The Finnish Environment 741

ENVIRONMENTAL PROTECTION

Sari Mitikka, Ritva Britschgi, Kirsti Granlund, Juha Grönroos, Pirkko Kauppila, Risto Mäkinen, Jorma Niemi, Sonja Pyykkönen, Arjen Raateland and Kimmo Silvo

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Introduction

Eutrophication of surface water is recognised as a significant environmental problem and a major environmental policy issue in Finland. On the national scale, approximately 50% of the total nitrogen (total N) and 60% of total phosphorus (total P) loading originate from agricultural sources (Silvo et al. 2002). Sewage from dwellings accounts for approximately 20% and industrial sources approximately 5% of the total N and total P discharges into the water bodies.

The implementation of the Nitrates Directive (91/676/EEC 1991) is one of the policy measures aimed at decreasing nutrient, nitrogen and phosphorus, discharges and losses from agricultural sources. Two national water protection target programmes and the EU agri-environmental support scheme also directly address the issue of decreasing nutrient discharges from agricultural sources.

The Finnish Government has adopted a Decision-in-Principle on the Water Protection Targets to 2005 (19 March 1998) (Ministry of the Environment 1998) accompanied by a specific programme of measures that address the problem of nutrient discharges from agriculture. The Decision-in-Principle sets out the general target of reducing phosphorus and nitrogen discharges from agricultural sources to 50% compared with the level of 1990–1993. Furthermore, the Government has approved another Decision-in-Principle on steps to be taken to protect the Baltic Sea (26.4.2002). The Decision states that in combating eutrophication, the most important action is to be taken in the agricultural sector. The Baltic Marine Environment Protection Commission (Helsinki Commission) has issued a revised recommendation on measures aimed at the reduction of emissions and discharges from agriculture (24/3, 25 June 2003).

In Finland, the Nitrates Directive is transposed to national legislation through the Environmental Protection Act (4th February 2000/86, paragraph 11.6) and Government Decree No 931/2000 (9 November 2000) on reducing the release of nitrates from agricultural sources into water bodies. The provisions of the Government Decree apply to the whole national territory of Finland without regional or local differentiation. The Decree contains provisions on good agricultural practices, storage of manure, spreading and allowable quantities of fertilizers and silage liquor, analysis and recording of nitrogen in fertilizers and enforcement of the Decree. The Regional Environment Centres and the municipal environmental authorities are responsible for the enforcement of the Decree.

In parallel with the implementation of the Nitrates Directive, farmers have widely adopted the EU agri-environmental support scheme in Finland. The coverage of the scheme was approximately 90% of the cultivated area during the first support scheme period 1995–1999 and 96% during the second period 2000–2006. Environmental support for basic and additional measures is paid to farmers who meet the eligibility criteria laid down in Government Decree No 644/2000 (26 June 2001) and undertake the basic measures related to the following activity areas for five years:

– environmental planning and monitoring in farming
– basic fertilization levels of arable crops
– plant protection
– filter strips
– biodiversity and landscape management

There are certain other basic measures available for livestock farms. The basic measures are supplemented with specific additional measures on the farm level.

In addition to the environmental protection measures and changes in farming practices, there are other factors such as the use of the agricultural land as well as the production and areal structure of agriculture that have an effect on nutrient discharges and losses. Among these factors, nutrient releases have been affected most significantly by the decrease in the field area kept fallow during the last decade.

This report on the implementation of the Nitrates Directive in Finland 2004 involves

1. measures to be taken by individual farms,
2. water quality of surface waters with special emphasis on waters affected by agriculture,
3. nitrate concentrations in groundwaters affected by agriculture and background information of nitrate levels in groundwaters with minor human impact, and
4. estimation on future development of water quality.

Implementation of the Nitrates Directive – measures to be taken by individual farms

The European Commission regulation on good farming practices has been incorporated in the system of compensatory allowance and the agri-environmental support scheme which are contained in the Horizontal Rural Development Programme for Finland and on which a Government Decree was issued on June 26, 2000 (644/2000, as amended 449/2001, 1220/2001, 361/2002 and 825/2002). The payment of agri-environmental support and compensatory allowance is conditional on adherence to the code of good agricultural practices. The code of good agricultural practices (Ministry of Agriculture and Forestry 2001) contains the obligations on good cultivation practices issued by the Commission and the obligations set out in the Finnish environmental legislation and regulations. The code also contains recommendations on environmentally friendly cultivation methods but the support is not conditional on adherence to the recommendations. The criteria for eligibility for the basic and additional agri-environmental support measures are contained in the Ministry of Agriculture and Forestry Decree 646/2000 (amended 1207/2000, 463/2001, 1278/2001, 398/2000 and 786/2002). The eligibility criteria for compensatory allowance are contained in Ministry of Agriculture and Forestry Decree 645/2000.

In accordance with the Nitrates Directive, the report must contain details of the preventive measures carried out in accordance with Article 4. Based on Article 4, the Nitrate Decree incorporates the code of good agricultural practices, which contains the provisions laid down in Annex II of the Directive. The report must contain a summary of the action programmes drawn up in accordance with Article 5 and, in particular, of the measures required under sub-items a and b of Article 5(4). Sub-item a refers to Annex III of the Directive (measures that must be incorporated in action programmes referred to in sub-item a of Article 5(4)). Sub-item b refers to the measures that are part of the code of good agricultural practices, except for those that have been replaced with measures referred to in Annex III. Thus paragraph 4 has been examined on the basis of Annex III by excluding the measures coming under good agricultural practices as mentioned above. In the report, consideration was given not only to requirements set out in the Directive but also to the document 'Reporting Guidelines For Member-States (art. 10) reports, Nitrates Directive, Status and trends of Aquatic Environment and Agricultural Practice', which was prepared for the 2000 report.

The information for the report was collected on the basis of the mid-term evaluation of the Horizontal Rural Development Programme commissioned by the Ministry of Agriculture and Forestry and prepared by the Economic Research Unit of the MTT Agrifood Research Finland, the Finnish Environment Institute and the Department of Applied Biology at the University of Helsinki. The report examines how well the development programme targets have been implemented in Finland as far as the impacts of the compensatory allowance and agri-environmental support are concerned. The mid-term evaluation covers the years 2000–2003 (the programming period covers the years 2000–2006). Most of the information in the report is from the period 2000–2002 and the information has been compared with the figures for the previous programming period (1995–1999).

The results of the MYTVAS study were used as a data source too. In that study the changes in cultivation measures and their impacts on nutrient loading of water bodies originating from farms was assessed on the basis of cultivation data covering basic parcels and sub-parcels collected for the study by interviewing farmers. The interviews were part of the process of monitoring the agri-environmental support scheme. The study covered the years 1994–2002 and consisted of four rounds of interviews. The results are presented in the following reports: Grönroos et al. 1997, Grönroos et al. 1998 and Palva et al. 2001. The information collected in the 2000–2002 interviews has been discussed by Pyykkönen et al. 2004. Areas located in different parts of Finland were selected for the study. The southern areas, the catchment areas of the Yläneenjoki and Lepsämänjoki rivers are areas where grain and special plants are grown, while the northern areas, the catchment areas of the Lestijoki and Taipaleenjoki rivers are characterized by grass cultivation. These areas were covered by all four rounds of interviews. The last round of interviews also covered farms in the Savijoki, Löytäneenoja and Kinarehenoja areas, which form part of the larger Lestijoki river catchment area. The cultivation information collected from these farms covers the period 1999–2002. During the last round, interviews were carried out on a total of 409 farms, which have a cultivated area of about 18,000 hectares. The farms participating in the study account for 0.8% of the area under cultivation in Finland and 0.5% of all farms. The results of the MYTVAS study do not represent the whole country. Because of some nationwide information were unavailable, results of the MYTVAS study have been used.

In addition, Yearbook of Farm Statistics 2003, which includes statistics of the Information Center of the Ministry of Agriculture and Forestry, was used as an information source. Ministry of Agriculture and Forestry delivered information on number of manure storage facilities and outdoor yards that have received funding as part of the environmental protection support scheme and in connection with new investment for livestock farms, in 2000–2002. In addition, Department of Agriculture in Ministry of Agriculture and Forestry delivered information on cautions made when the rules of the Government Decree were not conformed.

Provisions on the monitoring of the adherence to the Nitrate Decree are contained in Chapter 13 of the Finnish Environmental Protection Act. The responsibility for monitoring lies with municipal permit and supervisory authorities and the authorities of the Regional Environment Centres. In accordance with section 9 of the Government Decree (931/2000), the Employment and Economic Development Centres and municipal rural business authorities must provide Regional Environment Centres with the information needed for the monitoring of the compliance with the Government Decree and for preparing the reports required under the Nitrates Directive. The monitoring of farm subsidies is the responsibility of the Employment and Economic Development Centres. For this report, the Regional Environment Centres were asked to provide information on contravention of the Government Decree and summaries of the manure heap notifications required under it. The Regional Environment Centres were also asked to give the number of additional provisions and requests for additional information concerning deviation notifications required under section 84 of the Environmental Protection Act.

1.1 Data concerning the territory of the Member State (Finland)

Cultivated area
The area of cultivated field is presented in table 1. Cultivated field covers only farms with more than one hectare of field in 1996 and 1998. There were 893 farms in 2000, 1,001 farms in 2001 and 1,146 farms in 2002 which had less than one hectare of field.

Table 1. Cultivated area in Finland in 1996–2002. (Yearbook of Farm Statistics 2003).

Year	1996	1998	2000	2001	2002
Cultivated area (ha)	2,133,980	2,190,714	2,196,435	2,202,355	2,215,480

Number of farms in Finland
The number of farms in Finland has decreased in recent years (Table 2). In 2002 the total was 45,875 (38%) lower than in 1992 and 12,596 (14%) lower than in 1998.

Table 2. Number of farms in Finland in 1992–2002. (Yearbook of Farm Statistics 2003).

	1992	1994	1996	1998	2000	2001	2002
Number of farms in Finland	121,349	114,510	94,114	88,070	79,783	77,320	75,474

Number of active farms
An active farm is a farm that has at least one hectare of land under cultivation and is engaged in agricultural production or other business. Farms that have entered into a contract to reduce production or made a closure commitment are not considered active farms. Since 1995, only farms engaged in forestry or some other form of production that have cultivated land have been defined as 'active farms'. In 1995, there were 99,960 active farms in Finland and by 2000 the number had dropped to 79,780. In 2002, active farms numbered 74,200. In 1995, some 96% of all active farms received some kind of agricultural support, and in 2002 this proportion had risen to 99% (Ministry of Agriculture and Forestry 2004).

Number of livestock farms
The number of livestock farms decreased by 9,750 between 1995 and 1998 and by a further 3,800 between 2000 and 2002. In 2002, there were 32,990 livestock farms in Finland, which was 43.7% of all active farms. In 1995, livestock farms accounted for 54.0% of all active farms. Closures and change-over to crop production have been particularly common among small livestock farms. Southern Finland has been the area with the steepest decline in the number of livestock farms (Ministry of Agriculture and Forestry 2004).

Cultivated area of livestock farms
The cultivated area of livestock farms totalled 1,215,545 hectares in 2002. This includes both livestock farms that are committed to agri-environmental support and farms outside the system. (Information Centre of the Ministry of Agriculture and Forestry 2003). On farms committed to agri-environmental support, there was no change in the number of livestock in proportion to the area controlled by the farms between 1999 and 2002. On livestock farms outside the system, there was substantial growth in the number of livestock in proportion to the area controlled by them in the same period. However, there was a drop in the number of livestock farms outside the agri-environmental support scheme between 1999 and 2002. In 1999, the livestock farms outside the system had control over 58,600 hectares of

land and by 2002, the total had more than halved, to 24,800 hectares. The study showed that farms with a large number of livestock in proportion to their cultivated area tend to remain outside the agri-environmental support scheme. In fact, on such farms the proportion is much higher than on farms that have joined the system (Ministry of Agriculture and Forestry 2004).

Number of animals

Every year, when submitting their applications for farm subsidies, farms report the number of their animals on May 1. The number of animals by animal group in 1998–2002 is given in Table 3. Animal numbers have decreased in all animal groups. The number of fur farms and the number of pelts produced during each sales period (1.6.–31.5.) are given in Table 4. The number of fur farms decreased by 1,588 (47%) between 1992 and 2002, but the number of pelts produced has not declined in the same proportion. The number of mink and fitch pelts produced decreased by 0.6% between 1992 and 2002, while the number of fox and raccoon dog pelts increased by 47% during the same period.

Table 3. Number of animals in the entire country, May 1, 1998–2002 (thousands of animals). (Yearbook of Farm Statistics 2003.)

	1998	1999	2000	2001	2002
Cattle	1117.1	1086.8	1056.7	1037.4	1025.4
Pigs	1401.0	1351.3	1295.8	1260.8	1315.0
Poultry	11049.6	11033.6	12569.5	10553.6	10733.9
Sheep and goats	136.4	114.5	108.2	103.4	102.5
Horses	26.3	26.3	25.5	26.2	25.2

Table 4. Number of fur farms and pelt production units in the sales period (1.6.–31.5) 1991/92, 1993/94, 1995/96, 1997/98, 1999/00, 2000/01 and 2001/02. (Yearbook of Farm Statistics 2003.)

Year	Number of farms	Pelts produced	
		Mink and fitch	Fox and raccoon dog
1991/92	3,354	1,505,198	1,091,601
1993/94	2,406	1,659,534	1,220,807
1995/96	2,166	1,944,663	1,803,904
1997/98	2,152	1,828,210	2,493,410
1999/00	1,993	1,732,710	1,972,340
2000/01	1,855	1,497,859	1,862,643
2001/02	1,766	1,496,609	2,043,902

Compensatory Allowance and agri-environmental support

In the previous period (1995–1999) of the Horizontal Rural Development Programme, the area entitled to compensatory allowance covered 85% of all agricultural land in Finland. In the present programming period, the system applies to the whole country. In 1995, compensatory allowance covered 77,950 farms but in 1999, the number had dropped to 67,460. In 2000–2002, the number of farms entitled to compensatory allowance, which had now extended to cover the whole country, dropped from 73,269 to 70,620 (95.2% of all active farms). Between 2000 and 2002, the proportion of farms receiving compensatory allowance decreased from 96% to 93% of all active farms, which was due to a drop in the total number of farms. In the previous FAEP period

(1995–1999), the cultivated area of the farms receiving compensatory allowance averaged 1,622,400 hectares or 76% of all areas under cultivation in Finland. In 2002, the area covered by compensatory allowance totalled 2,171,000 hectares or 96.3% of all areas under cultivation (Ministry of Agriculture and Forestry 2004).

In 1995 a total of 78,750 farms in mainland Finland received agri-environmental support, but by 1999, the number had dropped to 73,480. In the period 1995–1999, an average of 84.4% of all active farms received agri-environmental support. Between 2000 and 2002, the number of farms covered by the agri-environmental support scheme dropped from 70,812 to 68,215. However, in 2002 a high proportion of all active farms (91.9%) received support. In the period 1995–1999, the area under cultivation on the farms receiving agri-environmental support averaged 1,891,000 hectares or 76.9% of all areas under cultivation on active farms. In 2002, the area covered by agri-environmental support totalled 2,171,000 hectares or 96.3% of all area under cultivation on active farms (Ministry of Agriculture and Forestry 2004).

Changes in cultivation practices

There were few changes in cultivation practices between 1998 and 2002. Support systems guiding cultivation practices have remained largely unchanged during the period in question. The biggest change was that in support areas A and B the demand for 30% winter covering of fields with plants or plant residues was removed. In Finland, the area under grass cultivation has decreased with the decreased number of cattle and because cereals have replaced grass in cattle feeds.

Even though there have been few changes in crops and crop varieties, there are signs that cultivation practices are becoming increasingly restricted. Ploughing has decreased while the use of field cultivator has increased. There has also been an increase in the area covered by direct-sown fields. The area treated with pesticides has grown and the amounts applied per hectare have increased. The increase in reduced tillage and direct sowing, lack of crop rotation and the fact that more and more headlands and buffer strips are left un-maintained have been given as the main reasons for this development.

The conclusion in the MYTVAS study (Pyykkönen et al. 2004) was that even though average fertilization levels are still lower now than in the years before Finnish EU membership, the use of cattle manure in particular remains a problem. Livestock production is increasingly concentrated into smaller and smaller areas, which means that manure is spread on the same parcels every year. As a result, nutrient levels, and most of all phosphorus levels, in these field parcels rice, and the risk of nutrient leaching from fields to water bodies increases. At the same time, the supply of and demand for manure do not meet as the suppliers and users are too far apart.

Nitrogen discharges to surface waters

Information on nitrogen discharges from agriculture, industry and built-up areas are given in Table 5. The average nitrogen load of livestock farming in 1990-1993 was estimated at 2,900 t a^{-1}, while the figure for crop production was put at 30,000 tonnes (Silvo et al. 2002). The total agricultural loading in 2002 was estimated at 39,500 tonnes.

Table 5. Nutrient load into waters and natural leaching in 2002. Measured emissions from industries, fishery and communities in 2002. Other emission sources and natural leaching has been estimated by the Finnish Environment Institute (SYKE 2004).

Source of emission	Nitrogen t a^{-1}	Nitrogen %
Pulp and paper industries	2,568	3.3
Other industries	946	1.2
Communities	11,843	15.1
Fishery	722	0.9
Fur production	430	0.5
Peat industry	1,000	1.3
Total peak load	**17,509**	**22.4**
Agriculture	39,500	50.5
Scattered settlement	2,500	3.2
Forestry	4,100	5.2
Total scattered loading	46,100	58.9
Fall out	**14,600**	**18.7**
Total loading	78,209	100
Natural leaching	70,000	

1.2 Information to be included in the reports referred to in Article 10

1.2.1 Council Directive, Annex II

A) Mandatory issues

1. Periods when the land application of fertilizer is inappropriate

Government Decree, Section 5
Nitrogen fertilizers must not be applied on snow-covered, frozen or water-saturated ground. Animal manure may be applied in the autumn up to November 15, and application may be started in the spring no earlier than April 1, provided the ground is not frozen and is sufficiently dry to avoid runoff into watercourses and any danger of subsoil compaction. Manure may not be applied on grassland after September 15.

Regional Environment Centres have issued some statements on contraventions concerning manure application in winter.

The times in which manure was applied during the years 2000–2002 was examined as part of the MYTVAS study. In the farms participating in the study, most of the manure was applied in accordance with the Decree. During that period manure was applied annually for about 20 parcels when spreading was not allowed. This is less than 2 percent about all field parcels, where manure was used. Most of these fields were grasslands.

2. Land application of fertilizer on steeply sloping ground

Government Decree, Section 5
Use of nitrogen fertilizers is prohibited on areas closer than five metres to a watercourse. Along the width of the next five metres, surface application of nitrogen fertilizers is prohibited if the field slope exceeds 2%. Surface application of animal manure is always prohibited on fields with an average slope of over 10%.

The information received from the Regional Environment Centres does not indicate that contraventions of the Government Decree coming to their attention would have concerned the manure application distance.

Information on the average slope of the parcels was also incorporated in the MYTVAS study if the slope had resulted in cultivation problems. This means that not all sloping parcels were reported. The parcels were classified in accordance with the decree of slope causing cultivation problems (2–10% or more than 10%). In the Lestijoki catchment area, there were a total of nine parcels for which a slope of more than 10% was given and on three of them cattle manure was used. On these parcels manure was applied each year during the period 2000–2002. In other areas, too, there were parcels with a slope of more than 10%, but no cattle manure was applied on them.

3. Land application of fertilizer to water-saturated, flooded, frozen or snow-covered ground

> *Government Decree, Section 5*
> *Nitrogen fertilizers must not be applied on snow-covered, frozen or water-saturated ground. Application of nitrogen fertilizers is prohibited between October 1 and April 15 on field areas that are repeatedly flooded in spring, but this does not apply when new growth is being established*

The Regional Environment Centres have issued statements on contraventions concerning manure application in winter.

On the farms participating in the MYTVAS study, there were a total of 86 field parcels that were repeatedly flooded during the spring and most of them were located in the Lepsämänjoki, Lestijoki and Kinarehenoja areas. These parcels were flooded each spring in the period 2000–2002. The parcels in Lepsämänjoki were mainly used for growing spring grain, while most of the parcels in Lestijoki and Kinarehenoja were used for grass cultivation. None of the parcels flooded during spring floods were fertilized in the period between October and the end of April in the years 2000–2002. Spring fertilization began in May, while autumn fertilization was concluded by the end of September.

4. The conditions for land application of fertilizer near watercourses

> *Government Decree, Section 5*
> *Use of nitrogen fertilizers is prohibited on areas closer than five metres to a watercourse. Along the width of the next five metres, surface application of nitrogen fertilizers is prohibited if the field slope exceeds 2%.*

The information received from the Regional Environment Centres does not indicate that contraventions of the Government Decree would have concerned the application of fertilizers near water bodies.

5. The capacity and construction of storage vessels for livestock manure, including measures to prevent water pollution by run-off and seepage into the groundwater and surface water of liquids containing livestock manures and effluents from stored plant materials such as silage

> *Government Decree, Section 4*
> *Animal manure storage for waste products excreted by animals must be sufficiently large for manure accumulated over 12 months, excluding manure remaining on pasture during the same grazing season. In determining the size of the storage, farmers' joint storage, appropriate small outdoor yards and loose housing sheds*

with litter bedding are also considered. Manure storages and manure gutters must be watertight. The structures and equipment used must be such that no leakage occurs when the manure storage is emptied and the manure is transferred. The size of storage must follow the principles set out in Annex 2.

Government Decree, Section 7
The silage effluent created in silage production must be retained and stored in watertight containers.

Government Decree, Annex 3
In Annex 3 there are recommendations on manure storaging.

Manure storage facilities

In 2000, an agricultural accounting was carried out in Finland. Farms were asked among other things whether they had solid manure storage, urine tank or slurry tank, how many months each of these storage systems could be used without emptying and whether the manure storage was covered. The results are presented in table 6. A total of 3,055 farms had both solid manure storage and slurry tank.

Table 6. Number of animal manure storages in Finland by type and the capacity of the storages, (how many months storage is sufficient without emptying) with information about covering of the storages. (Information Centre of the Ministry of Agriculture and Forestry 2004).

	Solid manure storage	Urine tank	Slurry tank
Number of farms with following manure application systems	26,508	17,080	12,190
Average capacity without emptying (months/year)	9.4	9.6	10.3
With cover (number)	7,845	11,042	2,675
Without cover (number)	18,194	5,708	9,234

Puumala and Paasonen (2001) examined the number of concrete slurry tanks and their age distribution. The figures were collected from Employment and Economic Development Centres, concrete product manufacturers, the Confederation of Finnish Construction Industries RT and central agricultural wholesalers. The information was collected for the years 1980–1999 and the tanks were divided into four categories according to the year of construction. The number of slurry tanks built between 1980 and 1999 was estimated at almost 13,000 and 60% of them were estimated to have been built in the 1990s (Table 7). The average capacity of slurry tanks built in the early 1980s was estimated at 300 m^3, while the figure for tanks constructed in the late 1980s was estimated at 500 m^3. The capacity of slurry tanks built in the 1990s was estimated to be larger that that of tanks from the 1980s. The average capacity of slurry tanks built in the early 1990s was estimated at 640 m^3 while the figure for tanks built in the latter half of the decade was 860 m^3 (range was 500–1500 m^3).

Table 7. Estimated number of slurry tanks by age distribution and the estimated age distribution (%) of slurry tanks which is based on estimates by Employment and Economic Development centres (TE Centres) and sales statistics from manufacturers and machinery dealers. (Puumala and Paasonen 2001).

Construction year	Estimated number of slurry tanks	Estimated age distribution %	
		TE Centre	Sales statistics
1980–1984	2,480	19	17
1985–1989	2,330	21	17
1990–1994	3,550	28	30
1995–1999	4,620	32	36
Total	12,990	100	100

Puumala and Paasonen (2001) based their assessments of the useful lifetime of the slurry tanks and age-related risks on expert opinions, studies made on concrete structures and the accident statistics compiled by the Farmers' Social Insurance Institution. The average useful lifetime of slurry tanks was estimated at 15 years. All accidents resulting from structural failures in the tanks had occurred during the construction of the manure storage facility. The study concluded that existing slurry tanks only cause environmental problems in exceptional cases. Only a very small number of tanks was found to have problems with sealings and prefabricated panels that required repairs.

In a study commissioned by the Ministry of Agriculture and Forestry (Ministry of Agriculture and Forestry 1998) the type and number of structural problems occurring in manure storage facilities built as prefabricated structures were studied. A total of 161 farmers participated in the study. In 76% of the farms the manure storage facility was dimensioned for all-year-round use while in 18% it was dimensioned for eight months' use. Of the facilities intended for all-year-round use, 59% were emptied twice a year and 12% more frequently. A total of 65% of the farms estimated that the facility was too small for the amount of manure generated, even though no consideration was given to the fact that both rainwater and the water coming from the service facilities and the areas in which the animals were kept increased the volume of the water. A total of 77% of the manure storage facilities also received the washing water from the service facilities and/or the areas in which the animals were kept. Some 76% of the manure storage facilities were trouble-free, but 19% had had some kinds of problems. At total of 15% of the manure storage facilities had suffered from structural and construction-related problems, operational difficulties and low temperatures, while 9% had serious damage (leaks, cracks or visible reinforcement). Most of the manure storage facilities with serious damage had been built between 1991 and 1993. In the instructions issued by the Ministry of Agriculture and Forestry (MMM-MRO-C 4) it is recommended that if prefabricated parts are used for the construction of a manure storage facility, only Ministry-approved parts be used. According to the study commissioned by the Ministry of Agriculture and Forestry, a total of 52% of all manure storage facilities had made use of approved prefabricated parts. The problems in manure storage facilities usually appeared during or after construction. In 63% of the facilities, the prefabricated parts had a maximum thickness of 10 cm. Nowadays, prefabricated parts with a thickness of less than 12 cm can only be approved on the basis of a special examination.

In 2002, some 33% of the farms participating in the MYTVAS study had insufficient manure storage capacity. The figure was 35% in 1999 and 59% in 1995.

Department of Agriculture in the Ministry of Agriculture and Forestry delivered information about cautions that were made when the regulations of the Government Decree had not been conformed. During the monitoring of the agricultural support 54 cautions were made in 2000 and 158 cautions in 2001. All cautions concerned imperfect manure storaging.

Farms can seek financial support from the Ministry of Agriculture and Forestry for their manure storage facility and outdoor-yard investments. The support is either co-financed by the EU or entirely from national funds. The figures for manure storage facilities and outdoor yards that have received funding as part of the environmental protection support scheme in 2000–2002 and for manure storage facilities and outdoor yards that have received support in connection with new investment for livestock farms in the same period are given in Table 8 (Information Centre of the Ministry of Agriculture and Forestry 2004). The types of financing have been divided into investment support co-financed by the EU and investment support funded with national financing.

Table 8. Number of manure storage facilities and outdoor yards that have received funding as part of the environmental protection support scheme and in connection with new investment for livestock farms, in 2000–2002. (Information Centre of the Ministry of Agriculture and Forestry 2004).

Type of facility	Type of funding	Number of funding decisions 2000	2001	2002	Total 2000-2002
Slurry tanks	EU co-financing	1	236	88	325
	National financing	16	229	211	456
	Total	17	465	299	781
Shallow manure pits	EU co-financing	3	390	140	533
	National financing	15	142	144	301
	Total	18	532	284	834
Urine tanks	EU co-financing	0	68	22	90
	National financing	2	54	34	90
	Total	2	122	56	180
Outdoor yards	EU co-financing	0	21	13	34
	National financing	0	19	11	30
	Total	0	40	24	64
Total		**37**	**1,159**	**663**	**1,859**

Recovery of silage effluents

Baling has become a more common method than a silage making method. On the farms participating the MYTVAS study, 30% of silage was baled in 1999 and 60% in 2002. In the same time silage storing in heaps decreased: in 1999 40% and in 2002 10% of silage was stored in heaps. About 30% of silage was stored in silos in 1999 and 2002. On the farms participating in the MYTVAS study, silage effluents were collected in 80–90% of silos and in 50% of heaps in 1999 and 2002. There are no nationwide figures available on the Decree of the recovery of silage effluents.

6. Procedures for land application, including rate and uniformity of spreading, of both chemical fertilizer and livestock manure, that will maintain nutrient losses to water at an acceptable level

Government Decree, Section 5
Organic fertilizer applied in the autumn must always immediately, and within 24 hours at the latest, be incorporated, or the field must be ploughed. The maximum amounts of manure that can be applied in the autumn are 30 tonnes/ha of solid manure, 20 tonnes/ha of cow slurry, 15 tonnes/ha of pig slurry or 10 tonnes/ha of poultry or fur animal manure. Animal manure may be applied on a field as fertilizer equivalent to up to 170 kg/ha/year of nitrogen, while taking into consideration what is laid down in section 6.

Government Decree, Section 6
The scale of use and application of nitrogen fertilizers is based on average crop yield, cultivation zone and crop rotation with the aim of retaining a balanced nutrient level in the soil. Farms may use the following maximum amounts of nitrogen on fields as fertilizer, contained in both mineral fertilizer and animal manure and organic fertilizers:

1) *winter cereals up to 200 kg of nitrogen/ha/year, of which 30 kg of nitrogen/ha in the autumn and 170 kg of nitrogen/ha in the spring, or if slowly dissolving nitrogen is used, up to 40 kg of nitrogen/ha in the autumn and 160 kg of nitrogen/ha in the spring;*
2) *potatoes 130 kg of nitrogen/ha/year;*

3) *grassland and pasture, silage and horticultural plants 250 kg of nitrogen/ha/year;*
4) *spring cereals, sugar beet, oilseed crops and other crops up to 170 kg of nitrogen/ha/year.*

For very fine sand and coarser mineral soils, 10 kg/ha/year is deducted from the nitrogen amounts laid down in paragraph 2 above. The total amounts of nitrogen presented in paragraph 2 above are reduced by 40 kg/ha in the case of cultivation of cereals or sugar beet on peat soil, and by 20 kg/ha in the operating areas covered by the Lapland, Northern Ostrobothnia and Kainuu Regional Environment Centres. For grasslands, the reduction is 10/ha on peat soil throughout the country. If the amount of permissible nitrogen fertilizer exceeds 170/kg/year, this amount must be split into at least two doses with at least two weeks between applications.

Government Decree, Section 7
The fertilizers referred to in section 6 above must be applied on the field evenly and so as to prevent discharges into waters as effectively as possible.

The fertilizing limit of 170 kg/ha/year laid down in section 5 refers to the amount of total nitrogen spread on the field.
Section 6 refers to the maximum amount of soluble nutrients spread on the field.

Methods of manure incorporation

Farmers do not need to keep records on the methods of manure incorporation and there are no nationwide figures available on such methods. On farms participating in the MYTVAS study, there were few changes in the methods of manure incorporation between 1999 and 2002. In most of them, both dry manure and slurry were spread and incorporated on the same day. In 20–60% of the fields, dry manure was incorporated within four hours of spreading, while in 30–50% of the fields, slurry was incorporated within four hours of spreading.

Use of nitrogen

Table 9 shows *the total amount of nitrogen sold to farms in concentrated fertilizers* and the amount per cultivated hectare in different fertilizing years. Since the fertilizing year 2000/01, the figures for the amounts of plant nutrients sold have also included imports. The amount of nitrogen contained in concentrated fertilizers sold has decreased continuously since the fertilizing year 1995/96. The reduction is also evident in the amounts of nitrogen fertilizers sold in different years for each cultivated hectare. The amount of nitrogen sold each year has dropped by 13% between the fertilizing years 1991/92 and 2001/02.

Table 9. Total sales of nitrogen to farms and quantity of nitrogen sold in fertilizers per hectare of cultivated land in fertilizing years (1.7.–30.6.) (Yearbook of Farm Statistics 2003).

	1991/92	1993/94	1995/96	1997/98	1999/00	2000/01	2001/02
Total sales of nitrogen (1000 kg)	163,229	169,138	179,529	169,928	167,276	165,621	160,403
Quantity of nitrogen kg/ha	92.8	94.1	92.3	85.0	84.2	83.2	80.5

It was also concluded in the MYTVAS study that on average, nitrogen fertilization had dropped by 10 kg/ha for grain and more than 20 kg/ha for grass intended as silage between 1995 and 1999 (Palva et al. 2001). Phosphorus fertilization decreased from about 20kg/ha to an average of 15 kg/ha. In 2000-2002, average nitrogen fertilization levels were the same as in the late 1990s. Average phosphorus fertilization was at the same or slightly lower level than in the previous FAEP period.

The number of animal units and total nitrogen contained in the manure produced by animals per total area under cultivation in Finland are given in Table 10. The number of animal units and total nitrogen contained in the manure produced by animals per cultivated area and areas of uncultivated pasture belonging to livestock farms are given separately for farms committed to agri-environmental support and for farms outside the system (Table 10) for the years 1999 and 2002. Most of the changes in the amounts of manure spread per unit area have occurred on farms not committed to agri-environmental support. The number of livestock farms outside the system has increased substantially in proportion to the area belonging to them. The total number of livestock farms outside the agri-environmental support scheme has, however, dropped between 1999 and 2002. The farms that have joined the agri-environmental support scheme are those with the lowest number of livestock per unit area, while most of the farms staying outside the system are farms with a large number of livestock in proportion to their area (Ministry of Agriculture and Forestry 2004).

Table 10. Animal units and nitrogen contained in manure was counted for arable land under cultivation and natural pasture (does not include fallow). Same information was counted also for domestic animal production farms that have committed to agri-environmental support scheme and farms outside the system. (Ministry of Agriculture and Forestry 2004).

	Land under cultivation		Farms committed to the agri-environmental support		Farms not committed to the agri- environmental support	
Year	Animal units/ha	N kg/ha	Animal units/ha	N kg/ha	Animal units/ha	N kg/ha
1999	0.48	44.5	0.73	68.0	0.98	92.4
2002	0.45	41.8	0.73	68.1	1.42	133.6

In the farms participating the MYTVAS study (Pyykkönen et al. 2004) the total amount of cattle manure spread decreased during 1994–1999 but remained at 1999 levels in the period 2000–2002. Compared with the results of the 1999 interviews, an increasing proportion of the manure was spread in the spring. Both the proportion of manure spread in autumn and amounts used per hectare also decreased. The area on which cattle manure was spread in the autumn was only a fraction of the total area studied and the total area belonging to the farms participating in the study. All farms adhered limits to the Governments Decree on the permitted amounts of manure and kept to its restrictions applying to different animal species and different types of manure.

Table 11 shows the amount of *municipal wastewater sludge* spread on the fields and the amount of nitrogen it contained in 1994, 1998 and 2000. The amount of sludge used in agriculture has dropped by more than 60% since 1994 and 17% in the period 1998–2000. The nitrogen content of the sludge was calculated on the basis that normally about 20% of the wastewater nitrogen is bound to the sludge during treatment. Often the sludge is also treated anaerobically so that nitrogen is released from it, but this has not been taken into account in the calculations.

Table 11. Agricultural use of municipal wastewater sludge and the nitrogen contained in it, in 1994, 1998 and 2002 (Sokka 2004).

Year	Sludge (tonnes)	Nitrogen (tonnes)
1994	52,000	1,360
1998	23,000	670
2000	19,000	540

The municipal wastewater sludge spread on fields must meet the quality requirements laid down in the Government Decision on the use of sewage sludge in agriculture (282/1994). The sludge spread on fields must be stabilized. On farms receiving agri-environmental support, the soluble nitrogen content of the nutrient values coming from the treatment plant and 75% of the total phosphorus must be taken into account when the amount of nutrients in the wastewater sludge is calculated. The Government Decree on treating domestic wastewater in areas outside sewer networks entered into force January 1, 2004. According to the Decree the wastewaters of the milk store at the dairy farms have to be treated in small wastewater treatment plants or in subsurface disposal systems of wastewaters. Farmers are allowed to use the wastewater sludge in their own fields. The amount of sludge used in the fields will probably increase as the amount of small wastewater treatment plants increase.

B) Voluntary issues

7. Land-use management, including the use of crop rotation systems and the proportion of the land area devoted to permanent crops relative to annual tillage crops

Cropping plan and crop rotation

There is no reference to cropping plans or crop rotation in the Government Decree. However, farms committed to agri-environmental support must have a cropping plan. Ensuring that cropping plans are drawn up is part of the process of monitoring the spending of the support money carried out by the Employment and Economic Development Centres. In good agricultural practices (Ministry of Agriculture and Forestry 2001), crop rotation is mentioned in the recommendations on plant protection but only as a voluntary measure. On organic farms, crop rotation is an essential part of cultivation practices. In 2002, a total of 5,438 farms covering 138,582.88 hectares had entered into a contract on organic farming or were in a transition to organic farming. This was 6.33% of the total area committed to agri-environmental support (Ministry of Agriculture and Forestry 2004).

Perennial plants

The area used for cultivating perennial plants and the area covered by perennial grass fallow (Table 12) and their proportion of the total area under cultivation was examined as part of the mid-term evaluation of the Horizontal Rural Development programme (Ministry of Agriculture and Forestry 2004). In the study, the following plants were considered as perennial: aromatic herbs, medicinal plants, fruits, berries, ornamental plants, nursery cultivation, perennial forage grass and permanently cultivated pastures. The most important perennial plants were forage grass and pastures. The total area covered all cultivated area, including fallow. The proportion of perennial plants of all cultivated area committed to agri-environmental support dropped by 6.6 percentage points between 1995 and 2002. The proportion of perennial plants was slightly higher in fields outside the agri-environmental support scheme than in fields committed to it and it was suggested that this was due to the differences in the type of production between farms committed to agri-environmental support and farms outside the scheme. The proportion of livestock farms cultivating grass was higher among the farms not committed to the system.

Table 12. Area used for the cultivation of perennial plants and area under green fallow and their percentages of all cultivated area in 1995, 1999 and 2002. Farms committed to agri-environmental support scheme. (Ministry of Agriculture and Forestry 2004).

	1995		1999		2002	
	ha	%	ha	%	ha	%
Perennial plants	645,486	34.4	615,517	30.0	594,701	27.8
Green fallow	134,073	7.1	111,678	5.4	121,528	5.7

The area used for the cultivation of perennial grass increased by 5,100 hectares and the area used for the cultivation of annual grass decreased by 43,800 hectares between 1998 and 2002 (Table 13). At the same time, the area used for cereals cultivation increased by 38,600 hectares.

Table 13. Grasslands and total cereal area in Finland years 1998–2002 (1000 ha). (Yearbook of Farm Statistics 2003).

	1998	1999	2000	2001	2002
Grasslands at least 5 years (ha)	21.6	21.0	25.7	25.3	26.7
Grasslands under 5 years (ha)	681.6	671.4	686.9	664.4	637.8
Cereals (ha)	1157.0	1134.0	1172.9	1161.0	1195.6

8. The maintenance of a minimum quantity of vegetation cover during (rainy) periods that will take up the nitrogen from the soil that could otherwise cause nitrate pollution of water

The Government Decree does not contain regulations on minimum vegetation cover or catch crop. Agri-environmental support scheme includes some measures concerning vegetation cover.

9. Establishing fertilizer plans on a farm-by-farm basis and keeping records on fertilizer use

Government Decree, Section 8
Farmers must keep a record of crop yields and the amount of nitrogen fertilizers used on their fields.

Farms committed to agri-environmental support must have a cropping plan and keep parcel-specific records. Ensuring that cropping plans are drawn up is part of the process of monitoring the spending of support money carried out by the Employment and Economic Development Centres.

Some 50% of the farms participating in the MYTVAS study (Pyykkönen et al. 2004) kept parcel-specific records in 1995, and in 1999 the figure had risen to 90%. Some 91% of the information collected in the 2002 interviews was from parcel-specific records. In this context, hand-written parcel cards and records entered in computers were considered parcel-specific records. This means that the proportion of farms adhering to the recording requirements of the agri-environmental support scheme has remained more or less unchanged.

10. Prevention of water pollution from run-off and the downward water movement beyond the reach of crop roots in irrigation systems

The Government decree does not contain any provisions on irrigation systems. Provisions on the matter are contained in the Finnish Water Act.

Crop irrigation is carried out on a small scale in Finland, as the irrigation of grain fields and grass is not economically viable. Thus, large-scale irrigation is only applied to vegetable and potato growing.

1.2.2 Council Directive, Annex III: Measures to be included in action programmes as referred to in Article 5 (4) (a)

1. Periods when application of certain types of fertilizer is prohibited

> *Government Decree, Section 5*
> *Nitrogen fertilizers must not be applied on snow-covered, frozen or water-saturated ground. Animal manure must not be applied between October 15 and April 15. Manure may be applied in the autumn up to November 15, and application may be started in the spring no earlier than April 1, provided the ground is not frozen and is sufficiently dry to avoid runoff into watercourses and any danger of subsoil compaction. Manure may not be applied on grassland after September 15.*

This item has already been examined above in chapter 1.2.1, scene 1.

2. The capacity of storage vessels for livestock manure; this capacity must exceed that required for storage throughout the longest period during which land application in the vulnerable zone is prohibited, except where it can be demonstrated to the competent authority that any quantity of manure in excess of the actual storage capacity will be disposed of in a manner that will not cause harm to the environment

> *Government Decree, Section 4*
> *The manure storage for waste products excreted by animals must be sufficiently large for manure accumulated over 12 months, excluding manure remaining on pasture during the same grazing season. In determining the size of the storage, farmers' joint storage, appropriate small outdoor yards and loose housing sheds with litter bedding are also considered.*

This item has already been examined above in chapter 1.2.1, scene 5.

> *Government Decree, Section 4*
> *Deviation from the required volume for manure storage referred to in paragraph 1 is possible if manure is transferred to another user who can accept it under a permit granted in accordance with section 28 of the Environmental Protection Act, or to another farmer to be stored as specified in this Decree or to be put into immediate reuse, or if the manure is stored in a properly made and covered manure heap provided the storage follows the procedure described in Annex 1 and releases into waters can be prevented. Any deviation must be reported well in advance to the municipal environmental protection authority, which can issue the necessary regulations pursuant to section 84 of the Environmental Act. The municipal environmental protection authority must make an annual report on any such deviation reported to the Regional Environment Centre.*
>
> *Manure heaps must not be sited in areas that may become flooded or in groundwater areas.*

Establishment of manure heaps and deviations from the Government Decree are discussed in section 1.4 (Contraventions of the Decree and summaries of the manure heap notifications required under the Nitrates Directive).

3. Limitation of the land application of fertilizers, consistent with good agricultural practices and taking into account the characteristics of the vulnerable zone concerned in particular

a) soil conditions, soil type and slope
b) climatic conditions, rainfall and irrigation
c) land use and agricultural practices, including crop rotation systems; and to be based on a balance between; (i) the foreseeable nitrogen requirements of the crops, and (ii) the nitrogen supply to the crops from the soil and from fertilization corresponding to:

- **the amount of nitrogen present in the soil at the moment when the crop starts to use it to a significant decree (outstanding amounts at the end of winter)**
- **the supply of nitrogen through the net mineralization of the reserves of organic nitrogen in the soil**
- **additions of nitrogen compounds from livestock manure**
- **additions of nitrogen compounds from chemical and other fertilizers**

a) Government Decree, Section 5
Use of nitrogen fertilizers is prohibited on areas closer than five metres to a watercourse. Along the width of the next five metres, surface application of nitrogen fertilizers is prohibited if the field slope exceeds 2%. Surface application of animal manure is always prohibited on fields with an average slope of more than 10%.

This item has already been examined above in chapter 1.2.1, scene 2.

b) Government Decree, Section 5
Nitrogen fertilizers must not be applied on snow-covered, frozen or water-saturated ground. Animal manure must not be applied between October 15 and April 15. Manure may be applied in the autumn up to November 15, and application may be started in the spring no earlier than April 1, provided the ground is not frozen and is sufficiently dry to avoid runoff into watercourses and any danger of subsoil compaction. Manure may not be applied on grassland after September 15. Organic fertilizer applied in the autumn must always immediately, and within 24 hours at the latest, be incorporated, or the field must be ploughed. The maximum amounts of manure that can be applied in the autumn are 30 tonnes/ha of solid manure, 20 tonnes/ha of cow slurry, 15 tonnes/ha of pig slurry or 10 tonnes/ha of poultry or fur animal manure.

This item has already been examined above in chapter 1.2.1, scenes 1, 3, 6.

c) Government Decree, Sections 6 and 8

Section 6
The scale of use and application of nitrogen fertilizers is based on average crop yield, cultivation and crop rotation with the aim of retaining a balanced nutrient level in the soil. Farms may use the following maximum amounts of nitrogen on fields as fertilizer, contained in both mineral fertilizer and animal manure and organic fertilizers:
1) winter cereals up to 200 kg of nitrogen/ha/year, of which 30 kg of nitrogen/ha in the autumn and 170 kg of nitrogen/ha in the spring, or if slowly dissolving nitrogen is used, up to 40 kg of nitrogen/ha in the autumn and 160 kg of nitrogen/ha in the spring;
2) potato 130 kg of nitrogen/ha/year;

3) grassland and pasture, silage and horticultural plants 250 kg of nitrogen/ha/year;
4) spring cereals, sugar beet, oilseed crops and other crops up to 170 kg of nitrogen/ha/year.

For very fine sand and coarser mineral soils, 10 kg/ha/year is deducted from the nitrogen amounts laid down in paragraph 2 above. The total amounts of nitrogen presented in paragraph 2 above are reduced by 40 kg/ha in the case of cultivation of cereals or sugar beet on peat soil, and by 20 kg/ha in the operating areas covered by the Lapland, Northern Ostrobothnia and Kainuu Regional Environment Centres. For grasslands, the reduction is 10/ha on peat soil throughout the country. If the amount of permissible nitrogen fertilizer exceeds 170/kg/year, this amount must be split into at least two doses with at least two weeks between applications.

Section 8
Manure nitrogen analysis must be conducted at five-year intervals after the analysis that had to be made in 1998 at the latest. Farmers must keep a record of the amount of nitrogen fertilizers used on their fields and of crop yields.

The keeping of parcel-specific records has already been examined above in chapter 1.2.1, scene 9.

Soil samples

The Government Decree does not contain any regulations on measuring soil nitrate concentrations or regulations on estimating the potentially mineralizing organic nitrogen amounts in soil. There are also no regulations on estimating the nitrogen uptake by the plants.

The cultivated fields of a farm receiving agri-environmental support must be subjected to a soil analysis at least every five years so that the content of the easily soluble phosphorus in the soil (mg/l) can be determined. Nitrogen content must not be analysed. In gardens, one of the additional agri-environmental support measures is a more careful nutrient follow-up in which the farmer must carry out a soil analysis every three years on specific parcels on which horticultural plants are grown. Another additional measure related to soil samples for gardens is more accurate nitrogen fertilization by means of measuring soluble nitrogen. The purpose of the measurements is to determine the amount of soluble ammonia and nitrate nitrogen in the soil. There are plans to make the measuring of soluble nitrogen an additional agri-environmental measure for crop production but it is not yet part of the support requirements in 2004.

Nutrient balance

The nitrogen balance on Finnish fields for 1990–2002 was presented as part of the mid-term evaluation of the Horizontal Rural Development programme (Ministry of Agriculture and Forestry 2004). The conclusion was that the average amount of nitrogen entering fields had dropped from 175 kg/ha in the early 1990s to 138 kg/ha in 2002. It was also concluded that the nitrogen loss resulting from the harvest varied between 65 and 80 kg/ha, depending on the climatic conditions during the growing season. During the period in review, nitrogen surplus dropped from nearly 90 kg/ha to about 50 kg/ha. At the start of the period, by far the highest nitrogen surplus occurred in areas dominated by livestock farming but in these areas, too, the surplus dropped towards the end of the 1990s. In the nitrogen balance calculated for each plant species grown in the areas covered by the MYTVAS study, the amount of total nitrogen remaining in the soil averaged 30–50 kg/ha (Pyykkönen et al. 2004). In years with poor harvests (1998 and 1999) the balance was high and the amount of nitrogen remaining in the fields amounted to as much as 60–80 kg/ha, depending on the crop plant and area studied. In 2000–2002 the harvests were fairly good. When the nutrient balance of different plant species was examined it was found out that oats make the most efficient use of nutrients during all years and that the nitrogen surplus was usually about 20 kg/ha.

Manure analysis

Of the 154 livestock farms participating in the MYTVAS study (Pyykkönen et al. 2004) 88% had carried out the manure analysis, and on 11% of them the analysis was more than five years old. This means that 77% of the farms had carried out the analysis in accordance with the Decree. After carrying out the manure analysis, 72% of the farms planned cattle manure fertilization on the basis of the nutrient content values produced by the analysis, while 14% of the farms carrying out the analysis carried out the fertilization on the basis of average national values. The remaining 14% of the farms used both the manure analysis and average national values, as applicable.

1.3 Environmental permits for agriculture

The Environmental Protection Act and Decree that came into force in 2000 determine the activities that may pose a risk of pollution and for which an environmental permit must be sought. Agricultural activities that are subject to environmental permits are animal sheds and manure storage facilities. The environmental permits contain provisions on such matters as the scope of the activities, and emissions and cuts in them. The permit can only be granted if the activities do not cause any health risks, substantial environmental pollution or a risk of pollution. A permit is always required when new activities are planned or when there are material alterations to existing activities. The activities subject to the permit may not be started before the permit is granted. All farms with more than 30 dairy cows, 80 fattening cattle, 60 sows, 210 finishing pigs, 60 horses or ponies, 160 ewes or goats, 2,700 egg-laying hens, 10,000 chickens or other poultry, 250 breeding female mink or 50 breeding female foxes/raccoon dogs, had to register into the environmental protection database in 2001 or 2002. The question of whether they must have environmental permits has been considered on a farm-by-farm basis. Registration is also a condition for the payment of investment aid. The environmental permit is granted by the municipal environmental protection committee or the Regional Environment Centre. The Regional Environment Centre acts as the permit authority when the farm has more than 75 dairy cows, 200 fattening cattle, 250 sows, 1,000 finishing pigs, 30,000 egg-laying hens, 50,000 chickens or other poultry, 2,000 breeding female mink or 600 breeding female foxes/raccoon dogs. The municipal environmental protection committee is the permit authority when the farm is smaller than preceding. The municipalities make notably more environmental permit decisions than the Regional Environmental Centres.

The number of environmental permit decisions concerning agriculture made by the Regional Environment Centres in 2000–2002 were got from the environmental protection database of the Finnish environmental administration. The number of permit decisions made by the Regional Environment Centres are shown in Table 14. The table also show the number of environmental permits pending in May 2004. Most of the permit applications have been initiated in 2003 and 2004.

The largest number of environmental permit decisions were made in the West Finland Regional Environment Centre, but the Southwest Finland Regional Environment Centre and the North Ostrobothnia Regional Environment Centre were not far behind. These regions accounted for 73% of all environmental permit decisions made by the Regional Environment Centres and they also had the largest number of environmental permit applications pending, which gives a good picture of how livestock farming in Finland is concentrated. When individual production sectors are examined, dairy and beef production accounted for 34%, pig farming for 26%, fur farming for 13% and poultry for 11% of all permit applications.

Table 14. The number of agricultural environmental permits granted by Regional Environment Centres in 2000–2002 and the number of environmental permits pending on May 10, 2004 (VAHTI, 2004).

Regional Environment Centres	2000	2001	2002	Pending	Total
Uusimaa	-	5	4	7	16
Southwest Finland	5	21	31	54	111
Häme	-	-	-	5	5
Pirkanmaa	-	6	4	0	10
Southeast Finland	-	6	4	4	14
South Savo	-	2	7	-	9
North Savo	1	16	20	1	38
North Karelia	3	4	9	3	19
Central Finland	-	3	1	1	5
West Finland	9	35	50	67	161
North Ostrobothnia	6	13	17	29	65
Kainuu	-	3	2	1	6
Lapland	2	4	4	-	10
Total	**26**	**118**	**153**	**172**	**469**

1.4 Contraventions of the Decree and summaries on the manure heap notifications required under the Government Decree

Of the 13 Regional Environment Centres, eight provided information about contraventions of the Government Decree and most of the information was about the nature of the contraventions. Investigations of possible contraventions are usually initiated as a result of complaints, denunciations and checks made by Employment and Economic Development Centres and other authorities. There are still differences between Regional Environment Centres concerning the statement procedure even though attempts have been made to harmonize it. The Employment and Economic Development Centres request the Regional Environment Centres or municipal environmental protection committees to submit statements on the nature and severity of the contravention.

In many environment centre regions, most of the comments are requested from the municipalities, which means that the Regional Environment Centres are necessarily not informed with the contraventions. According to the Regional Environment Centres themselves, they only provide a small number of statements on contraventions every year. In two environment centre regions, the statements were mostly requested from the environment centres themselves, and these submitted about 10 statements in 2001–2003. The statements concerned such matters as the absence or insufficient capacity of the manure storage facility, leaks in the manure storage facility, manure spreading, establishment of manure heaps, outdoor yards, arrangements concerning the recovery of silage effluents and the lack of manure analysis and parcel-specific records.

The number of contraventions of the Government Decree reported to the police by the Regional Environment Centres numbered one (by one Regional Environment Centre). Contraventions were also reported to the police by municipal environmental protection committees and individual citizens that have suffered inconvenience as a result of the contraventions. The Regional Environment Centres were unable to provide any information about their number or severity.

A total of nine Regional Environment Centres gave the number of additional provisions and requests for additional information concerning deviation notifications required under section 84 of the Environmental Protection Act. Additional provisions and requests for additional information in the regions coming under the environmental centres submitting answers totalled 321 in 2001, 173 in 2002 and 95 in 2003.

Table 15 shows the number of notifications on deviations to the provisions on manure and urine storage contained in the Government Decree and notifications concerning other types of remote manure storage as submitted by Regional Environment Centres, by type of deviation. The number of deviation notifications, both as a whole and by type of deviation, decreased between 2001 and 2002. The number of manure heap notifications decreased in the areas of the all Regional Environment Centres during 2001–2002. Most of all manure heap notifications were done in the area of Southwest Finland and West Finland Environment Centres.

Table 15. Number of announcements about deviation from the required volume for manure storage 2001–2003. Announcements were received from 9 Regional Environment Centres.

Year	Number of deviation means				
	User accepted in section 28 of Environmental Protection Act	Another farmer	Immediate reuse	Manure heaps	Total
2001	62	186	82	4,294	4,624
2002	45	150	41	3,326	3,562
2003	41	121	32	2,856	3,050

Regional Environment Centres provided summaries of manure heap notifications from 2001–2003, as required under the Decree. However, heap notifications from a large number of municipalities were left out of the summaries. Some Regional Environment Centres only included the number of heaps or the number of heap notifications in their summaries. In many environment centre regions, the number of manure heaps and the amount of heaped manure decreased between 2001 and 2003 (Table 16).

Table 16. Number of manure heaps and volume of manure in 2001–2003 in the area of the Regional Environment Centres.

Regional Environment Centres	Manure heaps					
	2001		2002		2003	
	heaps no.	manure m^3	heaps no.	manure m^3	heaps no.	manure m^3
Uusimaa	333	36,095	244	32,867	275	31,049
Southwest Finland	1,388	109,982	1,147	108,275	853	82,521
Häme	628	34,278	553	50,404	458	46,292
Pirkanmaa	1,097	67,720	1,010	57,723	619	52,162
Southeast Finland	*	*	*	64,471	318	*
South Savo	521	*	344	*	356	*
North Savo	*	*	*	*	*	*
North Karelia	564	35,056	600	41,448	439	30,714
Central Finland	700	44,670	502	36,700	451	36,330
West Finland	*	*	*	*	761	90,147
North Ostrobothnia	620	46,834	686	50,396	553	41,069
Kainuu	160	11,232	147	11,232	98	8,357
Lapland	116	6,455	100	7,965	117	7,280
Total	6,127	392,322	5,333	461,481	5,298	425.921

* information not available

The reasons for using manure heaps include the insufficient size or absence of the manure storage facilities, technical considerations or reasons related to manure hygiene. A total of 10 Regional Environment Centres specified the reasons for the use of manure heaps in 2001–2003. Substantially fewer farmers used heaps because of the insufficient size or absence of manure storage facilities in 2003 than in 2000 (Table 17). Many of the farms in question are planning to give up livestock farming within the next few years. During the last few years, technical considerations have been given as the most important reason for having manure heaps.

Table 17. Reasons for using heaps for storing manure in 2001–2003 (% of farms using manure heaps).

	Manure storage	Technical	Hygienic	Other reason
2001	44	44	1	11
2002	40	47	2	11
2003	21	68	2	9

2 Surface water quality

Agriculture involves manipulation of soil, water and other natural resources and therefore has significant effects on the environment. In Finland the average percentage of agricultural land is 9%, but in the large drainage basins of southwestern Finland it can exceed 30% (Ekholm et al. 1999). In these areas of intensive agriculture, non–point loading is the most significant source of eutrophication. Phosphorus and nitrogen losses from agricultural land are high, exceeding those of industrial and municipal loads added together. Particularly during recent decades, the proportion of agriculture as a source of phosphorus has increased, whereas the loads from point sources have decreased. Decreasing point loads are due to more effective purification of both municipal and industrial wastewaters.

The whole country has been evaluated as a nitrate vulnerable area. In this report, NO_3 concentrations and concentrations of other variables indicating eutrophication (total P, total N and chlorophyll *a*) were first studied in all Finnish surface waters during the last reporting period 2000–2002 (Chap. 2.2–2.3). Then seasonal and yearly changes in these 4 variables are described in 20 lakes, 23 rivers and 19 estuaries, which all receive nutrients primarily from agricultural sources. Investigation period covers mainly the years 1992–2002 (Chap. 2.4).

Long-term changes in agricultural nitrogen leaching were studied in detail in three agricultural catchments for the period 1981–2003 (Chap. 2.5).

2.1 Data collection

All data on surface waters used in this report were extracted from the National Water Quality database maintained by the Finnish Environment Institute (SYKE). The data originate from water quality monitoring and control programmes coordinated and carried out at national, regional and local levels (Niemi and Heinonen 2003). Sampling frequency varies by programmes.

The national monitoring programme covers 253 lake sites and 195 river sites – the Finnish Eurowaternet (Niemi et al. 2001a; 2002b) – and 100 sites in coastal waters. Some lakes, rivers and estuaries loaded mainly by agriculture are included in this national programme and presented in more detail in chapters 2.4.1–2.4.3. The Regional Environmental Centres carry out regular monitoring in regionally significant or otherwise interesting waters with varying frequency or as control samples on a non-frequent basis. In agricultural areas, some rivers and lakes are selected to present a typical situation and monitoring has been directed at them. Local monitoring is used here to mean monitoring of receiving waters of municipal waste water treatment plants, industry and others causing point-source loading. Supervised laboratories carry out the local monitoring.

Agricultural loading is mainly quantified on the basis of areal coefficients derived from measurements in small agricultural catchments (Rekolainen 1993; Rekolainen et al. 1995; Vuorenmaa et al. 2002). Long-term changes in agricultural nitrogen leaching in three of these small catchments are presented in Chap. 2.5.

These catchments are covered by the monitoring programme of the Finnish network of small representative catchments being also a part of the Finnish Eurowaternet monitoring network.

Nitrate data on all the surface waters stored in the national database were extracted to find NO_3 concentrations in Finnish surface waters in 2000–2002. For rivers, data from all sampling depths for each river site were used, but for lakes and coastal areas only data from the surface layer were included, for lakes data from 0–2 m and coastal waters data from 0–5 m (either grab or composite samples). Altogether, there were 7,041 sampling sites in lakes, ponds, rivers, ditches, streams and coastal waters.

Those sites where nitrate concentrations exceeded 20 mg l^{-1} (130 sites) were examined carefully to exclude sites just below a point-source loading. There were left only 35 sites affected by agriculture and with nitrogen concentration >20 mg l^{-1} (Table 18). The number of sites with concentrations below 20 mg l^{-1} NO_3 was 6,911. From these sites, the following were excluded:

- all lakes with an area below 0.5 km^2
- sites with strong influence from point-source loading such as municipalities, mines or dumping places
- small ditches between field areas used to measure non-point-source loading.
- all sites with only 1–4 results in 2000–2002.

This resulted in a total of 2,376 sites shown in Fig. 1. Concentrations of total phosphorus (total P), total nitrogen (total N) and chlorophyll *a* from these same 2,376 sites are presented in Figs. 3–4.

In the previous report for the period 1996–1998, data from some 1,150 sites were used (Antikainen and Kangas 2000). Thus the number of sites had doubled for the reason that more nitrogen data were available for period 2000–2002 and more strict criteria for data were used last time: only sites with two or more results in every three reporting years 1996–1998 were accepted.

Analytical methods

For total N, total P and NO_3-N, only data from unfiltered samples were used. These nutrients and chlorophyll *a* were analysed according to Finnish standard methods (see References). Laboratories have participated in proficiency testing (including inter-calibrations) carried out by SYKE.

NO_2-N is readily oxidized to NO_3-N in water, so separate analysis is difficult and the result is often expressed as a sum of NO_3-N and NO_2-N. The Nitrates Directive has settled a limit value of 25 mg l^{-1} for nitrogen, so in this report values for nitrate nitrogen NO_3-N were converted into nitrate (NO_3) by multiplying NO_3-N data by 4.427. In Finland NO_3-N is normally used in reporting on water quality and eutrophication.

2.2 Nitrate concentrations in 2000–2002

In Finland's surface waters, the average level of nitrate is generally low, <10 mg l^{-1} NO_3 (Fig. 1). This is mainly due to the northern location of the country, which as a result of cold climatic conditions, restricts agricultural activities. Elevated concentrations of nitrate were detected in southern and southwestern parts of the country. Owing to milder climate and more fertile soils, crop production is concentrated in these areas. In the southwestern areas, agriculture is the primary source of anthropogenic nitrogen load into the surface waters, and the field percentages (24–44%) are the highest in the country (Rekolainen 1993, Pitkänen 1994; Ekholm et al. 1999). In the northern coastal areas, the nitrate concentrations are lower as forestry is the dominating land-use activity.

Maximum NO_3 concentration exceeded 25 mg l^{-1} in 93 sampling sites, and 20 mg l^{-1} in 130 sampling sites of the 2,376 sites studied altogether in 2000–2002. After careful examination of those 130 sites, 35 sites were left in the group of significant waters where agriculture has considerable influence on water quality (Table 18, Fig. 1). These sites are situated in 20 rivers, streams or ditches, in one lake and in one bay in the Gulf of Finland. They are all located in southern Finland where agriculture is most intensive and also point-source loading is heaviest. In 2000–2002, total N load originating from agriculture was estimated to form 18–68% of all nitrogen sources, including natural discharge (Table 18). In those waters where agriculture formed <50% of total N load, point-source loading formed 17–69% of total N load. The River Rakkolanjoki and Lake Haapajärvi receive municipal wastewaters which form over 60% of the total N load. Lake Haapajärvi, located on the course of the River Rakkolanjoki, is a eutrophied lake with high internal loading. The Rivers Porvoonjoki, Vantaanjoki, Risupakanjoki and Myllyoja also receive municipal wastewaters. The Rivers Vantaanjoki and Mäyränoja were also heavily loaded by scattered settlements.

The River Koskenkylänjoki, which discharges into Pernajanlahti Bay, is mainly loaded by agriculture (63% of total N load). The high NO_3 values on the shallow site of Pernajanlahti 51 (only 1 m deep) in 2000–2002 (Table 18) were probably due to resuspension and did not reflect changes in land use, because the concentrations at the other sites in close proximity to the river mouth did not peak during the reporting period.

NO_3 concentration was typically high (max > 25 mg l^{-1} NO_3) in the upper reaches of the rivers, and lower in the sampling sites downstream, for example in the River Yläneenjoki. In the lower reaches, waters discharging from forested areas have a diluting effect. The River Yläneenjoki is situated in the drainage basin of Lake Pyhäjärvi, discussed in more detail in chapter 2.4.1.

According to the Finnish Lake Survey 1995 (Mannio et al. 1999), NO_3 concentrations were clearly below 25 mg l^{-1}. The median NO_3-N concentration was 11 μg l^{-1} (= 0.05 mg l^{-1} NO_3) and the 90 percentile was 54 μg l^{-1} (=0.24 mg l^{-1} NO_3). This survey was carried out in autumn 1995 and covered 978 lakes which were selected from the national lake database using stratified random sampling from the entire lake population with unequal sampling fractions. Lake waters of the southern coast showed the highest ammonium and nitrate values. This was expected since the region is subjected to high loads of these forms of nitrogen, both airborne loads and loads from drainage basins (Rekolainen 1989; Syri et al.1998). In autumn, the comparability of the concentrations of these forms might be biased due to differences in sampling temperature; concentrations increased as biological activity and temperature decreased. Seasonal changes in NO_3 concentrations are shown in Chap. 2.4.

Mapping of stream water quality was carried out by the Geological Survey of Finland in August-September 1990 in 1,166 small headwater catchments (ca. 30 km^2) all over Finland (Lahermo et al. 1996). Typical NO_3 concentrations were 0.2–3.0 mg l^{-1} (median 0.5 mg l^{-1}, mean 0.86 mg l^{-1}, the 98 percentile 5.48 mg l^{-1}). Highest concentrations were detected in coastal areas where population density is highest and agriculture intensive.

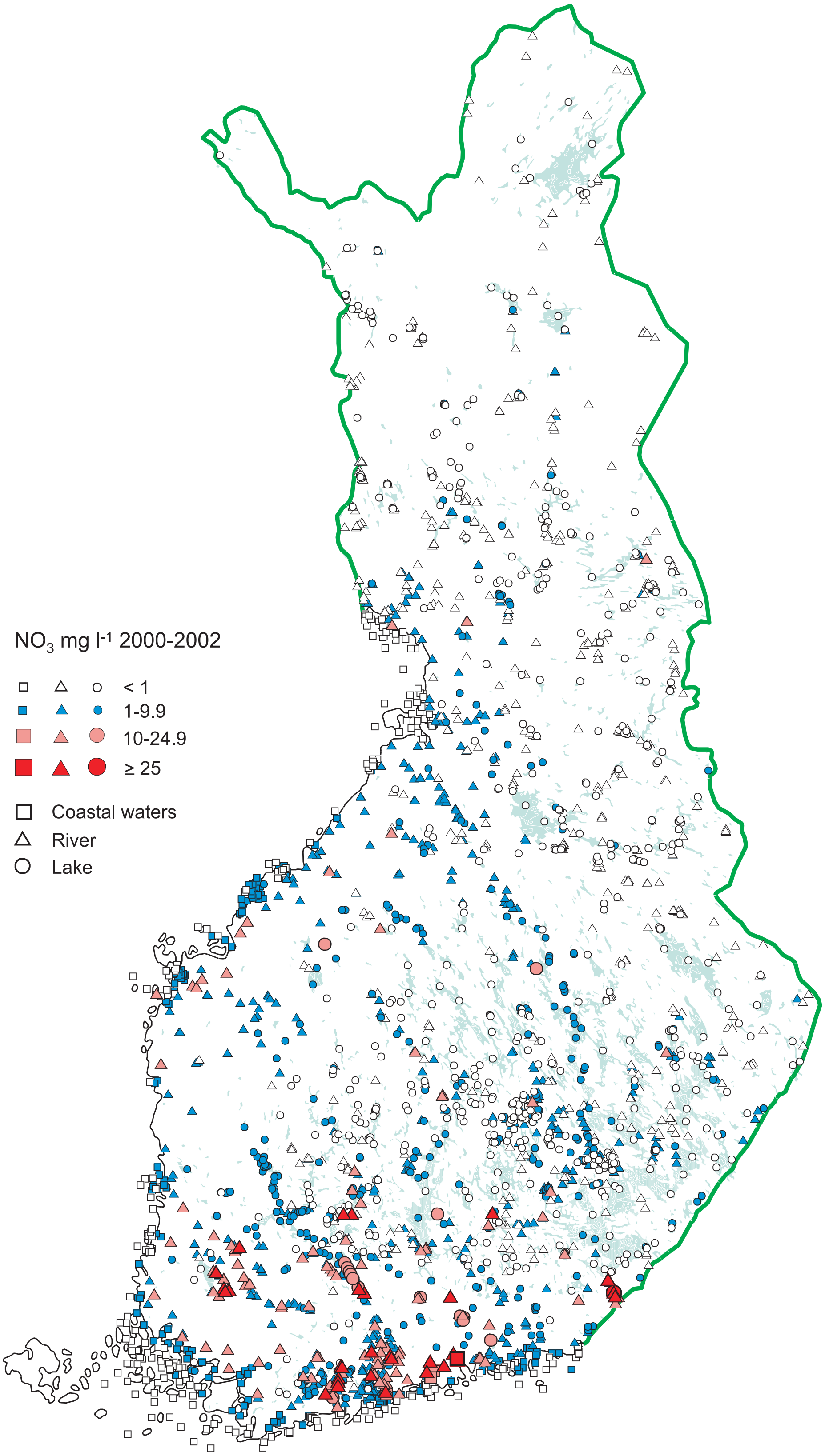

Figure 1. Maximum concentrations of nitrate (mg l^{-1} NO_3) in Finnish lakes, rivers and coastal waters in 2000–2002 based on data for the whole year.

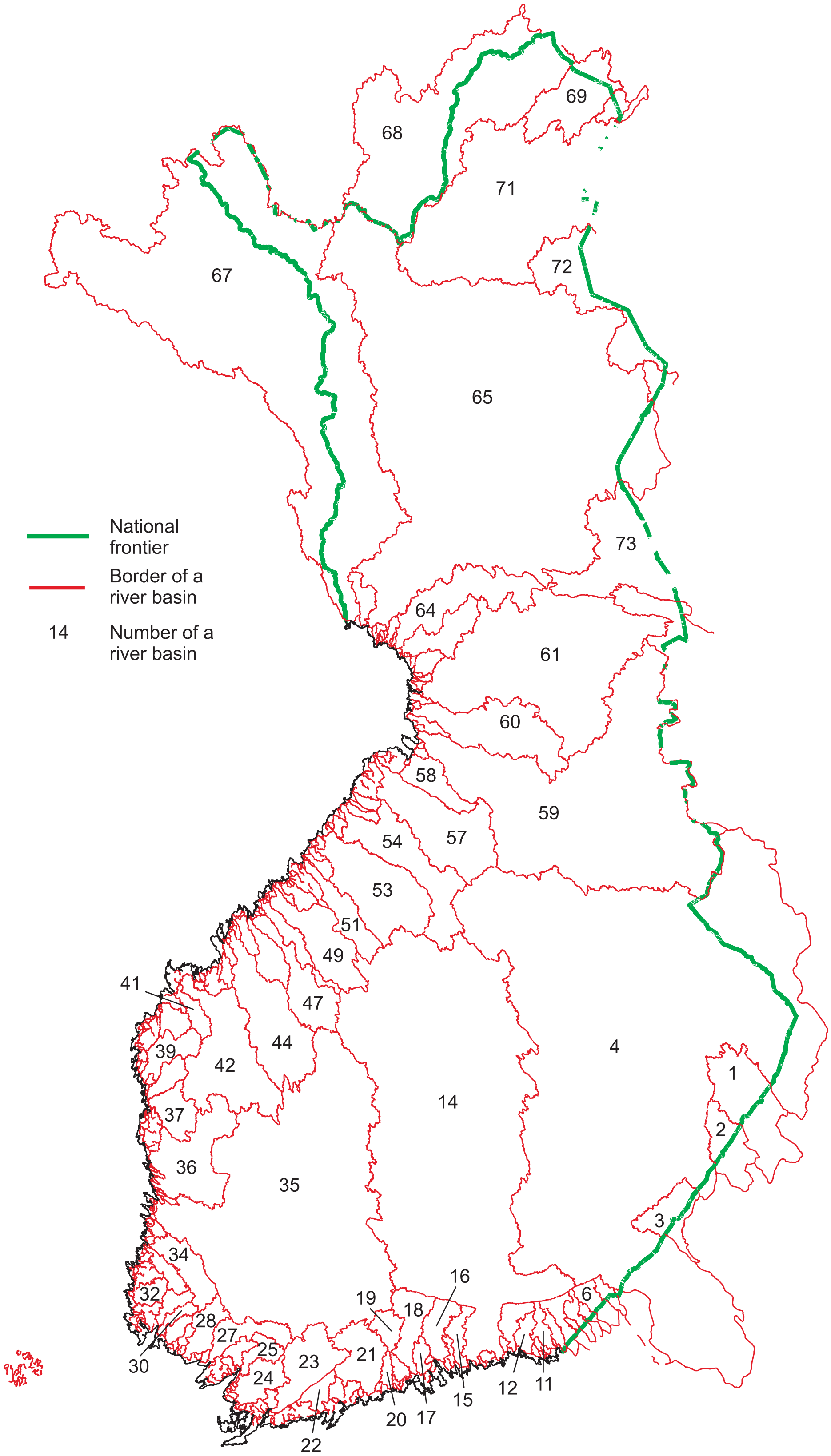

Figure 2. River basins in Finland (Ekholm 1993).

Table 18. Agriculturally loaded Finnish surface waters in 2000–2002 with maximum nitrate concentrations > 20 mg l-1. The area and field percentage of each river basin and estimation of total N load by sources are shown for downstream sites of each river. River basins are shown in Fig. 2. wwtp= wastewater treatment plant.

Sampling site	Water type	NO_3 (mg l^{-1})				River basin				Total N sources (%)					Remarks
		n	mean	std	max	No.	Area km²	Name (Ekholm 1993)	Field %	Agriculture	Natural discharge	Scattered settlement	Point-source loading	Other	
Rakkolanjoki 003	river	12	8.2	8.4	22.1	06.021	156	Rakkolanjoki lower part	17.9	21	13	2	63	1	Below a wwtp
Haapajärvi 006	lake	12	9.7	9.5	23.2	06.022		Rakkolanjoki upper part	23.2						Below a wwtp
Haapajärvi 014	lake	4	12.3	18.5	39.6	06.022		Rakkolanjoki upper part	23.2						Below a wwtp
Haapajärvi 015	lake	12	10.4	10.2	26.1	06.022		Rakkolanjoki upper part	23.2						Below a wwtp
Rakkolanjoki 005	river	12	9.2	10.0	27.4	06.022	105	Rakkolanjoki upper part	23.2	18	10	2	69	1	Below a wwtp
Rakkolanjoki 016	river	11	39.4	16.8	66.4	06.022		Rakkolanjoki upper part	23.2						Below a wwtp
Rakkolanjoki 019	river	13	55.3	22.2	97.4	06.022		Rakkolanjoki upper part	23.2						Below a wwtp
Rakkolanjoki 029	river	12	18.3	16.2	57.5	06.022		Rakkolanjoki upper part	23.2						Below a wwtp
Rakkolanjoki 131	river	12	68.2	29.1	111	06.022		Rakkolanjoki upper part	23.2						Below a wwtp
Taasianjoki 8,2	river	12	6.0	6.9	21.2	15.001	530	Taasianjoki lower part	30.5	63	31	2	2	2	
Taasianjoki 9,2	river	12	6.0	6.9	21.2	15.001		Taasianjoki lower part	30.5						
Taasianjoki 9,9	river	12	5.9	7.1	21.7	15.001		Taasianjoki lower part	30.5						
Koskenkylänjoki 3,0 6030	river	78	5.4	3.9	25.2	16.001	895	Koskenkylänjoki lower part	30.6	63	28	3	1	5	Koskenkylänjoki River
Ilolanjoki 1,3	river	23	6.0	7.6	37.2	17.001	309	Ilolanjoki lower part	26.2	59	31	4	0	6	
Porvoonjoki 11,5 6022	river	70	14.1	6.2	37.6	18.012	1138	Strömberg area	28.5	43	20	3	31	3	Porvoonjoki River
Mustijoki 4,2 6010	river	70	8.3	5.8	29.2	19.001	783	Mustijoki lower part	30.7	60	26	4	6	4	
Vantaa 1,3	river	50	8.0	4.7	27	21.011	1686	Vantaa river mouth area	23.4	44	23	12	17	4	Vantaa River
Vantaa 4,2 6040	river	73	7.8	3.4	23.9	21.011	1686	Vantaa river mouth area	23.4						Vantaa River

Table 18 continues.

Sampling site	Water type	NO3 (mg l-1)				River basin				Total N sources (%)					Remarks
		n	mean	std	max	No.	Area km²	Name (Ekholm 1993)	Field %	Agriculture	Natural discharge	Scattered settlement	Point-source loading	Other	
Lepsämänjoki 2,6	river	54	6.3	5.3	29.4	21.041	214	Lepsämänki lower part	24.8	53	29	9	4	5	Monitoring of results of EU agri- environmental support scheme
Sarsalanoja 1,6	stream	36	5.8	6.5	22.3	21.084	19	Sarsalanoja	43.4	68	25	5	0	2	Monitoring of drainage area of Lake Tuusulanjärvi
Mäyränoja 0,4	stream	36	8.8	8.5	34.8	21.085	16	Mäyränoja	35.8	58	24	16	0	2	Monitoring of drainage area of Lake Tuusulanjärvi
Ohkolanjoki 0,6	river	9	4.3	7.5	23.5	21.096	79	Ohkolanjoki	27.1	59	30	8	0	3	
Kirkkojoki 1,2	stream	24	8.1	5.9	22.1	22.006	142	Kyrkån	34.2	68	24	6	0	2	Monitoring of results of EU agri-environmental support scheme
Kirkkojoki 7,7	stream	24	8.2	6.8	30.1	22.006	142	Kyrkån	34.2	68	24	6	0	2	Monitoring of results of EU agri-environmental support scheme
Risupakanjoki 0,5	stream	24	25.4	18.8	88.6	22.007	42	Risubacka ån	21.6	23	12	3	61	1	Below a wwtp
Sirp 22 Lla-Uki va6600	river	19	8.6	5.2	20.4	32.001	378	Sirppujoki lower part	25.7	62	27	4	5	2	
Yläneenjoki P2 Vanhakart	river	91	3.6	3.3	22.1	34.042	197	Vanhan kartano	30.1	64	30	2	0	4	Monitoring of drainage area of Lake Pyhäjärvi
Yläneenj S13 Vuotavanoja	ditch	33	8.4	9.8	53.1	34.045	13	Latvanjoki	47.3						Monitoring of drainage area of Lake Pyhäjärvi
Sammaljoki Nanhiansuo ap	river	10	5.5	7.5	25.2	35.181	303	Sammaljoki lower part	25.8	63	31	2	0	4	
Vanajav. Hiidenjokisuu	river	5	6.2	10.7	25.2	35.233	2279	Hämeenlinna area	21.1	54	28	4	6	8	Hiidenjoki River, below wwtp
Tarpianjoki keskusta mts	river	10	3.9	6.0	20.4	35.281	597	Tarpianjoki lower part	20.8	50	34	3	3	10	
Kirkkojärven Myllyoja	river	50	7.6	6.0	32.8	35.729	42	Myllyoja	30.9	45	21	5	22	7	Below a wwtp
Hiidenjoki 7,4 (7310)	river	19	4.7	7.4	26.6	35.811	2192	Hiidenjoki mouth area	21.6	55	28	3	<6	14	Hiidenjoki River , upstream of a wwtp
Vaasa-Pori mts vp. 9300	river	20	7.4	4.5	20.8	41.001	507	Laihianjoki lower part	28.0	52	34	4	6	4	Laihianjoki River
Pernajanlahti 51	bay	6	10.9	11.3	25.7	91.31		Loviisa-Pernaja coastal area							Estuary of the Koskenkylänjoki River

2.3 Total phosphorus, total nitrogen and chlorophyll a concentrations in 2000–2002

The same 2,376 sites and sampling depths (in lakes, rivers and coastal waters) which were used to describe NO_3 concentrations in 2000–2002, were also used to analyse the trophic state of Finnish surface waters. Only summer data were used (July 16 – September 15). Chlorophyll *a* is primarily analysed from lakes and seawater and only from a few rivers.

Total P and chlorophyll *a* data (Figs. 3 and 5) were classified according to OECD trophic classification made for lakes (OECD 1982):

Trophic category	Total P $\mu g\ l^{-1}$ mean	Chlorophyll *a* $\mu g\ l^{-1}$ mean	Chlorophyll *a* $\mu g\ l^{-1}$ max
Oligotrophic	< 10	< 2.5	< 8.0
Mesotrophic	10–35	2.5–8	8–25
Eutrophic	35–100	8–25	25–75
Hyper-eutrophic	>100	>25	> 75

Chlorophyll *a* concentrations >100 $\mu g\ l^{-1}$ are also shown in Fig. 5. Total N data (Fig. 4) were classified according to the same scheme as Pietiläinen and Räike (1999), which is not, however, a generally agreed trophic classification.

The average summer concentrations of total P were mainly <35 $\mu g\ l^{-1}$ indicating oligotrophy or mesotrophy. The highest concentrations of total P (>100 $\mu g\ l^{-1}$) were found in lakes and rivers located near the coastal zone where population density is highest and consequently the human impact on waters is significant. Large lake basins included in the Finnish Eurowaternet monitoring network are mainly oligotrophic or mesotrophic according to a study made by Mitikka and Ekholm (2003). Chlorophyll *a* concentrations (Fig. 5) indicated higher trophic status than total P. It should be noted that during the period selected to represent summer (July 16 – September 15) also phytoplankton biomass and chlorophyll *a* concentration are highest. Thus chlorophyll *a* concentrations in Fig. 5 should then be compared with boundary values given above for maximum chlorophyll *a*. Most of the waters were oligotrophic or mesotrophic in 2000–2002. Chlorophyll *a* is analysed in rivers less often than in lakes or coastal waters.

According to the Finnish Lake Survey 1995 (Mannio et al. 1999) most Finnish lakes were oligotrophic or mesotrophic; the median total P concentration was 13 $\mu g\ l^{-1}$ and the 90 percentile 33 $\mu g\ l^{-1}$. Median concentration of total N was 410 $\mu g\ l^{-1}$ and the 90 percentile 750 $\mu g\ l^{-1}$.

According to the latest water quality classification (Fig. 6), about 80% of the lake area and 73% of the sea area had excellent or good water quality. Rivers were typically more polluted than lakes and only 43% were classified as excellent or good. This was mainly due to high concentrations of total P and hygienic indicator bacteria. Coastal waters receiving waters from these rivers have typically been classified as satisfactory or passable.

Water quality classification reflects the general quality of Finnish inland waters. It provides an overall picture of water quality and the suitability of waters for different uses, e.g. for water supply, fishing and recreational activities. Water quality classifications have been made since the 1970s. The latest classification (Fig. 6) was carried out on the basis of data on about 10,000 observation sites from 2000–2003 (SYKE 2005). The waters were classified into five classes on the basis of oxygen content, colour, turbidity, nutrients, hygienic indicator bacteria, chlorophyll *a*, algal blooms and toxic compounds (Heinonen and Herve 1987, Vuoristo 1998). The latest classification from the beginning of 2000s covered 82% of the total lake area (lakes with area over 1 km^2) and 16% of total river length (rivers more than 2 m in width) and almost 100% of coastal waters.

The most affected lakes are situated close to population centres and were typically eutrophic. Improvement of waters affected by wastewaters began during the 1970s and this positive trend has continued until the present. The deteriorating influence of diffuse load on waters has increased, whereas that of point-source loading has decreased. This was evident particularly in small lakes and rivers subject to the effects of agriculture and forestry. The Gulf of Finland was classified as satisfactory. Although the load of total P and N from point-sources has decreased, the internal loading maintains eutrophication in the Gulf of Finland.

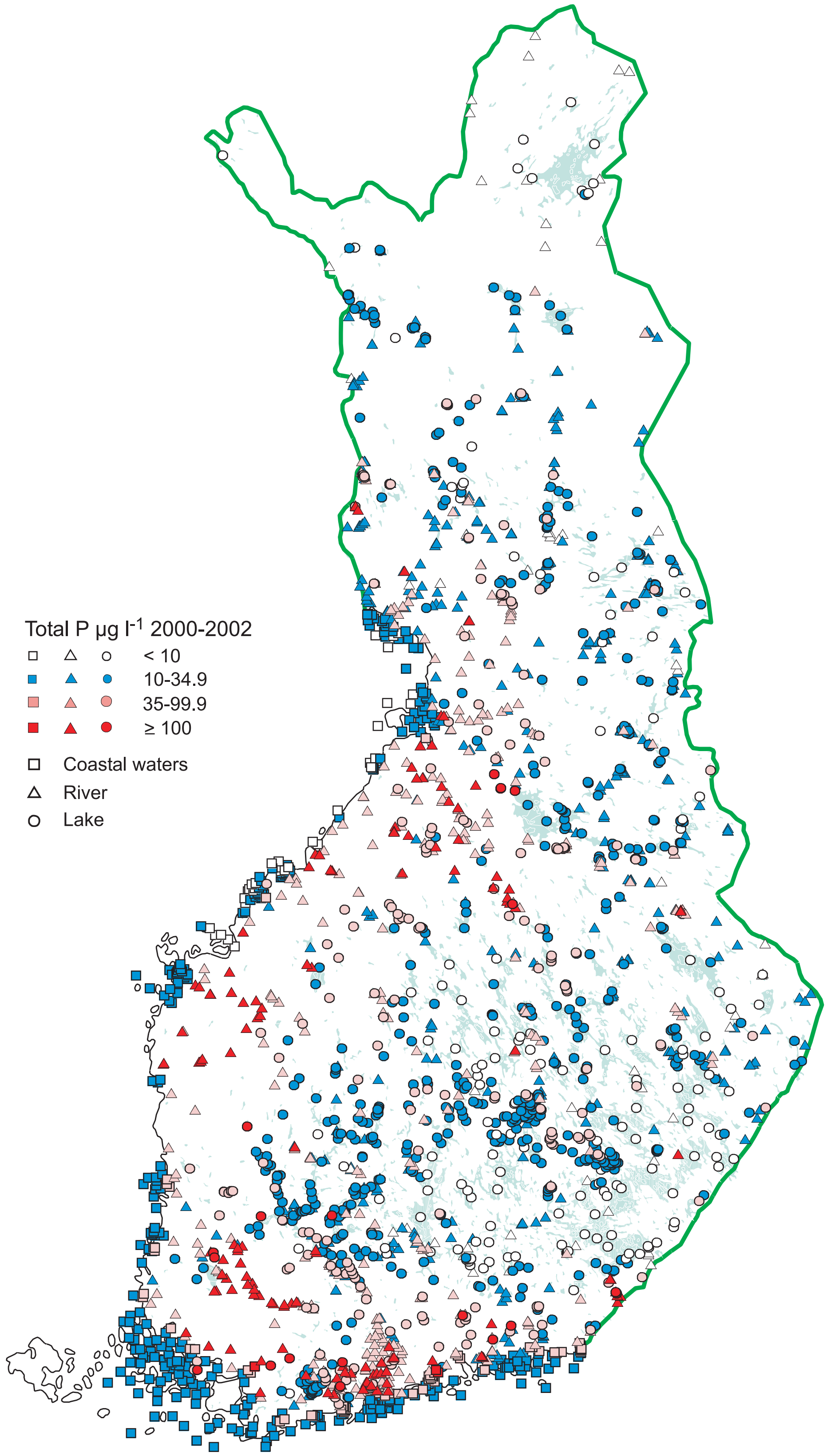

Figure 3. Average concentrations of total phosphorus (µg l-1) in Finnish lakes, rivers and coastal waters in 2000–2002 based on summer data.

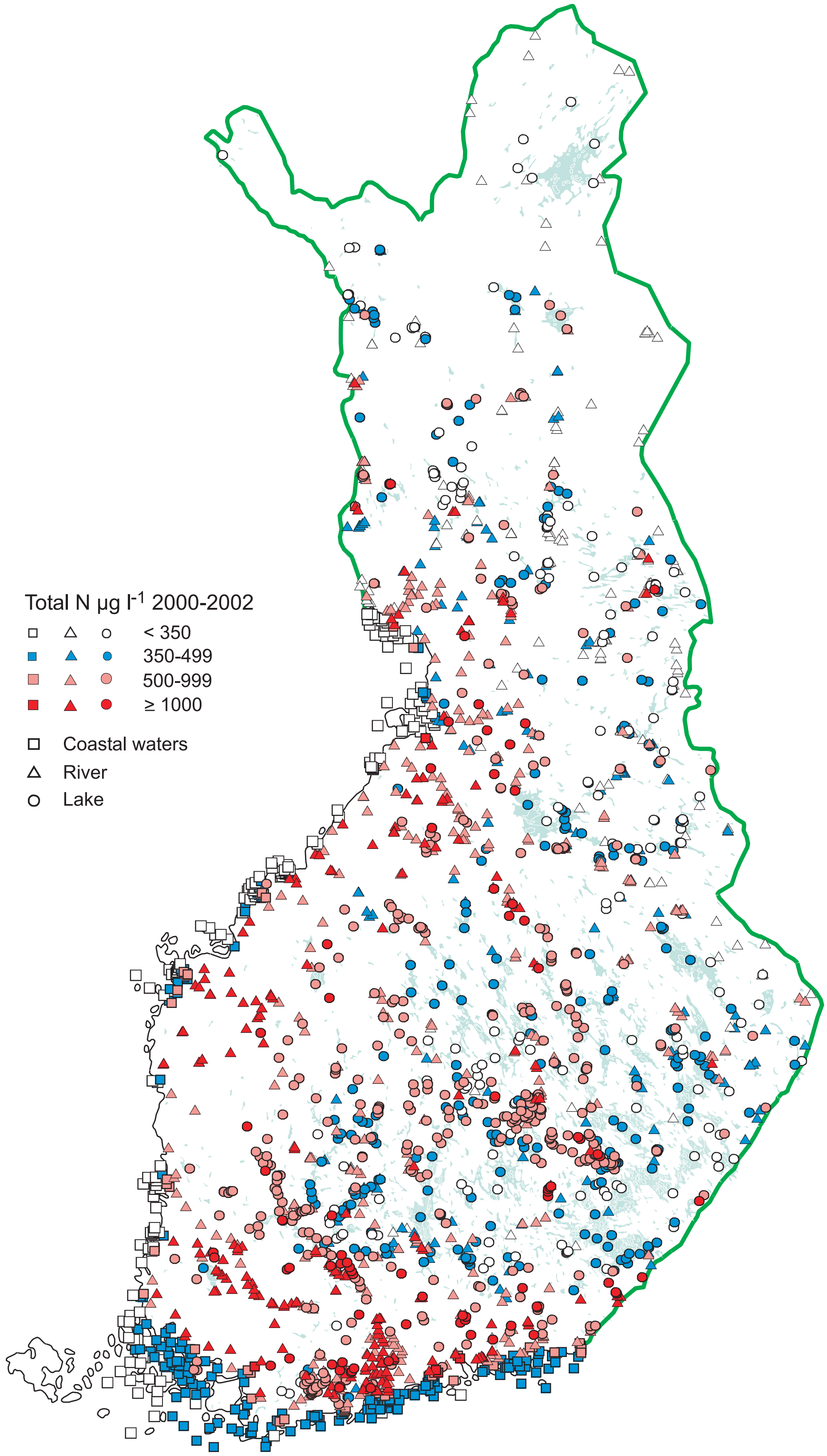

Figure 4. Average concentrations of total nitrogen (µg l⁻¹) in Finnish lakes, rivers and coastal waters in 2000–2002 based on summer data.

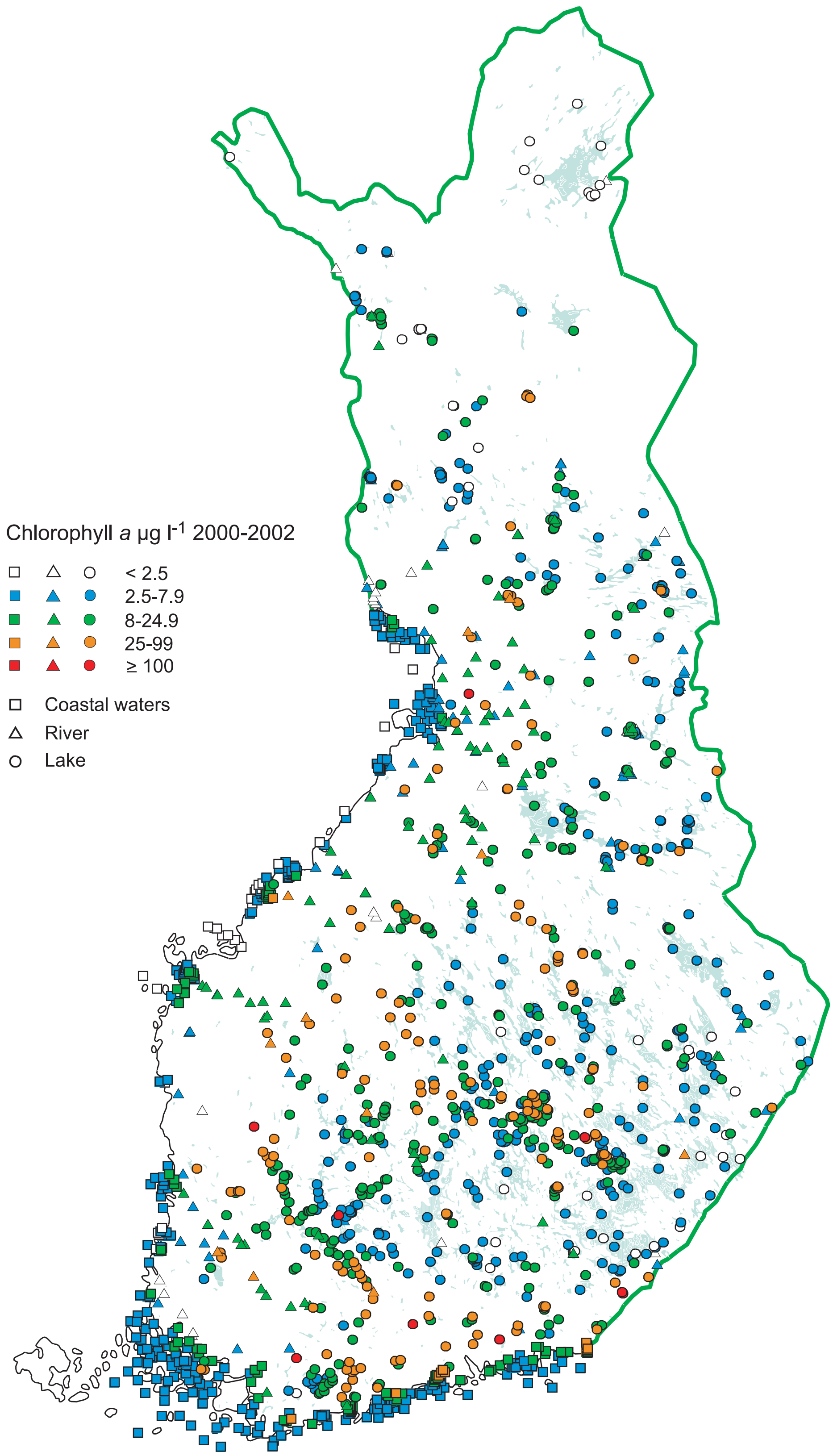

Figure 5. Average concentrations of chlorophyll a *(µg l[-1]) in Finnish lakes, rivers and coastal waters in 2000–2002 based on summer data.*

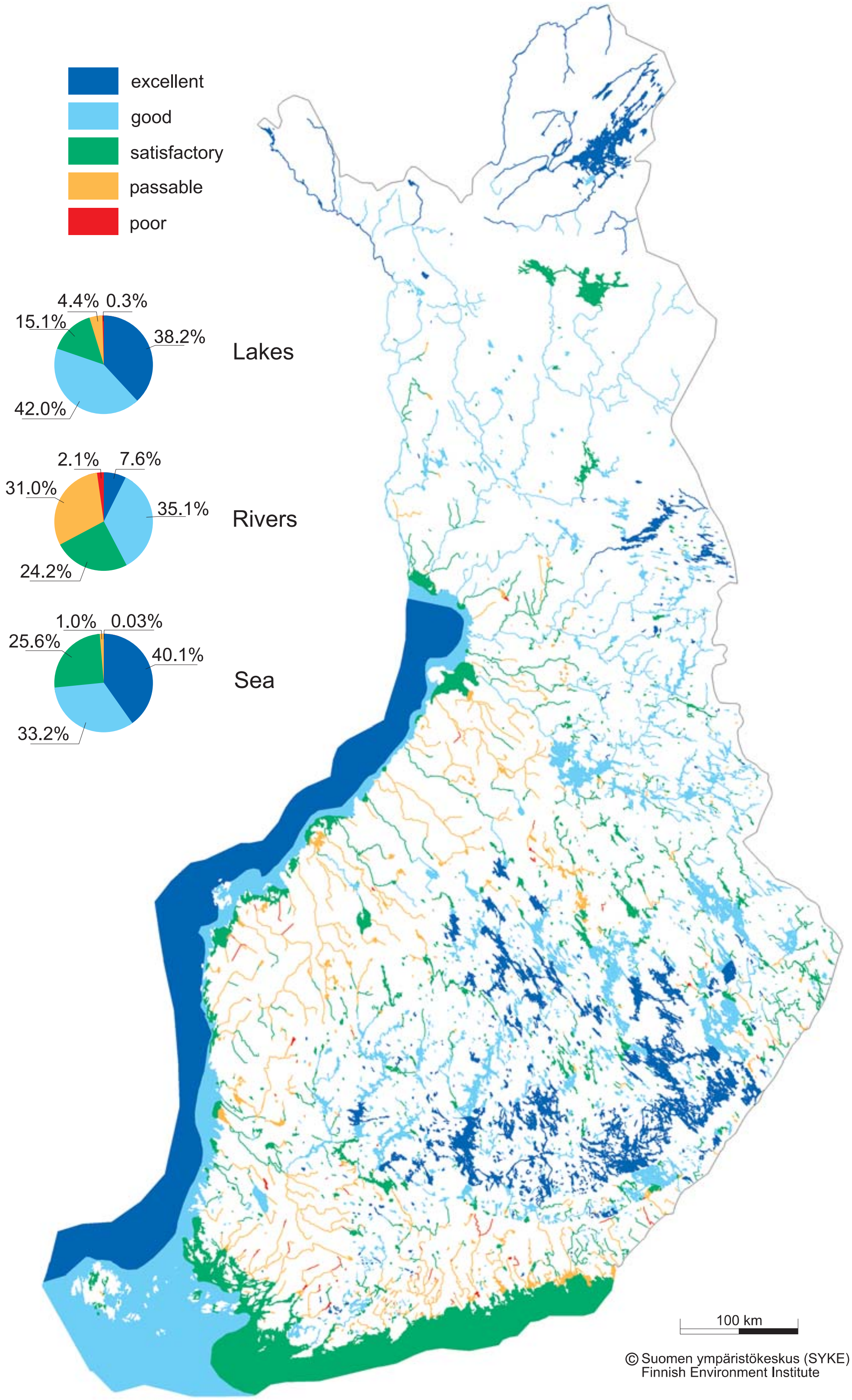

Figure 6. General classification of Finnish surface waters in 2000–2003 (SYKE 2005).

2.4 Water quality changes in surface waters affected by agriculture in 1992–2002

2.4.1 Lakes affected by agriculture

Water quality changes in agriculturally loaded lakes in 1992–2002 are illustrated with 20 example lakes located in southern and central Finland (Table 19, Fig. 2). Most of them are included in the current Finnish Eurowaternet monitoring network (Niemi et al. 2002a,b). The size of the lakes ranged 0.4–155 km^2 and the maximum depth 1.7–67 m (Table 19).

Symptoms of eutrophication were common in all studied lakes (Ekholm and Mitikka 2005); blue-green algal blooms were reported from almost all sites, oxygen depletion in near-bottom water layers was common and even fish kills and smell and taste defects in fish were found in some lakes (e.g. in Lake Enäjärvi). In all the lakes, agriculture was the major anthropogenic source of nutrients during our study period, although some lakes were earlier severely affected by point-source loading. The proportion of fields in the catchment area ranged from 6% to 41% (Table 19). The catchment area of Lake Ullavanjärvi has only 6% field but this lake is affected by animal husbandry. Based on the regional distribution of Finnish agriculture, most of the nutrient loading originated from crop production rather than animal husbandry, especially in lakes located in southern Finland.

The NO_3 concentrations (mean or maximum) never exceeded 25 mg l^{-1} in surface water layer of the agricultural lakes studied in the three reporting periods 1992–1994, 1996–1998 and 2000–2002 (Table 20) or at any time in 1992–2002. Maximum concentration 12 mg l^{-1} was analysed in winter 2000 in Lake Villikkalanjärvi, which is a small, shallow lake with high field percentage in the catchment area (Table 19). At the same time in bottom water layer of this lake NO_3 concentration was 32.3 mg l^{-1} (Ministry of Agriculture and Forestry 2004a, p. 126, attach. 5). This was the only time NO_3 concentration exceeded 25 mg l^{-1} in bottom water of these 19 studied agricultural lakes. Nitrate concentrations in lakes are normally higher in winter than in summer (Table 20, Fig. 7) due to the low biological activity in wintertime.

The relationship of total N: and total P (N:P) was frequently < 10 in summertime in Lakes Enäjärvi, Kirkkojärvi, Köyliönjärvi, Sääksjärvi and Ylisjärvi, indicating that nitrogen could be a growth-limiting factor for algae in these lakes. The NO_3 concentration actually decreased to near undetectable concentrations in the summer in 19 of the 20 agricultural lakes studied in at least one study period (Table 20, Fig. 7). Lake Pyhäjärvi (Artjärvi) was the only lake where the NO_3 concentration did not clearly decrease in the summer. In Lake Ylisjärvi, NO_3 concentrations decreased in the last period 2000–2002, being low also in the summer of 2003. In Lake Lappajärvi, summertime NO_3 concentrations have increased during the latest period. A slight increase was also detected in total N concentrations (Fig. 7). Teppo (2003) noted that the relationship of inorganic nitrogen and phosphorus (DIN:DIP) decreased in 1997–2000 in Lake Lappajärvi from May (140:5) to September (20:6), when blue-green algae blooms are common. Nitrogen is assumed to be a growth-limiting nutrient when DIN:DIP is < 5 (Forsberg et al. 1978). In the EU-financed Lappajärvi Life project 1999–2002, this lake was under restoration aimed at reducing both the external and internal load at the same time (Rautio 2003). Buffer zones were established and nutrient balance calculations were prepared for potato farms.

Table 19. Main characteristics of the 20 agricultural lakes studied. Data from the database of the Finnish Environment Institute. Modified from Ekholm and Mitikka (2005).

Lake				Catchment (excluding the lake)						Special features
Name	Area	Depth mean	Depth max	River basin no.[1)]	Area	Fields	Forest	Peat-land	Water	
	km^2	m	m		km^2	%	%	%	%	
Ahmasjärvi	3.8	-	4.5*	59.219	39	18	61	13	6	Bird conservation site, forest drainage
Ahveninen	1.6	-	4.3*	14.353	5.7	41	55	2	<1	
Enäjärvi	4.9	3.2	9.1	22.005	28.6	28	52	3	<1	Waste water load till 1976, fish removal from 1993, aerated from 1998
Juoksjärvi	0.6	-	8.5*	14.221	43.6	15	72	6	5	
Karhijärvi	33.3	2.1	7.3	36.092	464	14	65	16	2	
Kirkkojärvi	0.4	3	4.9	82	3.4	31	59	1	2	Chemical P-precipitation in 2002
Kirmanjärvi	3.0	6	10.1	4.516	26.4	33	54	4	4	Aerated from 1986,fish removal 1996–2001, upstream lakes restored
Köyliönjärvi	12.4	2.3	12.8	34.054	124	30	59	9	<1	Waste water load till 1974, fish removal since 1992
Lappajärvi	145	7.4	38	47.031	1290	18	48	27	2	Selective fishing 2001, oxygenation 2000–2002
Lehijärvi	7.0	6.5	18.1	35.237	55.5	29	59	1	1	Bird conservation site, aeration in the 1980s, fish removal
Pusulanjärvi	2.1	4.9	10.6	23.062	223	17	65	6	9	Waste water load till 1988, intensive fishing, aeration
Pyhäjärvi (Säkylä)	155	5.5	26.2	34.031	461	22	61	11	1	Intensive commercial fishing (+ fish removal)
Pyhäjärvi (Tammela)	22.8	-	3.9*	35.931	647	13	56	19	8	Moderate fishing?
Pyhäjärvi (Artjärvi)	12.9	-	66.6*	16.003	447	32	58	3	4	
Sotkamojärvi	2.1	-	16.7	59.821	13.5	14	68	10	2	
Sääskjärvi	5.1	-	4.3*	16.004	60.6	36	58	2	<1	Fish removal
Tiiläänjärvi	2.1	4.1	10.3	17.005	36.2	23	68	3	3	
Ullavanjärvi	13.1	-	1.7*	49.054	127	6	48	43	1	Aeration
Villikkalanjärvi	7.1	3.2	10	16.003	407	32	60	3	2	Fish removal, discharges into Pyhäjärvi (Artjärvi)
Ylisjärvi	1.7	2.1	4.3	24.043	126	27	61	6	4	

1) See Figure 2.

* = Depth of the deepest monitoring site; bathymetric survey not carried out

Many of the lakes were not regularly monitored before 2000. Water quality observations tend, therefore, to be sparse and discontinuous, which confounds the detection of trends in particular. Ekholm and Mitikka (2005) performed a nonparametric statistical test for trend analysis for 1976–2002 (Kendall's rank correlation between a seasonal median value of a water-quality variable and year). Kendall's tau-b considers whether the yearly change is positive or negative and ignores the magnitude of the change. In summer (July 16 – September 15), total P was increasing in 4 out of 18 lakes and decreasing in the intensively restored Lake Enäjärvi. Total N increased in 2/18 lakes and decreased in Lake Enäjärvi. The changes were most pronounced in Lake Pyhäjärvi, Säkylä. In this lake, total P, chlorophyll *a* and turbidity were increasing and Secchi depth decreasing (Ekholm and Mitikka 2005). The neighbouring Lake Köyliönjärvi, and Lake Lappajärvi, were also clearly becoming more eutrophic. Lake Kirkkojärvi was restored with chemical phosphorus precipitation in 2002 and in 2003–2004, total N, total P and chlorophyll *a* concentrations were lower than in the 1990s (Figs. 7 and 8).

In winter (January – April), total P increased in 3/20 cases and total N increased in 6/19 cases. Lake-wise, winter-time changes did not always correspond to summer-time changes. For instance, no increase was found in TP and TN in Lake Pyhäjärvi (Säkylä) in the winter (Ekholm and Mitikka 2005). Lake Pyhäjärvi, which was earlier renowned for its clear water and high fish catches, has been under a process of slow eutrophication during the 1980s and more extensively in the1990s due to excessive nutrients (Mattila et al. 2001). The nutrients come into the lake mainly as diffuse load from surrounding agricultural areas, and from the air in the form of dust and rain. In addition to national efforts for funding eutrophication control, a separate EU project called 'Lake Pyhäjärvi Restoration Project – Tool Development' started in 1996 and was completed in 2000 (Mattila et al. 2001). During this project, co-financed by the EU Life Environment Fund, new methods for water protection in agriculture and animal husbandry were examined.

The recovery of most eutrophied agricultural lakes would call for a substantial reduction in the external nutrient loading and also in-lake restoration measurements.

Table 20. Nitrate concentrations (mg l^{-1} NO_3) in the 20 agricultural lakes listed in Table 18. Basic statistics calculated for winters, summers and whole years for periods 1992–1994, 1996–1998 and 2000–2002. None of the measured concentrations exceeded 25 mg l^{-1}.

Lake name	1992–1994												1996–1998												2000–2002											
	Winter				Summer				Whole year				Winter				Summer				Whole year				Winter				Summer				Whole year			
	n	mean	min	max	n	mean	min	max	n	mean	min	max	n	mean	min	max	n	mean	min	max	n	mean	min	max	n	mean	min	max	n	mean	min	max	n	mean	min	max
Ahmasjärvi	4	2.39	1.24	3.14					5	1.92	0.03	3.14	6	2.93	1.51	4.03	1	0.02	0.02	0.02	15	1.35	0.00	4.03	6	2.21	1.42	2.92	4	0.03	0.01	0.05	17	0.87	0.01	2.92
Ahveninen					2	0.01	0.00	0.02	2	0.01	0.00	0.02					2	0.00	0.00	0.00	4	0.00	0.00	0.00	3	1.63	0.97	1.99	3	0.01	0.00	0.03	17	0.31	0.00	1.99
Enäjärvi	2	2.89	2.79	2.98	1	0.08	0.08	0.08	3	1.95	0.08	2.98	4	4.19	0.81	6.86	10	0.04	0.03	0.06	33	0.74	0.01	6.86	6	4.20	2.66	5.68	13	0.02	0.01	0.06	39	0.89	0.01	5.68
Juoksjärvi					3	0.04	0.00	0.11	3	0.04	0.00	0.11	4	1.84	1.37	2.66	7	0.21	0.00	1.02	14	0.84	0.00	2.66	3	2.58	2.35	2.92	3	0.08	0.00	0.22	17	1.23	0.00	3.14
Karhijärvi					2	0.06	0.01	0.11	2	0.06	0.01	0.11	1	2.83	2.83	2.83	1	0.01	0.01	0.01	2	1.42	0.01	2.83	2	2.88	2.83	2.92	3	0.01	0.00	0.01	7	0.83	0.00	2.92
Kirkkojärvi	6	2.36	0.84	4.07	1	0.11	0.11	0.11	10	1.97	0.02	4.87	6	4.04	1.64	5.76	6	0.21	0.01	0.84	31	1.02	0.00	5.76	3	3.05	2.12	4.40	12	0.06	0.01	0.38	32	0.39	0.00	4.40
Kirmanjärvi	3	1.05	0.32	1.68	3	0.02	0.02	0.02	12	0.29	0.02	1.68	3	1.03	0.12	1.68	4	0.06	0.02	0.15	12	0.36	0.01	1.68	6	1.36	0.97	1.64	4	0.01	0.01	0.01	15	0.60	0.01	1.64
Köyliönjärvi	3	3.57	2.63	4.87	4	0.06	0.00	0.19	10	1.25	0.00	4.87	4	2.85	0.27	6.20	3	0.03	0.01	0.04	9	1.29	0.01	6.20	3	3.53	2.21	4.43	5	0.01	0.01	0.01	9	1.19	0.01	4.43
Lappajärvi	1	0.53	0.53	0.53	6	0.15	0.02	0.36	13	0.27	0.00	0.71	3	0.33	0.15	0.49	6	0.08	0.01	0.16	15	0.17	0.01	0.49	3	0.94	0.66	1.15	8	0.26	0.01	0.93	23	0.58	0.01	1.64
Lehijärvi	5	1.23	0.84	1.82	3	0.03	0.00	0.05	14	0.57	0.00	1.82	5	0.99	0.84	1.11	10	0.01	0.00	0.06	30	0.23	0.00	1.11	4	1.46	1.20	2.08	9	0.07	0.00	0.31	24	0.47	0.00	2.08
Pusulanjärvi					2	0.19	0.01	0.36	2	0.19	0.01	0.36	2	5.77	5.33	6.21	9	0.38	0.02	1.17	24	1.72	0.02	6.21	6	5.32	3.89	9.31	12	0.06	0.01	0.22	40	1.69	0.01	9.31
Pyhäjärvi, Säkylä	1	0.33	0.33	0.33	4	0.01	0.00	0.02	23	0.20	0.00	0.75	5	0.50	0.40	0.62	17	0.01	0.00	0.09	45	0.13	0.00	0.62	3	0.41	0.20	0.53	15	0.02	0.00	0.17	39	0.12	0.00	0.58
Pyhäjärvi, Tammela	1	1.29	1.29	1.29	3	0.04	0.03	0.05	7	0.27	0.03	1.29													3	3.10	2.17	3.98	3	0.02	0.01	0.05	10	1.06	0.01	3.98
Pyhäjärvi, Artjärvi	1	5.31	5.31	5.31	3	3.25	1.75	4.34	4	3.77	1.75	5.31	3	3.93	3.72	4.08	4	2.56	1.12	3.41	12	3.24	1.12	4.08	3	6.44	3.90	9.32	3	3.50	2.10	4.42	7	4.80	2.10	9.32
Sotkamojärvi					4	0.02	0.01	0.03	9	0.04	0.01	0.13	1	0.97	0.97	0.97	3	0.02	0.01	0.05	5	0.21	0.01	0.97	3	1.08	0.84	1.37	4	0.01	0.01	0.01	14	0.26	0.01	1.37
Sääskjärvi					3	0.37	0.01	1.02	6	0.63	0.01	2.52	3	3.73	3.19	4.38	7	0.20	0.06	0.44	16	1.14	0.01	4.38	3	5.76	4.87	6.64	5	0.39	0.26	0.62	13	2.10	0.05	6.64
Tiiläänjärvi													3	4.81	2.48	6.86	2	0.48	0.20	0.75	9	1.92	0.04	6.86	3	5.99	4.56	8.19	2	0.68	0.20	1.15	12	2.35	0.01	8.19
Ullavanjärvi	6	0.44	0.18	0.70	5	0.01	0.01	0.01	17	0.19	0.01	0.70	6	0.69	0.40	1.04	3	0.01	0.01	0.03	12	0.36	0.01	1.04	8	0.78	0.33	1.28	5	0.02	0.01	0.06	21	0.33	0.01	1.28
Villikkalanjärvi													2	5.79	2.92	8.66	2	1.87	0.05	3.68	4	3.83	0.05	8.66	3	9.08	6.06	12.0	3	2.02	0.04	3.18	6	5.55	0.04	12.0
Ylisjärvi	3	2.85	1.82	4.12	1	1.46	1.46	1.46	5	2.97	1.46	4.87	3	3.69	2.83	4.43	2	1.32	1.20	1.44	5	2.74	1.20	4.43	2	2.74	2.35	3.14	4	1.19	0.01	3.94	9	1.15	0.01	3.94

Table 21. Total nitrogen concentrations (mg l-1) in the 20 agricultural lakes listed in Table 18. Basic statistics calculated for winters, summers and whole years for periods 1992–1994, 1996–1998 and 2000–2002.

Lake name	1992–1994												1996–1998												2000–2002											
	Winter				Summer				Whole year				Winter				Summer				Whole year				Winter				Summer				Whole year			
	n	mean	min	max	n	mean	min	max	n	mean	min	max	n	mean	min	max	n	mean	min	max	n	mean	min	max	n	mean	min	max	n	mean	min	max	n	mean	min	max
Ahmasjärvi	5	0.93	0.69	1.10	0				6	0.97	0.69	1.20	6	1.37	1.00	1.60	1	1.35	1.35	1.35	15	1.14	0.59	1.60	6	1.12	0.81	1.50	4	1.55	1.20	1.90	17	1.25	0.81	1.90
Ahveninen					3	0.83	0.77	0.92	5	0.70	0.44	0.92	2	0.71	0.65	0.77	2	0.76	0.73	0.78	8	0.66	0.53	0.78	5	0.86	0.70	1.00	3	0.84	0.71	1.10	22	0.76	0.57	1.10
Enäjärvi	3	1.15	0.99	1.25	1	2.10	2.10	2.10	4	1.39	0.99	2.10	4	1.51	0.75	2.10	10	0.99	0.71	1.65	33	0.96	0.56	2.10	6	1.51	1.05	1.80	13	0.97	0.77	1.40	39	1.08	0.70	1.80
Juoksjärvi	1	0.98	0.98	0.98	4	0.61	0.55	0.66	6	0.68	0.55	0.98	4	0.97	0.75	1.10	7	0.78	0.62	0.96	15	0.83	0.62	1.10	5	1.16	1.00	1.30	3	0.73	0.58	0.82	21	0.93	0.58	1.30
Karhijärvi	2	1.00	1.00	1.00	2	1.09	1.04	1.15	4	1.05	1.00	1.15	1	1.20	1.20	1.20	1	0.73	0.73	0.73	2	0.97	0.73	1.20	2	1.25	1.20	1.30	3	0.72	0.69	0.78	7	0.86	0.63	1.30
Kirkkojärvi	6	1.33	1.00	1.70	2	2.12	1.43	2.80	12	1.73	1.00	4.00	6	1.78	1.30	2.20	6	2.85	1.90	3.90	31	1.72	0.91	3.90	4	1.89	1.50	2.25	12	2.12	0.73	3.90	33	1.65	0.54	3.90
Kirmanjärvi	3	0.81	0.75	0.86	3	0.85	0.72	0.96	12	0.74	0.58	0.96	3	0.70	0.52	0.82	4	0.68	0.66	0.71	12	0.68	0.52	0.82	6	0.77	0.71	0.85	4	0.63	0.56	0.73	15	0.71	0.56	0.85
Köyliönjärvi	5	1.38	1.10	1.70	5	1.53	1.10	1.75	15	1.27	0.76	1.75	4	1.35	0.96	2.10	3	1.25	1.20	1.30	9	1.23	0.90	2.10	3	1.02	0.35	1.60	5	1.19	1.10	1.30	9	1.11	0.35	1.60
Lappajärvi	3	0.64	0.51	0.77	6	0.58	0.51	0.62	15	0.61	0.51	0.78	3	0.49	0.45	0.53	7	0.54	0.44	0.62	18	0.54	0.44	0.67	3	0.64	0.58	0.71	8	0.61	0.55	0.69	25	0.71	0.49	1.20
Lehijärvi	6	0.71	0.61	0.85	3	0.63	0.50	0.77	15	0.63	0.45	0.85	5	0.59	0.54	0.63	6	0.56	0.46	0.77	26	0.55	0.42	0.77	4	0.68	0.55	0.82	9	0.54	0.43	0.64	25	0.61	0.43	0.82
Pusulanjärvi	2	1.05	1.00	1.10	2	0.56	0.51	0.61	4	0.81	0.51	1.10	4	1.52	0.91	1.80	9	0.67	0.52	0.90	26	0.98	0.52	1.80	6	1.67	1.20	2.50	12	0.62	0.51	0.78	39	0.93	0.43	2.50
Pyhäjärvi, Säkylä	3	0.47	0.39	0.53	14	0.44	0.36	0.61	41	0.45	0.33	0.63	5	0.47	0.40	0.57	18	0.49	0.36	1.50	52	0.48	0.31	1.50	3	0.49	0.46	0.51	15	0.48	0.43	0.59	39	0.47	0.37	0.59
Pyhäjärvi, Tammela	3	1.04	0.87	1.15	3	0.74	0.67	0.88	9	0.81	0.51	1.15													3	1.33	1.10	1.60	3	0.77	0.74	0.80	10	0.93	0.62	1.60
Pyhäjärvi, Artjärvi	3	1.63	1.50	1.85	3	1.16	0.85	1.40	6	1.40	0.85	1.85	3	1.28	1.20	1.40	3	1.02	0.80	1.15	9	1.17	0.80	1.40	3	1.85	1.25	2.70	3	1.32	1.10	1.50	7	1.59	1.10	2.70
Sotkamojärvi	1	0.72	0.72	0.72	4	0.57	0.48	0.65	10	0.55	0.41	0.72	1	0.58	0.58	0.58	2	0.61	0.53	0.69	4	0.56	0.44	0.69	3	0.64	0.54	0.76	4	0.75	0.62	0.97	14	0.65	0.49	0.97
Sääskjärvi	1	1.40	1.40	1.40	4	1.24	0.87	2.10	9	1.08	0.59	2.10	3	1.47	1.20	1.70	7	1.01	0.74	1.20	16	1.08	0.72	1.70	3	1.90	1.70	2.30	5	0.98	0.65	1.40	13	1.35	0.65	2.30
Tiiläänjärvi	1	1.29	1.29	1.29	1	0.75	0.75	0.75	2	1.02	0.75	1.29	3	1.64	0.97	2.20	2	0.85	0.69	1.00	9	1.06	0.64	2.20	3	1.97	1.60	2.60	2	0.94	0.82	1.05	12	1.28	0.67	2.60
Ullavanjärvi	8	1.01	0.63	1.36	5	0.81	0.66	0.90	19	0.86	0.50	1.36	7	1.13	0.85	1.50	4	0.85	0.71	1.10	16	0.99	0.71	1.50	8	1.18	0.98	1.44	5	0.99	0.91	1.10	22	1.01	0.71	1.44
Villikkalanjärvi													2	2.10	1.10	3.10	2	1.18	0.75	1.60	4	1.64	0.75	3.10	3	2.60	1.90	3.30	3	1.42	1.10	1.70	6	2.01	1.10	3.30
Ylisjärvi	6	1.14	0.96	1.50	4	1.48	1.10	1.80	12	1.27	0.58	1.90	5	1.43	1.20	1.70	5	1.31	0.76	2.00	10	1.37	0.76	2.00	5	1.00	0.50	1.30	6	1.72	1.30	2.30	15	1.20	0.50	2.30

Table 22. Total phosphorus concentrations ($\mu g\ l^{-1}$) in 20 agricultural lakes listed in Table 18. Basic statistics calculated for winters, summers and whole years for periods 1992–1994, 1996–1998 and 2000–2002.

Lake name	1992–1994												1996–1998												2000–2002											
	Winter				Summer				Whole year				Winter				Summer				Whole year				Winter				Summer				Whole year			
	n	mean	min	max	n	mean	min	max	n	mean	min	max	n	mean	min	max	n	mean	min	max	n	mean	min	max	n	mean	min	max	n	mean	min	max	n	mean	min	max
Ahmasjärvi	5	25.0	17	37	0				6	36.5	17	94	6	34.2	20	65	1	120	120	120	15	54.6	20	120	6	31.3	24	39	4	117	97	130	17	70.3	24	130
Ahveninen	0				3	35.3	29	41	5	32.8	28	41	2	16.0	15	17	2	27.0	25	29	8	20.4	13	29	5	18.4	14	25	3	32.7	30	37	22	28.2	14	41
Enäjärvi	3	48.0	43	58	1	210	210	210	4	88.5	43	210	4	45.8	31	59	10	111	80	165	33	79.7	31	165	6	41.0	25	59	13	95.9	64	170	39	75.9	25	170
Juoksjärvi	1	53.0	53	53	4	34.3	32	36	6	36.0	26	53	4	31.3	26	42	7	36.0	28	44	15	33.0	21	44	5	30.0	25	34	3	37.3	29	44	21	34.0	25	48
Karhijärvi	2	32.5	28	37	2	70.8	60.5	81	4	51.6	28	81	1	38.0	38	38	1	61.0	61	61	2	49.5	38	61	2	36.0	32	40	3	52.2	48	55	7	48.4	32	59
Kirkkojärvi	6	80.9	9	160	2	213	190	237	12	113	9	237	6	83.5	54	140	6	303	140	530	31	138	54	530	4	99.0	2.5	150	12	291	53	485	33	180	2.5	485
Kirmanjärvi	3	27.7	24	31	3	58.3	40	68	12	45.1	24	68	6	20.0	11	38	4	36.8	30	47	15	27.5	11	47	6	19.8	19	22	4	34.3	29	43	15	29.1	19	43
Köyliönjärvi	5	33.6	19	51	5	142	105	190	15	81.5	19	190	4	38.8	17	64	3	90.3	86	99	9	62.0	17	99	3	51.7	32	73	5	116	100	139	9	92.7	32	139
Lappajärvi	3	20.7	16	28	6	27.5	25	32	17	28.1	16	43	3	13.0	12	15	7	21.8	17	25.5	18	21.0	12	39	4	20.5	16	25	8	24.5	20	28	26	24.0	12	33
Lehijärvi	6	29.3	22	41	3	49.0	44	54	15	33.5	19	58	6	24.3	17	31	9	37.6	22	50	30	33.8	17	57	4	29.3	23	37	9	35.4	22	60	25	34.8	22	60
Pusulanjärvi	2	25.0	24	26	2	48.5	37	60	4	36.8	24	60	4	35.5	22	61	9	42.7	35	59	25	42.6	22	64	6	37.7	33	44	12	54.3	37	65	39	45.9	20	69
Pyhäjärvi, Säkylä	3	10.7	9	12	14	19.9	14	25	40	18.1	9	27	5	11.9	10	15	18	19.3	11	29	52	19.0	10	32	3	13.7	10	21	15	22.5	15	28	38	20.9	10	39
Pyhäjärvi, Tammela	3	22.7	18	27	3	45.7	42	53	9	37.8	18	53													3	29.3	27	31	3	57.0	54	60	10	44.9	27	60
Pyhäjärvi, Artjärvi	3	55.7	50	67	3	30.8	25	35	6	43.3	25	67	3	54.3	53	57	4	37.0	34	42	13	45.0	29	71	3	68.0	57	80	3	36.0	32	42	7	50.9	32	80
Sotkamojärvi	1	24.0	24	24	4	30.3	23	34	10	28.6	23	34	1	21.0	21	21	3	34.0	30	41	5	27.4	14	41	3	19.3	13	23	4	38.8	32	45	14	33.1	13	45
Sääskjärvi	1	79.0	79	79	4	95.3	72	150	9	80.9	64	150	3	89.0	76	110	7	114	71	150	16	105	71	150	3	102	66	130	5	98.8	52	250	12	97.4	52	250
Tiiläänjärvi	1	57.0	57	57	1	48.0	48	48	2	52.5	48	57	3	70.0	36	98	2	51.0	48	54	9	56.3	36	98	3	76.0	58	93	2	57.0	57	57	12	62.3	41	93
Ullavanjärvi	17	47.8	28	68	5	49.6	44	63	30	45.5	28	68	19	39.0	26	53.5	4	49.3	39	73	28	46.9	26	200	16	46.0	35.5	59	5	53.2	45	59	30	47.4	28	67
Villikkalanjärvi													2	108	81	135	2	125	125	125	4	117	81	135	3	108	100	119	3	104	64	133	6	106	64	133
Ylisjärvi	6	102	47	160	4	200	135	255	12	138	47	255	5	92.9	67	116	5	185	115	270	10	139	67	270	5	91.2	42	119	6	223	180	310	15	147	42	310

Table 23. Chlorophyll *a* concentrations (µg l^{-1}) in the 20 agricultural lakes listed in Table 18. Basic statistics calculated for winters, summers and whole years for periods 1992–1994, 1996–1998 and 2000–2002.

Lake name	1992–1994												1996–1998												2000–2002											
	Winter				Summer				Whole year				Winter				Summer				Whole year				Winter				Summer				Whole year			
	n	mean	min	max	n	mean	min	max	n	mean	min	max	n	mean	min	max	n	mean	min	max	n	mean	min	max	n	mean	min	max	n	mean	min	max	n	mean	min	max
Ahmasjärvi									1	91.0	91	91					1	90.0	90	90	4	64.0	22	90					4	106	91	140	10	73.8	9	140
Ahveninen					3	33.3	23	43	5	23.9	7.4	43					2	26.0	23	29	3	19.9	7.8	29					3	31.3	20	49	10	23.1	7	49
Enäjärvi					1	120	120	120	1	120	120	120					11	61.0	19	180	27	49.0	16	180					13	46	32	86	32	42.8	10	86
Juoksjärvi					4	19.5	17	22	4	19.5	17	22					7	33.0	2	80	8	30.8	2	80					3	82.7	29	140	10	39.7	13	140
Karhijärvi					2	61.0	60	62	2	61.0	60	62					1	23.0	23	23	1	23.0	23	23					3	21.3	17	25	3	21.3	17	25
Kirkkojärvi					2	63.0	33	93	4	81.5	33	120					9	152	42	370	28	80.4	8.7	370					13	135	22	380	29	91.8	3	380
Kirmanjärvi					3	31.0	24	40	9	24.1	14	40					4	18.3	11	22	9	16.0	11	22					5	21.8	15	28	11	20.8	12	28
Köyliönjärvi					5	99.2	55	170	7	83.4	31	170					3	76.0	56	92	4	67.0	40	92					5	66.2	54	81	6	60.8	34	81
Lappajärvi					5	15.2	12	19	12	12.0	2	19					7	9.8	5.9	17	15	9.1	4.8	19					8	11.7	6.3	17	23	11.7	5	31
Lehijärvi					3	30.9	12	50	9	14.0	1.3	50					10	21.7	13	39	24	14.0	3	39					9	15.0	9.7	24	20	14.4	6	24
Pusulanjärvi																	8	26.3	18	34	19	22.6	1.7	37					12	30.6	22	59	34	22.0	1	59
Pyhäjärvi, Säkylä					11	9.9	5.8	17	23	8.2	2.6	22					5	4.7	2.5	7.5	14	4.8	2.5	8.8					7	12.7	7.5	16	14	10.3	3	17
Pyhäjärvi, Tammela					3	26.3	19	31	3	26.3	19	31																	3	26.3	22	31	4	27.5	22	31
Pyhäjärvi, Artjärvi					3	8.3	7.5	9	3	8.3	7.5	9					4	10.6	3.4	18	8	11.6	3.4	18					3	12.0	4	17	4	12.5	4	17
Sotkamojärvi					4	21.3	15	27	9	17.4	9.6	27					3	15.3	12	19	4	14.3	11	19					4	38.0	31	52	11	25.2	8	52
Sääskjärvi					3	81.0	17	190	6	52.5	17	190					1	47.0	47	47	1	47.0	47	47					5	41.8	12	88	10	54.2	12	220
Tiiläänjärvi																	2	29.0	21	37	4	26.0	21	37					2	31.0	29	33	9	37.6	13	99
Ullavanjärvi					5	35.8	19	57	9	25.6	7.8	57					4	50.8	10	160	6	39.7	10	160					5	37.7	29	51	10	34.0	18	51
Villikkalanjärvi																	2	47.5	46	49	2	47.5	46	49					2	38.5	31	46	2	38.5	31	46
Ylisjärvi	1	9.5	9.5	9.5	4	42.3	17	71	6	33.3	9.5	71					5	64.8	16	209	5	64.8	16	209					6	97.7	28	184	7	85.9	15	184

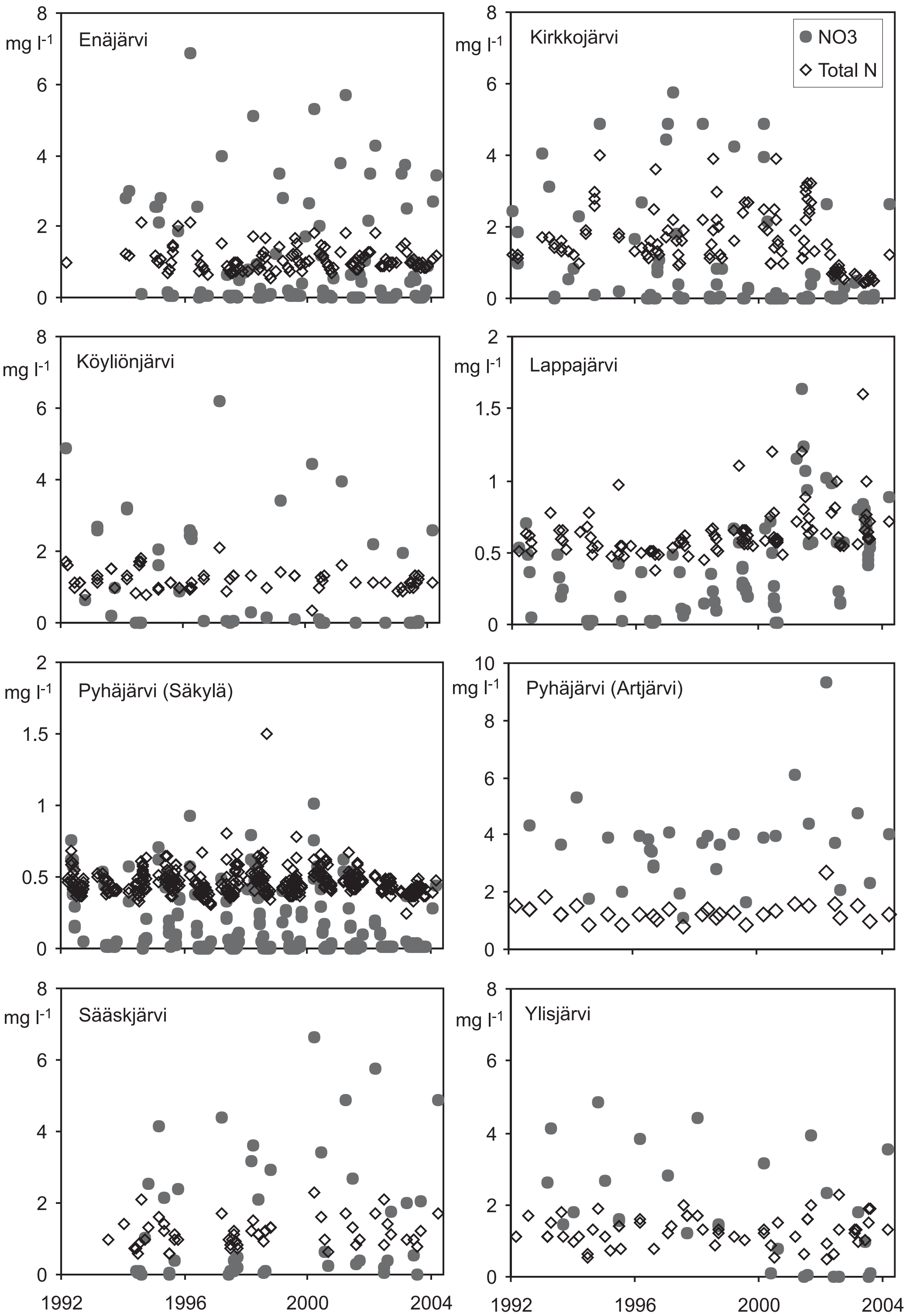

Figure 7. Nitrate (mg l^{-1} NO_3) and total nitrogen (mg l^{-1} N) concentrations in surface water of 8 selected agricultural lakes in 1992–2004.

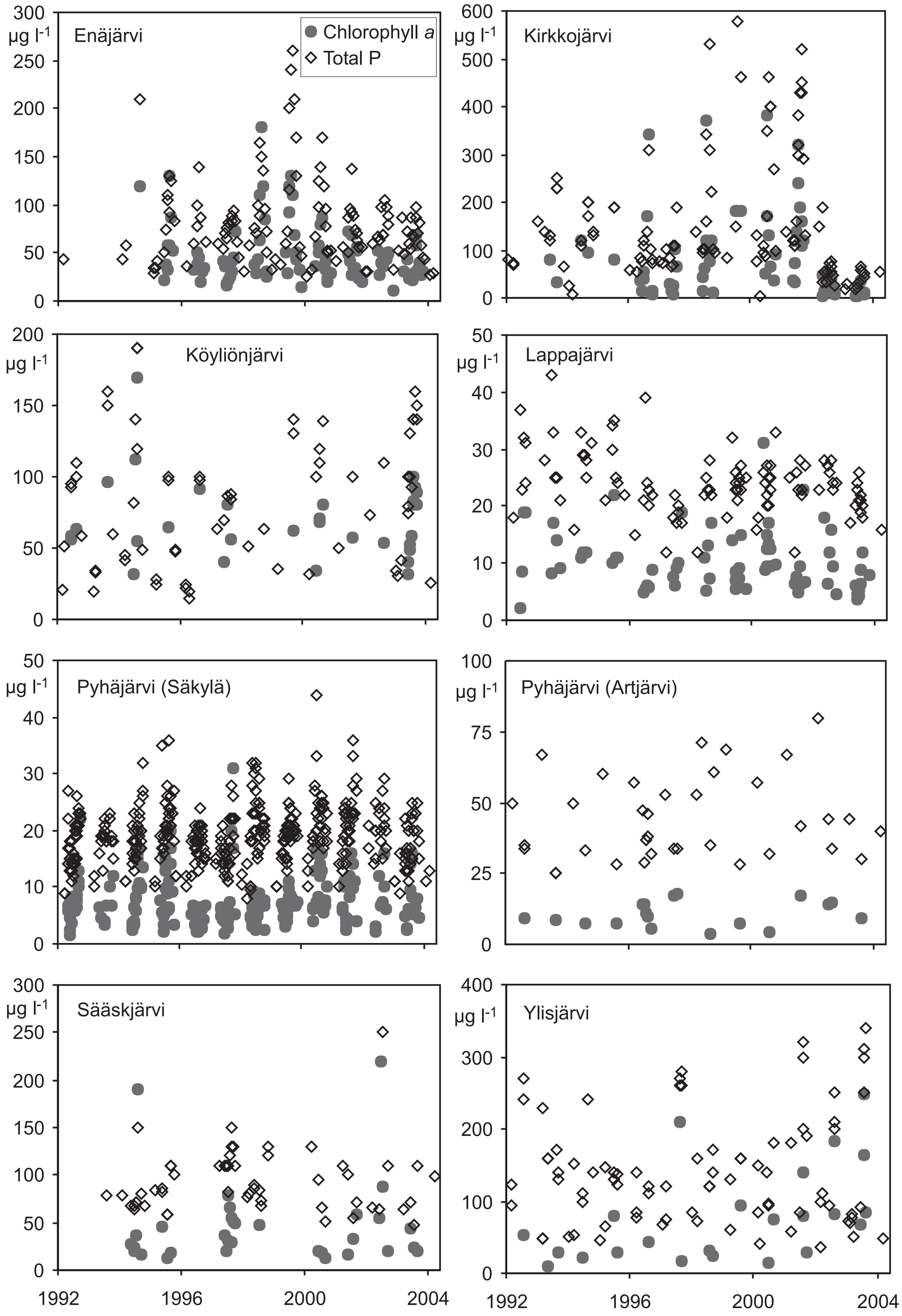

Figure 8. Chlorophyll a *(µg l*$^{-1}$*) and total phosphorus (µg l*$^{-1}$*) concentrations in surface water of 8 selected agricultural lakes in 1992–2004.*

2.4.2 Rivers affected by agriculture

Rivers with a high proportion of fields in the drainage basin (>9.4 %) were defined as affected by agriculture and selected for closer examination. In total, there were 23 such rivers (Table 24). These rivers have been monitored since the end of the 1970s with the objective of calculating material inputs into the Baltic Sea. Sampling frequency has therefore been high, typically 12 to 20 times a year.

It is difficult to find rivers affected solely by agriculture with no other sources of loading. The rivers listed in Table 24 are the best examples of typical Finnish agricultural rivers, although their water quality is not affected only by agriculture (Table 18). In addition, many of them are affected by other nutrient sources such as municipal wastewaters and diffuse loading from forestry and sparsely populated settlements outside sewage systems.

Statistical parameters for NO_3 concentrations were calculated for these 23 rivers for the periods 1992–1994, 1996–1998 and 2000–2002 and separately for summers and winters (summer: July 15 – September and winter: January – April). All available observations from all depths were used. During the period 1992–1994, maximum NO_3 concentration exceeded 25 mg l^{-1} once, in 1996–1998 four times and in 2000–2002 three times (Table 25). During the three periods, six maximum NO_3 values were between 20 mg l^{-1} and 25 mg l^{-1}. Concentrations in winter were typically higher than in summer. The maximum NO_3 values for the three periods are presented in Fig. 9. In one river (Porvoonjoki), the maximum NO_3 concentration exceeded 25 mg l^{-1} during all three periods.

Table 24. Main characteristics of the 23 agricultural rivers studied (Pitkänen 2004). The five highlighted river sites were examined more closely than the others. The river basin numbers are given in Fig. 2.

River name	River site	River basin No.	Area km^2	Lakes %	Fields %	Mean discharge 1970–1990 m^3s^{-1}	Discharges to
Aurajoki	Aura 54 ohikulku va6401	28	874	0.3	36.7	8.5	Archipelago Sea
Eurajoki	Eura 42 Pori-Rma va6900	34	1334	12.8	29.1	10.5	Bothnian Sea
Kalajoki	Kalajoki 11000	53	4247	1.9	14.9	41.4	Bothnian Bay
Kiskonjoki	Kisko 14 Vanhak va6111	24	1050	5.2	24.5	9.8	Archipelago Sea
Kokemäenjoki	Kojo 35 Pori-Tre	35	27046	10	27	270	Bothnian Sea
Koskenkylänjoki	Koskenkylänjoki 3.0 6030	16	895	4.4	24.9	8.4	Gulf of Finland
Kymijoki	Kymij Huruksela 033 5600	14	37159	17.3	24.6	334.4	Gulf of Finland
Lapuanjoki	Lapuanjoki 9900	44	4122	2.7	20.8	36.5	Bothnian Bay
Lestijoki	Lestijoki 10800 8-tien s	51	1373	5.9	12.1	12.6	Bothnian Bay
Karvianjoki	Merikarvianjoki Vaadinni	36	3438	4	10.2	34.7	Bothnian Sea
Mäntsälänjoki	Mustijoki 4.2 6010	19	783	1.5	26.8	7.5	Gulf of Finland
Karjaanjoki	Mustionjoki 4.9 15500	23	2046	12.2	29.9	18.7	Gulf of Finland
Isojoki	Myllykanava vp 9100	37	1098	0.2	11.5	15.7	Bothnian Sea
Paimionjoki	Pajo 44 Isosilta va6301	27	1088	1.5	43	9.4	Archipelago Sea
Perhonjoki	Perhonjoki 10600	49	2524	3	9.5	22.5	Bothnian Bay
Porvoonjoki	Porvoonjoki 11.5 6022	18	1273	1.3	28.5	13.8	Gulf of Finland
Pyhäjoki	Pyhäjoki Hourunk 11400	54	3712	5	9.4	32.2	Bothnian Bay
Kyrönjoki	Skatila vp 9600	42	4923	1.2	23.4	45.1	Bothnian Bay
Uskelanjoki	Uske 16 Salon yp va6101	25	566	0.6	43.7	5.5	Archipelago Sea
Laihianjoki	Vaasa-Pori mts vp. 9300	41	506	0.3	25.8	4.3	Bothnian Sea
Vantaanjoki	Vantaa 4.2 6040	21	1686	2.3	23.4	16.9	Gulf of Finland
Virojoki	Virojoki 006 3020	11	357	3.8	13.5	4.4	Gulf of Finland
Ähtävänjoki	Ähtävänjoki 10300	47	2054	9.9	13.3	16	Bothnian Bay

Table 25. Nitrate concentrations (mg l^{-1} NO_3) in the 23 studied agricultural rivers. Basic statistics calculated for winters, summers and whole years for periods 1992–1994, 1996–1998 and 2000–2002. Maximum values >20 mg l^{-1} are in bold and values >25 mg l^{-1} are in bold with box.

River	1992–1994												1996–1998												2000–2002											
	Winter				Summer				Whole year				Winter				Summer				Whole year				Winter				Summer				Whole year			
	n	mean	min	max	n	mean	min	max	n	mean	min	max	n	mean	min	max	n	mean	min	max	n	mean	min	max	n	mean	min	max	n	mean	min	max	n	mean	min	max
Aurajoki	36	5.2	1.4	9.7	8	3.9	0.0	8.8	83	6.5	0.0	**24.8**	34	7.3	4.4	12.4	13	4.7	2.5	14.6	92	7.7	2.2	**32.7**	54	5.7	1.8	15.0	10	4.7	0.7	10.6	110	5.4	0.1	15.0
Eurajoki	12	3.5	0.8	11.5	4	4.0	3.1	5.7	27	4.1	0.8	15.0	25	4.8	1.7	15.5	8	3.3	1.8	7.5	57	5.1	1.3	16.4	21	5.4	1.6	14.1	5	5.6	2.2	11.1	54	4.6	1.6	15.0
Kalajoki									1	1.9	1.9	1.9	5	2.6	1.4	4.8	3	0.9	0.1	1.4	22	2.4	0.1	4.8	19	4.8	2.3	8.4	4	1.4	0.1	2.5	45	3.9	0.1	8.4
Kiskonjoki	6	1.5	1.3	1.6	1	0.1	0.1	0.1	12	1.2	0.0	2.8	18	2.9	1.6	5.3	4	0.3	0.1	0.8	41	2.3	0.1	5.3	30	2.7	1.1	6.6	6	0.6	0.0	1.8	64	1.9	0.0	6.6
Kokemäenjoki	19	2.7	1.6	4.9	9	0.9	0.4	1.3	47	2.3	0.4	6.6	17	3.5	1.6	9.3	9	0.9	0.5	1.7	49	2.6	0.5	9.3	25	3.8	2.3	7.5	8	1.2	0.7	1.7	54	2.9	0.2	10.6
Koskenkylänjoki	5	5.4	4.1	7.9	4	0.6	0.1	2.0	18	3.1	0.1	7.9	28	6.4	3.6	**22.5**	7	1.7	0.0	5.7	66	5.1	0.0	**22.5**	35	7.0	4.4	**25.2**	11	1.8	0.4	3.0	79	5.4	0.1	**25.2**
Kymijoki	20	1.2	1.1	1.6	15	0.5	0.4	0.7	65	0.9	0.4	1.9	32	1.2	0.9	4.0	12	0.5	0.3	0.7	81	1.0	0.3	4.0	27	1.3	1.0	1.9	12	0.5	0.5	0.6	78	0.9	0.4	1.9
Lapuanjoki	17	2.7	1.3	5.8	13	2.1	1.1	3.9	62	2.4	0.5	6.7	10	3.8	2.3	7.5	4	2.5	1.7	3.3	36	4.0	1.7	7.5	17	6.0	2.7	12.4	5	1.5	0.5	3.3	48	4.5	0.5	12.4
Lestijoki	14	1.4	0.3	3.6	9	1.3	0.0	2.6	42	1.3	0.0	3.6	9	2.1	1.3	3.4	6	1.3	0.4	1.9	44	1.7	0.4	5.7	19	2.4	0.9	7.1	6	0.5	0.0	1.1	51	1.6	0.0	7.1
Karvianjoki	4	1.3	1.0	2.0	2	0.1	0.0	0.2	12	0.8	0.0	2.0	13	2.2	1.6	3.4	4	0.2	0.0	0.4	35	1.3	0.0	3.4	13	2.3	1.4	3.9	4	0.2	0.0	0.3	37	1.4	0.0	3.9
Mäntsälänjoki	5	4.9	3.4	5.8	1	0.1	0.1	0.1	11	4.3	0.1	7.5	25	9.7	4.1	**21.2**	5	2.4	0.1	4.9	56	8.7	0.1	**21.2**	32	10.4	4.9	**29.2**	8	2.0	0.5	3.3	70	8.3	0.5	**29.2**
Karjaanjoki	12	2.8	2.4	3.5	7	0.7	0.1	1.8	38	1.9	0.1	3.5	22	2.5	1.6	7.1	7	0.7	0.1	1.4	56	1.8	0.1	7.1	31	2.9	1.8	3.8	6	0.9	0.1	1.8	66	2.2	0.1	3.8
Isojoki	11	1.4	0.2	3.4	2	0.6	0.0	1.2	29	1.6	0.0	3.4	11	2.2	1.0	6.2	4	0.9	0.0	1.9	33	1.9	0.0	6.2	20	2.0	1.1	3.8	3	0.9	0.8	1.1	40	1.8	0.5	3.8
Paimionjoki	22	5.6	2.3	10.2	4	1.1	0.0	4.1	46	7.0	0.0	**20.8**	17	8.9	4.9	**20.3**	3	5.2	4.4	5.7	37	9.8	4.1	**28.7**	29	7.2	2.3	15.9	6	5.4	0.9	18.6	61	6.2	0.1	18.6
Perhonjoki																									18	2.6	1.6	4.9	6	1.3	1.0	1.6	48	2.0	0.9	4.9
Porvoonjoki	21	11.4	4.3	**27.5**	3	11.8	8.0	15.5	38	11.2	4.1	**27.5**	24	15.1	7.5	**40.3**	5	6.7	5.8	8.6	56	13.4	5.8	**40.3**	32	14.2	7.2	**37.6**	8	11.5	8.0	16.0	70	14.0	6.4	**37.6**
Pyhäjoki	13	1.7	0.8	2.2	3	0.7	0.9	1.1	39	1.2	0.1	2.2	16	1.8	0.8	3.0	6	0.6	0.0	1.1	51	1.5	0.0	3.0	19	2.7	1.5	6.2	7	0.4	0.0	0.8	52	1.7	0.0	6.2
Kyrönjoki	24	4.1	2.3	8.0	4	1.9	0.5	2.7	59	4.0	0.5	8.8	11	5.1	3.2	14.1	5	3.7	1.9	5.7	40	5.2	1.9	14.1	15	6.7	4.1	13.7	5	2.0	0.2	2.9	44	5.8	1.3	14.1
Uskelanjoki	5	4.0	2.1	5.3					10	5.2	1.9	15.0	17	8.2	4.9	15.0	3	3.5	2.1	4.4	36	9.5	2.1	**53.0**	29	6.2	3.3	12.4	6	5.3	0.0	9.7	63	5.4	0.4	12.4
Laihianjoki	6	8.9	2.1	18.2	1	5.5	5.5	5.5	13	6.8	1.7	18.2	6	8.2	3.9	17.2					12	6.0	2.2	17.2	3	7.5	6.6	8.8	3	3.5	3.1	4.4	12	7.4	2.6	**20.8**
Vantaanjoki	21	7.3	3.1	11.5	3	5.9	5.3	6.7	38	6.9	3.1	11.5	24	8.8	4.6	18.6	5	4.1	2.8	5.1	55	8.4	2.2	19.0	32	8.7	5.2	**23.9**	8	5.0	3.0	7.3	73	7.8	3.1	**23.9**
Virojoki													7	6.5	1.7	15.9	6	0.4	0.1	0.8	27	2.6	0.1	15.9	14	3.8	1.3	9.3	6	0.3	0.2	0.8	45	2.0	0.1	9.3
Ähtävänjoki					1	0.1	0.1	0.1	1	0.1	0.1	0.1	5	0.9	0.5	1.3	5	0.3	0.0	0.4	24	0.6	0.0	2.4	16	2.1	1.0	3.8	4	0.3	0.0	0.5	44	1.4	0.0	3.8

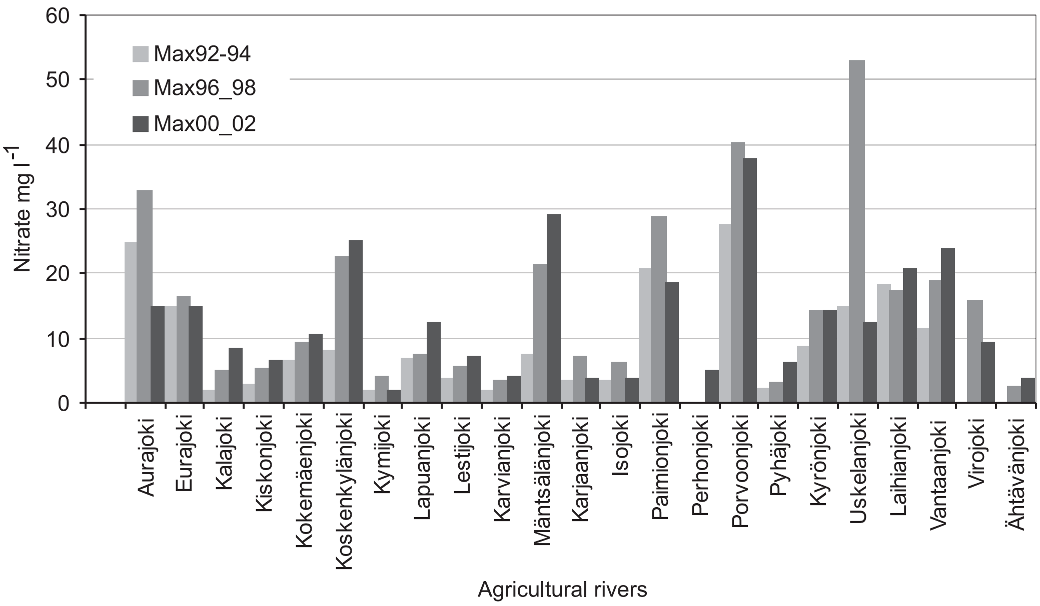

Figure 9. Maximum nitrate concentrations(NO_3, mg l^{-1}) based on annual data of the 23 agricultural rivers studied for the periods 1992–1992, 1996–1998 and 2000–2002.

Five river sites with elevated NO_3 concentrations (highlighted in Table 24) were examined more thoroughly. The frequency distribution of all nitrate observations for the period 1992–2002 was presented graphically (Fig.10). The majority of nitrate concentrations were relatively low. Only 26 out of a total of 1,060 observations (0.02%) exceeded 25 mg l^{-1}.

A rough estimation of possible trends in agricultural rivers was carried out by comparing the mean NO_3 values for the period 2000–2002 with those of 1996–1998 using the data presented in Table 25. The differences between the mean NO_3 concentrations in 2000–2002 and 1996–1998 were calculated. The Perhonjoki river site 10600 was omitted, because of missing data for the period 1996–1998. Differences in the means of the two periods were typically very small (Table 26). Of the means for the period 2000–2002, half (11) were lower or decreasing and half (11) higher or increasing compared with the means for the previous period 1996–1998. Differences were small so and the trends are hardly significant. In three cases, the decrease of mean NO_3 concentration between the periods was remarkably high, namely 4.1 mg l^{-1} in the River Uskelanjoki, 3.6 mg l^{-1} in the River Paimionjoki and 2.3 mg l^{-1} in the River Aurajoki. In the River Kalajoki, the upward trend (1.5 mg l^{-1}) was clearly higher than other upward trends.

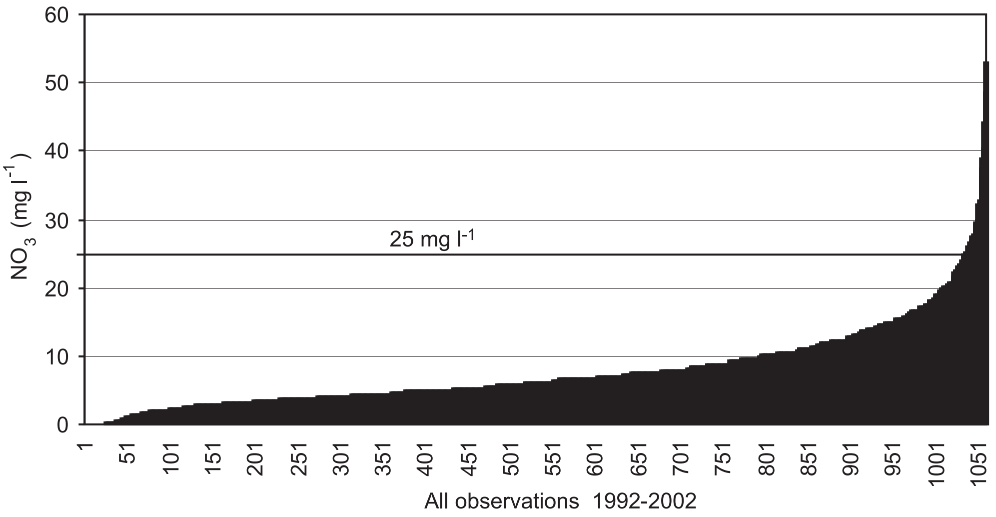

Figure 10. All nitrate observations from the five agricultural river sites highlighted in Table 24 for the period 1992–2002 (mean: 7.8 mg l^{-1}, min.: 0.027 mg l^{-1}, max.: 53 mg l^{-1}).

Table 26. Comparison of nitrate concentration means (NO_3, mg l^{-1}) for the periods 2000–2002 and 1996–1998.

River	1996-1998 mean1	2000-2002 mean2	mean2-mean1	trend
Aurajoki	7.7	5.4	-2.3	downward
Eurajoki	5.1	4.6	-0.5	downward
Kalajoki	2.4	3.9	1.5	upward
Kiskonjoki	2.3	1.9	-0.4	downward
Kokemäenjoki	2.6	2.9	0.3	upward
Koskenkylänjoki	5.1	5.4	0.3	upward
Kymijoki	1	0.9	-0.1	downward
Lapuanjoki	4	4.5	0.5	upward
Lestijoki	1.7	1.6	-0.1	downward
Karvianjoki	1.3	1.4	0.1	upward
Mäntsälänjoki	8.7	8.3	-0.4	downward
Karjaanjoki	1.8	2.2	0.4	upward
Isojoki	1.9	1.8	-0.1	downward
Paimionjoki	9.8	6.2	-3.6	downward
Porvoonjoki	13.4	14	0.6	upward
Pyhäjoki	1.5	1.7	0.2	upward
Kyrönjoki	5.2	5.8	0.6	upward
Uskelanjoki	9.5	5.4	-4.1	downward
Laihianjoki	6	7.4	1.4	upward
Vantaanjoki	8.4	7.8	-0.6	downward
Virojoki	2.6	2	-0.6	downward
Ähtävänjoki	0.6	1.4	0.8	upward

In addition, possible NO_3 trends were sought by examining the time series data from five selected rivers with elevated NO_3 maxima highlighted in Table 24. All NO_3 observations from these rivers for the period 1992–2002 were presented graphically and linear trends were calculated (Fig. 11). The concentrations varied widely and trends were very weak. A slight increasing trend was observed in three rivers (Porvoonjoki, Mustijoki and Koskenkylänjoki), and a slight decreasing trend in two rivers (Uskelanjoki and Aurajoki). At the beginning of the period studied, the frequency of the observations was lower than later on, which certainly affects the trends. Hydrological variations, e.g. changes in precipitation and runoff, strongly affect the concentrations of nutrients flushed into water bodies. Therefore, the trends observed should be judged with caution. It should be noted that the data presented in Fig. 11 include all the years 1992–2002 whereas Table 25 includes only the three periods. Consequently, their data is not totally comparable as Fig. 11 shows values not present in Table 25.

Nutrient trends in Finnish rivers have been studied in more detail by Räike et al. (2003). Their data consisted of a total of 68,000 monitoring results from 22 rivers and 173 lakes from the period 1975–2000. Thirteen of the rivers were the same as those presented in Table 24. Non-parametric Kendall Tau b and Seasonal Kendall tests were applied for detecting trends. In six rivers, an upward trend was detected for NO_3. Three of these, namely the Kokemäenjoki, Kyrönjoki and Pyhäjoki, are investigated in the present report.

Total P and total N concentrations were calculated for the period 1992–2002 for the same 23 agricultural rivers as for NO_3 (Table 25). Statistical parameters for total phosphorus are shown in Table 27. According to the Finnish water quality classification, the phosphorus concentration in the 'passable' national water quality class is 0.050–0.100 mg l^{-1} (Heinonen and Herve 1987; Vuoristo 1998). According to the water quality classification carried out on the basis of data from 2000–2003 (SYKE 2005) nearly all these rivers fell into the 'passable' class (Fig. 6).

Statistical parameters for total N for the same 23 rivers are shown in Table 28. Nitrogen concentrations of the agricultural rivers studied exceed the typical concentrations for all rivers in the country – a predictable and logical result in rivers affected by agriculture.

Nutrient trends were investigated in the five selected rivers highlighted in Table 24 for the period 2000–2002. All the observations on total P and total N from these rivers for this period were presented graphically and linear trends were calculated. Annual variations in total P concentration were high. No trends could be observed (Fig. 12). In total N, there was a slight upward trend in two rivers (Porvoonjoki and Mustionjoki) (Fig. 13). It should be pointed out that the trends observed are very weak and should be judged with caution for the same reasons as trends in NO_3 concentrations.

Räike et al. (2003) found a statistically significant downward trend for total P in 12 rivers for the period 1975–2000, e.g. in the Rivers Koskenkylänjoki, Porvoonjoki, Mustionjoki, Kokemäenjoki and Kyrönjoki and an upward trend in the Rivers Kiskonjoki, Eurajoki and Ähtävänjoki. For total N, Räike et al. (2003) found a downward trend in the River Mustionjoki and an upward trend in the Rivers Porvoonjoki, Eurajoki, Kyrönjoki and Lapuanjoki.

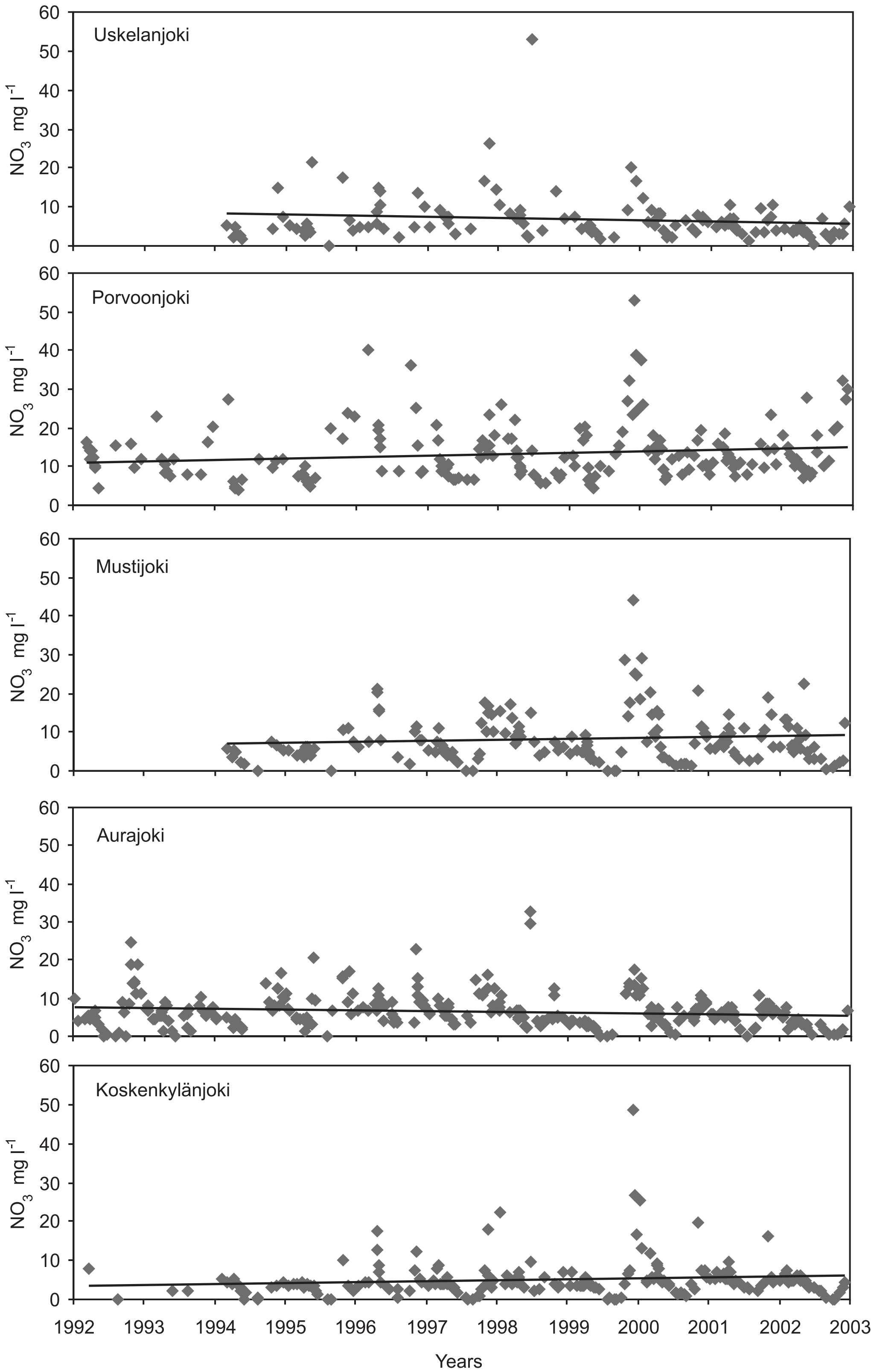

Figure 11. All nitrate observations from the five agricultural river sites highlighted in Table 24 for the period 1992–2002.

Table 27. Total phosphorus concentrations (mg l^{-1}) in the 23 agricultural rivers studied. Basic statistics calculated for winters, summers and whole years for periods 1992–1994, 1996–1998 and 2000–2002.

River	1992–1994												1996–1998												2000–2002											
	Winter				Summer				Whole year				Winter				Summer				Whole year				Winter				Summer				Whole year			
	n	mean	min	max	n	mean	min	max	n	mean	min	max	n	mean	min	max	n	mean	min	max	n	mean	min	max	n	mean	min	max	n	mean	min	max	n	mean	min	max
Aurajoki	42	0.19	0.09	0.42	10	0.18	0.12	0.23	100	0.19	0.09	0.43	38	0.19	0.08	0.41	15	0.21	0.13	0.30	108	0.22	0.07	0.85	60	0.18	0.06	0.39	12	0.18	0.06	0.25	125	0.18	0.06	0.53
Eurajoki	17	0.10	0.03	0.36	6	0.05	0.04	0.06	39	0.07	0.03	0.36	28	0.07	0.03	0.29	8	0.06	0.03	0.18	61	0.07	0.03	0.29	24	0.09	0.03	0.29	5	0.07	0.00	0.11	60	0.08	0.00	0.30
Kalajoki	27	0.15	0.07	0.38	10	0.09	0.06	0.15	61	0.11	0.06	0.38	10	0.17	0.07	0.37	5	0.10	0.05	0.19	42	0.12	0.05	0.37	27	0.11	0.06	0.27	4	0.07	0.06	0.08	53	0.09	0.05	0.27
Kiskonjoki	8	0.06	0.04	0.10	3	0.07	0.05	0.08	22	0.06	0.04	0.10	17	0.06	0.04	0.09	4	0.07	0.05	0.09	39	0.06	0.04	0.11	31	0.06	0.04	0.12	6	0.07	0.05	0.08	65	0.06	0.04	0.12
Kokemäenjoki	25	0.05	0.02	0.15	11	0.05	0.03	0.12	62	0.05	0.02	0.15	23	0.05	0.02	0.21	9	0.04	0.03	0.06	62	0.05	0.02	0.21	25	0.05	0.02	0.13	8	0.03	0.00	0.05	60	0.05	0.00	0.19
Koskenkylänjoki	8	0.13	0.05	0.34	6	0.08	0.06	0.12	28	0.09	0.05	0.34	28	0.11	0.05	0.29	7	0.10	0.05	0.18	67	0.10	0.04	0.29	36	0.08	0.05	0.15	11	0.07	0.04	0.08	80	0.08	0.03	0.32
Kymijoki	22	0.02	0.01	0.06	16	0.02	0.02	0.05	73	0.02	0.01	0.06	33	0.02	0.01	0.05	12	0.02	0.01	0.03	82	0.02	0.01	0.06	32	0.01	0.01	0.02	12	0.02	0.01	0.03	83	0.02	0.01	0.03
Lapuanjoki	17	0.16	0.06	0.43	14	0.10	0.08	0.14	63	0.10	0.04	0.43	10	0.10	0.03	0.22	4	0.07	0.04	0.10	36	0.07	0.02	0.22	17	0.08	0.03	0.19	5	0.08	0.06	0.11	48	0.07	0.03	0.19
Lestijoki	29	0.12	0.04	0.46	13	0.10	0.05	0.29	76	0.09	0.03	0.46	9	0.17	0.05	0.43	6	0.08	0.07	0.12	44	0.10	0.04	0.43	19	0.08	0.04	0.24	6	0.05	0.03	0.07	51	0.06	0.03	0.24
Karvianjoki	4	0.07	0.06	0.08	2	0.04	0.04	0.05	12	0.05	0.03	0.08	13	0.04	0.03	0.06	5	0.04	0.03	0.05	36	0.04	0.03	0.06	12	0.05	0.04	0.09	4	0.05	0.04	0.06	36	0.05	0.04	0.09
Mäntsälänjoki	7	0.19	0.07	0.40	3	0.07	0.05	0.09	19	0.12	0.05	0.40	25	0.13	0.06	0.36	5	0.17	0.08	0.37	57	0.14	0.06	0.42	33	0.09	0.05	0.17	8	0.07	0.05	0.12	71	0.10	0.04	0.44
Karjaanjoki	18	0.03	0.02	0.07	9	0.03	0.02	0.05	53	0.03	0.02	0.07	28	0.03	0.02	0.08	9	0.03	0.02	0.04	72	0.03	0.02	0.13	36	0.03	0.02	0.07	9	0.03	0.02	0.04	80	0.03	0.02	0.07
Isojoki	14	0.09	0.04	0.14	6	0.07	0.05	0.10	39	0.07	0.04	0.34	13	0.09	0.03	0.23	5	0.06	0.05	0.07	38	0.07	0.03	0.23	21	0.07	0.03	0.22	7	0.07	0.05	0.08	50	0.06	0.03	0.22
Paimionjoki	30	0.21	0.13	0.47	8	0.13	0.09	0.22	64	0.20	0.07	0.49	20	0.24	0.13	0.49	5	0.19	0.14	0.30	46	0.27	0.12	0.96	33	0.21	0.11	0.43	8	0.17	0.10	0.29	71	0.20	0.04	0.49
Perhonjoki	16	0.12	0.05	0.24	9	0.09	0.07	0.11	46	0.10	0.04	0.24	11	0.10	0.06	0.24	5	0.07	0.06	0.07	45	0.08	0.05	0.24	18	0.07	0.05	0.14	6	0.07	0.06	0.08	48	0.06	0.04	0.14
Porvoonjoki	21	0.15	0.08	0.28	3	0.09	0.05	0.13	38	0.12	0.05	0.28	24	0.15	0.07	0.34	5	0.14	0.07	0.21	57	0.15	0.05	0.44	33	0.10	0.06	0.18	8	0.10	0.04	0.15	71	0.11	0.04	0.32
Pyhäjoki	13	0.08	0.03	0.20	3	0.04	0.02	0.05	38	0.06	0.02	0.20	16	0.05	0.03	0.17	6	0.03	0.01	0.04	51	0.05	0.01	0.17	19	0.07	0.04	0.01	7	0.04	0.03	0.05	52	0.06	0.02	0.14
Kyrönjoki	53	0.12	0.06	0.32	6	0.13	0.10	0.17	91	0.11	0.06	0.32	14	0.10	0.02	0.23	5	0.07	0.05	0.10	46	0.08	0.02	0.23	16	0.10	0.05	0.30	6	0.09	0.07	0.10	49	0.09	0.04	0.30
Uskelanjoki	14	0.18	0.08	0.47	7	0.17	0.10	0.27	38	0.18	0.08	0.56	20	0.25	0.06	0.58	6	0.19	0.09	0.40	48	0.25	0.06	1.10	33	0.21	0.08	0.66	9	0.23	0.07	0.46	76	0.20	0.04	0.81
Laihianjoki	8	0.10	0.04	0.18	2	0.11	0.09	0.13	18	0.09	0.03	0.21	7	0.05	0.02	0.15					16	0.05	0.02	0.15	5	0.05	0.02	0.11	5	0.16	0.09	0.31	20	0.10	0.02	0.51
Vantaanjoki	21	0.13	0.06	0.29	3	0.07	0.05	0.09	38	0.11	0.05	0.29	24	0.13	0.05	0.32	5	0.10	0.06	0.17	56	0.13	0.04	0.46	33	0.09	0.05	0.22	8	0.09	0.05	0.22	75	0.10	0.02	0.44
Virojoki	2	0.04	0.03	0.04	2	0.04	0.04	0.05	8	0.05	0.03	0.10	7	0.07	0.04	0.11	6	0.05	0.04	0.07	29	0.06	0.03	0.14	14	0.05	0.03	0.11	6	0.04	0.04	0.06	45	0.05	0.03	0.11
Ähtävänjoki	15	0.05	0.02	0.24	5	0.03	0.03	0.04	30	0.04	0.02	0.24	20	0.04	0.02	0.12	8	0.03	0.02	0.04	46	0.04	0.02	0.12	16	0.06	0.02	0.16	4	0.03	0.03	0.04	44	0.05	0.02	0.16

Table 28. Total nitrogen concentrations (mg l-1) in the 23 studied agricultural rivers. Basic statistics calculated for winters, summers and whole years for periods 1992–1994, 1996–1998 and 2000–2002.

River	1992–1994												1996–1998												2000–2002											
	Winter				Summer				Whole year				Winter				Summer				Whole year				Winter				Summer				Whole year			
	n	mean	min	max	n	mean	min	max	n	mean	min	max	n	mean	min	max	n	mean	min	max	n	mean	min	max	n	mean	min	max	n	mean	min	max	n	mean	min	max
Aurajoki	42	2.09	1.40	3.70	10	2.12	0.75	3.40	95	2.42	0.75	7.20	38	2.52	1.70	3.90	15	1.99	1.50	4.30	102	2.66	1.20	9.20	59	2.12	0.67	4.00	12	2.42	0.98	6.30	119	2.11	0.67	6.30
Eurajoki	17	1.86	0.75	4.10	6	1.67	1.30	2.20	38	1.94	0.75	4.60	28	2.09	0.93	4.70	8	1.53	1.10	2.50	62	2.09	0.74	5.60	25	2.15	1.10	4.70	5	2.22	1.20	4.00	61	2.00	1.10	6.40
Kalajoki	27	1.83	1.10	3.10	10	1.08	0.71	1.61	61	1.50	0.71	3.10	10	1.96	1.30	2.50	5	1.46	0.88	2.00	42	1.70	0.81	2.70	27	1.80	1.10	2.70	4	1.14	0.84	1.50	53	1.66	0.84	2.70
Kiskonjoki	8	0.86	0.79	0.99	3	0.65	0.47	0.95	22	0.89	0.47	1.50	18	1.19	0.85	1.80	4	0.76	0.65	0.97	41	1.11	0.65	1.80	30	1.23	0.77	3.60	6	0.92	0.73	1.40	64	1.10	0.68	3.60
Kokemäenjoki	25	1.21	0.87	1.90	11	0.82	0.58	2.10	62	1.09	0.58	2.10	23	1.44	0.94	3.10	9	0.76	0.60	0.97	62	1.19	0.60	3.10	26	1.59	0.97	3.12	8	0.78	0.69	0.90	61	1.29	0.51	4.10
Koskenkylänjoki	8	2.14	1.45	2.85	6	0.84	0.54	1.35	28	1.47	0.54	2.85	28	2.17	1.24	6.10	7	1.04	0.50	1.65	67	1.82	0.50	6.10	36	2.18	1.40	6.90	11	0.97	0.75	1.20	80	1.83	0.42	6.90
Kymijoki	23	0.62	0.48	0.88	15	0.49	0.45	0.58	72	0.56	0.42	0.88	40	0.62	0.49	1.40	14	0.47	0.36	0.55	99	0.59	0.36	1.40	32	0.63	0.53	0.87	12	0.52	0.47	0.75	83	0.60	0.47	0.87
Lapuanjoki	18	1.97	1.50	3.50	14	1.46	1.20	1.90	64	1.63	0.79	3.50	10	2.15	1.60	3.00	4	1.55	1.30	1.80	36	2.01	1.20	3.00	17	2.29	1.50	3.50	5	1.26	1.10	1.70	48	1.92	1.10	3.50
Lestijoki	29	1.12	0.38	2.40	13	0.94	0.42	1.40	75	0.97	0.38	2.40	9	1.41	0.80	2.30	6	1.09	0.81	1.40	44	1.16	0.55	2.30	19	1.28	0.70	2.50	6	0.64	0.42	0.93	51	1.02	0.42	2.50
Karvianjoki	4	0.94	0.76	1.30	2	0.57	0.52	0.62	12	0.76	0.52	1.30	13	1.15	0.95	1.50	5	0.63	0.53	0.79	36	0.94	0.53	1.50	13	1.28	0.90	2.60	4	0.71	0.66	0.77	36	1.02	0.60	2.60
Mäntsälänjoki	7	2.16	2.00	2.50	3	0.90	0.62	1.30	19	1.91	0.62	3.90	25	3.08	1.70	5.90	5	1.94	1.05	3.10	57	2.89	1.05	5.90	33	3.11	1.80	7.60	8	1.17	0.95	1.50	71	2.66	0.80	7.60
Karjaanjoki	18	1.08	0.92	1.40	9	0.76	0.54	1.00	53	0.93	0.54	1.55	28	1.01	0.78	2.20	9	0.66	0.55	0.91	72	0.89	0.50	2.20	36	1.10	0.92	1.40	9	0.71	0.49	0.91	80	0.96	0.49	1.40
Isojoki	14	1.06	0.52	1.80	5	0.89	0.36	1.10	37	1.03	0.36	1.80	13	1.25	0.55	2.20	5	0.65	0.32	1.10	37	1.06	0.32	2.20	21	1.08	0.66	1.90	5	0.78	0.34	1.10	44	0.98	0.33	1.90
Paimionjoki	31	2.27	1.70	3.50	8	1.31	0.62	2.30	65	2.43	0.62	6.00	20	2.93	1.70	6.40	5	2.12	1.80	2.60	46	3.08	1.50	8.60	32	2.54	1.70	4.50	8	2.24	0.94	5.80	70	2.30	0.62	5.80
Perhonjoki	16	1.35	0.78	1.70	9	1.06	0.83	1.44	46	1.13	0.65	1.70	11	1.27	0.81	1.80	5	0.99	0.86	1.20	45	1.14	0.79	1.80	18	1.38	1.00	2.20	6	1.02	0.87	1.40	48	1.25	0.77	2.20
Porvoonjoki	21	3.62	2.10	7.50	3	3.53	3.20	4.10	38	3.53	2.10	7.50	24	4.50	2.70	10.00	5	2.50	2.20	2.90	57	4.01	2.00	10.00	33	4.08	2.30	10.00	8	3.25	2.50	4.10	71	4.00	2.10	10.00
Pyhäjoki	13	1.12	0.73	1.50	3	0.68	0.45	0.90	39	0.95	0.45	1.50	16	1.01	0.72	1.90	6	0.71	0.52	1.00	51	0.99	0.52	1.90	19	1.26	0.80	2.20	7	0.76	0.56	1.10	52	1.04	0.56	2.20
Kyrönjoki	53	2.21	1.60	3.70	6	1.50	1.20	1.70	91	2.08	1.20	3.70	14	2.24	1.70	4.50	5	1.80	1.40	2.20	46	2.21	1.40	4.50	16	2.53	1.70	4.40	6	1.35	1.20	1.40	49	2.29	1.20	4.70
Uskelanjoki	14	2.05	1.50	3.10	7	1.76	0.73	4.30	38	2.02	0.73	5.00	20	2.76	1.60	4.80	6	1.81	0.93	3.00	48	3.03	0.93	15.00	32	2.30	1.30	4.10	9	2.36	0.90	3.60	75	2.15	0.87	4.60
Laihianjoki	8	3.38	1.80	6.00	2	2.10	1.60	2.60	18	2.90	1.30	6.00	7	3.60	2.10	5.30					16	3.25	1.30	8.60	5	3.12	1.10	4.30	5	2.01	1.50	3.03	20	2.82	1.10	8.80
Vantaanjoki	21	2.53	1.55	3.30	3	1.97	1.80	2.20	38	2.39	1.35	3.50	24	2.88	1.90	5.20	5	1.66	1.30	2.00	56	2.74	1.30	5.90	33	2.68	1.70	6.60	8	1.75	1.10	2.50	75	2.56	1.10	7.50
Virojoki	2	1.09	0.98	1.20	2	0.59	0.58	0.60	8	1.28	0.58	4.20	7	2.27	0.97	4.90	6	1.33	0.56	4.30	29	1.44	0.56	4.90	14	1.59	0.89	3.00	6	0.71	0.57	0.93	45	1.15	0.46	3.00
Ähtävänjoki	6	0.83	0.56	1.13	5	0.69	0.51	0.93	21	0.76	0.47	1.13	7	0.93	0.56	1.30	8	0.64	0.50	0.94	33	0.81	0.50	1.60	16	1.17	0.70	1.80	4	0.74	0.64	0.84	44	0.99	0.54	1.80

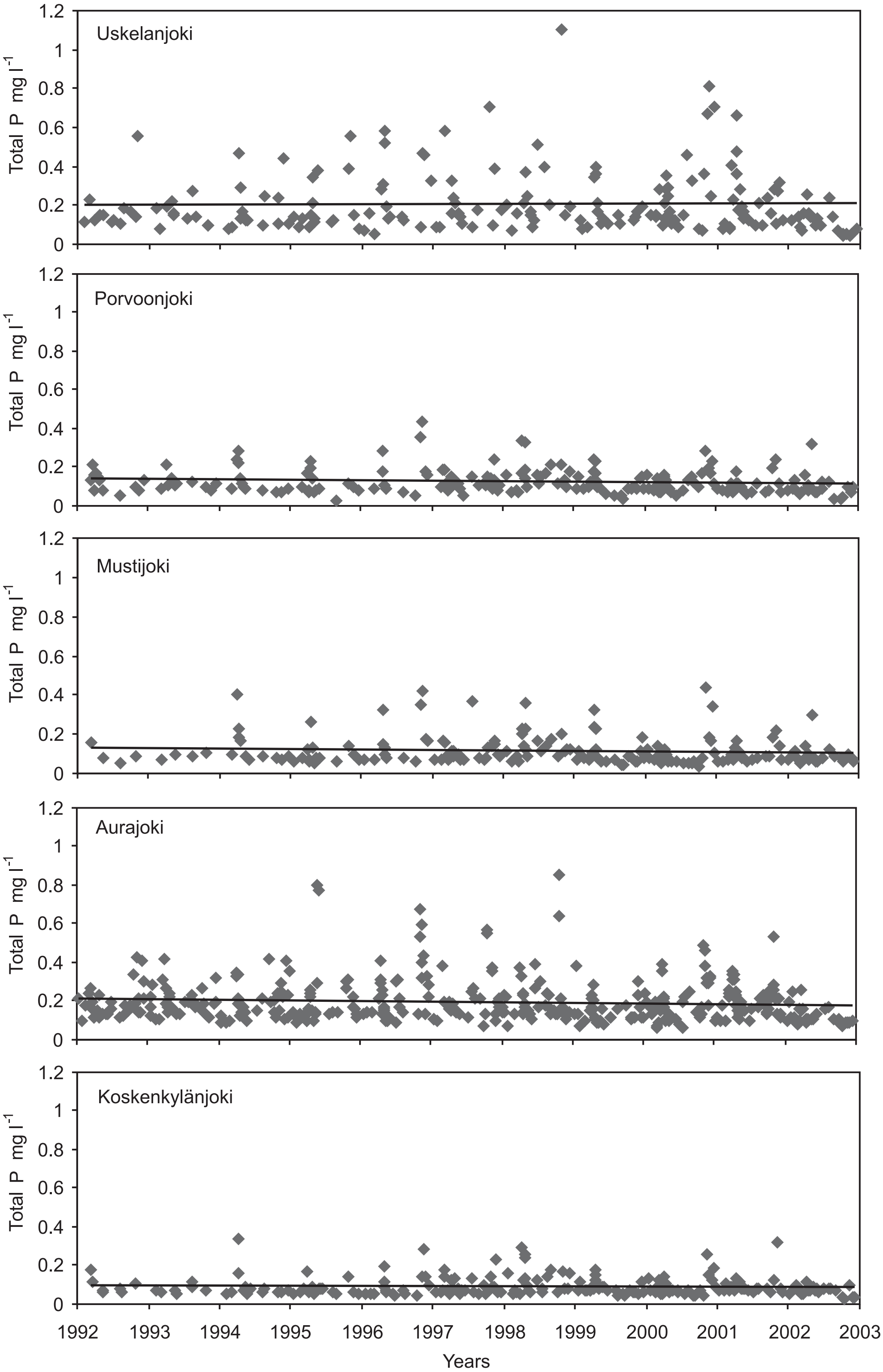

Figure 12. All observations of total phosphorus for the five agricultural rivers highlighted in Table 24 for the period 1992–2002.

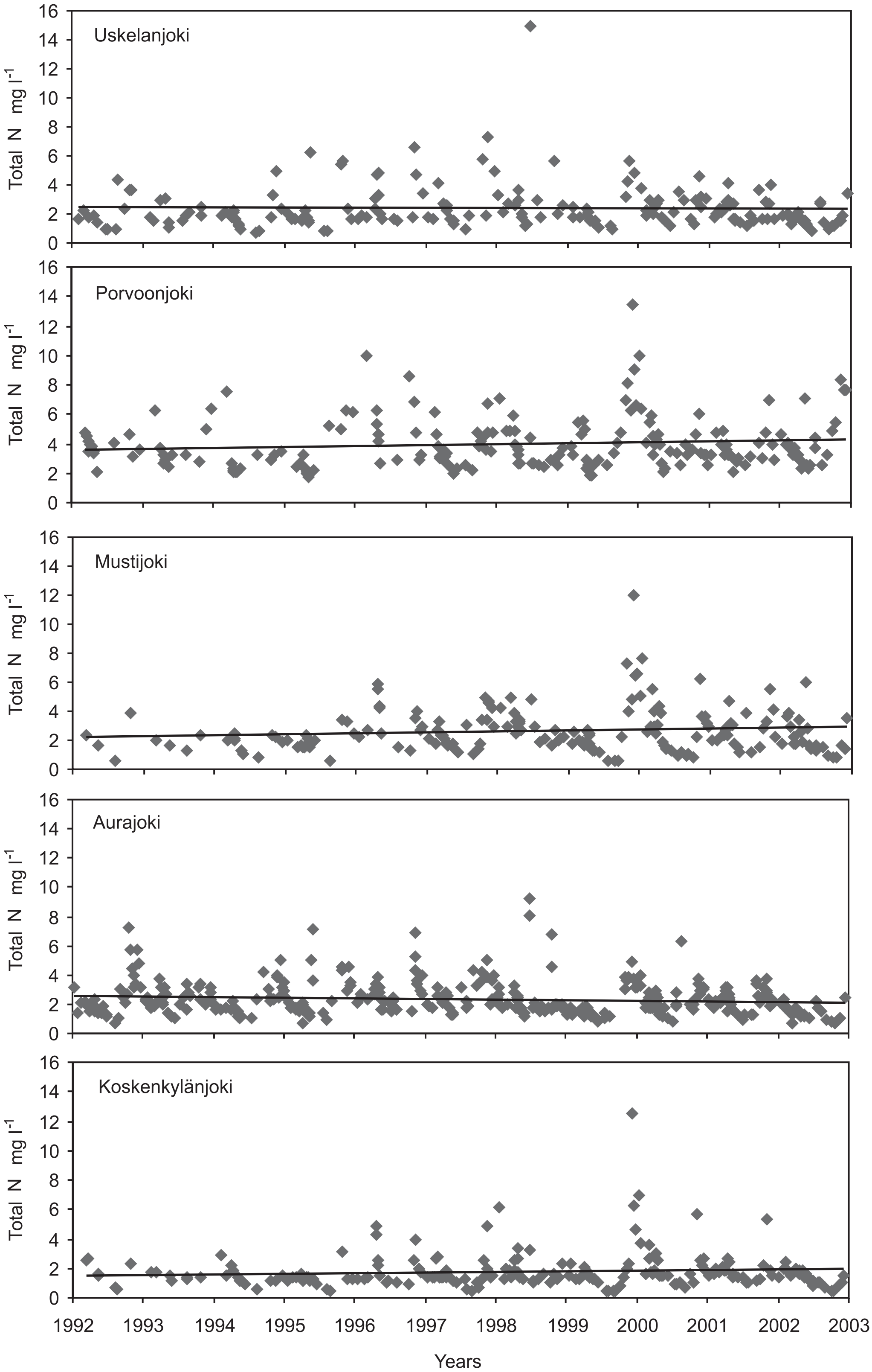

Figure 13. All observations of total nitrogen for the five agricultural river sites highlighted in Table 24 for the period 1992–2002.

2.4.3 Estuaries affected by agriculture

A separate set of data for the innermost coastal waters was compiled to study trends in NO_3, total N, total P and chlorophyll *a* in 1990–2003 and changes in the variables between the periods in 1992–1994, 1996–1998 and 2000–2002. This data set included a total of 22 sampling stations in 19 small Finnish estuaries, receiving nutrients primarily from agricultural sources (Table 29). The sampling stations studied were located in the innermost parts of the estuaries, which are most sensitive to nutrient loads from rivers.

Finnish estuaries are highly variable with regard to a number of characteristics. The coastal morphometry varies between well-mixed and stratified estuaries, which include relatively enclosed systems, winding, island-rich systems and relatively simple pocket estuaries. They are usually relatively small and shallow, the water area ranging from 2 to 145 km^2 and the mean depth from 3 to 18 m (Table 29). They are non-tidal, have low salinities and short residence times.

Table 29. Main characteristics of the 19 agriculturally loaded estuaries and their catchments (data from Kauppila et al. 2003). Eda = Estuary number coded by main river basins, see Tables 18 and 24, Fig. 2. Eda 25 receives waters from two river (Halikonjoki and Uskelanjoki).

		Estuary						Catchment				
Eda	Name	Area	Mean depth	Max depth	Volume	River disharge	Residence time	Area	Field	Forest	Urban	Population density
		km^2	m	m	10^{6}m^3	m^{3}s^{-1}	year	km^2	%	%	%	%
11	Virojoki	32.6	4.4	9.1	144.1	3.7	1.23	357	13.5	82.9	0.5	9.6
12	Haminanjoki	10	6	17.7	59.8	3.6	0.51	380	14	80.7	0.8	28.3
14	Kymijoki	51.8	4.9	14	251.5	172	0.02	37159	24.6	70.1	3.8	80.4
16	Koskenkylänjoki	.	.	18	.	2.9	.	895	30.6	63.4	0.4	.
18	Porvoonjoki	48.8	12.3	35	600.5	13.6	1.4	1273	28.5	67.9	2.4	64.7
19	Mäntsälänjoki	35.9	11.8	42	425.2	6.1	2.22	783	26.8	70.7	1.3	30.5
20	Sipoonjoki	2	3.8	12	7.5	2.1	0.11	220	32.3	64.8	2.5	46.9
21	Vantaa	5.5	4	6.3	20	16.4	0.06	1686	23.4	67.7	6.7	265.1
22	Siuntionjoki	16.9	6.2	22	104.5	4.8	0.07	487	28	67	2.5	.
23	Karjaanjoki	45.1	12.2	37	550.2	20.1	0.24	2046	29.9	65.3	2.8	37.8
24	Kiskonjoki	84.4	17.2	53	1451.7	10.3	0.8	1047	32	64	2.4	.
25	Halikonjoki	93.2	8.1	27	755	6.7	3.56	873	41.5	55.3	1.2	33.4
27	Paimionjoki	102	17.9	49	1826	10.1	5.62	1088	43	54.3	1.2	17.7
30	Mynäjoki	82.6	4.6	11	376.3	6.6	4.21	685	19	78.6	1.2	14
35	Kokemäenjoki	31.4	3.1	6.5	97.7	255.6	0.01	27046	27	67.7	1.4	26.4
39	Närpiönjoki	34.2	6.4	18	218.8	10.1	0.66	992	20.6	78	0.7	.
42	Kyrönjoki	.	.	7.5	.	53.2	.	4923	23.4	74.3	1	20
49	Perhonjoki	6.2	4.4	9.2	27	21.27	0.04	2524	9.5	87.2	0.3	11.7
58	Temmesjoki	86.2	3.1	4.7	265.5	12.08	0.7	1181	15.4	83.6	0.4	9

In 2000–2002, the wintertime concentrations of NO_3 ranged from 1.3 mg l^{-1} in the Närpönjoki Estuary (eda 39) to 13.1 mg l^{-1} in the Koskenkylänjoki Estuary (eda 16), the maximum concentrations there being 23.5 mg l^{-1} (Table 30). In the summer, nitrate levels were lower, varying from 0.01 mg l^{-1} in the Mynäjoki Estuary (eda 30) to 8.6 mg l^{-1} in the Koskenkylänjoki Estuary, where the summertime values also reached the critical level for NO_3. Wintertime levels of phosphorus were highest in the shallow Temmesjoki Estuary in NE Bothnian Bay and lowest in the Kymijoki Estuary (eda 14) in the Gulf of Finland (Table 31). By contrast, wintertime levels of total N were highest in the Koskenkylänjoki Estuary and lowest in the the Temmesjoki Estuary. The Vantaanjoki Estuary (eda 21) near the city of Helsinki was most eutrophied, measured by summertime chlorophyll *a* (39 mg l^{-1}, Table 32).

In 1990–2003, the <u>concentrations of NO_3</u> in Finland's coastal waters revealed normal seasonal variation with high wintertime and low summertime values (Fig. 14, Table 30). Inter-annual variations were generally small, and occasional peaks in autumn and winter could mainly be explained by differences in hydrological conditions. In most of the sites, maximum concentrations remained below 15 mg l^{-1}, but in the innermost Halikonjoki Estuary, (at Hala 110) NO_3 reached the critical level of 25 mg l^{-1} both in October 1992 and in May 2003, as a consequence of high runoff (Fig. 14a). In the 2000–2002 reporting period, however, the maximum value remained below 6 mg l^{-1} (Table 30). The shallow site is directly affected by two rivers carrying considerable amounts of nutrients into the estuary. The proportions of fields in the catchments are among the highest in Finland (Table 29). Additionally, dilution of nutrients in this canyon-like estuary is hampered by a slow water exchange.

In the Vantaanjoki Estuary (at Vanhankaupunginlahti 4), the concentrations of NO_3 reached the level of 25 mg l^{-1} between October 1995 and March 1996 (Fig. 14b). This was due to an exceptional collapse of the tunnel from the municipal treatment plant in Viikinmäki. In general, maximum concentrations have varied between the levels of 10 and 16 mg l^{-1} (cf. Table 30), but in December 2003 the concentration again reached the critical value as a consequence of a peak in the water flow of the River Vantaanjoki. Nutrient concentrations in the shallow estuary are affected by the intensive agriculture and resuspension of nutrients from the bottom. The estuary is sensitive to nutrient loading because the recipient water area (5.5 km^2) is very small relative to the catchment area (1,686 km^2). Furthermore, a restricted horizontal water exchange with the open sea in part maintains eutrophication there.

In most of the sites, NO_3 showed no trend during 1990–2003 (Fig. 14). However, a slight increase may be observed in the Kiskonjoki Estuary (at Hala 137), where wintertime concentrations in the late 1990s and early 2000s were at a higher level compared with the beginning of the decade (Fig. 14f, Table 30). The other exception was the innermost Koskenkylänjoki Estuary (Pernajanlahti 49), where wintertime concentrations of NO_3 in 1995–2003 increased to a level of 6 mg l^{-1} after the steep drop of the early 1990s (Fig. 14h). The trend of NO_3 in this coastal site responded both to the water flow and total N concentrations for the River Koskenkylänjoki, which varied according to hydrological conditions (Fig. 15). However, the other site (Pernajanlahti 51), located a little further from the river mouth, showed no trend. Somewhat higher concentrations for the site compared with the innermost area can be explained by an increase in the amount of resuspension due to a lower depth (see chapter 2.2).

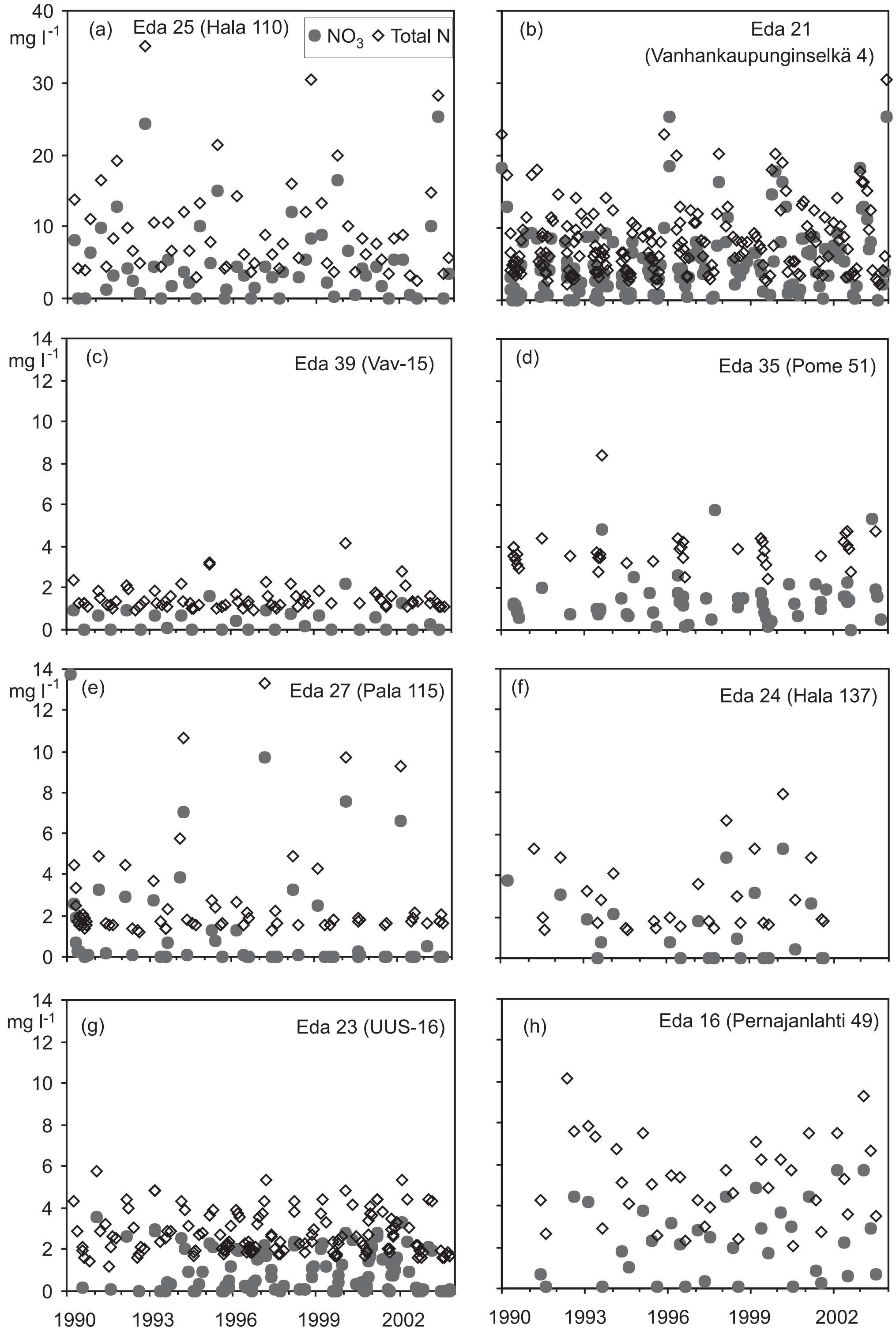

Figure 14. Nitrate (NO_3, mg l^{-1}) and total nitrogen (Total N, mg l^{-1}) in the estuaries of a) Halikonjoki, eda 25, b) Vantaanjoki, eda 21, Total N 7.2.1996 66.4 mg l^{-1}, c) Närpiönjoki, eda 39, d) Kokemäenjoki, eda 25, e) Paimionjoki, eda 27, f) Kiskonjoki, eda 24, g) Karjaanjoki, eda 23 and h) Koskenkylänjoki, eda 16 in 1990–2003. Sampling sites are in parentheses.

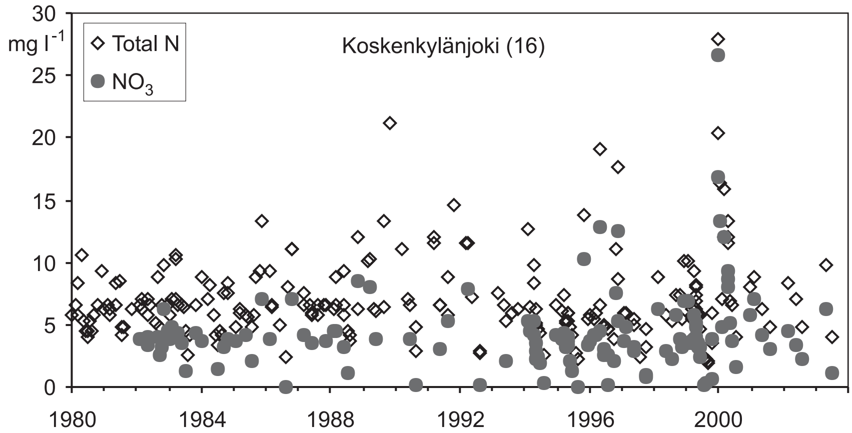

Figure 15. Nitrate (NO_3, mg l^{-1}) and total nitrogen (total N, mg l^{-1}) concentrations in the River Koskenkylänjoki in 1980–2003.

Changes in the level of eutrophication were also detected in some of the innermost coastal areas most sensitive to nutrient loads from the coast (Fig. 16, Tables 31–32). In the estuaries of Halikonjoki (at Hala 110) and Vantaanjoki (at Vanhankaupunginlahti 4), the concentrations of total P decreased slightly during the last decade as a consequence of a lower annual runoff in the late 1990s and the early 2000s (Kauppila et al. 2001, Figs. 16a, b). The decrease of total P in the Kokemäenjoki Estuary (at Pome 51) was due to the reduced concentrations of total P in the river (Räike et al. 2003) and the lower runoff at the turn of the century (Fig. 16c). This may be a sign of a reduced agricultural load.

By contrast, eutrophication in the Paimionjoki Estuary proceeded over the last decades despite water protection measures in agriculture which is the primary source of nutrients in the estuary (Vuoristo et al. 2002). The trend turned to a decline at the beginning of the 2000s (Fig. 16d). This development was a reflection both of variation in hydrological conditions and water protection measures, which may have started to have an effect by the beginning of the century. As a whole, eutrophication in the estuary is maintained by the restricted water exchange with the outer Archipelago Sea and generally week oxygen conditions in the summer, which during unfavourable hydrographical conditions have usually led to the release of inorganic nutrients from the sediment. Since the mid-1990s, internal loading has accelerated in the entire coastal Gulf of Finland as a response to weakened oxygen conditions (Pitkänen et al. 2001).

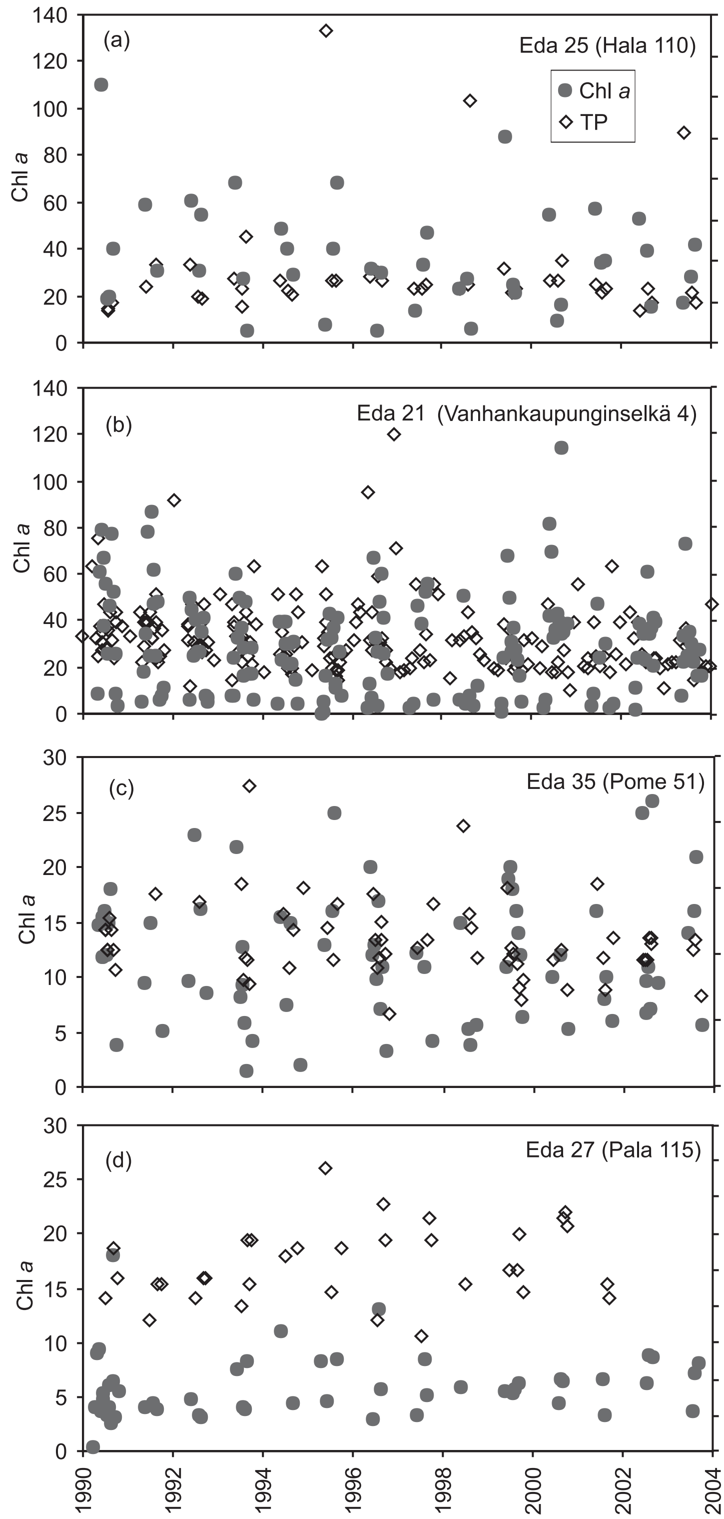

Figure 16. Concentrations of chlorophyll a *(Chl* a*, µg l*$^{-1}$*) and total phosphorus (TP, µg l*$^{-1}$*) in the estuaries of a) Halikonjoki, b) Vantaanjoki, c) Kokemäenjoki and d) Paimionjoki in 1990–2003. See locations of the estuaries, named according to Eda (=River basin code) in Fig. 1. Sampling sites are in parentheses.*

Table 30. Nitrate concentrations (mg l^{-1} NO_3) in the 19 agriculturally loaded estuaries. Basic statistics calculated for winters, summers and whole years for periods 1992–1994, 1996–1998 and 2000–2002. Maximum values >20 mg l^{-1} are in bold and values >25 mg l^{-1} are in bold with box.

EDA	Station	1992–1994											
		Winter				Summer				Whole year			
		n	mean	min	max	n	mean	min	max	n	mean	min	max
11	Virolahti 292					2	0.1	0.0	0.1	2	0.0	0.0	0.0
12	Hillonniemi 218	1	1.1			9	0.0	0.0	0.1	24	0.2	0.0	1.2
14	Kyvy-9	3	1.3	1.1	1.7	4	0.1	0.0	0.2	7	0.6	0.0	1.7
16	Pernajanlahti 51	1	8.7			1	**23.9**			3	13.1	5.8	**23.5**
18	Emäsalonselkä 10					9	0.6	0.0	1.8	14	0.8	0.0	4.4
18	Emäsalonselkä 24					13	0.8	0.0	3.0				
19	Sillvik 116					8	0.2	0.0	1.0				
20	Sipoonlahti 59					1	1.7			5	0.5	0.0	1.9
21	Vanhankaupung. 4	2	7.5	7.3	7.7	22	1.7	0.0	8.0	48	2.7	0.0	9.3
22	Pikkalanlahti 21					10	0.0	0.0	0.1	18	0.0	0.0	0.3
23	Pohjanp.lahti Storö 1												
23	UUS-16 Pohjanp. 92	5	2.5	1.7	2.9	6	0.1	0.0	0.3	16	1.0	0.0	2.9
24	Hala 137 Kiriholm	3	2.4	1.9	3.1	2	0.3	0.0	0.6	5	1.5	0.0	3.1
25	Hala 110 Fulkkila	3	3.5	2.8	4.2	6	0.9	0.0	4.2	15	3.0	0.0	16.2
27	Pala 115 Tryholm	4	4.2	2.8	7.1	3	0.2	0.0	0.7	10	1.8	0.0	7.1
30	Myla 317 Saarninen	2	1.7	1.5	1.9	2	0.1	0.0	0.1	5	0.7	0.0	1.9
35	Pome 51 Sådösaar	2	1.9	1.8	2.0	7	1.4	0.7	4.9	16	1.5	0.7	4.9
39	Vav-15 VII-3	3	0.7	0.6	0.8	3	0.1	0.0	0.1	6	0.4	0.0	0.8
42	Vassor M 1	4	4.7	3.3	8.0	2	2.7	2.1	3.3	10	4.0	2.1	8.0
49	Kokkolan edusta X					12	0.3	0.0	1.3				
49	Pe-1 Kokkolan ed.	1	0.9			1	0.2			2	0.7	0.2	1.2
58	Liminganlahti P10	2	1.5	1.2	1.9	3	0.0	0.0	0.1	10	0.5	0.0	1.9

EDA	Station	1996–1998											
		Winter				Summer				Whole year			
		n	mean	min	max	n	mean	min	max	n	mean	min	max
11	Virolahti 292					6	0.1	0.0	0.4	9	0.3	0.0	1.9
12	Hillonniemi 218	3	1.0	0.8	1.5	14	0.0	0.0	0.2	39	0.4	0.0	5.3
14	Kyvy-9	3	1.6	1.1	2.1	3	0.0	0.0	0.1	6	0.8	0.0	2.1
16	Pernajanlahti 51	3	6.7	0.1	16.4	1	0.04			3	8.6	0.0	**25.7**
18	Emäsalonselkä 10						1.8	0.0	4.4	6	2.2	0.0	6.2
18	Emäsalonselkä 24						0.8	0.0	4.9				
19	Sillvik 116						0.3	0.0	1.4				
20	Sipoonlahti 59						0.0	0.0	0.0	3	0.7	0.0	1.9
21	Vanhankaupung. 4	7	10.6	4.4	**23.9**	9	2.0	0.0	4.2	30	5.2	0.0	**23.9**
22	Pikkalanlahti 21					10	0.0	0.0	0.0	18	0.1	0.0	0.8
23	Pohjanp.lahti Storö 1					2	0.0	0.0	0.0				
23	UUS-16 Pohjanp. 92	5	1.7	1.5	1.9	10	0.1	0.0	0.2	23	0.6	0.0	1.9
24	Hala 137 Kiriholm	3	2.5	0.8	4.9	5	0.3	0.0	1.3	8	1.1	0.0	4.9
25	Hala 110 Fulkkila	3	5.9	3.5	10.6	6	1.9	0.0	5.3	15	3.4	0.0	10.6
27	Pala 115 Tryholm	3	4.8	1.3	9.7	4	0.0	0.0	0.0	10	1.5	0.0	9.7
30	Myla 317 Saarninen	3	2.0	1.2	2.9	5	0.0	0.0	0.0	8	0.8	0.0	2.9
35	Pome 51 Sådösaar	3	2.7	1.7	4.1	9	1.7	0.2	5.8	17	1.8	0.2	5.8
39	Vav-15 VII-3	3	0.6	0.4	0.8	3	0.1	0.0	0.1	6	0.3	0.0	0.8
42	Vassor M 1	2	5.0	3.9	6.2	1	3.6			5	4.9	3.6	6.2
49	Kokkolan edusta X					9	0.3	0.0	0.8				
49	Pe-1 Kokkolan ed.	3	1.3	1.2	1.4	2	0.1	0.1	0.1	5	0.8	0.1	1.4
58	Liminganlahti P10					6	0.0	0.0	0.1	2	0.0	0.0	0.0

EDA	Station	2000–2002											
		Winter				Summer				Whole year			
		n	mean	min	max	n	mean	min	max	n	mean	min	max
11	Virolahti 292					6	0.0	0.0	0.0	9	0.1	0.0	0.3
12	Hillonniemi 218	2	1.5	1.2	1.8	15	0.0	0.0	0.1	38	0.3	0.0	1.8
14	Kyvy-9	2	1.5	1.4	1.6	3	0.1	0.1	0.1	5	0.7	0.1	1.6
16	Pernajanlahti 51	5	6.9	0.1	16.4	2	12.0	0.0	**23.9**	6	10.9	0.0	**25.7**
18	Emäsalonselkä 10	1	10.2			4	0.2	0.0	0.8	1	10.2		
18	Emäsalonselkä 24					8	0.2	0.0	1.3				
19	Sillvik 116					8	0.1	0.0	0.4				
20	Sipoonlahti 59									12	0.0	0.0	0.1
21	Vanhankaupung. 4	8	7.8	5.5	16.6	9	1.7	0.0	7.1	34	4.7	0.0	16.6
22	Pikkalanlahti 21					7	0.0	0.0	0.0	12	0.0	0.0	0.1
23	Pohjanp.lahti Storö 1												
23	UUS-16 Pohjanp. 92	1	2.1			7	0.2	0.0	0.8	23	1.0	0.0	2.3
24	Hala 137 Kiriholm	2	4.0	2.7	5.3	3	0.1	0.0	0.4	5	1.7	0.0	5.3
25	Hala 110 Fulkkila	3	4.2	3.3	5.3	6	0.9	0.0	3.5	14	1.9	0.0	5.3
27	Pala 115 Tryholm	2	7.1	6.6	7.5	8	0.1	0.0	0.3	10	1.5	0.0	7.5
30	Myla 317 Saarninen	2	2.0	1.7	2.3	6	0.0	0.0	0.0	8	0.5	0.0	2.3
35	Pome 51 Sådösaar	3	2.7	2.5	3.1	7	1.2	0.0	2.3	16	1.7	0.0	3.1
39	Vav-15 VII-3	3	1.3	0.6	2.2	3	0.0	0.0	0.0	6	0.7	0.0	2.2
42	Vassor M 1					1	0.3			2	1.2	0.3	2.2
49	Kokkolan edusta X					10	0.3	0.1	1.1				
49	Pe-1 Kokkolan ed.	3	1.8	1.1	2.1	3	0.2	0.1	0.3	24	0.4	0.1	1.1
58	Liminganlahti P10	1	2.1			2	0.1	0.1	0.2	3	0.8	0.1	2.1

Table 31. Wintertime concentrations of total nitrogen (µg l^{-1}) and total phosphorus (µg l^{-1}) in the 19 agriculturally loaded estuaries. Basic statistics calculated for periods 1992–1994, 1996–1998 and 2000–2002.

Eda	Station	Total N µg l^{-1}												Total P µg l^{-1}											
		Winter 1992–1994				Winter 1996–1998				Winter 2000–2002				Winter 1992–1994				Winter 1996–1998				Winter 2000–2002			
		n	mean	min	max	n	mean	min	max	n	mean	min	max	n	mean	min	max	n	mean	min	max	n	mean	min	max
11	Suomenl Virolahti 294	3	808	735	875	3	688	510	855	3	1362	785	1800	3	38	31	47	3	37	32	40	3	41	30	53
12	Suomenl Hillonniemi 218	1	660			3	623	410	930	2	745	640	850	1	20			3	46	34	52	2	40	39	41
13	Suomenl Summanlahti 205	1	640			2	990	900	1080	3	833	735	890	1	65			2	58	54	63	3	40	39	41
14	Suomenl Ahvenkosk Kyvy-9	5	626	570	740	6	660	540	820	5	648	590	730	5	15	10	24	6	17	11	27	5	11	9	14
16	Pernajanlahti 51	2	4200	4110	4290	1	6930			3	3533	1800	6000	2	63	9	116	1	176			3	30	24	36
18	Emäsalonselkä 10					1	1375			1	2030							1	59			1	57		
19	Sillvik 116	1	1060			3	1098	910	1440	1	1240			1	55			3	60	49	76	1	49		
20	Sipoonlahti 61	4	1273	1077	1433	1	1435							4	84	55	110	1	58						
21	Vanhankaupunginselkä 4	3	2683	2250	3100	9	5978	1550	14000	8	2531	1850	4250	3	128	49	210	9	70	42	115	8	64	46	115
22	Pikkalanlahti 21	1	680			2	460	405	515	2	593	465	720	1	58			2	39	36	42	2	47	35	60
23	Pohjanp.lahti Åminne 2	3	1040	920	1100	3	900	800	950	1	530			3	27	24	31	3	26	21	36	1	29		
23	UUS-16 Pohjanp.lahti 92	6	958	775	1100	8	798	680	970	5	902	820	1045	6	25	19	36	8	23	19	35	5	25	23	27
24	Hala 137 Kiriholm lä	3	920	740	1100	3	917	440	1500	2	1450	1100	1800	3	31	25	44	3	29	21	41	2	46	43	49
25	Hala 110 Fulkkila	3	1802	1750	1850	3	2233	1500	3050	3	1515	1275	1800	3	102	80	131	3	119	54	240	3	78	58	92
27	Pala 115 Tryholm it	4	1383	830	2400	3	1570	610	3000	2	2150	2100	2200	4	49	35	79	3	112	31	260	2	96	42	150
27	Piik 105 Pirttikari	3	1020	860	1200	3	737	560	960	3	1313	740	2200	3	63	61	66	3	54	45	64	3	68	40	101
30	Myla 317 Saarninen loun	2	660	535	785	3	847	640	1070	2	823	780	865	3	31	23	44	3	31	23	41	2	40	40	40
35	Pome 51 Sådösaar et	3	1033	950	1100	3	1183	1000	1500	3	1190	1035	1400	3	29	26	31	3	29	24	38	3	28	27	29
39	Vav-15 VII-3	5	397	307	440	4	390	311	455	3	657	400	940	5	16	14	21	4	15	13	19	3	21	17	24
42	Vassor M 1	6	2100	1600	3600	2	2100	1700	2500	1	1800			6	92	49	120	2	67	47	87	1	62		
49	Pe-1 Kokkolan edusta	2	725	725	725	3	770	710	885	3	855	515	1200	2	43	39	46	3	37	32	42	3	43	28	52
58	Liminganlahti P10	4	1460	779	2700	2	884	747	1020	1	334			4	113	32	240	2	51	49	52	1	159		

Table 32. Summertime concentrations of chlorophyll *a* (µg l-1) in the 19 agriculturally loaded estuaries. Basic statistics calculated for periods 1992–1994, 1996–1998 and 2000–2002.

Eda	Station	Chlorophyll *a* µg l-1											
		Summer 1992–1994				Summer 1994–1996				Summer 2000–2002			
		n	mean	min	max	n	mean	min	max	n	mean	min	max
11	Suomenl Virolahti 292	7	19	14.3	27	6	18	13.9	25.1	6	31	21	44
12	Suomenl Hillonniemi 218	11	4.1	2.4	7.7	14	8.3	4.3	14.7	11	10	2	23
14	Suomenl Ahvenkosk Kyvy-9	11	9	4.7	17	11	10.1	6.1	16	9	11	8.2	16
18	Emäsalonselkä 10	9	20	5.6	81	4	36	14	79	4	11	3.2	20
18	Emäsalonselkä 24	13	46	11	123	12	36.8	7.4	62	12	25	7.3	65
19	Sillvik 116	8	15	2.1	65	12	22.9	2.5	66	12	11	1.2	28
20	Sipoonlahti 59	11	28	4.1	66	5	13.4	6.7	31				
21	Vanhankaupunginselkä 4	19	27	7.2	48	12	31.2	3.2	60	15	39	2.5	115
22	Pikkalanlahti 21	10	7.7	3.1	17	10	16	5.8	31	11	7.8	3.4	17
23	Pohjanp.lahti Storö 1	12	8	3.1	21	12	9.7	3.6	18	12	7.5	3.2	14
23	UUS-16 Pohjanp.lahti 92	13	8.2	2.4	16	25	8.1	4.4	14	16	6.1	2.3	11
24	Hala 137 Kiriholm lä	7	4.4	2.7	7.8	5	6.4	3.4	9.8	3	8	3.4	14
25	Hala 100 Viurilanlahti	6	53	7.7	93	6	56.6	3.7	150	6	35	7.7	62
25	Hala 110 Fulkkila	6	31	4.9	55	6	24.6	4.8	47	6	25	9.7	39
27	Pala 115 Tryholm it	7	4.7	3.1	8.2	4	8.1	5.2	13	8	6.6	3.3	10
27	Piik 105 Pirttikari	6	5.3	3.7	6.9	6	10.1	0.6	20	6	6.8	3.2	8.8
30	Myla 317 Saarninen loun	6	8.2	4.7	13	5	7.5	5.6	8.3	7	18	7.2	69
35	Pome 51 Sådösaar et	8	9.6	1.5	16	9	8.3	3.8	17	7	12	6.8	26
39	Vav-15 VII-3	6	2.5	1.4	4.1	6	2.2	1.3	3.7	5	2.4	1.3	3.4
49	Pe-1 Kokkolan edusta	3	3.8	3.2	4.1	2	7.8	4.6	11	3	4.8	2.6	8.7
49	Kokkolan edusta X	12	6.8	2.8	11	9	7.6	1.4	14	10	4	1.9	9.4
58	Liminganlahti P10	6	8.5	4.6	12	6	5.5	1.7	12.2	2	8.6	6.4	11

2.5 Nitrogen leaching in small agricultural catchments

Long-term changes in agricultural nitrogen leaching were studied in three small agricultural catchments in order to assess the potential effects of water protection measures included in the EU agri-environmental support scheme (Finnish Agri-Environmental Programme, FAEP). The selected catchments (Hovi, Savijoki and Löytäneenoja) are located in southern Finland and are core catchments for estimating agricultural nutrient loading in the country (Vuorenmaa et al. 2002). Most of the farmers in the study catchments are participating in the FAEP and thus undertake at least the basic measures, such as targeted levels for fertilizers. In these catchments, cereal crop cultivation is common, which is typical of southern and western Finland. The residence time is low, due to artificial drainage of fields and absence of lakes. Therefore, the retention of nutrients in surface waters is probably low. The characteristics of the three catchments are described in Table 33.

Table 33. Area and main land-use characteristics of the small catchments studied.

Catchment number	Catchment name	Area (km^2)	Cultivated land (% of area)	River basin number
11	Hovi	0.12	100	23
21	Löytäneenoja	5.6	68	35
22	Savijoki	15.4	39	28

Continuous measurements of discharges were available in all catchments. The sampling strategy is a combination of manual and automatic flow-weighted sampling. A more detailed description of the monitoring programmes is given by Vuorenmaa et al. (2002). Observed values of total N, NO_x-N (NO_2-N+NO_3-N) and NH_4-N concentrations were used in the analysis. Organic N (Org. N) concentration was estimated by substracting the sum of dissolved inorganic N fractions (DIN) from total N concentration.

Annual total N export from the catchments was analysed for the period 1990–2002. Five-year mean values were calculated in order to eliminate the effects caused by varying hydrological conditions. The years 1990–1994 provide background information before the FAEP, the years 1995–1999 represent the first period of the FAEP and the last period (2000–2002) represents the first part of the second period of FAEP. The calculated export values also include the load from forested areas, but this is assumed to be small in these catchments.

A trend analysis for the period 1981–2002 was carried out in the Savijoki and Löytäneenoja catchments in order to investigate whether changes in agricultural practices (e.g. detected decrease in fertiliser use) have already affected N concentrations in stream water (Granlund and Räike 2004). Flow-adjustment was conducted in stages by first modelling the regression between concentration and discharge. The residuals from this relationship (i.e. the variation which cannot be explained by discharge) were then tested with the Seasonal Kendall test (Hirsch et al. 1982; Hirsch et al. 1991). Possible trends were analysed from both flow-adjusted and non flow-adjusted N fraction concentrations (total N, NO_x-N, NH_4-N and Org. N). The magnitude of statistically significant trends was estimated according to the Seasonal Kendall slope estimator (Hirsch et al. 1982).

In the Hovi catchment, the total N export increased together with runoff during the period studied (Fig. 17). In Savijoki and Löytäneenoja, the load was highest during 1995–1999 and decreased a little during 2000–2002, but was still of the same order as during the background period. The results indicate that the new management practices suggested by the FAEP (e.g. restrictions in fertilizer use) have so far had little or no effect on agricultural nitrogen leaching in these areas.

Flow-adjustment had only a minor impact on the significance of the detected trends, because the correlation between water flow and concentrations of different N fractions was weak in most cases. The concentrations of different N fractions increased or remained at the same level during the study period, except the concentrations of NH_4-N (Table 34).

Table 34. Median concentrations and statistically significant (Seasonal Kendall test) flow-adjusted trends in different nitrogen forms in 1981–2003. Modified after Granlund and Räike (2004). The symbols ---, +++ = $P<0.001$ and --, ++ = $P<0.01$

Stream	Total N			NO_x-N			NH_4-N			Org. N		
	Median $\mu g\ l^{-1}$	Trend	Slope $\mu g\ l^{-1}\ yr^{-1}$	Median $\mu g\ l^{-1}$	Trend	Slope $\mu g\ l^{-1}\ yr^{-1}$	Median $\mu g\ l^{-1}$	Trend	Slope $\mu g\ l^{-1}\ yr^{-1}$	Median $\mu g\ l^{-1}$	Trend	Slope $\mu g\ l^{-1}\ yr^{-1}$
Löytäne	4200	+++	76	2900	+++	66	350	--	-8.5	920	+++	17.0
Savijoki	2500	0		1500	0		220	---	-15.0	760	++	9.6

Concentrations of total N, NO_x-N and Org. N increased in the Löytäneenoja Stream. In the Savijoki Stream, the Org.N concentration increased. The NH_4-N concentrations decreased in both streams. The results of trend analysis also indicate that the water quality response to reduced fertilizer application is still slow and limited.

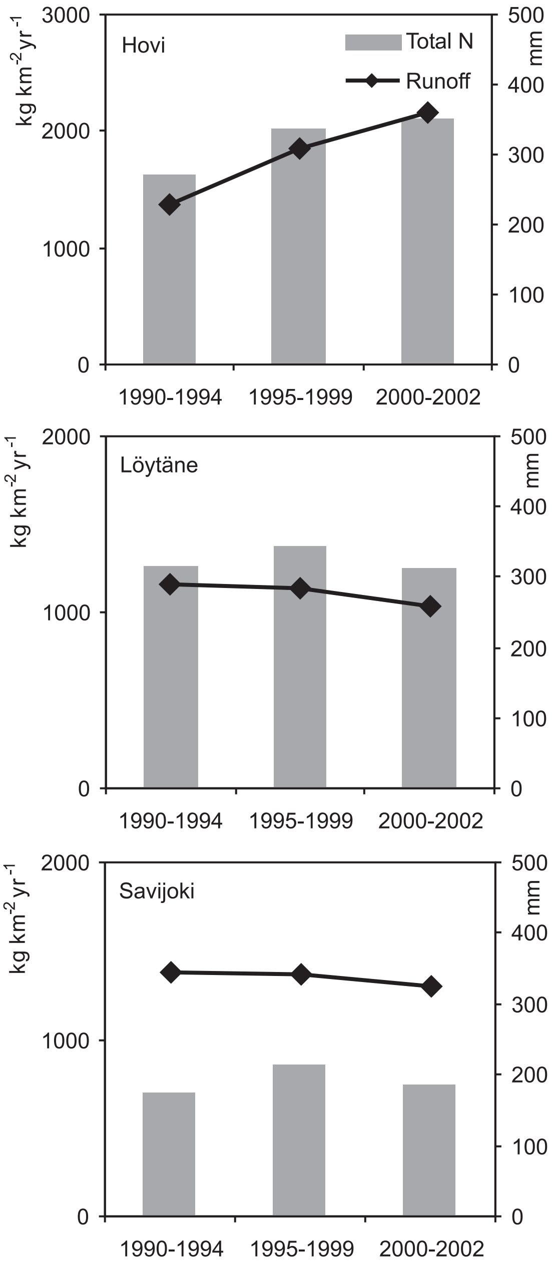

Figure 17. Mean export of total nitrogen (total N) and runoff from small agricultural catchments.

3 Groundwater quality

3.1 Data collection

In the Nitrate Directive (91/676/EEC) the Member States are obligated to identify groundwaters that contain more than 50 mg l^{-1} NO_3 or could contain more than 50 mg l^{-1} NO_3 if preventative measures are not taken. In addition, the Drinking Water Directive (98/83/EC) sets the maximum acceptable concentration for nitrate of 50 mg l^{-1}. It has been shown that drinking water in excess of the nitrate limit can result in adverse health effects, especially in infants less than two months old. Groundwater is a very important source of drinking water in Finland where approximately 60% of the people served by public waterworks now use groundwater or artificial groundwater. The rural population, which is about 350, 000 households, relies on local groundwater resources and uses private wells.

The effect of agriculture on NO_3 concentration in groundwater has been reported in numerous studies in Finland. Vainio (1984) studied NO_3 concentrations in the wells situated in agricultural areas in southern Finland, where the main crops were sugar beet and grain. Occasionally NO_3 concentrations in some wells were so high that groundwater was not potable. One of the study areas was the important groundwater area of Renko ridge, where in the period from 1974 to 1984 fields were treated with compound fertilizers and also with waste sludge from a potato flour factory. This practice polluted several wells. Round-the-year monitoring of twenty six private wells in the area was initiated in summer 1985, and went on until 1987. The average NO_3 concentration found in the wells near cultivated fields (20 mg l^{-1}) was over 60 times as high as the concentration in pristine groundwater (NO_3 = 0.3 mg l^{-1}). The highest NO_3 concentration found was 84 mg l^{-1} (Åkerla et al. 1985, Britschgi 1989, Huttunen and Rönkä 1994).

Korkka-Niemi (2001) considered cumulative geological, regional and site-specific factors affecting groundwater quality in domestic wells in Finland. In this study the contaminating influence of cultivation and agricultural settlement on groundwater was reflected in a marked increase in electrical conductivity, NO_3, chloride and potassium and higher incidences of total coliform bacteria, faecal bacteria and faecal streptococci.

In 1983–1987, the National Board of Waters and Environment investigated the effect of different human activities on groundwater quality, including fur farms situated in eskers. Field and laboratory studies were conducted in 1984–1987. According to the results, one of the best indicators of impact of fur farming was the total nitrogen concentration (Mälkki et al. 1988). High concentrations of total nitrogen near fur farming area in Mustio was reported also by Nysten (1988).

The impact of various cultivation and fertilization methods on quality of groundwater was studied in lysimeter experiments from 1987 to 1995 (Huttunen et al. 2000). Ploughing in autumn increased the volume of percolating water and consequently elevated the concentration of NO_3 in groundwater. The first autumn ploughing increased the NO_3 level 1.48 times, and the second autumn 2.03 times in comparison to unploughed fields.

In 2002 the Environmental Administration started using a nation-wide groundwater database (POVET), maintained by the Regional Environment Centres. This database contains detailed information about groundwater aquifers; for example, general information about hydrogeology, activities and land use (settlements, forestry, cultivation, industry) and risk activities (fur farming, pig houses, gravel extraction, petrol stations). There is also information about monitoring and sampling of groundwater from wells, sampling tubes, ponds and springs. The monitoring data in the POVET database includes also comprehensive dataset from 12 aquifers considered important for water supply and situated in or near agricultural areas (Table 35). There are altogether 11 monitoring wells and 9 monitoring tubes installed in these aquifers. Six of the wells are used by public waterworks. In these aquifers, high nitrate concentrations are caused by the use of fertilizers or manure, greenhouses or fur farming.

The background information on groundwater quality comes from 53 groundwater-monitoring stations operated by the environmental administration. These monitoring stations represent different climatological conditions and soil types in areas where initially the human impact on groundwater quality and quantity has been minimal. The stations are located in hydrogeologically unified groundwater basins or districts, that is, defined areas within larger basins. The size of the area investigated varies between 0.2 km^2 and 3.0 km^2. The groundwater of these monitoring stations is in most cases 'shallow groundwater' and its potential use for domestic water applies mostly to sparsely populated areas. The samples are taken six times (during 1992–2002) each year from springs, wells or sampling tubes (Soveri et al. 2001).

In its natural state groundwater in Finland is usually classified as high quality domestic water (Niemi et al. 2001a, Rusanen et al. 2004). However, due to fairly thin soil layers above the groundwater table, the risk of groundwater contamination is quite high.

3.2 Nitrate concentrations in 1992–2002; background values and those affected by agriculture

At aquifers in or near agricultural areas, the highest NO_3 concentration in groundwater (maximum value 378 mg l^{-1}, mean value 299 mg l^{-1}) was detected in a monitoring tube situated 350 m from an old fur-farming area (Table 36, Figs. 18–19). At a waterworks well situated 200 m from greenhouses, fertilization has increased NO_3 concentration in groundwater to a maximum value of 62 mg l^{-1} (mean value 28 mg l^{-1}). At aquifers under cultivation (cultivated area 6–82% of the groundwater area) NO_3 concentration in groundwater was usually below 10 mg l^{-1}, but at two aquifers NO_3 concentration was higher than 25 mg l^{-1}. In groundwaters affected by cultivation the highest NO_3 concentration detected was 62 mg l^{-1} (Nation-wide groundwater database, POVET 2004).

At the observation sites in the natural state, the NO_3 concentration in groundwater was usually below 1 mg l^{-1} (Table 37, Figs. 20–21). NO_3 concentrations in groundwater with minor human impact were higher in till formations than in sandy areas. In several cases, the seasonal variation of NO_3 concentration was considerable. The minimum value of NO_3 concentration was usually reached during the growth season in the middle of the summer. Changes in the land use policy in the groundwater recharge area usually have a strong influence on NO_3 concentrations. Forest cutting has increased NO_3 concentrations at several observation sites (Rusanen et al. 2004). There are also a number of gravel pits in the eskers. In gravel extraction sites the topsoil has been removed, making groundwater more sensitive to contamination by nitrogen emission (Rintala et al. 2001).

Table 35. Groundwater observation sites situated near agriculture or farming. REC= Regional Environment Centre, gwip=groundwater intake plant.

REC/ Municipal	Groundwater area Code and name	Observation site Code	Observation site Type	Land use at groundwater area Field %	Forest %	Settlement %	Others
Uusimaa							
Karjaa	01 220 51 C Meltola-Mustio	5530	Well	11	78	9	earlier fur farming
		8420	Tube				
		8421	Tube				
		8422	Tube				
Lohja	01 428 52 Kirkniemi	8416	Tube	8	81	2	earlier fur farming
		8425	Well				
Nurmijärvi	01 543 06 Nukari	2330	Tube	23	40	14	gravel extraction 15%
Pernaja	01 585 55 Panimonmäki	2369	Tube	49	22	13	
Loviisa		3159	Tube				
		3161	Tube				
		5993	Tube				
Southwest Finland							
Pyhäranta	02 631 01 Nihtiö		gwip	26	41	30	greenhouse
Häme							
Jokioinen	04 169 54 A Särkilampi		gwip	52	26	6	
Kärkölä	04 316 01 B Järvelä 1	27304	Well	13	74	4	gravel extraction 3.5%
		27305	Well				
	04 316 02 Supinmäki-Myllykylä	27298	Well	33	58	5	gravel extraction 2.5%
Lammi	04 401 01 Linnamäki	11763	gwip	23	50	6	gravel extraction 3.8%
Loppi	04 433 03 Läyliäinen	11818	gwip	6	79	6	gravel extraction 3.3%
	04 433 53 Launonen	11817	gwip	20	58	16	
North Ostrobothnia							
Haapavesi	11071003 Nevalanmäki		gwip	82	12	5	

Table 36. Nitrate concentrations (mg l^{-1} NO_3) measured in 1992–2002 in groundwaters in or near agricultural areas. Concentrations over 50 mg l^{-1} are in bold with box and concentrations between 25–50 mg l^{-1} in bold.

Groundwater site area, site and id codes	1992–2002				1992–1994				1996–1998				2000–2002				Main NO_3 load sources. based on land use at groundwater area
	n	mean	max	min	n	mean	max	min	n	mean	max	min	n	mean	max	min	
01 22051. K. 5530	9	5.86	6.64	5.53	0				0				7	5.91	6.64	5.53	fur farming, cultivation 11%
01 22051. HP202. 8420	12	**47.7**	**194.74**	4.87	3	**81.48**	**111.65**	**55.32**	4	18.37	**35.41**	5.31	3	17.41	**37.62**	4.87	**fur farming**, cultivation11%
01 22051. HP203. 8421	10	**238.92**	**378.42**	**151.89**	1	**151.89**	**151.89**	**151.89**	4	**235.68**	**301**	**163.76**	3	**298.76**	**378.42**	**239**	**fur farming**, cultivation 11%
01 22051. HP204. 8422	12	2.58	6.19	0.42	3	0.54	0.71	0.42	4	5.19	6.19	4.38	3	1.3	1.55	0.97	fur farming, cultivation 11%
01 428 52. HP200. 8416	17	0.19	0.27	0.08	3	0.19	0.27	0.16	6	0.18	0.26	0.08	5	0.19	0.26	0.15	fur farming, cultivation 8%
01 428 52. K1. 8425	18	**55.76**	**120.71**	8.19	3	**40.98**	**48.58**	**27.88**	7	**38.91**	**50.9**	8.19	5	**82.48**	**120.71**	**68.16**	**fur farming**, cultivation 8%
01 543 06. HPS4. 2330	6	8.26	9.29	7.08	0				0				6	8.26	9.29	7.08	cultivation 23%, settlement 14%
01 585 55. HP52. 2369	6	24.56	**26.11**	23.02	2	24.34	**25.67**	23.02	0				1	**26.11**	**26.11**	**26.11**	**cultivation 49%**, settlement 13%
01 585 55. HP204. 3159	6	19.25	20.36	16.82	1	20.36	20.36	20.36	1	20.36	20.36	20.36	1	16.82	16.82	16.82	cultivation 49%, settlement 13%
01 585 55. HP53. 3161	5	3.42	5.53	1.37	2	2.52	3.67	1.37	0				1	4.03	4.03	4.03	cultivation 49%, settlement 13%
01 585 55. HP200. 5993	6	20.29	21.24	19.92	1	21.24	21.24	21.24	1	19.92	19.92	19.92	1	19.92	19.92	19.92	cultivation 49%, settlement 13%
02 631 01. VO K	38	**32.9**	**85**	5.9	0				17	**41.7**	**85**	18	19	**28**	**62**	5.9	**greenhouse**, cultivation 26%, settlement 30%
04 169 54. VO H	3	1.72	2.8	0.65	0				0				3	1.72	2.8	0.65	cultivation 52%
04 316 01. K1. 27304	7	6.67	9.7	5.3	0				1	9.7	9.7	9.7	5	6.26	7.5	5.3	cultivation 13%
04 316 01. K2. 27305	6	1.07	1.2	<0.9	0				1	0.9	0.9	0.9	4	1.1	1.2	<0.9	cultivation 13%
04 316 02. K 1. 27298	4	**58.3**	**61.6**	**52.8**	0				0				3	**57.2**	**61.6**	**52.8**	**cultivation 33%**
04 401 01. VO H. 11763	9	0.47	1	0.04	0				0				5	0.04	0.05	0.04	cultivation 23%
04 433 03. VO H. 11818	3	<1	<1	<1	0				0				3	<1	<1	<1	cultivation 6%
04 433 53. VO H. 11817	3	7	7	7	0				0				3	7	7	7	cultivation 20%, settlement 16%
11 071 003. VO H	33	16.5	**34.6**	0.14	5	5.5	6.6	4.4	18	17.7	21.2	12.5	2	20.8	24	17.5	cultivation 82%

Table 37. Nitrate concentrations (mg l^{-1} NO_3) measured in 1992–2002 in groundwater sites representing areas in natural state. Concentrations between 5–10 mg l^{-1} are in bold and concentrations between 10–25 mg l^{-1} in bold with box.

Groundwater site	1992–2002				1992–1994				1996–1998				2000–2002				Main NO_3 load sources
	n	mean	max	min	n	mean	max	min	n	mean	max	min	n	mean	max	min	
Karkkila	51	1.2	1.95	0.66	17	1.37	1.95	0.77	17	1.19	1.77	0.66	17	1.03	1.43	0.8	
Myrskylä	49	0.99	1.12	0.82	18	1	1.11	0.82	18	0.98	1.06	0.89	13	1	1.12	0.91	
Lammi	23	0.65	4.87	0.01	16	0.05	0.18	0.01	4	3.42	4.87	0.44	3	0.13	0.36	0.01	Forest cutting
Kiikala	37	0.09	0.21	0.01	17	0.11	0.21	0.05	16	0.07	0.09	0.01	4	0.07	0.08	0.06	
Oripää	42	1.21	1.77	0.8	19	0.98	1.11	0.8	19	1.35	1.44	1.15	4	1.71	1.77	1.62	Gravel extraction
Nurmijärvi	46	**5.29**	**8.53**	1.28	12	2.52	3.76	1.28	17	**5.93**	**8.53**	1.77	17	**6.61**	**7.3**	**5.8**	Gravel extraction
Elimäki	40	3.3	**22.6**	0.11	18	0.41	1.24	0.11	16	**7.3**	**22.6**	0.43	6	1.28	1.55	0.75	Forest cutting
Valkeala	40	0.33	0.44	0.09	18	0.38	0.44	0.29	16	0.29	0.4	0.09	6	0.27	0.31	0.19	
Ruokolahti	41	0.9	3.5	0.1	19	0.16	0.26	0.1	16	1.72	3.5	0.23	6	1.03	2.08	0.58	
Parikkala	40	0.46	2.52	0.15	19	0.36	1.59	0.16	15	0.57	2.52	0.15	6	0.52	1.99	0.16	
Pertunmaa	41	**9.71**	**19.92**	2.97	18	**6.08**	**9.3**	2.97	12	**11.99**	**16.38**	**6.64**	11	**14.25**	**19.92**	**10.18**	Agriculture
Puumala	51	0.1	0.28	0.02	17	0.04	0.12	0.02	17	0.1	0.2	0.02	16	0.17	0.28	0.05	
Pieksamäen mlk	51	0.06	0.36	0.02	18	0.04	0.1	0.02	16	0.06	0.36	0.02	17	0.07	0.19	0.02	
Keitele	30	3.55	**6.2**	0.89	10	3.06	**5.05**	0.89	8	3.4	**5.31**	1.33	12	4.06	**6.2**	2.7	
Rautavaara	30	0.1	0.2	0.05	11	0.12	0.2	0.08	7	0.08	0.12	0.05	12	0.09	0.13	0.07	
Sonkajärvi	16	0.05	0.16	0.01	12	0.04	0.08	0.01	1	0.03	0.03	0.03	3	0.09	0.16	0.04	
Ilomantsi	41	0.03	0.07	0.01	18	0.04	0.04	0.01	11	0.03	0.06	0.02	12	0.03	0.07	0.02	
Kontiolahti	41	0.08	0.13	0.02	6	0.08	0.13	0.02	18	0.09	0.12	0.06	17	0.08	0.11	0.05	
Nurmes	41	**5.95**	**7.97**	1.42	17	4.97	**6.2**	1.42	12	**7.09**	**7.97**	1.46	12	**6.2**	**6.64**	**5.31**	Agriculture
Alavus	32	0.35	1.02	0.02	14	0.23	0.8	0.04	26	0.48	1.02	0.02	1	0.26	0.26	0.26	
Kauhava	32	1.48	**6.19**	0.04	16	0.06	0.15	0.04	15	3.04	**6.19**	0.05	1	0.84	0.84	0.84	
Joutsa	39	0.73	2.57	0.02	18	1.29	2.57	0.49	12	0.3	0.66	0.02	9	0.2	0.23	0.15	Forest cutting
Multia	41	0.93	2.17	0.25	18	1.43	2.17	0.8	13	0.67	0.89	0.58	10	0.37	0.44	0.25	
Laukaa	44	0.17	0.44	0.04	18	0.11	0.19	0.04	13	0.17	0.27	0.12	13	0.24	0.44	0.13	
Karstula	36	2.58	**5.31**	1.06	16	2.47	3.32	1.06	10	2.01	2.66	1.15	10	3.32	**5.31**	1.06	
Saarijärvi 111	45	0.51	0.97	0.37	9	0.63	0.97	0.38	18	0.49	0.89	0.37	18	0.47	0.71	0.38	
Saarijärvi 112	39	4.52	**8.85**	1.86	6	**7.23**	**8.85**	**5.75**	18	3.52	**5.31**	1.86	15	4.64	**8.41**	1.86	Gravel extraction
Saarijärvi 113	37	3.29	**5.31**	1.24	4	3.25	3.81	2.52	17	2.93	3.81	1.73	16	3.69	**5.31**	1.24	Gravel extraction
Halsua	47	0.41	1.02	0.23	18	0.35	0.45	0.26	15	0.33	0.49	0.23	14	0.55	1.02	0.25	
Haapajärvi	36	0.71	0.97	0.44	18	0.81	0.97	0.53	15	0.62	0.84	0.53	3	0.52	0.62	0.44	
Kalajoki	36	3.37	**22.58**	0.02	18	0.44	1.28	0.02	15	**6.53**	**22.58**	0.1	3	**5.14**	**7.97**	1.68	
Pyhäntä	44	0.21	0.32	0.08	11	0.22	0.27	0.15	18	0.26	0.32	0.15	15	0.16	0.23	0.08	
Ruukki	48	0.05	0.13	0.02	16	0.05	0.12	0.02	18	0.04	0.13	0.02	14	0.04	0.08	0.02	
Pudasjärvi	42	0.1	0.19	0.05	17	0.09	0.14	0.05	14	0.09	0.14	0.05	11	0.14	0.19	0.1	
Kuusamo	43	0.08	0.17	0.01	18	0.08	0.17	0.02	14	0.07	0.11	0.01	11	0.07	0.14	0.02	
Sotkamo	41	0.06	0.09	0.02	18	0.06	0.09	0.02	13	0.05	0.08	0.04	10	0.06	0.09	0.04	
Kuhmo	40	1.11	1.52	0.53	18	1.36	1.52	0.8	12	1.11	1.28	0.71	10	0.65	0.73	0.53	
Puolanka	40	0.17	0.2	0.12	18	0.18	0.2	0.15	12	0.16	0.18	0.12	10	0.16	0.16	0.13	
Suomussalmi	37	0.13	0.2	0.08	17	0.16	0.2	0.12	11	0.1	0.12	0.09	9	0.1	0.12	0.08	
Rovaniemen mlk	52	0.13	0.51	0.02	17	15	0.22	0.08	17	0.15	0.51	0.02	18	0.11	0.14	0.07	
Salla	53	0.56	0.8	0.02	18	0.57	0.8	0.02	17	0.5	0.71	0.4	18	0.6	0.71	0.53	
Sodankylä	54	0.42	0.93	0.1	18	0.52	0.93	0.23	18	0.45	0.66	0.28	18	0.29	0.58	0.1	
Muonio	53	3.59	**11.38**	0.02	18	3.55	**11.38**	0.02	18	3.41	**6.64**	0.3	17	3.82	**6.64**	0.22	Gravel extraction. trafic
Inari	51	0.35	0.46	0.25	18	0.38	0.46	0.31	18	0.38	0.42	0.35	15	0.28	0.32	0.25	

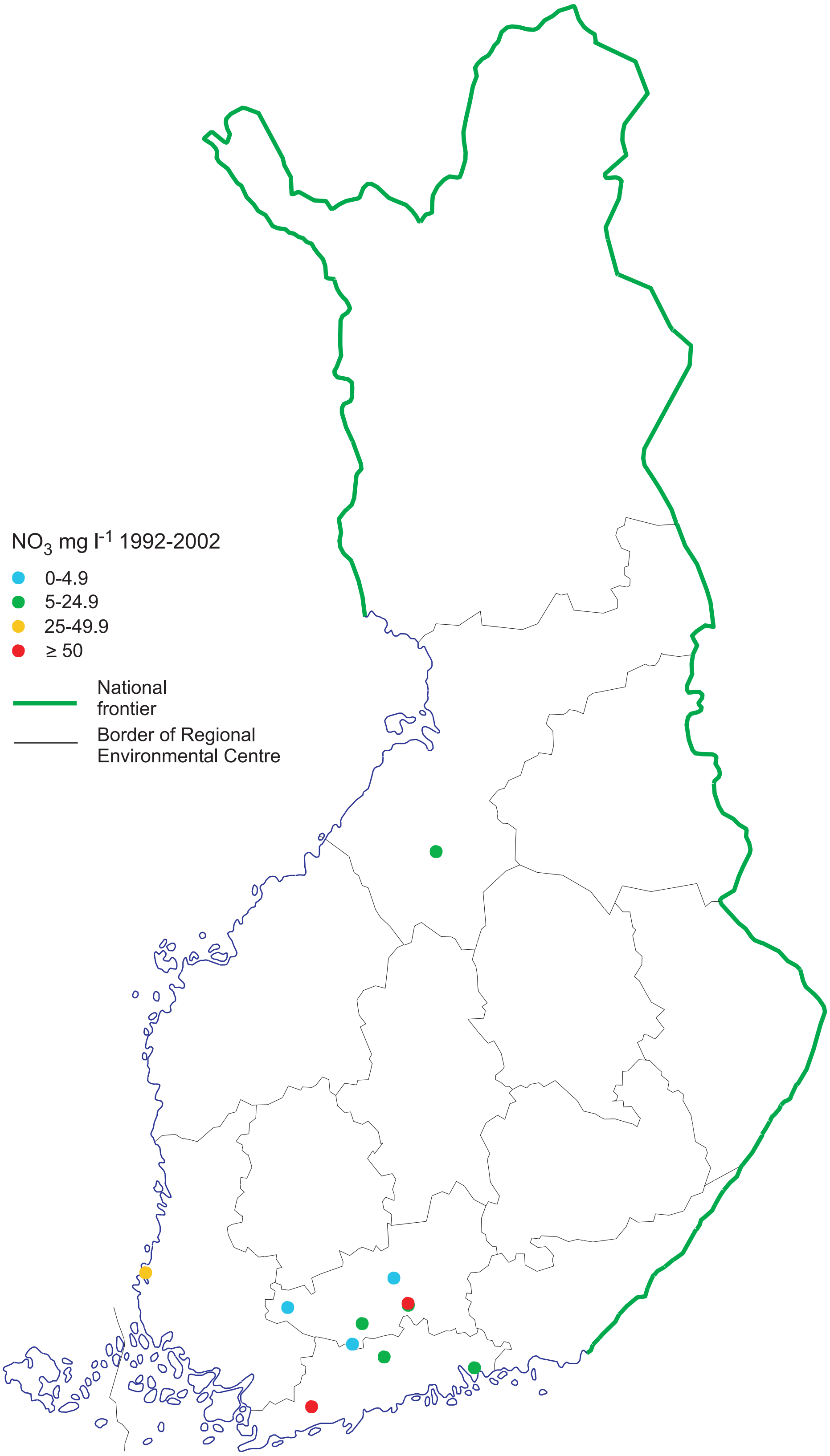

Figure 18. Mean nitrate concentrations (mg l^{-1} NO_3) in groundwater during the period 1992–2002 at groundwater observation sites situated near agriculture or farming.

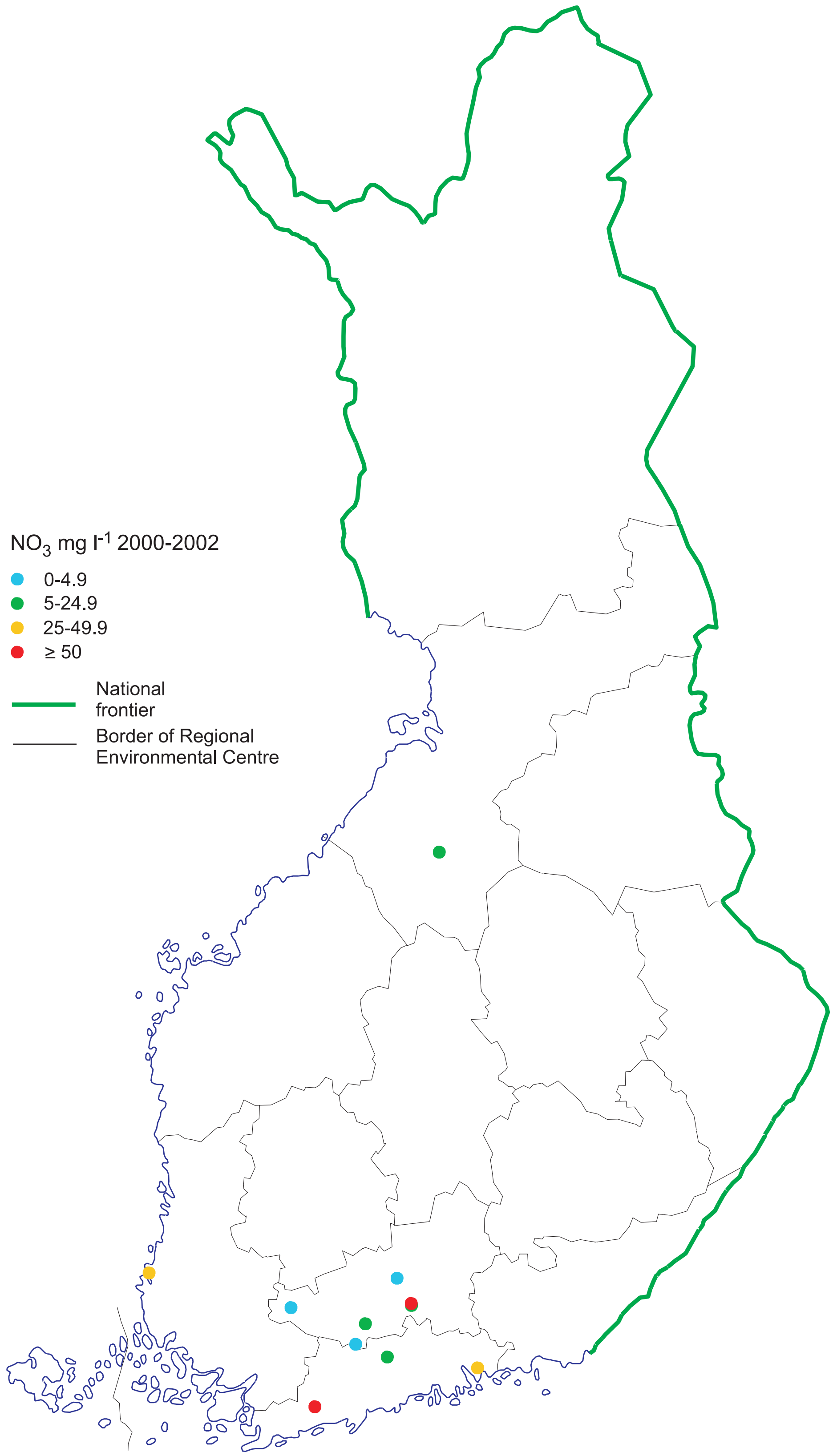

Figure 19. Mean nitrate concentrations (mg l^{-1} NO_3) in groundwater during the period 2000–2002 at groundwater observation sites situated near agriculture or farming.

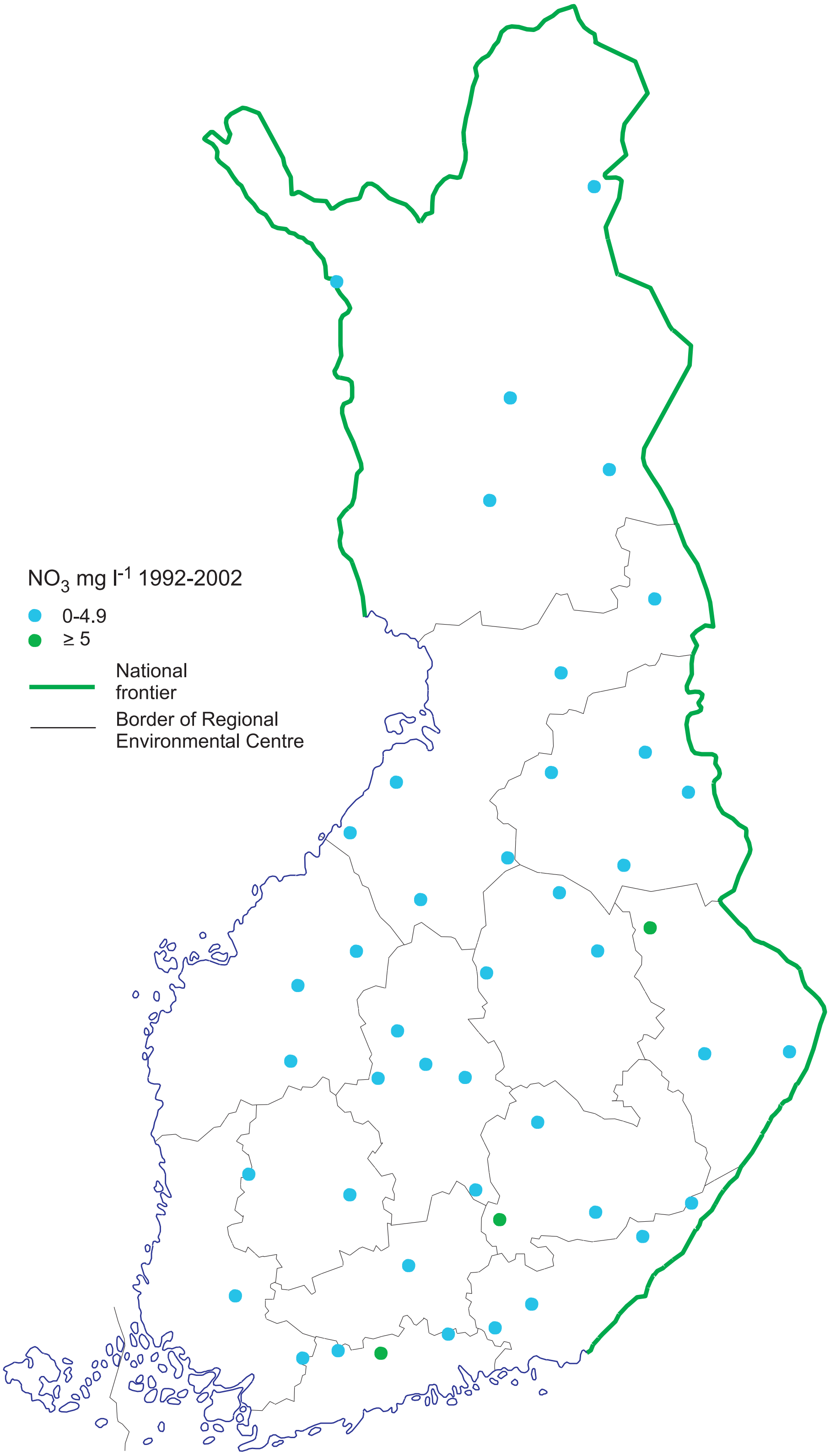

Figure 20. Mean nitrate concentrations (mg l^{-1} NO_3) in groundwater during the period 1992–2002 at observation sites with minor human impact.

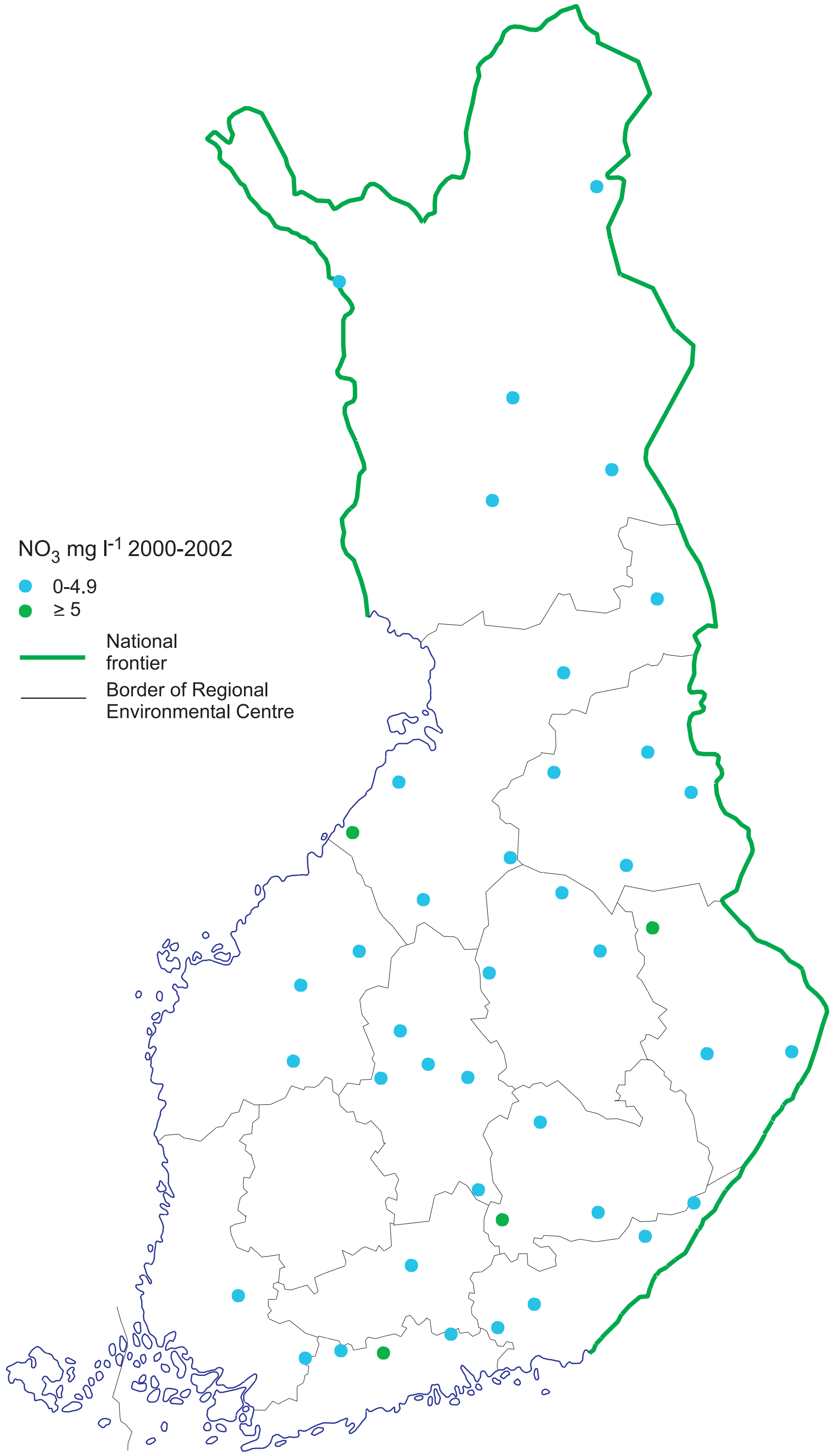

Figure 21. Mean nitrate concentrations (mg l^{-1} NO_3) of groundwater during the period 2000–2002 at observation sites with minor human impact.

4 Future development of water quality

Since 1995, strong emphasis has been directed towards reducing non-point nutrient loading from agriculture in Finland. By implementing two important policy measures – the Nitrates Directive and the Finnish Agri-Environmental Programme (FAEP) (Valpasvuo-Jaatinen et al. 1997; Ministry of Agriculture and Forestry 2004b) – it has become possible to introduce environmentally sound management practices on a wide scale. For instance, environmental support has reduced the total use per hectare of nitrogen and phosphorus in chemical fertilizers. The decrease of the nitrogen balance on fields indicates a lower leaching potential compared with the early 1990s. The area of filter strips has increased, as has the plant cover on arable land outside the growing season (Ministry of Agriculture and Forestry 2004a).

However, as a result of the structural development of agriculture, the concentration of livestock production in certain areas has continued, and in these regions the nutrient balances of arable land are higher than elsewhere. The recent mid-term evaluation of the Horizontal Rural Development Programme (Ministry of Agriculture and Forestry 2004a) suggests several improvements to the environmental support. Real plant cover during winter, by means of e.g. grass and green fallow, would be needed especially in southern Finland. At present, differences between regions and farms receive very little attention in the environmental support scheme and measures implemented on farms; however, the measures should be targeted at those areas which contribute most to the nutrient loading.

An assessment of the environmental impacts of the first period (1995–1999) of FAEP was carried out by Palva et al. (2001). Detailed data on cultivation practices were collected by interviewing farmers in four catchments in different parts of the country. The potential impacts of changes in cultivation practices on field-scale nutrient losses were assessed by mathematical modelling (Grönroos et al. 1998; Rekolainen et al. 1999; Granlund et al. 2000; Palva et al. 2001).

According to Palva et al. (2001), the average use of P and N in fertilizers during the first period of FAEP (1995–1999) decreased close to the crop-need levels defined in the programme. At present, smaller amounts of manure are applied, but application during the autumn was as common as before. The targeted winter green cover was mostly achieved by reduced tillage, but stubble and spring ploughing have also become more common. The estimated water quality effects were still small: e.g. in different study catchments a decrease of 4–15% in nitrate leaching was estimated to have taken place. Most of the reduction was due to decreased fertilization and manure application amounts.

It is difficult to estimate separately the water-quality effects of the Nitrates Directive and the agri-environmental support scheme because of their concurrent enforcement. Moreover, the high variability in short-term hydrological conditions impedes evaluation of water quality evolution. The positive effects of changed management practices may partly be masked by recent mild winter conditions. A hydrological time series analysis carried out in Finland by Hyvärinen (2003) showed that the annual maximum of the areal water equivalent of snow has been decreasing in the south and west during the period 1947–2001. The winter runoff has generally been increasing strongly in southern Finland. Annual discharge in the South and West has also increased to some extent. According to Drebs et al. (2002), the winters during the 1990s were warmer than normal. The year 2000 was considerably warmer than usual and the overall annual precipitation was high, on average 110–125% of the long-term mean. In 2001, the water storage in lakes and soils was decreasing, and in 2002, the dry weather caused severe droughts in the autumn (Monthly hydrological report 2000; 2001; 2002).

A recent comprehensive long-term (1975–2000) analysis of nutrient concentrations in Finnish rivers and lakes indicated no clear effects of decreasing non-point loading (Mitikka and Ekholm 2003; Räike et al. 2003; Ekholm and Mitikka 2004). On the contrary, increasing nutrient concentration trends were detected in southern and western Finland, especially in rivers flowing through agricultural areas (Räike et al. 2003). The results from the small agricultural catchments presented in chapter 2.5 are in accordance with those of Räike et al. (2003). The lower nitrogen export during 2000–2002 was related to dry weather. It is obvious that the water quality response to e.g. reduced fertilizer application can be slow and masked by variations in the hydrological regime. It will probably take several years before improvements in water quality can be observed in agricultural areas.

Several recent studies of agricultural catchments in Nordic and Baltic conditions have demonstrated that, especially in medium-sized and large catchments, the water quality response to reduced fertiliser application or to a decrease in agricultural intensity may be slow and limited (Löfgren et al. 1999; Stålnacke et al.1999; Grimwall et al. 2000; Stålnacke et al. 2003). According to a review by Grimvall et al. (2000), most of the interannual variation in the export of nutrients to the sea appears to be related to natural fluctuations in runoff, and the export of nitrogen has been particularly difficult to reduce. Moreover, it is important to consider the inertia of the aquatic and terrestial systems controlling the export of nutrients from land to sea (Grimwall et al. 2000). For example, according to Löfgren et al. (1999), large nutrient pools in soils provide a considerable potential for nutrient losses due to mineralisation and erosion.

Conclusions

5

There are several factors that affect nitrate concentrations in natural waters. Firstly, sector of production (crop cultivation, animal husbandry), and short term and long term measures in agriculture affect the amount of nitrogen loading. Annual hydrological conditions vary due to variations in precipitation and temperature. They affect runoff and discharges and consequently nutrient losses. During mild winters with occasional temperatures above zero and little snow, nutrients are transported to waters. On the other hand, during severe winters with low temperatures and thick snow cover, runoff and discharges are small and nutrients are not discharged in significant amount. Because of weather conditions nutrient loading to waters varies from year to year although no dramatic changes in the drainage basin have taken place. Furthermore, differences in sampling frequencies may affect the interpretation of results. Consequently weak upward and downward nitrate trends have to be judged with caution, in particular if the period investigated is short.

The cultivation measures

In Finland the number of farms has declined significantly since the early 1990s. However, the area under cultivation has not been reduced. The proportion of the farms with livestock went down by 10% from 1995 to 2002. In future, livestock farming will probably be concentrated in southwestern and western parts of the country. Animal units and nitrogen excreted by the animals have increased on farms which are not included in the Finnish Agri-Environmental Programme. The farms which are committed to the programme seem not to experience similar changes. The amount of chemical fertilizers applied on the fields has gone down by 12 kg ha^{-1} phosphorus since the beginning of the 1990s. Concentrations of soil phosphorus have also gone down because of lower fertilization levels.

Studies on manure storage have shown that storages that are in use do not cause harmful environmental effects. Slurry storages, which were built in 1980s, account for approximately 40% of the slurry storages that are in use. The average lifetime of a slurry storage is approximately 20 years. Because of this, these farms need to renew their manure storages within the next few years. According to the Government Decree, animal manure storage must be sufficiently large for manure accumulated over 12 months, excluding manure remaining on pasture during the same grazing season. In 1998, the manure storages were estimated to be too small in 65% of the animal farms. The Ministry of Agriculture and Forestry provided public investment aid for 1,795 manure storages and for 64 outdoor yards in the period 2000–2002. In many cases, farms with small manure storages are planning to give up livestock farming within the next few years.

The number of notifications made on deviation from the required volume for manure storage went down by 34% from 2001 to 2003. The number of manure heap notifications and manure heaps themselves have decreased, as has the amount of the manure sited in the manure heaps. A reduction was perceived in the areas of all the Regional Environmental Centres. Small manure storages were a less and less important reason for heaping manure. At the same time, technical reasons were increasingly the most common reason for heaping manure. In many cases, manure heaping is involved in plans to give up livestock farming within the rest few years. However, it is still a widely used method although the Nitrates Directive and the Government Decree have already been in force for several years. During the monitoring of the agricultural support (2000–2001), 212 cautions were issued about manure storage.

All livestock farms had to register with the Finnish environmental protection data system during the period 2001–2002. The authorities decided whether those farms needed an environmental permit for animal sheds or manure storages. The need for the permit depends on the number of animal, for example. An environmental permit must be applied for in the event of planning new activities or if current activities change significantly. In 2000–2002, the Regional Environmental Centres issued 297 environmental permits for farms classified as large production units. 63% of those units are situated in the area of Southwest Finland, West Finland or North Ostrobothnia Environmental Centres.

The Government Decree orders local authorities to report information on contraventions to the Regional Environmental Centres, which were asked to report such contraventions. Information about contraventions was received from only 8 Regional Environmental Centres because the local authorities did not report contraventions at all or reports were incomplete. Information on sanctions issued due to the contraventions is not available. Compliance with the Government Decree has been monitored in the context of the supervision of agricultural support. Monitoring files show that the rules have been conformed with.

Surface waters in Finland 2000–2002

In Finland's surface waters, the average level of nitrate is generally low, <10 mg l^{-1} NO_3. Maximum NO_3 concentration exceeded 25 mg l^{-1} at 93 sampling sites, and 20 mg l^{-1} at 130 sampling sites of a total of 2,376 sites studied in 2000–2002. After careful examination of those 130 sites, 35 sites were left in the group of significant waters where agriculture has a significant influence on water quality. These sites are situated in 20 rivers, streams or ditches, in one lake and in one bay in the Gulf of Finland. They are all waters in southern Finland where agriculture is most intensive and point-source loading is heaviest. In 2000–2002, total N load from agriculture into these waters was estimated to account for 18–68% of all sources, including natural discharge.

Lakes were mostly oligotrophic or mesotrophic and 80% of the lake area had excellent or good water quality. Total P concentration is higher in rivers than in lakes and this, together with high numbers of hygienic indicator bacteria, decreases the general water quality of rivers. Only 43% of rivers have excellent or good water quality. Coastal waters receiving waters from these rivers have typically been classified as satisfactory or passable.

Lakes affected by agriculture 1992–2002

Water quality changes in agriculturally loaded lakes in 1992–2002 were illustrated with 20 example lakes, where symptoms of eutrophication were common. Nitrate concentrations (mean or maximum) never exceeded 25 mg l^{-1} in these lakes in the three reporting periods 1992–1994, 1996–1998 and 2000–2002 or at any time in 1992–2002. A maximum concentration of 12 mg l^{-1} was found in winter 2000 in Lake Villikkalanjärvi, a small, shallow lake with a high field percentage in the catchment. Nitrate concentrations in lakes are normally higher in winter than in summer. NO_3 concentrations actually decreased to near undetectable concentrations in the summer in 19 of the 20 agricultural lakes studied in at least one study period.

Many of the lakes were not regularly monitored before 2000. Water quality observations tend, therefore, to be sparse and discontinuous, which confounds the detection of trends, in particular. In Lake Ylisjärvi, NO_3 concentrations decreased in the last period 2000–2002, being low in the summer of 2003, too. In Lake Lappajärvi, summertime NO_3 concentrations have increased during the latest period. A slight increase was also detected in total N concentrations in Lake Lappajärvi. NO_3, total P and total N concentrations decreased in the restored Lake Enäjärvi.

The recovery of most eutrophied agricultural lakes would call for a major reduction in the external nutrient loading supplemented with in-lake restoration measurements. Restoration has been carried out in many of these agricultural lakes, and some of the projects are co-financed by the EU Life Environment Fund.

Rivers affected by agriculture 1992–2002

The mean NO_3 concentration never exceeded 25 mg l^{-1} in river sites affected by agriculture during the three study periods 1992–1994, 1996–1998 and 2000–2002. However, the maximum NO_3 concentration exceeded 25 mg l^{-1} eight times and 20 mg l^{-1} six times. In rivers affected by agriculture, consistent trends could not be observed. In analysing all NO_3 observations from five agricultural rivers for the period 1992–2002 a weak upward trend was observed in three rivers and a weak downward trend in two rivers. It is hard to assess whether these trends are significant as there are several factors affecting the trends. For example, sampling frequency has varied substantially from 1992 to 2002, being higher in recent years. Furthermore, hydrological variations that were not studied also affect the NO_3 concentrations. The mean NO_3 concentration decreased considerably from 1996–1998 to 2000–2000 in three river sites, namely in Uskelanjoki, Paimionjoki and Aurajoki.

Nutrient concentrations in rivers affected by agriculture were higher than the general nutrient level in Finnish rivers, which is comprehensible. Total phosphorus concentrations in five agricultural rivers showed no trend in 1992–2002, whereas there was a slight upward trend in total nitrogen in two rivers.

Estuaries affected by agriculture 1992–2002

In coastal waters, nitrate concentrations have usually been small in all reporting periods. In 2000–2002 wintertime NO_3 concentration in the 19 estuaries studied were on average 4.4 mg l^{-1}, varying from 1.3 to 13 mg l^{-1}. Concentrations were occasionally elevated in some agriculturally loaded estuaries of the southern and southeastern Finland, but the maximum values remained below 15 mg l^{-1}. The critical value for NO_3 (25 mg l^{-1}) was exceeded in one shallow estuary, but this could mainly be explained by the high rate of resuspension. During the 1990s and 2000s, NO_3 concentrations showed no trend that could be linked to agricultural loading.

In general, the concentrations of NO_3 and other nutrients strongly depend on hydrological conditions. The occasional peaks in autumn and winter during 2000–2002 followed high runoff periods, which increased nutrient leaching from soil. Finland's estuaries are typically sensitive to nutrient loading, because they are usually shallow and have restricted water exchange with the open sea. Nevertheless, eutrophication in coastal waters is not only connected to loading, but also to climatic and hydrographical conditions. Especially during the stratified season, when the thermocline deepens and becomes stronger, oxygen concentrations near the bottom decrease and may cause phosphorus to release from the sediment to the water column. Thus, internal loading of phosphorus also contributes to the progress of eutrophication in some deep, semi-enclosed estuaries.

Groundwaters affected by agriculture 1992–2002

At aquifers under cultivation (cultivated area 6–82% of the groundwater area) the NO_3 concentration in groundwater was usually below 10 mg l^{-1}, but at two aquifers the NO_3 concentration exceeded 25 mg l^{-1}. In groundwater in cultivated areas, the highest NO_3 value was 62 mg l^{-1}. It is very difficult to prove a direct link between agricultural practices (type of nitrogen fertilizer, spreading time and practices, crops) and NO_3 content in groundwater as there is often a significant time lag between changes in agricultural practices and changes in NO_3 concentrations in groundwater. In most cases there is also a lack of information about historical and current agricultural practices in groundwater areas.

At the observation sites in the natural state, the NO_3 concentrations in groundwater were mostly between 0–1 mg l^{-1} and greater in till areas than in sandy areas. The seasonal variation of NO_3 in groundwater was considerable in several cases. The minimum value for NO_3 concentration was usually reached during the growing period in the middle of summer. Changes in land use in the groundwater recharge area usually have a strong influence on NO_3 concentrations. Forest cutting has increased NO_3 concentrations at several observation sites. There are also a number of gravel pits in the eskers. This type of gravel extraction removes the topsoil, making groundwater more sensitive to contamination by nitrogen emissions.

Future development of water quality

Water quality studies on agricultural catchments in Finland have indicated so far no effects on decreasing nutrient loading, even though massive expensive and widely adopted efforts have been put towards more environmentally friendly management practices since 1995. The slow response of water quality to changed practices (such as decrease of fertilization) has also been detected in other Nordic and Baltic countries. In addition, it is obvious that within a short time period (5–10 years) a possible decrease in potential loading may be masked by variations in the hydrological regime. As a result it can be concluded that no dramatic changes in water quality in agricultural catchments is to be expected within the next 5–10 years.

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Title of publication	Report on the implementation of the Nitrates Directive in Finland 2004	
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Abstract	This publication is the Finnish implementation report on the EU Nitrates Directive (91/676/EEC) given to EU in June 2004. The implementation of the Nitrates Directive is one of the policy measures aimed at decreasing nutrient, nitrates and phosphates, discharges and losses from agricultural sources. In Finland, the Nitrates Directive is transposed to national legislation through the Environmental Protection Act (2000/86) and Government Decree No 931/2000. The provisions of the Government Decree apply to the whole national territory of Finland. The Decree contains provisions on good agricultural practices, storage of manure, spreading and allowable quantities of fertilizers and silage liquor, analysis and recording of nitrogen in fertilizers and enforcement of the Decree. The Regional Environment Centres and the municipal environmental authorities are responsible for the enforcement of the Decree. The whole country has been evaluated as a nitrate vulnerable area. In this report, concentrations of nitrate and other variables indicating eutrophication (total P, total N and chlorophyll a) were studied in all Finnish surface waters during the last reporting period 2000-2002. In addition, seasonal and annual changes in these 4 variables were investigated in 20 lakes, 23 rivers and 19 estuaries, which all receive nutrients primarily from agricultural sources. Investigation period focused mainly on years 1992-2002. However, long-term changes in agricultural nitrogen leaching were studied in detail in three agricultural catchments for the period 1981-2003. The background information about the quality of groundwater came from 53 sites of the Environment Administration's ground water monitoring. The impact of agriculture on groundwaters was asessed with monitoring data from 12 aquifers situated in or near agricultural areas. Changes in cultivation measures were not noticed to have significant effect on discharges or water quality.	
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Tiivistelmä

Julkaisu on EY:n nitraattidirektiivin (91/676/EEC) toimeenpanosta Suomessa laadittu raportti, joka on toimitettu EU:lle kesäkuussa 2004. Nitraattidirektiivin toimeenpanolla pyritään vähentämään maataloudesta peräisin olevien ravinteiden, typen ja fosforin, joutumista vesiin. Direktiivi sisältyy kansalliseen lainsäädäntöön ympäristönsuojelulaissa (2000/86) ja valtioneuvoston asetuksessa maataloudesta peräisin olevien nitraattien vesiin pääsyn rajoittamisesta. Valtioneuvoston asetuksen säännökset koskevat koko Suomea. Asetus sisältää säännöksiä, jotka koskevat hyviä maatalouskäytäntöjä, lannan varastointia, lannoitteiden levitystä ja määriä, lannan typpianalyysiä ja sen kirjaamista sekä asetuksen täytäntöönpanoa.

Suomen kaikki pinta- ja pohjavedet on arvioitu herkiksi nitraatin aiheuttamalle rehevöitymiselle. Raportissa selvitettiin ensin nitraatin ja muiden rehevöitymistä indikoivien muuttujien (kokonaisfosfori ja -typpi, a-klorofylli) pitoisuudet kaikissa pintavesissä viimeisellä direktiivin raportointijaksolla 2000-2002. Pitoisuusvaihteluita tarkasteltiin jaksolla 1992-2002 tarkemmin 20 järvessä, 23 joessa ja 19 estuaarissa, jotka kaikki olivat pääosin maatalouden kuormittamia. Nitraatin huuhtoutumisen pitkäaikaisvaihteluita tarkasteltiin kolmella maatalousvaltaisella pienellä valuma-alueella jaksolla 1981-2003. Pohjavesien pitoisuuksia tarkasteltiin 53 lähes luonnon-tilaisella alueella sekä 12 alueella, joilla maatalous on merkittävä nitraatin lähde.

Viljelytoimenpiteiden muutosten ei ole havaittu vaikuttaneen merkittävästi vesistökuormitukseen tai edelleen veden laatuun.

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Sammandrag	Publikationen är en rapport om implementeringen av Europeiska unionens nitratdirektiv (91/676/EEG) i Finland, avgiven till EU i juni 2004. Genom implementering av nitratdirektivet vill man minska mängden näringsämnen, snarast kväve och fosfor, som kommer från jordbruket i vattnen. Direktivet ingår i den nationella lagstiftningen i miljövårdslagen (2000/86) och i statsrådets förordning om begränsning av utsläpp i vatten av nitrater från jordbruket. Stadgandena i statsrådets förordning gäller hela Finland. Förordningen innehåller stadganden som gäller god jordbrukspraxis, lagring av stallgödsel, spridning av och mängden gödselmedel, kväveanalys av gödseln och bokföring av kvävegödselmängderna samt ikraftträdande av förordningen. Alla yt- och grundvatten i Finland har bedömts vara känsliga för eutrofiering förorsakad av nitrater. I rapporten redogjordes först för halterna av nitrat och andra eutrofieringsindikatorer (totalfosfor, totalkväve, a-klorofyll) i alla ytvatten under direktivets senaste rapporteringsperiod 2000-2002. Variationerna av dessa halter undersöktes närmare för perioden 1992-2002 i 20 sjöar, 23 vattendrag och 19 estuarier som alla huvudsakligen belastades av jordbruket. Långtidsvariationerna av nitrathalterna under perioden 1981-2003 undersöktes med data från tre jordbruksdominerade små avrinningsområden. Halterna i grundvatten undersöktes i 53 områden som befann sig nästan i naturtillstånd samt i 12 områden där jordbruket är en betydande nitratkälla Förändringar i jordbrukspraxis tycks inte ha påverkat belastningen på vatten och därmed inte heller vattenkvaliteten i någon betydande grad.	
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