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THE FINNISH ENVIRONMENT

ENVIRONMENTAL PROTECTION

Mikko Kiirikki, Pirjo Rantanen, Riku Varjopuro, Anne Leppänen, Marjukka Hiltunen, Heikki Pitkänen, Petri Ekholm, Elvira Moukhametshina, Arto Inkala, Harri Kuosa and Juha Sarkkula

Cost effective water protection in the Gulf of Finland

Focus on St. Petersburg

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Contents

Summary

The present work was carried out using the best information and methods available. However, there are still gaps in our knowledge both in nutrient loading and its long term effects on the brackish water ecosystems. Therefore our results should be considered as preliminary guidance, showing only the direction, approximate scale and coarse location of the effects that could be achieved by reducing the anthropogenic nutrient load. We have concentrated here on the Gulf of Finland, because it is clearly the most eutrophied sub-basin of the Baltic Sea. However, our work also covers the adjacent Archipelago Sea and the northern parts of the Baltic Proper. Especially in the case of the morphologically complex Archipelago Sea with thousands of small islands, our tools have been rough. Despite this, we believe that the results presented here could offer a new starting point for discussion about the measures needed to remedy the ecosystem of this unique part of the Baltic Sea.

The main effort of the present work was directed to clarifying the state of the St. Petersburg water sector and quantifying both the cost and the load decreases, which could be achieved by the planned water protection measures. In the case of the Finnish national efforts, we relied on previously published sources.

We tried to make both the nitrogen- and phosphorus-dominated nutrient load reductions comparable in order to facilitate the cost effectiveness calculation. We call this new concept “the nitrogen equivalent ton”, which refers here either to one ton of biologically available nitrogen or 0.14 tons of biologically available phosphorus. According to our calculations, the lowest removal cost of one nitrogen equivalent ton, below 1 000 €, can be achieved by chemical phosphorus removal in the present St. Petersburg waste water treatment plants. The construction of the St. Petersburg South-Western waste water treatment plant, as well as improved nitrogen removal in the Finnish coastal waste water treatment plants, were estimated to be equally cost effective with a removal cost of ca. 5 000 €/ton. There are several uncertainties associated with the cost estimation of the Northern collector sewer. Based on different cost calculations, the removal cost may vary between 5 500 and 11 000 €/ton.

Despite cost-effective measures, such as improved nitrogen removal, the average cost of the national nutrient load reductions defined in the “Finnish Programme for the Protection of the Baltic Sea” reaches 28 000 €/ton, mainly because of the very high cost of applying waste water treatment in sparsely populated areas. The effective treatment of the waste waters from scattered settlements may be expensive if considered for the Baltic Sea, but it may be the only way to improve water quality in lakes with high recreational value.

The Finnish national water protection measures appear to be effective in combating eutrophication in the Archipelago Sea and along the Finnish Gulf of Finland coast, especially close to the major loading points e.g. the Helsinki and Kotka archipelagos. The national measures were found to be actually the only means for effective improvement of the state of the Archipelago Sea. None of the measures in St. Petersburg can solve the eutrophication problem of the whole Gulf of Finland alone. However, development of the St. Petersburg waste water sector to meet the Finnish standards together with effective measures in Finland could diminish the algal biomass in the whole Gulf of Finland considerably. In practice, the national

load reductions should be observable in the coastal zone and in the archipelago as increasing water clarity and cleanness of beaches. However, the risk of cyanobacteria blooms now only occasionally entering the archipelago, would probably become temporarily slightly higher. This effect is caused by changes in the nitrogen/ phosphorus -ratio promoting the competition of of cyanobacteria over other algal species. We believe that in a longer perspective than our 5-year model simulations can demonstrate, all nutrient load reductions would have a decreasing effect on the cyanobacteria blooms in the open Gulf of Finland and in northern parts of the Baltic Proper. The only single measure that might have a rapid decreasing effect on the cyanobacteria biomass is chemical phosphorus removal in the present waste water treatment plants of St. Petersburg. This alone would cut the biologically available phosphorus load to the Gulf of Finland by 18%. The same measure also seems to be the best way to decrease phytoplankton biomass in front of the most important recreational area near St. Petersburg, the Kurort resort zone (Terijoki).

People in Finland, especially those who live by the coast, are well aware of the eutrophication problem. Toxic algal blooms on the open sea are naturally seen as a serious problem, but other eutrophication-related phenomena such as water turbidity and fouling of beaches are also considered important. Because both the coastal and the open sea phenomena must be taken into account, there is no single water protection measure which could solve the nuisance problem. Both national and international measures are necessary. Generally the effects of own activity, such as untreated waste waters from summer houses, are evaluated to have little effect on water quality. The scapegoats are found either on the Russian side of the border or in Finnish industry, municipalities and agriculture. The population living on the coast and in the archipelago has the most positive attitude towards the investment of Finnish government money in water protection measures carried out in neighbouring countries. Over 50% supported the idea that Finland could take part in the financing of waste water treatment in St. Petersburg.

Introduction

1

Eutrophication is still the most serious environmental problem in the Gulf of Finland (GoF), although considerable load reductions have taken place in both Russia and Estonia (Pitkänen *et al.* 2001). The load from Finland has also been reduced and local improvement of water quality has been observed close to important point sources (Kauppila & Bäck 2001). However, the symptoms of eutrophication have not disappeared mainly because the internal nutrient load has remained high in the eastern GoF during the late 1990s (Pitkänen *et al.* 2001). The poor situation in the eastern GoF has also affected the western parts of the GoF and probably also the Archipelago Sea.

In the process of internal loading, nutrients already bound to bottom sediments are released back to water. High internal nutrient loading is induced by oxygen deficiency caused by accumulation of decaying phytoplankton biomass, detritus, to the bottom. The largest oxygen depleted areas have been observed in the open eastern GoF, and also locally in deep depressions along the Finnish archipelago zone. The biomass production of phytoplankton increases towards the east, peaking in the estuary of the river Neva (Pitkänen *et al.* 1993). Thus the settling detritus biomass is high in the eastern GoF, making it vulnerable to internal loading. The distribution of detritus carbon is illustrated in Fig. 1, representing modelled organic carbon concentration in the active surface layer of the bottom sediment. The only possible way to decrease internal loading in the sub-basin scale is to further cut external nutrient load in order to decrease production of phytoplankton biomass.

The cost of cutting nutrient load varies over several orders of magnitude depending on the loading sector and country. It has already been theoretically demonstrated that equal load reduction percentages for every country around the Baltic Sea do not lead to a cost-effective solution, because the present standards for water protection vary between the western and the transition economy countries (Wulff *et al.* 2001, Ollikainen & Honkatukia 2001). In the western countries the politically easy and relatively cheap measures have already mainly been carried out.

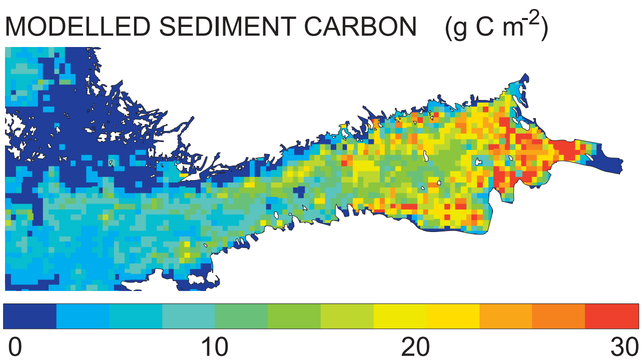


Fig. 1. Output from the Baltic Sea ecosystem model describing the accumulation of detritus carbon to the active surface layer of the bottom sediment. The resolution of the model is 5 km, which prevents it from describing small scale accumulation areas in the archipelago.

The whole Baltic Sea is not equally vulnerable to nutrient loading. From the ecological point of view, the load reductions should be directed into the areas where biomass production is already so high that oxygen deficiency is a regular phenomenon, such as in the eastern GoF, or in the archipelago where water exchange is limited. The only way to evaluate the ecosystem response to the load reductions is to use mathematical models describing the main features of both the physical and chemical environment where the biological processes take place.

In the present work, the existing knowledge on the present and planned water protection programs and individual important water protection measures within the drainage areas of the Gulf of Finland and the Archipelago Sea is summarised. The potential effects of these measures on water quality are visualised by using models operating in two scales. Large scale effects are evaluated using the Baltic Sea ecosystem model (Kiirikki *et al.* 2002) and local effects close to the coastline and within the archipelago using local ecosystem model applications (Kiirikki *et al.* 2002, Korpinen *et al.* 2002).

The research consortium of the project was formed by the Finnish Environment Institute (SYKE), Environment Impact Assessment Centre of Finland Ltd (EIA) and the Finnish Institute of Marine Research (FIMR). The cooperation group of the project consisted of representatives of the environmental administration, consulting companies and private enterprises operating in the St. Petersburg area (Table 1). The group provided invaluable help in collection of the fractured information of the St. Petersburg water sector. The Russian co-operation partners were St. Petersburg Waterworks "Vodokanal" and the Ministry of Natural Resources. The cooperation group held four meetings. The project was financed by the Environment Cluster Research Programme of the Finnish Ministry of the Environment.

The original objectives of the work were:

- To produce information on the cost and effects of planned water protection measures for the Finnish and Russian environment authorities and for the Helsinki Commission.
- To produce preliminary information on the present state and development plans of the St. Petersburg water sector for the preparation of the "Finnish Program for the Protection of the Baltic Sea" during the years 2000-2001.
- To clarify the potential effects of Finnish and Russian water protection measures in the remediation of the Gulf of Finland.
- To produce supportive information for the preparation of an international financing program for the St. Petersburg Waterworks.
- To develop a methodology which can be used in the evaluation of remediation strategies in similar water bodies around the world.

Table 1. Cooperation partners and researchers in the Environment Cluster Research Programme project "Cost effective water protection in the Gulf of Finland".

Co-operation group	
Finnish Ministry of the Environment	Eeva-Liisa Poutanen (supervisor)
	Tapani Kohonen
St. Petersburg waterworks "Vodokanal"	Tatyana Perednya
Russian Ministry of Natural Resources	Irina Markovetc
Finnish Institute of Marine Research	Matti Perttilä
Uusimaa Regional Environment Centre	Leena Villa
Southeast Finland Regional Environment Centre	Pentti Välipakka
Southwest Finland Regional Environment Centre	Pasi Laihonen
Finnish Environment Institute	Heikki Pitkänen
	Juha Sarkkula
Plancenter Ltd	Timo Markkanen
Water Pro Partners Oy	Matti Iikkanen
Soil and Water Ltd	Jyrki Kaija
Kemira Chemicals Ltd	Hannu Luhtala
Finnish Centre for Russian and East-European studies	Antti Helanterä
Finnish Game and Fisheries Research Institute	Antti Lappalainen
Ympäristö ja talous ry	Ilkka Herlin
WWF	Anita Mäkinen
Environment Impact Assessment Centre of Finland Ltd	Jorma Koponen
Helsinki Water	Esko Tiainen
SCC Viatek Ltd	Kai Vakkila
Research group	
Finnish Environment Institute	Mikko Kiirikki
	Pirjo Rantanen
	Riku Varjopuro
	Anne Leppänen
	Marjukka Hiltunen
	Petri Ekholm
	Elvira Moukhametshina
Finnish Institute of Marine Research	Harri Kuosa
Environmental Impact Assessment Centre of Finland Ltd	Arto Inkala

2 Nutrient load

2.1 Development of nutrient loading from the late 1980s to 2000

Heikki Pitkänen

During the 1990s, nutrient discharges from the catchment area to GoF decreased significantly, approximately by 40 % of the total nitrogen and phosphorus load (Fig. 2). The decrease was especially steep during the first half of the 1990s (Pitkänen *et al.* 2001). The most important factors for the reduction were economic changes and subsequent decrease in both agricultural and industrial production in Russia and Estonia at the beginning of the 1990s, after the collapse of the Soviet Union. Thus, especially nutrient load to the eastern and southern GoF decreased. The change was only to a small extent due to active water protection measures (Lääne *et al.* 2002). No decrease can be observed in the total nutrient load entering the Archipelago Sea (Fig. 3), although the load from fish farming decreased considerably in the late 1990s (Silvo *et al.* 2002). In fact, during 1996-2001 a clear increasing trend is evident in the riverine nutrient inputs.

According to the available data, no major changes took place in the total nutrient input to GoF between 1997 and 2000. The Estonian load still continued to decrease, which can possibly be explained by the present low levels of agricultural activity. There was some increase in the Finnish values. The increase is clear especially for nitrogen discharges of agricultural rivers and appears to be strongly connected with simultaneous high water flows in the winter and autumn of 2000. Despite agricultural water protection measures, such as decrease in the use of fertilizers and implementation of protection zones, no decreasing trend can be observed in riverine nutrient fluxes during the 1990s (Vuorenmaa *et al.* 2002). The estimated Russian values for 2000 are slightly lower than those for the late 1990s, but this could be a result of minor differences in the calculation and estimation of the inputs.

According to the present data, the annual external nutrient inputs to the GoF were about 6 400 t of total phosphorus and 120 000 t of total nitrogen in the year 2000. Of these amounts c.a. 70 % of phosphorus and 50 % of nitrogen enters the GoF in its easternmost part. About 40 % of the phosphorus (2 800 t a^{-1}) and 60 % of nitrogen (77 000 t a^{-1}) inputs are estimated as readily bioavailable for primary producers (Ekholm 1998, Silvo *et al.* 2000) (Table 2). The largest single source of bioavailable phosphorus is the city of St. Petersburg, whereas the river Neva is responsible for the largest single proportion of bioavailable nitrogen (Fig. 4). The mean ratio of bioavailable N/P (ca. 30 w/w) of the inputs demonstrates a clear excess of nitrogen when compared to the optimum Redfield ratio (7.2 w/w) for primary production in the sea. Despite the generally positive development, the area specific nutrient load of the late 1990s to the whole GoF was 2 to 3 times the load of the whole Baltic Sea. In the eastern Gulf the corresponding factor was about 4 to 5 (Pitkänen *et al.* 2001).

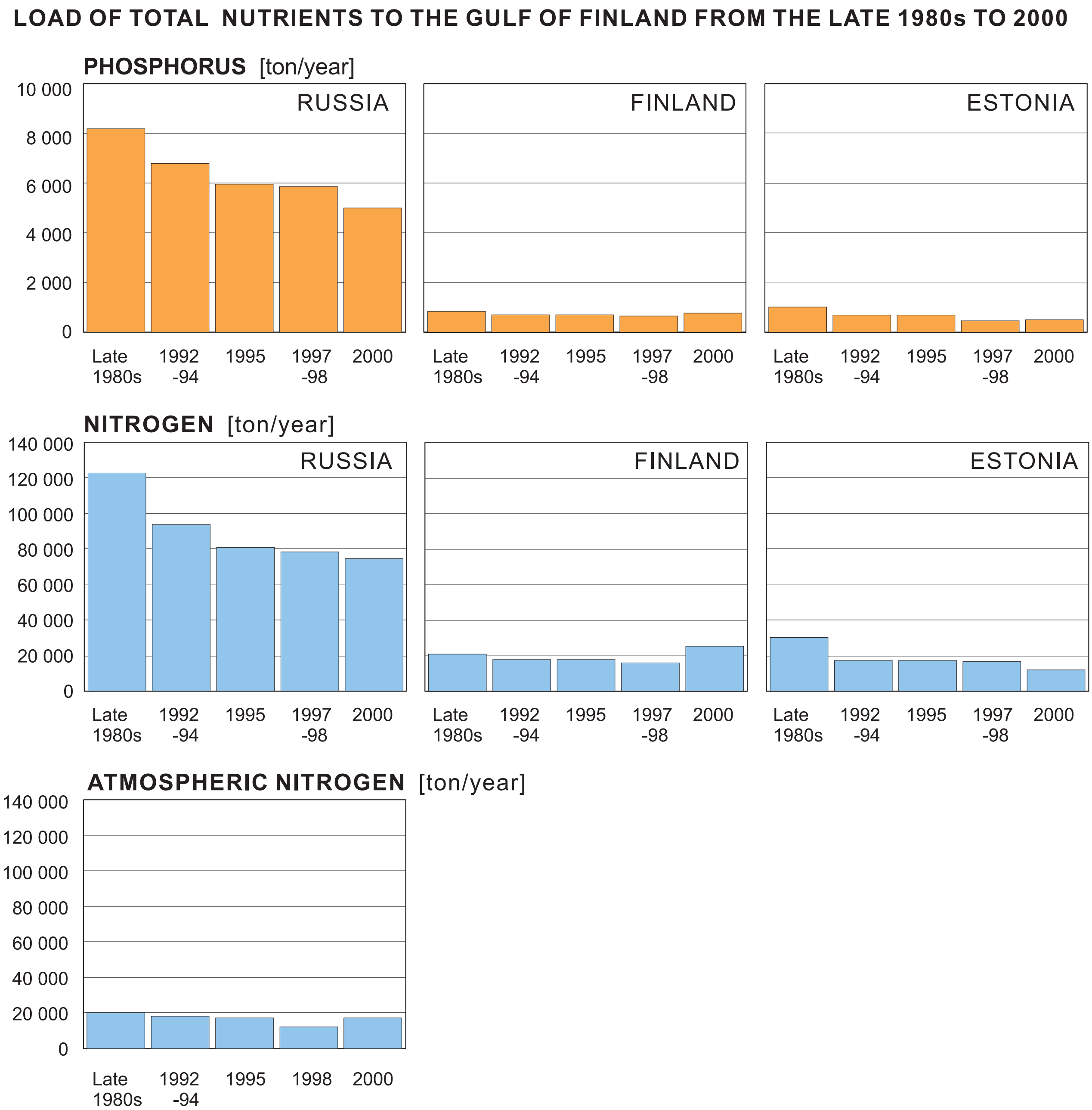


Fig. 2. Development of total nutrient load to the Gulf of Finland from the late 1980s to the year 2000. The data until 1998 is from Pitkänen et al. (2001). The Estonian data for 2000 comes from the Estonian Environment Information Centre, the Finnish data from the Finnish Environment Institute and the Russian data from the PLC4 data set (Ecology and Business: L. Korovin, pers. comm.). The last available atmospheric load represents the year 2000 (Bartnicki et al. 2002). The load from the river Narva has been divided between Estonia (1/3) and Russia (2/3) on the basis of the area of the drainage basin.

LOAD OF TOTAL NUTRIENTS TO THE ARCHIPELAGO SEA FROM THE LATE 1980s TO 2001

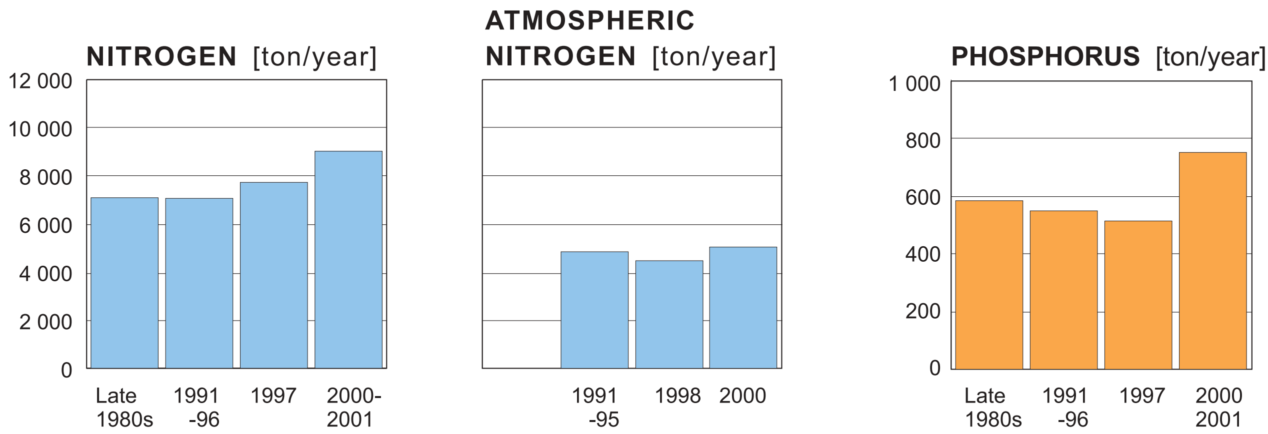


Fig. 3. Development of total nutrient load to the Archipelago Sea from the late 1980s to the year 2001. The data until 1998 is based on Kauppila & Bäck (2001) and that for 2000-2001 Pitkänen and Räike (pers. comm.). The atmospheric nitrogen load for 1991-1995 is based on Kirkkala et al. (1998), for 1998 on Bartnicki et al. (2001) and for 2000 on Batnicki et al. (2002).

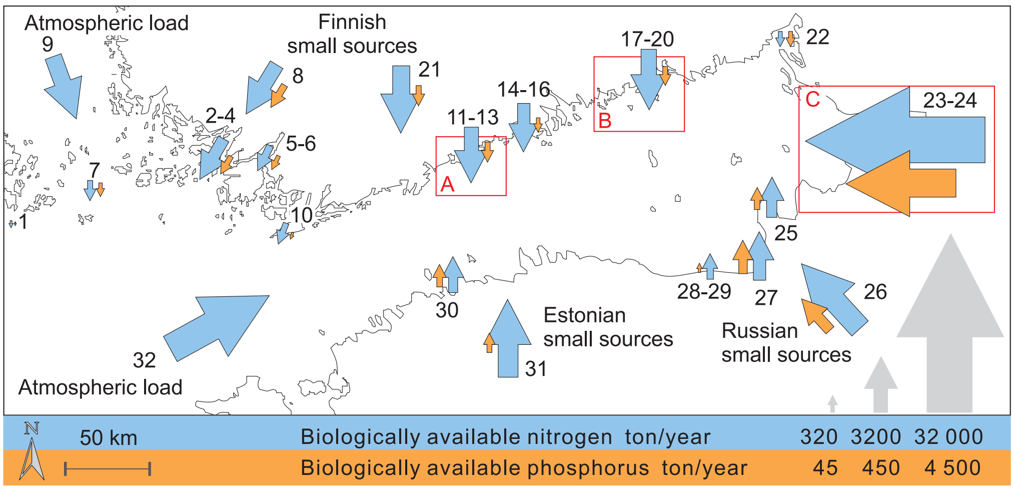


Fig. 4. Biologically available nutrient load to the Gulf of Finland and the Archipelago Sea in the year 2000. The numbers of the major loading points refer to Table 2, where the original data is presented. The high resolution areas of the local ecosystem model applications are presented in the figure: A) Helsinki–Espoo, B) Kotka–Hamina, C) St. Petersburg – Neva.

Table 2. Biologically available nutrient load to the Gulf of Finland and the Archipelago Sea. The locations of the major loading points are presented in Fig. 4. The Estonian data originates from the Estonian Environment Information Centre (EEIC), the Finnish data from the Finnish Environment Institute (SYKE) and the Russian data from the PLC4 data set (Ecology and Business: L. Korovin, pers. comm.). The load from the river Narva has been divided between Estonia (1/3) and Russia (2/3) based on the area of the drainage basin. The biological availability of the total nutrient loads follows Ekholm & Krogerus (2002) and Silvo et al. (2000). River loads include scattered and natural background loading.

Number in Fig 4.	Name of loader	Type	Year	Biologically available nitrogen (ton/year)	Biologically available phosphorus (ton/year)	Reference
1	Mariehamn	municipal	2000	52	0,4	SYKE
2	Turku	municipal	2000	446	5	SYKE
3	Aurajoki	river	2000	659	27	SYKE
4	Paimionjoki	river	2000	959	36	SYKE
5	Kiskonjoki	river	2000	294	7	SYKE
6	Uskelanjoki	river	2000	470	27	SYKE
7	Fish farming in Archipelago Sea		2000	487	30	SYKE
8	Small sources to Archipelago Sea		2000	3 838	148	SYKE
9	Atmospheric load to Archipelago Sea		1998	4 400		Bartnicki et al. 2001
10	Karjaanjoki	river	2000	413	7	SYKE
11	Espoo	municipal	2000	399	5	SYKE
12	Helsinki	municipal	2000	1 224	21	SYKE
13	Vantaanjoki	river	2000	1 449	29	SYKE
14	Mustijoki	river	2000	728	11	SYKE
15	Porvoonjoki	river	2000	1 483	20	SYKE
16	Porvoo	municipal	2000	124	0,5	SYKE
17	Kymijoki	river	2000	2 726	62	SYKE
18	Kotka	municipal	2000	130	0,8	SYKE
19	Koskenkylänjoki	river	2000	528	9	SYKE
20	Virojoki	river	2000	130	2	SYKE
21	Small Finnish sources to Gulf of Finland		2000	4 520	68	SYKE
22	Vyborg	municipal & industri	1996	249	36	Anonymous 1997a
23	St. Petersburg	municipal	2000	11 900	1 310	SYKE
24	Neva	river	2000	19 000	520	SYKE
25	Luga	river	2000	1 344	30	PLC-4
26	Russia: small sources		2000	7 874	355	PLC-4
27	Narva	river	2000	2 367	160	EEIC
28	Sillamäe	industri & municipal	2000	467	3	EEIC
29	Kohtla-Järve	municipal	2000	306	9	EEIC
30	Tallinn	municipal	2000	1 289	80	EEIC
31	Estonia: small sources		2000	6 063	51	EEIC
32	Atmospheric load to the Gulf of Finland		1998	12 700		Bartnicki et al. 2001
	Gulf of Finland: Total			**77 000**	**2 800**	
	Gulf of Finland: Finland			**14 000**	**240**	
	Gulf of Finland: Estonia			**8 900**	**200**	
	Gulf of Finland: Russia			**42 000**	**2 360**	
	Archipelago Sea: Total			**12 000**	**280**	

2.2 National load reduction targets for Finland, Estonia and Russia

Mikko Kiirikki

Because Estonia was able to reach the goal of the year 1988 HELCOM Minister Declaration by reducing its anthropogenic nitrogen load by 65 % and phosphorus load by 50 % between the late 1980s and 1995, there has not been a national need to set more specific targets for further load reductions (Lääne *et al.* 2002). However, in 1997 the Estonian Parliament adopted the National Environment Strategy in order to implement EU directives and international agreements. At present, major investments are channelled for the implementation of the Urban Waste Water Treatment Directive. The total cost of implementation is estimated to be more than 325 M€. In addition to domestic waste waters, the directive implementation will also cut the industrial load, because in Estonia industrial and domestic waste waters are treated in common treatment plants (Lääne *et al.* 2002). It seems highly probable that there will not be any considerable changes in the Estonian nutrient load in the near future. The implementation of EU-directives will probably compensate the pressures caused by economic growth.

Finland has not been as successful in reaching the goal of the HELCOM Minister Declaration as its neighbouring countries Estonia and Russia, partly because the starting situation was better, at least in the case of municipal and industrial waste water treatment. The Finnish reduction in nitrogen load was 15% and in phosphorus load 18% between the late 1980s and 1995 (Lääne *et al.* 2002). More specific targets to further reduce the nutrient load are specified in a decision-of-principle of the Finnish Council of State ”Water Protection Targets to 2005”, which aims at further 45% reduction in the phosphorus and 40% reduction in the nitrogen load entering the surface waters (Anonymous 1998a). Updated targets for a longer perspective, 10-20 years, are presented in a decision-of-principle of the Finnish Council of State ”Finnish Programme for the Protection of the Baltic Sea” (Anonymous 2002a). The main emphasis in this programme is to reduce the load from agriculture, which is the dominating loading sector in Finland. There is also a proposal to improve nitrogen removal efficiency in inland waste water treatment plants. Support for the development of the waste water treatment in St. Petersburg is part of the program.

The additional water protection cost caused by the program is estimated to be ca. 700 M€ for the whole period (Anonymous 2002a). This figure includes only a minor part of the agro-environmental support and it does not include the costs to industry at all. No reliable estimate of the total cost is available. In the present work we used the cost estimate for ”Water Protection Targets to 2005” calculated for the GoF drainage basin by Kiirikki *et al.* (2000). These targets are fully included in the “Finnish Programme for the Protection of the Baltic Sea”. Thus the estimated present value for a 20-year period, 1400 M€ may be considered as a minimum value of the actual cost.

For Russia, there are no quantitative water protection targets available either for the federal or regional level.

2.3 Municipal nutrient load from St. Petersburg

Pirjo Rantanen & Petri Ekholm

2.3.1 Sewage treatment in St. Petersburg

The wastewater flow data of St. Petersburg and the Leningrad Region was acquired from several sources (Table 3). It is regrettable that these sources do not agree about the flows. The statistics were also somewhat difficult to interpret. In this study the most reliable reference for municipal flow data was considered to be the internal statistics of Vodokanal (Vodokanal 2001a). The decision was based on the knowledge that Vodokanal was the source of the primary data of purified waste water. This data was collected by the Neva-Ladoga Basin Water Management Administration for the environmental statistics of St. Petersburg (V. Budarin 8.5.2001 pers. comm., Anonymous 2002b). Nevertheless these references do not agree with each other. The flow of industrial direct discharges, 300 000 m^3/d, is taken from the environmental statistics of the city of St. Petersburg (Anonymous 2002b). The values selected to be used in the further calculations are presented in the first column of Table 3. The total waste water flow was estimated to be 3 420 000 m^3/d and the flow of untreated waste water 960 000 m^3/d, representing 28 % of the total flow.

In the year 2000, there were three major waste water treatment plants (later in this text WWTP) in the city of St. Petersburg: Central, Northern and Krasnoselskaya WWTPs. The amount of wastewater treated in these plants was 2 200 000 m^3/d in 2000. The total capacity of the three plants is 2 770 000 m^3/d. The whole capacity is not in use because the Northern WWTP receives wastewater only for half of its capacity. Outside St. Petersburg but under the auspices of St. Petersburg waterworks, SUE Vodokanal of St. Petersburg, there are 16 other treatment plants ranging in treatment capacity from 200 to 66 000 m^3/d (Table 4).

The treatment plants are conventional activated sludge treatment plants with mechanical screening, sand removal, primary sedimentation, aeration and secondary sedimentation. No chemicals are added to remove phosphorus. However, the influent water has a rather high concentration of iron (e.g. 7.5 mg/l at the Northern WWTP in 2000, Vodokanal 2001d), which partially precipitates phosphorus. At the Central and Northern WWTPs nitrogen is removed by nitrification and denitrification. Nitrification is achieved by sufficient aeration and sludge age. No special denitrification compartment exists, since the whole length of the activated sludge basin is aerated. Obviously the aeration is insufficient, thus enabling anoxic conditions and denitrification to occur. At the Central WWTP the sludge formed in the treatment process is dried with centrifuges and incinerated. At the Northern, Krasnoselskaya and other WWTPs the sludge is dried with centrifuges and transported to sludge disposal sites inside St. Petersburg.

The reported nutrient concentrations of the industrial waste waters, 0.9 mg/l of total nitrogen and 0.3 mg/l of total phosphorus in the year 2000 (Neva-Ladoga basin water management administration: V. Budarin 8.5.2001 pers. comm.), were so low that if the concentrations are correct it is questionable whether they should be treated as waste water at all. It is also impractical to lead this water into WWTPs, where it dilutes the incoming water, thus making the nutrient removal inefficient. Parts of the waste waters are probably stronger than others. Since no reliable data exists, the industrial waste waters are not dealt with in the load calculations. Thus the total waste water flow in the year 2000 discussed in this text is ca. 3 100 000 m^3/d.

Ca. 270 000 m^3/d of the untreated waste water is already led to the collector sewers but by-passed from pumping stations and WWTPs because of the lack of treatment capacity or missing tunnel collectors. The rest of the untreated waste water of both Vodokanal and the industrial enterprises, ca. 690 000 m^3/d, is discharged as so called “direct discharges“ by over 400 separate sewers not connected to collector sewers (Vodokanal: M. Probirsky 22.8.2001 pers. comm.).

Table 3. Summary of the information on the waste water flow in St. Petersburg and Leningrad Region obtained from various sources: 1) Vodokanal 2001a. 2) Anonymous 2002b, 3) Neva-Ladoga Basin Water Management Administration: V. Budarin 8.5.2001 pers. comm., 4) Anonymous 2000a, 5) Vodokanal 2001b, 6) Vodokanal 2001c. The values selected to be used in the calculations of the present study are presented in the first column.

<table>
<tr><th>Reference/Year</th><th>Used in the present work</th><th>1) 2000</th><th>2) 2000</th><th>3) 2000</th><th>4) 1999</th><th>5) 1999</th><th>2) 2001</th><th>6) 2001</th></tr>
<tr><td>Total flow (Mm^3/d)</td><td>3.42</td><td></td><td>3.47</td><td>4.1</td><td>3.6</td><td></td><td>3.40</td><td></td></tr>
<tr><td>Purified waste water</td><td>2.46 (72%)</td><td>2.46</td><td>2.22</td><td>2.77</td><td>2.25</td><td>2.15[1]</td><td>2.19</td><td></td></tr>
<tr><td>By-passes at pumping stations and WWTPs</td><td>0.27</td><td>0.27</td><td rowspan="2">0.96</td><td rowspan="2">0.99</td><td rowspan="2">1.05</td><td>0.24[1]</td><td rowspan="2">0.89</td><td></td></tr>
<tr><td>Municipal direct discharges</td><td>0.39</td><td>0.39</td><td rowspan="2">0.52[1]</td><td rowspan="2">0.67</td></tr>
<tr><td>Industrial direct discharges</td><td>0.30</td><td></td><td>0.30</td><td>0.35</td><td>0.33</td><td>0.33</td></tr>
</table>

[1] Only the city of St. Petersburg included

Table 4. The flows and concentrations of treated wastewater in St. Petersburg in the year 2000 according to Vodokanal’s statistics (Vodokanal 2001a). The nutrient concentrations analysed by the Southeast Finland Regional Environment Centre are marked with an asterisk (*) (Finnish Environment Institute: Petri Ekholm, unpublished data).

Plant	Influent flow (Mm^3/d)	Effluent phosphorus (mg/l)	Effluent nitrogen (mg/l)
Central WWTP	1.504	1.2/1.5*	9.4/11.0*
Northern WWTP	0.631	0.7/0.6*	9.3/10.5*
Krasnoselskaya WWTP	0.070	2.0	13.0
Other 16 WWTPs	0.258	1.8	12.6
Total/mean	2.463	1.2	9.8

2.3.2 Load estimate for the city of St. Petersburg in the year 2000

The influent concentrations in the Central WWTP in 2000 were 3.5 mg/l of total phosphorus and 23 mg/l of total nitrogen. At the Northern WWTP the corresponding figures were 8.0 mg/l of total phosphorus and 38 mg/l of total nitrogen (Vodokanal 2001a). These values include the internal recycling at the WWTPs, which increases the concentrations significantly especially at the Northern WWTP. The concentrations of the raw waste water in the sewers can be estimated from the concentrations analysed from the untreated waste water. The estimates are 3.0 mg/l of total phosphorus and 18.4 mg/l of total nitrogen (Vodokanal 2001a). Generally the treatment results of the two largest WWTPs are good, especially since no specific nutrient removal process exists. They comply already with the HELCOM recommendation of 1.5 mg/l phosphorus concentration in effluent.

The Southeast Finland Regional Environment Centre and the Finnish Environment Institute have conducted a survey on the effluent nutrient concentrations at the two largest WWTPs in St. Petersburg (Finnish Environment Institute: Petri Ekholm, unpublished data). The data collected in the survey is well aligned with the data reported by Vodokanal (Vodokanal 2001a, Table 4). Since the sampling interval in the Finnish monitoring data is more scattered than in the Vodokanal data, the concentrations reported by Vodokanal are considered to be more representative and will be used as the basis for load calculations. The effluent loads from the WWTPs are presented in Table 4. The nutrient loads based on the estimates above, including the nutrient loads of treated waste water, are presented in Table 5. Biologically available phosphorus was estimated on the basis of bioassays performed on waste water samples. The estimated biologically available loads for the year 2000, 1 310 tons of phosphorus and 11 900 tons of nitrogen, differ slightly from the estimates given in the Finnish Programme for the Protection of the Baltic Sea (Anonymous 2002a).

Table 5. Estimated nutrient loads of St. Petersburg waste waters and background load from the River Neva to the Gulf of Finland in the year 2000.

	Total phosphorus (ton/year)	Biologically available phosphorus (ton/year)	Total nitrogen (ton/year)	Biologically available nitrogen (ton/year)
Central WWTP	680	540	5 200	4 600
Northern WWTP	150	120	2 100	1 900
Krasnoselskaya WWTP	50	40	330	300
Other 16 WWTPs	170	140	1 200	1 100
Untreated wastewater	720	470	4 400	4 000
Total St. Petersburg	1 770	1 310	13 230	11 900
River Neva (Volodarsk)	1 300	520	43 000	19 000

2.3.3 Unknown factors and error sources

The Central WWTP operates at its full capacity, 1.5 Mm^3/d according to the influent flow measurements. This flow leads to a remarkably high mean of the hydraulic surface load on the secondary sedimentation basins, 2.7 m^3/m^2h. The mean load recommended for secondary sedimentation basins by Metcalf & Eddy (1991) in the Handbook of Waste Water Engineering is only 0.7-1.4 m^3/m^2h depending on the type of the basin. With higher loads the sedimentation process does not occur and water and sludge remains mixed instead of separating from each other. Nevertheless, the secondary sedimentation basins at Central WWTP are operating perfectly. This contradiction leads to the conclusion that the influent flow into the Central WWTP may possibly be considerably less than the measured value. However, in this text the measured value, 1.5 Mm^3/d, is used because the actual flow is not known. The total amount of wastewater produced in St. Petersburg is also somewhat uncertain as discussed above. Especially the flows of the direct discharges are difficult to estimate because there are no proper measurements.

2.4 Load from the River Neva drainage area in the year 2000

Petri Ekholm

The river Neva drains an area of 280 000 km^2, of which 80% is located in Russia and 20% in Finland. A special feature of the Neva drainage area is that it includes the vast lake Ladoga (18 000 km^2). The lake has several inflows, of which the rivers Volkhov and Svir transport most of the nutrients to the lake. The Neva itself, starting from Ladoga, is 74 km long, has a catchment of 5 000 km^2 and a mean residence time of 18 h. The long-term mean flow in the lower reaches of the river Neva is about 2 500 $m^3\ s^{-1}$.

During 2000, water samples were taken and analysed from various sites along the Neva in order to estimate the fluxes and origin of nutrients transported by the river. The sampling and analysis was divided between the Southeast Finland Regional Environment Centre (Kouvola, Finland) and the Water Research and Control Centre (St. Petersburg, Russia). The estimate of biologically available nutrient load presented in this report is based on samples taken on the Volodarsk Bridge in the outskirts of St. Petersburg. The sampling site represents the water quality in the river Neva before the municipal and industrial load from the city of St. Petersburg enters the river. In total, 14 water quality surveys were made in 2000.

Total phosphorus and total nitrogen were analysed from all water samples. In addition, the sum of nitrate and nitrite nitrogen (NO_x-N) and ammonium nitrogen (NH_4-N) were analysed in the surveys performed by the Finnish party in order to obtain an estimate of biologically available nitrogen. Finally some samples were analysed at the Pirkanmaa Regional Environment Centre using an algal bioassay to obtain an estimate of the biological availability of phosphorus (Finnish Environment Institute: Petri Ekholm, unpublished data).

In 2000, about 1 300 tons of total phosphorus and 43 000 tons of total nitrogen entered the city of St. Petersburg via the river Neva. Based on the analysis, a preliminary estimate can be made that 40% of total phosphorus and 44% of total nitrogen were potentially biologically available in the river Neva. Thus the corresponding biologically available load would be 520 tons of phosphorus and 19 000 tons of nitrogen. The estimated nutrient flux to the GoF via the river Neva in the late 1980s (Lääne *et al.* 1991) was 100% higher for total nitrogen and 37% higher for total phosphorus.

Planned water protection measures in St. Petersburg

3

Anne Leppänen, Pirjo Rantanen & Mikko Kiirikki

3.1 South-Western Waste Water Treatment Plant

The construction of the South-Western WWTP was started in 1987, but the work stopped after the collapse of the Soviet Union. According to the plans, the South-Western WWTP would be able to treat 330 000 m^3/d including ca. 70 000 m^3/d of waste water now treated at the Krasnoselskaya WWTP and ca. 250 000 m^3/d of by-passes from the South-Western and Central sewerage areas. The total investments of the new WWTP are estimated to be ca. 120 M€ and annual operation costs ca. 3.8 M€. The estimated accomplishment year is 2005 (Anonymous 2001a). The amount of untreated wastewater will be ca. 400 000 m^3/d after the completion of the WWTP.

The estimate of the achieved nutrient load reduction is 900 ton/year of biologically available nitrogen and 120 ton/year of biologically available phosphorus, representing 8% and 9% of the St. Petersburg municipal load, respectively (Table 6). The reduction estimate is based on the following assumptions:

- The process will be a biological nutrient removal process with effluent concentrations 1.1 mg/l of total phosphorus and 9 mg/l of total nitrogen based on the biological nutrient removal tests carried out in the Krasnoselskaya WWTP (Rantanen 1999).
- Treatment capacity 330 000 m^3/d.
- The estimated nutrient concentrations of untreated waste water are 3 mg/l of total phosphorus and 18.4 mg/l of total nitrogen, as in the year 2000. The influent concentrations of the Krasnoselskaya WWTP are not used because the samples taken for analysis contain internal recycling from sludge dewatering in the WWTP and are thus overestimates.
- No changes from the state of the year 2000 in water consumption, specific nutrient loads per person or sewer leakages are assumed.
- The biological availability of phosphorus after biological phosphorus removal is 80% and the availability of nitrogen 90% (Ekholm 1998).

Table 6. Nutrient load reduction by the water protection measures in St. Petersburg. The estimates are based on the sewage flows and influent concentrations in the year 2000. The load reductions are also shown as percentages of the St. Petersburg municipal load.

	P_{tot} (ton/year)	Biologically available P (ton/year)	N_{tot} (ton/year)	Biologically available N (ton/year)
South-western WWTP	-200	(-9%) -120	-1000	(-8%) -900
Northern collector sewer	-220	(-8%) -100	-1400	(-11%) -1300
Chemical phosphorus removal	-520	(-39%) -510	0	0

The South-Western WWTP will be financed by several organisations. NIB, EBRD and EIB will support the project with loans. The Finnish and Swedish governments and TACIS will donate funds. The Vodokanal of St. Petersburg, NEFCO, Finnfund, Swedfund, NCC International Ab, Skanska BOT Ab and YIT Rakennus Oy will all support the project by capital investments. The construction will be completed by a consortium of the three construction companies (NCC, YIT and Skanska), which will from a company called SWTP Construction Oy. The financing plan of the project was signed at the end of the year 2002 and the construction work was started in spring 2003.

3.2 Northern collector sewer

The construction work of the 12 km long Northern collector sewer was started in 1987. According to the Russian legislation, the collector sewer is planned to consist of two parallel tunnels, the first of which is almost ready (Anonymous 1997a). The investment cost estimate for finishing of the work is 35 M€ for the first tunnel. At present, Vodokanal is carrying out the construction work with local funds. The estimated accomplishment year of the first tunnel is 2007. The sewer will be built by Russian constructors. In other countries, there is no technological experience available to enable the building work in the special geological conditions of St. Petersburg (Vodokanal: M. Probirsky 29.3.2001, pers. comm.).

Completion of the first tunnel of the Northern collector sewer can bring ca. 450 000 m^3/d of waste water from the Northern sewerage area to the Northern WWTP (Vodokanal: M. Probirsky 29.3.2001, pers. comm.) The wastewater consists of ca. 150 000 m^3/d which is led from the Northern sewerage area to the Central area (Vodokanal 2001b) and ca. 300 000 m^3/d which is the flow of direct discharges in the Northern sewerage area (Vodokanal: K. Adder 22.8.2001, pers. comm.). The investment cost of closing the direct discharges is estimated by Vodokanal to be 310 M€ including both Vodokanals and industrial discharges. Approximately half of the cost relates to the Northern Sewerage area (Vodokanal 2001c, 2001e).

The sludge handling at the Northern WWTP must be upgraded before more waste water can be led to the plant. Vodokanal is already planning to construct a sludge incineration unit in the Northern WWTP. The preliminary cost estimate for the incineration unit is 30 M€ (Vodokanal: M. Probirsky 29.3.2001, pers. comm.).

It is uncertain whether the second sewer line required by the legislation will ever be built. In 1997 its investment cost, which includes at least partly the cost of closing direct discharges in the Northern sewerage area, was estimated to be 453 M€ (Anonymous 1997a). However, the cost estimate is based on Soviet-era roubles, and thus cannot reliably be converted into present currencies. It is also doubtful whether the collector sewer can be operated with only one line. The sewer must go under the River Okhta as an inverted siphon, which is considered to be a technically dubious and possibly unreliable solution. It may be necessary to build the second line to guarantee the operation of the collector.

The estimate of the achieved nutrient load reduction is 1300 ton/year of biologically available nitrogen and 100 ton/year of biologically available phosphorus, representing 11% and 8% of the St. Petersburg municipal load, respectively (Table 6). The reduction estimates are based on the following assumptions:

- Influent flow to the Northern WWTP will be 1 080 000 m^3/d, which is 90% of the capacity of the plant.
- The effluent concentrations are estimated to be 1.1 mg/l of total phosphorus and 9.5 mg/l of total nitrogen. The Northern WWTP will be operating at 90% of its capacity. The effluent concentrations are assumed to be slightly lower than at the Central WWTP, which operates at its full capacity.

- The estimated nutrient concentrations of untreated waste water are 3 mg/l of total phosphorus and 18.4 mg/l of total nitrogen as in the year 2000. The influent concentrations of the Northern WWTP are not used because the samples taken for analysis contain internal recirculation from the sludge dewatering in the WWTP and thus are overestimates.
- No changes from the state of the year 2000 in water consumption, specific nutrient loads per person or sewer leakages are assumed.
- The biological availability of phosphorus after biological phosphorus removal is 80% and the availability of nitrogen 90% (Ekholm 1998).

There are so many uncertainties in the construction work of the Northern collector sewer that we have used a range of cost estimates in the cost effectiveness calculations. We have considered the original cost estimate of 453 M€ as the upper limit and the new cost estimate 220 M€ as the lower limit. The new estimate includes:
- Completion of the first tunnel, 35 M€
- Half of the cost of closing the direct discharges, 155 M€
- Sludge incineration unit to the Northern WWTP, 30 M€

3.3 Chemical phosphorus removal

Chemicals are not used to precipitate phosphorus at the WWTPs in St. Petersburg. Chemical precipitation is a well-known and reliable way to enhance phosphorus removal. Simultaneous precipitation is the most widely used method in Finland. Most often it is performed using ferrous sulphate ($FeSO_4$ x 7 H_2O), which is dosed partly before the pre-sedimentation basin and partly in the stream entering the secondary sedimentation. Ferrous iron is oxidised into ferric iron in the aeration basin where the main precipitation effect occurs.

The use of simultaneous precipitation with ferrous sulphate requires basins to dissolve the solid chemical and store the solution, dosing pumps and piping. The amount of total solids produced will increase somewhat. On the other hand, the dewaterability of chemical-biological sludge is better than that of purely biological sludge. These opposite effects may compensate each other, in which case no extra capacity in the sludge treatment will be needed.

The estimate of the achieved nutrient load reduction is 520 ton/year of biologically available phosphorus, representing 39% of the municipal load from St. Petersburg (Table 6). The reduction estimate is based on the following assumptions:
- The precipitation is implemented at the Central and Northern WWTPs.
- The effluent concentration is assumed to be 0.4 mg/l of total phosphorus after simultaneous precipitation. No effect on nitrogen removal is assumed.
- The amount of treated water is the same as in the year 2000 at the Central and Northern WWTPs, i.e. 2 140 000 m^3/d.
- No changes from the state of the year 2000 in water consumption, specific nutrient loads per person or sewer leakages are assumed.
- The biological availability of phosphorus after simultaneous precipitation with ferrous sulphate is 50% (Ekholm 1998).

If the chemical is purchased outside Russia, the annual operation cost is estimated to be ca. 6 M€ and the investments in the WWTPs to remain below 1.5 M€ (Kiirikki *et al.* 2000). However, it is questionable whether Vodokanal is willing to use chemical precipitation because of the increased operation costs. Although the cost of the chemical precipitation may appear low, it nevertheless causes a significant increase in the present operation costs.

4 Future scenarios of nutrient loading

Marjukka Hiltunen, Pirjo Rantanen, Anne Leppänen & Elvira Moukhametshina

4.1 Background information for scenario building

4.1.1 Water consumption in St. Petersburg

Water consumption has been high in the city of St. Petersburg. High consumption increases the amount of municipal waste waters and decreases the nutrient concentrations, making effective treatment difficult and expensive. The total consumption estimate for the early 1990s was over 550 l/capita/day, which is more than twice the consumption in comparable western cities. Since then the water consumption trend has slightly decreased throughout the 1990s (Anonymous 2000b). In 1999, the total water consumption was 453 l/capita/day. The recent water demand projections cover the development until 2010, when the total consumption is expected to decrease to 300 l/capita/day (Vodokanal 2000).

Water and waste water charges used to be low in the Soviet Union. In addition, there were no water meters so that the amount paid was not based on actual consumption. These factors resulted in high water consumption compared with European and other western countries. (Anonymous 1997a). One of the main goals of St. Petersburg Vodokanal in the 1990s was to increase tariff levels for both domestic and non-domestic customers. Despite the annual tariff increases, the real water supply and waste water disposal charges have decreased since 1996 due to the rapid inflation (Vodokanal 2001e). One reason for this is that Vodokanal's tariff adjustments must be approved by the City Administration, which makes the adjustment process slow. After 1.1.2001 it was legislatively put into force that the water tariffs in St. Petersburg will be adjusted annuallu according to the Consumer Price Index. Vodokanal also plans to increase domestic and non-domestic tariffs in real terms in the period 2001-2005 (Vodokanal 2001e).

Despite the decrease of prices due to inflation, in the year 2000 the cost of total water and waste water services of the average household income was relatively high, 3.5 %. In the international comparison, a 4-5 % service cost is regarded as a high level. Due to the high proportions of retired and young people in St. Petersburg, the payment capacity is relatively low. This may limit tariff increases in the future (Anonymous 2001a).

The population of St. Petersburg has declined slowly since 1990. In 1990 there were 5.3 million inhabitants (Anonymous 1998b), whereas in 1998 the number was only 4.7 million. The Federal Committee for Statistics predicts that the declining trend will continue. The main reasons are migration, age structure and declining birth rate. According to the estimates, the population of St. Petersburg will be 4.2 million in 2015 (Anonymous 1999a). The decreasing population is likely to slightly decrease the municipal nutrient load.

4.1.2 Industrial production in St. Petersburg

Metal and machine building industry has been and still is the major industrial sector in St. Petersburg. During the Soviet era, St. Petersburg became one of the major centres of the Soviet armaments production. After 1991, major conversion efforts were made, but only a few companies succeeded in introducing competitive products. The adaptation and restructuring process of the former military industry is still under way, which decreases the local industrial output (Dudarev *et al.* 2000).

The second largest industrial sector is the food and beverages industry. During the transition period, its production has increased rapidly in the St. Petersburg region. In 1990, the share of the sector was only 13% of the total production but in 1999 it was 32% (Anonymous 2000b). When considering tax revenues, the share of the food and beverages industry is even higher, 45% of the total taxes collected in 1998, which shows that the sector is the most profitable and rapidly growing industry in the area. The 1998 crisis and the subsequent devaluation of the rouble sharply increased prices of imported foods and beverages, which increased the demand for Russian products and started a new boom in local food production. It can be assumed that food and beverage production will continue its growth in the area, whereas the traditional heavy industries will continue their declining trend (Dudarev *et al.* 2000).

In 1999, the industrial sector produced 14% of the waste waters discharged in St. Petersburg and 10% of the untreated or insufficiently treated waste waters in the city. All industrial discharges contained 1% of the total discharged nitrogen and 2 % of the total discharged phosphorus (Anonymous 2000a). The metal and machine building industry do not produce significant nutrient loads, whereas food and beverage production can potentially produce substantial amounts of discharges. The effect which the increasing food industry will have on the environment depends firstly on the production technologies used, and secondly on the percentage of industries connected to the sewer system.

Most of the technologies used in the food and beverage industry are imported, because hitherto there have been very few Russian equipment producers (Dudarev *et al.* 2000). It can be assumed that the technologies employed in the future will be of reasonably high quality in environmental terms. The existing factories will gradually be connected to the sewer system, which means that the industrial share of the direct discharges will continue to decline (Neva-Ladoga basin water management administration: V. Budarin 8.5.2001 pers. comm.).

In the scenarios, the total industrial nutrient load has been assumed to remain unaltered, because the effects of increasing industrial production and on the other hand improved technologies will probably compensate each other.

4.1.3 Agriculture in the Leningrad region

In the Leningrad region, only 11% of the whole area is under farming (Anonymous 1999b). Agriculture plays a secondary role in the economy of the region and its production accounts for half of the total foodstuff required by the population. Agricultural producers in the region are specialised in milk, animal breeding, poultry, and vegetables. The share of animal husbandry is almost 70% of the total agricultural production (Anonymous 1999b, 2000b).

In the early 1990s, Russian agriculture experienced severe shocks and only since 1998 started generating momentum and recovering from the past. The first of the shocks was caused by the decrease in agricultural subsidies, the weakened purchasing power of the population after the collapse of the Soviet Union and the initiation of economic reforms. Large, but financially weak Russian farms were unable to compete with imported food supplies However, the economic crisis and devaluation of the rouble in 1998 restored the competitive advantage of the Russian food industry.

The share of agriculture of the nutrient load to the river Neva cannot be estimated on the basis of the currently available data. However, after the collapse of the Soviet Union and the subsequent decrease of agricultural production, the load from the Neva to the GoF decreased notably. This trend cannot continue forever. According to some studies, manure storage capacities are still often inadequate, causing high levels of nutrient leaching (Anonymous 2000c). For this reason increasing agricultural production, with the main emphasis on animal husbandry, still has a high nutrient loading potential. In the scenarios, the load from the river Neva is either considered to stay at the present level or to increase back to the high level of the late 1980s.

4.2 Loading scenarios

4.2.1 National measures in the Finnish Programme for the Protection of the Baltic Sea

The Finnish national measures concentrate on agriculture, which is the major loading sector in the Finnish part of the GoF drainage basin as well as in the Archipelago Sea. According to the Programme, agriculture alone would be responsible for half of the planned load reduction. Altogether, the reduction would be some 40% of both the nitrogen and the phosphorus load. The target years of the programme are set to 2015-2025 (Anonymous 2002a).

In this scenario, the reference load represents the average for the years 1991-1996 used in the preparation of the Programme. The reduced loads are obtained by subtracting the planned load reductions by each loading sector from the source apportioned load information obtained from VEPS and VAHTI database systems by SYKE. The load data is calculated for the whole Finnish coastline. The estimated reduction in the biologically available nutrient load entering the GoF would be 4% of nitrogen and 3% of phosphorus. In the Archipelago Sea, which receives direct nutrient load only from Finland, the reduction in the biologically available nutrient load would be 34% of nitrogen and 37% of phosphorus

4.2.2 South-Western Waste Water Treatment Plant in St. Petersburg

The next water protection measure taking place in St. Petersburg is the construction of the South-Western WWTP started in 2003. The project is also included in the Finnish programme for the protection of the Baltic Sea, and Finland has reserved a grant of 10 M€ to support the project in 2003-2005. This scenario presents the combined effects of the Finnish national measures and the construction of the South-Western WWTP. The accomplishment year for the South-Western WWTP is estimated to be 2005. The nutrient load reduction by the new WWTP is presented in Table 6. The Finnish national measures and South-Western WWTP together would reduce the biologically available nutrient load entering the GoF by 5% of nitrogen and 7% of phosphorus.

4.2.3 Development of St. Petersburg waste water treatment to meet the Finnish standards

This scenario includes the targets of both the Finnish Programme for the Protection of the Baltic Sea and the St. Petersburg Long-Term Water Sector Development Programme. The target years of the scenario are 2015-2025. The total amount of municipal waste water from St. Petersburg in this scenario is 2 300 000 m^3/d with the following assumptions:

- Total water consumption will be 300 l/capita/d, which is the consumption assumed in the year 2015 in the Vodokanal's Long-Term Plan.
- Combined sewer network leakage and unregistered consumption stays at the level of 2000.
- Population is 4.2 million, including St. Petersburg and suburbs.

All Vodokanal's direct discharges will be closed and led to WWTPs. The total amount of waste water led to the WWTPs will be 2 300 000 m^3/d, corresponding to ca. 70% of their hydraulic capacity, 3 300 000 m^3/d. By-passes will be negligible. The concentration of the raw waste water will be 4.3 mg/l of total phosphorus and 25 mg/l of total nitrogen, calculated from the per capita loads used in the previous scenarios (2.3 g P/capita/d and 13.5 g N/capita/d).

Chemical precipitation will be implemented in the Central and Northern WWTPs. The nutrient concentrations in the effluent can be assumed to be 0.4 mg/l of total phosphorus and 12 mg/l of total nitrogen in the Central and Northern WWTPs. Biological nitrogen and phosphorus removal is assumed to be implemented in the South-Western WWTP and the effluent concentrations to be 0.9 mg/l of total phosphorus and 8 mg/l of total nitrogen. The average concentrations at the small WWTPs are assumed to be 1.5 mg/l of total phosphorus and 15 mg/l of total nitrogen. No specific nutrient removal processes are assumed to be implemented in the small WWTPs. The estimated Russian loads in the scenario are presented in Table 7. The combination of Finnish and Russian measures would reduce the biologically available nutrient load entering the GoF by 9% of nitrogen and 41% of phosphorus.

4.2.4 Failure in water protection

This scenario describes the situation in which all the Finnish and Russian attempts at water protection would fail and the nutrient load to the GoF would rise back to the peak level of the late 1980s or even higher. The highest load increase would come from the river Neva drainage basin, the main reason being the agricultural production concentrating on animal husbandry. The total amount of municipal waste water from St. Petersburg in this scenario is 3 250 000 m^3/d with the following assumptions:

- Total water consumption will stay at the level of 2000, 450 l/capita/d.
- Combined sewer network leakage and unregistered consumption will increase by 20% to 1 200 000 m^3/d due to neglected repair of sewers and pumping stations.
- Population decreases somewhat to 4.5 million inhabitants

The total capacity of the waste water treatment plants will be at the level of the year 2000, i.e. 3 030 000 m^3/d. No additional water protection measures are carried out compared to the 2000 situation. The Northern WWTP will not be operating at full capacity because the Northern collector is not yet finished. Furthermore the sludge handling at the Northern WWTP will be poor increasing the internal recycling of nutrients inside the plant and thus also the effluent phosphorus concentrations. Krasnoselskaya WWTP will be in poor condition. No direct discharges will be closed compared to the situation in the year 2000.

The year 2000 nutrient concentrations measured in the raw waste water lead to loads of 2.0 g P/capita/d and 12.3 g N/capita/d. For comparison, the Finnish loads in 1999 were 2.5 g P/capita/d and 14.4 g N/capita/d including domestic and industrial load (Anonymous 2001b). It is thus probable that the per capita loads in St. Petersburg may increase slightly, when the general standard of living rises. Especially if the use of phosphate-containing detergents increases the load of phosphorus will increase notably. If the loads are assumed to be 2.3 g P/capita/d and 13.5 g N/capita/d, the concentrations of raw waste water will be 3.2 mg/l of total phosphorus and 19 mg/l of total nitrogen.

No specific nitrogen or phosphorus removal is assumed at the WWTPs. The effluent concentrations are assumed to be 1.3 mg/l of total phosphorus and 10 mg/l of total nitrogen at the Central WWTP, 1.4 mg/l of total phosphorus and 11 mg/l of total nitrogen at the Northern WWTP, 2 mg/l of total phosphorus and 14 mg/l of total nitrogen at Krasnoselskaya and 1.8 of total phosphorus and 13 mg/l of total nitrogen at the small WWTPs. The concentrations at the Northern WWTP are assumed to be higher than at the Central WWTP because of the poor condition of the sludge handling unit.

The estimated St. Petersburg loads in the scenario are presented in Table 7. The River Neva load is estimated to increase back to the late 1980s level. The Finnish load is estimated to remain at the level of the years 1991-1996. This scenario would increase the biologically available nutrient load entering the GoF by 13% for nitrogen and 18% for phosphorus.

Table 7. Estimated changes of wastewater flows and nutrient loads in the future scenarios. Increase is marked as a positive and decrease as a negative value. The load changes are also given as percentages of the St. Petersburg municipal load.

	Waste water flow (Mm^3/d)	Waste water flow (Mm^3/a)	P_{tot} (ton/year)	Biologically available P (ton/year)	N_{tot} (ton/year)	Biologically available N (ton/year)
Development of St. Petersburg waste water treatment to meet the Finnish standards	–0.8	–300	–1 300	–1 000 (-76%)	–3 300	–3 000 (-25%)
Failure in water protection	+ 0.2	+ 50	+ 330	+ 250 (+ 19%)	+ 1 200	+ 1 100 (+ 9%)

Ecological effects of loading scenarios

5

Mikko Kiirikki, Harri Kuosa, Arto Inkala

5.1 Ecosystem model

The ecological effects of the loading scenarios were analysed and visualised using a mathematical ecosystem model (Kiirikki *et al.* 2001). The working principles of our model follow the oceanic phytoplankton model described by Tyrrell (1999). Phytoplankton is defined as two competing groups of organisms: nitrogen-fixing cyanobacteria (*Aphanizomenon*, *Nodularia*) and other phytoplankton. The other phytoplankton grows faster and out-competes the nitrogen-fixers at all temperatures if both biologically available nitrogen and phosphorus are present. When nitrogen is consumed almost completely but phosphorus is still abundant, the nitrogen-fixers gain a competitive advantage. Blooming is possible only in relatively high surface water temperatures (Kononen and Leppänen 1997).

Our model calculates the load and transport of biologically available nutrients, the growth of the two above-mentioned competing groups of phytoplankton, one group of littoral filamentous algae based on the ecological features of a brown filamentous species *Pilayella littoralis* (L.) Kjellm. (Kiirikki *et al.* 1998), as well as the settling, sedimentation and regeneration of nutrients in the dead algal biomass.

5.1.1 Model applications

We were able to utilise ecosystem model applications operating in two spatial and temporal scales in the present work. Large scale effects are simulated with the Baltic Sea model using a horizontal resolution of 5 km and covering the whole Baltic Sea east of Bornholm. The model is capable of simulating a 5-year period and it is equipped with a module describing oxygen-dependent sediment processes such as internal loading and denitrification (Kiirikki *et al.* 2002). The new module makes it possible to include the connection between external nutrient loading, oxygen conditions and internal loading in the evaluation of the scenarios. The simulation period of five years is a long enough time to show medium-term effects of the scenarios in the GoF, where the theoretical residence time of water is ca. 3 years (Alenius *et al.* 1998).

A horizontal resolution of 5 km is not sufficient to visualise the ecological effects in the immediate vicinity of the loading points and especially in the morphologically complex and narrow archipelago zone of the GoF. For this purpose we have used high resolution applications which are focused to cover the main areas of interest. We call these applications the local models. Hitherto, there exists four local models in the GoF area. Three of them were utilised in the present work. The local models are used to demonstrate short term effects of the measures on water quality. The simulations with the local models last only one growing season.

The Helsinki–Espoo model (Korpinen *et al.* 2002) covers the archipelago in front of the capital area, where municipal waste waters make up a major part of the nutrient load. The treated waste waters are led via tunnels to the outer margin of the archipelago and released in two separate points. The Kotka–Hamina model (Kiirikki *et al.* 2002) covers the eastern archipelago, where the main loaders are four separate branches of the River Kymijoki as well as pulp and paper industry located in the rivermouth. The St. Petersburg–Neva application is included in the work to demonstrate the local effects of water protection measures on the water quality along the famous recreational areas in the vicinity of St. Petersburg such as the Kurort resort zone (Terijoki). In this case, the major loaders are both treated and untreated municipal waste water outlets as well as the river Neva. The high resolution areas of the local model applications are presented in Fig. 4. A similar application would also be necessary for the detailed analysis of the eutrophication problem in the morphologically complex Archipelago Sea.

In the local models, the horizontal resolution increases in several steps towards the target area described with a resolution of 0.25 to 0.60 km depending on the application. The whole GoF is included in the model area with lower resolution. There is a two-way connection between the nested grids of different horizontal resolutions, meaning that all calculated variables can be transported from the coarse grids to the finer grids and vice versa.

5.1.2 Model calculations

Nutrient load to the study area is divided into major loading points, which are presented in Fig. 4. These points are rivers, major cities and industrial areas. In the case of Finland, more precise information was available, which explains the high number of relatively small loading points. In addition to loading points, the remainder of the nutrient load originating from small rivers and settlements is divided equally over the whole coastline of each country. Atmospheric nitrogen deposition is given separately for the sub-basins of the Baltic Sea. The load information is fed to the models on a monthly basis to describe the seasonal pattern of loading. Load from municipalities and industry is relatively stable throughout the year. Load from rivers is highly seasonal, concentrating in the spring and autumn peak flows.

The Baltic Sea model simulations were started from the beginning of 1995. Interpolated nutrient starting values were obtained from the DAS-database system (Sokolov *et al.* 1997) representing the conditions of January-March 1995. The model was run for 5 years (1995-1999) by using SMHI real analysis weather data as an atmospheric forcing. The local model simulations were started from the beginning of 1999 and lasted for one growing season.

An identical simulation was carried out by using each of the loading scenarios as well the reference load. The average biomasses of three algal groups were stored during the last growing season. The biomasses of each scenario simulation were then compared with biomasses of the reference load simulation. The results are presented as percentage biomass change caused by the scenario. Changes lower than 2% were considered as no change. The results of the Baltic Sea model are presented for an area covering the GoF and Archipelago Sea from Mariehamn to St. Petersburg. In the case of the local models, only results for the high resolution area are presented.

The ecological effects of the scenarios are presented as biomass changes of three algal groups:

Phytoplankton describes all other plankton algae except nitrogen-fixing cyanobacteria. Phytoplankton biomass is best observed as water turbidity in the open sea.

Cyanobacteria describes the nitrogen-fixing genera (*Nodularia, Aphanizomenon*) forming potentially toxic floating accumulations on the open sea.

Littoral filamentous algae describes a brown filamentous alga *Pilayella littoralis* responsible for fouling of beaches and fishing gear in spring and early summer.

In the St. Petersburg–Neva local model application only ”Phytoplankton” was included in the simulations, because the high nitrogen concentration suppresses the growth of nitrogen-fixing cyanobacteria and low salinity the growth of marine littoral filamentous algae.

5.1.3 Load data

In the present work, detailed nutrient load information was available for Finland, Russia and Estonia. In the case of Finland, we have used the same reference data set as in the preparation of the Finnish Programme for the Protection of the Baltic Sea, representing mean values for the years 1991-1996 (Kauppila & Bäck 2001). The source apportionment of Finnish river loads, needed for the calculation of the sector-based load reductions, is based on the VEPS-database system developed by SYKE. In the case of St. Petersburg and the river Neva the best available load information is based on monitoring data collected by SYKE in cooperation with Vodokanal in 2000. Load data from the city of Vyborg and to Vyborg Bay is based on analysis and monitoring by SE Regional Environment Centre of Finland (Anonymous 1997b), representing the year 1996. For the rest of the Russian and Estonian loading points we used data obtained directly from the environmental authorities describing the loads for the year 2000. The atmospheric nitrogen load was taken from Bartnicki *et al.* (2001). For the rest of the Baltic Sea, HELCOM PLC-3 data (Anonymous 1998c) was used as load information in the model calculations. All load data were converted, if given as total nutrient loads, into bioavailable loads by using conversion coefficients (Ekholm 1998, Silvo *et al.* 2000).

5.2 Ecological effects

5.2.1 Finnish Programme for the Protection of the Baltic Sea - National measures

The national measures under the Finnish Programme for the Protection of the Baltic Sea concentrate on diminishing nutrient load from agriculture, which is today the major loading sector in Finland. The nutrient load from agriculture enters the sea mainly via rivers originating from heavily cultivated areas such as the SW Finland. It is not surprising that the model simulations indicate the most distinctive positive effects as taking place on the SW coast and in the Archipelago Sea, where the biomass of phytoplankton and littoral filamentous algae decreases by 5-25% (Fig. 5A). The decrease of littoral filamentous algae appears to take place mainly north of the Archipelago Sea. The shift of the spatial distribution is an artefact created by a sharp biomass boundary and the relative manner of the presentation.

In the GoF, the impact area is rather narrow and clear decrease in biomasses can only be observed close to the coastline. Finland’s share of the biologically available nutrient load to the GoF is ca. 8% of phosphorus and 18% of nitrogen, which explains why the national load cuttings can only reach a level of 3-4% of the total load. In the Archipelago Sea, Finland is the main source of direct nutrient load which means an order of magnitude higher decrease of the total load.

The minor share of Finland in the total GoF load does not mean that the national measures would have no effect on the coastal zone most intensively affected by for human activities. The local model simulations for the Helsinki–Espoo (Fig. 5B) and Kotka–Hamina (Fig. 5C) archipelagos indicate that already during the first growing season clear positive effects can be observed in the phytoplankton and littoral filamentous algae, the biomass of which decreases close to the loading points by 5-20%. The decrease in the littoral filamentous algae is centred very close to the loading points because littoral algae grow attached to hard bottoms and do not move with currents like phytoplankton. The effects of national measures become more important towards the west, because of the decreasing influence of the transboundary effects from the eastern GoF.

The cyanobacteria show increase in areas where the other algal groups decrease. These areas, such as the inner parts of the Archipelago Sea and the narrow GoF archipelago, have generally avoided the most severe cyanobacteria blooms. In reality, as well as in the model calculations, the share of nitrogen fixing cyanobacteria is in these areas on average below 10% of the total phytoplankton biomass (Kauppila & Bäck 2001). Thus the increasing cyanobacteria biomass does not have an important effect on the total phytoplankton production.

The short term (1-year) simulation by the Helsinki–Espoo local model indicates an increase in the cyanobacteria biomass of 5-25%. In the medium term simulation (5-year) by the Baltic Sea model, the increase is no longer greater than 5%. This indicates that the increase in cyanobacteria biomass is at least partly a temporary effect. Load cuttings decreasing the phytoplankton biomass will also decrease the amount of dead algal biomass settling to the sediment bottoms and thus oxygen consumption in the deep water layers. Better oxygen conditions mean decrease in the internal loading of phosphorus and subsequently in the biomass of nitrogen-fixing cyanobacteria. We believe that this effect will compensate for the increases indicated by the model when considered over a time scale longer than 5 years. Despite this, the national measures do not appear to be an effective way to regulate cyanobacterial biomass.

It may seem difficult to understand why almost equal reduction percentages of both nitrogen and phosphorus (4% and 3% in the GoF, 34% and 37% in the Archipelago Sea, respectively) lead to changes in the N/P-ratio, which are the primary reason for the temporary increase of cyanobacterial biomass predicted by the model. The problem can be illustrated with the aid of an example: Let us imagine a present load of 10 000 units of nitrogen and 200 units of phosphorus, in which the N/P-ratio is 50. If we cut the load by 40%, we end up with a reduced load of 6000 and 120 units, in which the N/P-ratio is still the same 50. The primary production of an imaginary estuary, where the nitrogen-dominated load first enters, is clearly phosphorus-limited. When phosphorus is exhausted in the water mass according to the Redfield-ratio, there will be in the present loading conditions 8560 units of excess nitrogen, which is eventually transported out of the estuary to the nitrogen-limited archipelago or open sea. In the reduced loading conditions, the amount of excess nitrogen would be 5136 units, which is exactly 40% less than the present export from the estuary. The behaviour of the phosphorus-limited estuary explains why the N/P-ratio in the surrounding sea or archipelago may change, even though the N/P-ratio of load stays the same. All estuaries where primary production is phosphorus-limited behave in the way described above, at least in our ecosystem model. The best documented example of this filtering effect is the Neva Estuary, which exports practically only nitrogen in summer conditions (Pitkänen 1991). In winter conditions, when biological activity is minimal, export of both nutrients takes place.

National measures in the Finnish Programme for the Protection of the Baltic Sea

Reduction in the biologically available nutrient load to the Gulf of Finland
4 % of nitrogen
3 % of phosphorus

Reduction in the biologically available nutrient load to the Archipelago Sea
34 % of nitrogen (no atmospheric load included)
37 % of phosphorus

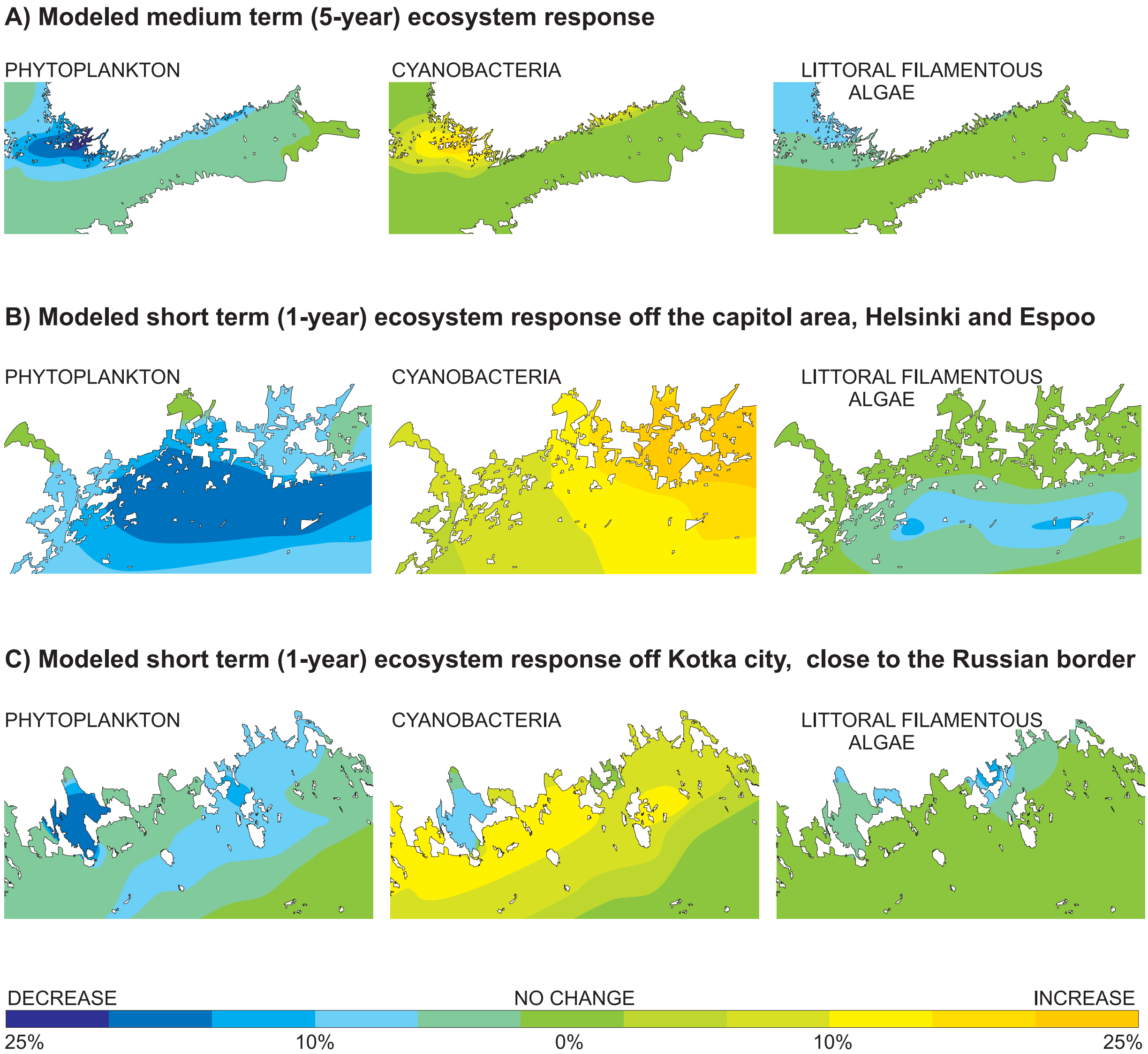


Fig. 5. Ecological effects of the national measures described in the Finnish Programme for the Protection of the Baltic Sea. A) Medium term (5-year) effects illustrated with the aid of the whole Baltic Sea ecosystem model operating with a horizontal resolution of 5 km. B) Short term (1-year) effects illustrated with the aid of the local Helsinki-Espoo ecosystem model, operating with the horizontal resolution of 0.25 km. C) Short term (1-year) effects illustrated with the aid of the local Kotka-Hamina ecosystem model operating with a horizontal resolution of 0.3-0.6 km.

5.2.2 Water protection measures in St. Petersburg

The Finnish Programme for the Protection of the Baltic Sea also includes support for the development of the water sector in St. Petersburg. Direct financial support has already been reserved for the construction work of the South-Western WWTP. Other important projects listed in the Programme are the construction of the Northern tunnel collector and start-up of chemical phosphorus removal in the present WWTPs.

According to the model results (Fig. 6A), the South-Western WWTP supports the Finnish national water protection measures in the eastern and central parts of the GoF, but it does not affect the Archipelago Sea. However, South-Western WWTP is only a medium size unit approximately in the same size class as Viikinmäki treatment plant in Helsinki. It alone cannot solve the whole problem.

St. Petersburg waste water treatment will approach the Finnish standards when the South-Western WWTP and Northern Tunnel Collector are ready, the chemical phosphorus removal started and direct discharges closed. From the point of view of the load reductions, the most important single measure is the chemical phosphorus removal, which alone will cut the biologically available phosphorus load in the GoF by 18%. This measure will have a notable effect on the cyanobacteria blooms throughout the GoF making the N/P-ratio unfavourable for the nitrogen-fixing cyanobacteria (Fig 6B). The combination of Finnish national measures and the modernisation of the St. Petersburg waste water treatment would also dramatically decrease both the phytoplankton and littoral filamentous algal biomass in practically all parts of the GoF. The positive effects of the St. Petersburg measures would also be observable in the outer parts of the Archipelago Sea.

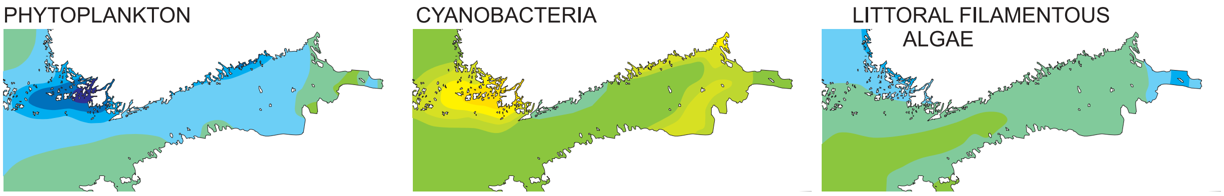
The short term effects of individual measures were analysed with the St. Petersburg–Neva local model application (Fig. 7). The short term local effects of both the South-Western WWTP and the Northern tunnel collector are relatively low, 5-10% of the phytoplankton biomass, but the decrease takes place mainly outside the Flood Protection Barrier in the so-called Neva estuary, where the recreational areas are located. The famous Kurort resort zone (Terijoki) is located on the northern shore outside the barrier. The most effective single water protection measure from the point of view of St. Petersburg appears to be the chemical phosphorus precipitation, which effectively cuts the phytoplankton biomass both on the southern side of the Neva Bay inside the barrier and along the Kurort resort zone outside the barrier. The model results indicate that the immediate short term response would be a 15-25% decrease in phytoplankton biomass.

5.2.3 Failure in water protection

If the Finnish Programme for the Protection of the Baltic Sea fails and no further water protection measures are carried out in St. Petersburg, economic growth in NW Russia may cause the GoF nutrient load to climb back to the high level of the late 1980s. The main increase would probably take place in the load originating from the drainage area of the River Neva. This would mean considerable increase in both the biologically available nitrogen (13%) and phosphorus (18%) load and a notable increase in the phytoplankton and littoral filamentous algal biomass in the whole GoF (Fig 6C). The cyanobacteria blooms, first observed in the eastern GoF in late 1990s (Kahru *et al.* 2000), would probably recede from the easternmost parts. However, the biomass of nitrogen-fixing cyanobacteria would be replaced by a higher biomass of other phytoplankton species.

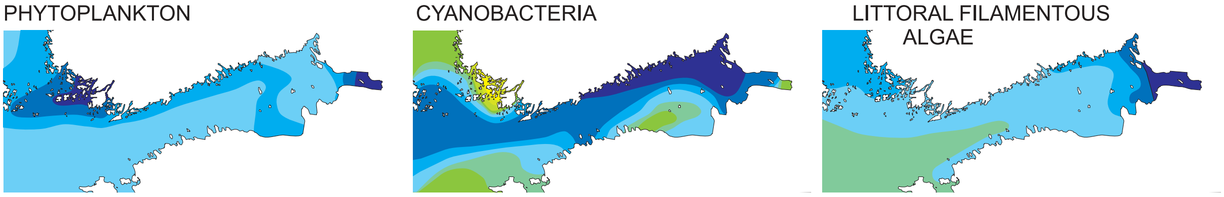
A) South-western wastewater treatment plant in St. Petersburg and the Finnish national measures

Reduction in the biologically available nutrient load to the Gulf of Finland
5 % of nitrogen
7 % of phosphorus



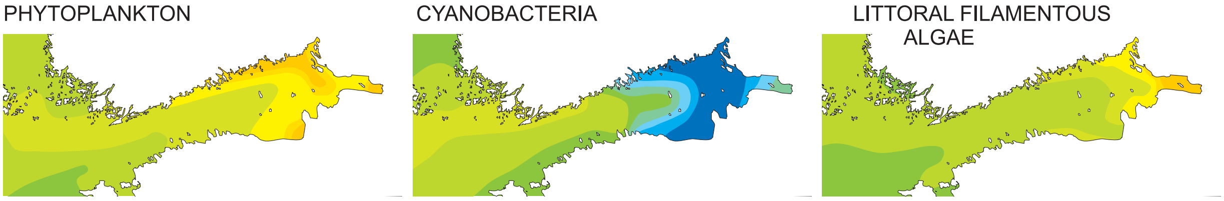
B) Development of St. Petersburg waste water treatment to meet the Finnish standards and the Finnish national measures

Reduction in the biologically available nutrient load to the Gulf of Finland
9 % of nitrogen
41 % of phosphorus



C) Failure in water protection

Increase in the biologically available nutrient load to the Gulf of Finland
13 % of nitrogen
18 % of phosphorus



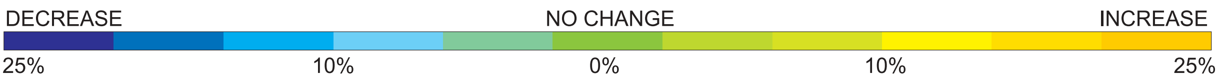


Fig. 6. Medium term (5-year) effects of water protection measures illustrated with the aid of the whole Baltic Sea ecosystem model operating with a horizontal resolution of 5 km. A) Construction of the South-Western wastewater treatment plant in St. Petersburg and the national measures described in the Finnish Programme for the Protection of the Baltic Sea. B) Development of St. Petersburg waste water treatment to meet Finnish standards and the Finnish national measures. C) Complete failure in water protection both in Finland and Russia: No decrease in the load from Finland or St Petersburg, load from the river Neva drainage basin increases back to the high level of the late 1980s.

5.3 Relevance of the model simulations from the point of view of the pelagic ecosystem

The present model structure is very simplified, as all ecological models necessarily are. The division into two different algal groups, nitrogen-fixing cyanobacteria and other phytoplankton, is ecologically meaningful in the Baltic Sea due to their apparently different limiting nutrients. Grouping together of the two cyanobacterial species *Nodularia spumigena* and *Aphanizomenon flos-aquae* assumes rather similar ecology in the model. Normally, this should lead to competitive exclusion of the other species, but in nature the two species behave quite differently. There is a rather high winter biomass of *Aphanizomenon* present in the water and that feature is also represented in the model, which includes a relatively high winter biomass of nitrogen-fixing cyanobacteria.

According to a recent study by Larsson *et al.* (2001), filamentous cyanobacteria (mostly *Aphanizomenon* sp.) had low C/ N and C/ P-ratios in spring, indicating internal storage of both N and P. During the summer bloom, during which *Aphanizomenon* grows rapidly in warm water, the C/P-ratio can reach 420, almost four times the Redfield-ratio being 13 times higher than in spring. *Nodularia*, which is a superior competitor to *Aphanizomenon* for phosphorus, is more strict in its ecology, producing blooms only in warm waters containing excess phosphorus. *Nodularia* produces resting cells, and it is not present during the spring period. This mismatch in phosphorus uptake and growth dynamics explains the presence of two nitrogen-fixing species at the same time, and probably also explains the dominance of *Nodularia* in open sea areas. The water protection measures probably have a greater effect on the intensity of the blooms of *Nodularia*, which are directly dependent on the summer phosphorus concentrations.

The model does not include *Anabaena lemmermannii*, which is a very common bloom-producing nitrogen-fixing cyanobacteria species in shallow bays. The species is apparently a good competitor in basins with low visibility and absent thermocline such as the inner bays around Helsinki (Lappalainen & Pesonen 2000). However, as the ecology of *Anabaena* is apparently rather similar to that of other nitrogen-fixing cyanobacteria, the responses of cyanobacteria blooms in shallow areas are relatively well described in the model if the internal circulation of phosphorus in shallow areas is realistic.

The algal group ”other phytoplankton” represents dozens of common species. There is no certainty that the species composition will remain unchanged after nutrient load reductions. This also has a potential effect on the turbidity of the water mass, as small species tend to make water more turbid than larger species. The species composition most probably changes due to the improvement of light availability and the general exhaustion of nutrients in the surface layer. The latter benefits species with the capability for vertical migrations to the lower nutrient-rich water mass, and these two changes together may shift the phytoplankton biomass maximum into deeper water layers.

The nutrient-poor ecosystem may also become rich in mixotrophic species, i.e. species with, in addition to photosynthesis, the capability to feed on other organisms. However, these phenomena should not affect the general trend, as the overall productivity is based on available nutrients. They may still result in local ecosystem effects, which are not evaluated in the present project. The food web effects, such as changes in grazing and bacterial productivity, were not taken into account, but they could affect the ecosystem behaviour to some degree, specifically the disappearance of produced algal biomass and the cycling of phosphorus.

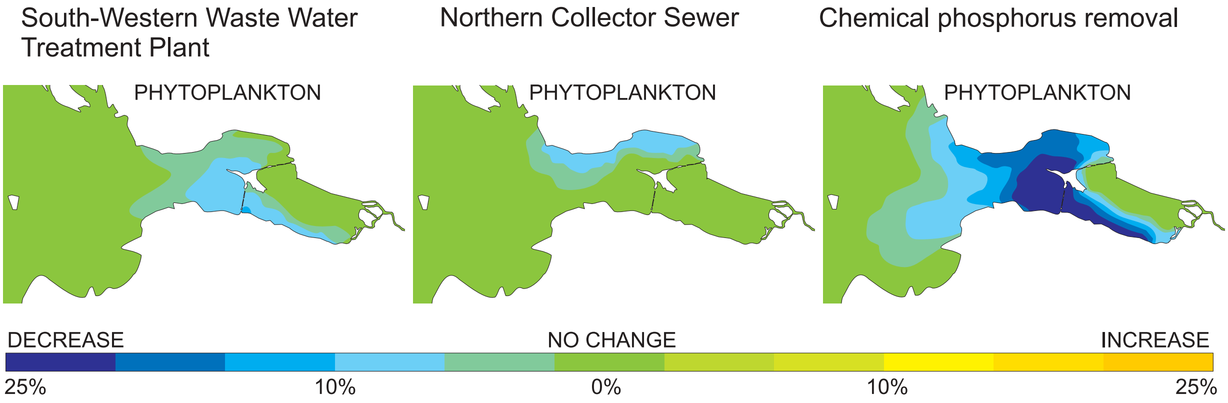


Fig. 7. Modelled short term (1-year) phytoplankton response to three major water protection measures in front of St. Petersburg. In the St. Petersburg–Neva local model application only phytoplankton biomass was included in the simulations, because salinity in the Neva estuary is too low for the growth of marine cyanobacteria species and littoral filamentous algae.

6 Nuisance caused by eutrophication

Riku Varjopuro

6.1 Nuisance questionnaire

Information about the experiences of the general public concerning the symptoms of eutrophication was surveyed by a self-administered questionnaire. This information provides support for discussion and valuation of the benefits gained by water protection measures. The survey also collected information about the respondents' perceptions of the state of the GoF. The respondents were asked e.g. to assess harmfulness of various effects that are caused by eutrophication. Other questions dealt with the use of the GoF coastal areas as well as views about the need for water protection and targeting of possible measures.

Altogether 500 questionnaires (494 valid) were sent out in the winter of 2001-2002 to the inhabitants of the county of Eastern Uusimaa. The county consists of 10 municipalities, five of which are on the coast of the GoF, and there are both urban and rural areas in the region. Thus Eastern Uusimaa represents different aspects of Finnish society. The sampling frame was "inhabitants older than 15 years of age". The response rate to this self-administered questionnaire, i.e. the respondents filled the questionnaires themselves, was 48% (237 responses). The original questionnaire, both in Finnish and in Swedish, can be found as Appendix 1.

6.2 Users of the Gulf of Finland

The respondents were asked about their different uses of GoF. The questions dealt with the location of their homes and summer houses, occupations that take them to the sea and about various recreational activities on the coastal area. The most common uses of the GoF were recreation on the beach, e.g. sunbathing, swimming or walking, and cruising e.g. between Helsinki and Tallinn or Stockholm.

Recreational users were divided into three groups. The first group consisted of those whose hobbies were boating, recreational fishing, diving or recreation on the beach. These hobbies take place near the water providing an opportunity to observe water quality. The second group of users consisted of those whose only GoF-related hobby was cruising. The GoF is here used as a means of transportation and the activity itself takes place mostly inside ferries and at the destination. Observations of water quality are incidental in this group. The third group consisted of respondents who did not have any GoF-related hobbies. The last two groups are exclusive. The first group includes those who have conducted at least three of the close-to-water activities more than "once" or at least one "often". The respondents were also asked whether they live on or have a summer house on the shore of the GoF (less than 500 meters from the shoreline). One third of the respondents (78) gave a positive answer to this question. The relative shares of the groups are presented in Fig. 8.

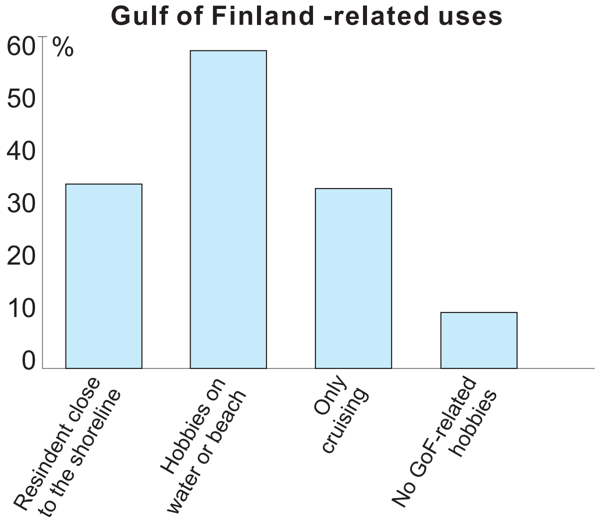


Fig. 8. Uses of the Gulf of Finland. The bar 'resident close to the shoreline' indicates the proportion of respondents living near the shoreline (500 meters or closer) or owning a summer house close to the shoreline. The other three bars show the proportions of different recreational uses of water areas and beaches of the Gulf of Finland (see text).

6.3 Reported experience of nuisance

Half (53%) of the respondents answered that the water quality of the GoF has deteriorated during recent years (either slightly or significantly). About one tenth (9%) had observed a positive change. The rest could not assess whether the change had been positive or negative.

In the questionnaire, one set of questions examined damage caused by eutrophication. The respondents were asked how harmful they had found several effects related to eutrophication. These were: "algal blooms on open sea", "fouling of beaches", "toxicity of algae", "fouling of boats", "turbidity of water" and "fouling of fishing gear". The respondents indicated whether they had found the effects "very harmful", "harmful" or "not harmful". They were also given an opportunity to answer "do not know". The results are shown in Fig. 9.

Fouling of beaches and turbidity of water were experienced to be harmful by the largest number of respondents. Toxicity of algae was indicated most often as a very harmful effect. This effect is related to cyanobacterial blooms when they drift to shores and form visible blooms. In general the risk of being exposed to toxic algal blooms is rather low. However, as indicated in other studies, health threats caused by environmental deterioration influence how risks are perceived (Fransson & Gärling 1999). Fouling of boats and fishing gear as well as algal blooms on the open sea have been personally experienced only by a limited number of respondents. However, the cyanobacteria blooms in the open GoF have regularly been in the headlines of all media.

When compared between different user groups, the results did not provide any surprises. Those respondents whose hobbies take place on or by the waters of the GoF or who live or have a summer house on the shore experienced the effects of eutrophication as being clearly more harmful than did the other respondents.

One way to assess the benefits of the water protection measures is to relate the model-simulated changes in the symptoms of eutrophication to the perceived nuisance. The effects of eutrophication that were used in the questionnaire can be linked to the three different ecosystem model variables in the following way:

- Phytoplankton – "Turbidity of water"
- Cyanobacteria – "Toxicity of algae" and "Algal blooms on the open sea"
- Littoral filamentous algae – "Fouling of beaches" and "Fouling of fishing gear"

Effective water protection measures will reduce the effects of eutrophication and we can assume that they will also reduce experienced harms caused by eutrophication. When the experienced harms (Fig. 9) are compared to the variables in the model, we do not find one variable that would clearly be more important than others. Three of the most harmful effects ("fouling of beaches", "turbidity of water" and "toxicity of algae") each relate to different parameters of the model. Fouling of beaches was found harmful or very harmful by the largest number of respondents. Hypothetically the water protection measures that will decrease the amount of littoral filamentous algae could be seen as the most beneficial ones, but the conducted survey does not allow a real comparison between the benefits of water protection measures. The questionnaire gives the respondents' qualitative assessments of their experiences. In this work these are not used to deduce numerical values for the harms caused by eutrophication.

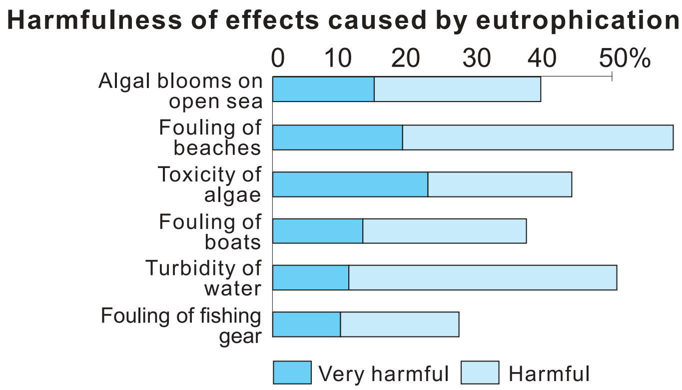


Fig. 9. Perceived negative consequencies of different symptoms related to eutrophication of the Gulf of Finland.

6.4 How to combat eutrophication?

The majority of the respondents answered that the water quality in the GoF had deteriorated during recent years. Many of the effects of eutrophication were found to be harmful. Not surprisingly, when asked whether there is a need for more water protection measures, as many as 83% of the respondents answered "yes". Only 1% answered "no".

The respondents were asked to rank where to target water protection measures to combat eutrophication. Figure 10 shows the results - the average ranking given to each of the measures. The respondents were of the opinion that more measures should be targeted especially to reduce the nutrient load from Russia (St. Petersburg and other parts of Russia) and from Finnish industry. Coastal Finnish towns and agriculture were also seen as being rather important. Houses outside the sewerage infrastructure as well as summer houses were not seen as important.

Waste water treatment requires resources. The respondents were asked who should finance the water protection measures. As much as 70% were of the opinion that the society and polluters together should bear the costs, 18% answered that the polluters should pay the costs alone. The question about Finland financing water protection measures in Russia and Estonia divided the opinions more, although water protection measures in Russia were seen as the most urgent. The majority of the respondents (48 %) thought that Finland should finance activities outside Finland. This idea was rejected by 32 %. If we take a closer look at who supported and who opposed the idea, we can see certain differences between the users of GoF. "The active users" of the GoF - those whose hobbies take place on the waters or shores of GoF or who live or own a summer house on the shore – were mostly positive towards the idea that Finland would finance water protection measures in Russia and Estonia. Over half of them (54%) supported the idea. However, the proportion of those who opposed it was not insignificant. Almost one third (30%) were of the opinion that Finland should not finance these measures. In the group that had no GoF-related hobbies or other direct uses of GoF, 41% opposed the idea and 24% supported it.

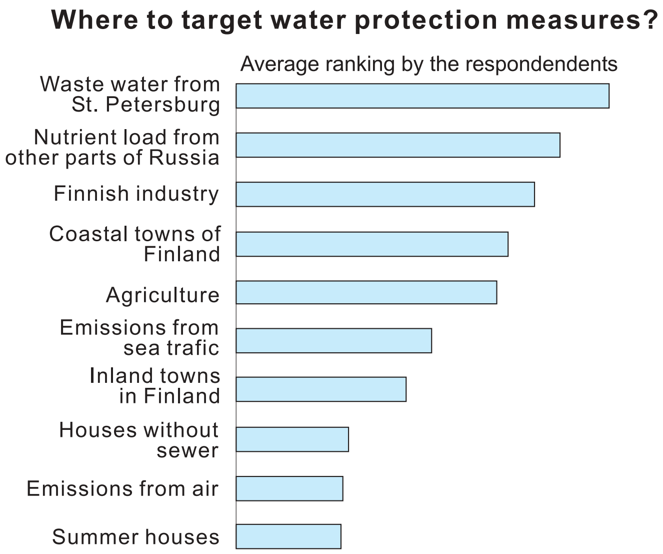


Fig. 10. Preferred targets of future water protection measures on an arbitrary scale. The bars show the average importance assigned to different water protection measures by the respondents.

7 Cost-effectiveness of water protection

Mikko Kiirikki

No cost estimate of the nutrient load reductions by the Finnish Programme for the Protection of the Baltic Sea was available during the present work. Instead, we used a cost estimate for the Water Protection Targets to 2005, which includes practically the same measures. The estimate for the GoF drainage basin, ca. 1400 M€, was calculated as a present value over a 20-year-period using a 3% interest rate (Kiirikki *et al.* 2000). The estimate is related to a biologically available nutrient load reduction of 2 100 tons/year of nitrogen and 62 tons/year of phosphorus estimated in the same work. The cost estimates for the measures in St. Petersburg were also converted into present values by using the same time scale and interest rate as above. Some specific estimates are available for the costs of reduction of nitrogen emissions by some loading sectors in Finland (Anonymous 2002a). The most thoroughly investigated sector is municipal waste water treatment. The present value of reducing the load of nitrogen by one ton is estimated on the basis of detailed information about the necessary investments and additional running costs of treatment plants (Anonymous 2001c). A reliable cost estimate for agriculture is more difficult to obtain, because of uncertainties in both the cost calculation and the impact assessment.

In order to compare both nitrogen- and phosphorus-dominated load cuttings we converted the phosphorus load into nitrogen equivalents by multiplying it with the Redfield-ratio 7.2 (w/w). The Redfield ratio describes the optimum N/P-ratio for the growth of phytoplankton. In this work, one nitrogen equivalent ton refers either to one ton of nitrogen or 0.14 tons of phosphorus.

The cost estimates for reducing one nitrogen equivalent ton are presented in Figure 11. They vary between 850 and 28 000 €/ton. The most cost-effective measure appears to be chemical phosphorus removal in the Central and Northern WWTPs, in which the reduction cost remains below 1 000 €/ton. There also exist cost-effective Finnish national measures such as improved nitrogen removal in municipal waste water treatment plants, in which the cost of one nitrogen equivalent ton is estimated to be 5 500 €, rather close to the cost in the St. Petersburg South-Western WWTP, 4 500 €/ton. The uncertainties associated with the construction work of the Northern collector sewer make it difficult to obtain a reliable cost estimate. We used two independent cost estimates in the calculation of the reduction cost, yielding a range of 5 500–11 000 €/ton. The average cost of removed nitrogen equivalent ton by the Finnish national measures was estimated to be 28 000 €. There are two main reasons for the high cost. The Programme includes sectors in which cost-effectiveness is low, and a major part of the measures are carried out inland so that the impacts do not reach the GoF in full extent. The most expensive sector appears to be scattered settlements, where the cost of reduction of a nitrogen equivalent ton is estimated to be 31 600 € (Hiltunen 2003). When the nutrient retention in the drainage area is taken into account, the cost of a nitrogen equivalent ton entering the GoF is estimated to be approximately in the range of 100 000€ (Kiirikki *et al*. 2000). This is ca. 100 times higher than the most cost effective measures. Although investment in load reductions from scattered settlements does not appear to be rational from the point of view of the Baltic Sea, it may be the only effective way to improve water quality in lakes with high recreational value.

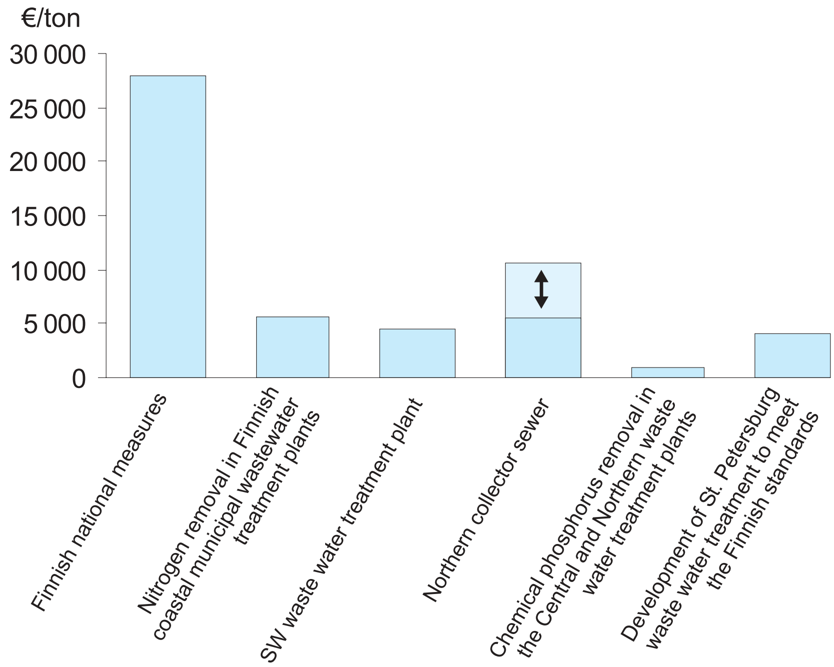


Fig 11. Reduction cost for a biologically available nitrogen equivalent ton entering the Gulf of Finland in several water protection measures. Nitrogen equivalent ton refers to either one ton of nitrogen or 0.14 tons of phosphorus. The cost estimates are present values calculated over a 20-year-period by using a 3% interest rate.

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Enkät om Finska viken

Finlands miljöcentral

Följande frågor ger oss grundfakta om svorarna.

1. Vilket år är ni född? Födelseår 19____

2. Är ni man eller kvinna?
Ringa in rätt alternativ .

Kvinna	1
Man	2

3. Vad har ni för yrke?
____

4. Vad har ni för utbildning?
Har ni avlagt:
Ringa in den siffra som beskriver er högsta examen

högskoleexamen	1
mellanstadieexamen	2
grund- eller mellanskoleexamen	3
folkskoleexamen	4

5. I vilken kommun bor ni?
____

Följande frågor berör såväl den bofasta befolkningen som fritidsbebyggelsen vid **Finska vikens kust**.

6. Är er bostad belägen vid Finska vikens strand (närmare än 500 meter från stranden)?
Ringa in rätt alternativ.

Ja	1
Nej	2

7. Till Finska vikens kust räknas kustkommunerna från Hangö till Vederlax. Har ni någonsin varit bosatt i någon av kustkommunerna vid Finska viken?
Ringa in rätt alternativ.

Ja	1
Nej	2

8. Har ni eller er familj en fritidsbostad i någon av kustkommunerna vid Finska viken?
Ringa in rätt alternativ.

Ja	1
Nej	2

9. Ligger er eller er familjs fritidsbostad vid Finska vikens strand (närmare än 500 meter från stranden)?
Ringa in rätt alternativ.

Ja	1
Nej	2

10. Ifall ni eller er familj har en fritidsbostad vid Finska vikens strand, hur många dagar i året tillbringar ni där?

Jag tillbringar ca _______ dagar i året vid min fritidsbostad.

Följande frågor berör yrkesmässigt fiske och sjöfart eller övrig yrkesmässig trafikering till havs. Ifall ni inte bedriver eller inte har tidigare bedrivit yrkesmässigt fiske eller annars å yrkets vägnar rört er på Finska viken, kan ni hoppa direkt till fråga 15

Med yrkesmässigt fiske avses här fiske där fångsten eller en del av den saluförs.

11. Bedriver ni yrkesmässigt fiske på **Finska viken**?
Ringa in rätt alternativ.
Ja 1
Nej 2

12. Har ni tidigare bedrivit yrkesmässigt fiske på **Finska viken**?
Ringa in rätt alternativ.
Ja 1
Nej 2

13. Rör ni er å yrkets vägnar på **Finska viken**?
Ringa in rätt alternativ.
Ja 1
Nej 2

14. Har ni tidigare rört er å yrkets vägnar på **Finska viken?**
Ringa in rätt alternativ.
Ja 1
Nej 2

Följande frågor berör rekreationsbruk av Finska viken.

15. Hur ofta har ni under de senaste åren (ca 1998–2001) sysslat med följande fritidsaktiviteter på **Finska viken**?
Ringa in för varje aktivitet det alternativ som bäst beskriver hur ofta ni sysslat med ifrågavarande aktivitet.

	Inte alls	*En gång*	*Då och då*	*Ofta*
a) Nätfiske (icke yrkesmässigt)	1	2	3	4
b) Övrigt fritidsfiske	1	2	3	4
c) Åkning med småbåt (inkluderar också åkning med t.ex. kanot, segelbräda, vattenskoter)	1	2	3	4
d) Simning, vistelse på stranden eller promenad på havsstranden	1	2	3	4
e) Dykning	1	2	3	4
f) Kryssning eller resande med passagerarfartyg	1	2	3	4
g) Annat Vad?	1	2	3	4
h) Annat Vad?	1	2	3	4

Följande frågor behandlar vattenkvaliteten i Finska viken.

16. Anser ni att vattenkvaliteten i Finska viken har förändrats under de senaste åren?
Ringa in rätt alternativ.
Ja 1
Nej 2
Vet ej 3

17. Anser ni att vattenkvaliteten i Finska viken försämrats eller förbättrats?
Ringa in det alternativ som bäst beskriver förändringen.

Förbättrats avsevärt	Förbättrats något	Vet ej	Försämrats något	Försämrats avsevärt
1	2	3	4	5

18. Tycker ni att följande fenomen har ökat eller minskat i Finska viken?
Ringa in för varje fenomen det alternativ som bäst beskriver era observationer av förändringen.

	Minskat avsevärt	*Minskat något*	*Vet ej*	*Ökat något*	*Ökat avsevärt*
a) Förekomst av slem på stränderna och trådformiga alger i strandvattnet	1	2	3	4	5
b) Vattnets grumlighet	1	2	3	4	5
c) Algansamlingar på öppna havet	1	2	3	4	5
d) Algblomningars giftighet	1	2	3	4	5
e) Nedsmutsning av båtskrovet	1	2	3	4	5
f) Slem på fångstredskap	1	2	3	4	5
g) Annat Vad?	1	2	3	4	5

19. Fenomenen i föregående fråga (punkt 18) kan försvåra användningen av vattnen. Till hur stort förtret tycker ni att de har varit för er?
Ringa in för varje fenomen det alternativ som beskriver era upplevelser bäst.

	Till stort förtret	*En aning till förtret*	*Inte till förtret*	*Vet ej*
a) Förekomst av slem på stränderna och trådformiga alger i strandvattnet	1	2	3	4
b) Vattnets grumlighet	1	2	3	4
c) Algansamlingar på öppna havet	1	2	3	4
d) Algblomningars giftighet	1	2	3	4
e) Nedsmutsning av båtskrovet	1	2	3	4
f) Slem på fångstredskap	1	2	3	4
g) Annat Vad?	1	2	3	4

Eutrofieringen d.v.s. övergödningen av Finska viken är ett allvarligt hot mot miljön. Det förekommer också en rad andra miljöhot.

20. Vilket av följande hot mot miljön anser ni att man borde åtgärda med det snaraste?
Ange följande hot mot miljön i viktighetsordning med siffrorna 1–9 (1= viktigast, 2= näst viktigast, 3= tredje viktigast, o.s.v.).

	Viktighet
a) Klimatförändring (den s.k. drivhuseffekten)	
b) Ökade gifthalter i naturen	
c) Nedsmutsning av grundvatten	
d) Minskning av naturens mångfald (t.ex. djur- och växtarter dör ut)	
e) Försämring av insjövattnens kvalitet	
f) Eutrofiering av Finska viken	
g) Radioaktiv strålning	
h) Oljeolyckor	
i) Annat *Vad?*	

Mången verksamhet inverkar på vattnens tillstånd – direkt eller indirekt.

21. Tycker ni att er egen verksamhet inverkar menligt på vattenkvaliteten i **Finska viken**?
Ringa in det alternativ som bäst beskriver följderna av er verksamhet

	Stor menlig inverkan	*Ringa menlig inverkan*	*Ingen menlig inverkan*	*Vet ej*
a) Avloppsvattnen från min bostad	1	2	3	4
b) Mitt arbete	1	2	3	4
c) Avloppsvattnen från min fritidsbostad	1	2	3	4
d) Mina hobbyn	1	2	3	4
e) Annat Vad?	1	2	3	4

22. Har ert arbete och/eller era hobbyn en **positiv** inverkan på vattenkvaliteten i Finska viken?
Ringa in rätt alternativ.
Ja 1
Nej 2
Vet ej 3

23. Ifall ni svarade Ja på föregående fråga (punkt 22), vad för arbete eller fritidssysselsättning är det fråga om?

24. Är er bostadsfastighet ansluten till det kommunala avloppsnätet?
Ringa in rätt alternativ.
Ja 1
Nej 2

25. Ifall ni eller er familj har en fritidsfastighet i någon av kustkommunerna vid Finska viken, är den ansluten till det kommunala avloppsnätet?
Ringa in rätt alternativ.
Ja 1
Nej 2

Det förekommer en mängd olika metoder med vilka man kan förbättra vattenkvaliteten i Finska viken, och dessa kan verkställas på flera håll och plan.

26. Anser ni att det krävs **fler åtgärder än vad som vidtas nuförtiden** för att förbättra vattenkvaliteten i Finska viken?
Ringa in rätt alternativ.

Ja	1
Nej	2
Vet ej	3

27. Vem borde finansiera de åtgärder som vidtas för att förbättra vattenkvaliteten i Finska viken?
Kryssa för det alternativ som bäst motsvarar er syn på saken.

Åtgärder för att förbättra vattenkvaliteten i Finska viken borde finansieras av…

a) Ĭ samhället

b) Ĭ de som belastar vattnet.

c) Ĭ samhället och belastarna.

d) Ĭ Vet ej

28. Anser ni att Finland borde finansiera sådana projekt i de andra kuststaterna vid Finska viken (Estland och Ryssland) vars mål är att förbättra vattenkvaliteten i Finska viken?
Ringa in rätt alternativ.

Ja	1
Nej	2
Vet ej	3

29. Vilka av följande faktorer som eutrofierar Finska viken tycker ni att man borde åtgärda?
Ange följande faktorer i viktighetsordning med siffrorna 1–10 (1= viktigaste faktor vars eutrofierande utsläpp borde åtgärdas, 2= näst viktigaste, 3= tredje viktigaste, o.s.v.).

	Viktighet
a) Inhemsk industri	
b) Avloppsvatten från finska kuststäder	
c) Avloppsvatten från städer inne i landet	
d) Fartygstrafik	
e) Lantbruk	
f) Avloppsvatten från Sankt Petersburg	
g) Näringsutsläpp från andra delar av Ryssland	
h) Glesbebyggelse (bostäder som inte är anslutna till avloppsnätet)	
i) Fritidsbebyggelse	
j) Näringsbelastning via luften	
k) Annat *Vad?*	

Tack för ert svar!

Var vänlig och returnera det ifyllda frågeformuläret i bifogade svarskuvert före den 9 januari 2002. Finlands miljöcentral betalar portot.

Ytterligare information får ni av:
Riku Varjopuro
forskare
Finlands miljöcentral
Tel. 09-4030 0331, e-post. riku.varjopuro@vyh.fi

På denna sida kan ni skriva ner era synpunkter på denna enkät och dess tema, d.v.s. användningen och skyddet av Finska viken.

Suomenlahtikysely

Suomen ympäristökeskus

Seuraavat kysymykset kartoittavat perustietoja vastaajista.

1. Minä vuonna olette syntynyt? Syntymävuosi 19____

2. Mikä on sukupuolenne?
Ympyröikää oikea vaihtoehto.

Nainen	1
Mies	2

3. Mikä on ammattinne?
____

4. Mikä on koulutuksenne?
Oletteko suorittaneet:
Ympyröikää korkeinta tutkintoa kuvaava numero.

korkeakoulututkinnon	1
keskiasteen tutkinnon	2
perus- tai keskikoulututkinnon	3
kansakoulututkinnon	4

5. Mikä on asuinkuntanne?
____

Seuraavissa kysymyksissä käsitellään vakituista ja vapaa-ajan asumista Suomenlahden rannikolla.

6. Sijaitseeko asuntonne Suomenlahden rannan läheisyydessä (alle 500 metriä rannasta)?
Ympyröikää oikea vaihtoehto.

Kyllä	1
Ei	2

7. Suomenlahden rannikkoon lasketaan kuuluvaksi rannikkokunnat Hangosta Virolahdelle. Oletteko koskaan asuneet Suomenlahden rannikkokunnassa?
Ympyröikää oikea vaihtoehto.

Kyllä	1
Ei	2

8. Onko teillä tai perheellänne vapaa-ajanasunto Suomenlahden rannikkokunnassa?
Ympyröikää oikea vaihtoehto.

Kyllä	1
Ei	2

9. Onko teidän tai perheenne vapaa-ajanasunto Suomenlahden rannassa tai rannan läheisyydessä? (alle 500 metrin päässä)
Ympyröikää oikea vaihtoehto.

Kyllä	1
Ei	2

10. Mikäli teillä tai perheellänne on vapaa-ajanasunto Suomenlahden rannassa tai rannan läheisyydessä, kuinka monena päivänä olette siellä vuoden aikana?

Olen vapaa-ajanasunnolla noin _______ päivänä vuoden aikana.

Seuraavat kysymykset liittyvät ammattimaiseen kalastukseen ja merenkulkuun tai muuhun ammattimaiseen liikennöintiin merellä. Jos ette harjoita nykyään tai ole aiemmin harjoittaneet ammattimaista kalastusta tai muuten liikkuneet ammattinne vuoksi Suomenlahden vesillä, voitte siirtyä suoraan kysymykseen 15.

Ammattimaisella kalastuksella tarkoitetaan tässä yhteydessä kalastusta, josta saatava saalis tai osa saaliista myydään.

11. Kalastatteko ammattimaisesti **Suomenlahden alueella**?
Ympyröikää oikea vaihtoehto.
Kyllä 1
Ei 2

12. Oletteko aikaisemmin kalastaneet ammattimaisesti **Suomenlahden alueella**?
Ympyröikää oikea vaihtoehto.
Kyllä 1
Ei 2

13. Liikutteko ammattinne vuoksi **Suomenlahden vesillä**?
Ympyröikää oikea vaihtoehto.
Kyllä 1
Ei 2

14. Oletteko aikaisemmin toimineet ammatissa, jossa liikuitte **Suomenlahden vesillä**?
Ympyröikää oikea vaihtoehto.
Kyllä 1
Ei 2

Seuraavaksi käsitellään Suomenlahden alueen virkistyskäyttöä.

15. Kuinka usein olette harrastaneet joitakin seuraavista **Suomenlahden alueella** viime vuosina (noin 1998-2001)?
Ympyröikää jokaisen harrastuksen kohdalta numero, joka kuvaa harrastuskertojanne parhaiten.

	En lainkaan	*Kerran*	*Satun-naisesti*	*Usein*
a) Verkkokalastus (ei-ammattimainen)	1	2	3	4
b) Muu vapaa-ajan kalastus	1	2	3	4
c) Veneily pienveneellä (myös melonta, purjelautailu, vesiskootterilla ajelu, ym.)	1	2	3	4
d) Uiminen, uimarannalla oleilu tai meren rannalla kävely	1	2	3	4
e) Sukellus	1	2	3	4
f) Risteily tai matkustaminen matkustaja-aluksilla	1	2	3	4
g) Muu Mikä?	1	2	3	4
h) Muu Mikä?	1	2	3	4

Seuraavissa kysymyksissä käsitellään Suomenlahden veden laatua.

16. Onko Suomenlahden veden laatu muuttunut mielestänne viime vuosina?
Ympyröikää oikea vaihtoehto.
Kyllä 1
Ei 2
En osaa sanoa 3

17. Onko Suomenlahden veden laatu mielestänne parantunut vai heikentynyt?
Ympyröikää numero, joka mielestänne kuvaa parhaiten muutosta.

Parantunut paljon	Parantunut vähän	En osaa sanoa	Heikentynyt vähän	Heikentynyt paljon
1	2	3	4	5

18. Ovatko seuraavat ilmiöt mielestänne vähentyneet vai lisääntyneet Suomenlahdella?
Ympyröikää jokaisen ilmiön kohdalta numero, joka kuvaa havaintoanne muutoksesta parhaiten.

	Vähentynyt paljon	*Vähentynyt vähän*	*En osaa sanoa*	*Lisääntynyt vähän*	*Lisääntynyt paljon*
a) Rantojen limoittuminen ja rihmamaisten levien määrä rantavedessä	1	2	3	4	5
b) Veden sameus	1	2	3	4	5
c) Levälautat avomerellä	1	2	3	4	5
d) Leväkukintojen myrkyllisyys	1	2	3	4	5
e) Veneenpohjan likaantuminen	1	2	3	4	5
f) Pyydysten limoittuminen	1	2	3	4	5
g) Muu Mikä?	1	2	3	4	5

19. Edellisessä kysymyksessä mainitut ilmiöt saattavat vaikeuttaa vesialueen käyttöä. Kuinka haitallisina olette ne kokeneet?
Ympyröikää jokaisen ilmiön kohdalta numero, joka kuvaa kokemaanne haittaa parhaiten.

	Olen kokenut sen erittäin haitallisena	*Olen kokenut sen jonkin verran haitallisena*	*En ole kokenut sitä haitallisena*	*En osaa sanoa*
a) Rantojen limoittuminen ja rihmamaisten levien määrä rantavedessä	1	2	3	4
b) Veden sameus	1	2	3	4
c) Levälautat avomerellä	1	2	3	4
d) Leväkukintojen myrkyllisyys	1	2	3	4
e) Veneenpohjan likaantuminen	1	2	3	4
f) Pyydysten limoittuminen	1	2	3	4
g) Muu Mikä?	1	2	3	4

Suomenlahden rehevöityminen on yksi ympäristöön kohdistuvista uhkista. Myös muista ympäristöuhkia esiintyy.

20. Mihin seuraavista ympäristöön kohdistuvista uhkista mielestänne pitäisi puuttua mahdollisimman nopeasti?
Merkitkää seuraavat uhat numeroilla tärkeysjärjestykseen (1= tärkein, 2=toiseksi tärkein, 3=kolmanneksi tärkein, jne.).

	Tärkeys
a) Ilmastonmuutos (ns. kasvihuoneilmiö)	
b) Myrkkypitoisuuksien kasvu luonnossa	
c) Pohjavesien pilaantuminen	
d) Luonnon monimuotoisuuden väheneminen (esim. eläin- tai kasvilajien häviäminen)	
e) Sisävesien laadun heikkeneminen	
f) Suomenlahden rehevöityminen	
g) Ydinsäteilyn uhka	
h) Öljyonnettomuuksien uhka	
i) Muu *Mikä?*	

Monet ihmisten toimista vaikuttavat vesistöjen tilaan suoraan tai välillisesti.

21. Vaikuttaako mielestänne oma toimintanne **Suomenlahden** veden laatuun haitallisesti?
Ympyröikää kunkin toiminnan kohdalta numero, joka kuvaa toimintanne vaikutusta parhaiten.

	Suuri haitallinen vaikutus	*Pieni haitallinen vaikutus*	*Ei lainkaan haitallista vaikutusta*	*En osaa sanoa*
a) Asunnon jätevedet	1	2	3	4
b) Tekemäni työ	1	2	3	4
c) Loma-asunnon jätevedet	1	2	3	4
d) Harrastukset	1	2	3	4
e) Muu Mikä	1	2	3	4

22. Onko työllänne ja/tai harrastuksillanne Suomenlahden veden laatua **parantavia** vaikutuksia?
Ympyröikää oikea vaihtoehto.
Kyllä 1
Ei 2
En osaa sanoa 3

23. Mikäli vastasitte kysymykseen 22 kyllä, mistä työstä ja/tai harrastuksesta on kyse?

24. Onko asuinkiinteistönne liitetty kunnalliseen viemärijärjestelmään?
Ympyröikää oikea vaihtoehto.
Kyllä 1
Ei 2

25. Mikäli teillä tai perheellänne on vapaa-ajankiinteistö Suomenlahden rannikkokunnassa, onko se liitetty kunnalliseen viemärijärjestelmään?
Ympyröikää oikea vaihtoehto.
Kyllä 1
Ei 2

Suomenlahden veden laadun parantamiseksi on olemassa monenlaisia keinoja ja niitä voidaan toteuttaa eri tahoilla.

26. Tarvitaanko Suomenlahden veden laadun parantamiseksi mielestänne **nykyistä enemmän** toimia?
Ympyröikää oikea vaihtoehto.

Kyllä 1
Ei 2
En osaa sanoa 3

27. Minkä tahon pitäisi rahoittaa Suomenlahden veden laadun parantamiseksi tehtävät toimet?
Merkitkää rastilla väitteistä se, joka kuvaa parhaiten omaa näkemystänne.

Suomenlahden veden laadun parantamiseksi tehtävät toimet tulisi rahoittaa…

a) Ĭ yhteiskunnan varoista.

b) Ĭ kuormittajien itsensä rahoittamana.

c) Ĭ yhteiskunnan ja kuormittajien yhteisesti rahoittamana.

d) Ĭ En osaa sanoa

28. Pitäisikö mielestänne Suomen rahoittaa muissa Suomenlahden rannikkovaltioissa (Venäjä ja Viro) Suomenlahden veden laadun parantamiseen tähtääviä toimia?
Ympyröikää oikea vaihtoehto.

Kyllä 1
Ei 2
En osaa sanoa 3

29. Mihin seuraavista Suomenlahtea rehevöittävistä tahoista teidän mielestänne pitäisi puuttua?
Merkitkää kaikki tahot tärkeysjärjestykseen (1= tärkein taho, jonka rehevöittäviin päästöihin tulisi puuttua, 2= toiseksi tärkein taho, 3= kolmanneksi tärkein taho, jne.).

	Tärkeys
a) Kotimainen teollisuus	
b) Kotimaisten rannikkokaupunkien jätevedet	
c) Sisämaan kaupunkien jätevedet	
d) Laivaliikenne	
e) Maatalous	
f) Pietarin jätevedet	
g) Muualta Venäjän alueelta tulevat ravinnepäästöt	
h) Haja-asutus (viemäröimättömät asunnot)	
i) Vapaa-ajan asutus	
j) Ilman kautta tuleva ravinnekuormitus	
k) Muu *Mikä?*	

Kiitoksia vastauksistanne!

Pyydän teitä palauttamaan vastauksenne **9. 1. 2002** mennessä ohessa olevassa vastauskuoressa. Postimaksu on maksettu puolestanne.

Lisätietoja kyselystä:
Riku Varjopuro
tutkija
Suomen ympäristökeskus
puh. 09-4030 0331, e-mail. riku.varjopuro@vyh.fi

Tälle sivulle voitte kirjoittaa kommentteja kyselystä tai sen aiheesta eli Suomenlahden vesialueiden käytöstä ja suojelusta.

Documentation page

Publisher	Finnish Environment Institute	Date June 2003
Author(s)	Mikko Kiirikki, Pirjo Rantanen, Riku Varjopuro, Anne Leppänen, Marjukka Hiltunen, Heikki Pitkänen, Petri Ekholm, Elvira Moukhametshina, Arto Inkala, Harri Kuosa and Juha Sarkkula	
Title of publication	Cost effective water protection in the Gulf of Finland - Focus on St. Petersburg	
Parts of publication/ other project publications	The publication is also available in the Internet: www.environment.fi/publications	
Abstract	The present study concentrated on collecting information concerning the ongoing and planned water protection measures in St. Petersburg, Russia. The estimated cost and achieved load reductions of the measures were used in cost effetiveness calculations. Comparison with the Finnish national measures was carried out. The ecological effects of the measures were visualised with the aid of 3D-ecosystem models describing the algal growth in the Gulf of Finland. The study also included a questionnaire for the general public about the nuisance caused by eutrophication. The most important water protection measures carried out in St. Petersburg in the near future are the construction of the South-Western waste water treatment plant and the Northern collector sewer as well as starting of chemical phosphorus removal. The cost effectiveness of phosphorus removal was estimated to be clearly the highest. The other measures in St. Petersburg were estimated to be in the same cost category with the improved nitrogen removal in the Finnish coastal municipal waste water treatment plants. The average cost of Finnish national measures was relatively high, mainly because of the high treatment cost of waste waters in the rural areas. The measures carried out in St. Petersburg were shown to be effective in the remediation of the open Gulf of Finland and the Finnish measures along the coastline and in the archipelago. General public in Finland is well aware of the eutrophication problem. Toxic algal blooms on the open sea are naturally seen as a serious problem, but other eutrophication-related phenomena such as water turbidity and fouling of beaches are also considered important. Generally the effects of own activity, such as untreated waste waters from summer houses, are evaluated to have little effect on water quality. The scapegoats are found either on the Russian side of the border or in Finnish industry, municipalities and agriculture. The population living on the coast has the most positive attitude towards the investment of Finnish money in water protection measures carried out in neighbouring countries. Over 50% supported the idea that Finland could take part in the financing of waste water treatment in St. Petersburg.	
Keywords	ecosystem modelling, municipal waste water, algal bloom, cyanobacteria, blue-green algae, Baltic Sea, nutrient load, questionnaire	
Publication series and number	The Finnish Environment 632	
Theme of publication	Environmental protection	
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Kuvailulehti

Julkaisija	Suomen ympäristökeskus	Julkaisuaika Kesäkuu 2003
Tekijä(t)	Mikko Kiirikki, Pirjo Rantanen, Riku Varjopuro, Anne Leppänen, Marjukka Hiltunen, Heikki Pitkänen, Petri Ekholm, Elvira Moukhametshina, Arto Inkala, Harri Kuosa ja Juha Sarkkula	
Julkaisun nimi	Kustannustehokkaat vesiensuojelutoimet Suomenlahdella - Tarkastelukohteena Pietarin kaupunki	
Julkaisun osat/ muut saman projektin tuottamat julkaisut	Julkaisu on saatavana myös internetistä: www.environment.fi/publications	
Tiivistelmä	Tutkimuksessa keskityttin keräämään tietoa Pietarissa käynnissä olevista ja sinne suunnitelluista vesiensuojeluhankkeista. Toimenpiteiden arvioituja kustannuksia ja päästövähennyksiä käytettiin niiden kustannustehokkuuden laskennassa. Toimenpiteiteitä verrattiin kotimaisiin vesiesuojelutoimiin. Suomenlahden levien kasvua kuvaavia 3D-ekosysteemimalleja käytettiin vesiensuojelutoimenpiteiden ekologisten vaikutusten havainnollistamiseen. Tutkimuksessa selvitettiin myös kansalaisten mielipiteitä rehevöitymisen aiheuttamista haitoista ja niiden torjunnasta. Lähitulevaisuuden tärkeimmät vesiensuojeluhankkeet Pietarissa ovat Lounaisen puhdistamon ja Pohjoisen kokoojatunnelin rakentaminen sekä kemiallisen forforinpoiston käynnistäminen. Fosforinpoiston kustannustehokkuus arvioitiin selvästi korkeimmaksi. Muiden Pietariin suunniteltujen toimenpiteiden arvioitiin olevan kustannustehokkuudeltaan samaa luokkaa Suomen rannikkoseudun jätevedenpuhdistamoilla toteutetun tehostetun typenpoiston kanssa. Kotimaisten toimenpiteiden keskimääräiset kustannukset olivat korkeahkoja. Kustannuksia nosti erityisesti haja-asutuksen jätevesien käsittelyn korkeat yksikköhinnat. Pietarissa toteutettavien toimien vaikutukset kohdistuvat selvityksen mukaan voimakkaimmin avoimelle Suomenlahdelle ja ulkosaaristoon. Kotimaisten toimien vaikutukset näkyvät selvimmin rannikon läheisyydessä ja saaristossa. Kansalaiset olivat kyselytutkimuksen mukaan hyvin selvillä rehevöitymisen aiheuttamista haitoista. Avomeren myrkyllisiä sinileväkukintoja pidettiin ilman muuta vakavana ongelmana. Myös veden sameuden ja rantojen limoittumisen aiheuttamia haittoja pidettiin merkittävinä. Omien toimien kuten kesämökkien jätevesien vaikutuksia veden laatuun pidettiin vähäisinä. Syntipukit löytyivät rajan takaa Venäjän puolelta tai kotimaisesta teollisuudesta, yhdyskunnista ja maataloudesta. Rannikon lähellä asuvalla väestöllä oli positiivisin asenne kotimaisen rahan sijoittamiseen naapurimaissa toteutettaviin vesiensuojelutoimiin. Yli 50% kannatti ajatusta että Suomen pitäisi tukea Pietarin jätevesien puhdistamista.	
Asiasanat	ekosysteemimalli, yhdyskuntajätevedet, leväkukinta, sinilevä, Itämeri, ravinnekuormitus, kyselytutkimus	
Julkaisusarjan nimi ja numero	The Finnish Environment 632	
Julkaisun teema	Ympäristönsuojelu	
Projektihankkeen nimi ja projektinumero	Kustannustehokkaat vesiensuojelutoimet Suomenlahdella	
Rahoittaja/ toimeksiantaja	Ympäristöministeriö: Ympäristöklusteriohjelma	
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ЛИСТ ОПИСАНИЯ ПУБЛИКАЦИИ

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Редактор (ы)	Микко Кииркки, Пирьё Рантанен, Рику Варьёпуро, Анне Леппянен, Марьюкка Хилтунен, Хейкки Питкянен, Петри Экхольм, Эльвира Мухамечина, Арто Инкала, Харри Куоса & Юха Сарккула	
Название публикации	Экономически эффективные водоохранные меры в Финском заливе – в центре внимания г. Санкт-Петербург	
Резюме	В рамках исследования главное внимание уделялось сбору информации о водоохранных проектах, проводимых и намечаемых в г. Санкт-Петербурге. Предполагаемые расходы и сокращения сбросов в результате данных мероприятий были использованы для расчета их экономической эффективности. Меры были сопоставлены с водоохранными мерами в Финляндии. Трехмерные экосистемные модели, характеризующие рост водорослей в Финском заливе, были использованы для наглядной демонстрации экологического эффекта водоохранных мероприятий. В рамках исследования был также проведен опрос общест-венного мнения о вреде, причиненном эвтрофикацией залива, и о мерах по борьбе с эвтро-фикацией. Основные водоохранные проекты ближайшего будущего в г. Санкт-Петербурге – заверше-ние строительства Юго-Западных очистных сооружений сточных вод и Северного коллек-тора, введение химического удаления фосфора. Экономическая эффективность удаления фосфора была явно определена как самая высокая. Согласно оценкам, экономическая эф-фективность других мер, намечаемых в г. Санкт-Петербурге, совпадает с экономической эффективностью мер по повышению степени удаления азота на очистных сооружениях сточных вод в прибрежных территориях Финляндии. В среднем, затраты на выполнение аналогичных мер в Финляндии относительно большие, и они возросли особенно сильно за счет высоких цен на единицу очистки сточных вод в сельской местности. В соответствии с результатами исследования, выполняемые в г. Санкт-Петебруге меры оказывают самое сильное воздействие на открытую часть Финского залива и на отдаленные от прибрежной зоны острова. Меры в Финляндии оказывают наиболее ощутимое воздействие на прибреж-ную зону и близлежащие шхеры. Результаты опроса общественного мнения показали, что граждане хорошо осведомлены о вреде, наносимом эвтрофикацией залива. Цветение токсичных сине-зеленых водорослей в открытой части залива считали весьма серьезной проблемой. Мутность воды и покрытие береговых участков слизистыми водорослями также рассматривались как значительный вред. Влияние собственной деятельности, например, дачных сточных вод, на качество во-ды люди считали незначительным. Они считают, что главными виновниками являются предприятия и населенные пункты за границей, в России, или же промышленность, насе-ленные пункты и сельское хозяйство в Финляндии. Население, проживающее на прибреж-ных территориях, наиболее положительно относится к инвестициям Финляндии в водоох-ранные мероприятия в соседних странах. Более 50 % опрошенных поддерживают финансо-вое участие Финляндии в очистке сточных вод г. Санкт-Петебурга.	
Ключевые слова	экосистемная модель, муниципальные сточные воды, цветение водорослей, сине-зеленые водоросли, Балтийское море, нагрузка питательными веществами, опрос общественного мнения	
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Финансирующая орга-низация/Заказчик	Министерство окружающей среды Финляндии: Комплексная программа по охране окружающей среды	
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ENVIRONMENTAL PROTECTION

Cost effective water protection in the Gulf of Finland - Focus on St. Petersburg

The effects of water protection actions taken in Finland and in St. Petersburg in order to solve the eutrophication problem, and the costs of such actions, have been estimated in a research project coordinated by the Finnish Environment Institute (SYKE). The new South-Western sewage treatment plant of St. Petersburg is presently under construction with international funding.

The most cost-efficient action would be to start the chemical removal of phosphorus at the present sewage treatment plants of St. Petersburg. However, it has not so far been possible to find funding for it as it is difficult to get international funding for permanent running costs. For the present sewage treatment plants, the yearly costs for chemicals are assumed to stay below 10 M€.

The ecological effects of the actions in St. Petersburg would be different from those carried out in Finland. Finnish national efforts would improve the water quality especially in the Archipelago Sea but also along the coast of the Gulf of Finland. The effects of the actions in St. Petersburg would been seen in open sea areas, in the outer archipelago and in the vicinity of St. Petersburg.

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