenfold increase in biomass of phytoplankton in Lake Roukajärvi indicating algae blooming.

The reference lakes represent two types of lakes regarding origin, oligotrophic and naturally eutrophic lakes (Fig. 15). There is also a difference in the natural trophic state between the impacted lakes. Two comparative lake groups were composed, the eutrophic lake group (L. Saari-Kiekki and L. Iso Akonjärvi) and the oligotrophic lake group (L. Itäjärvi and L. Pirttijärvi). Lakes Matalanjärvi and Roukajärvi are most likely oligotrophic lakes in origin and thus were compared to Lake Itäjärvi.

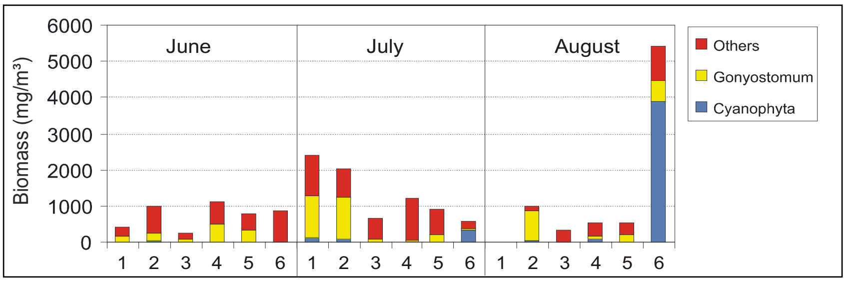


Fig. 16: Total biomass of phytoplankton (mg/m³) and composition (Cyanophyta, Gonyostomum semen, Other phytoplankton) from the 6 study lakes (1=Saari-Kiekki, 2=Iso Akonjärvi, 3=Itäjärvi, 4=Pirttijärvi, 5=Matalanjärvi, 6=Roukajärvi) in summer 2005

3.3.3.3 Water quality

Monthly water quality (n=3; June, July and August) and phytoplankton samples were taken and analysed using Finnish standard methods (Table 8). According to the total phosphorus concentrations all study lakes are mesotrophic (10-35 µg l^{-1}), with Lake Roukajärvi almost eutrophic.

	Saari-Kiekki	Itäjärvi	Iso Akonjärvi	Pirttijärvi	Matalanjärvi	Roukajärvi
Secchi depth (m)	1.17	1.25	1.05	1.05	1.27	0.93
colour (mg Pt/l)	113	127	160	160	130	200
pH	6.2	6.3	6.7	6.1	6.7	6.4
Conductivity	1.3	1.8	2.7	1.9	2.9	1.9
COD	14.3	16.0	20.3	21.0	22.3	20.7
total N (µg/l)	377	283	457	463	640	523
total P (µg/l)	26.7	17.0	31.7	27.0	25.5	33.7
chlorophyll a (µg/l)	14.9	3.7	16.1	6.2	5.1	12.6

Tab. VIII: Water quality data of the surface water during summer 2005 (average values)

3.3.3.4 Phytoplankton

Phytoplankton is a well-known biological group and often responds more rapid to nutrient loading than macroinvertebrate, macrophyte or fish assemblages. The phytoplankton assemblages were described by total biomass (biomasses of blue-greens, *Gonyostomum semen* and other phytoplankton) and concentration of chlorophyll *a* (Fig. 16, Table VIII).

In the group of eutrophic lakes, the phytoplankton biomass reached a maximum in July. Plankton communities were dominated by *Gonyostomum semen*, its abundance and

3.3.3.5 Aquatic macrophytes

The number of species was relatively low ranging from 22 to 31. The highest number of species were found in the impacted lake L. Roukajärvi and the lowest number in the reference lake L. Itäjärvi. The vegetation index of different growth forms showed that helophytes were the most dominant with *Equisetum fluviatile*, *Carex rostrata* and *C. lasiocarpa* being the most common species. *Nuphar lutea* was the most common species from the nyphaeid vegetation. The vegetation index of isoetid vegetation differed between the study lakes, but *Isoetes echinospora* and/or *I. lacustris* were found in most of the lakes. *Utricularia* sp. was the most common ceratophyllid. Bryophytes were the second most dominant growth form, but species varied strongly between the lakes. Lemnids were absent from all the study lakes.

The vegetation index value of different trophy shows the indifferent species to be the most frequent and abundant in all the lakes (Fig. 17). The share of oligotrophy species was generally low except in the impacted lake L. Roukajärvi, and the vegetation index of different trophy states for oligo-mesotrophy species was highest in the reference lake L. Saari-Kiekki and in the impacted lakes L. Itäjärvi and L. Matalanjärvi. Same index for mesotrophy vegetation was highest in the impacted lakes L. Roukajärvi and L. Pirttijärvi.

In the aerial photograph interpretation, the cover of aquatic macrophyte vegetation only in the reference lake L. Saari-Kiekki had remained somewhat stable during the study period but the cover had decreased since 1969 (Fig. 18). In the impacted lakes the vegetation cover had increased substantially. Only in the impacted lake L. Iso Akonjärvi vegetation cover had diminished.

In the paleolimnological analysis the reference lakes differed considerably. Total phosphorus content of L. Saari-Kiekki had not changed, but in L. Itäjärvi phosphorus content had increased during the study period. The amount of phosphorus had increased in all the impacted lakes except in L. Iso Akonjärvi, where phosphorus seems not to be the limiting nutrient.

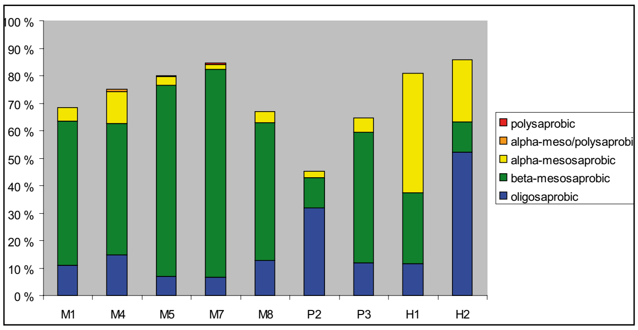


Fig. 17: Vegetation index representing different trophic states. e = eutrophic, me = meso-eutrophic, m = mesotrophic, om = oligo-mesotrophic, o = oligotrophic, i = indifferent

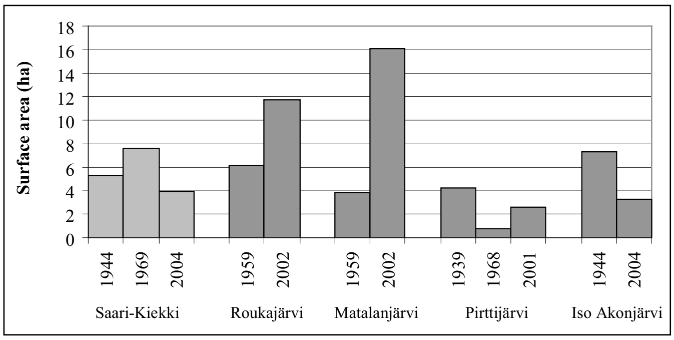


Fig. 18: Surface area (hectares) of emergent and floating leaved vegetation detected from aerial photographs between different study years

3.3.3.6 Benthic fauna

Benthic invertebrates of the one profundal and two sublitoral zone were collected in September using an Ekman-sampler. To describe the state of the benthos we used the *Chironomidae*-based index (BQI; Wiederholm 1980). It takes account 7 *Chironomidae* species, which represent different trophic state (of the benthos). Oligotrophic species have higher ranking scores, eutrophic and low-oxygen tolerating species have lower ranking scores. The BQI correlates to eutrophication of a lake.

Based on invertebrate samples all our study lakes have at least mesotrophic conditions in the benthic sediment of the profundal zone (Fig. 19). In the impacted lakes Matalanjärvi and Pirttijärvi the benthic fauna was composed of *Chironomidae* species, which tolerate unfavourable conditions. In Lake Pirttijärvi only 1 species, *Chaoborus flavicans,* was found in the profundal samples, indicating that there may be some quality problems in the benthic conditions. In Lake Iso Akonjärvi the number of taxons was 14, partly because the sample site was more sublittoral than profundal due to the bottom profile. Lakes Itäjärvi and Pirttijärvi had the smallest amounts of taxa. In conclusion, the profundal area of the reference lakes and Lake Iso Akonjärvi are in moderate condition. Benthic conditions in the sublittoral area seem to be more equal between the study lakes than in the profundal area. The composition of invertebrate taxa in Lake Matalanjärvi's sublitoral area differs from the taxon composition in other lakes reflecting also a (morphological) difference of this lake compared to others. Lake Matalanjärvi has also suffered from hypolimnetic oxygen depletion in winter seasons.

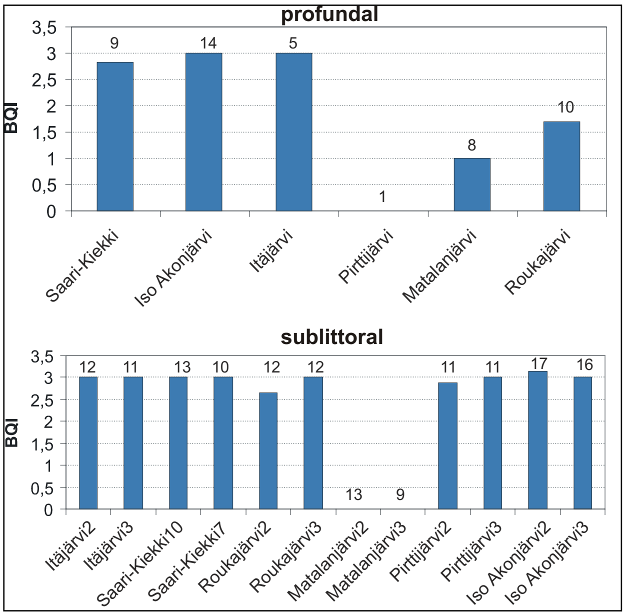


Fig. 19: Bottom quality of profundal and sublittoral areas of the study lakes based on BQI (bottom quality index). Above the bars are the number of taxa found at the sample site.

3.3.3.7 Fish

Sampling of fish was carried out in June and July using NORDIC multimesh survey nets. Stratified random sampling was used to select fishing sites. Fish community parameters applied include relative biomass of fish species, relative number of individuals of fish species and proportion of piscivorous (>15 cm) perch and cyprinids out of the total catch.

Perch and roach formed the main part of the catch species in all study lakes (Fig. 20). Pike was also a common species, although it was lacking from the net catch of Lake Matalanjärvi. The proportion of roach was highest in Lake Saari-Kiekki. In Lake Iso Akonjärvi total catch per unit effort (CPUE) was highest and the catch consisted mostly of perch. In oligotrophic lakes the total catch of the impacted lake (Lake Pirttijärvi) was four times larger than the catch of the reference lake (Lake Itäjärvi). In Lake Roukajärvi the main part of the catch was made up of perch, in Lake Matalanjärvi of perch and roach. The proportion of piscivorous percids was highest in Lake Iso Akonjärvi. The proportion of cyprinids in Lake Saari-Kiekki and Lake Matalanjärvi reflects more productive conditions compared to the other lakes.

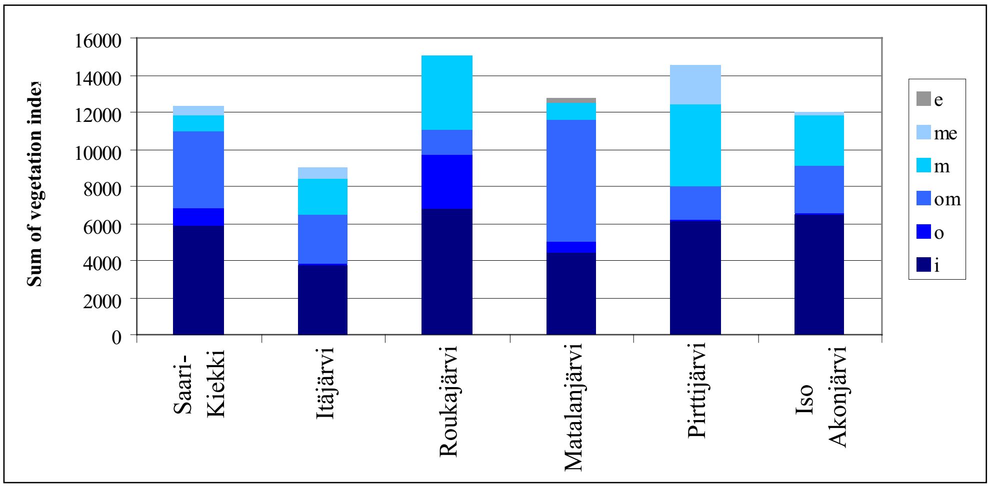


Fig. 20: Mean catch per unit effort (CPUE) of all species of one Nordic-net/night.

3.3.4 Current ecological status of the study lakes

Environmental effects on different biological quality elements are estimated by applying WFD preliminary classification schemes (EQR-calculations), which compare the results of monitoring of impacted lakes with reference values (see Pilke et al. 2002, Heinonen et al. 2004). According to the phytoplankton biomass the calculated EQR of Lake Itäjärvi and Lake Matalanjärvi was 0.93 and 0.80 suggesting good condition (Table IX). Mostly due to dense *Gonyostomum semen* population, the EQR-values of Lake Saari-Kiekki and Lake Iso Akonjärvi varied between 0.49-0.53. Cyanophyta blooming in August caused Lake Roukajärvi to be classified as bad condition (0.19). Lake type species of the whole taxa of macrophyte EQR scored moderate or good ecological status for the impacted lakes (0.58-0.85). Other macrophyte EQR indexes showed no difference between the study lakes. Based on the EQR values of benthic invertebrates (BQI) the study lakes were divided into two groups. The reference lakes as well as Lake Iso Akonjärvi have higher values (0.79-0.84) indicating high to good status. Calculated EQRs were clearly lowest in Lake Pirttijärvi (0) and in Lake Matalanjärvi (0.28), in Lake Roukajärvi the value of 0.47 indicates moderate status. For fish assemblages EQR, the number of species and biomass of perches indicated the largest difference in ecological status of the study lakes. In both the indices, lakes Saari-Kiekki and Itäjärvi were identified in good or excellent class.

Table X shows two physico-chemical parameters (total phosphorus in winter and Chlorophyll-a concentration in August) and four biological quality elements from the study lakes. Status classes of Tot.P and Chlorophyll-a are based on ranges defined by OECD (1982) and Forsberg and Ryding (1980). The physico-chemical results show that only Lake Itäjärvi is in near oligotrophic state, Lake Saari-Kiekki and the impacted lakes remain mostly in meso/eutrophic state. However, there were some inconsistencies between the physico-chemical results and some results of different biological elements. Based on professional judgement of the ecological status, our reference lakes and also Lake Iso Akonjärvi are most probably in good ecological status. In the rest of the impacted lakes the ecological status has decreased to moderate mostly because of loading from forestry, and in the case of Lake Roukajärvi also because of agriculture.

	Biological element	Saari-Kiekki	Itäjärvi	Iso Akonjärvi	Pirttijärvi	Matalanjärvi	Roukajärvi
Aquatic macrophytes	Number of taxa	1,09	0,92	0,92	0,83	0,77	1,04
	Similarity of species	1	1	1,22	1,15	0,94	0,91
	Lake type species	0,92	1,08	0,92	0,92	0,88	0,58
	Lake type species of the whole taxa	1	1	0,85	0,76	0,68	0,58
Benthic invertebrates	BQI	0.79	0.84	0.84	0.00	0.28	0.47
	Number of species	1.20	0.67	1.87	0.13	1.07	1.33
	Number of ind.	1.60	0.53	0.41	0.30	0.17	0.36
Phytoplankton	Total biomass	0.53	0.93	0.49	0.72	0.80	0.19
Fish	Number of species	0,8	1	0,8	0,6	0,4	0,6
	Total biomass	0,60	2,99	0,37	0,48	0,45	0,65
	Biomass of roaches	0,37	6,62	0,86	3,43	0,49	1,23
	Biomass of perches	1,17	0,88	0,65	0,21	0,27	0,46

Tab. IX: Ecological quality ratios and preliminary estimates of ecological status of studied lakes. Calculations are based on a comparison with results of reference lakes, in case of total biomass of phytoplankton with best values of distribution (10 %). In the macrophyte EQR, lakes Saari-Kiekki and Itäjärvi scored 1 in similarity of species and type species of the whole taxa, because the small number of reference lakes prevented more detailed calculations.

		Saari-Kiekki	Itäjärvi	Iso Akonjärvi	Pirttijärvi	Matalanjärvi	Roukajärvi
Physico-chemical	Tot.P (µg/l)	26	14	19	20	22	33
	Chlorophyll a (µg/l)	16	4	20	9	6	24
Biological	Macrophyteindex						
	BQI_Chironomidae						
	Fish						
	Phytoplankton						

Tab. X: Trophic indicator classification of study lakes. Values and results are classified into three trophic classes, oligo-oligo/mesotrophic (blue), mesotrophic (green) and meso/eutrophic-eutrophic (red) class.

3.3.5 Questionnaire on public observations

Public opinion of forestry effects on lakes was established using questionnaires. Enquiry forms (145 in total) were posted to randomly selected local inhabitants around the Kainuu region and also to inhabitants living near the study lakes. They were asked to evaluate the state of their nearby lake on a general level, environmental changes in lake status, activities that have caused changes and also how to improve the quality of the lake. The response activity was approx. 67 %. Most of the local people evaluated the status of the lake in question to be moderate. Only 7 % of answers classified study lakes to be in good condition (other lakes - 19 %). Changes are mostly thought to go in a negative direction, i.e. from good to bad or worse (study lakes - 79 %, other lakes - 55 %). Most commonly observed changes in the study lakes were increased vegetation and phytoplankton biomass, in other lakes increased phytoplankton biomass and siltation in littoral areas. The main reason for the negative progress of the lakes was identified as forestry, in other lakes also the decrease in water-level caused by agriculture and forestry. Suggested enhancement actions for the lakes included removal of non-commercial fish (46 %) or macrophytes (26 %) and raising the water level (23 %).

3.3.6 Summary

Land use for forestry has its environmental impacts. In this case study's area extensive clearcutting, rapid regeneration, efficient draining and fertilisation were typical activities of forestry management operations between the 1960s and 1980s. Some of these impacts were local and limited, others cumulative, extensive and long-term, affecting watercourses below. The duration and the amount of loading depends on the extent of the area in which forestry actions were implemented, the intensity and method of the operation, local hydrology, the soil type and topography of the area, and the development of the forest after the operation (Kenttämies and Saukkonen 1996). Based on an average cycle of 80 years there will be no large scale clear cutting operations until the 2030s. Forest ditch maintenance will cause the largest loads of all forestry operations in the near future (Finer et al. 2005). The primary aims are to diminish the loading of these forest management operations.

Based on paleolimnological samples all study lakes have undergone changes over the past 30-40 years. This can mainly be seen in the eutrophication process and increasing siltation. Currently, calculated loads based on water samples exceeded acceptable loads in most of the lakes.

Because of the short monitoring period and the fact that information related to effects of forestry on small lakes is scattered, you can only speculate about potential influences of loadings on different biological quality elements:

PHYTOPLANKTON

- increasing in biomass
- taxonomic changes

MACROINVERTEBRATES

- decreased number of species and individuals in profundal zone

MACROPHYTES

- increased biomass
- taxonomic changes

FISH

- increasing biomass of fish
- increasing cyprinid population

There is also a difference between the lakes with regards to tolerating loading. More sensitive to nutrient loading seem to be the lakes, which are naturally oligotrophic and have long residence times. Also, climatic factors, in our case long winters, and some drainage area characteristics decrease tolerance.

Loadings to surface waters and groundwater are regulated by the Water Act and the Environmental Protection Act, the latter also regulating the wastewater treatment in rural areas. Under the same Environmental Protection Act the polluter is also obliged to clean up any contaminated soil or groundwater. However, in many cases this has not been efficient in preventing the problems caused by pollution from diffuse sources such as forestry. One way to improve this gap in water protection is spatial planning, which takes into account sustainable river basin management, however, there is currently no guidance available on land use planning with regards to forestry. Because simultaneous or consecutive actions in different parts of the same catchment area may amplify the impacts of forestry operations, spatial planning in conjunction with improving forestry planning systems would be the best tool to solve these types of problem.

3.4 Determination of ecological potential of rivers modified for hydropower production

Seppo Hellsten, Laura Kyykkä, Mika Visuri and Mika Marttunen

3.4.1 Introduction

Hydropower greatly affects the status of water courses. According to the WFD these hydrologically and morphologically altered water bodies can be designated as heavily modified, meaning they do have lower environmental goals called good ecological potential. The definition of this ecological potential is relatively unclear, because mitigation measures to improve ecological status cannot cause significant harm for the main use of the water body. The general trend of the WFD is to limit modifications caused by hydropower. On the other hand, commitments relating to the Directive on the promotion of electricity produced from renewable energy sources in the internal electricity market (2001/77/EY) demands an increase in hydropower production by 10 – 20 % at national level.

The substudy on hydropower will focus on determination of good ecological potential of rivers and lakes initially designated as heavily modified. Definitions of ecological potential are determined in more detail by applying the available methods and especially focussing on determination of different mitigation measures and their effects on the use of the water bodies. The case study will focus on the modified downstream stretch of the River Oulujoki and one initially designated lake. The substudy was initiated together with the project's environmental objectives for heavily modified water courses financed by the Ministry for Agriculture and Forestry and the Finnish hydropower industry.

3.4.2 General effects of hydropower

The effects of hydropower on Finnish water courses are quite clear. Finland is known as the country of thousands of lakes; in fact, there are more than 188,000 lakes with a size of at least 0.05 ha. This amounts to a total area of 32.600 km^2, which is approximately 10 % of Finland´s total area. More than 330 lakes are regulated, including many of the largest, making up approximately one third of the total area of lakes.

Most of Finland's large rivers are also regulated. Large northern rivers such as the rivers Kemijoki, Iijoki and Oulujoki are fully developed except some tributaries protected by environmental legislation. On the other hand, most of the small rivers in the western part of Finland are dredged mainly for flood protection and land drainage purposes.

The main objectives of the regulation are flood protection and hydro power production; 40 % of the regulation schemes primarily serve hydro power production, 25 % relate to flood protection, 25 % to water supply, 4% to recreational use, 2% to lake restoration purposes and 4% to other purposes (Vähäsöyrinki, 1997). Most of the regulation is multipurpose, combining several objectives. For example, the objectives of both hydro power production and flood protection are broadly in line with water level drawdown during the winter.

General ecological effects of water level regulation are widely known (Fig. 21). Changes in the water level fluctuation regime cause significant changes in the littoral zone, which is the most visible part of the lake ecosystem for normal lake users. The impacts of water level fluctuation depend on changes in the water level regime and on lake-specific characteristics, e.g. the quality of soil and water, exposure, slope of the littoral zone, and fish population (Hellsten, 2000).

In rivers effects of changes in flow both on an annual as well as on a daily basis will cause significant changes in environmental conditions for flora and fauna. The water level is usually raised to increase hydropower energy production causing significant changes to the structure of the littoral zone. The ecological continuum is largely cut by dams and weirs causing significant changes in the natural lifecycle of migratory fish.

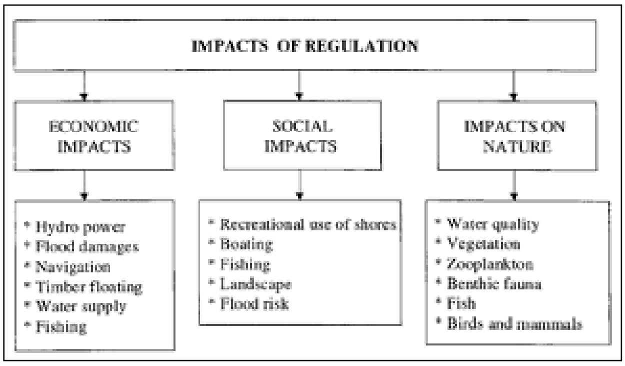


Fig. 21: General effects of water level and discharge regulation (Marttunen et al. 2001)

3.4.3 Methods for definition of ecological potential

The Water Framework Directive (WFD) reforms EU water legislation by introducing a new model for water management. From an environmental point of view, the WFD's ultimate aim is preventing further deterioration and achieving "good status" in inland waters (e.g. lakes), transitional waters (e.g. estuaries), coastal waters and groundwater. The WFD's approach – integrated water management at the river basin level - aims at ensuring overall coordination within each River Basin District. The Water Framework Directive permits Member States to identify artificial and heavily modified water bodies (Fig. 22). Heavily modified water body (HMWB) means a body of surface water, which has substantially changed in character as a result of physical alteration caused by human activity. For HMWB the objective is the achievement of good ecological potential, which may strongly deviate from good ecological quality, which is the objective for natural water bodies (Fig. 23). The designation of heavily modified water bodies is an important issue in Finland, where most of the largest lakes and rivers are regulated for the purpose of hydropower, flood protection and water supply.

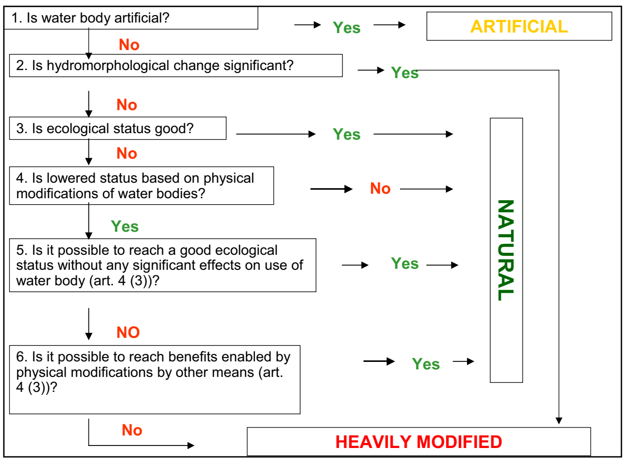


Fig. 22: Designation of heavily modified water bodies according to the WFD

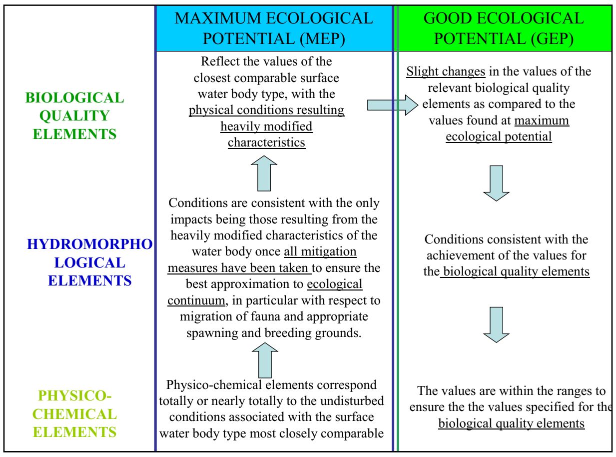


Fig. 23: Determination of ecological potentials in the framework of physico-chemical, hydromorphological and biological quality elements

The case study hydropower focuses on the determination of ecological potential. Due to the very vague determination of ecological potential in the WFD, a more practical approach was taken by the Finnish specialist team preparing environmental legislation for artificial and heavily modified water bodies (Ympäristöministeriö 2006). Maximum ecological potential was determined according to the following Fig. 24. There are several steps, which should be taken into account when the ecological potential is defined.

- First of all, ecological quality ratios for all relevant biological quality elements (macrophytes, zoobenthos, fish) should be determined. Taxonomic composition, abundance, or sensitive species should be used and one or several variables per quality element should be established.
- After determination of ecological status, there should be a clear decision of chosen mitigation measures and variables.
- Finally, an estimation of effects of mitigation measures on these variables should be carried out.

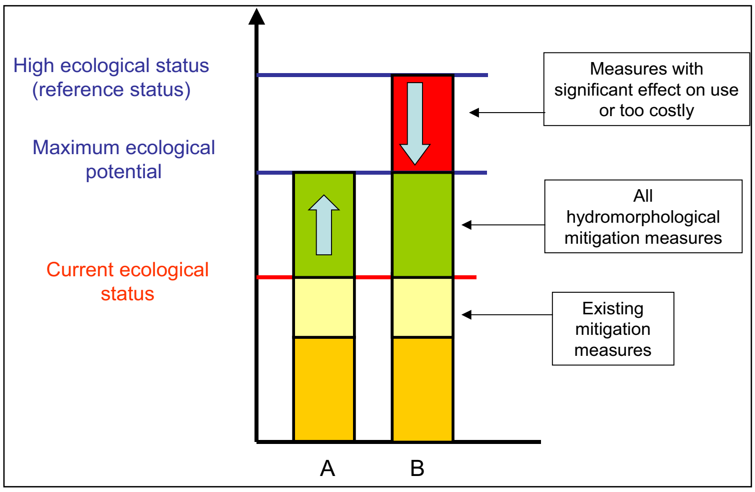


Fig. 24: Two possibilities for determination of maximum ecological potential. A) Derivation from current ecological status including all hydromorphological mitigation measures. B) Derivation from high ecological status removing all measures with significant effects on use (Ympäristöministeriö 2006).

A one-day seminar was organised for the case study on 6 September 2005 where a group of key-experts reviewed these determinations and evaluated the ecological potential for the River Oulujoki and for Lake Kemijärvi. Results from the River Oulujoki are presented in the following chapters. The Lake Kemijärvi case study was reported at the Workshop on WFD and Hydromorphology organised by the EU Commission in Prag (November 2005). Both case studies are described in detail in separate Finnish reports (Kyykkä et al. 2005).

3.4.4 Description of study area

The River Oulujoki is 101.3 km long with an elevation difference of 122 metres. Its drainage area is 22 925 km^2 with a lake percentage of 11.4 % (see chapter 3.1). Average flow is approx. 259 m^{3}s^{-1}. Main tributaries are the rivers Sanginjoki, Muhosjoki, Utosjoki and Kutujoki.

The River Oulujoki is fully developed for hydropower production by seven hydropower plants (Fig. 25). Additionally, there is a small plant (Ala-Utos) at the mouth of the River Utosjoki. The total amount of hydropower is 450 MW with a total production of 2 TWh. The River Oulujoki is effectively used for short-term regulation, its annual flow rhythm also changes considerably from high spring flood to higher flows during the winter period (Fig. 26). Total regulation capacity is 60 %, which means that 60 % of the annual discharge can be stored in regulated lakes. Short-term regulation means that the hydropower production can be changed rapidly between 50 MW and 450 MW depending on the demand for electricity.

Short-term regulation also affects water levels; water levels fluctuate less than 0.5 meters in the upper reservoirs of power plants, but during weekends and nights it can be more extensive. Typical water level fluctuation between the Montta and Merikoski hydropower plants can be more than 1.5 meters, which causes significant harm to recreational users. The water level is also significantly raised, which means that former shore area is protected or consisting of embankments by 44 %, while 36 % of this river is dredged.

All these changes have caused significant changes in biota of the River Oulujoki. After building of the first power plant in Merikoski in 1947 the continuity of the river has been disturbed and a flourishing Salmon and Sea Trout fishery has to be supported by intensive stocking. Significant adverse impacts on ecological status consist also of a loss of rapids and the disappearance of flood meadows and eroding shores typical for natural rivers. The first fishway was built as late as 2003 enabling migratory fish to reach the river stretch between the Merikoski and Montta power plants.

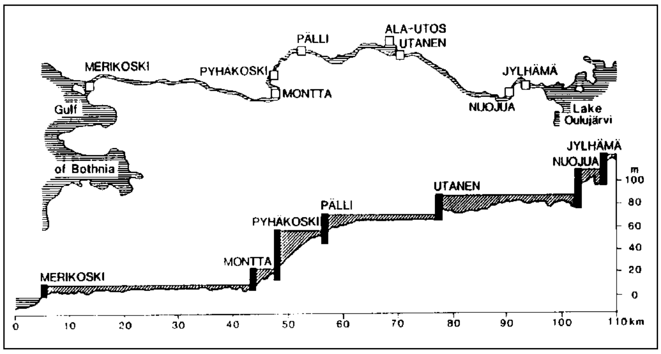


Fig. 25: The River Oulujoki between Lake Oulujärvi and the Gulf of Bothnia. Hydropower plants are marked with open squares.

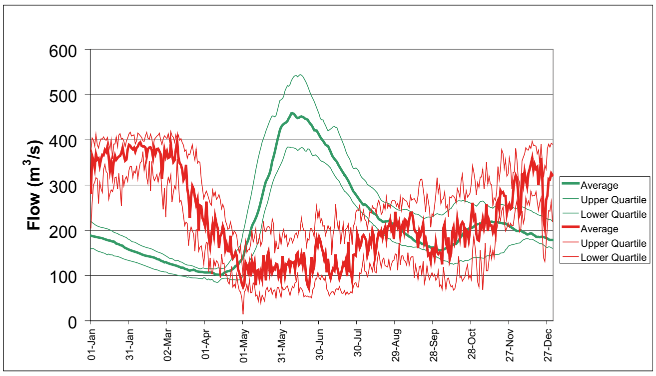


Fig. 26: Average flow of the River Oulujoki measured at the outlet of Lake Oulujärvi. Re-calculated natural flow between 1980-99 (green thick line with quartiles as thin green line), regulated measured flow between 1980-99 (red thick line with quartiles as thin red line).

3.4.5 Current ecological status

3.4.5.1 Aquatic macrophytes

The ecological status estimation of macrophytes is based on data from regulated rivers gathered by Riihimäki and Kerätär (2003). The reference data is based on a literature review of Hellsten et al. (2005). It should be noted that the reference data is not very representative due to differences in sampling methods.

The EQR-values of type specific species of shore- and aquatic plants were 0.56 and 0.47, respectively. Plants were already adapted to disturbance, and there were hardly any good indicators, although *Potamogeton*-species seem to be very rare, while helophytes such as *Schoenoplectus lacustris* and *Eleocharis palustris* were completely missing due to their poor resistance against ice erosion.

Species composition	Number of type specific aquatic macrophytes Number of type specific shore and aquatic macrophytes	EQR 0.47 EQR 0.56

3.4.5.2 Benthic fauna

The data is based on kick-net samples taken at two places of the main stream of the River Oulujoki and at one place of the River Emäjoki by Vuori et al. (2005). The reference data stems from samples of the free flowing rivers Tornionjoki and Simojoki.

The present status of benthic fauna differs very much from the natural reference conditions. The number of sensitive EPT-species as well as the total number of species fluctuates between 0.4 – 0.5, whereas the total diversity (total amount of species between 20 - 27) is achieving relatively high values. The taxonomic composition differs clearly from the non-regulated reference sites. The species composition also reflects certain types of lake fauna.

Species composition	Total number of species	EQR 0.4...0.5
Abundance	EPT –species	EQR 0.4...0.5

3.4.5.3 Fish

The ecological status estimation of fish is based on recent monitoring results (PSV – Maa ja Vesi Oy 2005) and historical data. The total amount of species is app. 22, if migratory salmon and lamprey using the recently built fishway between the sea and lowest reservoir are also included. Rainbow trout is a stocked species, while the populations of pike perch, salmon and white fish are also heavily affected by stocking. In addition, the fish fauna includes some species coming from Lake Oulujärvi, such as vendace and pike perch.

The total catch of the River Oulujoki in 2004 mainly consists of northern pike and perch although roach and rainbow trout were also common (PSV-Maa ja Vesi Oy 2005). Electrical fishing between the power plants Pyhäkoski and Pälli showed that young individuals of salmon, trout and grayling representing typical fast flowing rivers are completely missing and have been replaced by perch and roach.

Fast flowing rapids habitats can be seen as key habitats of the whole river. Migratory fish from the sea need these areas for spawning. Before the development of the River Oulujoki these habitats totalled more than 550 hectares (Salojärvi 1986). Nowadays, these habitats are almost completely missing in the main branch of the Oulujoki. After building the Merikoski fishway migratory fish can enter again the lowest part of the River Oulujoki and also reach two tributaries, namely the rivers Sanginjoki and Muhosjoki, where suitable habitats exit but need to be restored after heavy siltation.

Species composition	Total amount of species	20 (Merikoski-Montta stretch 22)
Abundance	Amount of salmonids	-
Age structure	Age structure of salmonids	-

3.4.6 Selection of mitigation measures

The selection of mitigation measures in the case study is based on the list of the following tasks;

- Identification hydro-morphological measures, which improve the ecological status
- Removal of those measures, which can have significant adverse effects on the specific use or wider environment.
- Definition of measures, which do not have significant adverse effects on the specific use or wider environment.

Reduction of weekly water level fluctuation below the Montta powerplant from 150 cm to 130 cm:

The effects on hydropower production were not estimated, but the adverse effects should be relatively low. However, according to expert opinion this does not have any significant positive ecological effect.

Enhancing river continuity through fish ways and bypass channels:

This option includes the construction of fishways or bypass channels between the Montta and Jylhämä powerplants, including also the Ala-Utos tributary. The total amount of water used for this purpose fluctuates between 0.5 - 2 m^3s^{-1}. Also, options with higher discharges of 5 m^3 s^{-1} and 10 m^3 s^{-1} were used.

The total height of fall between the Bothnian Bay and Lake Oulujärvi is 122 m, so 1 m^3 s^{-1} permanent flow means about 1 MW in power and loss in total energy production it is about 9 100 000 kWh. With an average price of 3 cent/kWh, this costs €270 000. This amount is very close to the cost of the current compensative stocking of salmon and seatrout (300 000 smolts, 1 €/pc). Correspondingly, 2 m^3/s would cause annual losses of €540 000, 5 m^3 s^{-1} €1,035 mio and 10 m^3 s^{-1} €2,7 mio.

Bypass channels need flowing water every day, while fishways are watered only during the summer season. Natural bypass channels are usually the better option from a diversity point of view, because the amount of suitable habitats is increased. On the other hand, energy losses are much higher. Järvenpää (2005) has demonstrated that it is possible to build bypass channels beside all powerplants, although there might be some problems regarding very steep slopes. Technically, fishways may be a better option in some places. It may be possible to build a common bypass channel passing the two powerplants Pyhäkoski and Montta.

Restoration of main channel and shores:

The main streams include approx. 12 ha of potential areas to be restored for spawning. The most important ones (Laukka, Ahmas- and Kurenkoski) have already been restored, totalling 2-3 ha.

Restoration of bypass channels:

Bypass channels include a lot of potential habitats depending on discharge. With the inclination of 1:100 there are totally about 6 ha (2 m^3 s^{-1}), 15 ha (5 m^3 s^{-1}) and 30 ha (10 m^3 s^{-1}) of potential habitat in bypass channels.

Restoration of tributaries: If all suitable habitats are restored in the main tributaries of the rivers Sangin-, Muhos and Kutujoki a total 40 ha of habitats would be available.

Removal of old protection structures and modification of littoral areas:

Almost 44 % of the shores of the River Oulujoki are protected by stones and gravel. Modification of these structures will increase the amount of suitable habitats especially for littoral vegetation.

The following measures were excluded because they were neither affecting hydro-morphological conditions, nor causing significant adverse effects.

Measures, which would not improve hydro-morphological conditions included:

- Fish stocking
- Re-planting of threatened plant species
- Fishery restrictions Measures, which would cause significant adverse effects on use include:
- Removal of power plants
- Reductions in short term regulation
- Reductions of daily flow changes to 75-100 m^3 s^{-1}
- 75-100 m^3s^{-1} minimum flow (currently 50 m^3 s^{-1})
- Restoration of spring flood
- Restrictions of water level fluctuation to less than 80 cm below the Montta powerplant (currently ~1,5 m)

Shorterm regulation is very sensitive from the economical point of view. Sinisalmi et al. (1997) showed in their investigations that nowadays the capacity of the whole power plant chain fluctuates between 50-450 MW. A restriction of the water level fluctuation range to 80 cm below the Montta power plant means that half of the total regulatory capacity of the River Oulujoki is lost.

3.4.7 Effects of mitigation measures on biological quality elements

The expert judgement after examining all mitigation measures lead to the following outcome (Table XI). Aquatic macrophytes would not be affected by measures and the benthic fauna would only be affected if a shore protection was almost completely removed. Effects on fish fauna were relatively difficult to estimate, although most measures would show a slightly positive effect.

Additionally, the experts estimated that modification of littoral areas with a more diverse set of methods instead of the normal civil engineering works would improve biological status. On the other hand, these effects are almost impossible to estimate.

Measure	Effects on		
	Macrophytes	**Benthic fauna**	**Fish**
River continuity: fishways and by-pass channels	no effects	no effects	number of species : 20→22 abundance: +
Restoration of bypass channels	no effects	no effects	relative share of salmonids: + age structure: +
Restoration of main channel and shores	no effects	no effects	relative share of salmonids: + Age structure: +
Restoration of tributaries	no effects	no effects	relative share of salmonids: + age structure: +
Removal of old protection structures and modification of littoral areas	no effects	When the amount of protected shores is less than 35 % it is more likely to achieve good status	no effects

Tab.XI: Effects of different measures on biological quality elements. + = positive effect.

3.4.8 Determination of reference conditions

The following step includes an estimation of the effects of the mitigation measures on the biological status. Based on the approach presented in Fig. 24, the biological status after mitigation measures is the reference status for heavily modified water bodies. Reference status is defined as maximum ecological potential. In the following chapters the maximum ecological potential is defined for different biological quality elements in the River Oulujoki.

Maximum ecological potential of macrophytes: Measures would not have any significant effects on aquatic vegetation. Therefore macrophytes, have already reached maximum ecological potential.

Maximum ecological potential of benthic fauna: The status of the benthic fauna could be improved by removing protecting structures. A rough estimation based on material from other rivers shows that the status could increase by 0.1 EQR units (EQR 0.4...0.5 → 0.5…0.6), if a third of the protected shores are restored. This would mean that only 10 % of shores would be protected causing significant harm for recreational users. The maximum ecological potential of the benthic fauna is approx. EQR = 0.55.

Maximum ecological potential of fish: It was very difficult to estimate qualitative changes in fish fauna, although some improvements would naturally be visible (Table XII). The total amount of species would increase in the upper parts of the river along with the removal of the migration barriers. If the changes could only be observed in the lowest Merikoski reservoir, changes in the number of species would be insignificant. Generally, changes in the number of species are relatively small and it is unclear how much one or two new species (10 % increase in total number of species) could improve the definition of ecological status.

The age structure of fish would not improve, if only the migration barriers are removed. Therefore, the building of fishways would not merely affect the status of fish. Restoring the stream habitats could support the natural life cycle of the salmonids, increase their proportion and improve their age structure. Any influence is estimated with 2, 5 and 10 $m^3 s^{-1}$ discharge to the bypass channels. This report does not answer the question, whether this harm (1, 2, and 5 % loss of the hydropower production) would be significant or not.

By restoring all stream habitats in the main channel, the tributaries and in the bypass channels, the total amount of stream habitat would increase to 58, 67 or 82 ha, depending on the discharge. In this case study it is postulated, that at the present status of the rivers fish fauna is classified as poor ecological status according to the WFD's definition (scoring 0.1 in the class). Restoring the stream habitats could significantly change the age structure and abundance relationships of fish, thus increasing the status in bypass channels to high (value 1). The estimation of maximum ecological potential of fish in the whole River Oulujoki was calculated using the changes in the amount of stream habitats in proportion to the amount of stream habitats of the natural River Oulujoki (Table XIII).

The experts did not offer a unanimous opinion on the question, if the change in the amount of salmonid spawning areas should be compared to the present status or to the natural status of the River Oulujoki. It was roughly estimated that in the natural status of the River Oulujoki the amount of stream habitats would be approx. 400 ha. If a value of 500 ha was used instead, the significance of any influence would be smaller. On the other hand, a smaller value could be used, if it could be estimated to be sufficient for the salmonid life cycle. This means that there should have been more than enough stream habitats for fish in the natural status of the RiverOulujoki. The value used is going to contribute significantly to the results, because it is going to be put into proportion to the whole river. Therefore, this part should be considered critically.

The appraisal varies regarding the usefulness of stream habitats in the bypass channels for fish. In this case the amount of stream habitats is scaled like the other actions and the value it has been given is 1, even though a smaller value (0.9) of high ecological status would have been possible, too. At present, fish can migrate via the main channel up to the second power station Montta, i.e. approx. 40 % of the total length of the river, and also to the tributaries Sanginjoki and Muhosjoki. When adjusting the present status, it has not been decided yet, how to take into account fish migration possibilities to only limited parts of the river.

	Amount of stream habitat (ha)				Number of species	Abundance	Age structure	Average
	Main channel	Tributaries	Bypass channels	Total				
Present status	3	40	0	43	20	serious changes	serious changes	
EQR					(20/22=) 0.91(EQR)	0.1 (EQR)	0.1 (EQR)	0.37 (EQR)
Reference status	12	40	6 - 30	58 - 82	22			
EQR*	12	40	6	58	0.91 (EQR)[1]	0.23 (EQR)	0.23 (EQR)	0.46 (EQR)
	12	40	15	67	0.91(EQR)[1]	0.25 (EQR)	0.25 (EQR)	0.47 (EQR)
	12	40	30	82	0.91(EQR)[1]	0.28 (EQR)	0.28 (EQR)	0.49 (EQR)

Tab.XII: Present status of fish, amount of stream habitat and reference status (maximum ecological potential) at 2, 5 and 10 $m^3 s^{-1}$ discharge to bypass channels. The EQR-values of the present status are appraisals based on verbal classification. *= EQR scaled to the size of the area.

[1]Number of fish species is not related to the amount of stream habitat.

3.4.9 Summary

In a scenario where the River Oulujoki has achieved maximum ecological potential:

- Old protecting structures on the shores have been removed so that the total amount of protected shores is not more than 10 %.
- There is a bypass channel at every power station and the year round discharge is 2 - 10 $m^3 s^{-1}$, depending on the definition of significant harm.
- All streamhabitats in the main channel (12 ha) and in the tributaries (40 ha) have been restored.

The technical possibilities of bypass channels have been considered speculatively, but not the economical possibilities. According to the WFD, all actions must be realisable both technically and economically. Therefore, the comparison status may still change after clarifying the economical possibilities of bypass channels.

The reference status is the ecological status that can be reached when taking into account effects of all the above mentioned actions (Table XIII). The choice of actions for estimating the reference status depends on the significance of harm that can be accepted for the use of the watercourse (e.g. energy production). The only action, that clearly increases the harm, is the discharge past the power stations. It is proposed in this study, that an improvement of the water quality would not affect the life forms in the main channel of the River Oulujoki.

The end result of this study is, that the actions decided upon only slightly affect the status of the River Oulujoki. Therefore, the comparison status also differs only slightly from the present status, which means this can be regarded as the maximum ecological potential of the River Oulujoki. According to this case study, the aim congruent with the WFD can be reached and compliance with the Directive does not require any action for improvement of the ecolological status.

	Macrophytes	Benthic fauna	Fish	Average
Unscaled present status (EQR)	0.56	0.45	0.37	
Unscaled reference status (EQR)	0.56	0.55	0.46 (1) 0.47 (2) 0.49 (3)	
Reference status (EQR^{vm})	1	1	1	
Present status (EQR^{vm})	(0.56/0.56) = 1	(0.45/0.55) = 0.82	(0.37/0.46)= 0.81 (1) (0.37/0.47)= 0.79 (2) (0.37/0.49)= 0.75 (3)	0.88 0.87 0.86
Lower limit of good ecological potential (EQR^{vm})				0.60

Tab.XIII: Total estimation of reference status, present status and good ecological potential. Uncertainties of estimation are described in the text. EQR describes the status of the River Oulujoki after all measures in the scenario where the River Oulujoki is in a natural state and there is no need to estimate the significant effect for the use of the River Oulujoki. The values for fish are roughly based on the WFD's verbal definition. EQR^{vm} describes the status of the River Oulujoki as a heavily modified water body on a scale of 0-1.
(1) Significant effect on hydropower production caused by discharge to the bypass channels, app. 1 % loss of production
(2) Significant effect on hydropower production caused by discharge to the bypass channels, app. 2 % loss of production
(3) Significant effect on hydropower production caused by discharge to the bypass channels, app. 5 % loss of production

3.5 Protected areas - Natura 2000 sites and the Water Framework Directive

Ville Hokka

3.5.1 Introduction

Areas harbouring aquatic ecosystems or aquatic biota of high nature conservation value need to be addressed and promoted in water protection as well as in land use practices. According to Article 6 and Annex IV of the Water Framework Directive (WFD), Member States have to establish register(s) of several different protected areas. Of these, the "relevant Natura 2000 sites", as defined in Annex IV (v), are of specific interest due to their conservational value. Furthermore, such sites need to be addressed in the river basin management plan in accordance to any related Directives.

However, identification, classification and evaluation principles of the conservation values (in the Natura 2000 areas) that are considered "relevant" under the WFD are currently unclear and not yet well established. Moreover, the relationships between the WFD objectives and the objectives of the Birds and Habitat Directives need to be explored and further defined in order to be applied to water and land use management practices.

The sub-study on protected areas investigates the criteria and the objectives of the Birds Directive (79/409/EEC), the Habitats Directive (92/43/EEC) and the WFD and encourages water managers and spatial planners to conserve these in applied water management and land use planning in the case study.

3.5.2 Approach for Assessing Natura 2000 Areas According to the WFD

According to the Water Framework Directive (WFD), *relevant* Natura 2000 areas have to be included in the register or registers of protected areas (WFD Article 6 and Annex IV, Paragraph 1.v). The Directive further states that in the Natura 2000 sites of the register, maintenance or improvement of the status of water is *an important factor* in the protection of habitats or species (WFD Annex IV, Paragraph 1.v). Since the Natura 2000 sites included in the register of protected areas are defined only loosely in the WFD using terms such as *relevant* and water quality being an *important factor in protection*, much freedom is given to the water managers, administrators and competent authorities in interpreting and applying the Directive in practice.

To clarify the relevant conservation values in the Natura 2000 areas in relation to the WFD objectives, a systematic approach for selecting the areas was determined based on the conservation values recognised in establishing the Natura 2000 network in Finland (reported in Kokko and Hokka 2005; Leikola et al. 2005). First, the habitats and species of the Habitats Directive and Birds Directive that are directly and unequivocally connected to the occurrence of water, were identified on a national level. The identified set of conservation values of Natura 2000 sites was applied in practice in the Lake Lentua case study (chapter 3.5.5).

3.5.3 Defining Relevant Conservation Values

The Habitats Directive as well as the Birds Directive defines a set of habitats and species that require specific protection in the Member States. In Annexes I and II of the Habitats Directive legally binding habitats and species of community interest are listed that require designation of Special Conservation Areas (SACs). Similarly, in Annex I of the Birds Directive species are listed for which Member States are obliged to establish Special Protection Areas (SPAs, Article 4.1 of the Birds Directive). Both SACs and SPAs form part of the Natura 2000 network. Member States must also take regularly occurring migratory bird species into account when implementing the Birds Directive, i.e. designating protection areas and executing conservation measures (Article 4.2); special emphasis on migratory species has to be placed within the protection of wetlands. In practice, legally binding migratory bird species must be determined by the Member State.

The Habitats Directive aims at maintaining favourable conservation status of habitats and species, which are defined as follows (Article 1 e and i).

(e) The conservation status of a natural habitat will be taken as 'favourable' when:

- its natural range and areas it covers within that range are stable or increasing, and
- the specific structure and functions which are necessary for its long-term maintenance exist and are likely to continue to exist for the foreseeable future, and
- the conservation status of its typical species is favourable as defined in (i);

(i) The *conservation status* (of a species) will be taken as 'favourable' when:

- population dynamics data on the species concerned indicate that it is maintaining itself on a long-term basis as a viable component of its natural habitats, and
- the natural range of the species is neither being reduced nor is likely to be reduced for the foreseeable future, and
- there is, and will probably continue to be, a sufficiently large habitat to maintain its populations on a long-term basis.

The Birds Directive (Article 2) requires more briefly that

Member States shall take the requisite measures to maintain the population of the species…at a level which corresponds in particular to ecological, scientific and cultural requirements.

The Water Framework Directive, however, focuses particularly regarding surface waters and ground waters on achieving good status by 2015 (Article 4.1 a ii, 4.1 b ii) if no derogations for extending the deadlines to 2021 or 2027 are applicable (as defined in Article 4.4).

(a, ii) Member States shall protect, enhance and restore all bodies of surface water… with the aim of achieving good surface water status at the latest 15 years after the date of entry into force of this Directive.

(b, ii) Member States shall protect, enhance and restore all bodies of groundwater, ensure a balance between abstraction and recharge of groundwater, with the aim of achieving good groundwater status at the latest 15 years after the date of entry into force of this Directive.

For protected areas the above objectives of the WFD are more stringent, since no extension periods due to possible derogations are allowed (Article 4.1 c):

(c) Member States shall achieve compliance with any standards and objectives at the latest 15 years after the date of entry into force of this Directive, unless otherwise specified in the Community legislation under which the individual protected areas have been established.

Moreover, whenever several objectives have to be applied to surface waters, ground waters and protected areas, the most stringent shall apply (Article 4.2).

In practice, then, it may be concluded that in Natura 2000 sites the water quality standards defined in the WFD have to be met by 2015 unless maintaining favourable conservation status of habitats and / or species requires fulfilling a different set of criteria. In other words, the objectives of the Birds and Habitats Directives are given first priority in relation to the objectives of WFD. The good status defined in the WFD should be reached if this does not compromise the Natura 2000 values under which the areas have been established.

Based on this conclusion, together with the main objective of the WFD dealing strictly with water quality i.e. aquatic environments, the general approach for assessing relevant conservation values in Natura 2000 areas arises from the aquatic and semi-aquatic habitats and species included in the Habitats and Birds Directive.

It is therefore concluded, that the selection of relevant Natura 2000 areas into the protected areas register is based on:

1. the habitats and species that are legally binding in Member States for establishing conservation areas, and
2. depending directly and unequivocally on the occurrence of water.

Protection of these criteria also directs future management and spatial planning in the catchment area.

It follows that the legally binding habitats and species of community interest, recognised in Annexes I and II of the Habitats Directive (92/43/EEC), Annex I of the Birds Directive (79/409/EEC) and the national migratory bird species in accordance with the Birds Directive, need to be analysed for identifying the water dependent species. The direct and unequivocal dependence on water should be understood broadly

- with habitats as a necessary component of stable persistence of the habitat (ranging from regular flooding and groundwater influence to standing water)
- with species as breeding, feeding or habitat requirements necessary for stable persistence of the species (i.e. breeding habitats, feeding habitats or more generally primary habitats).

The approach formulated above is rather similar to e.g. the description of the Scottish Environment Protection Agency on the selection of **areas designated for the protection of habitats or species** (SEPA 2005) for the protected areas register of the Water Framework Directive. The areas selected in Scotland comprise the aquatic part of Natura 2000 sites designated under the Birds Directive (79/409/EEC) and the Habitats Directive (92/43/EEC).

3.5.4 Relevant Natura 2000 Habitat Types and Species in Finland

The habitats and species of Natura 2000 sites that occur in Finland have been recently assessed by Finnish Environment Institute in order to determine relevant conservation values in accordance with the WFD (in reports Hokka and Kokko 2005, Leikola et al. 2005). Of the Natura 2000 species, bird species are recognised in the Birds Directive (Annex I) and other taxa and specific habitats in the Habitats Directive (Annexes I and II). Some habitats and species are prioritised in the Habitats Directive for identifying the species and habitats, which the European Community has particular conservation responsibility based on the proportion of their natural range and danger of disappearance.

Of the 68 Natura 2000 habitat types that occur in Finland, as described by Airaksinen and Karttunen (1998), 23 were estimated to depend directly and unequivocally on the occurrence of water (Table XIV). Of these, three habitats were considered to consist only partially of water dependent habitats. Since Finnish mires may be divided into several categories that differ in the level of water dependency, all mire types were systematically excluded from the assessment of water dependent habitat types. However, paludified, flood depended shoreline wetlands that have been included in the transition mires and quaking bogs habitats, were singled out as water dependent habitats.

Inland water habitats (A)	Sea and Coastal habitats (B)	Semi-aquatic Habitats (C)
Oligotrophic waters containing very few minerals of sandy plains (*Littorelletalia uniflorae*) (3110)	Sandbanks which are slightly covered by sea water all the time (1110)	Northern boreal alluvial meadows (6450)
Oligotrophic to mesotrophic standing waters with vegetation of the *Littorelletea uniflorae* and/or of the *Isoëto-Nanojuncetea* (3130)	Estuaries (1130)	Fennoscandian mineral-rich springs and springfens (7160)
Hard oligo-mesotrophic waters with benthic vegetation of *Chara* spp. (3140)	* Coastal lagoons (1150)	* Calcareous fens with *Cladium mariscus* and species of the *Caricion davallianae* (7210)
Natural eutrophic lakes with *Magnopotamion* or *Hydrocharition* – type vegetation (3150)	Large shallow inlets and bays (1160)	* Petrifying springs with tufa formation (*Cratoneurion*) (7220)
Natural dystrophic lakes and ponds (3160)	Reefs (1170)	* Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior* (*Alno-Padion,Alnion incanae, Salicion albae*) (91E0)
Fennoscandian natural rivers (3210)	Boreal Baltic narrow inlets (1650)	* Fennoscandian deciduous swamp woods (9080)
Alpine rivers and the herbaceous vegetation along their banks (3220)	# Baltic esker islands with sandy, rocky and shingle beach vegetation and sublittoral vegetation (1610)	## Transition mires and quaking bogs (7140)
Water courses of plain to montane levels with the *Ranunculion fluitantis* and *Callitricho-Batrachion* vegetation (3260)	# Boreal Baltic islets and small islands (1620)	

Tab.XIV: Finnish Natura 2000 habitat types of Annex I in the Habitats Directive that depend directly and unequivocally on the occurrence of water. Natura 2000 habitat codes (Annex I in the Habitats Directive) are in brackets.
= underwater parts, ## = only the shore habitats paludified by frequent flooding, * = prioritised habitats

The legally binding species listed in Annex II of the Habitats Directive and in Annex I of the Birds Directive have been assessed in a similar fashion. Finland has received reservations from the EU for the following aquatic or semi-aquatic species: European beaver (*Castor fiber*), asp *(Aspius aspius),* spined loach (*Cobitis taenia*), bullhead *(Cottus gobio)*, lamprey (*Lampetra fluviatilis*), brook lamprey (*Lampetra planeri*) and salmon (*Salmo salar*). Species with reservations are not legally binding in establishing Natura 2000 areas and were therefore excluded from the assessment. It needs to be noted that Finnish reservations include all fish species of Natura 2000 importance. In Member States that have no such reservations, the protection of these fish species has specific value in relation to the good ecological status required by the WFD.

The main guideline in water management under the WFD, including catchment area land use management practices, is to maintain and improve the favourable conservation status of the identified habitats and species in the Natura 2000 areas. In practice, the main aim of water management is enhancing and maintaining the environmental conditions necessary in conserving the habitats required by the identified species. The required water management measures need to be extended in the catchment area especially with regards to the protected species that migrate in or from the given conservation area.

In setting maintenance objectives for the species, the The World Conservation Union (IUCN) criteria can be used in case specific management activities need to be prioritised and no measures for maintaining several species with a common measure can be foreseen. In practice, this means that conserving critically endangered species should be given more attention than endangered species but only if no means common for maintaining or rehabilitating the area for several Natura 2000 species can be found.

3.5.5 Lake Lentua Case

Lake Lentua is a large, unregulated lake with 90 km^2 water area and a total catchment sise of 2065 km^2 located in the River Oulujoki catchment area in the Kainuu region, Northern Finland (coordinates 3626408 E: 7129852 N); (Fig. 27). The nearest town, Kuhmo, lies within 15 kilometres south of the relatively deep lake (maximum depth 52 m in Timonniemi, mean depth 7.4 m), whose water quality has been monitored since the 1960s. Lentua is amongst the most surveyed lakes of the Oulujoki River Basin.

The oligotrophic lake, whose mean water colour was 56 mg Pt l^{-1} in 2000-2005 (296 samples from five monitoring stations with a minimum of 10 samples each; median 50 mg Pt l^{-1}, range 25-200 mg Pt l^{-1}), was reported to the European Commission in March 2005 as a large, naturally humic lake of Type 2 according to the interim lake typology applied in Finland (Pilke 2004). Lake Lentua has been studied as a reference for a large unregulated lake (e.g. Alasaarela et al. 1989, Hellsten et al. 1989, see also Hellsten 2000) and it may become a type specific reference lake for Type 2, although currently this status has not been officially decided (personal communication, Hämäläinen 2005).

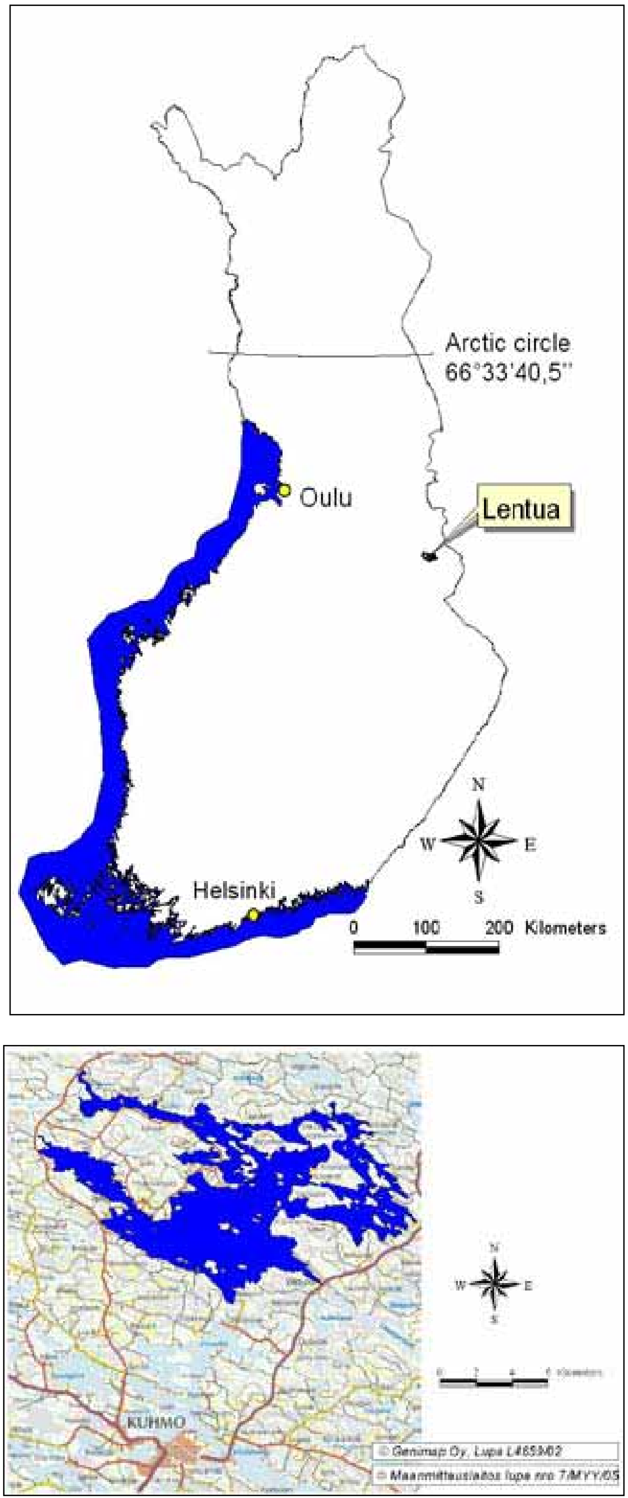


Fig. 27: Location of Lake Lentua in the northern part of Finland

In earlier studies (Alasaarela et al. 1989, Hellsten et al. 1989) the mean water colour of Lentua has been reported as 54-55 mg Pt l-1 in 1984-1986, which indicates no overall change in water colour in comparison with the current mean of 56 mg Pt l-1. In the Kainuu Regional Environment Centre, which is the responsible authority for water management and monitoring in Lake Lentua, Virtanen (unpubl.) has analysed trends in water chemistry between the 1960s and 1990s during the runoff periods in spring (March) and autumn (August).

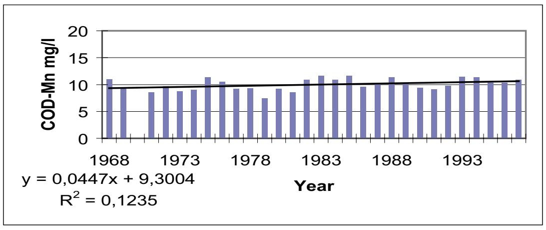
In the permanent deep monitoring station (nro 132) providing the longest monitoring results in Lake Lentua, chemical oxygen demand (COD) and total phosphorus levels all show slight but steady increase from the year 1968 to 1996 (Fig. 28). The results are highlighted in the benthic samples (46-51 meters).

Similar results have been found in oxygen saturation levels of Lake Lentua, which have decreased roughly from 40 to 5-10 percent in spring (March) and from 60 to 45-50 percent in summer (August) in the benthic station between 1964 and 1999 (Markkanen et al. 2001). Also, Sandman et al. (1994) reported a decreasing trend in oxygen saturation levels in the benthic layers of Lake Lentua from the early 1970s to 1994.

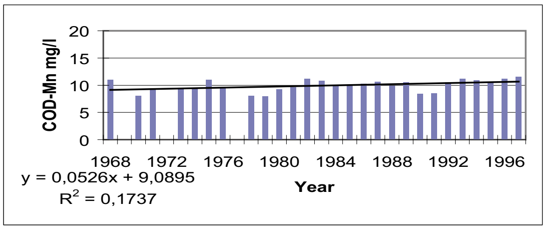
Chemical oxygen demand

a) Surface layer (0-5 meters)

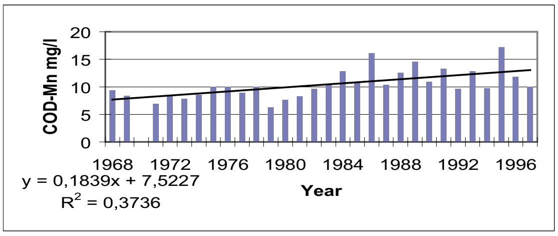
March

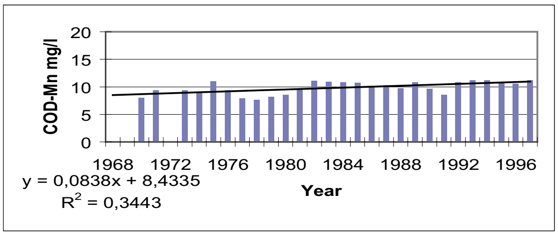


August



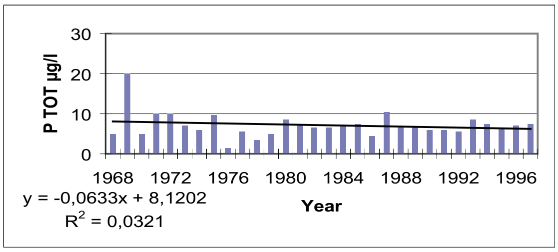
b) Bottom layer (46-51 meters)



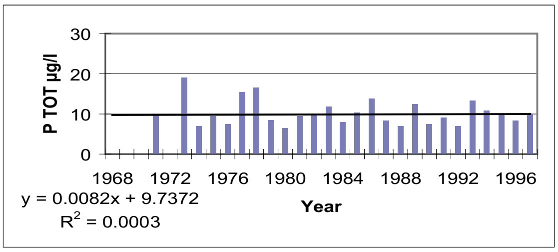


Total Phosphorousa) Surface layer (0-5 meters)

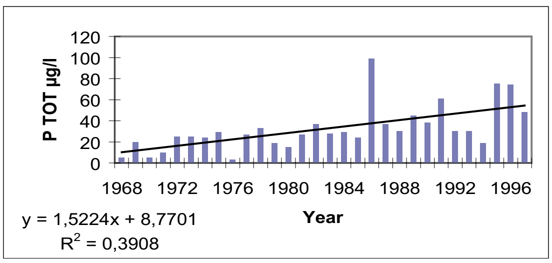
March



August



b) Bottom layer (46-51 meters)



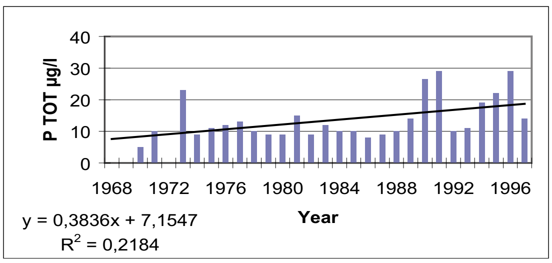


Fig. 28: Trends (regression analysis) of chemical oxygen demand (COD) and total phosphorous in varying depths (Station 132) in Lake Lentua during winter (March) and autumn (August). The winter time values are on the left, the autumn values on the right. (Virtanen unpubl.).

Chlorophyll a levels have been monitored in an annually differing number of stations in Lake Lentua throughout the years. Between 2000-2004 chlorophyll a was sampled at nine stations of which four took a minimum of 10 samples (total number of samples in 2000-2004). A comparison the chlorophyll a levels of these stations by total depth between 2000-2004 and 1990-1995 from summer period samples in June-August shows a decrease in chlorophyll a levels at each station (Table XV). The difference decreases towards the deep station suggesting that the phytoplankton production has decreased especially in the shallow areas of lakes.

Years	Station Lentua 6 (3 m)	Station Lentua 14 (13.5 m)	Station Lentua 12 (24.5 m)	Station Lentua 132 (48.5 m)
Abundance	1990-1995 2000-2005	6.14 3.95	5.86 4.91	5.43 4.34

Tab. XV: The mean chlorophyll a values (µg l^{-1}) of water column (0-2 m) at stations with more than 10 samples in 1990-1995 and 2000-2005. All sam ples taken between June and August. Total depth of sampling stations in brackets.

Hellsten et al. (1989) reported the littoral macrophyte vegetation of Lake Lentua for different shoreline types in 1984-1987. The shores were identified in relation to moraine, rock, gravel, sand and peat substrates. In all, roughly 60 percent of the total shoreline of Lake Lentua was divided into shoreline types. The most abundant shores are rocky and moraine shores that comprise respectively 41 and 36 percent of the shorelines. Sandy and peaty shores covered 13 and 10 percent of the lake shores respectively. Macrophytes were assessed in three successive years in 38 sampling sites (29 transects and 9 sampling quadrats of 0.5 x 0.5 m), 100 sampling sites (42 transects and 58 quadrats) and 112 sampling sites (10 transects and 102 quadrats). The most frequently recorded species were *Isoetes lacustris* (20.4 %), *Lobelia dortmanna* (12.2 %), *Isoetes echinospora* (11.4 %), *Ranunculus reptans* (8.0 %), *Equisetum fluviatile* (7.1 %), *Phragmites australis* (6.9 %), *Eleocharis acicularis* (6.9 %) and *Subularia aquatica* (5.0 %) account together 77.9 % of the species met. The total macrophyte species number was 42 with 28 species recorded in less than 1 percent of the sampling sites. In general, the abundance of large isoetids was seen as an indication of unregulated pristine conditions (Hellsten et al. 1989).

In an analysis of abundance and occurrence of different ecomorphological life-forms of macrophytes (Hellsten et al. 1989), it was noticed that isoetids and helophytes were the most frequent groups accounting for 32.1 % and 15.4 % of the species, respectively, while 3.8 % of the species belonged to nympheids and 2.5 % to elodeids. Bryids, ceratophyllids and charids were all represented by less than 1 percent amongst the species. In Finnish vegetation based lake typology (Maristo 1941), Lake Lentua has been classified as an *Equisetum-Phragmites* lake (Hanhela and Vainio 1987). In comparison with other *Equisetum-Phragmites* lakes in the Kainuu region, Lake Lentua has a distinctively higher number of isoetid species (Hellsten et al. 1989). The sandy shores, however, are inhabited especially by helophytes with a typical species composition including *Equisetum fluviatile, Phragmites australis, Eleocharis palustris, Lysimachia thyrsiflora* and *Juncus species*. On rocky shores, the helophyte species included *Molinia caerelua* and *Potentilla palustris*, whilst the *Carex* species favored peaty shores.

In a classification of macrophytes according to trophic levels (Toivonen 1981), the dominant species in the years 1984-1987 fall under oligotrophic, meso-oligotrophic and indifferent species (Table 24) indicating a clear dominance of oligotrophic macrophyte species in the studied littorals. When the nine transects studied in 2004 and in 1984-1987 are compared, there is a slight increase of oligotrophic indicator species, i.e. *I. echinospora, I. lacustris* and *L. dortmanna* in 2004. Also, *C. acuta*, indicating meso-eutrophy, had an increased frequency. Since the transect assessment method of 2004 differed from the study of the late 80s, in that the frequencies were calculated by each transect while the 80s data was based on abundance, the slight changes may be artefacts of the study design. Also, the sample size consisting of nine transects may not be adequate for reliable comparisons, as the percentage change resulting from one observation per transect influences the results heavily (±11% per species).

In a study of Lake Lentua sediment profiles and benthic layers (Sandman et al. 1994), altered diatom species composition indicating increased nutrient levels from the beginning of 1970s was reported. The diatom investigation, in which 180 species and 150 species from two sample sites (54 meters and 36 meters respectively) were recorded, showed a decrease in indicator species of oligotrophy (*Cyclotella iris*) and increased eutrophic indicator species (*Asterionella formosa*) towards the 1990s. In general the diatom analysis revealed that the eutrophication of Lake Lentua had increased especially since the beginning of the 1980s. The diatom species composition had not returned to the earlier oligotrophic species composition by 1990 but indicated mesotrophic conditions instead. The findings were strongly supported by increased conductivity in the benthic layer indicating clear eutrophication.

It can be therefore concluded that Lake Lentua is in the process of gradual and slow eutrophication already seen in increased nutrient levels, decreased oxygen saturation levels and altered diatom species composition especially in the benthic layer. There seems to be a minute increasing trend in chlorophyll a levels between 2000-2004. The slight eutrophication, however, is not captured in the littoral macrophyte species composition. In all, Lake Lentua is still in a very pristine condition although the signs of eutrophication are present.

The main sources of current nutrient loading in Lake Lentua have been presented by Markkanen et al. (2001). The annual total phosphorus load is roughly 25 000 kg and annual nitrogen load 395 000 kg; the limiting nutrient for algae is phosphorus. Natural background loading accounts for 39 % of the annual P load, while agricultural sources cover 23 %, forestry activities 21 %, aerial deposit 12 %, fish farming 3 % and scattered settlement 2 % of the annual P load. Of the annual N load, 51 % consists of natural loading, 21 % of aerial deposit, 16 % of forestry activities, 9 % of agriculture, 2 % of fish farming and only 1 % of scattered settlement. Although the nutrient loading originating from fish farms is quite small, some localised impacts were reported to be noticeable. It needs to be noted, that forestry and agriculture account together for 44 % of the annual P load.

The fish farms are located along the rapids of the Rivers Kaarneenkoski and Vuonteenkoski flowing into Lake Lentua from the Northwest (Markkanen et al. 2001). Most swamps that have been drained for forestry via ditchs are located at the eastern shores, south-western shores and northern shores of Lake Lentua (Luoma-Aho 1988), while most of the harvested forests in the late 1980s were reported specifically from the southern, south-eastern and eastern shore areas and in the northern shores surrounding the rapids of the River Kaarneenkoski (Hanhela and Vainio 1987).

In an analysis of the most significant natural recourses in Lake Lentua, Luoma-aho (1988) identified main fields at eastern and south-western shores and also at south-eastern shores. The pressure areas recognised in Lake Lentua (Luoma-aho 1988, Hanhela and Vainio 1987) have been identified in Fig. 30 (Management Activities).

The increased eutrophication seen in the benthic layers of Lake Lentua has been connected to forestry activities of the 1980s (Sandman et al. 1994). However, the internal loading in Lake Lentua is more significant than the loading from outer sources (Markkanen et al. 2001). According to Sandman et al. (1994), the decreasing trend in C/N ratio towards the sediment surface layer suggests that the organic matter originated from internal algae production. It has been concluded, that the total nutrient loading of Lake Lentua from outer sources has reached a level that does not allow any increases without the risk of eutrophication (Markkanen et al. 2001).

3.5.6 Relevant Natura 2000 Values of Lake Lentua

Lake Lentua belongs to the Nature Reserve Friendship national park co-governed by Finland and Russia and has been included partially in the Natura 2000 network. The authority maintaining the Nature Reserve Friendship is Metsähallitus acting as an authority of the state owned forest management in Finland. Metsähallitus is also responsible for developing the maintenance and management plan of the national park. The Kainuu Regional Environment Centre, however, bears responsibility for water monitoring and Water Framework Directive implementation in Lake Lentua. In the Finnish river basin district governance Lake Lentua belongs to the Oulujoki-Iijoki River Basin District (RBD 4) and the operations of the Kainuu Regional Environment Centre. A prognosis of this case study is, that the requirements arising from the WFD need to be acknowledged in the maintenance and management plan of the national park.

Despite the national park and Natura 2000 status of Lake Lentua, only few comprehensive nature surveys have been carried out in the area this far. The Natura 2000 habitats are being currently revised in field studies of Metsähallitus conducted between May-August 2005, which may also reveal other conservation values recognised in the Birds and Habitats Directives. The assessment provided below is based on the data stored in the Natura 2000 database by June 2005 (Finnish Environment Institute 2005) and the Natura 2000 species and habitats that the Kainuu Regional Environment Centre (2005) has identified as the basis for protection. A comprehensive vegetation survey of Lake Lentua (Hanhela and Vainio 1987) and the vegetation data provided in studies of Hellsten et al. (1989) were also investigated for species of the Habitats and Birds Directive. It seems that no comprehensive vegetation or nature surveys have been conducted between 1987 and 2005 in Lake Lentua (personal communication Meriruoko 2005, Vainio 2005).

The protected Natura 2000 area of Lake Lentua with 6591 hectares (Fig. 29) consists of ten recorded Natura 2000 habitats of Annex II and eight bird species recognised in the Birds Directive's Annex I (Tables 16,17; Kainuu Regional Environment Centre 2005 and Metsähallitus 2005). Altogether, three habitats and four bird species are considered water dependent and hence relevant according to the requirements of the WFD.

Of the different habitats, oligotrophic waters containing very few minerals of sandy plains (*Littorelletalia uniflorae*) is the main habitat type covering 4790.5 hectares or roughly 72 percent of the Natura 2000 area, while the dystrophic lakes and ponds, and transition mires and quaking bogs account both for less than 1 percent of the protected area. In 2005, the habitat areas located in the Natura 2000 area were assessed in field surveys conducted by Metsähallitus; the surveys did not cover the total Natura 2000 area (Metsähallitus 2005). The field survey area covered amounted to 33.3 hectares of bog woodlands, 0.2 hectares of Fennoscandian lowland species-rich dry to mesic grasslands, 77.8 hectares of Western Taïga and 0.2 hectares of Siliceous rocky slopes with chasmophytic vegetation. Area data of other habitat types were not given.

The habitats and species relevant to the WFD, therefore, define the primary objectives as well as the designation of water management measures in practice. It has to be noted, however, that although the Bird Directive species found in Lake Lentua are not particularly rare according to the IUCN criteria, they nonetheless need to be given specific consideration in water management for securing favourable conservation status. Of the habitats, oligotrophic waters containing very few minerals of sandy plains (*Littorelletalia uniflorae*) cover the actual lake area of Lake Lentua, while the three small dystrophic ponds are located at the islands of the protected area.

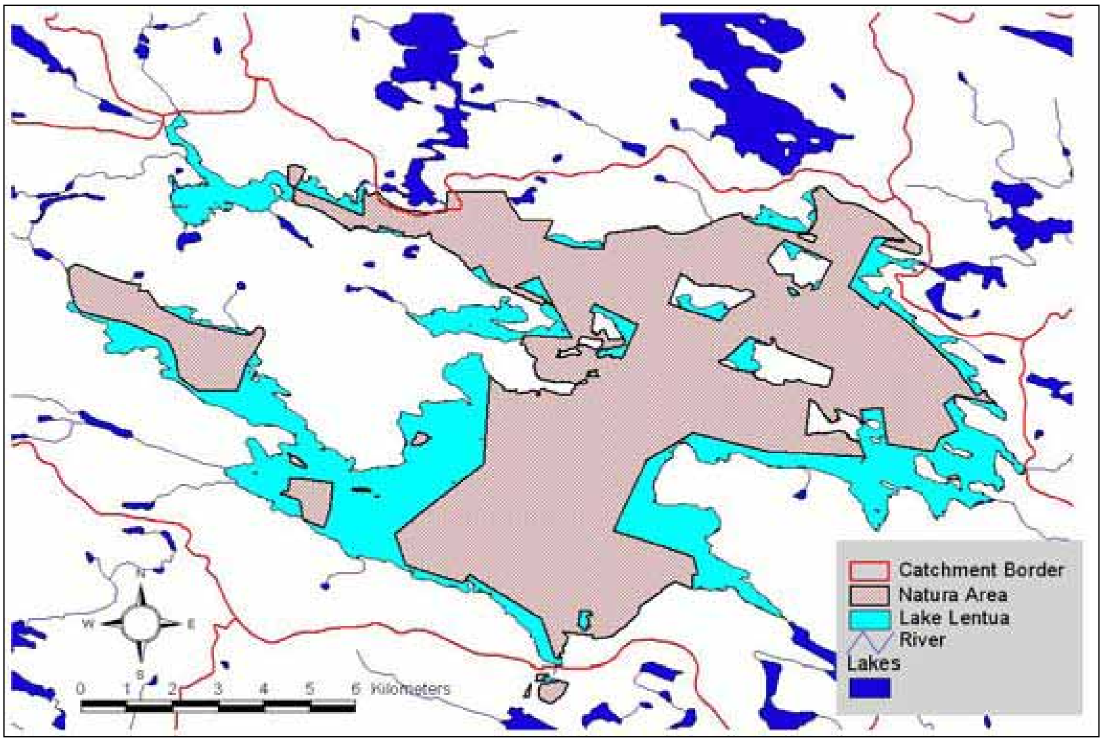


Fig. 29: Natura 2000 area delineation in Lake Lentua.

Habitat types in Lake Lentua Area	Area ha *	WFD Importance
Oligotrophic waters containing very few minerals of sandy plains (*Littorelletalia uniflorae*) (3110)	4790.5	Yes
Natural dystrophic lakes and ponds (3160)	-	Yes
Transition mires and quaking bogs (7140)	-	Yes
Siliceous rocky slopes with chasmophytic vegetation (8220)	0.2	No
Siliceous rock with pioneer vegetation of the *Sedo-Scleranthion* or of the *Sedo-albi-Veronicion dillenii* (8230)	-	No
Western Taïga (9010)	77.8	No
Fennoscandian herb-rich forests with *Picea abies* (9050)	-	No
Coniferous forests on, or connected to, glaciofluvial eskers (9060)	-	No
Bog woodland (91D0)	33.3	No
Fennoscandian lowland species-rich dry to mesic grasslands (6270)	0.1	No

Tab. XVI: The recorded Natura 2000 habitats (Annex I, Habitats Directive) in the Lake Lentua area. The water dependent habitats are considered to have importance according to the WFD. (* = Field surveys of 2005 covering part of the Natura 2000 area. Area of the habitats marked with minus were not given.

Bird Species Occurring in Lake Lentua	WFD Importance	Endagered Status IUCN 2000
black-throated diver (*Gavia arctica*)	Yes	LC
red-throated diver (*Gavia stellata*)	Yes	NT
common tern (*Sterna hirundo*)	Yes	LC
common redshank (*Tringa totanus*)	Yes [1]	LC
lesser black-backed gull (*Larus fuscus fuscus*)	Yes [1]	VU
merlin (*Falco columbarius*)	No	VU
honey buzzard (*Pernis apivorus*)	No	NT
black woodpecker (*Dryocopus martius*)	No	-

[1] = migratory species; LC=Least Concern; NT = Near Threatened; VU = Vulnerable.

Tab. XVII: The bird species recognised for Natura 2000 (Annex I, Birds Directive and official migra tory species) recorded in the Lake Lentua area and their endangered status in 2000 according to IUCN criteria (Rassi et al. 2001). The water dependent habitats are considered to have im portance according to the WFD.
[1] = migratory species; LC=Least Concern; NT = Near Threatened; VU = Vulnerable.

3.5.7 Harmonising Management of Natura 2000 and the WFD in Lake Lentua

The Lake Lentua Natura 2000 area is governed by a maintenance and management plan of the Nature Reserve Friendship formed by Metsähallitus. However, the water management plan of the Water Framework Directive (WFD) and regional water management activities fall under the responsibilities of the competent authority for the River Basin District, i.e. the Kainuu Regional Environment Centre.

According to the Water Framework Directive (Article 14, 1b), the significant issues of water management need to be addressed via public participation in 2007. Therefore, the specific issues identified and suggested below are proposed to be planned in 2005-2006 and discussed in 2007 at the latest, by the competent authorities. Currently, a new maintenance and management plan of the Nature Reserve Friendship is drafted by Metsähallitus to be finalised by the end of 2005 (personal communication, Meriruoko 2005). The preliminary draft plan does not include specific water management issues in accordance with the WFD implementation, so the water management issues identified here can be considered also in the development of or as a supplement to the future management and maintenance plan.

3.5.7.1 General guidelines and objectives

In practice, three guidelines cut across the overall design of water management in Lake Lentua:

1) As a general guideline, reaching good status of waters as defined in the WFD should not jeopardise the favourable conservation status required by the Habitats Directive and the Birds Directive.
2) Therefore, protection of the water dependent Natura 2000 habitats and species is given first priority in defining the water management practices.
3) The water management practices are implemented following the WFD whenever this is possible without causing conflict with the objectives of the Habitats and Birds Directives.

In Lake Lentua, the objectives of the WFD and the Habitats Directive are in harmony, since maintaining the pristine, oligotrophic conditions of the main habitat (oligotrophic waters containing very few minerals of sandy plains) is a shared objective. Preserving the oligotrophic conditions that form the legal basis of Lake Lentua conservation according to the Habitats Directive, is synonymous with maintaining the good water status in Lake Lentua. The possible reference status of Lake Lentua in the Finnish WFD lake typology, representing natural conditions of large humic lakes (type 2), imposes similar requirements for preserving oligotrophy in the management plan.

The main objectives of water management in Lake Lentua can therefore be stated as follows:

Objective 1

Maintain the oligotrophic conditions of Lake Lentua by securing the favourable conservation status of the Natura 2000 habitat (oligotrophic waters containing very few minerals of sandy plains) as required by the Habitats Directive.

Objective 2

Prevent deterioration of the good status of Lake Lentua by implementing necessary measures as required by the WFD (Article 4a.i).

3.5.7.2 Management activities

Since signs of steadily increasing eutrophication are found in one benthic sampling station but not in the current littoral macrophyte monitoring of Lake Lentua, there is a need to assess the impacts of eutrophication more thoroughly. Also, the recent trends in chlorophyll a levels suggest an increasing productivity in the surface waters in 2000-2004 surpassing the 1994-95 levels, thus supporting the need for further assessments. These requirements are of high importance because of 1) the possible reference status of Lake Lentua and 2) oligotrophic conditions based on the Habitats Directive. Since Lake Lentua is a possible reference site for the WFD lake typology, the current and historical status of the lake should be investigated thoroughly and reliably.

Due to the reference status of the lake and its pristine conditions, it seems evident that Lake Lentua has a central role in the national monitoring network of the WFD, as well as in the River Basin District monitoring network. Monitoring requirements for surface waters and protected areas are stipulated in the WFD (Article 8.1). To summarise briefly, the monitoring programmes need to establish the ecological and chemical status of waters in each River Basin District. In protected areas, however, the monitoring programmes need to be supplemented with the specifications of those Directives under which the areas have been established. The monitoring programmes have to be operational by the end of 2006.

In practice, investigations of Lake Lentua are essential 1) for assessing the current ecological and chemical status in accordance with the WFD, and 2) for providing information of the favourable conservation status as defined by the Habitats Directive and Birds Directive. The investigations of the current status of Lake Lentua need to be designed in a way that includes continuous monitoring schemes. Therefore, the following water management activities have been identified:

Management Activity 1

Assess the current ecological and chemical parameters of Lake Lentua in accordance with the WFD quality elements for establishing reference conditions and impacts of eutrophication.

1.1 Assess Ecological Parameters

Carry out thorough investigations of the ecological parameters and the chemical parameters of Lake Lentua identified in the WFD for establishing reference conditions and the current status of the lake according to the Water Framework Directive.

In accordance with the WFD (lake status normative definitions in Annex V, 1.2.2), investigations of ecological status require:

- Phytoplankton studies of the taxonomic composition and biomass and the frequency of plankton blooms.
- Benthic invertebrate studies of the taxonomic composition and abundance, sensitive indicator taxa vs. insensitive indicator taxa and taxonomic diversity.
- Fish studies of species composition and abundance, occurrence of sensitive species and age structure assessments.
- Macrophyte and phytobenthos studies of the taxonomic composition and abundance.

A diatom study is recommended for confirming the current species composition and the eutrophication trend noted in 1970-1990s (Sandman et al. 1994). Preferably, the diatom study should include a minimum of 5 sites including the two used by Sandman et al. (1994).

The ecological studies of macrophytes, benthic invertebrates and fish should be carried out at integrated monitoring sites representing the shorelines of Lake Lentua. Also, pelagic sampling sites for fish and benthic invertebrates need to be investigated. The initial studies should be used for forming the basis for long term monitoring (described in Management activity 4). The initial study sites should therefore include potential impact sites near identified nutrient loading sources, i.e. fish farming and forestry.

The macrophyte study of 1985 using 100 sampling sites (42 transects and 58 quadrats, see Hellsten et. al 1989) should be repeated with the same methodology allowing direct comparisons with sufficient data. Littoral electric fishing transects and invertebrate sampling should be combined with the macrophyte study according to shore type (rocky shores, moraine shores, sandy shores, peaty shores). It is recommended that the initial investigation include 10 sampling sites per each shore type, i.e. 40 sites of combined electric fishing transects and invertebrate sampling sites. Of these, five sites per shore should be located in potential impact sites. The vegetation coverage in bays should be assessed in particular for evaluating changes in vegetation cover and growth.

The following potential impact sites of fish farming, forestry and agriculture are identified based on earlier studies (Hanhela and Vainio 1987, Luoma-aho 1988); (Fig. 30).

- Korppilahti Bay, one effluent of the River Kaarneenkoski (fish farming and forestry)
- Mouth of the River Kaarneenkoski (fish farming and forestry)
- Lapinlahti Bay (agriculture and forestry)
- Nuottalahti Bay (agriculture and forestry)
- Hietalahti Bay (agriculture and forestry)
- Varalahti Bay (agriculture)

Of the proposed possible impact sites, one macrophyte transect of 1984-1987 (nro 21) is located in Lapinlahti Bay, and water samples are taken infrequently near the mouthof the River Kaarnenkoski and Nuottalaht Bayi. Other sites, however, are not included in the current monitoring of Lake Lentua. Also, pelagic sites should be chosen for assessing the current fish species composition and age structure.

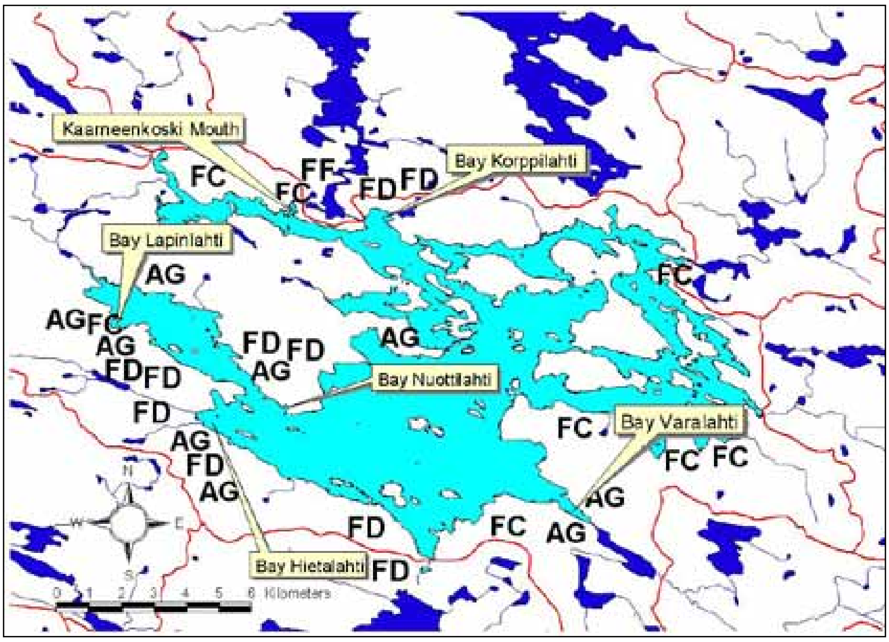


Fig. 30: Identified pressures and proposed monitoring sites for assessing possible impacts of eutrophication. FF = Fish Farming, FC = Forestry harvesting, FD = Forestry drainage, AG = Agricultural fields. Drainage indicates areas of > 10 ha of drained swamps, agricultural fields are the most valuable fields per 25 hectare squares (Luoma-aho 1988). Red borders indicate the catchment area of Lake Lentua.

1.2 Assess the Chemical Parameters and Priority Substances

Carry out investigations of the chemical parameters for assessing the priority substances identified in Annex X of the WFD and proposed nationally in Finland. The proposed national priority substances together with specified methodology for Finland are described in detail in Londesborough (2003).

Records of the chemical substances produced in Finland are stored in the register KETU of the Ministry of Social Affairs and Health. It is recommended, that the assessments for identifying the substances is estimated in the River Basin District

1) according to the chemical substance register of the Ministry of Social Affairs and Health;
2) by questionnaires to the potential producers and end user of the substances.

These initial assessments of priority substances should be confirmed using water analyses based on the results of the register records and the questionnaire. In case the register and questionnaire show data gaps, it is recommended to carry out water analyses directly.

Based on the findings of the assessments, the lake area may be divided into different water bodies. In case the pressures show impacts, such as increased eutrophication in bay areas associated with the adjacent land use (Fig. 30), some areas may be identified as being at risk of failing the good status.

Management Activity 2

Consider delineating Lake Lentua into different water bodies in case the ecological and / or chemical parameters support this.

It is possible to divide Lake Lentua into different water bodies if natural conditions of the sub-basins differ or noted human impacts support this. For instance, if eutrophication or influences of other sources are noticed at a proposed impact site in Lapinlahti Bay (Fig. 30), the southern part of the bay could be defined as a water body with significant impacts. The WFD identifies a minimum size for typology as 50 hectares, which should be followed as a minimum.

In case a water body delineated in Lake Lentua is at risk of failing the good status, these sites have to be included in the operational water monitoring programme by the end of 2006; the monitoring programmes are to be reported to the EU by 22 March 2007.

It needs to be acknowledged that water body delineations affect the course of future management activities. For instance, if the Lapinlahti Bay area would be separated as a water body, this would place more emphasis on the Natura 2000 values present in the bay area (see Fig. 30). These may require differing and more specific measures than the main area of Lake Lentua.

Different parts of the fragmented Lake Lentua Natura 2000 area (Fig. 30) are likely to have differing natural characteristics. The dystrophic ponds are located in the islands, which introduces a possible need for a different set of measures and management activities than maintaining the oligotrophic conditions of Lake Lentua. For instance, if the red-throated diver (Gavia stellata) should breed in the ponds, the management activities would need to secure this.

Although the nature of Lake Lentua has been studied and described in the late 1980s, and the lake is among the most surveyed lakes in the Oulujoki River Basin, there seems to be a lack of recent studies and relevant biological information for the WFD assessments of the lake area. The Natura 2000 habitat inventories in summer 2005 focused mainly on the islands and did not include vegetation studies (personal communication, Metsähallitus). There is a need for more thorough knowledge of the current biological values in Lake Lentua to develop more detailed management activities.

Few bird species that are considered water dependent (Table 26) have been recorded in the Lake Lentua area. In the bird surveys of summer 2005, the red-throated diver (*Gavia stellata*) and black-throated diver (*Gavia arctica*) were observed as resting but not breeding in the area. A breeding colony of the common tern (*Sterna hirundo*) comprised of 18 adults (9 breeding pairs) and a minimum of 10 offspring is located on a reef in Juurikkalanselkä. Also, ten breeding pairs of the lesser black-backed gull (*Larus fuscus fuscus*), a migratory Birds Directive species, were found in the conservation area in 2005 (personal communication Sorvari 2005, Metsähallitus).

In a water bird count conducted in July 1996 (Sorvari V-M. unpublished, records of Metsähallitus), red-throated divers (*Gavia stellata*) were observed to feed in the assessed shore areas of the Lake Lentua Natura 2000 area, but no observation of breeding was made. Black-throated divers (*Gavia arctica*) were noticed breeding in the Natura 2000 area with a total estimated breeding pair number of 15-20 in the conservation area and its vicinity. The lesser black-backed gull (*Larus fuscus fuscus*) population consisted of 25-30 breeding pairs in 1996, whilst 18-24 breeding pairs of the common tern (*Sterna hirundo*) were counted in the conservation area and its vicinity. One solitary smew (*Mergus albellus*) was noticed to take into flight and one osprey (*Pandion haliaetus*) was recorded in the conservation area; the osprey nesting site was located at Isosuo mire approximately one kilometre outside the conservation area.

Management Activity 3

Carry out comprehensive nature inventories in the Lake Lentua Natura 2000 area complementing the inventories of summer 2005 especially in terms of the habitats and species relevant for the WFD.

The nature inventories should give specific consideration to the habitats and species of the Habitats and Birds Directive considered water dependent (Tables 25, 26). In the inventories, species of the Habitats Directive should be recorded on a map for assessing the required management and conservation measures based on the ecological and chemical investigations (Management activity 1). Also, nesting, breeding and feeding sites of the bird species should be located and their current population numbers counted for estimating the conservation status and required measures based on the ecological and chemical investigations.

It is recommended that the known breeding sites of the common tern and the lesser black-backed gull together with the known feeding sites of the black-throated diver and red-throated diver are recognised as specific areas in the Lake Lentua management plan based on both the Birds Directive and the Water Framework Directive.

Breeding of the black-throated diver (Gavia arctica) has possibly ceased in Lake Lentua after 1996, and the breeding success of both lesser black-backed gull and common tern seem to have decreased significantly from 1996 to 2005. It is recommended that the breeding success of these species is followed with continuous monitoring (see Management Activity 4) to confirm these results; the two available bird counts render the results unsure. The reasons for possible decreased breeding success and population numbers should be investigated: the studies should assess potential connections to the steadily increasing eutrophication levels.

An investigation of the possible breeding sites of red-throated divers (Gavia stellata) in the vicinity of Lake Lentua should be conducted, since Lake Lentua has provided feeding areas for the species for more than 10 years. Although the species may travel hundreds of kilometres in search of food and breeds in small fishless mire ponds, the current feeding sites increase the conservation value of Lake Lentua in terms of water management. It is recommended that the known feeding sites are mapped and restrictions of net fishing are applied in enhancing the protection of the species. Similarly, the known feeding sites of black-throated divers should be identified and mapped.

The protection requirements of the water dependent bird species observed breeding in Lake Lentua in 2005, i.e. the common tern and the lesser black-backed gull, can be prioritised in accordance to their IUCN classification: the lesser black-backed gu ll is classified vulnerable and the common tern of least concern, which indicates increased focus on the protection of the lesser black-backed gull. It is advised that the breeding sites are identified in the management plan for restricting human disturbance.

Of the different water dependent bird species, the findings of the ecological and chemical investigations (Management activity 1) should reflect especially the population status of the lesser black-backed gull and the required measures for maintaining the population in the area. In case increased eutrophication poses threats to the breeding success or to the habitat suitability for breeding, management activities should be targeted to counteract this.

Water quality monitoring of Lake Lentua in 2000-2004 consisted of nine lake stations and one station located in rapids (water monitoring information system HERTTA of the Finnish environment administration). Of these stations, more than 10 samples have been recorded from only four lake stations and one rapids station in 2000-2004. Currently, permanent chlorophyll a sampling is based centrally on four stations in the lake area and there are nine macrophyte transects. Benthic invertebrate samples have been collected from five stations. These are the stations that provide the only direct data for ecological status of the lake. However, the monitoring programme of Lake Lentua is currently under revision for WFD purposes.

The currently known Natura 2000 values of Lake Lentua include water dependent habitats and species, whose conservation is a priority objective in the future water management as defined in the management guidelines. Although the water dependent bird species recorded in Lake Lentua's Natura 2000 area are not significantly threatened or rare, they should play a specific role in monitoring compliance with the Birds Directive and the Habitats Directive, whilst conducting water management according to the WFD. Article 8.1 of the WFD states that the monitoring programmes for ecological and chemical status in protected areas have to be "supplemented by those specifications contained in Community legislation under which the individual protected areas have been established". In Lake Lentua the decreasing population numbers of the bird species considered water dependent between 1996 and 2005 highlight the importance of their monitoring.

Management Activity 4

Design an extended monitoring programme of Lake Lentua covering both Natura 2000 values and quality elements of the WFD.

The current chlorophyll a sampling varies annually with four permanent stations collecting a minimum of 10 samples a year and other stations with differing amounts of samples. It is recommended to increase chlorophyll a sampling in the vicinity of the potential impact sites (Fig. 30) to a minimum of 10 samples a year for detecting signs of eutrophication.

The monitoring programme should be established based on the thorough assessment of the ecological parameters (Management Activity 1.1) covering macrophytes, benthic invertebrates, diatoms and fish. A minimum cycle of 3 years per rotating monitoring cycle for different biological quality elements is recommended for detecting changes in the ecological parameters.

The repetition of the 1985 macrophyte study should reveal long term changes in the vegetation indicative for the current water management planning period ending in the publication of the first River Basin District management plan in 2009. Since fish and invertebrate data is largely missing from Lake Lentua, and the latter influences all of the water depended bird species occurring in Lake Lentua, the monitoring cycle should be repeated in 2 to 3 years. The diatom study should be conducted once every 6 years.

The water bird counts should be conducted annually with specific focus on the lesser black-backed gull population numbers, common tern population numbers and the breeding status of the black-throated diver. Similarly, the feeding behaviour and breeding sites of the red-throated diver in the vicinity of Lake Lentua's Natura 2000 area should be included in the assessments.

Natural loading accounts for 39 % of the annual P load, while agricultural sources cover 23 %, forestry activities 21 %, aerial deposit 12 %, fish farming 3 % and scattered settlement 2 % of the annual P load. Of the annual N load, 51 % consists of natural loading, 21 % of aerial deposit, 16 % of forestry activities, 9 % of agriculture, 2 % of fish farming and only 1 % of scattered settlement. Although the nutrient loading originating from fish farms is quite small, some localised impacts were reported to be noticeable. It needs to be noted that forestry and agriculture account together for 43 % of the annual P load.

The fish farms are located along rapids in the rivers Kaarneenkoski and Vuonteenkoski flowing into Lake Lentua from the northwest (Markkanen et al. 2001). Most swamps that have been drained for forestry with ditches are located at the eastern shores, south-western shores and northern shores of Lake Lentua (Luoma-Aho 1988), while most of the harvested forests in late 1980s were reported specifically located along the southern, south-eastern and eastern shore areas and the northern shores surrounding the rapids of the River Kaarneenkoski (Hanhela and Vainio 1987). In an analysis of the most significant natural recourses in Lake Lentua, Luoma-aho (1988) identified main fields along the eastern and south-western shores and also the south-eastern shores. The pressure areas recognised in Lake Lentua (Luoma-aho 1988, Hanhela and Vainio 1987) have been identified in Fig. 30.

The increased eutrophication seen in the benthic layers of Lake Lentua has been connected to forestry activities of the 1980s (Sandman et al. 1994). However, the internal loading in Lake Lentua is more significant than loading from outer sources (Markkanen et al. 2001). According to Sandman et al. (1994), the decreasing trend in C/N ratio towards the sediment surface layer suggested that the organic matter originated from internal algae production. It has been concluded, that the total nutrient loading of Lake Lentua from outer sources has reached a level that does not allow any increases without the risk of eutrophication (Markkanen et al. 2001).

The history of land use from the 1980s in areas surrounding Lake Lentua, as depicted in Figure 30, together with the increasing eutrophication trends and the overall management objective of maintaining the oligotrophic conditions, create a need for designing land use management practices preventing nutrient loading.

Management Activity 5

Design and implement a buffer zone and collection pond plan for decreasing nutrient leaching into Lake Lentua.

Of the different land uses, forestry and agriculture account for 44 % of the annual P load and 25 % of the annual N load. Most harvesting in the 1980s has taken place in the southern, south-eastern and eastern shore areas and in the northern shores surrounding the rapids of the River Kaarneenkoski (Hanhela and Vainio 1987), whilst most swamp draining has happened along eastern shores, south-western shores and northern shores (Luoma-Aho 1988). The main agricultural fields are located at eastern and south-western shores and also in south-eastern shores. The fish farms are located along the rapids of the Rivers Kaarneenkoski and Vuonteenkoski, flowing into Lake Lentua from the north.

It is therefore recommendable, that the collection ponds and buffer zone creation is directed towards the eastern shores with most agricultural land and forestry areas. Another focus area is in the north, along rapids of the Rivers Kaarneenkoski and Vuonteenkoski collecting both forestry and fish farming loading.

Acknowledgements

I would like to warmly thank Metsähallitus personnel Kristiina Hoikka, Veli-Matti Sorvari and Ari Meriruoko for providing valuable first-hand information and unpublished results for this piece of work. Similarly, the unpublished work of Kimmo Virtanen and valuable information given by his colleagues in the Kainuu Regional Environment Centre, Maarit Vainio and Sirkka-Liisa Markkanen, were significant contributions for the harmonisation of points of view of these two difficult Directives in Lake Lentua. Of the co-operation in identifying relevant Natura 2000 species and habitats that included the help of colleagues working in Finnish Environment Institute (SYKE), i.e. Markku Mikkola-Roos, Ulla-Maija Liukko, Jari Ilmonen, Ilpo Mannerkoski and several habitat specialists, I am deeply grateful.

4 Potential solutions

4.1 Peat production – RiverLifeGIS-tool (RLGis) used in loading estimation

In this sub-study a visual GIS-based planning system for pinpointing land use derived loading sources to river catchments is created. Peat production is used as an example of these sources. The planning system developed uses simple mathematical run-off and loading models to evaluate and visualise the effects of loading on water quality. In the sub-study the system is used to find best possible sites for peat production, to assess integrated impacts of separate peat production plans in the same river catchment and also to consider loading from peat production areas in proportion with the total loading in the catchment.

The tool was used in the River Muhosjoki catchment in several tasks (see chapt. 4.2). Corine Land Cover data was generalised and supplemented with nature protection area data and with information on stages of peat production (Fig. 6). Then the tool was used to define drainage areas to sampling sites (Fig. 7) and to compute land use distribution on these areas. Nutrient loading (Fig. 12) was estimated on the basis of landuse and specific loads used in Finland's environmental administration (Table 4). Monitoring data (Fig. 8, Table 2) was gathered and a phosphorus concentration map (Fig. 9) was produced.

For peat producers the goal is to have all their land areas in production, so the locations of new peat production areas are seldom an alternative. However, the effects of location of peat production area on total nitrogen concentration were evaluated in the Utosjoki River Basin (Fig. 31). The River Utosjoki is a tributary to the River Oulujoki. The upper map presents the real planned peat production area (100 hectares) with overland flow fields as water protection structure. The lower map presents a theoretical alternative location alongside a smaller stream. The nitrogen loading was estimated to be 2.6 kg/day.

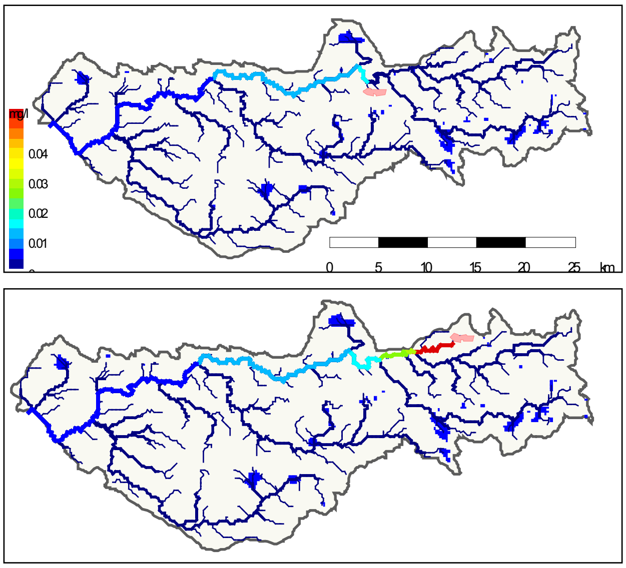


Fig. 31: Two different locations for a peat production rea and their effect on total nitrogen concentration during mean flow period.

The RiverLifeGIS-tool was used also to assess the integrated impact of separate peat production plans on the same river catchment. The upper map of the Fig. 32 presents a theoretical situation that all areas in the Utosjoki River Basin reserved for peat production in the Master Plan would be taken into production all at the same time. The lower map is a comparison where only the uppermost peat production area is utilised.

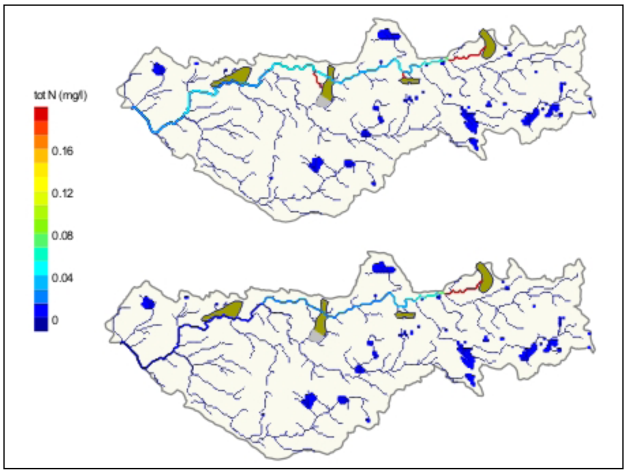


Fig. 32: Integrated impact of all peat production areas in the Master Plan compared to the effect of just the uppermost peat production area on its own

The effect of the same loading during minimum flow period is visualised in Fig. 33. In the next phase, all these River Utosjoki scenarios should be carefully evaluated jointly with the environmental authority and peat producers, and the usability of RiverLifeGIS in tasks like this should be assessed.

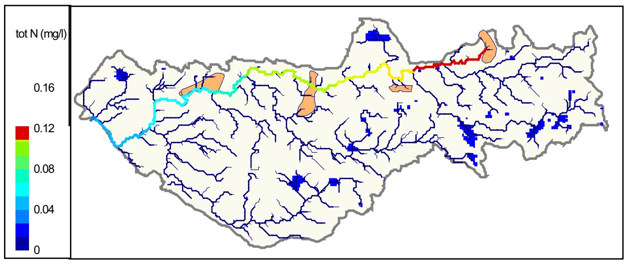


Fig. 33: Same loading from the uppermost peat production area as in Fig 5.1, but now during the minimum flow

In order to increase the general motivation to use the planning system developed, the sub-study also includes demonstrations on the effects of loading and water pollution control methods, and on the environmental impacts of suspended solids and nutrient loading in the riverine environment.

There is also an urgent need to start monitoring of deposited and transported material in the river bottoms in Finland, as well as for research into the ecological impacts of this matter. Also, according to the Water Framework Directive, substrate conditions (river bottom structure and quality) are distinguished among those qualitative factors that support biological data in ecological status assessment.

In the sub-study the role of regional plans for land use in planning peat production is also analysed and developed. In addition, the current process of peat production permit application is analysed, points of contact are sought within the regional planning process, and recommendations are presented for the cost-effective environmental impact estimation process in regional planning of land use. The planning processes are developed in cooperation with all the parties concerned, workshops and meetings being important methods of this work.

4.2 Forestry – basic data of effects

4.2.1 Evaluation of forestry originated loading

There are many different ways to evaluate forest loading depending on sources used and calculation methods. One of them is VEPS, which is a suitable system above all on a large scale level (watercourse level). Loading calculations of VEPS are based on forest statistics and loading coefficients from different studies, and because of this, loading estimations are inaccurate when going into a catchment area scale. Accurate emission values to a single lake from forestry require detailed information of forest management in a catchment area. Due to the prolonged nature of forestry impacts, it is necessary to be familiar with the management history of the catchment area for a period of many decades. This kind of information is, however, difficult to obtain, and many operations that have significant impacts on runoffs are not included in the statistics (Kenttämies and Vilhunen 1999). In this case study the following problems were encountered:

- ignorance of statistics available;
- to obtain forest management data of total catchment area several databases of different forestry associations need to be perused;
- older management data is provided in manual form on files and thus not easily available (shortage of resources);
- management data and boundaries of the catchment area do not correspond.

4.2.2 Biological effects of forestry originated loading

Harmful effects of forestry on small lakes are especially seen in the eutrophication process and increasing siltation. The occurrence of increased nutrient values and biological changes in many headwater catchment lakes were timed to coincide with the most intensive drainage period (Kenttämies and Saukkonen 1996). In this particular case it varied between the 1960s to 1980s. It is reported that big lakes such as Lake Lentua have an ability to self-recover from forestry loading (Sandman et al. 1994), which is not the case when considering small lakes (Sandman et al. 1995). The following is a list of factors that make it difficult to evaluate the biological effects of forest loading in this case study:

- problems in evaluation of loading (loading history);
- no previous knowledge of biota in study lakes (before impact/after impact);
- short sampling and monitoring period;
- only few studies dealing with long-term forestry effects on water biota;
- interactions between different biological quality elements are complicated;
- the prolonged nature of the impacts.

4.3 Hydropower – setting up environmental objectives

4.3.1 Tools for the designation process

The designation of heavily modified water bodies is an official way to handle waters, which are physically modified for human use. The designation process itself provides a very challenging approach with several steps. In applied water management several tools as well as related roles are needed for reaching final decisions. The Finnish approach developed in a parallel process partly in the Watersketch project uses several direct hydromorphological criteria, which are presented in the following chapters.

A) Designation of artificial water bodies:

- More than 50 % of impoundment area used be land => artificial lake or reservoir
- Canal is constructed totally on dry land

B) Designation of heavily modified lakes

- Winter draw down more than 3 m or
- winter draw down at least half of average depth or
- total lake area is decreased to half during winter

C) Designation of heavily modified rivers

- At least half of the river stretch is under the effects of damming, dredging, embankments or is straightened or
- at least half of the natural height of the river fall is lost

D) Designation of transitional or coastal waters

- natural connection to sea water is cut by dams

In addition to these indirect criteria, several tools were used to estimate the biological effects of flow and water level regulation. The REGCEL lake water level analysis – model was developed in the Finnish Environment Institute (SYKE) between 1999-2000 (Hellsten et al. 2002, Ulvi et al. this publication). It uses more than thirty parameters of daily water level values in its calculations. Critical water levels for the aquatic environment and recreational use have been identified on the basis of field investigations and statistical analysis. The identification of water level characteristics as indicators was formulated in several research projects recently published in a review by Marttunen et al. (2001). These indicators have been used to assess the impact of lake regulation and to compare regulation alternatives. Use of this method is described in detail in Hellsten et al. (2002).

The Dundee Hydrological Regime Assessment Method (DHRAM) method was used for water flow analysis. This analysis is based on the Indicator of Hydrologic Alteration (IHA) method developed by Richter et al. (1996). The method has been largely applied in Scotland by Black et al. (2000). This approach compares differences between the impacted and un-impacted flow data and is therefore descriptive without any measured biological response. The Excel-based application FINDHRAM is described in detail in Hellsten et al. (2002) and Ulvi et al. (in this publication).

4.3.2 Importance of environmental objectives

The definition of ecological potential forms a basic approach for management of heavily modified water bodies. The approach developed in this study is based on detailed investigations of biological quality elements and cannot be used in cases, where biological quality elements are not available. In such cases, direct hydromorphological criteria should be used in the designation process, and even the definition of ecological potential can be based on a list of hydromorphological or other mitigation measures, as suggested by the new hydromorphological activity in the Common Implementation Strategy (CIS) of the WFD.

On the other hand, an approach based on ecological quality elements is the only correct one if the suggestions of the WFD are taken literally. Surveillance monitoring starting at the beginning of 2007 all across Europe will increase the knowledge of biological status, and therefore, this method becomes increasingly valid. Our approach showed quite clearly that it is very difficult to improve the ecological condition without significant effects on use. Therefore, according to the definition of heavily modified water bodies and strict delineation of ecological potential it is quite obvious, that the River Oulujoki has already reached a good ecological potential. Demands for maximum ecological potential are relatively high and there are several additional measures to be realised.

4.4 Protected areas – Starting points for Natura 2000 sites

The approach for assessing Natura 2000 sites in accordance with the Water Framework Directive (WFD) and for specifying the important conservation values for management objectives can be based on those water dependent habitats and species that are recognised in the Habitats Directive (Annex I and II) and the Birds Directive (Annex I) occurring in a given Member State. Once identified, the objectives can be incorporated into spatial planning so that the conservation of these habitats and species is given first priority in management activities.

Spatial planners and water managers should establish close cooperation for:

1) Identifying the pressures originating from spatial planning and current land use practises that have impacts on the conservation values (part of characterisation of River Basin Districts, WFD Article 5).
2) Establishing joint means in the catchment area for maintaining the identified water dependent conservation values (part of setting the Programme of Measures, WFD Article 11).
3) Including spatial planning solutions into the River Basin Management Plan in order to carry out comprehensive planning on a catchment level (part of the River Basin Management Plan, WFD Article 13).

Ideally, joint planning is carried out on a catchment scale so that the factors influencing a given water body can be analysed and governed efficiently. Below are some starting points for implementing the three central tasks in co-operative river basin planning involving protection of Natura 2000 values and water management according to the WFD. References are made to the Lake Lentua case study (chapter 3.5)

In relation to the identified conservation values recognised in the legislation relating to Natura 2000 sites, pressures originating from land use can be classified e.g. as harmful, non-relevant and supportive for the Natura 2000 habitat(s) and/or species occurring in the planning area. On the basis of the protected values present, and the analysis of pressures and impacts, management guidelines should be formulated to cover the catchment area. In the specific case of Lake Lentua (chapter 3.5), for example, it could be argued that maintaining the oligotrophic conditions of the Natura 2000 lake habitat also serves the protection of the water dependent bird species. Protection of this value, therefore, would seem to furthermore include protection of other known water dependent species in the lake. The spatial planning solutions regarding e.g. the location of agricultural lands and forestry (swamp drainage) could be, therefore, aimed at reducing nutrient loading from these areas.

However, if a protected species occurred that requires slightly eutrophicated conditions (such as reeds) in e.g. Lake Lentua, management activities allowing or maintaining slight eutrophication should be considered. Such decisions could be based on the endangered status of the species: if the species is highly endangered, it requires strict protection measures possibly outweighting less endangered species. Such decision-making could consider whether only some areas of the lake should be allowed to maintain eutrophic state to a certain degree or whether the establishment of a wetland could be sufficient to maintain the species. A similar approach could be applied to the migration of aquatic species in a water course running through the catchment. So, whenever spatial planning might involve placing obstacles in the watercourse or compromising the continuity of aquatic environments (e.g. minor dams or small harbours), securing the migration of protected aquatic species may become an issue of joint planning.

Planning buffer zones as well as placing wetlands and collection ponds in the catchment area is one of the simplest examples of joint planning tasks of spatial planners and water managers. Relocating current land use practises and assessing nutrient load limits of a planning area for conserving water dependent species or habitats is a more complex issue requiring extensive cooperation between water managers and spatial planners. In the planning phases of the Water Framework Directive, the River Basin Management Plan preparation includes defining significant water management issues in the river basin by 2008 (Article 14, 1b), which is well suited for official recognition of the conservation values.

Once the conservation values in the river basin area have been identified, one solution for cooperation would be defining ecological guidelines for spatial planners by water managers. Such guidelines may be based on e.g. those ecological and / or chemical requirements necessary for the species or habitats to persist. In the case study of Lake Lentua, for instance, the observation made by a water manager (Markkanen et al. 2001) that the external nutrient loading of the lake cannot be increased without the risk of eutrophication could be translated in terms of land use practises as follows:

"The land use practises should not increase nutrient loading into Lake Lentua since this is required for maintaining the Natura 2000 habitat 'oligotrophic waters containing very few minerals of sandy plains'."

Inclusion of spatial planning solutions in the River Basin Management Plan may be initiated by defining the guidelines for protecting water dependent Natura 2000 values on catchment level. These guidelines should then be adopted in regional and local spatial planning tasks. The mapped field data from the Natura 2000 inventories together with the identified pressures and impacts influencing the conservation values in the catchment area should be acknowledged as the general basis influencing spatial planning solutions. Decisions for reserving areas in a regional and / or local plan, e.g. for summer houses, should take into account habitat maps and species observations. Breeding sites or migratory areas of endangered water dependent bird species might cause restrictions for building that need to be incorporated on a regional and local planning level. Similarly, impacts of nutrient loading from intensive land use practises on a breeding site of several threatened species could lead to developing alternative land use scenarios in the catchment. In Lake Lentua, for instance, discovering a nesting site of the red-throated diver may be acknowledged in the River Basin Management Plan as a specific site that should not be built on if there are alternative locations available for development.

A systematic approach to joint planning would be to specify the particular spatial planning phases that belong to the River Basin District management plan. After this, synergies could be defined in the specific plans jointly by water managers and spatial planners. In general, the assessed water quality and the conservation values need to be specified for the planners in order to link land use practises and related nutrient leaching with the conservation of the specific Natura 2000 values.

5 Experiences gained and contribution to sustainable river basin management

5.1 Location of peat production sites

RiverLifeGIS was observed to be beneficial in estimating and visualising land-derived loading and its influence on nutrient concentrations. There are factors affecting nutrient concentrations that are not taken properly into account in loading estimations due to lack of information (more accurate specific loads) or data (GIS-based information on agricultural and forestry measures). Also, the tool itself could be developed further.

The ecological spectra of diatom taxa in the upper part of the Stream Hanhioja indicated the effects of loading of peat production. The effect of the peat production area could not be distinguished from the water quality of the stream with the diatom indeces used. This seems to indicate that diatom taxa are suitable as indicators of loading from peat production area, but diatom indices (IPS, GDI, TDI) are not. However, the majority of differences in water quality by diatom indices in different parts of the river system corresponded with the chemical water quality

In this case aquatic macrophytes did not seem to be suitable as indicators for loading from peat production areas as described in section 3.2.3.4. But the differences in water quality when assessed using aquatic macrophytes in different parts of the river system were mainly parallel with chemical water quality and diatom indices (smallest stretches excluded). Apart from the Stream Hanhijoki, analyses of aquatic macrophytes and of phosphorus concentrations led to similar results regarding water quality (Table 3). Aquatic macrophytes probably give a good indication regarding the bottom quality of the stream.

5.2 The role of spatial planning in water protection measures of forestry

The aim of spatial planning is to promote ecologically, economically, socially and culturally sustainable development. Land use planning operates on regional and municipal levels. Regional planning has national and regional goals setting out the principles of land use and community structure. Master planning, respectively, provides general guidance regarding to the community structure and land use.

Present plans divide forestry areas in M (Forestry and agricultural area), MU (Forestry and agricultural area with specific recreational use) and MY (Forestry and agricultural area with specific environmental value). Although specific watercourse protection measures can be focussed on in MY-areas, so far these land use planning marks have been assigned because of functions other than for water protection. Possible reasons that current land use planning provides no guidance regarding forestry and water protection are for instance:

- there are no working methods considering water protection in spatial planning;
- insufficient amount of suitable ecological data;
- only little biological expertise in spatial planning organisations;
- lack of co-operation between different organisations.

5.3 Hydropower and sustainable management of water courses

Hydropower is one way to reduce the release of green house gases and produce energy in a sustainable manner. Despite huge effects of hydropower production on regulated streams and lakes, the ecological status was relatively stable and according to the definition of the WFD in good ecological potential. On the other hand, several discussions with stakeholders including local NGOs raised the question of possibilities to improve specifically the river continuity by developing fish ladders and especially by-pass channels. The Watersketch project actively cooperated with the Oulujoki Pilot River Basin Project and the "kala-alma"-project, which focussed its activities on improving the potential for natural reproduction of salmon and sea-trout in the lower Merikoski basin (Laajala et al. 2006). Another co-operation was started with a project developing by-pass channels in the River Oulujoki area (Järvenpää 2005).

Rivers and lakes affected by hydropower are dominant especially in the northern part of Baltic Sea Region. Our study showed that their ecological status is relatively high when hydromorphological modifications are accepted, but mitigation measures related to river continuity will also increase the potential to create suitable areas for recreational use. For example, the opening of the fish ladder and by-pass channel at the lower Merikoski power plant in 2002 launched a flourishing recreational fishery, which had a significant effect on the local tourism business.

5.4 Natura 2000 sites and their management

Setting and clarifying water management objectives that include the Water Framework Directive implementation and protection of Natura 2000 values is important for acknowledging the different values that influence river basin management. It needs to be recognised that the protection of water dependent conservation values is a primary objective and cannot be jeopardised by achieving good status as requested by the WFD. This influences both the water management plan of the WFD, including the Programme of Measures and monitoring of water bodies, and the activities planned in the catchment area.

One systematic approach for clarifying management objectives can be developed by identifying the legally binding habitats and species of the Habitats and the Birds Directives that are water dependent for each Member State. Once these have been identified, sustainable water management practises and activities in the catchment area may be designed so that the protected values are maintained. While the water dependent conservation values need to be recognised in the spatial plans of the catchment area, spatial planning also offers a means for Programmes of Measures for reducing nutrient leaching: Joint planning and implementation of buffer zones and collection ponds is recommended as a joint tool for spatial planners and water managers to reduce nutrient losses and related eutrophication.

In the Lake Lentua case study the buffer zones could be suitable for reducing nutrient runoff, which is required for maintaining the oligotrophic conditions of a Natura 2000 habitat and the water dependent species recognised in the Birds Directive. However, since the water dependent habitats and species heavily influence the water management objectives, it is also possible that protected and threatened species that gain from eutrophic conditions may actually need a certain level of eutrophication in a given catchment area.

6 Conclusions

6.1 Peat production as a part of diffuse loading

Peat production, as well as other land use in river catchments, results in increased transport of nutrients and suspended solids (SS) to river channels causing eutrophication and siltation of the river bed. These are significant environmental problems in most Finnish rivers today, and most of the loading imposed to the watercourses in northern Finland comes from non-point sources.

In the Stream Hanhioja peat production is the main source of loading as there are no agricultural areas or scattered settlement. The nutrient and suspended sediment concentrations did not indicate heavy loading from the catchment area. Aquatic macrophytes indicated poor water quality in the Stream Hanhioja, but as section 3.2.5.4 described, aquatic macrophytes may not be suitable as indicators of loading from peat production areas in such a small stream. The diatom taxa seemed to better indicate the loading from peat production.

In the River Poikajoki the catchment consists of agricultural areas and scattered settlement besides peat production areas, and the total loading is much higher. Hence, it is likely that all these loading sources have deteriorated the water quality in the River Poikajoki.

The water quality also shows that there are less loading sources in the middle part of the River Muhosjoki than in the upper and lower part of the river. These loading sources are agriculture, forestry, settlement, and also peat production. The biggest source is agriculture, however, it is quite difficult to reduce loading from there due to the scattered nature of farms.

In order to avoid negative environmental changes in the river, it is important to decrease the nutrient pollution derived from land use and imposed on the river as effectively as possible.

6.2 The effects of forestry on small lakes

Land use for forestry has its environmental impacts (Rask et al. 1993). In this case study areas of extensive clearcutting, rapid regeneration, efficient draining and fertilisation were typical activities of forestry management operations in the 1960s to 1980s. Some of these impacts were local and limited, others cumulative, extensive and long-term impacting on watercourses below. The duration and the amount of loading depends on the extent of the area in which forestry actions were implemented, the intensity and method of the operation, local hydrology, the soil type and topography of the area, and the development of the forest after the operation (Kenttämies and Saukkonen 1996). Based on an average forest cycle of 80 years there will be no large scale clear cutting operations until the 2030s. Forest ditch maintenance will cause the largest loads of all forestry operations in the near future (Finer et al. 2005). The primary aim is to diminish the loading of these forest management operations.

Based on paleolimnological samples all study lakes have undergone changes over the past 30-40 years, which can mainly be observed in the eutrophication process and increasing siltation. Currently, calculated loads exceed acceptable loads in most of lakes. Because of the short monitoring period and the fact that information related to effects of forestry on small lakes is scattered, possible influences of forestry loading on different biological quality elements in our study lakes are difficult to detect.

Phytoplankton is sensitive to changes in nutrient levels of the water body (Heinonen 1980). The eutrophication process manifests itself mainly in increasing turbidity and algal blooms due to the increasing biomass of phytoplankton. Impacts of forestry management operations on phytoplankton of small lakes have been observed in southern Finland, where clearcuttings and controlled burnings in the catchment area have doubled the phytoplankton biomass of the nearby lake soon after the activities (Rask et al. 1993).

Variations in the abundance of phytoplankton indicate that there are differences between the nutrient contents of the study lakes. In the reference Lake Itäjärvi the average total biomass of phytoplankton in the period of growth was 0.42 mg l^{-1}, which is below the level of reference lakes in this lake type (9; Lepistö et al. 2003a). On the other hand, in Lake Saari-Kiekki the average biomass was at the same level as in the impacted lakes on average.

Usually, phytoplankton assemblages react to non-point loading by increasing amounts of Cyanophyceae, and in humic waters by increasing amounts of *Gonyostomum semen* (Lepistö et al. 2003b). This was also seen in the August sample of Lake Roukajärvi, which showed an increased loading. The composition of phytoplankton assemblage also depends on physical and biological factors, meaning that dominant species may vary at any given successive stage (Lepistö et al. 2003a).

Forestry management also has effects on benthic invertebrates. Based on the BQI-index, which describes the trophic state of the lake (Wiederholm 1980, Johnson 1998), forestry operations have most likely increased the trophic level of benthic areas in the study lakes. The response of the macrozoobenthos to increased nutrient loading is observed as elevated benthic biomass (Huuskonen et al. 2000). Typically in the natural state, macroinvertebrates do not usually disappear suddenly after loading has started unless the disturbance is very effective. Commonly these species or populations decline step by step, or they could remain uncommon in the benthic communities (Vuori et al. 2006).

Forestry loading, especially organic matter, which concentrates in small-sized profundal areas, causes increasing oxygen consumption, and sometimes pronounced oxygen depletion. This process could be one reason for a benthic community of only one species in the deepest basin of Lake Pirttijärvi. On the other hand, the profundal zones of the coloured small lakes are also often naturally oxygen depleted (Crisman et al. 1998) making the separation of impacted lakes from pristine ones more difficult (Tolonen et al. 2005).

Early eutrophication increases species richness as shown in several studies (Rørslett 1991). Vegetation indices were clearly lower in the reference lake L. Itäjärvi indicating a more oligotrophic condition (Ilmavirta and Toivonen 1986). On the other hand, Lake Saari-Kiekki did not differ very much from the impacted lakes, but it seems that from a limnological point of view it is slightly more eutrophic. Its higher nutrient status and primary production may be caused by more nutrient rich soils and permanent flooding caused by a beaver (*Castor canadiensis*) dam at the outlet of the lake.

Aerial photographs indicate that forestry practices may not have decreased the growth of aquatic vegetation. The vegetation seems to have increased since the 1940s, but in some lakes (Saari-Kiekki and Iso Akonjärvi) the rise of the water level may have cut back this trend. *Utricularia* –species are one of the best indicators for water level rise, and their frequency is slightly higher in Lake Saari-Kiekki, but not in Lake Iso Akonjärvi (Koskenniemi 1989).

Changes in the total phosphorus content resemble those of aerial photographs. It seems that an increase of the nutrient load, especially phosphorus, is the primary cause for the alteration of vegetation during the study period. It seems that the forestry practices have indeed increased the volume of vegetation during the past decades.

The results are comparable to other small boreal lakes as the number of species varied between 21-29 in the study of Leka et al. (2003). Moreover, in their study the impacted lakes also had more species than the reference lakes. Species indicating (mesotrophy-) eutrophy, such as *Lemna minor, Alisma plantago-aquatica, Elodea Canadensis and Myriophyllum verticillatum,* were absent in this study but recorded by Leka et al. (2003) implying differences in the nutrient status between the study sites of the two studies.

It is typical for small humic waters, such as the study lakes, that there are only 2-6 fish species. Fish communities are mostly formed by perch, roach and pike, which are tolerant of their environmental requirements, and because of that, they exist commonly in various waters. This flexibility is one reason why the eutrophication process can only be seen to slowly affect changes in the fish communities.

Lakes with a high proportion of cyprinids reflect more productive conditions. In the study of the effects of eutrophication on fish and fisheries in Finnish lakes (Tammi et al. 1997) the median value of total phosphorus was 37 µg l^{-1} in clearly cyprinid dominated lakes. In this study, roach formed the main biomass of the catch only in the naturally eutrophic Lake Saari-Kiekki. In Lake Roukajärvi, which showed the largest impact with the highest loading (Tot P 34 µg l^{-1}) the biomass of roach was 20 % despite the clear eutrophication process. As seen in Lake Iso Akonjärvi, a high proportion of predators delays the development process of an increasing cyprinid population.

There is also a difference between lakes regarding their tolerance of nutrient loading. More sensitive to nutrient loading seem to be lakes, which are naturally oligotrophic and have a long residence time. Also, climatic factors, as in this case long winters, and some drainage area characteristics decrease tolerance.

Loading of surface waters and groundwaters are regulated by the Water Act and the Environmental Protection Act; the latter also regulates the wastewater treatment in the rural areas. Under the same Environmental Protection Act the polluter is also obliged to clean the contaminated soil or groundwater However, in many cases this has not been efficient in preventing problems caused by pollution from diffuse sources such as forestry. One way to improve this gap in water protection is spatial planning, which takes into account sustainable river basin management, however, there is currently no clear guidance regarding land use planning and forestry. Because simultaneous or consecutive actions in different parts of the same catchment area may amplify the impacts of any forestry operation, spatial planning together with improved forestry planning systems would be the best tool for solving similar problems.

6.3 Rivers and hydropower

The River Oulujoki can easily be designated as heavily modified by using direct hydromorphological criteria. The natural fall of rapids is almost totally lost and the free flowing river is changed to a series of reservoirs affected by short-term regulation. The evaluation of the current ecological status showed the following values:

- Aquatic macrophytes – moderate status
- Benthic fauna – moderate status
- Fish – obviously relatively good, but migratory fish are only reaching the lowermost reservoir, and natural reproduction does not exist.

The definition of ecological potential is based on careful estimation of mitigation measures and their effects on biological status. The selection of mitigation measures was based on the following approach:

- Identify hydro-morphological measures, which improve the ecological status.
- Remove those measures, which can have significant adverse effects on the specific use or on the wider environment.
- Define measures, which do not have significant adverse effects on the specific use or on the wider environment.

The following measures were finally applied:

- Reduction of weekly water level fluctuation below the Montta power plant from 150 cm to 130 cm
- Enhancing river continuity through fish ways and bypass channels
- Restoration of main channel and shores
- Restoration of bypass channels
- Restoration of tributaries

  Removal of old protection structures and modification of littoral areas.

In conclusion, in a scenario where the maximum ecological potential of the River Oulujoki has been reached:

- Old protection structures on the shores have been removed so that the total amount of protected shores is not more that 10 %.
- There are bypass channels at every power station and the annual discharge is 2 - 10 m3 s^{-1}, depending on the definition of significant harm.
- All stream habitats in the main channel (12 ha) and in the tributaries (40 ha) have been restored.

The essential result of this study is that the actions decided upon only slightly affect the status of the River Oulujoki. Therefore, the reference status also differs only slightly from the present status, and thus it can be regarded as the maximum ecological potential of the River Oulujoki. According to this case study, the environmental goal of heavily modified water body can be reached and compliance with the Directive does not require actions for improvement.

6.4 Protected areas

Areas included in the protected areas register of the Water Framework Directive (Article 6) are regulated by different objectives than what is stipulated in Article 4 of the WFD. The register of protected areas includes Natura 2000 areas but also sensitive areas of the Nitrates Directive and Urban Wastewater Directive. It is essential to clarify objectives of the specific Directives regulating the areas in relation to the WFD so that water management practises and catchment activities can be planned in a sustainable manner.

Water managers and spatial planners need to recognise the specific objectives directing water management planning and proceed in close cooperation and dialogue in order to follow these through. A systematic analysis and identification of e.g. the water dependent Natura 2000 conservation values that occur in the catchment, should guide planning and objective setting so that the water related conservation values are also protected in the future.

In the case where habitats and/or species protected by Natura 2000 require a different set of objectives than what is defined in the general objectives of the WFD, this needs to be explained by water managers to planners and maintained jointly. In case eutrophic conditions need to be maintained strictly, spatial means for more efficient nutrient reductions (such as buffer zone plans) may be implemented in close cooperation between water managers and spatial planners as a Programme of Measures. Similarly, if a highly endangered water dependent species would suffer say from increasing agricultural field area or urbanisation, the suitable water habitats may form limits of expansion, which spatial planners need to follow.

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