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Ecological State of the Kola River, Northwestern Russia

– The Kola Water Quality -project

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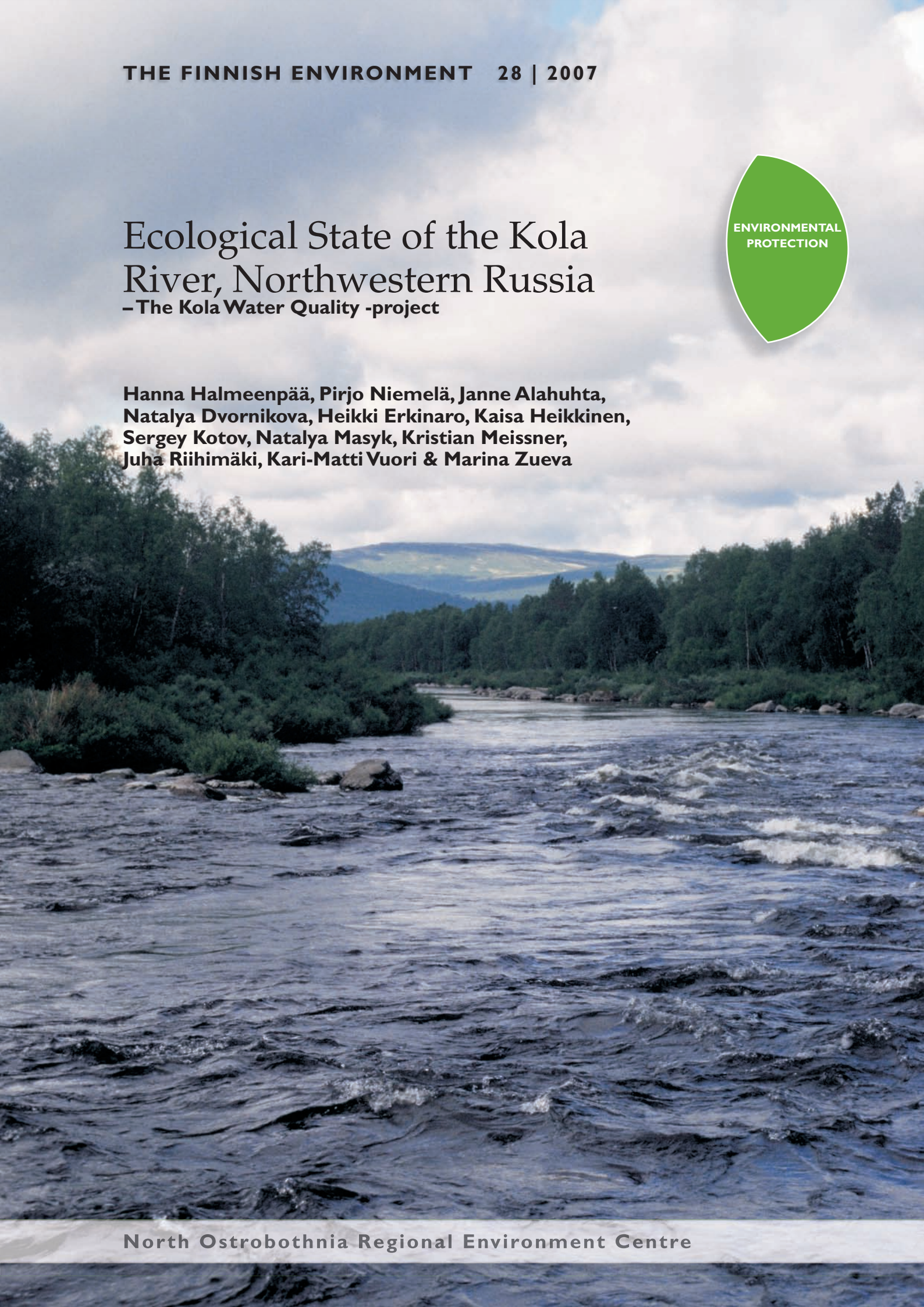

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PREFACE

The Kola Water Quality Project (KWQ) was an international collaboration during years 2000–2004. One of the main aims of project was to develop the environmental impact assessment of pollutants in the Kola River, northwestern Russia. The project was financed by the EU/ INCO-Copernicus programme (ICA2-CT-2000-10051), the Finnish Ministry of the Environment, Finnish Environment Institute, North Ostrobothnia Regional Environment Centre and Luleå University of Technology. The project was divided into six work packages:

1. Pollution status identification,
2. River status identification,
3. Decision support system and protocol for cost-effective monitoring,
4. Identification of sites for artificial wetland,
5. Constructing and testing pilot artificial wetland for wastewater purification,
6. Technical and financial co-ordination, and leading dissemination of results.

Both the scientific and financial management was carried out by project co-ordinator Arnold Pieterse (Royal Tropical Institute, KIT, The Netherlands). Steering group of the project, with Mr. Pieterse in the chair, was formed by the representatives of participating organisations: Björn Öhlander (Luleå University of Technology, LTU, Sweden), Raimo Ihme (Finnish Environment Institute, SYKE, Finland), Kaisa Heikkinen and Tero Väisänen (North Ostrobothnia Regional Environment Centre, NOREC, Finland), Margarita Ryabtseva and Viktor Chapin (The Federal State Institution for the Murmansk Territorial Fund on Geological Information, FGU MurTFGI, Russia), Olga Mokrotovarova and Anatolij Semenov (The Murmansk Areal Department for Hydrometeorology and Environmental Monitoring, MUGMS, Russia), Felix Stolberg, Viktor Ladyzhenskij (Kharkiv State Academy of Municipal Economy, KSAME, Ukraine) and Ülo Mander (The Institute of Geography, University of Tartu, UoT, Estonia). The consortium was aided by the already existing network co-ordinated by Åke Mikaelsson (The Kola River Environment Program, KREP, Russia).

This report is a compilation of the ecological status assessment carried out in the work package 2, in which the biota and the hydromorphological state of the Kola River were compared to a river in reference condition, the Näätämöjoki River. North Ostrobothnia Regional Environment Centre (NOREC) under the guidance of the project managers Kaisa Heikkinen and Tero Väisänen took the main responsibility on the ecological studies. The chapters concerning the macroinvertebrate studies were written by Kristian Meissner (NOREC), the chapters on fish communities by Heikki Erkinaro (NOREC and Finnish Game and Fisheries Research Institute), the chapters on diatom community analysis by Hanna Halmeenpää and Pirjo Niemelä (NOREC) and the chapters on the River Habitat Survey by Janne Alahuhta (NOREC). Studies concerning the aquatic bryophytes were reported by Hanna Halmeenpää (NOREC) and Kari-Matti Vuori (SYKE), chapters on macrophyte survey were written by Juha Riihimäki (SYKE). Hanna Halmeenpää and Pirjo Niemelä (NOREC) took the responsibility of editing the report and writing of common chapters. The report is made up by Mari Wuolio (NOREC).

Murmansk Areal Department for Hydrometeorology and Environmental Monitoring (MUGMS) co-ordinated by the project manager Olga Mokrotovarova performed river status assessment according to federal Russian hydrobiological monitoring methods. The chapters on bacterioplankton and phytoplankton were written by Natalya Masuk (MUGMS), the chapters on zooplankton by Natalya Dvornikova

(MUGMS) and the chapters concerning macrozoobenthos survey by Sergey Kotov (MUGMS). Articles on physical and chemical water quality concerning the Kola River and the Näätämöjoki River were written by Marina Zueva (MUGMS) and Hanna Halmeenpää (NOREC).

We are most grateful to all the people who participated the work during the project; Mari Sallmén, Riitta Ilvonen, Ann-Marie Airaksinen, Mirja Heikkinen, Juha Salonen (NOREC), Anatoli Rättel (Finnish Game and Fisheries Research Institute), Jouni Satokangas, Martti Salminen, Ilona Grekelä (Lapland Regional Environment Centre), Alexey Kudravtsev (MUGMS), Victoria Rumiantseva (KREP), Jouko Mosnikoff and Elias Mosnikoff.

ПРЕДИСЛОВИЕ

Международный проект по изучению качества воды реки Колы (KWQ) был реализован в период с 2000 по 2004 год. Одной из основных целей проекта было совершенствование оценки загрязнения реки Колы (Северо-Западная Россия). Проект финансирован Евросоюзом (EU) через программу INCO-Copernicus (ICA2-CT-2000-10051), министерством окружающей среды Финляндии, Институтом окружающей среды Финляндии, региональным центром окружающей среды Северной Эстерботнии и Технологическим университетом Лулео (Luleå University of Technology). Проект был разделен на шесть рабочих модулей:

1. Определение степени загрязненности,
2. Определение экологического состояния реки,
3. Система поддержки решений и протокол для эффективного мониторинга,
4. Определение участков для создания искусственных биоплато,
5. Сооружение и испытание экспериментального биоплато для очистки сточных вод,
6. Техническая и финансовая координация и публикация результатов.

Проект координировался «Королевским Тропическим Институтом» (Royal Tropical Institute, KIT, Нидерланды). Научным и финансовым руководителем был Арнольд Пиетерсе (Arnold Pieterse). В руководящую группу проекта во главе с Арнольдом Пиетерсе вошли представители участвующих в реализации проекта организаций: Бьёрн Охландер (Björn Öhlander), из Технологического университета Лулео (LTU, Швеция), Раймо Ихме (Raimo Ihme) из Института окружающей среды Финляндии (SYKE, Финляндия), Кайса Хейккинен (Kaisa Heikkinen) и Теро Вяйсянен (Tero Väisänen) из Регионального центра окружающей среды Северной Эстерботнии (NOREC, Финляндия), Маргарита Рябцева и Виктор Чапин из Федерального государственного учреждения "Территориальный фонд геологической информации" по Мурманской области (FGU MurTFGI, Россия), Ольга Мокротоварова и Анатолий Семёнов из Управления по гидрометеорологии и мониторингу окружающей среды Мурманской области (MUGMS, Россия), виктор Ладыженский из Академии коммунального хозяйства Харьковской области (KSAME, Украина) и Уло Мандер (Ülo Mander) из Института Географии Университета Тарту (UoT, Эстония). Консорциум получал поддержку ряда других заинтересованных организаций, участвовавших ранее в проекте по созданию программы в области охраны окружающей среды по реке Кола (KREP, Россия), координированным Оке Микаельсеном (Åke Mikaelsson).

В данном отчете представлена оценка экологического состояния реки, проведённая в рабочем модуле 2. Состояние биоты и гидроморфологические характеристики реки Колы сравнивались с состоянием фоновой реки Наатамёйоки. Региональный центр окружающей среды Северной Эстерботнии (NOREC) под руководством менеджеров проекта Кайсы Хейккинен (Kaisa Heikkinen) и Теро Вайсанен (Tero Väisänen) отвечал за экологические исследования. Главы, посвящённые исследованиям макробеспозвоночных, были написаны Кристианом Мейсснером (Kristian Meissner, NOREC), исследованиям сообществ рыб - Хейкки Эркинаро (Heikki Erkinaro, NOREC и Институт исследования охотничьего и рыбного хозяйства), исследованиям сообществ диатомовых водорослей - Ханной Халмеенпаа (Hanna Halmeenpää, NOREC) и Пирьё Ниемеля (Pirjo Niemelä, NOREC), гидроморфологические характеристики реки - Янне Алахухта (Janne Alahuhta, NOREC). Результаты исследований гидробриофитов предоставлены Ханной Халмеенпаа (Hanna Halmeenpää, NOREC) и Кари-Матти Вуори (Kari-Matti Vuori, SYKE), исследования

макрофитов описаны Юхой Риихимяки (Juha Riihimäki, SYKE). Ханна Халмеенпаа (Hanna Halmeenpää) и Пирьё Ниэмеля (Pirjo Niemelä) (NOREC) отвечали за редакцию отчёта и написание глав общего характера. Вёрстку выполнила Мари Вуолио (Mari Wuolio) (NOREC).

Специалисты Управления по гидрометеорологии и мониторингу окружающей среды Мурманской области (MUGMS) под руководством Ольги Мокротоваровой провели оценку состояния реки согласно российским стандартам водного мониторинга. Главы по бактериопланктону и фитопланктону были написаны Натальей Масюк (MUGMS), главы по зоопланктону - Натальей Дворниковой (MUGMS), а главы об исследовании макрозообентоса согласно российским стандартам, - Сергеем Котовым (MUGMS). Гидрохимический состав воды реки Колы был описан Мариной Зуевой (MUGMS), а реки Наатамёйоки - Ханной Халмеенпаа (Hanna Halmeenpää, NOREC).

Мы сердечно благодарим всех, кто участвовал в полевых исследованиях в ходе проекта: Мари Саллмен (Mari Sallmén), Риитту Илвонен (Riitta Ilvonen), Анн-Мари Аираксинен (Ann-Marie Airaksinen), Мирью Хеиккинен (Mirja Heikkinen), Юху Салосена (Juha Salonen, NOREC), Анатолия Раттела (Anatoli Rättel, Институт исследования охотничьего и рыбного хозяйства**)**, Ёоуни Сатокангаса (Jouni Satokangas), Мартти Салмисена (Martti Salminen), Илону Грекеля (Ilona Grekelä, региональный центр окружающей среды Лапландии), Алексея Кудрявцева (MUGMS), Викторию Румянцеву, Оке Микаэльссона (Åke Mikaelsson, KREP), Ёуко Мосникоффа (Jouko Mosnikoff) и Элиаса Мосникоффа (Elias Mosnikoff).

CONTENTS

1 Introduction

1.1 Methods for river status assessment

Water quality has traditionally been assessed using indirect measures of aquatic health, emphasising chemical testing. However, chemical analyses only give us a snapshot of the current state of a river. Biological assessments, on the other hand, integrate the effects of water quality over time, and are more sensitive to multiple aspects of water and habitat quality than chemical and toxicity tests alone. Furthermore, biological assessments define the effects of point source discharges and provide an appropriate means for evaluating discharges of non-chemical substances (e.g. sedimentation and habitat destruction). The relevant assessment of water resource condition necessitates the right kind of measurements, usually the concurrent use of chemical and biological data.

1.1.1 Macroinvertebrates

Benthic macroinvertebrates are a key component in maintaining healthy aquatic systems and are among the most commonly used and effective biological assessment tools for water quality management and watershed condition evaluation. Most fish species, including commercially important ones, such as salmon, use benthic macroinvertebrates as a source of food. In addition, many benthic macroinvertebrates are well-known indicators of water quality. Benthic macroinvertebrates are cost-effective environmental indicators since their response times are from instantaneous to months. The monitoring of benthic macro-invertebrate communities can be divided into two major components; 1) using benthic macro-invertebrate communities as an assessment tool to help prioritise watershed improvement projects, evaluate project success and measure long-term trends in water resource condition; 2) measuring the quantity and quality of benthic macroinvertebrates as a source of food for aquatic, riparian and terrestrial organisms. Monitoring of benthic macroinvertebrates may thus provide a direct measure of success for the programmes that aim at improving the watershed status.

1.1.2 Fish communities

Freshwater fish populations have long been monitored for the purposes of fisheries. The monitoring has mainly focused on economically important species like salmonids. The use of fish communities as indicators of ecological water quality has increased recently as well (Malmquist et al. 2001). Many factors make fish relevant for environmental assessment purposes. They are easy to identify and most of the responses to anthropogenic disturbances are well understood. Fish are usually long-lived organisms, which have different ontogenetic stages. These properties provide an integrated picture of functional ecosystem alterations over a long time span (Malmquist et al. 2001). In addition, fish populations are socio-economically important resources, which attract attention among politicians as well as the general public with recreational interests.

Mainly single measures such as composition, abundance and diversity of fish communities as well as the occurrence of certain effect-sensitive indicator species have been used in fish-based monitoring. Recently, a range of composite indices; often modifications derived from the IBI index (index of biotic integrity) (Karr 1981), have been developed (e.g. Oberdorff and Hughes 1992; Appelberg et al. 2000; Kestemont et al. 2000). These approaches integrate various biological functions and human impacts on the fish community by a set of metrics.

1.1.3 Benthic diatoms

Diatoms are an important part of aquatic ecosystems and constitute a water quality monitoring tool, in which the primary objective is either a measure of general water quality or a specific component of water quality (e.g. eutrophication, acidification or saprobia). The methodology is based on the fact that all diatom species have optima with respect to the tolerance to different environmental conditions (organic pollution, pH, nutrients, salinity). Polluted waters will typically support an increased abundance of those species whose optima correspond to the levels of the pollutant in question; whereas

pollutant intolerant species will decrease in abundance. There are several benefits in using diatoms for evaluating the quality of running waters:

1. there are several thousands of diatom species and diatoms are ecologically a very diverse group
2. the ecology of different diatom species is well-known
3. diatoms exist in almost any waterbody
4. sampling and preparing diatom slides is rather quick and easy, and the diatom slides last practically forever.

1.1.4

Aquatic bryophytes

Metal concentrations in river ecosystems are affected by natural soil and bedrock sources as well as by anthropogenic loading from atmospheric deposition and various point and non-point sources (Förstner and Wittman 1979). Aquatic bryophytes (e.g., *Fontinalis* species) are considered ideal indicators of metal pollution for a wide range of river types (Say and Whitton 1983; Vanderpoorten 1999; Vuori et al. 2003). They are widely distributed, long-lived, have a considerable capacity to accumulate heavy metals and are relatively tolerant to pollution (Lopez and Carballeira 1993). Since bryophytes do not possess roots or vascular systems, there is no internal transfer of pollutants (Cenci 2000; Nimis et al. 2002). Metal uptake in bryophytes occurs primarily straight from the water by adsorption and absorption through the cell surfaces (Welsh and Danny 1980; Empain 1985; Cenci 2000). Bryophytes accumulate ambient metal concentrations and retain the increased levels for several days or even weeks after concentrations in water have decreased. This enables the monitoring of both chronic metal contamination and sudden discharges (Say and Whitton 1983; Wehr and Whitton, 1983; Mouvet et al. 1993).

1.1.5

River Habitat Survey (RHS)

River Habitat Survey (RHS) is a method for assessing the physical character and the quality of river habitats. It was developed to help the conservation and restoration of wildlife habitats along rivers and their flood plains. Its main purpose is to provide river managers with information needed to sustain and enhance biodiversity, using catchment management plans and environmental impact assessment as two mechanisms for realising this objective. The attributes recorded by the RHS capture the structural variation in rivers relevant to a wide range of organisms, from microscopic algae to fish, birds and mammals. Until the year 2000, the RHS had been used for many different purposes, from identifying habitats for protected species to locating the sources, sinks and mechanisms affecting the sediment movement in catchments and finding out how this relates to sustainable flood defence solutions. The RHS was developed in Britain in the 1990´s by the Environment Agency. The system is based on information from a major baseline survey of rivers and streams in the United Kingdom and on the Isle of Man. More than 5 600 sites were sampled during the years 1994–97. The RHS has four distinct components: 1) a standard method for field survey, 2) a computer database for survey sites and for comparing them with information from other sites, 3) a suite of methods for assessing the habitat quality, and 4) a method for describing the extent of artificial channel modification (Raven et al. 1998b).

1.2

Human impacts on the Kola River

The Kola River in the northern part of the Kola Peninsula is culturally and an economically important area for north-western Russia. The river is vital for the reproduction of salmon and it is also an important source of drinking water for about half a million people in the city of Murmansk and in the surrounding settlements. The Kola Peninsula has been a large industrial centre for nickel and copper mining and smelting for about 70 years (Reimann et al. 1998; Dauvalter et al. 2000). The industrial development has given rise to concerns about metal pollution in the Kola River. However, information on the pollution status of the river basin is sparse. Almost all human activities in this area are close to the Kola River. A large proportion of the areas mining and other industry is located within or adjacent to the river basin. Similarily, minor settlements and agricultural enterprises are mainly set along the railway and the highway between Murmansk and St. Petersburg, in close proximity to the Kola River.

The main polluters within the Kola River basin are the Olenegorsk open-cast iron ore mine and concentration plant in the upper part of the basin. In addition, farming activities, such as poultry, pig, fox, and cattle farms impair the water quality in the lower part of the Kola River basin (Jonsson and Mikaelsson 1997; Mokrotovarova 1999; Rytter 2001). The copper and nickel smeltery, Severonikel, in

Monchegorsk is located 25 km south of the catchment area, but it is a major source of airborne pollution within the watershed, especially during the wintertime, when south- and southwesterly winds predominate (Mokrotovarova 1999). The open-pit iron mine and ore concentration plant in Olenegorsk are located between two lakes, Lake Imandra and Lake Kolozero. Leakage of sludge deposits, the discharge of improperly treated mine- and process waters from the steelworks directly into Lake Kolozero constituted 0.4 million m^3 in 2002 (The Federal State Institution for the Murmansk Territorial Fund on Geological Information 2003). The pollutants from the Olenegorsk opencast iron ore mine and concentration plant reach the Kola River via Lake Kolozero.

The annual organic waste produced by the farms in the lower part of the river basin amounts to 106 000 m^3 of liquid waste, 37 000 tonnes of solid waste, 332 tonnes of carcasses and 2595 tonnes of slaughter waste (Rytter 2001). The pollutants from the poultry farms, related to the leakage from the overloaded manure ponds, reach the Kola River via the Medvegiy and the Zemlanoy Creeks, while the pollutants from the pig, fur, and cattle farms reach the Kola via the Varlamov Creek. Other local sources of pollution in the Kola River basin are the railway stations, nearby roads, Macadam plant in Magnetity village, reindeer, fox and cattle farms near the Loparskaja village, a fish farm upstream the Taibola sampling site, wastewater treatment plants and urban housing (The Federal State Institution for the Murmansk Territorial Fund on Geological Information 2003).

The amount of wastewater discharges within the Kola River basin during year 2002 was about 7.7 million m^3, 3.7 million m^3 of which were non-properly treated. A major share of the annual wastewaters is discharged at treatment plant in Olenegorsk (about 40%). In the lower part of the basin treatment facilities (20%) and flushing waters (25%) in the village of Molochny are the biggest wastewater sources. Inputs by other industries are not significant and do not exceed 5% of the annual wastewater discharge within the river basin (The Federal State Institution for the Murmansk Territorial Fund on Geological Information 2003).

The upper and middle parts of the Kola River are popular fishing areas. Fishing in the Kola River basin concentrates on salmon, with other fish species having no, or little commercial or recreational value. The river has not been structurally modified and hence in principle guarantees free migration of fish. In the Kola River, all spawning salmon are caught at a fish counting fence locating 25 kilometres upstream from the river mouth (Jensen et al. 1997). Spawning salmon have free access to the upper reaches only during the spring flood, because the fence cannot be operated until the high flood has subsided. The fence has been operated since 1959 with the aim of prohibiting illegal fishing and reinforcing the salmon stocks by stocking of reared salmon juveniles. Because the spawning run is interrupted for most of the salmon population the river could be defined as semi-natural. Between 110 000–370 000 hatchery-reared juveniles are yearly released back to the river. Since salmon rearing uses the indigeneous genetic material the Kola River salmon population can be considered as as naturally reproducing. With the exception of approximately 300 adult salmon taken yearly as hatchery material (Zubchenko et al. 2003) commercial harvesting of salmon has ended in 1999. Since then all fish have had free access to the river's upstream reaches.

The Kola River basin area is sparsely populated and current levels of pollution are mostly low or at least considerably lower than in most urban and industrialized areas. Still, human pollution causes concern because of indications that ecosystems in northern latitudes are susceptible to biological damage at low levels of pollutants. Many organisms are adapted to storing biological energy therefore may potentially accumulate and concentrate organic pollutants and toxic metals in their tissues. As a consequence, humans consuming local food display elevated pollutant concentrations compared to ambient levels of concentration (Canadian Arctic Resources committee 1990).

2 Material and methods

2.1 Study areas

The Kola Water Quality Project's study area of ecological studies consisted of two river basins. The main study area was the Kola River (69° N, 33° E) located on the Kola Peninsula, in northern Russia, whereas the Näätämöjoki River (69° N, 28°E) in northernmost Finland and Norway was selected to act as a reference area to the Kola River. Both rivers Kola and Näätämöjoki are large northern boreal or sub-arctic rivers draining into the Barents Sea. They are nearly equal in length and in size of the catchment areas. The basin of the Kola River lies in the northern boreal coniferous zone, whereas the Näätämöjoki River flows mainly in the sub-arctic birch zone (Table 1). The study areas are located in northern parts of the northern boreal climate zone, which shows characteristics of both a maritime and a continental climate, depending on the direction of air flow.

The overall human impact differs markedly between the rivers. The upper- and mid-reaches of the Näätämöjoki River are in virtually pristine condition with no industrial, farming or forestry activities. In the lowest reaches minor human influences are possible. The spawning migration of Atlantic salmon has been facilitated in the Näätämöjoki River by constructing a fish-pass in the 1960´s at the biggest waterfall (Kolttaköngäs) some 12 kilometres upstream from the river mouth (Niemelä et al. 2001). The Kola River, instead, has long been affected by human disturbance, both from household and industrial sources (see chapter 1.4 above).

There were 13 sampling sites for biological and water chemistry parameters in the Kola River, and 5 in the Näätämöjoki River. Sampling sites were chosen to represent the upper, the middle and estuary sections of the rivers. In addition sampling site selection gave consideration to main loading points. Most sampling points were situated in riffles, since different bio-indicators predominate in high velocity habitats.

Macroinvertebrates, fish, benthic diatoms, aquatic bryophytes, macrophytes, zoo-, phyto-, and bacterioplankton samples were taken from the sampling points in 2001 (7–11 July) and 2002 (8–17 July and 2–11 September). The River Habitat Survey (Environment Agency 1997and 1999, Raven et. al. 1998b) as well as the chemical and physical properties of the rivers were monitored at the same time. All the sampling sites are introduced in more detail in the following text.

Table 1.
General overview of the studied rivers.

	The Kola River	The Näätämöjoki River
Length (km)	83	79
River basin (km^2)	3 850	2 962
Lake percentage	6	> 9.8
Riffles (km)	25.5	
Slope (promille)		2.6
Fall (m)	141	193
Mean discharge (m^3/s)	30	27
Precipitation (mm)	532–576	450–500
Runoff (mm)		250–350
Evapotranspiration (mm)		100–200
Bedrock type	Granite, gneiss	Granite, gneiss
Vegetation zone	Northern boreal coniferous zone	Sub-arctic birch zone
Human impacts	Industry, poultry-, fur-, pig-, and fish farming, railway, City of Kola, several villages	Reindeer farming, fishing, hunting, travelling, hiking, small villages (Näätämö and Sevettijärvi)

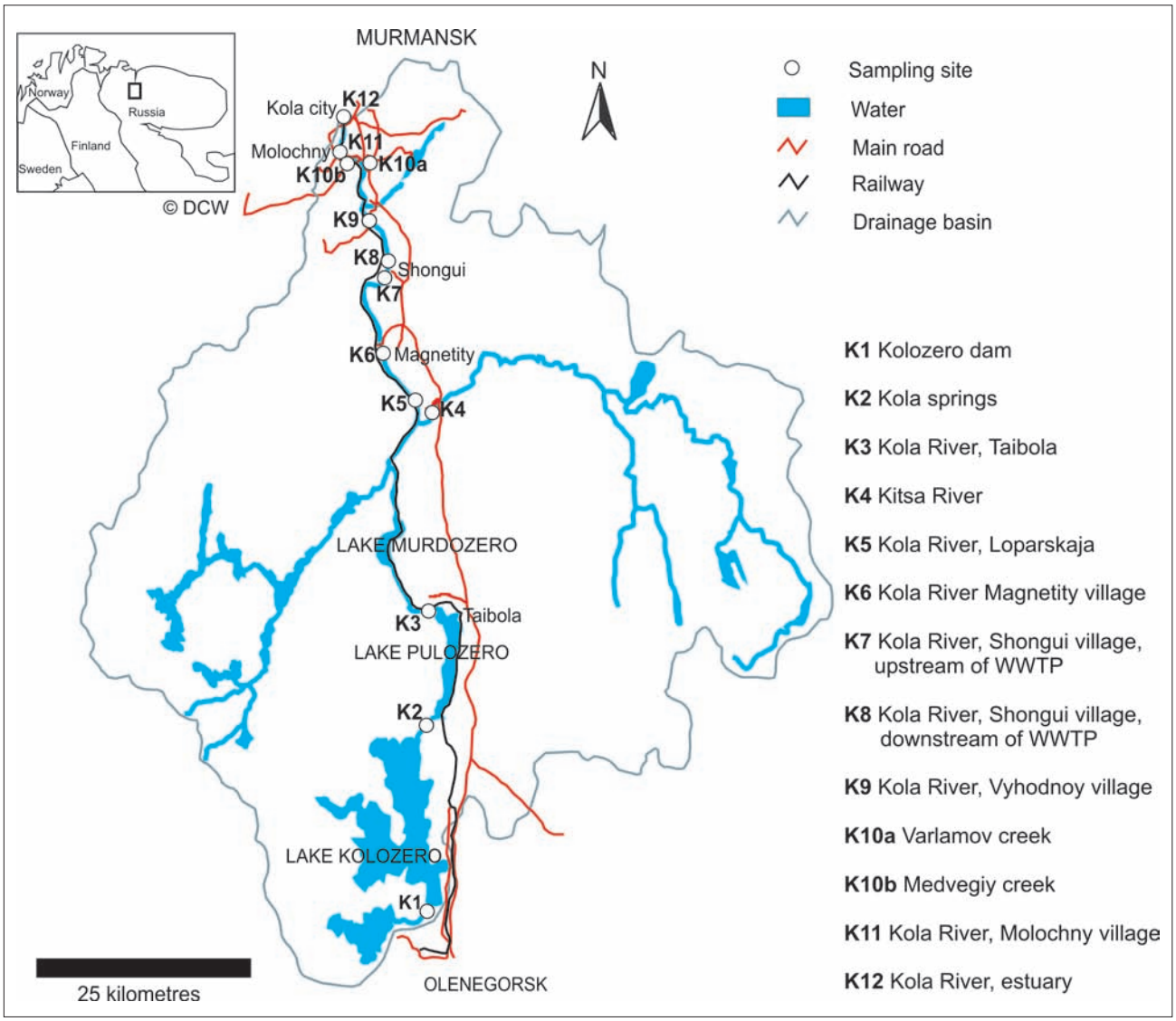

Fig. 1. Study site locations within the Kola River basin.

Fig. 2. View to Lake Kolozero from the Kolozero dam, site K1. Photo: Tero Väisänen.

Fig. 3. Sampling at K2, Kola springs, July 2001. Photo: Riitta Ilvonen.

2.1.1

Kola River sampling sites

K1. Kolozero dam

Sampling site at the Kolozero dam was located about 90 km from the Kola River estuary, at the Lake Kolozero alongside the Olenegorsk iron mines and ore concentration plant (Fig. 2). The Kola River springs from the Lake Kolozero, about 6.5 km northwards from the sampling location K2 (Fig. 1). A dam and a settling pond between the deposit area and the lake prevent wastewater discharge from the mine tailings into the Lake Kolozero.

K2. Kola springs

The sampling site at Kola springs was located near the Lake Kolozero outlet. The sampling area consisted of two riffle sections and a glide (Fig. 3). The average velocity of the flow was 0.28 m/s, the channel depth was 41 cm and the width about 60–70 m. The channel substrate was mainly of cobbles and boulders. On both sides of the river, there were continuous carrs and mixed forest. Remnants of an old wooden bridge were situated directly upstream of the sampling location .

Fig. 4. K3, Taibola sampling site, rapid section. Photo: Pirjo Niemelä.

Fig. 5. View of the bridge upstream of sampling site K4, at Kitsa River. Photo: Tero Väisänen.

Fig. 6. Mid-channel bar in the river, seen from the cable bridge above sampling area K5. Photo: Riitta Ilvonen.

Fig. 7. Boulders at sampling site K6, in Magnetity. Photo: Tero Väisänen.

Fig. 8. Sampling site K7 in the short riffle section seen from above the mid-channel bar. Photo: Tero Väisänen.

K3. Kola River, Taibola

The Taibola sampling site was the outlet of the Lake Pulozero. The sampling area consisted mainly of, riffles and runs (Fig. 4). In addition there was a mature island in the channel. The average velocity was 0.86 m/s, mean channel depth 34 cm and mean width about 60–70 m. The channel substrate was mostly of cobbles and boulders. Riparian vegetation on both sides of the river consisted of mixed forest, scrubs and herbs. On the right bank top there was a railroad track.

K4. Kitsa River

The sampling site at Kitsa River was located about 2 km upstream of its inflow to the Kola River. Within the sampling site there were rapid sections, riffles and runs (Fig. 5). Average flow velocity at the sampling area was 0.61 m/s, depth was about 40 cm and channel width about 80–100 m. Cobbles and boulders predominated in the channel substrate. There was also leaf-litter in the channel. Many side bars and mature islands characterized this site. Extensive forests covered both sides of the sampling area. A brigde of the Murmansk-St. Petersburg highway was situated 200 m upstream from the sampling location. Paralell to the the right side of the river there was also a smaller road.

K5. Kola River, Loparskaja

The Loparskaja sampling site located about 2 km downstream of the Kitsa River inflow. This sampling site was characterized by a riffle section, runs and glides. Average flow velocity was 0.82 m/s, channel depth about 31 cm and width about 120 m. The main channel substrate formed a cobble mid-channel bar alongside the sampling site. Aa cable bridge crossed the river right upstream of the sampling site (Fig. 6). Coniferous forests and gravel covered the right river bank, herbs and scrubs the left side of the river. Human settlement was obvious on both river banks. In addition a railway track was found on the left bank.

K6. Kola River, Magnetity village

The Magnetity sampling site in the middle section of the Kola River contained one riffle section, several runs, and glides. Average flow velocity was about 0.43 m/s, channel depth about 40 cm and width about 120 m. Channel substrate was of cobbles and large boulders (Fig. 7). Extensive coniferous forest span both sides of the river.

K7. Kola River, Shongui village, upstream of wastewater treatment plant

This sampling site was located about 500 m upstream of the Shongui wastewater treatment plant (WWTP). While runs and glides predominated at the site, a short riffle section ran on the right riverside. Average flow velocity at the sampling area was 0.48 m/s, channel depth was 28 cm and channel width 120–140 m. The substrate was mainly cobbles. Both side- and mid-channel bars were found at this site. Banks were covered by herbs and scrubs. Human settlement was present on both sides of the river, being more extensive on the right side (Fig. 8).

K8. Kola River, Shongui village, downstream of the wastewater treatment plant

About 100–200 m downstream of the Shongui wastewater treatment plant (WWTP) there were no distinct runs, glides or riffle sections, (Fig. 9). Mean flow velocity was about 0.46 m/s, mean channel depth about 39 cm and width about 100 m. Channel substrate was composed of sand, gravel and cobbles.Various litter was found at this site. The river channel displayed side and mid-channel bars. Riparian vegetation consisted of mixed forest on the right riverside, scrubs and herbs on both river banks. Human settlement was present on both sides, with a military installation on the left side.

Fig. 9. Mid-channel bar at Shongui sampling site K8, downstream of the WWTP. Photo: Tero Väisänen.

K9. Kola River, Vyhodnoy village, upstream of the poultry farms

This sampling site was located about 1.5 km upstream of the lower part of the Kola River basin, which is heavily polluted by agricultural activity, such as poultry, pig, fur and cattle farms. Glide was the only flow type at this site, and the channel substrate was of sand (Fig. 10). The channel displayed side bars and contained various litter of human origin. The sampling area was surrounded by human settlement, woodland and scrubs.

Fig. 10. Sampling site K9 at Vyhodnoy village. Photo: Riitta Ilvonen.

K10a. Varlamov creek

At Varlamov creek the sampling site located right downstream of a trunk road bridge. Sewage waters were running into the creek. There was one small riffle section, runs and glides as flow types. Mean flow velocity reached 0.64 m/s, channel depth was about 24 cm and channel width about 3 m. Substrate in the channel was mainly of cobbles, but concrete reinforcement plates were present. The channel was braided and meandered and displayed many point bars. Channel banks were covered by tall herbs, scrubs and mixed woodland (Fig. 11).

Fig. 11. Site K10a, Varlamov creek. Photo: Tero Väisänen.

K10b. Medvegiy creek

This site was added to the sampling programme during the second sampling period, in July 2002. There were runs and glides in the creek, average flow velocity was about 0.50 m/s, channel depth about 18 cm and width about 2–3 m. Gravel and cobbles were the main substrate in the channel, also artificial concrete particles and crushed stones were present. Banks were covered by tall herbs, scrubs and mixed woodland (Fig. 12). A railway bridge was located right downstream of the sampling site.

Fig. 12. Electrofishing at K10b, Medvegiy creek, September 2002. Photo: Hanna Halmeenpää.

K11. Kola River, Molochny village

Sampling site at Molochny village located downstream of the creeks draining the area of two large poultry farms. There was one long rapid section, riffles and runs (Fig. 13). Mean flow velocity was 0.39 m/s, mean channel depth 44 cm and channel width about 80 m. Substrate was mainly of boulders, in addition there was also a lot of litter in the channel. Human settlements were present on both sides of the river, more extensively so on the left side. On the left bank there was also a railway track. Whereas the right riverbank was covered by extensive forest.

Fig. 13. The Kola River at K11, Molochny village. Photo: Riitta Ilvonen.

Fig. 14. Sampling site K12 in the river estuary located in the city of Kola. Photo: Tero Väisänen.

Fig. 16. Sampling site N1 in the Näätämöjoki River, Lake Opukasjärvi inlet. Photo: Hanna Halmeenpää.

Fig. 17. Macroinvertebrate sampling at N2, Lake Opukasjärvi outlet. Photo: Hanna Halmeenpää.

Fig. 18. Bedrock on riverbanks at site N3, Saunakoski. Photo: Janne Alahuhta.

Fig. 19. Sampling at N4, Kallokoski was carried out downstream the cable bridge. Photo: Janne Alahuhta.

K12. Kola River estuary

The Kola River estuary sampling site located about 0.5 km upstream of the river mouth, about 100–200 m downstream of a road and railway bridge near the city center of Kola (Fig. 14). There was one long rapid section, riffles and runs as flow types. Average flow velocity was about 0.43 m/s. Channel depth was about 45 cm and channel width about 60–80 m. Mostly boulders covered the river bottom, litter in channel was also seen. River banks were partly covered by scrubs. The site was surrounded by urban housing, industry, railway and roads.

2.1.2

Sampling sites at the Näätämöjoki River

N1. Näätämöjoki River, Lake Opukasjärvi inlet

This sampling site located about 100 m upstream of a cable bridge over the Lake Opukasjärvi inlet (Fig. 15, page 17, and Fig. 16). The site was characterized by one long rapid section, riffles and runs. Flow velocity reached 0.84 m/s. Channel depth was about 36 cm, width about 40 m. Channel substrate was consisted of cobbles and boulders, and partly covered also the banks. Scrubs, herbs and broadleaved forest grew on both sides of the river.

N2. Näätämöjoki River, Lake Opukasjärvi outlet

At this site sampling was carried out about 100 m downstream of the Lake Opukasjärvi outlet (Fig. 17). Flow types included one rapid section, but mostly riffles and runs. Average flow velocity was about 0.43 m/s, channel depth about 29 cm and width about 50 m. Cobbles covered the river bottom. Banks were partly covered by gravel, partly by scrubs and herbs. Mixed forest dominated both sides of the river.

N3. Näätämöjoki River, Saunakoski

The Saunakoski sampling site located in the middle section of the Näätämöjoki River. There was one riffle section and several runs at this site. Flow velocity was about 0.36 m/s, channel depth about 31 cm and width about 55 m. Channel substrate was mainly of cobbles and boulders. River banks were partly covered by bedrock or cobbles, on the left side also by gravel, scrubs and herbs (Fig. 18). Coniferous forest grew on both riversides.

N4. Näätämöjoki River, Kallokoski

At Kallokoski sampling was carried out right downstream of the cable bridge and also downstream from tributary River Kallojoki (Fig. 19). One rapid section and several runs characterized the flow types of this site, average flow velocity was about 0.36 m/s. Channel depth was about 56 cm and width about 50 m. Boulders covered the river bottom. Banks were either of bare bedrock, or partly covered by scrubs and herbs. Mixed forest grew on both sides of the river.

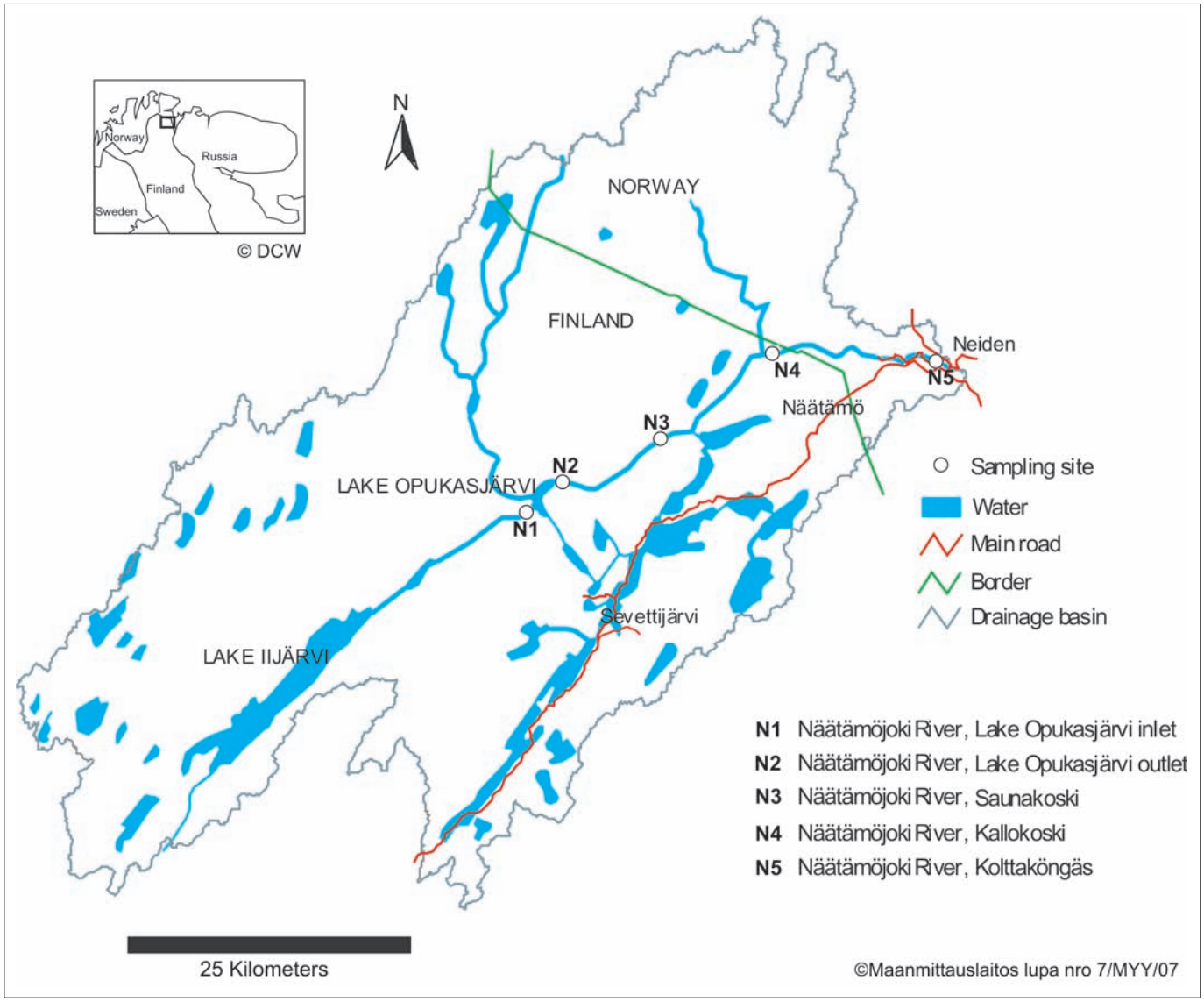

Fig. 15. Study site locations in the Näätämöjoki River.

N5. Näätämöjoki River, Kolttaköngäs

Kolttaköngäs sampling site located about 12 km from the river mouth. There was one long riffle section, several short rapids and runs. Flow velocity was about 0.51 m/s, channel depth about 28 cm and channel width about 60m. Channel substrate was cobbles and boulders. Banks were covered by bedrock or boulders, scrubs and herbs. Extensive mixed forest covered both riversides (Fig. 20). Near the right bank of the river there was a road.

Fig. 20. Sampling site N5 in the Näätämöjoki River, above the Kolttaköngäs waterfall. Photo: Tero Väisänen.

2.2

Biological and hydrochemical analysing

2.2.1

Macroinvertebrates

The objectives of the benthic sampling in the Kola Water Quality Project were twofold: (i) determine the overall ecological status of the Kola River with respect to other, 'reference condition', rivers in the northern boreal region and (ii) determine the effectiveness of the installment of a biological treatment stage (BTS) at the wastewater treatment plant (WWTP) in Shongui. Sampling of benthic macroinvertebrates was originally designed to similarly serve the two main objectives of the KWQ. Samples were collected on three occasions in the Kola River (in 7-11 July 2001, 8-12 July and 2-5 September 2002) and on two occasions in the Näätämöjoki River (in 14-17 July and 8-11 September 2002).

The benthic sampling was conducted using a quantitative Surber sampler (frame size 0.28 x 0.28 m, mesh-size 330 µm), described in detail in SFS-EN 28265 (1994). Eight Surber samples were taken form each sampling location. Sampling spots were approached from downstream. The Surber sampler frame and the quadrate frame were tightly pressed onto the substrate. The operator then disturbed the substrate within the quadrate frame by hand. The substrate was disturbed to a depth of 50-100 mm and all stones within the perimeter of the quadrate frame were lifted into the net (stones partially within the perimeter were not lifted). When no more material could be dislodged, the net was lifted and brought to the riverbank for further processing. The contents of the Surber sampler were placed into a bucket. The net of the Surber sampler was carefully checked for animals, and all animals found inside the net were added to the sample. Stones and other coarse material were separated from the rest of the sample after careful rinsing. All organic material was separated and transferred to a small net (SFS-EN 28265 1994 for details) before placing it in a sampling container. If the sample contained lots of small stones and sand, the organic material was separated using a decanting technique. The remaining sample was immediately preserved using 70% ethanol and each sample was labelled. Individual samples were not pooled in the field or in laboratory. In addition to benthic samples, current and depth measurements across randomly chosen transects were taken from each sampling site on each sampling occasion.

Sampling processing followed the Finnish national standard SFS-5077 (1989). Samples were brought to the laboratory and the contents of a sample were poured in small portions on a white tray. All benthic animals were separated from the other material using sharp tweezers. For sorting, sample dilution with water and lenses with six-fold magnification were used. All animals were transferred to smaller tubes, preserved in 70% ethanol, properly labelled and tightly capped.

Using a dissecting microscope, individuals were identified to the lowest feasible taxonomic level, usually species. Simuliids and Chironomidae as well as several other Diptera were identified to family level.

2.2.1.1

Environmental impact assessment

To address the question of the biological effects of the BTS at the WWTP in Shongui, an environmental impact assessment design was used. Assessments of single impact situations (e.g. effluents from a plant, building of nuclear power stations) call for these special statistical designs. As an extension of Green's 'optimal BACI design', Stewart-Oaten et al. (1986) introduced the BACIPS (Before After Control Impact Paired Series) design. This approach is used although the data of the Kola Water Quality Project is not ideal for such analytical approach. In an ideal case, the BACIPS design focuses on the difference in the parameter values between the Impact and the Control areas ($\Delta_{Bi} = I_{Bi} - C_{Bi}$) instead of using the initial values of Control and Impact in the analysis. Thus, the basic data is formed by the deltas of multiple sampling occasions before (Δ_{Bi}), as well as after (Δ_{Ai}), the impact. The mean of Δ_{Bi} is the basic difference between the Impact and Control sites and approximates the mean delta expected for the After period in the absence of an impact. The magnitude of the actual impact ('net effect') is calculated as the difference between the means of Before and After deltas (effect size = $\Delta_B - \Delta_A$). Variation in deltas among sampling dates in the Before and After periods (S_Δ), and the number of replicates (i.e. sampling dates; $n_B + n_A = n$) in each period provide confidence intervals for the effect size estimate (Osenberg et al. 1994). In the

simplest BACIPS design, the variability (S_Δ) and the sample size are assumed to be equal in the Before and After periods and ultimately, BACIPS designs allow the testing of whether the Before data differs from the After data. For this comparison, a t-test is used (Stewart-Oaten et al. 1992). In the absence of an effect, the deltas (Impact-Control differences) should be equal among the sampling occasions and no statistical difference should be observed (Stewart-Oaten et al. 1986).

Benthic sampling was planned to be carried out both in the summer and autumn preceding and again in the summer and autumn following the commencement of the operation of the biological treatment stage. Due to extremely high autumn flood, sampling did not take place at either the Näätämöjoki River or the Kola River in the autumn of 2001 (i.e. the 'before' period). Therefore, the Before period was sampled only once (in 2001) in the Kola River, whereas the After period was sampled twice (i.e. in 2002) in both rivers. As a consequence, there is no adequate temporal replication (i.e. there are only two similar temporal replicates) in the data to satisfy the needs of a traditional BACIPS design. The data is, however, spatially replicated, as benthic invertebrates were sampled at a total of eleven locations along the Kola River and at five locations on the Näätämöjoki River. Thus, to compensate for the loss of symmetry in the BACIPS design, the sampling sites upstream of the WWTP were used as substitutes for temporal replicates. Problems inherent in this approach will be discussed in more detail in discussion.

Since Non-metric Multidimensional Scaling (NMS) analysis revealed that the position of sites K2 and K3 in the ordination space was different from all the other sites (see the results for details), these sites were not used as control sites. Furthermore, the tributary sites were also omitted, leaving a total of six sites (3 control and 3 impact sites) for BACIPS analysis (Table 2).

The BACIPS analysis was run in two different ways: (i) using a modified, henceforth referred to as 'strict' BACIPS approach, where multiple impact sites downstream were individually paired with only one specific control site using only the July data (n=6) and (ii) using approach (i) but including also the September data. The latter approach resulted in an unbalanced, henceforth referred to as 'asymmetrical' design (n=9).

2.2.1.2

Indices

In order to evaluate the effect of the BTS at the Shongui WWTP with BACIPS, several average benthic index scores were calculated. The indices were: (i) 'Average Score Per Taxon' (ASPT), (ii) Ephemeroptera/Plecoptera/Trichoptera index (EPT), (iii) total number of individuals, (iv) total number of taxa, and (v)% EPT species. The ASPT index divides the total 'Biological Monitoring Working Party' (BMWP) index score by the number of

Table 2.
Sampling sites of benthic macroinvertebrates. The omission of sites in BACIPS-analysis is indicated by brackets, the impact site abbreviations are in italics, and the control site abbreviations are in bold. See text for details.

Sampling site	Abbreviation	Distance from the estuary (km)	Main channel/ Tributary
Kola springs	(K2)	84	M
Kola River, Taibola	(K3)	69	M
Kitsa River	(K4)	38	T
Kola River, Loparskaja	K5	36	M
Kola River, Magnetity village	K6	28	M
Kola River, Shongui village, upstream WWTP	K7	19	M
Kola River, Shongui village, downstream WWTP	K8	18	M
Varlamov creek	(K10a)	6	T
Medvegiy creek	(K10b)	4	T
Kola River, Molochny village	K11	4	M
Kola River estuary	K12	0,5	M
Näätämöjoki River, Lake Opukasjärvi inlet	(N1)	56	M
Näätämöjoki River, Lake Opukasjärvi outlet	(N2)	53	M
Näätämöjoki River, Saunakoski	(N3)	42	M
Näätämöjoki River, Kallokoski	(N4)	29	M
Näätämöjoki River, Kolttaköngäs	(N5)	12	M

scoring taxa. The BMWP score system is described elsewhere in detail (see Armitage et al. 1983). Both ASPT and BMWP are sensitive to pollution status and as such should indicate possible effects of the Shongui wastewater treatment plant fairly well. Similarly, the EPT index was originally used to indicate polluted waterbodies but has also been used more generally as an index for water quality (Lenat 1988). Raw ASPT and EPT index scores can be compared between individual sampling sites in a specific river. Low scores indicate declined water quality while higher scores indicate good water quality. While no general interpretation guidelines for these indices exist, ASPT scores can generally vary from 2–7, with scores above 6 indicating good water quality. However, ASPT scores may change between seasons, even if there are no actual changes in water quality (Clarke et al. 2002), and therefore, the scores should be compared only intra-seasonally. Similarly, there are no clear interpretation criteria for EPT index scores, but as for the ASPT scores, higher EPT scores indicate better water quality and the scores can be used to compare sites intra-seasonally.

For the BACIPS analysis, average values were calculated for every sampling site and sampling time, for the EPT index, the%EPT (percentage of EPT taxa of the total number of taxa at a given site), and the ASPT and BMWP scores. Differences between impact and control sites (deltas) were then further analyzed using t-tests. To check the validity of the test assumptions, both serial correlation and non-additivity were tested against (Stewart-Oaten et al. 1986).

2.2.1.3

Multivariate analysis

Multivariate analysis was used to assess the ecological status at the sampling stations along the rivers. For this purpose, the data obtained from the Tenojoki River was used in addition to the data gathered during the project in order to evaluate the effects of anthropogenic influences on the Kola River. This dataset from the Tenojoki River was gathered using a different sampling technique (i.e. a kicknet was used, and the sampling took place only in the autumn, see Huttula et al. 1996 for details) and therefore, it is not directly comparable to the data obtained during the project. However, the results are indicative of some general trends. Initial multivariate analysis involved Non-metric Multidimensional Scaling (NMS) to describe and investigate the general properties of the data. NMS is an ordination based on ranked distances between samples and is especially suitable for data containing numerous zero values (Minchin 1987) and rare species (Faith and Norris 1989; Muotka et al. 2001). This makes NMS especially valuable for the analysis of this data since the data includes numerous zeros and many species of which there is only one occurrence at individual sampling sites.

The a priori assumptions for the NMS included that the Näätämöjoki River and the Kola River sites should group differently in combined ordinations due to anthropogenic influences in the Kola River watershed. For ordinations including all sampling occasions, July vs. September sampling times were assumed to result in different groupings within the same river system. To further analyze the effect of season on the species pool, Detrended Correspondence Analysis (DCA) was used. DCA is a variant of Correspondence Analysis (CA). Both DCA and CA have serious flaws (Minchin 1987) and thus the ordinations produced by DCA will not be interpreted as such. However, DCA was used to analyze the species turnover between sampling occasions in 2002, which is indicated through the length of the gradient of the first ordination axis. Large turnover indicates different community structure for different sampling dates. If there was a temporal persistence over the years, the NMS ordinations of both July samplings within rivers should display similar groupings. NMS ordinations were therefore also used to make a preliminary assessment of the persistence of differences between sampling sites. In a joint NMS ordination aimed at the comparison of the ecological status of the Kola River and the Tenojoki River data for September, the Kola and Tenojoki sites were expected to show similar ordination in space (due to anthropogenic influence) when compared to the Näätämöjoki River sites. All NMS were run using PC-Ord 4.17 (McCune and Mefford 1999).

To further investigate the observed patterns and to better explain NMS ordinations, a Canonical Correspondence Analysis (CCA) was used. CCA is also a variant of Correspondence Analysis (CA) but involves additional mathematical steps to reach its solution and is less flawed than DCA or CA. The additional steps use not only the species data but include additional environmental variables as well. CCA produces ordination plots, which plot environmental variables as vector arrows along the species and site ordinations. If appropriate scaling is used, the length of an arrow indicates the importance of the environmental variable, and its direction indicates how well it is correlated with the various species composition axes. In addition, the angle between arrows indicates the degree of correlation between variables, the location of site scores relative to the arrows indicate the environmental characteristics of the sites, and the location of species scores relative

to the arrows indicates the environmental preferences of each species (Palmer 1993).

The use of CCA may thus offer explanations whose environmental variables explain most of the differences between individual sites for the observed patterns in NMS ordinations. CCA used a number of chemical and physical measurements taken at each site on each sampling occasion. The chemical and physical parameters included in CCA were: Ca (mg/l), Cl (mg/l), Conductivity (µS/cm), Distance from source (km), Fe (µg/l), K(mg/l), Mg (mg/l), Na (mg/l), O_2(sat%), P_{Total} (µg/l), pH, total suspended load (TSL) (mg/l), SO_4 (mg/l), colour (mg Pt/l), 8 water current (cm/s) and depth (cm). Despite the vast amount of chemical variables measured (see Pekka and Öhlander 2003 for details), the set of variables that were available for use in CCA was limited, since not all chemical variables were measured in all benthic sampling occasions. All CCA were run using Canoco For Windows (ter Braak and Šmilauer 1998).

The classification of river water quality follows the general guidelines provided in standards SFS-EN ISO 8689-1 (2000) and SFS-EN ISO 8689-2 (2000).

2.2.2

Fish community studies

In this study, the statuses of fish communities in the Rivers Kola and Näätämöjoki were assessed by comparing species composition, abundance, age structure and reproduction of the fish populations. In addition, the applicability of a composite fish-based index (FIX) was tested for the first time in sub-arctic riverine fish communities.

The status of fish stocks in the Rivers Kola and Näätämöjoki was studied by electrofishing. In addition, some earlier electrofishing data from both rivers (Jensen et al. 1997; Niemelä et al. 2001) was used in fish stock assessment.

In the Kola River, field surveys were conducted at 11 sampling sites between 2-5 September 2002, and in the Näätämöjoki River at 28 sites between 26th August and 12th September 2002 (Fig. 21). In the Kola River, electrofishing was done in the same riffle areas as the other sampling activities of the project, whereas electrofishing sites of the Näätämöjoki River were stationary sampling areas in a monitoring programme carried on since 1990 by the Finnish Game and Fisheries Research Institute (FGFRI).

In the Kola River, two of the sampling sites were in creeks (K10a and K10b) and the site K4 was a tributary site located two kilometres upstream of the confluence of the rivers. In the Näätämöjoki River, all sampling sites were in the main stem. All electrofishing sites were located in riffle areas with current velocity ranging from 0.3 to 0.8 m/s (mean of all sampling sites 0.5 m/s) in the Kola River and from 0.1 to 1.1 m/s (mean of all sampling sites 0.5 m/s) in the Näätämöjoki River. Mean sizes of the sampling sites were 115 m² (range 33-171 m²) in the Kola River and 110 m² (range 60-202 m²) in the Näätämöjoki River (Table 3). Electrofishing was performed in the Näätämöjoki River by three persons and in the Kola River by two persons - an operator using the anode was followed by two or one hand-netters, respectively. Direct Current (DC) equipment powered by a 650 W generator was used. Areas were not fenced with stop nets. Successive removal (i.e. three sweeps) was used for the density estimation when the catch of salmonids (Atlantic salmon or brown trout) exceeded 10 specimens in the first run. The Zippin maximum likelihood method was used to estimate juvenile salmon densities (Zippin 1956). Fork lengths of all fish were measured, and a scale sample was taken for age determination from all juvenile salmonids greater than 50 mm in length. Individuals smaller than 50 mm were classified as fry. Growth parameters from the scales were not analysed in this study. In addition to measuring, all fish were checked for external anomalies.

In the Kola River, all sampling areas were visually checked to find out possible spawning grounds nearby. In the Näätämöjoki River, all suitable spawning areas have been mapped earlier in a habitat inventory (Erkinaro et al. 2001). Many abiotic factors were registered at each sampling place: channel width, water depth and temperature, current velocity and the quality of bottom substrate in the habitat.

2.2.2.1

Fish-based environmental assessment method (FIX)

In the Swedish multi-metric assessment approach (FIX), a set of metrics were selected, based on the standardised electrofishing method, for assessing changes in the fish communities of Swedish lakes and streams caused by environmental disturbances (Appelberg et al. 2000). Reference values for the fish community metrics and scoring criteria in relation to regional and local environments were estimated using stream fish community data from the Swedish national electric fishing register. Establishment of the reference conditions in a pristine or natural state is a critical aspect in all fish monitoring approaches assessing the ecological quality of water. In absence of real reference sites, the method often used in IBI index (Karr 1981) and its succes-

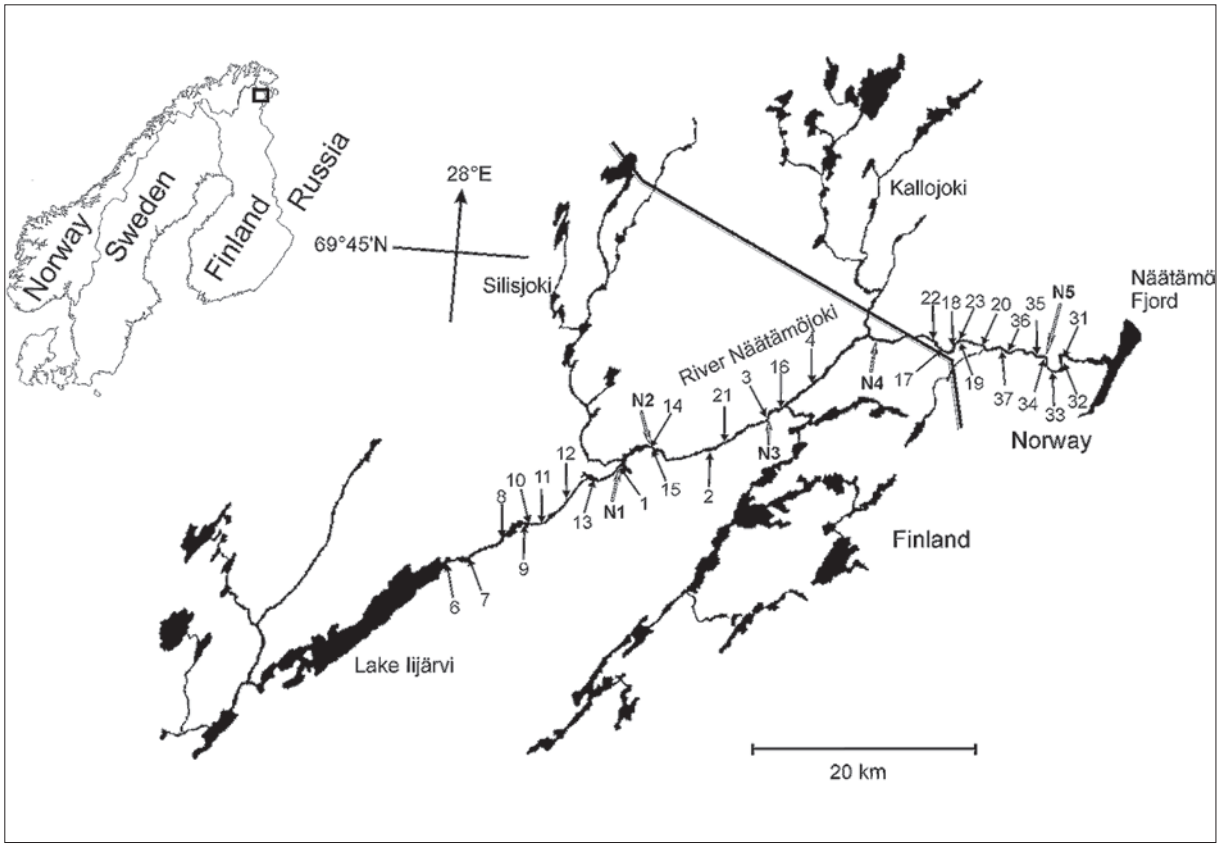

Fig. 21. Permanent electrofishing stations in the Näätämöjoki River. Sampling sites of the Kola Water Quality Project (KWQ) bolded. Sampling sites of the KWQ lay adjacent to the electrofishing sites except for site N4. Figure: Finnish Game and Fisheries Research Institute.

sors is to define the reference conditions subjectively by using professional judgement. In opposite to this, the reference values for the FIX index were predicted assuming that all important stream types and all levels of fish community degradation were already represented in the above-mentioned large Swedish database including 6988 stream sites.

To ensure as broad a coverage of the fish community characteristics as possible in the index, seven different metrics related to species richness and composition, community structure, and function were included (Table 3). For metrics in which the reference values were set in relation to environmental or biological variables, as for example species richness (or species abundance for lakes), linear regression was used to establish the relationship between dependent and independent variables. Raw metrics were then calculated as the ratio between measured and reference values. For all community metrics, except for the occurrence of acid sensitive species, measured values were used as raw metrics. Each raw metric was categorised in accordance with the common scoring criterion (cf. Directive 2000/60/EC) containing five classes (Table 4). The scoring criterion for class boundaries was based on the distribution of each metrics in the database. Median, 25%, 10%, and 5% percentiles were used as scoring criteria for single-sided metrics, and for double-sided 2%, 5%, 10%, 25% and 75%, 90%, 95%, and 98% percentiles, respectively.

For stream fish communities, reference values were calculated only for species richness. Stream

Table 3.
Metrics used for describing fish communities in streams. Biomass and abundance are calculated as weight and number per 100 m² (Appelberg et al. 2000).

Category	Metric description
Structure	Number of fish species native to the habitat
Structure	Catch per unit effort in weight of fish species native to the habitat
Structure	Catch per unit effort in numbers of fish species native to the habitat
Function	Proportion biomass of salmonid species in relation to total biomass
Function	Reproduction of salmonid species native to the habitat
Env. disturbance	Occurrence of acid sensitive fish species and stages
Env. disturbance	Proportion biomass of non-native fish sp. in relation to total biomass

Table 4.
Final scoring criteria for the index, based on the mean values of seven metrics. Final index is adjusted to the distribution of the final index values for all fish communities included in the database in such a way that 50% will fall into class 1, 25% into class 2, 15% into class 3, and 5% into each of classes 4 and 5, respectively (Appelberg et al. 2000).

Final score	Criteria description	Mean score of all metrics
1	None, or minor deviation from reference	< 2.8
2	Small deviation from reference	2.8–3.3
3	Evident deviation from reference	3.3–4.5
4	Large deviation from reference	4.5–4.9
5	Very large deviation from reference	> 4.9

width, catchment area, proportion of upstream lakes and altitude were used as predictors for fish communities. Latitude was shown to be of less importance in predicting the fish fauna in Sweden (Appelberg et al. 2000), and it was omitted from the formula of richness calculation. Relative abundance and biomass of native fish species declined naturally with increasing altitude, and the scoring criteria were thus based on the distribution in four altitude classes (Appendix 1.). Scoring criteria for the proportion of salmonid species were based on the distribution within four altitude classes and three flow discharge classes, respectively. The recruitment success in salmonids was estimated as the proportion of salmonid species with under-yearlings (fry) present. The proportion of non-native fish species was calculated on the basis of biomass (Appendix 1.). The mean value of all metrics was then used to calculate the final index (Table 4). The resulting quality classification matches quite well the ecological status classification of the EU Water Framework Directive (Directive 2000/60/EC).

2.2.3

Diatom community analysis

Sampling and pre-treatment of benthic diatoms were carried out following standardised methods (SFS-EN 13946 2003). Three replicate samples of benthic diatoms were taken from sampling sites in the Kola River (sampling occasions in 7-11 July 2001, 8-12 July and 2-5 September 2002) and in the Näätämöjoki River (sampling occasions in 14-17 July and 8-11 September 2002). For each replicate sample five small stones were collected from different parts of the sampling site and put into a plastic container. The upper sides of the stones were washed clean using a toothbrush and water from the river. The samples were poured into plastic bottles and preserved by adding ca 1 ml of Lugol's iodine in every bottle. The samples were stored in a cool and dark place. The bottles were labelled in order to separate the replicate samples, and running numbers were also used. Original sample material was stored as long as the slides had been checked with a microscope.

The current velocity was measured in each sampling point, near the place where the stones were picked. The velocity was calculated as a mean of three different measures. The water depth was registered at the same time.

Before preparing the diatom slides, organic material was removed using acid boiling. Removing the organic matter is important in order to get the figures on diatom frustules visible. The diatom sample was mixed thoroughly and ca 30 ml of it was put into a test tube. Then, 5 ml of strong acid (HNO_3 + H_2SO_4; 2:1) were added and the test tubes were put into boiling water for 2-3 hours. If it was not certain that all the organic material was oxidised, ca. 1 ml of hydrogen peroxide (H_2O_2) was added into the test tubes. The samples were ready when the hydrogen peroxide did not cause clear long-lasting foaming. After the boiling, the samples were centrifuged (at least 4000 rpm/10-20 min), the acid was poured away and distilled water was added into the tubes in order to clear the acid away. The centrifugation and the changing of water were repeated 3-4 times. After the cleaning, the diatom suspension was stored into a pure 96% ethanol.

Object glasses and cover slips used in diatom slides were cleaned carefully with ethanol. 1-2 drops of diatom-ethanol suspension were spread on a cover slip. The suspension was let to dry in peace in room temperature. A drop of diatom mountant (Naphrax®) was dropped onto the dry and a little bit warmed object glass. A cover slip with diatom-ethanol suspension was then put onto the object glass. The slide was then warmed on a stove in order to get the solvent evaporated and the mountant hardened. After this, the slides were cooled and carefully labeled.

The diatom samples were counted using a light microscope (magnification 400–1000x) and phase contrast-optics. At least 300 diatom frustules were counted, and the species, and variation or form level were identified in every sample (about 900 frustules per sampling site). The nomenclature of Krammer and Lange-Bertalot (1991-1997) was used.

Taxonomic data of the three replicate samples in each study site was combined for the diatom com-

munity analyses. *Achnanthes minutissima*, which was dominant in most samples, was excluded from the data when calculating indices and ecological spectra. The species is a generalist and its indicative value is rather poor (e.g. Hofman 1994).

2.2.3.1

Omnidia

The diatom database software 'Omnidia 3' (Lecointe et al. 1993) was used to calculate indices developed by different authors to describe saproby and trophic degree of the water. Pollution Sensitivity Index (IPS, Coste in Cemagref 1982), Generic Diatom Index (GDI, Coste and Ayphassorho 1991) and Trophic Diatom Index (TDI, Kelly and Whitton 1995) were used to evaluate the ecological status of the Kola River. IPS and GDI indicate saprobity of the water, whereas TDI is an index of the trophic conditions. The index values vary on the scale 0-20. The bigger the index value, the better is the water quality. In the TDI index, however, the values are to be interpreted the other way around. To ease the interpretation of the water quality, limit values for diatom indices were determined. In this study, the limit values used in IPS, GDI and TDI indices as well as assessed trophic level of the river based on TDI index are presented in Table 5.

'Omnidia 3' also displays diatom community-based ecological characteristics, like pH, salinity, nitrogen uptake, oxygen requirements, trophic state, moisture, saprobity, life form, and current (Lange-Bertalot 1979; Renberg and Hellberg 1982; Eloranta 1990; Denys 1991; Håkansson 1993; Hofmann 1994; Van Dam et al. 1994). For the Kola River, the mean values calculated from the diatom community data of July 2001 and 2002 were used to display the 'Omnidia 3'. The number of diatom species used in the calculation of each ecological spectrum in relation to the number of all the observed diatom species in each sample was summed up from the percent proportions of species in every class. If this number was below 50 (that is <50% of the species in the sample were used), the ecological spectra were not considered very reliable.

2.2.3.2

Multivariate analyses

For further investigation of the diatom data (relative abundances of taxa), multivariate analyses were used. Diatom taxa, whose abundance was ≥1% of the total cells in each community, were included in the analyses. Non-metric Multidimensional Scaling (NMS) was first used to describe the general properties of the diatom data and the possible site-specific differences. Detrended Correspondence Analysis (DCA) was used to calculate the maximum amount of variation in the species data. The diatom data and the environmental variables (Ca, Cl, colour, conductivity, Fe, K, Mg, Na, NH_4-N, $O_{2(sat}$%), P_{Total}, pH, total suspended load (TSL), SO_4 (Pekka and Öhlander 2003)) were then analysed using Canonical Correspondence Analysis (CCA, ter Braak 1986; ter Braak and Verdonschot 1995). Water sampling frequency affected the selection of environmental variables especially in the case of Näätämöjoki River. CCA forms linear combinations of environmental variables that act to maximally separate the niches of the taxa. Diatom communities and species are constrained by the environmental variables. The environmental variables, except for pH, were log-transformed because of their skewed distributions. Abundances of the diatom taxa were arcsine square root transformed. The significance of the CCA axes was assessed using Monte Carlo permutation test (199 permutations). NMS, DCA and CCA analyses were performed using the programme PC-Ord 4.17 (McCune and Mefford 1999).

2.2.4

Macrophytes

Macrophyte studies were conducted at the Kola River and at the Näätämöjoki River in 8-17 July 2002. Study sites for the river margin macrophytes extended 200 m along the river shore. The starting point (upstream) for each study site was preferably placed so that the sampling site where other ecological measurements were taken would be included,

Table 5.
Diatom indices and limit values used in this study in assessing the water quality and trophic level of the river.

Water quality	IPS	GDI	Trophic level	TDI
excellent	> 18	> 18	oligotrophy	< 7
good	16–18	16–18	oligo-mesotrophy	7–10
moderate	14–16	14–16	mesotrophy	10–13
poor	12–14	12–14	meso-eutrophy	13–16
bad	< 12	< 12	eutrophy	> 16

but this was not always possible. The vertical extent of each site was divided in two parts: channel and river margin. Channel was defined as an area that was below the water level at the time when the data was collected and river margin was defined as the area between the spring high-water level and the summer low-water level. The definitions of the levels were made in the field by searching the marks of the high water levels from the trees and bushes and from the ground. At each site, the species composition of vascular plant species was recorded (only presence/absence data at river margins). The width of the river margin from the water level to the spring high water level was recorded at the starting point, at the middle and at the end of the 200 m long study site. These measures were used to calculate the total area of the river margin surveyed. Because the sampled areas of the river margins varied, the species richness was corrected using calculation where richness = the number of observed species / $\log_{10}$ of sampled area (Nilsson et al. 1991).

This data was analysed using the data of River Habitat Survey (RHS, see chapter 3.2.6) for each site as an indicator of human impact. The total number of species at each study site was compared to the results of habitat modification score (HMS), human modification index (HMI) and habitat quality assessment (HQA) of each site using nonparametric Spearman's rho correlation analysis.

Also the plant species composition of the Kola River (catchment area 3850 km^2) was compared to the species composition of the Näätämöjoki River (3160 km^2) and also three other Finnish rivers of the same size: River Ivalojoki, 3882 km^2 (Kujala 1961), River Simojoki, 3159 km^2 (Kerätär et al. 2003) and River Kiiminkijoki, 3813 km^2 (Uotila 1987). The ecological quality ratio (EQR) for the plant composition of the Kola River was analysed by using the method described by Hämäläinen et al. (2003) where the ecological quality ratio (EQR) is used in the definition of the ecological state of a river. EQR can be determined based on the relation of the observed number of species or an abundance value and expected values. The species abundance was calculated three times:

1. taking all the observed species,
2. taking the aquatic and amphibious species and
3. taking only the aquatic species into consideration.

Expected values were calculated as:

$$EQR_{\text{composition of taxa}} = \frac{\text{observed value}}{\text{expected value}} = \frac{O_{kji}}{E_{kj*i}} \qquad (1)$$

The composition of taxa was calculated so that the information about the presence (i=1) and absence (i=0) of a species (i) was used. The probability of the presence of each species in the river (j*) of each type (k) was estimated as the relation of the number of the observed occurrences of comparison rivers (j_0) to the total number of reference rivers.

$$Pkj*i = \frac{\sum kj_0 i}{\sum kj_0} \qquad (2)$$

A plant species was considered to be typical for a certain river type if Pk j*i ≥ 0.5; that is, a species was typical if it was found at least in every second reference river. Because the probability of appearance of many typical species is smaller than 1, a simultaneous occurrence of all of them cannot be expected in any river, and the expected value for each typical species is:

$$E\,kj*i = \sum Pkj*i \,\big|\, Pkj*i \geq 0.5 \qquad (3)$$

The number of observed species for every river of the type is:

$$O\,kji = \sum kji \,\big|\, Pkj*i \geq 0.5 \qquad (4)$$

that is the number of those observed species whose probability in reference conditions is at least 0,5. The ecological quality ratio of the composition of species is

$$EQR_{\text{composition of species}} = \frac{\text{observed value}}{\text{expected value}} = \frac{O_{kji}}{E_{kj*i}} \qquad (5)$$

When using an equal division of classes of ecological status, the EQR values above 0.8 would indicate high ecological status (value 1 is the mean for reference rivers), values between >0.8 – 0.6 indicate good, >0.6 – 0.4 moderate, >0.4 – 0.2 poor, and less than 0.2 bad ecological status.

2.2.5 Aquatic bryophytes

Sampling of aquatic bryophytes was performed on two different occasions (7-11 July 2001 and 8-12 July 2002), at seven sampling sites along the Kola River (K2, K3, K5, K6, K8, K11, K12) and at four sites in the Näätämöjoki River (N2, N3, N4, N5) (Table 6). The main sample medium was the

Table 6.
Moss sampling sites and sampled species at the Kola River basin and the Näätämöjoki River.

Sampling site	Sampling[1] in July 2001	Sampling[2] in July 2002	Distance (km) to estuary[3]	Species
K2	x	x	83.5	*Fontinalis antipyretica*
K3	x	x	68.5	*Fontinalis antipyretica*
K5	x	-	35.5	*Fontinalis antipyretica*
K6	x	x	27.5	*Fontinalis dalecarlica*
K8	-	x	18.0	*Fontinalis antipyretica*
K10a	x	x	6.0	*Hygrohypnum ochraceum*
K11	x	x	3.5	*Hygrohypnum ochraceum*
K12	x	x	0.5	*Hygrohypnum ochraceum*
N2	-	x	53	*Hygrohypnum alpestre*[4]
N3	-	x	42	*Blindia acuta*[4]
N4	-	x	29	*Fontinalis antipyretica*[4]
N5	-	x	12	*Fontinalis dalecarlica*

[1] whole shoots of Fontinalis species.
[2] whole and young terminal shoots of Fontinalis species, whole shoots of Hygrohypnum ochraceum
[3] Kola Bay for the Kola River, Neiden fjord for the Näätämöjoki River.
[4] Insufficient sample for metal analyses.

Fontinalis species. However, at sites K10a, K11 and K12, *Hygrohypnum ochraceum* was sampled, since no *Fontinalis* species were not found. The amount of mosses in samples from the Näätämöjoki River sites N2, N3 and N4 was insufficient for heavy metal analyses. Amounts of mosses for metal analyses were not always sufficient for every Kola River sampling site either (e.g. K8 in 2001 and K5 in 2002). Data on metal concentrations in the river water was obtained from Pekka and Öhlander 2003.

One to 2 litres (3-5 tufts) of mosses were collected from each site, using plastic gloves. The moss tufts were rinsed in the river water to remove sand and other particles and gently squeezed before being placed in clean plastic bags. The sampling was restricted to submerged plants growing in the relatively constant current, as far as possible in the middle part of the streambed. The samples were frozen within two to six hours after collection.

Pretreatment of the moss samples took place in the laboratory of the West Finland Regional Environment Centre in Kokkola, Finland (EN ISO/IEC 17025). Whole shoots were separated and washed with distilled water. Five replicates were made from each sample. All laboratory equipment used was acid-washed. Samples were freeze-dried (-40 °C) and their dry weight was determined. The samples were digested with 3.0 ml of HNO_3 and heated at 60 °C for two hours and then at 110 °C for 6 hours. The digest was made up to a final volume of 20 ml with distilled water. Analyses of metal concentrations (Al, As, Ba, Cu, Cd, Co, Fe, Mn, Mo, Pb, Zn and Ni) were carried out in the laboratory of the Finnish Environment Centre in Helsinki, Finland (EN ISO/IEC 17025) using ICP-MS technique (in-house methods K206 and K208). For all the samples of year 2001 and all *Hygrohypnum ochraceum* samples, only whole shoots were analyzed.

Mann-Whitney U-tests (Zar 1996) were used to determine significant differences between contents of elements in whole and young terminal shoots of *Fontinalis* samples collected in year 2002, and between heavy-metal concentrations of whole shoots of the bryophytes in years 2001 and 2002. Differences in bryophyte metal concentrations between the Kola River and respective reference sites were also analyzed with the Mann-Whitney U-test (Zar 1996). Box-plot graphics were produced based on exploratory data analysis (EDA) methods (Tukey 1977; Velleman and Hoaglin 1981). Box plots enable representation of metal-concentration distributions in mosses with respect to reference data grouping. Pearson correlations were calculated to examine the relationships between the average concentrations of metals in water and in bryophytes.

2.2.6 River Habitat Survey (RHS)

The RHS data from the Kola River was collected at 11 sites (K2-K9 and K11-K12), of which two were in creeks draining into the Kola River. The other sites were along the whole length of the Kola River. In Molochny village site K11 was divided in upper

(K11a) and lower (K11b) sections. In the Näätämöjoki River the survey was done at five sites (N1-N5). The RHS survey was carried out in 8-12 July 2002 at the Kola River and in 14-17 July 2002 at the Näätämöjoki River.

The survey was organised in two major sections at each site: spot-checks and sweep-ups. Each research site was 500 metres long (Fig. 22). This 500 metres consisted of ten spot-check sites, which were located at 50 metre intervals. The measurements were paced out. During the field survey, features of the channel (both instream and banks) and of the adjacent river corridor were recorded, and the data was collected on a RHS form of the Environment Agency (Raven et al. 1998b) (Appendix 2). Spot-checks took into account the flow types, physical features, vegetation structure, land use, and vegetation types. Physical features (Appendix 2, Section E) were assessed from a one metre wide transect across the channel, while vegetation structure, land use (Section F) and channel vegetation types (Section G) were examined within a ten metre wide transect across the river. Land use was identified within five metres of the banktop, and the vegetation structure within one metre of the banktop. Channel substrate was assessed using the Wentworth scale.

In addition to these spot-checks, a sweep-up assessment of the whole 500 metres was done on each study site (Appendix 2, Section D and Sections from H onwards). The sweep-up collected significant features and modifications not mentioned in the spot-checks. The overall occurrence of the features was measured as absent, present or extensive. An extensive feature covered 33 per cent or more. Finally, the channel dimensions (Section L) were measured at one location within the 500 metres. The precise point was selected on the basis of being in a straight or uniform reach with clearly defined banks and, if possible, with a riffle. The location of the selected point did not have to coincide with a spot-check. Ordinary maps (1:100 000, 1:200 000) were used in describing the study sites, but small-scale maps (1:20 000) or aerial photos from the Kola River were not available. Sites were photographed during the survey.

The collected data was processed with the River Habitat Survey Database, version 3.1 (Environment Agency 1999). Using the database, Habitat Quality Assessment (HQA) and Habitat Modification Score (HMS) were calculated for each survey site. HQA is a wide measure of biodiversity and wildness in nature and of habitat structure in the channel and banks. The presence and extent of habitat fea-

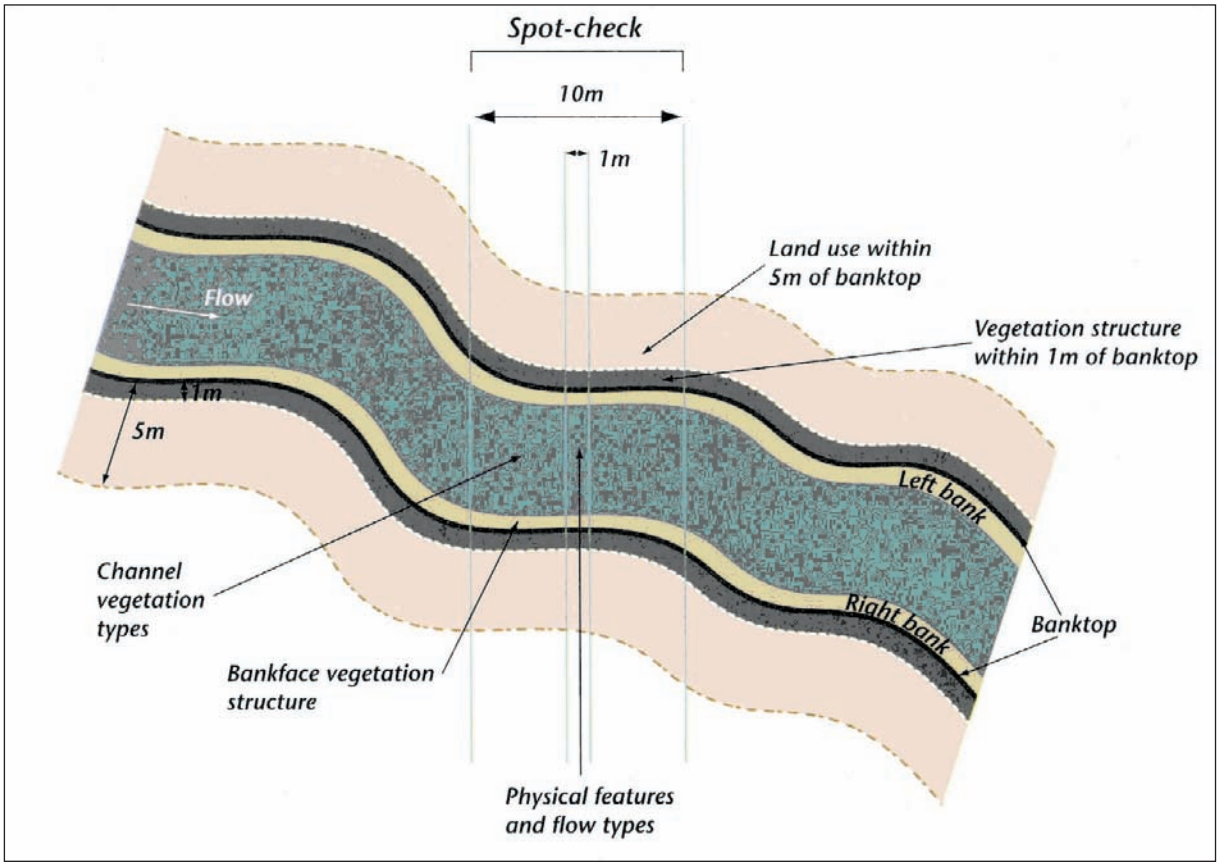

Fig. 22. The dimensions of the spot-checks (Raven et al. 1998b: Figure 2).

tures of known wild natural interests determine the scores in HQA. The average HQA score is an average score of 10 individual categories. In addition, the HQA score should only be compared with rivers of same type. The HQA score is constituted from features in the channel and river corridor. On the contrary to HQA, HMS consists of man-made modification and features in the channel. Moreover, the HMS scores are comparable with different types of rivers (Raven et al. 1998a; 1998b).

The field survey was recorded on the latest recording forms in the summer of 2002. However, the computer database version was not updated by the time of the analysis phase. The database did not recognise certain new features and they were left out from the study.

2.2.7

Hydrobiological water quality control after federal Russian monitoring methods

Hydrobiological observations were made on bacterioplankton, phytoplankton, zooplankton and macrozoobenthos. Samples were taken from all the sampling sites at the Kola River basin (K1–K12) in 7–11 July 2001, 8–12 July and 2–5 September 2002, excluding site K10b (Medvegyi Creek), which was sampled only for bacterioplankton and phytoplankton analyses in 5th of September 2002. An additional site K10c (Zemlanoy Creek) at the lower part of the Kola River basin was also sampled for bacterioplankton and phytoplankton analyses in 5th of September 2002 in order to observe the influence of organic wastewaters entering the Kola via the Zemlanoy Creek. On sites K1, K2, K4, K9 and K12 The Murmansk Areal Department for Hydrometeorology and Environmental Monitoring carries out continuous monitoring and thus these sites were sampled once a month during summer time (June–September). At the Näätämöjoki River (N1–N5) sampling was performed in 14–17 July and 8–11 September 2002.

For bacterioplankton analysis the total amount (number) of bacteria was identified, as well as the amount of indicator microflora (saprophyte, oil-oxidizing and phenol-oxidizing bacteria). When studying phytoplankton, zooplankton and zoobenthos the total amount of organisms, total biomass, total amount of species, abundance and biomass of each group of organisms, number of species in a group, mass species and saprobe indicator species were identified, as well as their abundance and biomass. Water quality according to phytoplankton and zooplankton communities was assessed based on the Panthle and Buck saprobity index (Sládeček 1973). For zoobenthos biotic index of Woodiviss and *Oligochaeta* percentage from the total amount of organisms were calculated. Total scale for water quality assessment is presented in Table 7.

2.2.7.1

Bacterioplankton

Bakterioplankton (total of micro-organisms) samples were taken from the surface water using sterile

Table 7.
Classification of surface water quality based on hydrobiological parameters (Abakumov 1992).

		Macrozoobenthos		Phyto- and zooplankton	Bacterioplankton		
Water Class	Water quality	Relative amount of Oligochaeta, % from total amount of bottom organisms	Woodiviss Biotic index	Panthle and Buck Saprobity index	Total amount of bacteria, million/ml, "a"	Saprophyte bacteria, thousand/ml, "b"	"a"/"b"
I	Very clean	1–20	8–10	Less than 1	0.5	0.5	More than 10^4
II	Clean	21–35	5–7	1.1–1.5	0.5–1.0	0.5–5.0	More than 10^3
III	Moderately (slightly) polluted	36–50	3–4	1.51–2.5	1.1–3.0	5.1–10.0	10^3–10^2
IV	Polluted	51–65	1–2	2.51–3.5	3.1–5.0	10.1–50.0	Less than 10^2
V	Heavily polluted	66–85	0–2	3.51–4.0	5.1–10.0	50.1–100	Less than 10^2
VI	Very heavily polluted	86–100 no macrozoobenthos	0	More than 4.0	More than 10	More than 100	Less than 10^2

bottles. Before sampling the bottles were thoroughly washed with a chrome mixture in order to get rid of organic substances and bacteria cells on the bottle's inner surface. A wadding cork with gauze tissue was put in the bottle's neck. Tissue of tough paper was put on top, and all was tied up with thread.

For sampling, the bottle's neck was taken in one hand while the other hand removed the tissue and the cork. The bottle was put 5–10 cm under the water at arm's length. After the bottle was filled with water, a part of the water was poured away, and the flask was shut by the sterile cork. Bacteria culture was done not later than 1 hour after the sampling, or within few hours if the samples were kept in a temperature of 3–5 °C. All necessary precautions were followed in order to avoid contamination of the samples; the table and hands were wiped with alcohol, necks of sterile flasks, bottles and test tubes were opened above a burner's flame. Sterile pipettes were taken out from their wrappings and kept above a burner's flame. Separate pipettes were used for each bacteria culture. All operations were performed as quickly as possible.

The following microbiological parameters were defined: total amount of bacteria on membrane filters; amount of saprophyte bacteria that are indicators of organic contamination; amount of micro-organisms of different physiological groups that are identified by contents and amount of wastewaters.

The medium used in microbiological analyses were sterilised in autoclaves in a temperature of 120 °C for 20 minutes. Water for separation, rubber materials (corks, tubes), metal instruments, and laboratory equipment, if necessary, were also sterilised in autoclaves. Sterilisation by dry heat was performed in a drying cupboard in a temperature of 150–170 °C. Before sterilisation, all equipment was thoroughly washed, dried and wrapped in paper. Equipment was placed in the drying cupboard and sterilised in 150 °C for 2 hours, in 160 °C for 1 hour, and in 170 °C for 20 minutes. The sterilised equipment was kept in a special cupboard.

The analysed sample was let through a membrane filter with a pore diameter of 0.3–0.7 µm at a filtration stand consisting of a thick-walled Bunsen's retort, a metal Zeits's funnel, and a vacuum pump enabling the pressure to be reduced down to approximately 0.4 atmospheres (or about 400 gPa). Filters were preliminarily boiled in distilled water that was changed several times. A series of filters were put on a Petri dish and dried in the air. 1–2 drops of 40%-formalin were dropped onto the Petri dishes cover. In order to calculate the number of micro-organisms detained on the membrane filter, a drop of immersion oil was poured onto an object-glass; then the filter was laid over by its filtration surface onto the object-glass. Above the filter, another oil drop was dropped and then the sample was studied through an immersion lens with 90x magnification using an ocular with 10x magnification. A grid (net) (approximately 2500 μm^2) was placed in the ocular.

$$X = K^* d - e / a$$

Calculation of bacteria concentration in 1 litre of water (X) was made with the following formula:

where K stands for transmission coefficient, which is constant for this microscope, filtration apparatus and calculating grid (net), and is the ratio d / (ÿ g).

The formula can be simplified by adding one joint coefficient K / a (in case of filtrating the same amount of water), which should be multiplied by d–e.

a – amount of filtrated water, ml
b – filtrating area of the apparatus, μm^2
ÿ – area of the view field, μm^2
g – number of counted view fields
d – number of bacteria in the 'g' view fields
e – number of bacteria on the control filter in the ' g' view fields

In case of water sample containing large amounts of oil products, cellulose, phenols or sulphur compounds, culture on selective media was made enabling detection of micro-organisms breaking down such compounds.

Dianova-Voroshilova Medium for hydro-carbonating (oil oxidising) bacteria (Abakumov 1992):

- Distilled water – 1 l
- NH_4NO_3 – 1 g
- K_2HPO_4 – 1 g
- KH_2PO_4 – 1 g
- $MgSO_4 \cdot 7H_2O$ – 0.2 g
- $CaCl_2 \cdot 6H_2O$ – 0.2 g
- $FeCl_2$ – 2 drops of concentrated solution
- pH = 7.2

Sterilised mineral water by Dianova-Voroshilova was separated by 1/3 into sterile flasks or biological test tubes (approx. 4–5 ml). Four to five drops (0.05 ml) of oil product was then added. The sterilised oil was soldered in ampoules made from test tubes by stretching and strapping their ends above a Bunsen burner's flame. The ampoules were filled on 1/2 with oil product (petroleum, fuel oil, diesel fuel, machinery oil) and soldered in the strapping place. Ampoules were sterilised for 20 minutes in an autoclave, with 1 atmosphere, or boiled upon steam during three days for 1 hour each day.

Culture is usually made within 0.1 ml to 0.0000001 ml (i.e. 10^{-7}). Flasks and test tubes were placed in a thermostat with 30°C, and changes in the medium were observed on the 3rd, 7th and 14th day. Muddiness, appearing of pellicle, sediment and colour of the medium were noted. As the final result, the maximum titre was taken when the medium change had occurred. For example, for the culture within 0.1 ml to 0.0000001 ml, the bacteria development is noted at the 0.00001 separation, then the final result would be the 10^{-5} titre, which is approximately equal to the concentration of 100 000 cells of oil oxidising bacteria in 1 ml.

Medium for phenol oxidising bacteria (Abakumov 1992):

- Distilled water – 1 l
- K_2HPO_4 – 1 g
- $MgSO_4$ – 0.2 g
- NaCl – 0.2 g
- $CaCl_2$ – 0.1 g
- $FeCl_3$ – 0.02 g
- $(NH_4)_2SO_4$ – 0.1 g
- $MnSO_4$ – 0.01 g
- $(NH_4)_2HPO_4$ – 0.5 g
- Phenol – 1 g

Cultures were made within 1 ml to 0.0001 ml on the medium that was earlier poured in penicillin flasks. The results were examined in the same way as for oil oxidising micro-organisms.

Phenol- and hydrocarbon (oil) oxidising bacteria in the amounts exceeding 10^2-10^3 cells/ml mean that contamination with such substances do exists.

2.2.7.2

Phytoplankton

For examining phytoplankton (micro-organisms moving passively in the water and performing photosynthesis) a water sample of 1 litre was taken from a 0.1–0.2 m horizon and fixed by 20 ml of 40% neutral formalin. After 10–14 days of sedimentation, the fixed sample was concentrated down to 10 ml by a siphon tube. Tank processing of the phytoplankton sample was done by the direct microscoping method to identify the algae and calculate their amounts. For quantitative processing of the phytoplankton, a tank of 1 mm^3 was used. Total amount of phytoplankton was calculated according to the following formula:

$$N = nV_1 / V_2 V_3$$

N stands for number of cells in 1 litre, V_1 stands for volume of the concentrated sample, cm^3, V_2 stands for the tank (chamber) volume and V_3 stands for volume of the filtrated sample, cm^3.

The phytoplankton biomass calculation was based on identification of the amount of cells for different algae species. During biomass calculations, the algae density (specific gravity) was taken as 1, and then the total phytoplankton biomass was quantitatively equal to its total volume.

In assessing the freshwater ecosystems status by the phytoplankton status, the saprobity index of Panthle and Buck modified by Sládeček (1973) was used. The method allows getting a saprobity index, which is calculated with the following formula:

$$S = Sh / h$$

S stands for the indicator correlation of each of the species (identified according to the list of saprobe organisms), h stands for the number of species or the relative frequency of occurrence according to a scale of measurements by eye.

The saprobity index was calculated to within 0.01. The index for the xenosaprobe (x-saprobe) zone is within 0–0.5, for the oligosaprobe (o-saprobe) zone 0,51–1,50, for the β-mesosaprobe (o-b-saprobe) zone 1,51–2,50, for the α-mesosaprobe (a-saprobe) zone 2,51–3,50 and for the polysaprobe (p-saprobe) zone within 3,51–400. (Kozina 1977, Abakumov 1992).

The phytoplankton data was analysed together with environmental variables with Canonical Correspondence Analysis (CCA) (ter Braak 1986). The chemical and physical parameters included in CCA were: Ca (mg/l), Cl (mg/l), conductivity (µS/cm), Fe (µg/l), K (mg/l), Mg (mg/l), Na (mg/l), O_2 (sat%), P_{Total} (µg/l), pH, total suspended load (TSL) (mg/l), SO_4 (mg/l) and colour (mg Pt/l) (data from Pekka & Öhlander 2003). CCA analyses were performed using the programme PC-Ord 4.17 (McCune and Mefford 1999). The phytoplankton CCA ordination was compared to the results of CCA analysis of benthic diatom and macroinvertebrate data. In this way the differences caused by the statistical analyses were eliminated and the effects of different biota (diatoms, macroinvertebrates and phytoplankton) to the ecological classification were estimated.

2.2.7.3

Zooplankton

The samples of zooplankton (total number in the water column) were taken by filtering 100 litres of water taken by a 5-litre polyethylene bucket through the quality net by Upstein (64–77 meshes/cm^2) Separate plankton was poured from a glass of plankton net to a jar and fixed by 40% neutral formalin to get its 4% solution (1 part of formalin to 9 parts of water).

Zooplankton were identified to species when possible. The quantitative processing was made by

using the Bogorov's tank (chamber). A part of the sample taken by a stamp pipette was poured into the tank and then the number of organisms of each species was calculated according to age stages or size groups. To calculate the total amount of organisms in 1 m^3 the following formula was used:

$$N = n1000 / V$$

where, N stands for number of organisms per m^3, n stands for the number of organisms in the sample and V stands for the volume of water filtered through the net.

The zooplankton biomass was identified by multiplying the individual weight of each of the organisms by its amount (numbers). During processing, it was necessary to make out the sex, stage and size of an individual. To assess the freshwater ecosystems status by zooplankton, the saprobity index of Panthle and Buck (Sládeček 1973) was used.

2.2.7.4

Macrozoobenthos

In the Kola River, the sampling of macrozoobenthos (totality of invertebrates habiting the waterbody bottom) was made by a bottom-scoop fixed to a rod with a sampling area of 0.025 m^2. The scoop allowed to take the upper and most productive ground layer undisturbed. Subsurface substrate was also enclosed within the sampler, which is very important during quantitative and qualitative analysis of the fauna of riparian biotopes and biological indication of the ecosystem. In the Näätämöjoki River, the sampling was made by hand using tweezers. The area used for sampling in the Näätämöjoki River was the same as in the Kola River.

Before zoobenthos sampling, depth and substrate type were identified. The sample was put into a bucket; all substrate from the bottom-scoop was carefully rinsed into the bucket with stream water. The sample was then sieved (23 meshes/cm^2). The number of replicate samples depended on the dissemination character, total number, and biomass of benthic organisms within the surveyed area.

Benthic organisms were fixed in 75–80% alcohol or 4% formalin neutralised by a saturated soda solution. During the chamber (tank) processing of benthos, were keyed to the lowest taxonomic level feasible.

Animals were counted and wetweighed with a help of a balance. When only animal fragments were found in a sample, weight was estimated by head width/weight (head ends for worms) regressions. Before weighing, animals were dried on filtration paper for one minute. The results of counting and weighing were adjusted to the area of 1 m^2.

The biotic index of Woodiviss as well as relative amount of Oligochaeta (see chapter 3.2.7) were calculated (Abakumov 1992). In addition, an indicator organism method based on the saprobity system was used for water quality assessment. The saprobity index (Kozina 1977, Abakumov 1992) was calculated for dominant organism groups.

2.2.8

Physical and chemical water quality

Water sampling at the Kola River and analysing the samples were carried out by the Murmansk Areal Department for Hydrometeorology and Environmental Monitoring. Methods based on Russian standards (Kozina 1977; GHI 1995; Hydrometeoizdat 1996) were used. The following parameters were analysed from the water samples: odour, transparency, colour-index, content of oxygen (chemical oxygen demand COD and biochemical oxygen demand BOD_5), suspended substances, pH, specific electro-conductivity, hardness, sulphates (SO_4), chlorides (Cl), hydrocarbonates (HCO_3), phosphates (PO_4), nitrogen-ammonia (NH_4), nitrate (NO_3), nitrite (NO_2), calcium (Ca), magnesium (Mg), potassium (K), sodium (Na), silicon (Si), copper (Cu), nickel (Ni), manganese (Mn), iron (Fe), chromium (Cr), lead (Pb), molybdenum (Mo), cobalt (Co), zink (Zn), mercury (Hg), aluminium (Al), phenols, oil hydrocarbons in water and in the ground.

Water quality monitoring of the Kola River was also performed by Luleå University of Technology, which data was used when considering metal contamination. Methodology is described in detail by Pekka and Öhlander 2003 and Pekka et al. 2004.

In the Näätämöjoki River, water sampling was carried out by the Lapland Regional Environment Centre according to the guidelines provided by the Finnish Water and Environment Ministry (Mäkelä et al. 1992). The parameters analysed were identical to the ones in the Kola River, but the analysing was fleshed out with total nitrogen and phosphorus (N-tot and P-tot). Most of the metal analyses were dropped out (Cu, Ni, Si, Mn, Cr, Pb, Mo, Co, Zn, Hg) as well as the oil hydrocarbon analyses.

2.2.8.1

Hydrological observations

Hydrological observations are continuously carried out at two sampling sites in the Kola River: Kola springs (K2) and Vyhodnoy (K9). Hydrological monitoring include daily observations of the water level and the temperature, river velocity measurements and monthly observations of ice cover. Hydrological data made it possible to calculate the flow and discharge for a river section.

3 Results

3.1 Macroinvertebrates

A total of 98 macroinvertebrate taxa were identified from the Kola River and its tributaries during sampling occasions of July 2001, July 2002 and September 2002 (Appendices 3–5). The keying of samples of July and September 2002 from the Näätämöjoki River identified a total of 60 taxa (Appendices 6–7).

3.1.1 Environmental impact assessment and indices

The statistical test underlying the BACIPS (Before After Control Impact Paired Series) analysis makes several assumptions about the statistical properties of the data, namely that there is no serial correlation (i.e., consecutive sampling times are not correlated), and that the data should be additive. Although analysis of the test assumptions revealed no serial correlation (Durbin Watson > 3 in all cases), the BACIPS- data was non-additive in all cases in the Kola River. Violations against the additivity assumption may weaken statistical tests, making them over-conservative (Stewart-Oaten et al. 1986). The average benthic index score values tended to increase in the impact area, downstream the Shongui wastewater treatment plant (WWTP) during the after period (Fig. 23), which is also reflected in statistical tests for the effects of the biological treatment stage (BTS) of the WWTP.

Most tests for the strict and asymmetrical BACIPS design only bordered statistical significance (Table 8, Fig. 24). However, considering the low number of replicates (n=2) and violations against test assumptions (i.e. additivity), the results may indicate improved water quality at impact sites in the period following the installment of the BTS of the WWTP.

Average site scores for the BMWP index generally indicated good or acceptable water quality when comparing scores to those obtained for the Iberian peninsula (Zamora-Munoz and Alba-Tercedor 1996, Table 9). Only one site (K01b, Medvegiy creek) is to be classified as heavily polluted and similarly, sampling at the Kola mouth (K12) in July 2001 indicated moderate pollution.

3.1.2 Multivariate analysis

3.1.2.1 NMS

NMS was used to ordinate sampling sites according to their averaged inherent species composition. In an ordination that included all sites, Taibola (K3) outlet site clearly separated from the other sites (Fig. 25). In addition, other outlet sites (K2, N2) were more closely associated with each other than with other sites. The Näätämöjoki River sites sampled in July were all grouped closely with the mid-section Kola River sites. September sampling of the Näätämöjoki River sites formed a distinct group and also the Kola River September samples were spaced differently from their July counterparts. As expected, DCA showed that the turnover of species between sampling dates was high

Table 8.
Results for independent sample t-tests (BACIPS analysis) between 'before' and 'after' averaged differences (deltas) for Impact and Control site index scores. Two different approaches (strict vs. asymmetrical, see material and methods for details) were used on the different metrics.

	Strict			Asymmetrical		
Index	t	df	Sig.(2-tailed)	t	df	Sig.(2-tailed)
BMWP	-2.55	4	.063	-2.65	7	.033
ASPT	-2.335	4	.08	-2.73	7	.029
EPT	-2.48	4	.068	-1.49	7	.181
Total taxa	-1.84	4	.14	-1.9	7	.099
% EPT	-3.2	4	.033	-1.94	7	.093

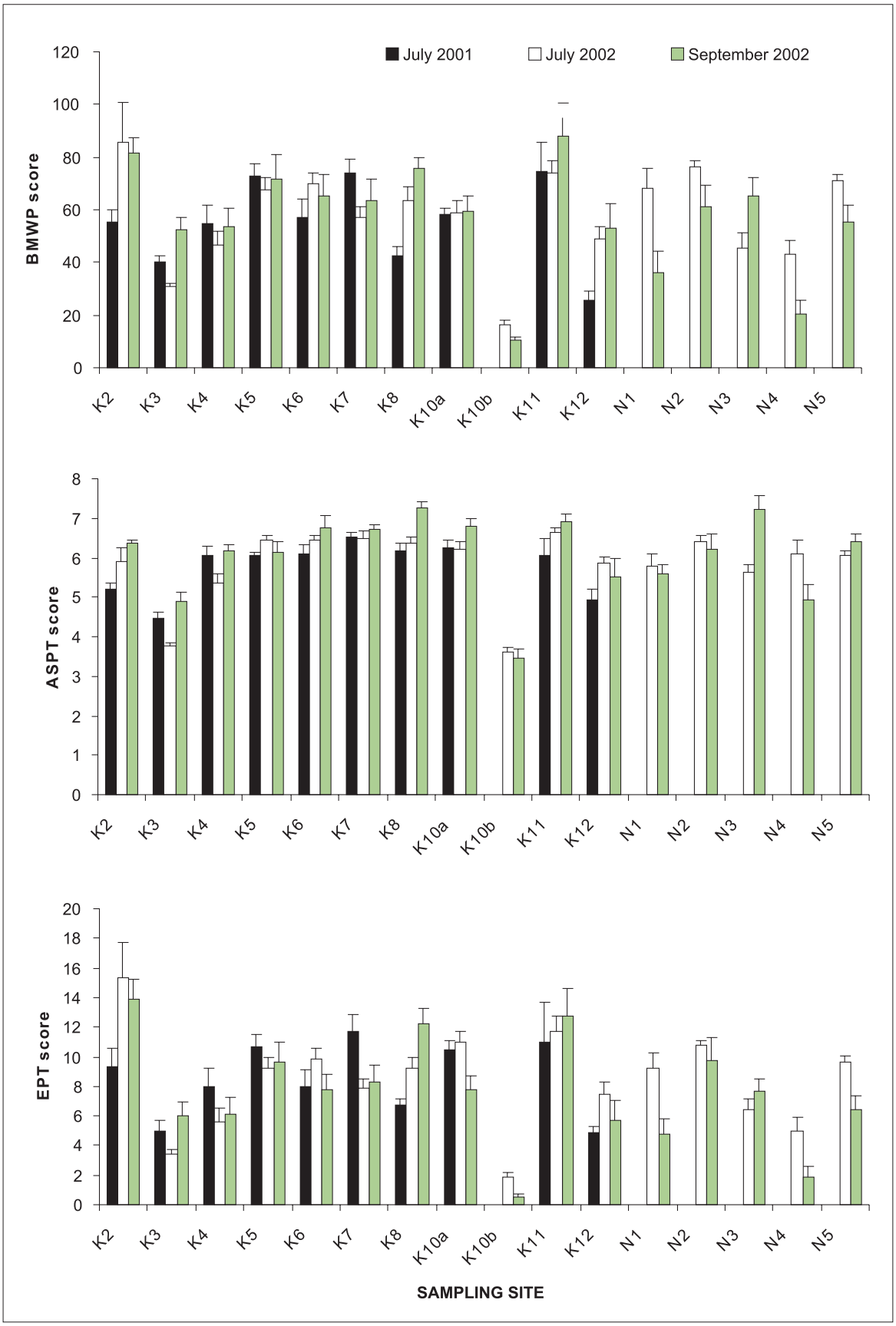

Fig. 23. Average BMWP-, ASPT- and EPT index scores (+- 1 SE) for different sampling occasions at the Kola River (K) and the Näätämöjoki River (N). Sampling occurred before (July 2001) and after (July and September 2002) installment of the BTS at the WWTP at Shongui.

for both the Kola River (gradient length =3.318) and the Näätämöjoki River (gradient length 2.4) sites. To simplify this general NMS focusing only on main stream river sites and July sampling times, all creek sites and September samplings were dropped (Fig. 26). This ordination of July sites again showed Taibola outlet site (K3) to group differently from all other sites. Finally, in a further reduction of the data, outlet sites, the tributary site Kitsa (K4), and all the Näätämöjoki River sites were dropped to solely investigate trends for sites included in BACIPS (Fig. 27). This ordination for BACIPS sites showed that distances between 'before' and 'after' sampling occasions were fairly constant for all except the Shongui sampling sites. This particular finding will be discussed in more detail below.

Table 9.
Scores for the Iberian peninsula adaptation of the BMWP index. Scores are related to general water quality classes.

Score	Class	Status
> 101	I	Unpolluted or lightly polluted
100–61	II	Slightly polluted, acceptable situation
36–60	III	Moderately polluted, doubtful situation
16–35	IV	Heavily polluted - critical situation
< 16	V	Very heavily polluted, very critical situation

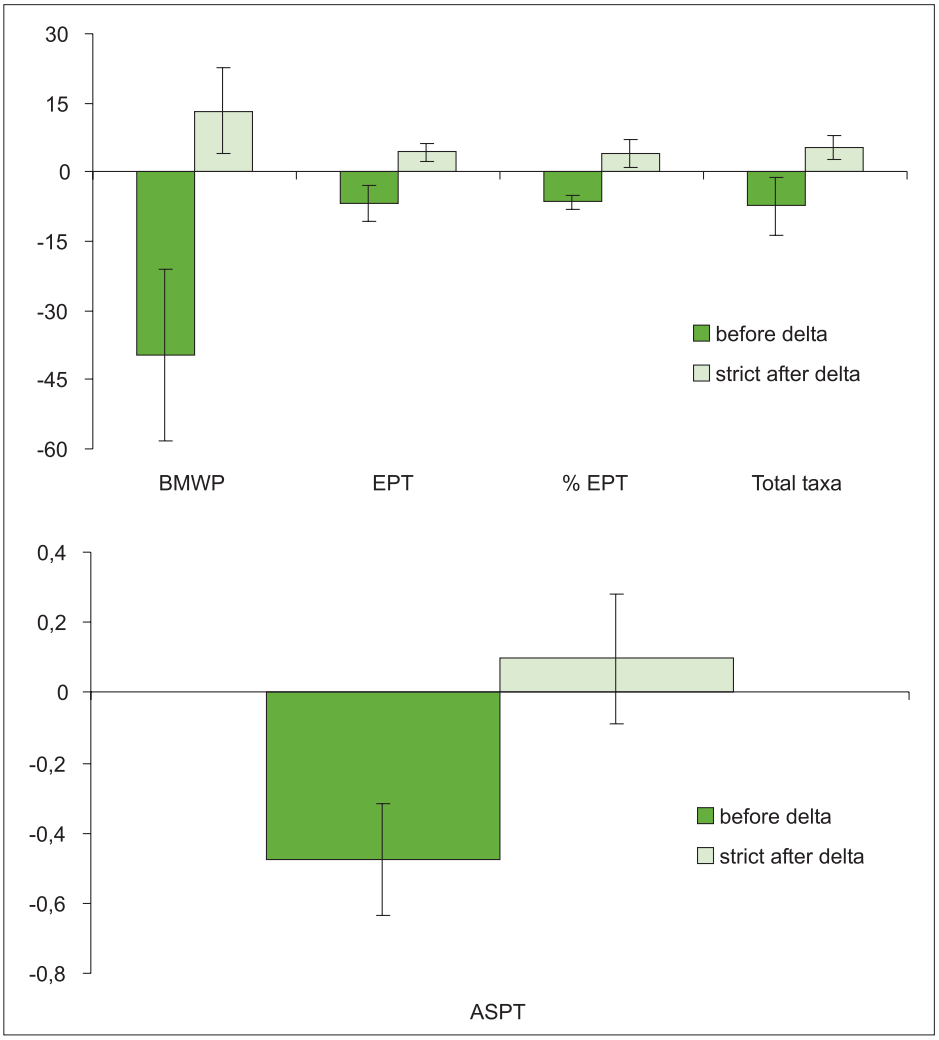

Fig. 24. BACIPS averaged differences (deltas) for Impact and Control site index scores (± 1SE). Deltas were calculated for 'before' and separately for the two different approaches on the 'after' data (see text for details).

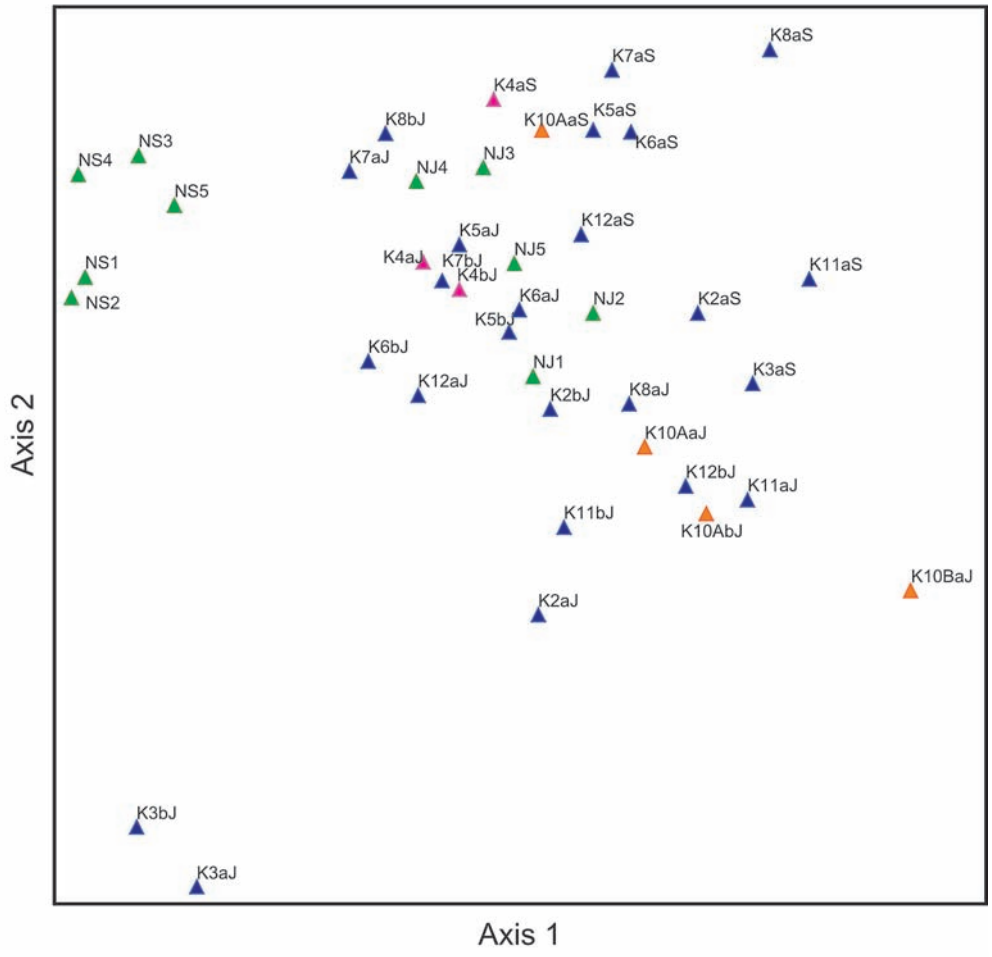

Fig. 25. NMS ordination of all sampling sites and occasions for averaged site data (mean of 8 Surber samples/sampling occasion). Abbreviation K (Kola R. blue, Kitsa R. pink, creeks orange) stands for the Kola River system, N (green) for the Näätämöjoki River, J for July, S for September a for 'after' and b for 'before' data. Site coding is described in detail in the text (see table 2).

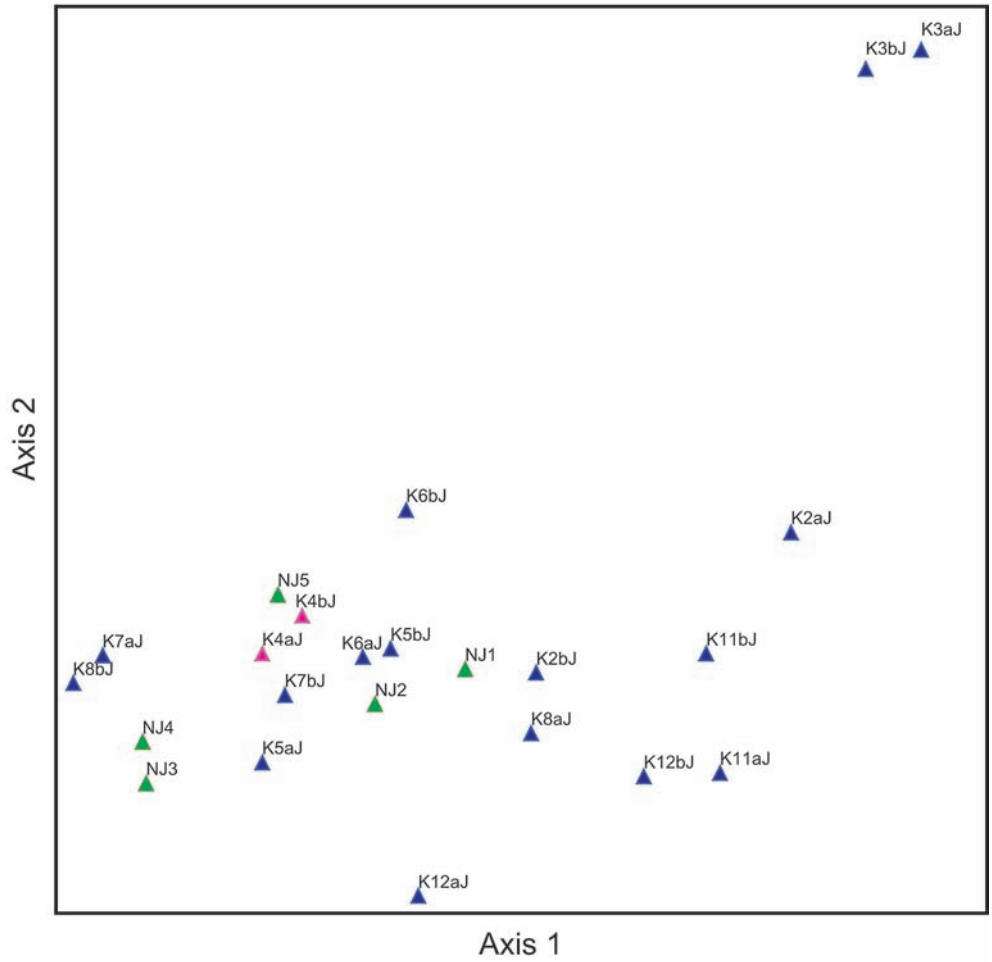

Fig. 26. NMS ordination of the Kola River (excluding creek sites) and the Näätämöjoki River sites for July averaged site data (mean of 8 Surber samples/sampling occasion). Abbreviation K (Kola R. blue, Kitsa R. pink) stands for the Kola River system, N (green) for the Näätämöjoki River, J for July, a for 'after' and b for 'before' data. Site coding is described in detail in the text (see table 2).

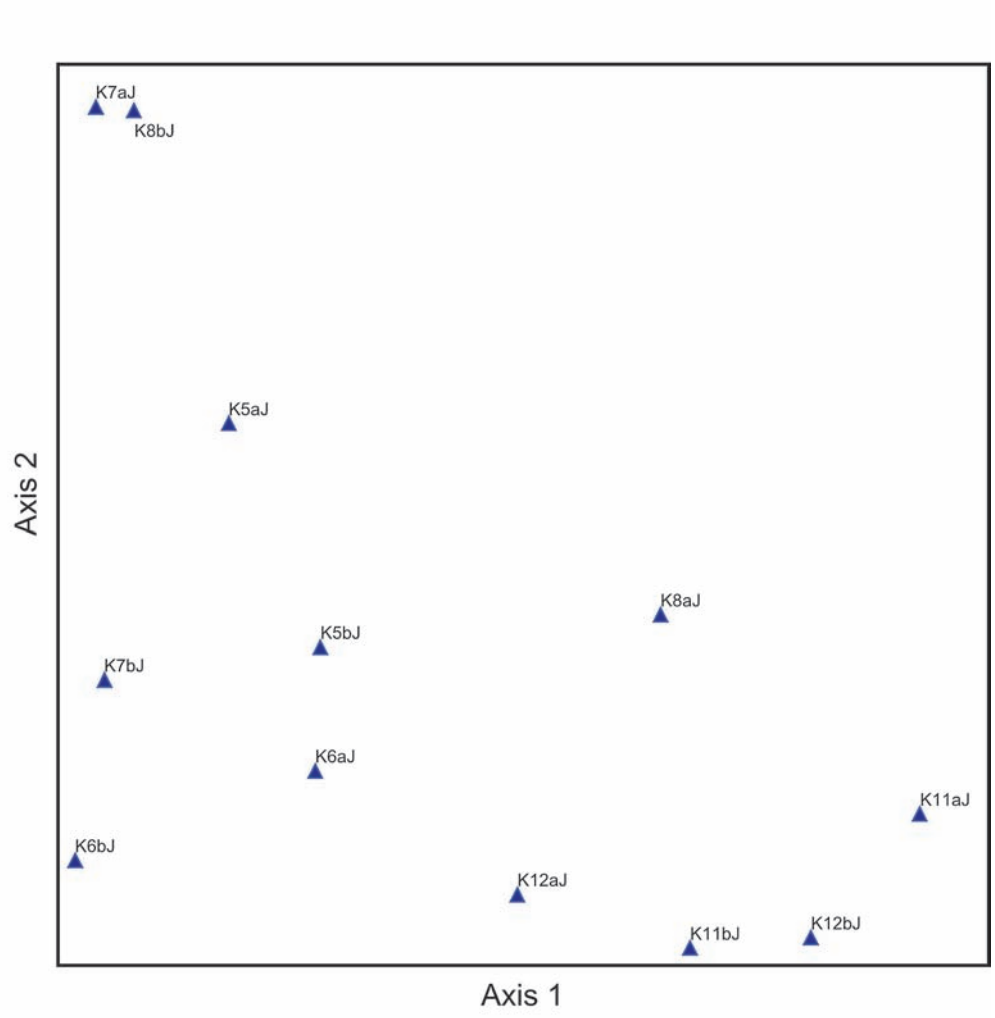

Fig. 27. NMS ordination of the Kola River sites for July averaged site data (mean of 8 Surber samples/ sampling occasion) that were chosen as control and impact sites in BACIPS analysis. Abbreviation K stands for the Kola River J for July, a for 'after' and b for 'before' data. Site coding is described in detail in the text (see table 2).

3.1.2.2
CCA

A total of 109 taxa were used in CCA. Environmental variables were tested using Monte-Carlo permutation tests and selection stopped at P=0.05. For brevity, only one of the many produced ordination bi- or triplots will be shown. In general, CCA repeated the main trends of the NMS ordinations. CCA of July's Kola River sampling occasions clearly displays that lake outlets (K2 and K3) differ substantially from all the other sites; therefore their omission as control sites in BACIPS analyses seems justified (Fig. 28). Note that the CCA solution for a joint ordination of the Näätämöjoki River sites and the Kola River sites in July (Fig. 28) does not differ from that for only Kola sites in the July (Fig. 29, page 42) of the 'before' and 'after' period with respect to the Kola River sites, since the environmental variables explaining most of the variation are identical in both ordinations. The first two axes explained 80.5% of the variance in the species-environment matrix (Table 10). The first axis of both CCAs strongly correlated positively with potassium content and negatively with distance from the source. The second axis was strongly correlated to water colour (Table 11). Ordinations of both the Kola River and the Näätämöjoki River samplings in July spaced the Näätämöjoki sites slightly separately from the Kola sites. This finding is somewhat different from the NMS ordination that did not separate the Näätämöjoki River sites in July from the Kola River sites. It is important to note however, that NMS did not make use of environmental data and thus may miss patterns associated with environmental variables.

Table 10.
Eigenvalue reports for the combined Kola River and the Näätämöjoki River CCA (total inertia = 1.081).

Axis	1	2	3	4
Eigenvalue	0.163	0.103	0.064	0.149
Cumulative variance (%)				
- of species data	15.1	24.6	30.6	44.4
- of species environment relation	49.3	80.5	100	0

Table 11.
Correlation between environmental variables and CCA-axis (Pearsons product moment correlation coefficient).

Variable	Axis1	Axis2
Colour	-.1256	-.6842
K (µg/l)	.8353	-.2417
Distance	-.8219	-.4271

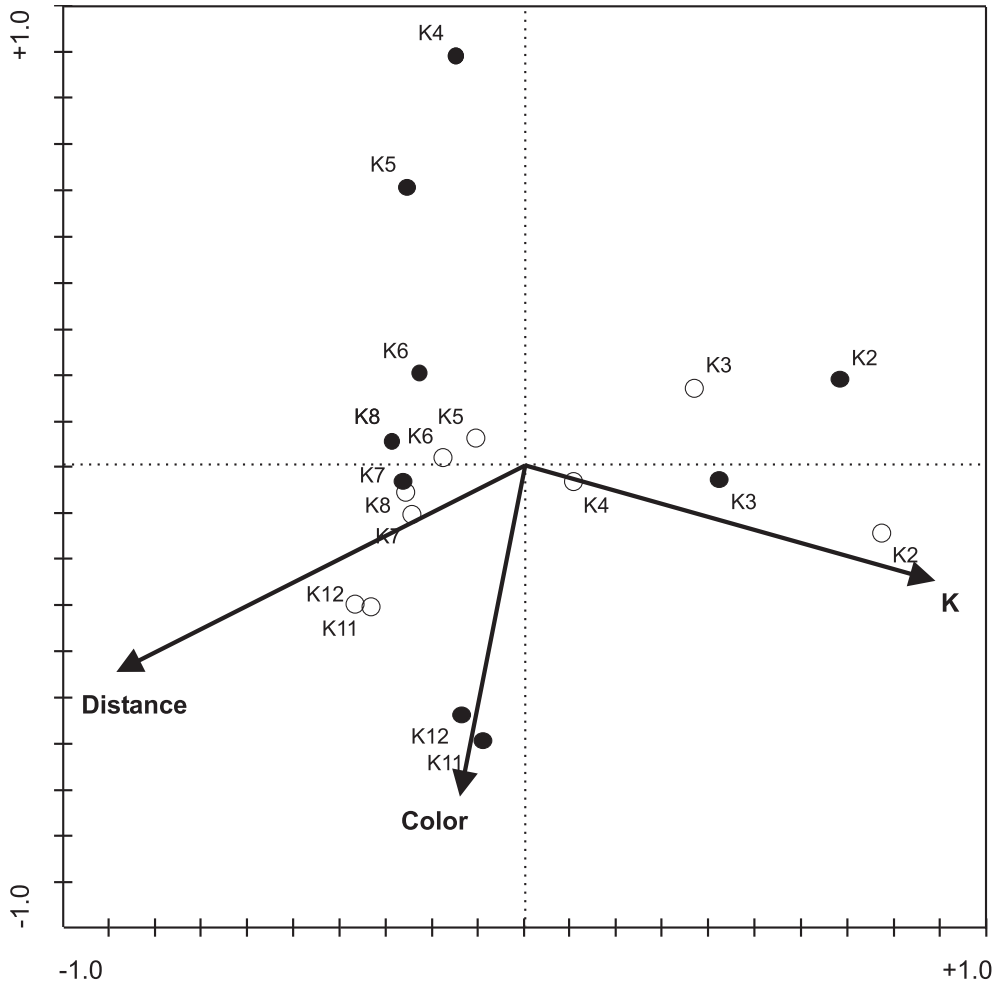

Fig. 28. CCA ordination of the Kola River (K) sampling sites in relation to environmental variables for July (J) sampling occasions before (●) and after (○) the installment of the BTS of the WWTP.

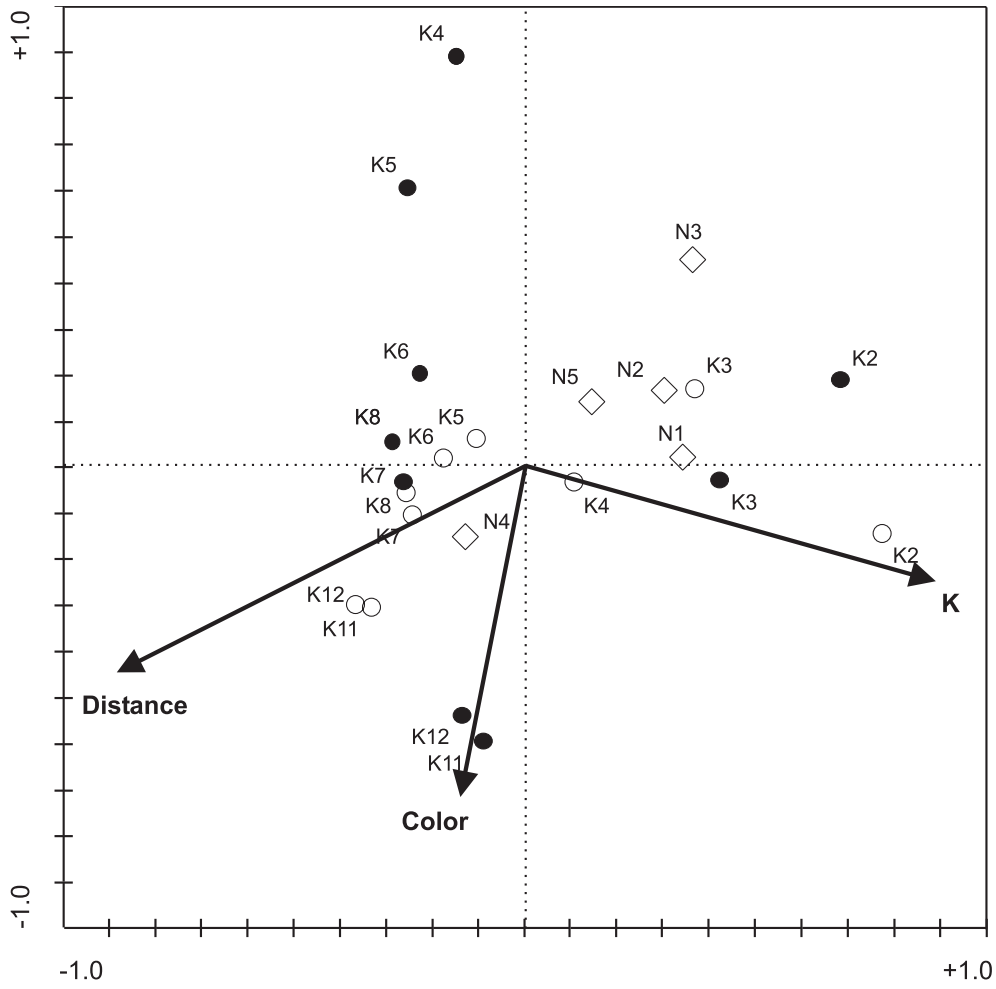

Fig. 29. CCA ordination of the Kola River (K, circles) and the Näätämöjoki River (N, diamonds) sampling sites in relation to environmental variables for July (J) sampling occasions before (●) and after (○) the installment of the BTS of the WWTP.

3.2

Fish communities

3.2.1

Species composition

A total of 6 and 8 different fish species occurred in the Rivers Kola and Näätämöjoki, respectively. In both rivers, the most commonly caught species were Atlantic salmon, minnow and brown trout. List of the fish species with documented occurrence from either of these rivers is presented in Table 12.

3.2.2

Abundance

Mean densities of fish in the Kola River and the Näätämöjoki River are presented in Tables 13 and 14. All species included, the total mean densities of fish were 28.2 ind./100 m² and 50.4 ind./100 m² in the rivers Kola and Näätämöjoki, respectively. The mean density of fish in the main stem of the Kola River was 29.0 ind./100 m² (sites K4, K10a, and K10b excluded). The mean density of Atlantic salmon juveniles differed markedly between the rivers being 5.5 ind./100 m² (range 0–24.8) in the Kola River and 48.0 ind./100 m² (range 0–109.1) in

Table 12.
Fish species present in the rivers Kola and Näätämöjoki. The occurrence frequencies (%) refer to the occurrence of the species in the electrofishing areas (n=11 and n=28, respectively). Presence/absence data (+/-) is from Jensen et al. (1997) and Niemelä et al. (2001).

Species	The Kola River	The Näätämöjoki River
Atlantic salmon (Salmo salar L.)	82	93
Brown trout (Salmo trutta L.)	36	29
Arctic char (Salvelinus alpinus (L.))	-	+
Grayling (Thymallus thymallus (L.))	+	4
Pink salmon (Oncorhynchus gorbuscha (Walbaum))	+	+
Whitefish (Coregonus lavaretus sp. (L.))	+	+
Vendace (Coregonus albula L.)	+	-
Pike (Esox lucius L.)	+	+
Perch (Perca fluviatilis L.)	+	+
Burbot (Lota lota (L.))	+	14
Minnow (Phoxinus phoxinus (L.))	64	29
Three-spined stickleback (Gasterosteus aculeatus L.)	18	7
Nine-spined stickleback (Pungitius pungitius (L.))	27	4
Flounder (Platichtys flesus (L.))	9	7
European eel (Anguilla anguilla (L.))	+	+
Lamprey (Lampetra sp. (L.))	-	+

Table 13.
Mean densities of fish in the Kola River. Densities are given as individuals per 100 m². Asterisk (*) denotes estimated densities with three fishing runs. Otherwise densities are calculated from raw data. Abbreviations used are acronyms of Latin names (see table 11.).

Site	Date	Area m²	Total density /100 m²	Salmon density /100 m²	Density of other species /100 m²	Runs
K2	2.9.02	130	28.5	0.8	Ph.ph 27.7	1
K3	2.9.02	170	7.1	1.8	Ph.ph 4.7 G.a 0.6	1
K4	3.9.02	120	53.0*	20.6*	S.t 32.4*	3
K5	3.9.02	98	49.3*	24.8*	S.t 6.1 Ph.ph 18.4	3
K6	3.9.02	78	68.4*	5.1	S.t 30.0* Ph.ph. 33.3	3
K7	4.9.02	152	5.3	4.6	S.t 0.7	1
K8	4.9.02	171	-	-	-	1
K10a	4.9.02	105	24.8	1.0	Ph.ph 1.9 G.a 1.0 Pu.pu 21.0	1
K10b	5.9.02	33	-	-	-	1
K11	5.9.02	68	44.5	1.5	Ph.ph 40.0 Pu.pu 3.0	1
K12	5.9.02	144	29.2	0.7	Ph.ph 21.5 Pu.pu 4.9 P.f 2.1	1

Table 14.
Mean densities of fish in the Näätämöjoki River. Densities are given as individuals per 100 m². Asterisk (*) denotes estimated densities with three fishing runs. Otherwise densities are calculated from raw data. Abbreviations used are acronyms of Latin names (see table 12.).

Site	Date	Area m²	Total density/100 m²	Salmon density/100 m²	Density of other species/100 m²	Runs
6	26.8.02	117	1.7	-	S.t 1.7	1
7	27.8.02	88	9.0	-	S.t 9.0	1
8	27.8.02	97	22.7	22.7	-	1
9	27.8.02	106	12.2	10.4	Ph.ph 0.9 L.l 0.9	1
10	27.8.02	120	50.6*	49.8*	L.l 0.8	3
11	28.8.02	90	60.1*	53.5*	S.t 3.3 Ph.ph 3.3	3
12	28.8.02	153	4.6	3.9	Ph.ph 0.7	1
13	29.8.02	152	69.2*	65.9*	Ph.ph 2.0 T.t 1.3	3
1	30.8.02	117	10.3	9.4	S.t 0.9	1
14	30.8.02	85	62.3*	58.8*	Ph.ph 3.5	3
15	31.8.02	98	94.4*	92.3*	Ph.ph 2.1	3
2	31.8.02	85	16.6	16.6	-	1
21	31.8.02	92	93.3*	93.3*	-	3
3	1.9.02	96	73.7*	72.7*	Ph.ph 1.0	3
16	1.9.02	134	75.8*	75.1*	Ph.ph 0.7	3
22	2.9.02	86	22.2	22.2	-	1
17	16.9.02	104	18.3	18.3	-	1
18	2.9.02	60	104.5*	102.8*	L.l 1.7	3
23	2.9.02	88	60.2*	60.2*	-	3
19	3.9.02	97	63.1*	63.1*	-	3
20	3.9.02	65	96.3*	96.3*	-	3
37	12.9.02	152	118.3*	109.1*	S.t 9.2*	3
36	14.9.02	101	14.8	14.8	S.t 3.0	1
35	14.9.02	133	63.1*	60.1*	S.t 2.3 L.l 0.8	3
34	13.9.02	129	66.6*	63.5*	-	3
33	13.9.02	146	49.9*	49.9*	G.a 7.0 P.f 5.0	3
32	13.9.02	100	23.0	11.0	S.t 1.5 G.a 1.5 Pu.pu 0.5	1
31	12.9.02	202	54.0*	49.5*	P.f 1.5	3

the Näätämöjoki River. In the Kola River, the abundance of brown trout did not differ from that of Atlantic salmon (6.3/100 m², range 0–32.4/100 m²), whereas in the Näätämöjoki River, the mean density of brown trout was much lower (1.2 ind./100 m², range 0–9.2 ind./100 m²). In the main stem of the Kola River (sites K4, K10a, and K10b excluded), the mean densities of Atlantic salmon and brown trout were 4.9 ind./100 m² and 4.6 ind./100 m², respectively.

3.2.3

Age structure

The age structure of Atlantic salmon and brown trout juveniles in the Kola River are not specified in detail due to scarcity of analysed scale material. The regeneration of the scales rendered over 30% of the scale samples unusable in age-determination. The high percentage of useless scales was at least partly caused by the hatchery origin of the fish. The identifiable scale material included all age classes Under-yearling salmon (fry) dominated the sample at the site K5. In addition, fry were met only at the sites K7 and K11. Brown trout fry were not caught in the Kola River, but older age classes (1+ – 3+) occurred evenly among the study sites. In the Näätämöjoki River, salmon fry were caught at 23 out of those 26 sites where salmon occurred. While brown trout densities were generally low in the River Näätämöjoki, brown trout fry were still caught at three study sites.

Table 15.
Mean score statistics and final index scores for the fish communities of all sample sites in the Kola River. See criteria descriptions in table 4.

Site	Mean score of all metrics	Final index score (1-5)
K2	3.0	2
K3	2.4	1
K4	2.4	1
K5	2.4	1
K6	2.0	1
K7	2.7	1
K8	(5)	(5)
K10a	3.0	1
K10b	(5)	(5)
K11	2.6	1
K12	3.1	2

Table 16.
Mean score statistics and final index scores for the fish communities of all sample sites in the Näätämöjoki River. See criteria descriptions in table 4.

Site	Mean score of all metrics	Final index score (1-5)
6	3.7	3
7	2.6	1
8	2.0	1
9	1.7	1
10	1.4	1
11	1.7	1
12	3.0	2
13	1.3	1
1	2.9	2
14	1.7	1
15	1.7	1
2	3.3	2
21	1.9	1
3	1.7	1
16	1.6	1
22	2.3	1
17	2.3	1
18	1.4	1
23	1.7	1
19	1.7	1
20	1.6	1
37	1.4	1
36	2.4	1
35	1.6	1
34	1.7	1
33	1.9	1
32	3.1	2
31	1.4	1

The Finnish National Veterinary and Food Research Institute diagnosed epidermal papillomatosis in two sick brown trout caught at the site K6. were 13.5 and 14.7 cm in length and 3+ and 4+ in age, respectively. Both specimens were precocious males. For brown trout, these epidermal papillomatosis findings are first ever reported in the northern rivers.

3.2.4
Fish community index (FIX)

Final index values varied usually between classes 1 and 2 in both rivers (Tables 15 and 16.) corresponding to verbal definitions 'none or minor deviations' and 'small deviations from the reference conditions'. Two study sites were empty of fish in the Kola River, and were hence given the status of class 5, although the actual index cannot be numerically calculated in a total absence of fish. When regarding the separate metrics (not included in the tables below), the most often deviating ones from the reference were metrics describing 'number of fish species native to the habitat' and 'reproduction of salmonid species native to the habitat' in both study rivers. In contrast, metrics describing 'proportion biomass of non-native fish species in relation to total biomass' scored to the class 1 in every sampling occasion.

Although quite similar in overall distribution of the final index scores, the rivers differed clearly in the mean scores of all metrics. The median for mean scores of all metrics was 2.7 in the Kola River and 1.7 in the Näätämöjoki River. The result was consistent also when the two empty areas of the Kola River were omitted (median 2.6).

3.3
Diatom community analysis

Total of 296 diatom species from the Kola River (Appendices 8–10), and 177 from the Näätämöjoki River (Appendices 11–12) were identified. *Achnanthes minutissima* was the most common species in both rivers. Other common species in the Kola River were *Achnanthes pusilla*, *Fragilaria capucina*, *Fragilaria tenera*, *Fragilaria ulna*, *Tabellaria flocculosa* and in the Näätämöjoki River *Achnantes pusilla*, *Anomoeoneis vitrea*, *Cymbella microcephala*, *Fragilaria capucina*, *Fragilaria tenera* and *Tabellaria flocculosa*. The species composition varied from one sampling point to the other. In the Kola River the species richness was highest at the Kitza River estuary (K12), and in the Näätämöjoki River at the Lake Opukasjärvi outlet (N2).

3.3.1

Indices

According to the diatom indices, water quality in the Kola River varies slightly between study sites in the upper and lower reaches and the middle reach of the river. In most of the study sites in the main channel, the Pollution Sensitivity Index (IPS) showed excellent or good water quality (Fig. 30). In the site K2 in the upper course of the river, water quality classified based on IPS was moderate and in the creeks of the lower course, it was poor (K10a) or bad (K10b). The index values from different sampling occasions were rather similar except for the study site K11 where the IPS value in July 2002 had decreased from that of July 2001 and the water quality according to IPS had changed from good to the moderate class. At site K10a IPS records of July 2001 and July2002 dropped in September 2002 lowering water quality classification from poor to bad. At the site K3, the classification changed from good to excellent between sampling periods of 2001 and 2002. In the Näätämöjoki River, the IPS values represented good or excellent water quality in every study site.

While the values of the Trophic Diatom Index (TDI) varied more than those of IPS the main trend was still the same. The middle course of the Kola River showed oligotrophic or oligo-mesotrophic conditions, but in 2002 the trophic level, based on TDI, changed to mesotrophic level at the study sites K6 and K7 (Fig. 31). In all diatom samples

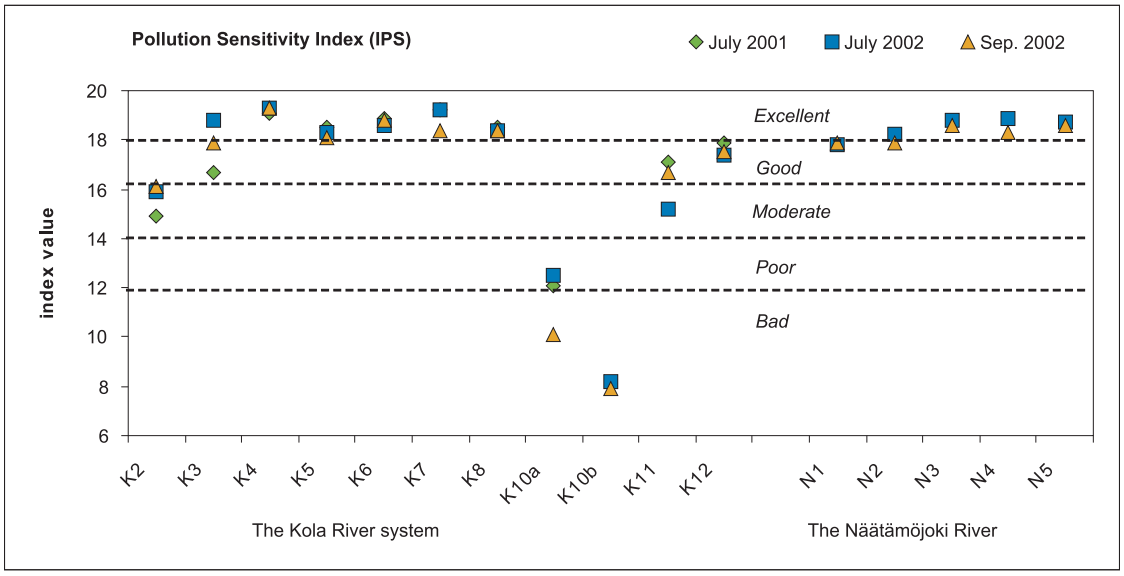

Fig. 30. Water quality according to IPS values in the Kola River system and in the Näätämöjoki River.

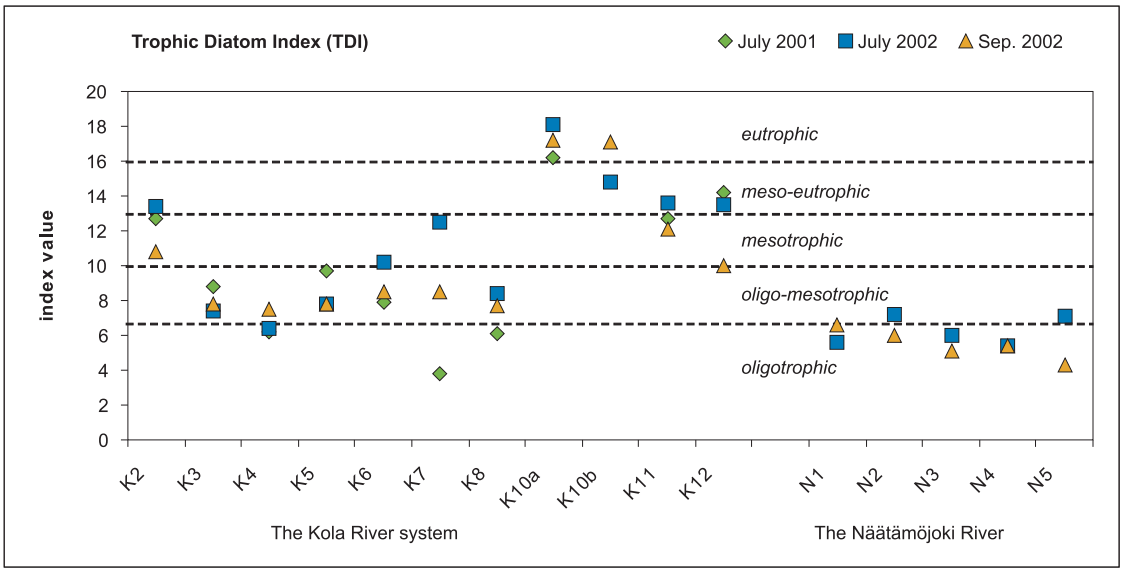

Fig. 31. Trophic level of the river water according to TDI values in the Kola River system and in the Näätämöjoki River.

from the Varlamov creek (K10a) and in September 2002 samples from the Medvegiy creek (K10b) TDI indicated eutrophic level. The rest of the lower course sites (K11, K12) as well as the site K2 in the upper course of the Kola River were classified to represent mesotrophic or meso-eutrophic level. In the Näätämöjoki River, the TDI values indicated oligotrophic conditions all along the river.

Generic Diatom Index values classified the water quality in the Kola River more or less similarly as the other two indices used (Fig. 32). The highest index values scored in the middle reach of the Kola River and the lowest in the sites K2, K10a, and K10b. At the site K3 (Taibola), GDI indicated an interesting improvement of water quality between sample periods of July 2001 and 2002. In the Näätämöjoki River, GDI values were rather high, indicating good or excellent water quality for the entire watercourse .

3.3.2

Ecological characters

Proportion of species taken into account when calculating different ecological distributions of the diatom communities was more than 50% of the observed taxa in every sample except in the study site K12 (the Kola River estuary) where this proportion was generally about 40–45%. Ecological spectra of the site K12 are therefore not quite reliable, but they can be considered suggestive.

In the Kola River basin, the proportion of eutraphentic diatom species that indicate nutrient pollution was greatest in the creeks Varlamov (K10a) and Medvegiy (K10b) (Fig. 33). In the study sites located in the main flow below these creeks (K11 and K12), the proportion of eutraphentic species was also slightly elevated. The site K2 (Kola springs) in the upper reach of the Kola River showed a fairly great share of eutraphentic diatoms as well.

Both in the Kola River and in the Näätämöjoki River a majority of the diatom species were classified into oligo- or mesosaprobe saprobity classes (Fig. 34). The greatest amount of polysaprobes, which indicate an elevated level of organic pollution, was observed at the creeks in the lower course of the Kola River (sites K10a and K10b). Also at the site K11 in the main flow, the proportion of polysaprobes was slightly higher than on average. In Medvegiy creek (K10b), a major portion of the species consisted of polysaprobes.

The study sites, in which organic pollution according to saprobity classification was the heaviest (K10a and K10b), also contained large proportions of diatoms whose oxygen requirements are low or even very low (Fig. 35). In addition, the effect of an oxygen consuming organic load could be detected in the sites K11 and K12. Oxygen-rich conditions seemed to predominate in the middle course of the Kola River and in the whole length of the Näätämöjoki River.

The trend in the distribution of diatom taxa to classes of nitrogen uptake was similar to the two previous ecological spectra. Facultatively or obligately nitrogen heterotrophic species, needing periodically or continuously elevated concentrations of organically bound nitrogen, were observed in the creek sites (K10a and K10b), and at the main channel sites K11 and K12 in the Kola River (Fig. 36). In Medvegiy creek (K10b), 80% of the diatom

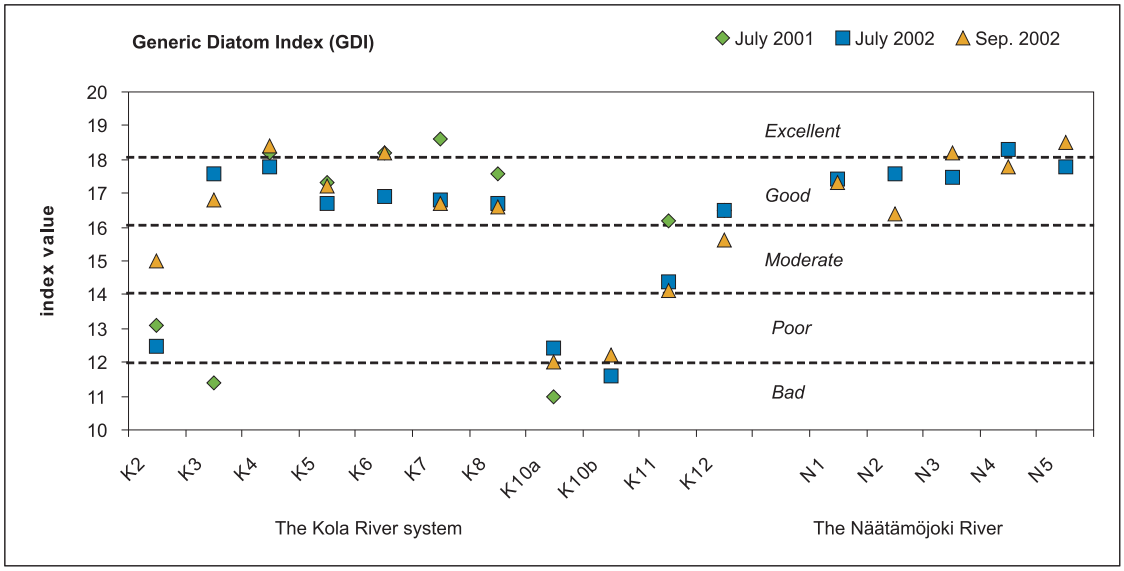

Fig. 32. Water quality according to GDI values in the Kola River system and in the Näätämöjoki River.

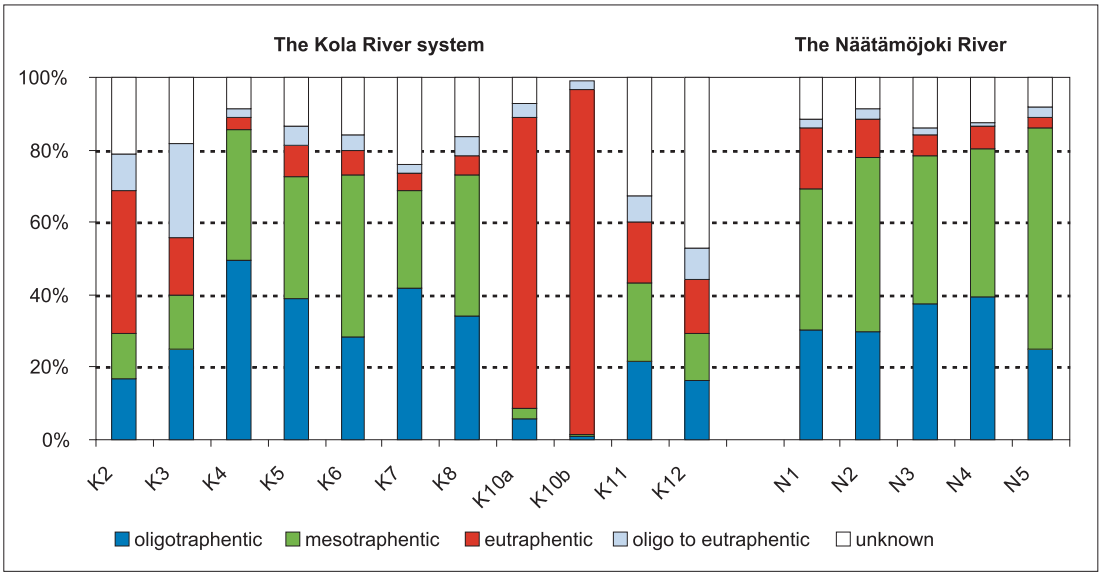

Fig. 33. Distribution of diatom taxa in different classes of trophic state (Van Dam et al. 1994) in the Kola River system (average of July 2001, 2002 and September 2002) and in the Näätämöjoki River (average of July and September 2002).

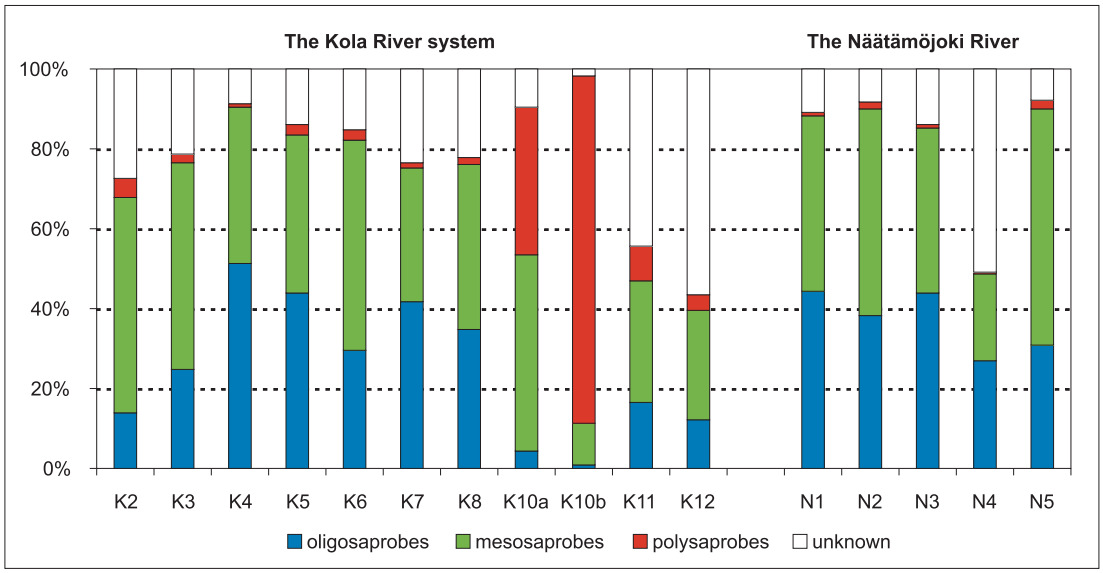

Fig. 34. Distribution of diatom taxa in different classes of saprobity (Van Dam et al. 1994) in the Kola River system (average of July 2001, 2002 and September 2002) and in the Näätämöjoki River (average of July and September 2002).

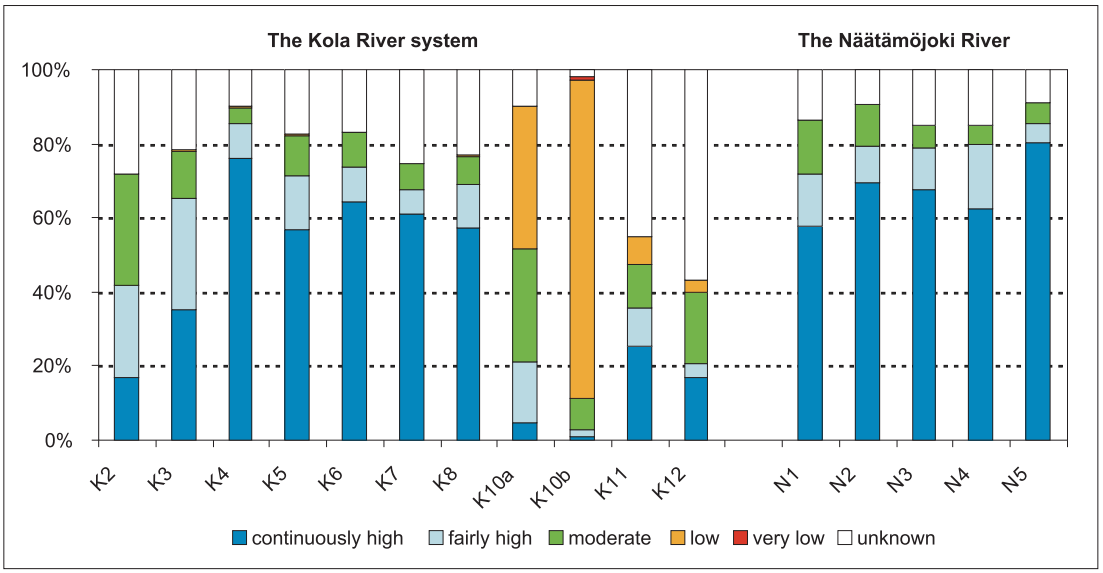

Fig. 35. Distribution of diatom taxa in different classes of oxygen requirements (Van Dam et al. 1994) in the Kola River system (average of July 2001, 2002 and September 2002) and in the Näätämöjoki River (average of July and September 2002).

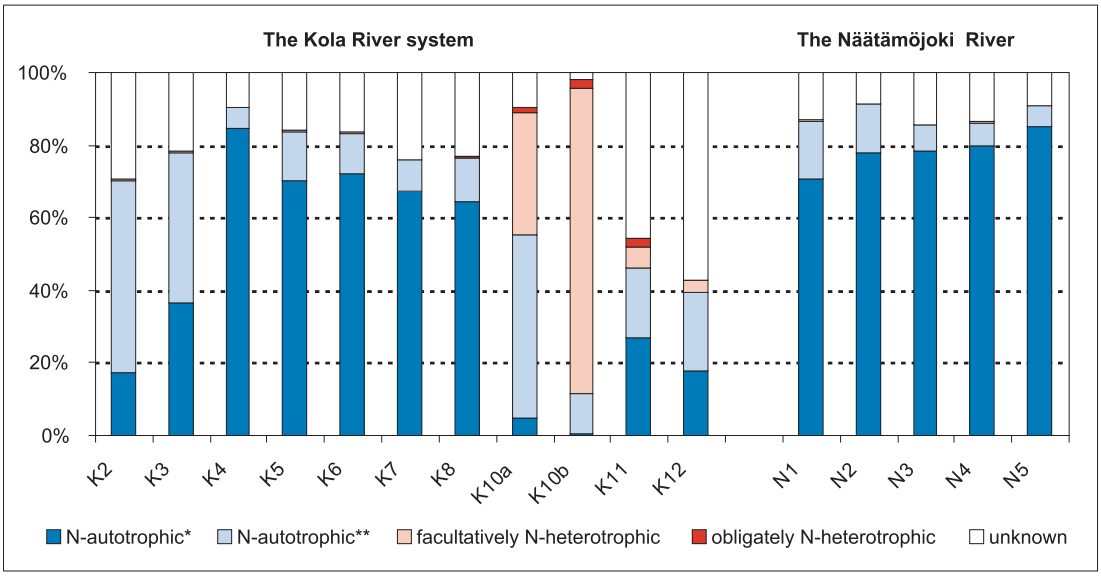

Fig. 36. Distribution of diatom taxa in different classes of nitrogen uptake (Van Dam et al. 1994) in the Kola River system (average of July 2001, 2002 and September 2002) and in the Näätämöjoki River (average of July and September 2002). N-autotrophic taxa, tolerating *very small or **elevated concentrations of organically bound N.

species were facultatively N-heterotrophic. In the Näätämöjoki River and in the middle section of the Kola River, most of the species represented N-autotrophic taxa, tolerating very small concentrations of organically bound nitrogen. At the sites K2 and K3 in the upper reach of the Kola River, the diatom community consisted also of a great share of the other N-autotrophic taxa, tolerating elevated concentrations of organically bound nitrogen.

3.3.3

Multivariate analyses

3.3.3.1

NMS

After deleting the rare taxa (abundance < 1% of the total cells in each sample) and *A. minutissima* the number of species in the analysis was 109 when ordinating the species data of all sampling sites (16) and sampling occasions (3) of the Kola River and the Näätämöjoki River. The non-metric multidimensional scaling (NMS) with 42 iterations resulted in a two-dimensional ordination reflecting site-specific dissimilarities and similarities in the diatom species data along the rivers Kola and Näätämöjoki (Fig. 37). Small tributaries (K10a, K10b) on the lower course of the Kola River separated clearly from all the other sites, most probably due to higher nutrient content caused by agricultural wastewaters discharged into these creeks, but also due to different size, flow velocity and habitat structure of these watercourses compared to the main channel sites. Also Kola springs (K2, lake outlet) seemed to differ from other sites. Different sampling occasions for this site grouped close to each other but far form other sites, which is probably due to larger nutrient and mineral inputs from the Lake Kolozero to this outlet site. Sampling sites of the Näätämöjoki River grouped among the mid-section Kola River sites, which indicates similar environmental conditions for these sites. Site Taibola (K3, lake outlet) and the lower course main channel sites (K11 and K12) together with the July 2002 samplings of the sites K7 and K8 grouped between the mid-section Kola sites and Kola springs (K2). This seems to reflect the increasing of nutrients downstream the river continuum, and also supports the conclusion that lake outlets represent unique habitats when compared to other river sections.

To focus only on July samplings of the main channel sites (including K4 as it did not separate from other sites in the first NMS), all September samplings and small tributaries of the Kola River (K10a, K10b) were dropped. As a result, the data was reduced to 103 diatom taxa sampled on two occasions from nine Kola sites and on one occasion from five Näätämöjoki sites. This NMS ordination with 80 iterations displayed a clear grouping of the Näätämöjoki River sites close to the mid-section Kola sites (Fig. 38). Interestingly, sites at the Näätämöjoki River could be separated into two distinct groups, in which July samplings of N1, N3 and N4 stood apart from all the other sites, prob-

ably indicating oligotrophy and high water quality. The outlet of Lake Opukasjärvi (N2) together with the estuary site N5 grouped together with the Kola mid-section sites. This reflects elevated nutrient concentrations, of the lake outlet (N2) and river mouth (N5). As in the first NMS ordination (Fig. 37), the lower course Kola sites (K11 and K12) and the lake outlets (K2 and K3) as well as the July 2002 samplings of the sites K7 and K8 were scattered separately from the above-mentioned sites. The differences in location of the sites K7 and K8 according to sampling year may suggest that conditions had somewhat changed, possibly reflecting differences in available nutrients between July 2001 and July 2002. The changes could also be a result from differences in hydrological conditions (e.g. water level, discharge) between years.In addition the sampling locations slightly differed between years, due to different observers. Changes of sampling locations could have resulted in differences in habitat structure, e.g., bottom material, water depth and flow velocity.

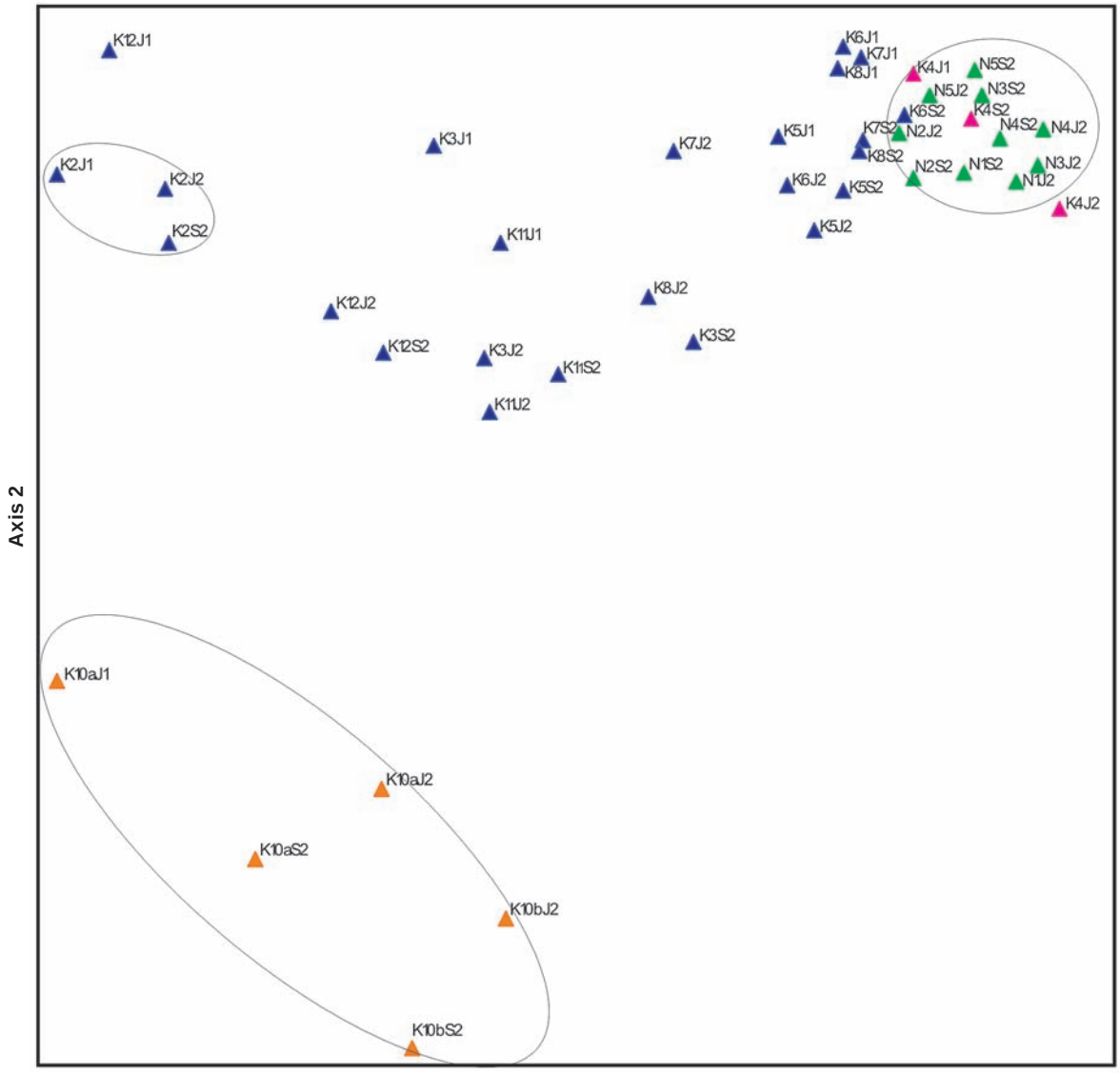

Fig. 37. NMS ordination of all sampling sites and occasions for relative abundances of diatom taxa. Abbreviations: after the sampling site code J stands for July, S for September, 1 for year 2001 and 2 for year 2002. Kola R. blue, Kitsa R. pink, creeks orange, Näätämöjoki R. green.

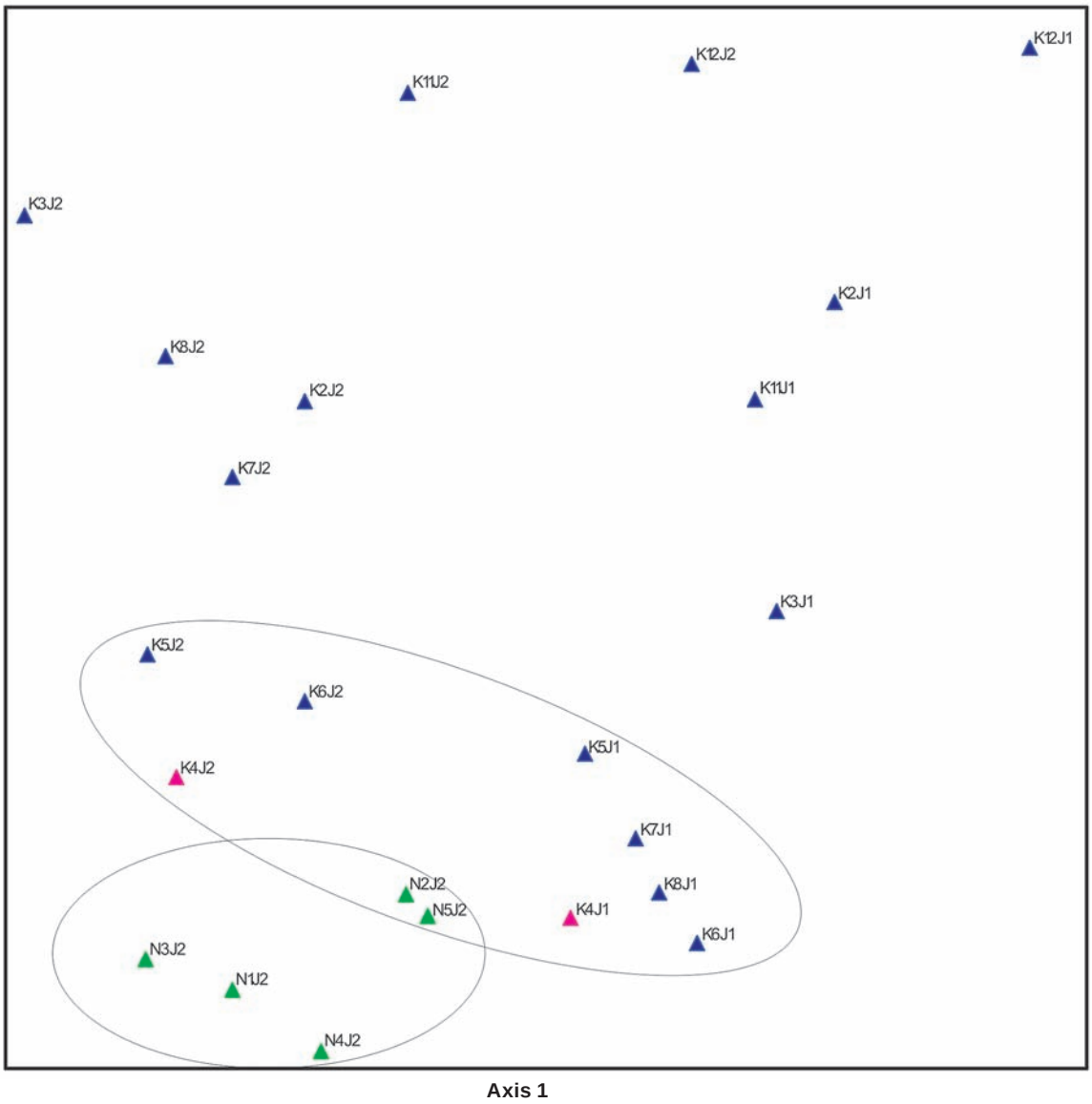

Fig. 38. NMS ordination of July 2001 and 2002 samplings (excluding creeks K10a and K10b) for relative abundances of diatom taxa. Abbreviations: after the sampling site code J stands for July, 1 for year 2001 and 2 for year 2002. Kola R. blue, Kitsa R. pink, Näätämöjoki R. green.

3.3.3.2

CCA

CCA analysis of the whole diatom data from the rivers Kola and Näätämöjoki (109 taxa, 16 sampling sites, three sampling occasions) mainly confirmed the general conclusions made from the diatom data based on NMS. The eigenvalues of the first two CCA axes (Fig. 39) were 0.575 (axis 1, p=0.005) and 0.360 (axis 2, p= 0.015). They explained 24.2% of the total variance in the diatom communities (Table 17). The diatom-environment correlations for CCA axis 1 and axis 2 were high indicating a strong correlation between diatoms and environmental variables. The canonical coefficients and intraset correlations indicated that total P, Na, Cl, conductivity, and Mg made the most significant contribution to the axis 1, and O_2-%, total P, and Fe to the axis 2. According to the coefficients, intraset correlations, and biplot scores (arrow length) of the environmental variables, species distributions were most affected by total P, conductivity, Na, Cl, Mg and O_2-% (Table 18). The colour of water, Fe, K, NH_4-N, and total suspended load (TSL) had a slightly weaker effect on the diatom community.

Table 17.
Axis summary statistics for CCA ordination of the whole diatom data (total variance, 'inertia' in the species data = 3.8667).

Axis	1	2	3
Eigenvalue	0.575	0.360	0.322
Cumulative variance (%) of species data	14.9	24.2	32.5
Pearson correlation, species-environment	0.988	0.900	0.961

Table 18.
Correlations and biplot scores (arrow lengths in Fig. 39) for 14 environment variables used in CCA ordination of the whole diatom data.

Variable	Correlations*			Biplot Scores		
	Axis 1	Axis 2	Axis 3	Axis 1	Axis 2	Axis 3
Ca	-0.449	-0.030	0.295	-0.341	-0.018	0.167
Cl	-0.892	-0.100	0.104	-0.677	-0.060	0.059
Colour	-0.725	0.125	0.109	-0.550	0.075	0.062
Conductivity	-0.881	0.012	0.381	-0.669	0.007	0.216
Fe	-0.746	-0.186	-0.434	-0.566	-0.112	-0.246
K	-0.739	0.100	0.572	-0.561	0.060	0.325
Mg	-0.837	0.103	0.441	-0.635	0.062	0.250
Na	-0.913	-0.153	0.277	-0.693	-0.092	0.157
NH_4-N	-0.670	-0.103	0.346	-0.508	-0.062	0.196
O_2-%	0.621	-0.299	0.302	0.471	-0.180	0.172
Total P	-0.947	0.243	-0.074	-0.718	0.146	-0.042
SO4	-0.470	0.056	0.728	-0.356	0.033	0.413
TSL	-0.690	0.057	0.192	-0.523	0.034	0.109
pH	-0.131	-0.006	0.414	-0.100	-0.004	0.235

*Correlations are 'intraset correlations' of ter Braak (1986)

Like NMS analysis, CCA ordination separated clearly chemically different small tributaries Varlamov (K10a) and Medvegiy (K10b) from the Kola River. Sites K10a and K10b were associated with total P, NH_4-N, Fe, Na, Cl, Mg, K, conductivity, colour, and TSL ,whereas other sites were positively associated with oxygen saturation (O_2-%). The Näätämöjoki River sites grouped towards the most oligotrophic and oxygen-richest corner in the ordination diagram, together with the Kola River mid-section sites. Diatom species of the same sites are ordinated together with environmental variables in Figure 40. Most of the diatom taxa were grouped close to the lower concentrations of minerals and nutrients, conductivity, colour and TSL. Only a few species, e.g. *Craticula accomoda*, *C. minusculoides*, *Mayamaea atomus*, *Navicula gregaria*, and *Achnanthes lanceolata* plotted to the direction of electrolyte-rich and oxygen-poor conditions. For instance *Anomoeoneis brachysira var. zellensis*,

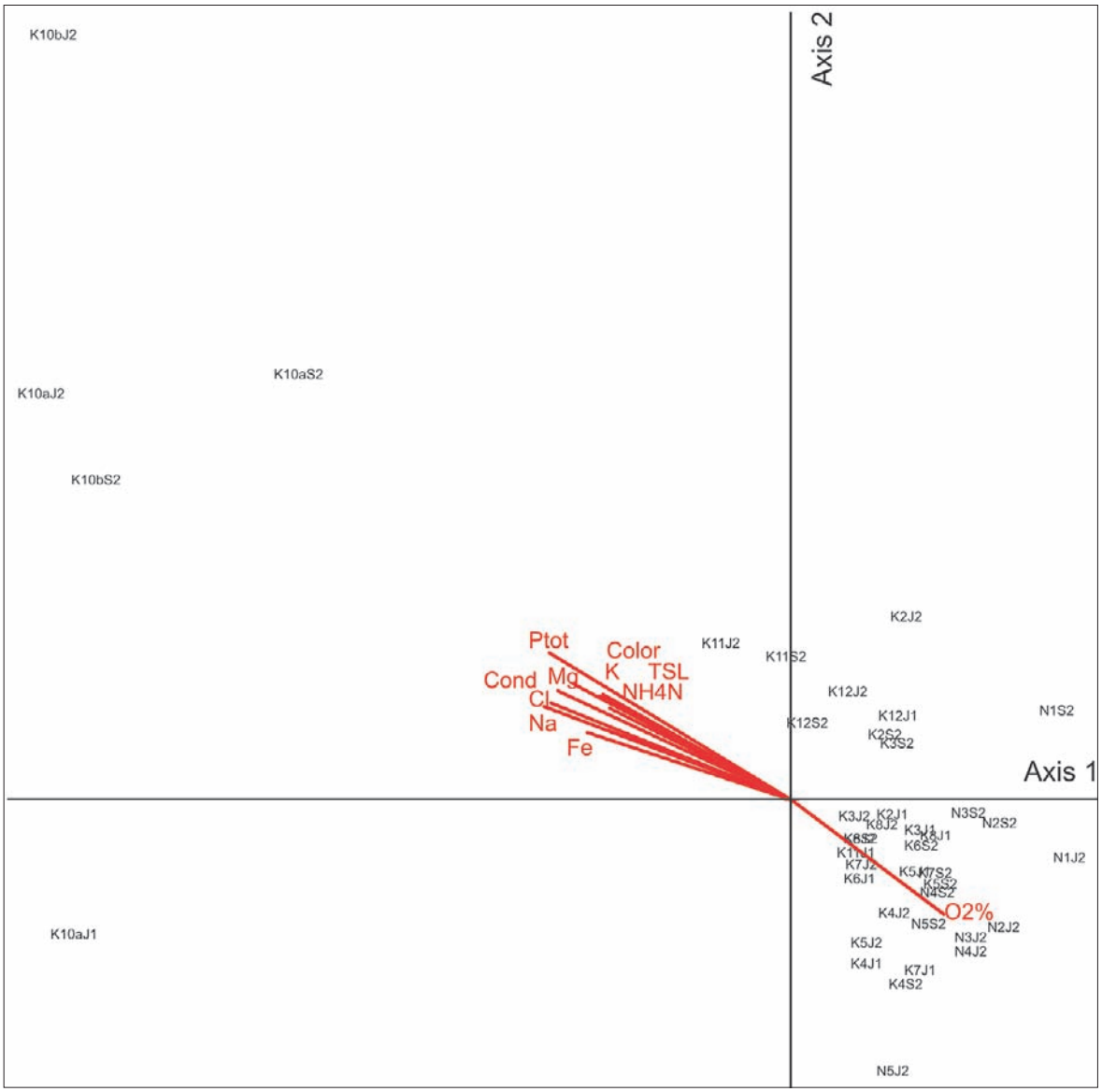

Fig. 39. The CCA ordination diagram of 11 Kola and five Näätämöjoki river sites sampled in July 2001, July 2002, and September 2002. Abbreviations: after the sampling site code J stands for July, S for September, 1 for year 2001 and 2 for year 2002.

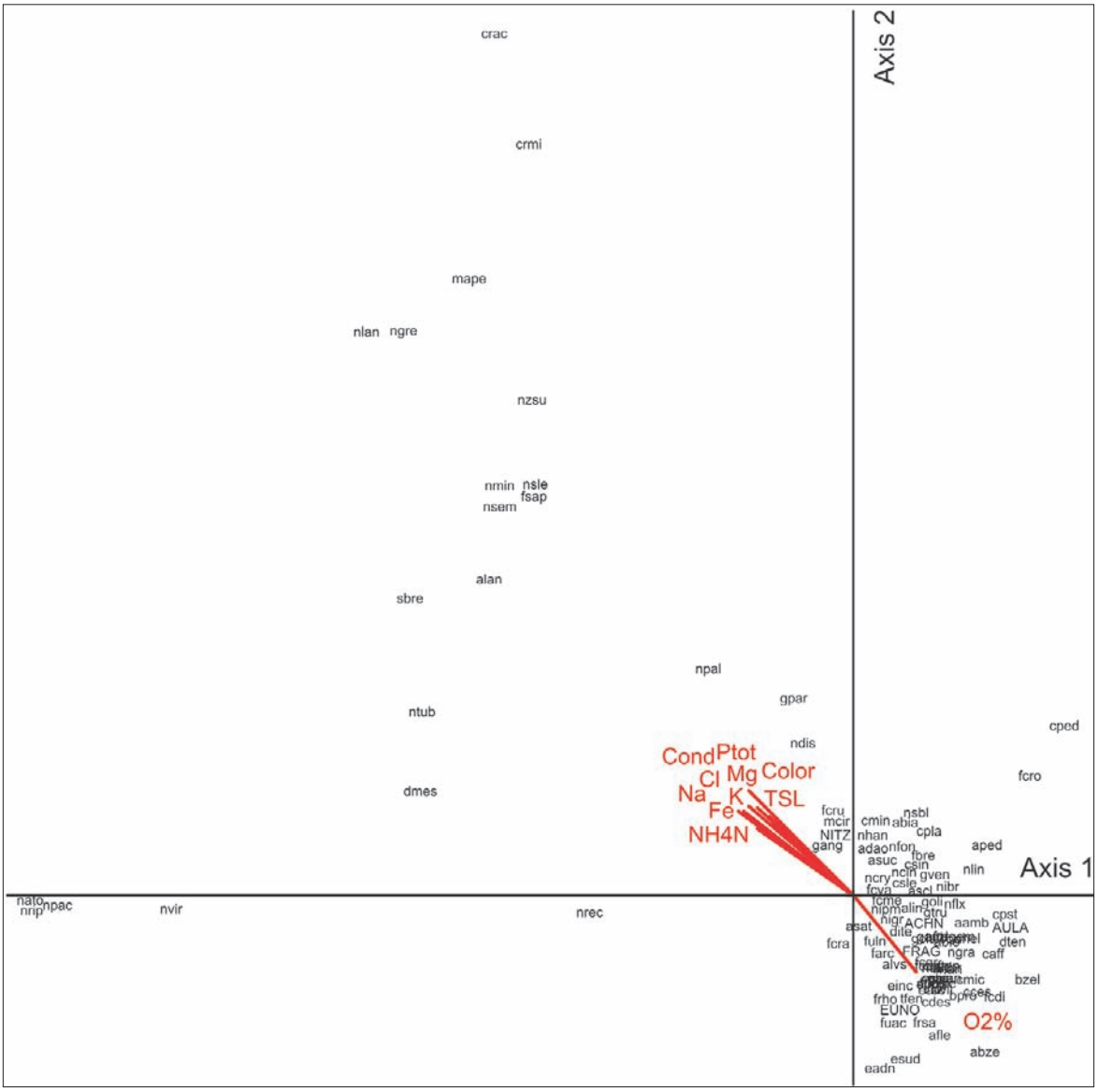

Fig. 40. The CCA ordination diagram of 109 diatom taxa (species with abundance < 1% of the total cells in each sample and *A. minutissima* omitted) occured in the Kola and Näätämöjoki rivers. See Appendix 13 for full names.

Epithemia adnata, Achnanthes flexella, and *Fragilaria capucina var. distans* grouped to the oligotrophic and oxygen-rich direction in the ordination.

When the data was reduced to July 2001 and 2002 sampling occasions, and the small tributaries were excluded, of the data encompassed 101 diatom taxa and 14 sites. The eigenvalues of the first two CCA axes (Fig. 40) were 0.357 (axis 1, p= 0.005) and 0.285 (axis 2, p= 0.045). They explained 25.7% of the total variance in diatom communities. Correlations between diatoms and environmental variables were high (0.994 and 0.977). This CCA solution clearly displays that diatom communities of lake outlets of the Kola River (K2, K3) and lower course main channel sites (K11, K12) differ from those of the other sites. Environmental variables that affect the species distributions the most are seen in Fig. 41. Site K8, downstream from the wastewater treatment plant, grouped towards higher nutrient and electrolyte concentrations when compared to the other sites. Interestingly, K8 sampled in July 2002 grouped close to the site K7 (upstream the WWTP), whereas July 2001 samplings of these sites were clearly separated. This may indicate improved purification effect on wastewaters at site K8, as a result of the constructed wetland. Differences in results however, may be related to slight differences in sampling locations of sites K7 and K8 between 2001 and 2002.

The Näätämöjoki sites plotted towards the most oligotrophic corner of the diagram with the exception of lake outlet site N2, which plotted somewhat closer to the Kola sites. All the mid-section Kola sites located in between the above-mentioned groups (Fig. 42).

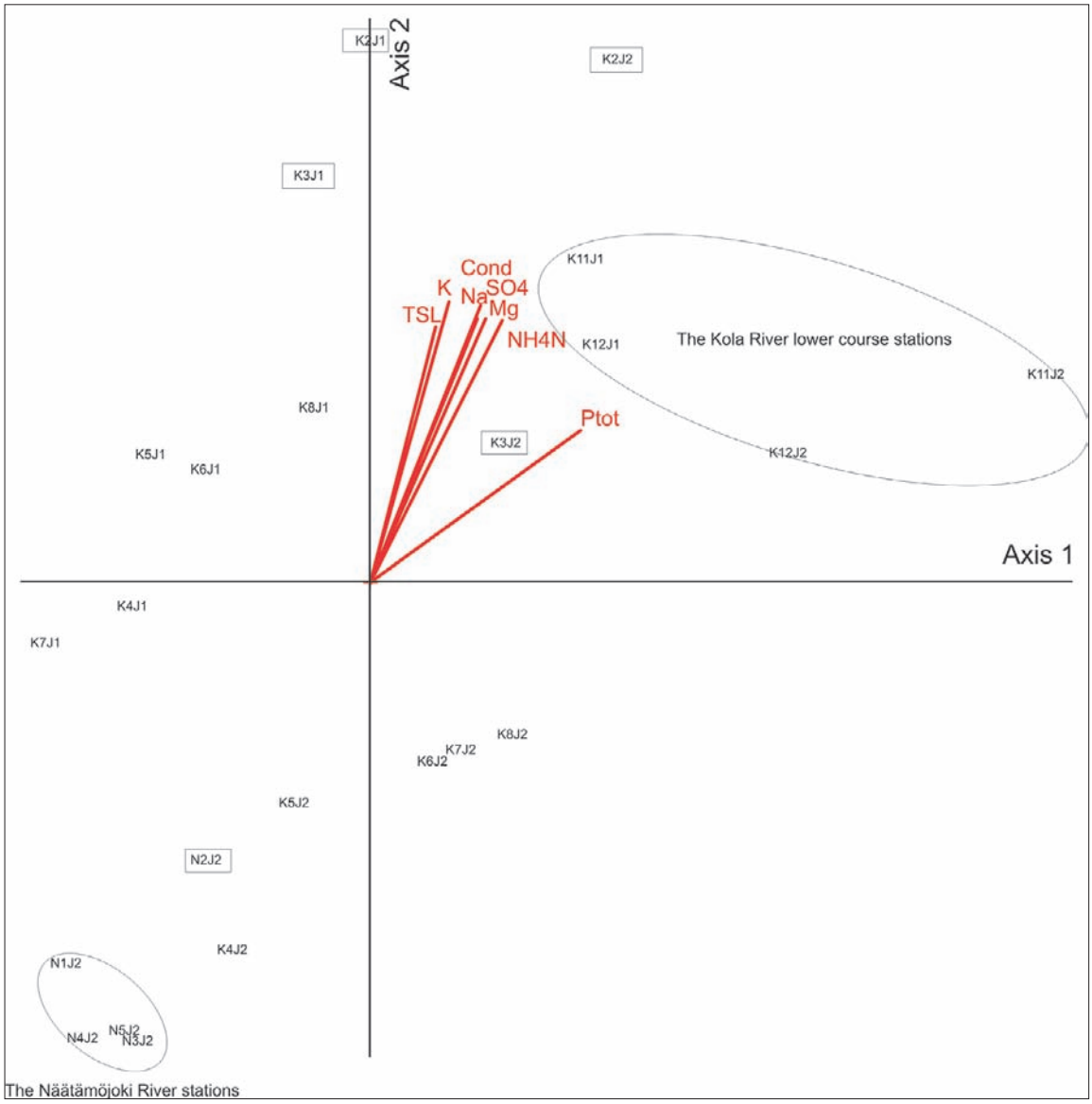

Fig. 41. The CCA ordination diagram of Kola and Näätämöjoki main channel sized sites sampled in July 2001 and July 2002. Abbreviations correspond to those in Fig. 40. Lake outlet sampling sites in boxes.

Further reduction of data resulted in a CCA ordination with 86 diatom taxa sampled in September 2002 (Fig. 42). In this ordination, the eigenvalues were 0.414 (axis 1) and 0.247 (axis 2) with p = 0.005. 34.0% of the total variance in species data was explained with significant (1.000) diatom-environment correlations of the first two axes. Conductivity, Mg, K, and Ca seemed to increase to the direction where the lake outlet sites K2 and K3 were located, whereas the increase of Na, NH_4-N, total P, and SO_4 reflected most clearly in the separate grouping of sites K11 and K12. The Kola mid-section sites grouped to the opposite direction from the lake outlets. Sampling sites of Näätämöjoki slightly separated from the mid-section Kola sites and were located to the opposite direction from the lower course Kola sites.

3.4

Macrophytes

The number of macrophyte species at the river margins varied from 37–67 and within the the channel from 2–10 (Table 19). The total number of observed plant species at the Kola River was 173, of which 168 species were found on the river margins and 34 species within the channel. The number of species was lower at the Näätämöjoki River, where the total number of species was 115, of which 112 species were found at the river margins and 12 species within the channel. The mean number of plant species at the river margins was 53.2 at the Kola River and 55.2 at the Näätämöjoki River, and in the channel the numbers were 6.7 and 3.6 respectively. The total number of species found

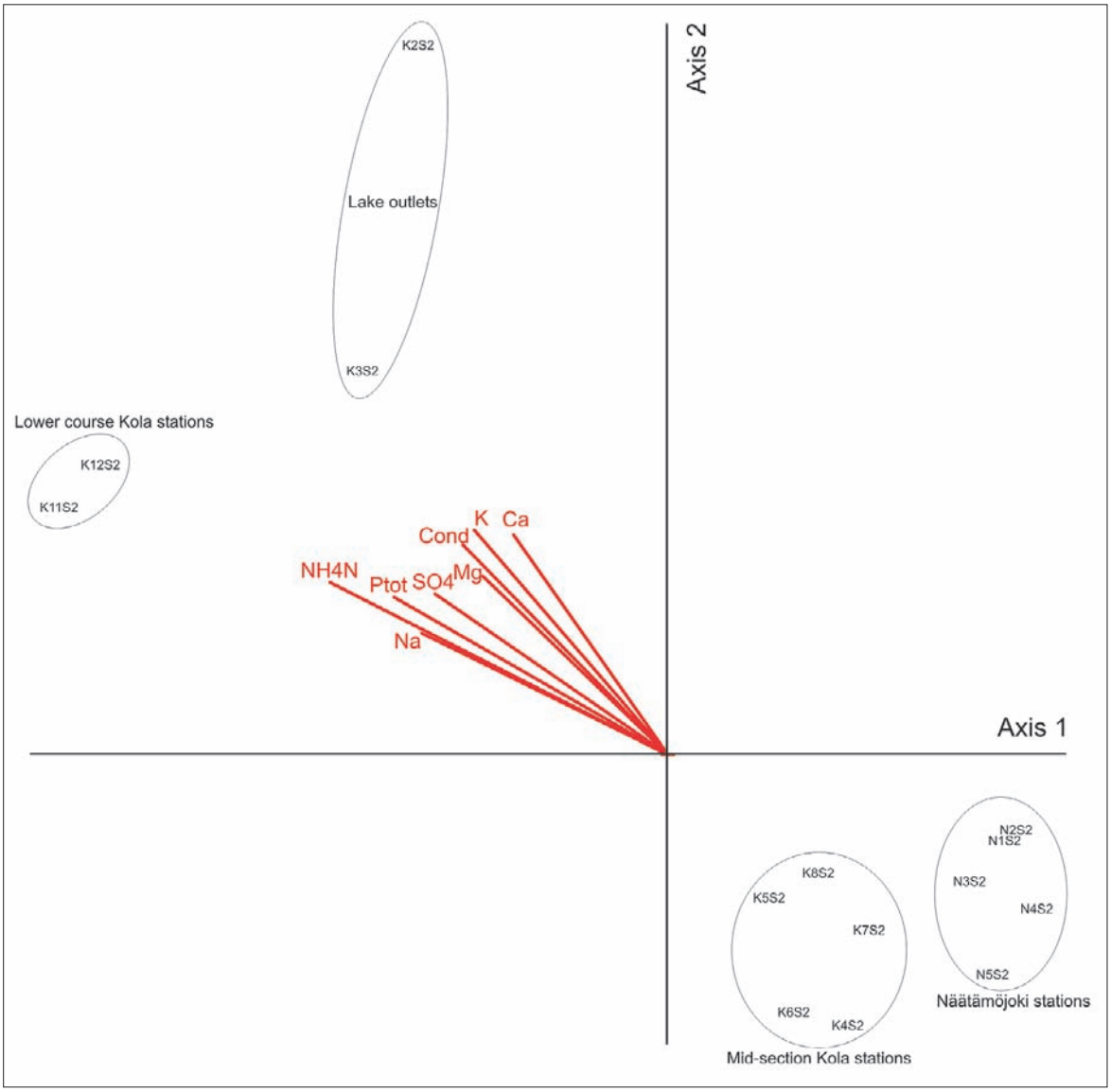

Fig. 42. The CCA ordination diagram of Kola and Näätämöjoki main channel sized sites sampled in September 2002. Abbreviations correspond to those in Fig. 40.

was higher at the Kola River probably due to more sites surveyed. This would also be supported by the fact that the mean number of species per site at river margins was higher at the Näätämöjoki River. Detailed data of the vegetation on the study sites is presented in Appendix 14.

Ecological quality rate calculations including all species resulted in an EQR value for the Kola River above 1 (Fig. 43a). EQR calculations based on typical species (i.e. species occurring at least in half of the reference rivers) also resulted above 1 (Fig. 43b). However, when the analysis was conducted using only aquatic and amphibious species, the ecological quality rate of the Kola River was just above 0.6 (Fig. 44a). Using only typical species, the EQR value was less than 0.6 (Fig. 44b). Using only aquatic species, the ecological status of the Kola River scored also lower than 0.6 (Fig. 45a and 45b).

The Näätämöjoki River was used as one of the reference rivers. EQR values for the Näätämöjoki River in all the calculations were clearly lower than those of the Kola River. Scores of the other rivers used for comparisons in macrophyte survey are presented in figures 43–45.

3.5 Heavy metals in aquatic bryophytes

Metal concentrations in whole shoots of *Fontinalis* from the Kola River (sites K2–K8) and the Näätämöjoki River (site N5) were in general higher than in young terminal shoots (Tables 20–21). Statistically significant (p <0.05) this difference was for As, Ba, Mn and Mo. In the whole length of the Kola River

Table 19.
The number of vascular macrophyte species recorded on 200 m long study sites at the rivers Kola and Näätämöjoki, and sample area corrected species richness.

Site nr	Study site	Number of species: Channel	Number of species: River margins	Species richness: River margins/ $\log_{10}$ area
	The Kola River basin			
K2	Kola Springs	10	46	15.85
K3	Kola River, Taibola village	6	62	17.95
K4	Kitsa River	4	66	21.70
K5	Kola River, Loparskaja	4	63	21.60
K6	Kola River, Magnetity village	2	68	24.11
K7	Kola River, Shongui, upstream WWTP	8	52	14.04
K8	Kola River, Shongui, downstream WWTP	10	46	16.56
K9	Kola River, Vyhodnoy village	10	67	22.68
K11A	Kola River, Molochny village (upper section)	9	46	15.85
K11B	Kola River, Molochny village (lower section)	6	37	13.00
K12	Kola River estuary	11	43	15.33
	The Näätämöjoki River			
N1	Näätämöjoki River, Lake Opukasjärvi inlet	2	47	13.94
N2	Näätämöjoki River, Lake Opukasjärvi outlet	4	59	15.82
N3	Näätämöjoki River, Saunakoski	5	54	18.78
N4	Näätämöjoki River, Kallokoski	2	57	18.78
N5	Näätämöjoki River, Kolttaköngäs	6	65	20.85

Table 20.
Metal concentrations (mg/kg, mean of five replicates) in whole shoots of aquatic bryophyte samples from the Kola River and the Näätämöjoki River (N5). F = *Fontinalis* species H = *Hygrohypnum ochraceum*. The upper value for a sampling station is the concentrations in whole shoots in July 2001, the lower value for that in in July 2002.

Site	Sp.	Al	As	Ba	Cd	Co	Cu	Fe	Mn	Mo	Ni	Pb	Zn
K2	F	354.63 355.36	1.19 1.23	191.54 207.28	0.29 0.29	2.52 3.53	42.41 41.44	970.24 1109.67	8861.22 9954.07	1.50 2.90	56.77 92.40	1.25 1.06	37.64 49.69
K3	F	1079.55 282.40	1.40 0.21	206.25 29.63	0.89 0.14	8.42 0.86	32.83 14.10	3222.31 712.06	8563.60 869.89	2.15 0.63	69.78 13.81	1.95 0.57	73.79 38.43
K5	F	757.17 -	0.77 -	86.91 -	0.58 -	7.67 -	18.23 -	2801.04 -	2975.63 -	0.42 -	43.10 -	1.35 -	60.77 -
K6	F	909.30 -	0.82 -	86.36 -	0.34 -	6.54 -	17.22 -	3084.70 -	2548.70 -	0.42 -	37.20 -	1.42 -	52.06 -
K8	F	- 1500.11	- 0.65	- 85.75	- 0.40	- 8.38	- 22.04	- 4694.10	- 2698.63	- 0.73	- 32.08	- 3.18	- 54.02
K10a	H	7059.14 5322.34	1.62 1.05	509.25 296.64	0.75 0.56	58.30 36.73	22.05 21.34	16039.76 16073.80	15984.05 7575.80	0.85 0.68	55.61 45.46	3.89 4.55	158.14 169.46
K11	H	1 897.83 3238.60	0.55 0.99	106.15 156.06	0.43 0.70	9.50 18.40	22.43 29.41	6068.13 8475.47	3665.30 6208.70	0.76 0.90	26.03 59.70	3.82 6.51	73.17 129.26
K12	H	3607.44 4822.91	0.96 1.12	159.55 147.46	0.78 0.95	24.00 17.82	32.83 34.04	7495.38 11023.64	7036.27 5547.02	0.95 0.87	61.54 75.38	4.61 6.67	135.63 130.29
N5	F	- 2466.74	- 1.16	- 128.47	- 1.30	- 30.74	- 20.10	- 7518.54	- 7574.02	- 1.17	- 42.70	- 2.80	- 113.24

Table 21.
Metal concentrations (mg/kg, mean of five replicates) in terminal tips of aquatic bryophyte samples from the Kola River and the Näätämöjoki River (N5) in July 2002. F = *Fontinalis* species.

Site	Sp.	Al	As	Ba	Cd	Co	Cu	Fe	Mn	Mo	Ni	Pb	Zn
K2	F	124.47	0.33	44.12	0.30	0.64	25.82	386.41	1740.99	0.74	27.15	0.73	28.50
K3	F	229.61	0.10	25.13	0.15	0.68	15.18	347.40	567.81	0.32	15.56	0.65	20.97
K8	F	917.26	0.22	51.10	0.29	3.26	18.36	2048.78	1042.74	0.45	18.54	1.35	40.02
N5	F	632.10	0.15	28.29	0.35	4.47	14.15	1428.18	1014.76	0.48	13.94	0.83	58.55

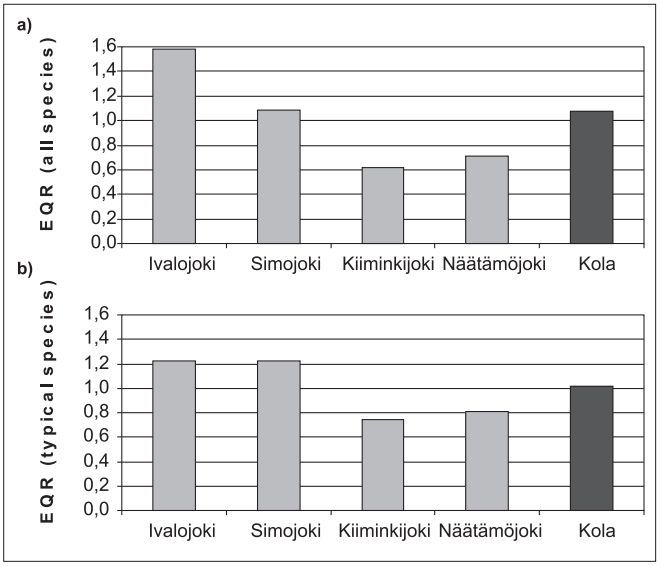

Fig. 43. The ecological quality rates (EQR) of the Kola River and the reference rivers based on (a) all macrophyte species and (b) with typical macrophyte species.

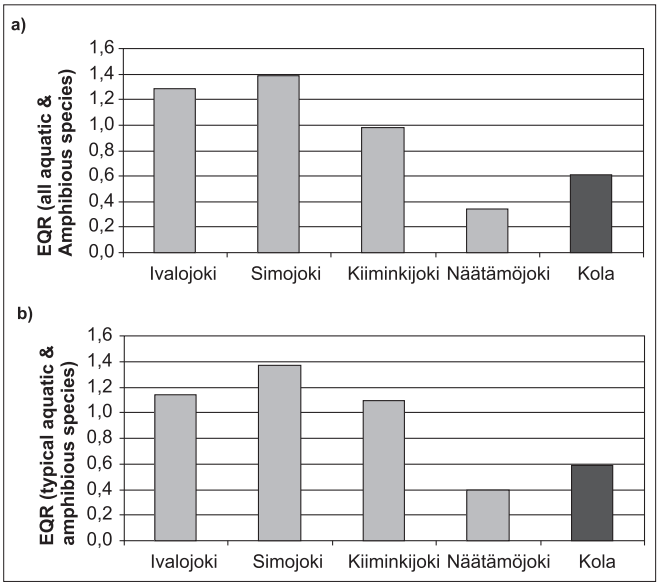

Fig. 44. The ecological quality rates (EQR) of the Kola River and the reference rivers based on (a) all aquatic and amphibious species and (b) typical aquatic and amphibious species.

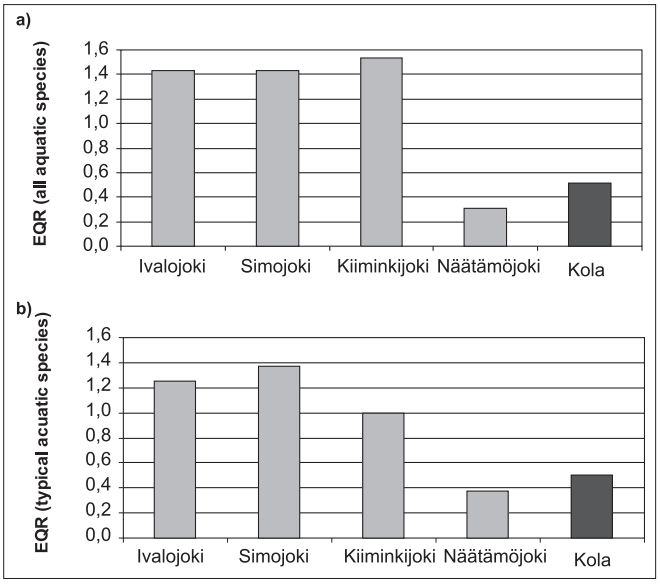

Fig. 45. Ecological quality rates (EQR) of the Kola River and the reference rivers based on (a) all aquatic species and (b) typical aquatic species.

there were no significant differences between metal concentrations (whole moss shoots) between 2001 and 2002 (p <0.05).

Spatial variations in average concentrations (n=10 for K2, K3, K10b, K11, K12, n=5 for K5, K6, K8) of Al, Cd, Co, Fe, Pb and Zn in bryophytes along the Kola River showed a clear increase downstream, with highest values in the lower part of the basin (K11–K12) (Table 20, Figure 43). Levels of As, Ba, Cu, Mn, Mo and Ni decreased notably from K2 to K3, were fairly constant throughout the middle reaches (K5–K8), but increased again in the lower course (K11–K12). Bryophytes and water of the tributary site K10a (Varlamov Creek) showed clear metal concentration peaks in Al, As, Ba, Co, Fe, Mn and Zn. Suspended Cu concentration and both, suspended and dissolved Ni and Pb concentrations in water of K10a were also elevated from those of the other sampling sites. Samples of site K6 from July 2002 were discarded due to possible contamination during sampling.

All the investigated metal concentrations showed similar patterns and good correlation between aquatic bryophytes and water throughout the water course, except for site K12 (Fig. 46). Significant positive correlations were found between concentrations of elements in water and in bryophytes. The concentrations of As (R^2=0.83, p<0.05) and Cu (R^2=0.72, p<0.05) in the aquatic bryophytes in the Kola River reflected mostly the dissolved phase

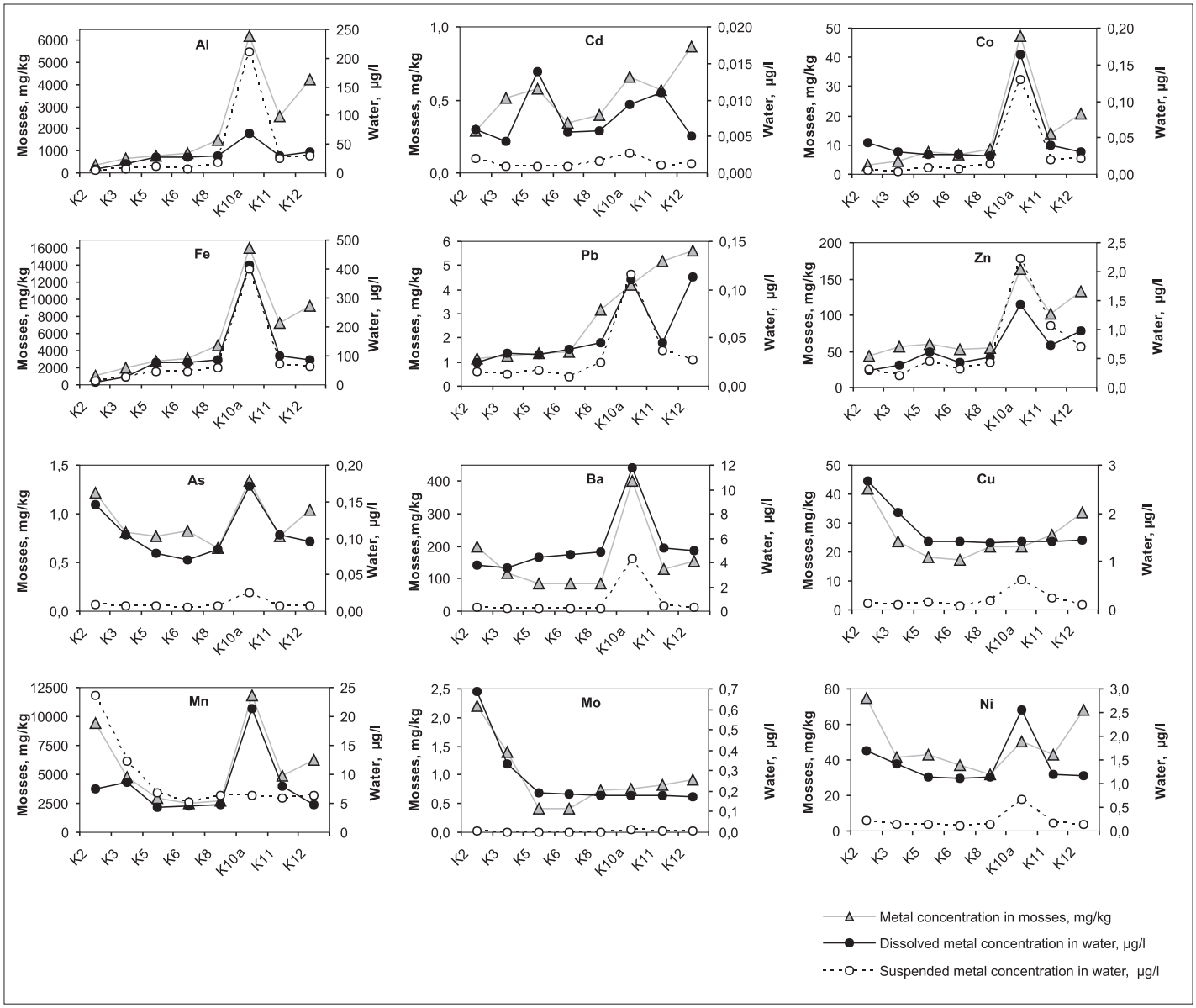

Fig. 46 Mean (n=5–10 for each sampling site, July 2001 and July 2002) metal concentrations in whole shoots of *Fontinalis* species (K2–K8) and *Hygrohypnum ochraceum* (K10a–K12) (left Y-axis) in comparison with mean (n=5 for each sampling site, July 2001–July 2002) dissolved (<0.22 µm) and suspended (>0.22 µm) metal concentrations in the Kola River water (right Y-axis).

Fig. 47. The survey site K2 (The Kola Springs) at the Kola River attained the best Habitat Quality Assessment (HQA) score due to extensive forest in the riparian zone and complex flow types. Photo: Tero Väisänen.

Table 22.
The Habitat Modification Score (HMS) and the average Habitat Quality Assessment (HQA) values, and the score values for different factors in HQA in the survey sites at the Kola River, July 2002.

Survey site:	K2	K3	K4	K5	K6	K7	K8	K9	K11A	K11B	K12
HMS	0	0	0	1	0	2	0	0	2	7	4
HQA (average)	61	56	53	40	52	47	40	37	36	47	38
Flow type	12	11	8	7	5	11	5	3	4	11	10
Channel substrate	3	5	4	6	7	3	6	4	3	3	5
Channel feature	3	4	3	3	4	5	4	0	0	3	1
Bank features	0	0	2	4	2	5	2	3	3	1	9
Bank vegetation structure	12	11	12	10	11	12	12	12	12	12	8
Point bars	0	0	0	0	0	0	0	0	0	0	0
Channel vegetation	7	6	8	3	7	6	4	5	4	4	2
Land use	14	9	9	2	9	0	2	2	2	7	0
Trees	10	10	7	5	7	5	5	8	8	6	3
Special features	0	0	0	0	0	0	0	0	0	0	0

of the metal in water, while the concentrations of Ba (R^2=0.63, p<0.1) Co (R^2=0.94, p<0.001) and Mn (R^2=0.83, p<0.01) reflected mainly the suspended phase. Fe, Al, Mo, Ni, Pb and Zn in mosses correlated both with the dissolved and with the suspended phase of these metals in water.

3.6

River Habitat Survey (RHS)

3.6.1

The Kola River

In the Kola River, Habitat Quality Assessment (HQA) average score varied from 36 to 61 (Table 22). The site K2 got the highest HQA score (61) due to the combination of extensive semi-natural woodland along the riparian zone and variable flow types in the channel (Fig. 47). The land use score was high as well, and based mainly on extensive forest along the bank sides. The lowest HQA score (36) was observed in the site K11A because there was no forest on the left bank and the flow types in the river channel are monotonous. Rather heavy man-made modification, especially on the left bank side, lowered the average HQA score in K11A as well. Based on HQA scores of the Kola River, the river can be divided into two parts. The first part comprises sites at the upper course of the river (K2–K7), and the second part sites at the lower course (K8–K12). The HQA scores were higher in the upper part of the river with the exception of

site K11B where the complexity of flow types and the extensive forest on the right bank side caused a high score (HQA =47).

Human modifications were almost absent at the upper half of the survey sites. The Habitat Modification Score (HMS) varied between 0 and 7 (Table 22). In the most modified survey sites, K11B and K12, there were reinforced riverbanks with human settlements, roads or a railway. Human settlement was not extensive along the riparian zone at other sites than K12 (the Kola River estuary).

HMS categories describe the physical state of a river channel in river habitat survey sites. Survey sites with a pristine channel and no artificial modification score zero in the HMS. Semi-natural channels do not score higher than two, while more modified channels attain scores of at least three (Raven et al. 1998a). Most of the survey sites at the Kola River were classified as pristine or semi-natural. Only two sites, K11B and K12, were classified as predominantly unmodified (Table 23).

Table 23.
Human modification scores (HMS) at the Kola River, July 2002 (Raven et al. 1998b, modified by the author).

HMS	State of the Channel	Number of sites at the Kola River
0	Pristine	6
1–2	Semi-natural	3
3–8	Predominantly unmodified	2
9–20	Obviously modified	-
21–44	Significantly modified	-
> 45	Severely modified	-

3.6.2

The Näätämöjoki River

The average Habitat Quality Assessment (HQA) score in the Näätämöjoki River varied between 40 and 54 (Table 24). At all survey sites, there were continuous or semi-continuous, extensive forests along the riparian zone. Human influence on the channel or on the riparian zone was very modest (Fig. 48). The site N1 scored lowest (40), while the site N3 scored highest (54). Compared to the other sites, N3 achieved notably higher scores due to stable and eroding cliffs and extensive woodland along the the right bank side.

In the Habitat Modification Scores (HMS), there was only little variation between the sites (Tables 24 and 25). Man-made modification on the channel was very modest along the whole river. The Näätämöjoki River flows mostly far away from continuous human disturbance, except for a few wilderness cabins on the shore. Near the site N5, there was a bridge and a road close to the river. There was also a small path on the left bank of the river, so the riverbank was slightly trampled.

3.6.3

Comparing the Kola River and the Näätämöjoki River

The RHS results differed slightly between the rivers. Generally the hydromorphological state of the Kola River was somewhat lower than that of the Näätämöjoki River. The average HQA scores in the Kola River decreased markedly downstream of the site K7. Flow type sores varied considerably among sites of the Kola River. Possible reasons

Table 24.
The HMS and the average HQA values, and score values for different factors in HQA in the survey sites at the Näätämöjoki River, July 2002.

Survey site:	N1	N2	N3	N4	N5
HMS	1	1	1	2	0
HQA (average)	40	46	54	48	52
Flow type	10	11	11	12	13
Channel substrate	3	5	5	5	4
Channel feature	3	3	3	5	3
Bank features	0	0	6	1	1
Bank vegetation structure	7	10	8	6	11
Point bars	0	0	0	0	0
Channel vegetation	5	4	4	7	7
Land use	4	4	9	4	4
Trees	8	9	8	8	9
Special features	0	0	0	0	0

Table 25.
Human modification scores (HMS) at the Näätämöjoki River, July 2002 (Raven et al. 1998b, modified by the author).

HMS	State of the Channel	Number of sites at the Näätämöjoki River
0	Pristine	1
1–2	Semi-natural	4
3–8	Predominantly unmodified	-
9–20	Obviously modified	-
21–44	Significantly modified	-
>45	Severely modified	-

for the variability of the scores include high water level, the subjectivity of the survey method and absence of moss shoots. In the Näätämöjoki River, the flow type scores were rather uniform and generally higher than those of the Kola River.

The Kola River achieved maximum scores for bank vegetation structure category at most of the sites, whereas Näätämöjoki River scores were considerably lower. An explanation for these differences might be the bareness and rockiness of the bank faces of the Näätämöjoki River. In the land use category, there was also large variation between the sites, especially in the Kola River. According to Raven et al. (1998a; 1998b), the category relays only on following vegetation types: broadleaf woodland, wetland, and moorland. Therefore, any other vegetation types do not get any points, despite the fact that there are several other options available in the RHS form (Appendix 2). The variations in the scores of the land use category were caused by the differences in extensity of the woodland because any of the two other scoring vegetation types were neither present in the survey sites of the Kola River, nor in those of the Näätämöjoki River. On the sites with high score in the land use category, extensive woodland along the bank sides was the only land use form. Low score in the land use category was generally a result of low levels or absence of forest in the riparian zone.

Some differences between the rivers were noticeable in the tree category as well. The category consists of two variables: trees and associates features (Raven et al. 1998a). The extent of trees constitutes less than a half of the category points. The rest of the points come from the associated features, such as the shading of the channel, overhanging boughs, exposed tree roots, fallen trees and coarse woody debris (Environment Agency 1997). On the sites where the score was low, the extent of trees was less than semi-continuous, at least on the other bank side, and no associated features were present. At the Näätämöjoki River, continuous forest on the bank sides resulted in good scores. At the Kola River, where forest was absent in some sites, scores were lower.

There were no remarkable differences in the HMS scores between the rivers. For the Kola River, the sites K11B and K12 got the highest scores because there were distinct traces of man-made modifications in the channel. Trampling of the bank side was the main reason for all sites that scored one or two. The HMS score represented mostly pristine or semi-pristine situation in both rivers. The only exceptions were the sites K11B and K12 in the

Fig. 48. The survey site N3 (Saunakoski) at the Näätämöjoki River got a high Habitat Quality Assessment (HQA) score due to stable and eroding cliffs and extensive woodland on the bank sides. Photo: Tero Väisänen.

Kola River, which were predominantly modified. In the other categories, the scores were more or less uniform between the rivers and differences were negligible.

3.7

Bacterioplankton

Total amount of bacteria in the Lake Kolozero (K1) during the observation period ranged from 1.69–1.98 million cells/ml, from which 2.0–2.2 thous. cells/ml represented saprophyte bacteria (Fig. 49 and 50). Bacteria densities peaked in July, during period of water's maximum temperature. Based on bacterioplankton the Lake Kolozero is considered moderately polluted.

In the main stem of the Kola River total amount of bacteria fluctuated from 1.07 to 1.72 million cells/ml, being lowest in sites K3 and K5, highest in the lower part of the basin (Fig. 49). The amount of saprophyte bacteria varied between 0.2 and 2.0 thous.cells/ml (Fig. 50). The lowest amount of saprophyte bacteria was observed in sites K3 and K5, whereas the highest in the lower river section, K11–K12.

In the Kitsa Creek estuary (K4) the amount of bacteria varied from 1.02 to 1.15 million cells/ml. The low amount of saprophyte bacteria (0.1–0.6 thous.cell/ml) indicates absence of wastewater discharges. Bacteria densities peaked during maximum temperature of water. Based on bacterioplankton the Kitsa Creek waters are clean.

The maximum density of bacteria in the Kola River basin, 2.78 million cells/ml, was observed in September 2002 in the Medvegiy Creek (K10b), flowing into the lower section of the Kola River. The Creeks Medvegiy (K10b) and Zemlanoy (K10c) in Molocny village bring organically polluted wastewaters from poultry farms. In the Varlamov Creek (K10a) the amount of bacteria exceeded 1.99–2.38 million cells/ml, also reflecting organic pollution from agricultural enterprises.

Minor amounts of oil-oxidizing bacteria (up to 100 cells/ml) were observed at Kola springs (K2), nearby the villages of Shongui (K7–K8) and Molochny (K11), and in the Varlamov Creek (K10a). In general, contamination with oil products is not typical in the Kola River basin. Phenol-oxidizing bacteria up to 100 cells/ml were observed in the river sections nearby the village of Molochny (K11) and in the Varlamov Creek (K10a), which indicates presence of phenol compounds in the industrial discharges.

In the Näätämöjoki River total amount of bacteria varied from 0.55 to 0.61 million cells/ml. Saprophyte bacteria reached densities of 0.1–0.2 thous. cells/ml and there were no oil-oxidizing or phenol-oxidizing bacteria. As can be seen on figures 51 and 52, the level of bacteria development in the Kola River was higher than in the Näätämöjoki River reference sites. Based total amount of bacterioplankton, the waters of the Kola River can be characterized as moderately polluted whereas the Näätämöjoki River is clean. Amount of saprophyte bacteria however reflects clean water quality in both rivers, except the small tributaries Medvegiy

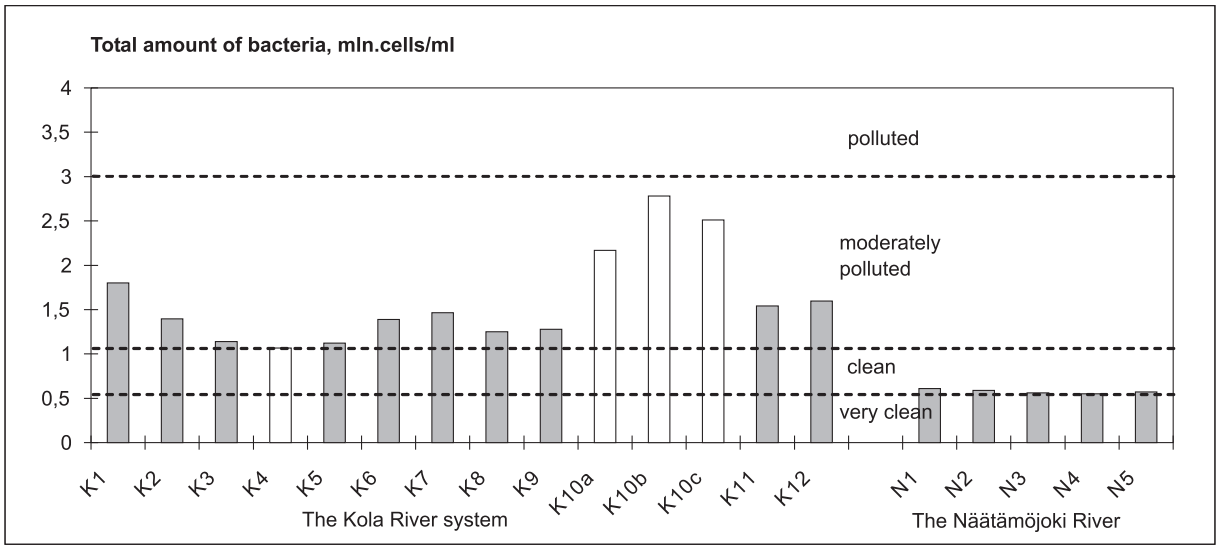

Fig. 49. Total amount of bacteria and water quality classification (Abakumov 1992) in the Kola River system and the Näätämöjoki River. (Average of July 2001, July 2002 and September 2002, n = 1–3 per sampling site).

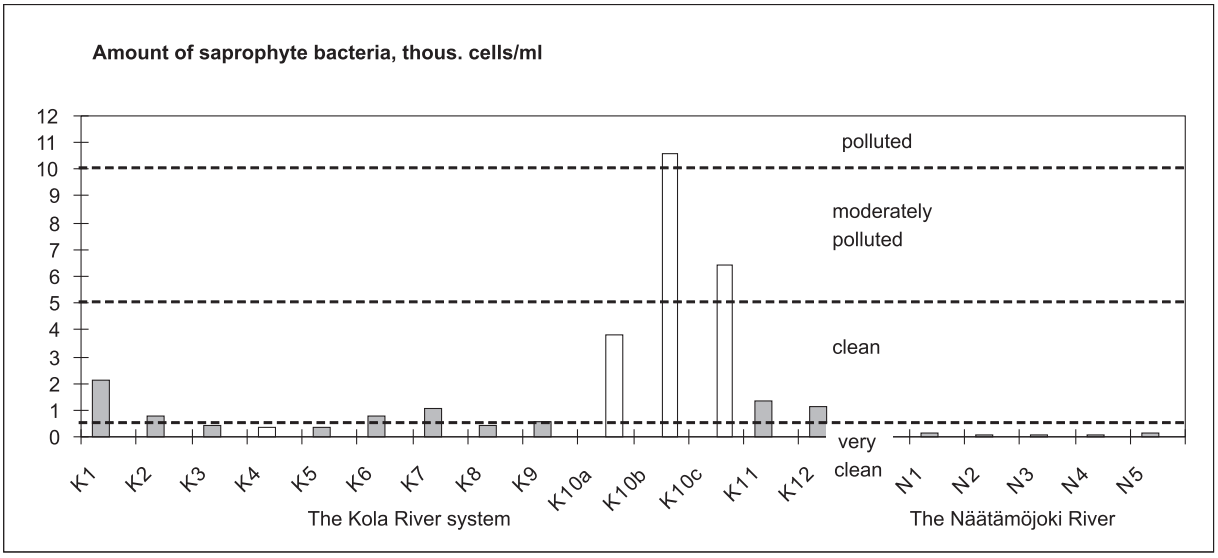

Fig. 50. Amount of saprophyte bacteria and water quality classification (Abakumov 1992) in the Kola River system and the Näätämöjoki River. (Average of July 2001, July 2002 and September 2002, n = 1–3 per sampling site).

(K10b) and Zemlanoy (K10c) of the Kola River, which can be classified as moderately polluted.

3.8

Phytoplankton

Phytoplankton samples of the Kola River in the year 2001 comprised 105 algae species and in the year 2002 – 101 species. In the samples from the Näätämöjoki River, 121 species were identified (Table 26). Detailed species lists with Panthle and Buck saprobic index values and classifications of saprobic zones based on Sládeček list of indicator organisms are presented in Appendices 15 and 16. Quantitave parameters of phytoplankton of sites included in the continuous monitoring program of the Murmansk Areal Department for Hydrometeorology and Environmental Monitoring (K1, K2, K4, K9, K12) are presented in Appendix 17.

Sampling site K1 is located in the Lake Kolozero and therefore its phytocenosis differs from those of all the other sampling sites along the Kola River basin. Phytoplankton in the Lake Kolozero (K1) revealed a wide range of species with high quantitative parameters (Fig. 51, Appendix 17). Based on mass species, the lake is characterized as follows: mixed diatom species (*Bacillariophyta*) with domination of *Fragilaria crotonensis*, *Diatoma elongatum*, *Synedra berolinensis*, eutrophic blue-green algae (*Cyanophyceae*) with domination of *Oscillatoria limosa* and *Aphanothece clathrata*, eutrophic *Chlorococcales* with dominating species from such genera as *Chlorococcum*, *Scenedesmus*, *Ankistrodesmus* and *Dictyosphaerium*. Saprobity index scores by Panthle and Buck in site K1 ranged from 1,65–1,78 which indicates moderately polluted water quality (Fig. 52).

Table 26.
Species structure of phytoplankton in the Kola River in years 2001 and 2002 and the Näätämöjoki River in year 2002.

Group/ Number of species	The Kola River, 2001	The Kola River, 2002	The Näätämöjoki River, 2002
Cyanophyta	13	15	23
Chrysophyta	9	12	10
Bacillariophyta	42	31	40
Xanthophyta	-	-	1
Pyrrophyta	5	6	8
Euglenophyta	4	7	3
Chlorophyta	32	30	36

In the whole length of the Kola River main stem, *Bacillariophyta* was dominating. Diatom species of such genera as *Melosira*, *Tabellaria*, *Asterionella*, *Fragilaria* and *Synedra* were also common. Most of these forementioned species are indicators of o-β-saprobe zone. Saprobity index in the Kola River varied between 1,39 and 1,83, reflecting clean or moderately polluted water quality (Fig. 52). Compared to the Näätämöjoki River, the genus *Euglenophyta*, which mostly indicates water pollution by organic substances, was wider presented in the Kola River.

In the Kitsa Creek (K4) diatoms dominate the community, and indicator species of clean water are found. The Saprobity index value (1.27–1.48) for K4 also indicates clean water quality. Varlamov

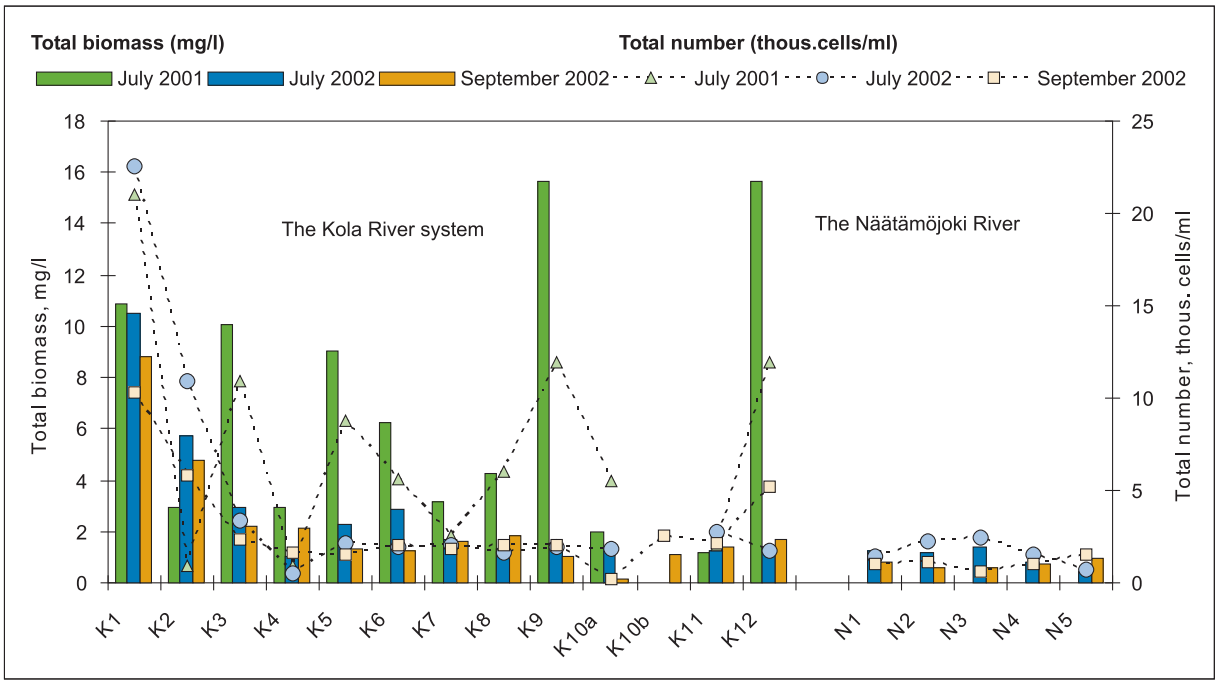

Fig. 51. Quantitative parameters of phytoplankton in the Kola River system and the Näätämöjoki River.

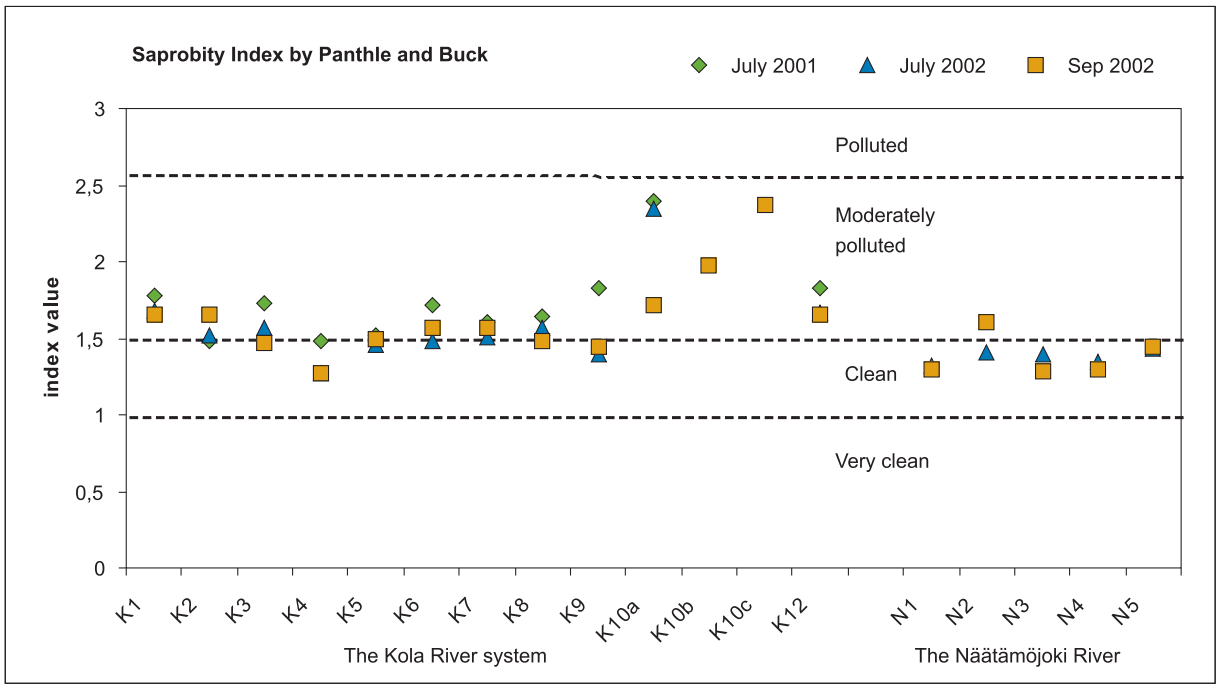

Fig. 52. Water quality according to values of Saprobity Index by Panthle and Buck (Sládeček 1973) for phytoplankton in the Kola River system and the Näätämöjoki River.

Creek (K10a) and Medvegiy Creek (K10b) instead suffer from organic contamination, which result in saprobity index values (1.72–2.40) typical for moderately polluted waters. The phytoplankton community of creeks Varlamov (K10a), Medvegiy (K10b) and Zemlanoy (K10c) is characterized by low quantitative values (Fig. 51) and increased abundance of β-α saprobity indicators. Dominating species (*Oscillatoria tenuis*, *Euglena proxima* and *Ankistrodesmus falcatus*) of *Cyanophyta*, *Euglenophyta* and *Chlorophyta*, indicate pollution of waters.

Phytoplankton abundance in the Näätämöjoki River is lower than at the Kola River (Fig. 51), which can be explained by the oligotrophic conditions of the river water. The number of species was rather high (24–42 species per sample). The *Chlorophyta* group with genus *Cosmarium*, *Staurastum* and *Pediastrum* is widely represented in the

Näätämöjoki River. The most common group in all sampling sites of Näätämöjoki was *Bacillariophyta* with indicator species of clean water such as *Tabellaria* genus: *Tabellaria flocculosa, Tabellaria fenestra v. intermedia, Cyclotella comta* and *Melosira distans*. The *Chrysophyta* was dominated by *Dinobrion sertulari* and *Dinobrion stipitatum*. The most abundant *Pyrrophyta* genus was *Peridinium*. The *Cyanophyta* were more diverse at Näätämöjoki River (23 species) than in the Kola River (15 species).

The saprobity analysis of phytoplankton species composition, based on the Sládeček list of indicator organisms (Kozina 1977) revealed 42 indicators of clean water in the Näätämöjoki River and 37 in the Kola River. Phytoplankton of the Kola River is represented by 28 β, α-mesosaprobes, and that of the River Naatamojoki by 17. In general, saprobity indices based on phytoplankton classifies the Kola River as moderately polluted (class II–III) and the Näätämöjoki River as clean (class II) (Fig. 52, see also Table 7) .

3.8.1 CCA

Phytoplankton data from 15 sites sampled in July 2002 and 16 sites sampled in September 2002 was used in Canonical Correspondence Analysis. Data included 141 species after elimination of insignificant data (only one observation of species and small biomass compared to total biomass in sampling occasion). The eigenvalues of CCA axes were 0.803 (axis 1, p=0.0380), 0.542 (axis 2, p=0.0080) and 0.436 (axis 3, p= 0.01) (Table 27). They explained 31.9% of the total variance in phytoplankton biomass. The Pearson correlations for all CCA axes indicated strong correlation between phytoplankton and environmental variables. The CCA ordination with axis 1 and axis 2 didn't indicate very clear differences between sampling sites (except for sites K10a and K10b), but results with axis 1 and axis 3 (Fig. 53) were clearer.

When the small tributaries Varlamov (K10a) and Medvegiy (K10b) were separated from other sites in CCA ordination the result was resembled that for the diatom data (see chapter 4.3.3.2). Lake outlets (K2 and K3) in the upper Kola River grouped together and apart from other sites, indicating higher nutrient concentrations than in other parts of the main channels of the rivers Kola and Näätämöjoki. This concurred the results of CCA analysis on benthic diatoms and macroinvertebrates from main channel samples of July 2001 and 2002. However, unlike the CCA for diatoms and macroinvertebrates the CCA analysis of phytoplankton did not separate the lowest main channel stations K11 and K12 (see chapters 4.1.2.2. and 4.3.3.2). In the CCA of phytoplankton lake outlets K2 and K3 showed remarkably higher associations with SO_4 concentrations than other sampling sites. The Kitsa tributary (K4) was grouped to the most oligotrophic and SO_4 poor corner together with the Näätämöjoki River (N2, N3, N4 and N5). Also other Kola River mid-section sites grouped close to the Näätämöjoki River sites, but not as strongly as the Kitsa River.

Table 27.
Axis summary for CCA ordination of phytoplankton data (total variance ("inertia") in the species data: 5.5865)

Axis	1	2	3
Eigenvalue	0.803	0.542	0.436
Variance in species data (% explained)	14.4	9.7	7.8
Cumulative variance (%) in species data	4.4	24.1	31.9
Pearson Correlation, species – env.variables	0.992	0.988	0.966

The sabrobe index for phytoplankton (Fig. 52) displayed largely the same ecological information about the Kola River than the CCA analyses. The Näätämöjoki River and the Kitsa River seemed to have very good water quality and tributaries Varlamov and Medvegiy quite poor water quality. However, the sabrobe index did not separate lake outlets K2 and K3.

The most significant environmental variables in CCA analysis of phytoplankton were NH_4N, SO_4, conductivity, total P, K and Fe (Table 28). For diatoms the most significant environmental variables were total P, conductivity, Na, Cl, Mg and O_2 (see chapter 4.3.3.2).

3.9 Zooplankton

Zooplankton samples of the Lake Kolozero (K1) included 27 species in the year 2001 and 23 species in the year 2002. Plankton species structure of K1 is presented in the Table 29.

Total amount of zooplankton organisms of K1 in the year 2001 reached 31–271 thous. ind./ m^3 and in the year 2002 0.19–601 thous. ind./m^3. Total biomass varied in the year 2001 from 169 up to 6866 mg/m^3 and in the year 2002 from 7 up to 5630 mg/m^3. Maximum abundance and biomass were observed in July (Appendix 18). Species with wide environmental resistance to pollution were dominant: *Bosmina obtusirostris*, *Keratella cochlearis*, *Asplanchna priodonta*. β-saprobe *Bosmina obtusiros-*

Table 28.
Correlations and Biplot Scores (arrow lengths) for 14 environmental variables used in CCA analysis of phytoplankton data.

Variable	Correlations			Biplot Scores		
	Axis 1	Axis 2	Axis 3	Axis 1	Axis 2	Axis 3
Ca	0.381	-0.091	0.517	0.341	-0.067	0.342
Cl	0.501	-0.432	0.604	0.449	-0.318	0.399
Color	0.427	-0.349	0.246	0.383	-0.257	0.163
Conductivity	0.637	-0.270	0.641	0.571	-0.199	0.424
Fe	0.507	-0.429	-0.614	0.455	-0.316	-0.405
K	0.598	-0.125	0.733	0.536	-0.092	0.484
Mg	0.491	-0.208	0.661	0.440	-0.153	0.437
Na	0.519	-0.657	0.388	0.465	-0.484	0.256
NH_4N	0.886	0.119	0.197	0.794	0.088	0.130
O_2%	-0.490	0.492	0.005	-0.439	0.363	0.003
Ptot	0.595	-0.664	0.242	0.533	-0.489	0.160
SO_4	0.087	-0.119	0.832	0.078	-0.088	0.550
TSL	0.562	-0.246	0.254	0.504	-0.181	0.168
pH	0.523	0.175	0.180	0.469	0.129	0.119

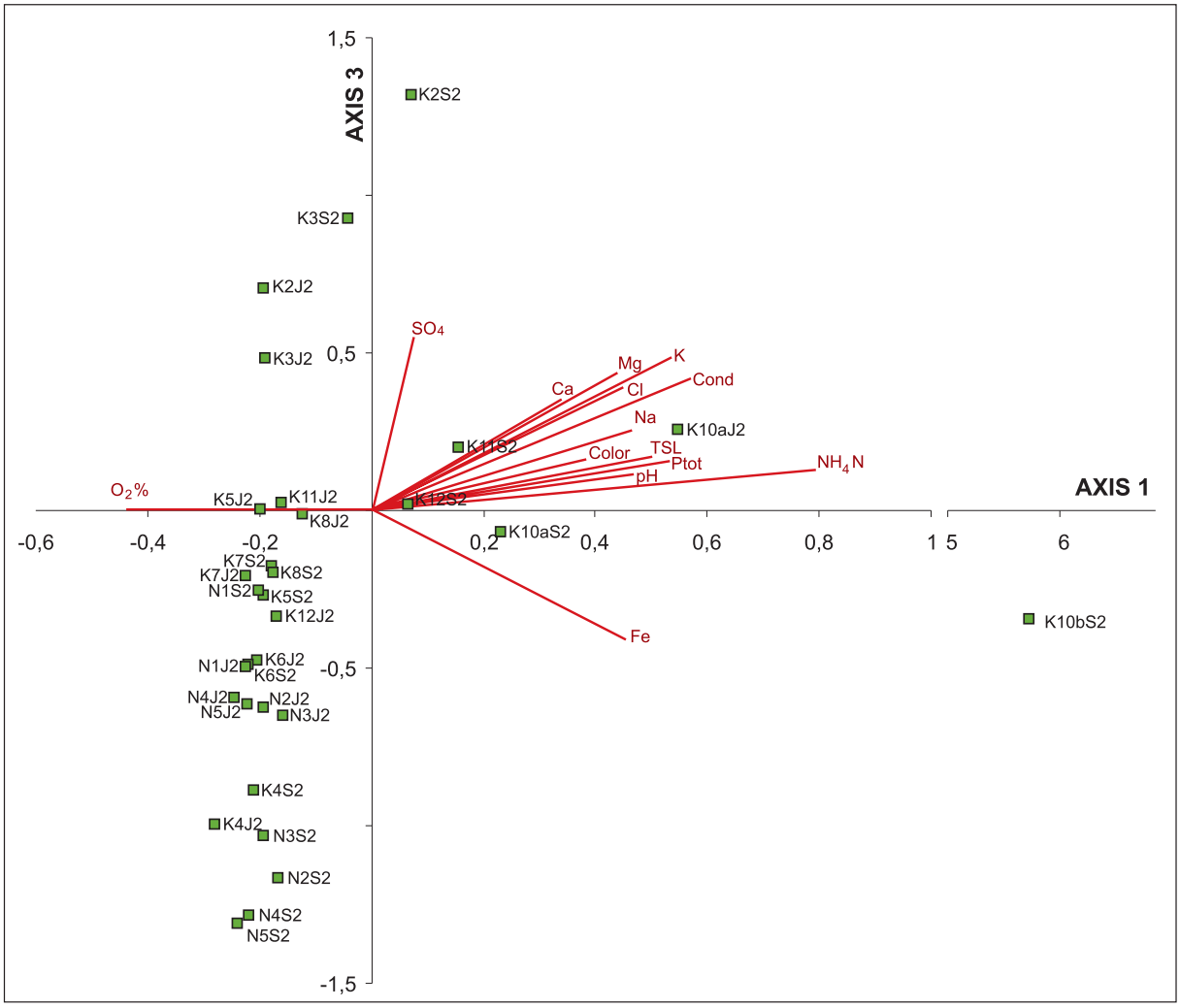

Fig. 53. The CCA ordination diagram of the phytoplankton data from Kola River and The Näätämöjoki River sites sampled in July 2002 and September 2002. Sampling sites are coded like in figures 1 and 15, J stands for July and S for September, 2 for year 2002.

tris presented 60–80% of all zooplankton in K1. Saprobity index for site K1 was 1.76 – 2.00, which reflects moderately polluted water quality.

In the Kola River the zooplankton comprised 40 species in year 2001 and 36 species in year 2002 (Appendix 19). Quantitative parameters of zooplankton for sites included in the continuous monitoring program of Murmansk Areal Department for Hydrometeorology and Environmental Monitoring (K2, K4, K9, K12) are presented in Appendix 18. The total abundance of zooplankton in the Kola River ranged between 23–136 thous.ind./m^3 in July, and 0.42–23.88 thous. ind./m^3 in September. The total number of species varied between sampling sites (Fig. 54). Quantitative parameters in the Kola River main stem were highest at site K2, which is strongly affected by lacustrine species from the Lake Kolozero. The total number of zooplankton at K2 varied in the year 2001 from 6.61 up to 99.09 thous.ind./m^3 and in the year 2002 from 2.42 up to 136.34 thous.ind./m^3. Total zooplankton biomass ranged from 58–470 mg/m^3, in year 2001 and from 11–421 mg/m^3 in year 2002 (Fig. 55, Appendix 18).

High biomass and abundance were observed also at site K3. Here, a large portion of the plankton is formed by the Pulozero Lake's lacustrine species. Similarly high abundance and biomass were observed at K9, which is the widest and biggest quiet water part of the Kola River (Appendix 18, Fig. 55). The number of zooplankton individuals (thous. ind./ m^3) in these river sections was highest in July, and caused by *Rotatoria*. Other river sections had rather low total number of zooplankton individuals (0.4–35.7 thous.ind./m^3) and low biomass (5–58 mg/m^3). On all sampling occasions *Rotatoria* was dominant in both numbers and biomass. The most dominant species were *Keratella cochlearis*, *Polyarthra major* and *Bosmina obtusirostris*.

Table 29.
Number of species in different zooplankton groups in the Lake Kolozero (K1).

Group	Number of species, 2001	Number of species, 2002
Rotatoria	13	11
Cladocera	9	7
Cyclopoida	3	3
Calanoida	2	2

In the Kitsa Creek (K4) a total of 23 species were observed, of which 11 belong to *Rotatoria*, 8 to *Cladocera* and 4 to *Copepoda*. The total number of zooplankton varied from 0.3 up to 9.3 thous.ind./m^3, and biomass from 1.8 up to 33.2 mg/m^3 (Appendix 18, Fig. 55). The dominant species groups reflect the natural state of the water body. In the beginning of June nauplial phases of *Copepoda* represent up to 77% of all plankton; during summer - *Rotatoria* (42–97%), and in September – *Cladocera* (up to 63%). Species with wide ecological resistance such as *Keratella cochlearis* and *Bosmina obtusirostris* are dominant. Clean water indicators represent 5–7% of the total amount of plankton. The saprobity index of K4 ranged from 1.62 – 1.92, which corresponds to β-saprobity.

Zooplankton in the Näätämöjoki River comprised 29 species, including *Rotatoria* – 15, *Cladocera*

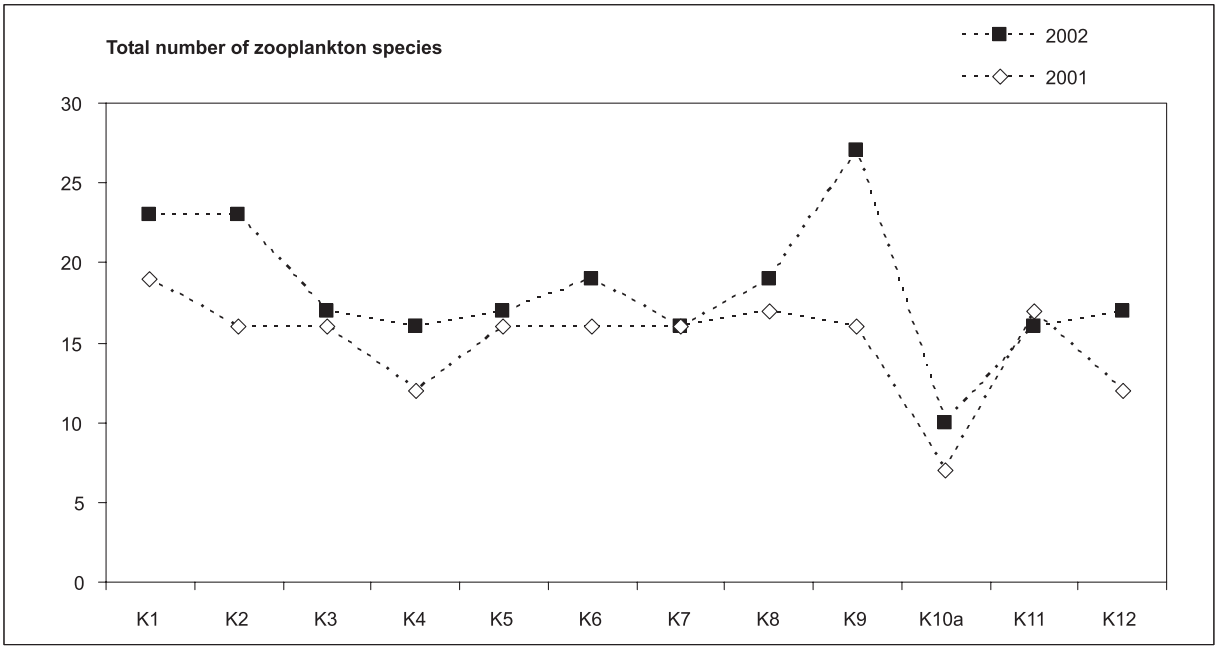

Fig. 54. Total number of zooplankton species in the Kola River system in years 2001 and 2002.

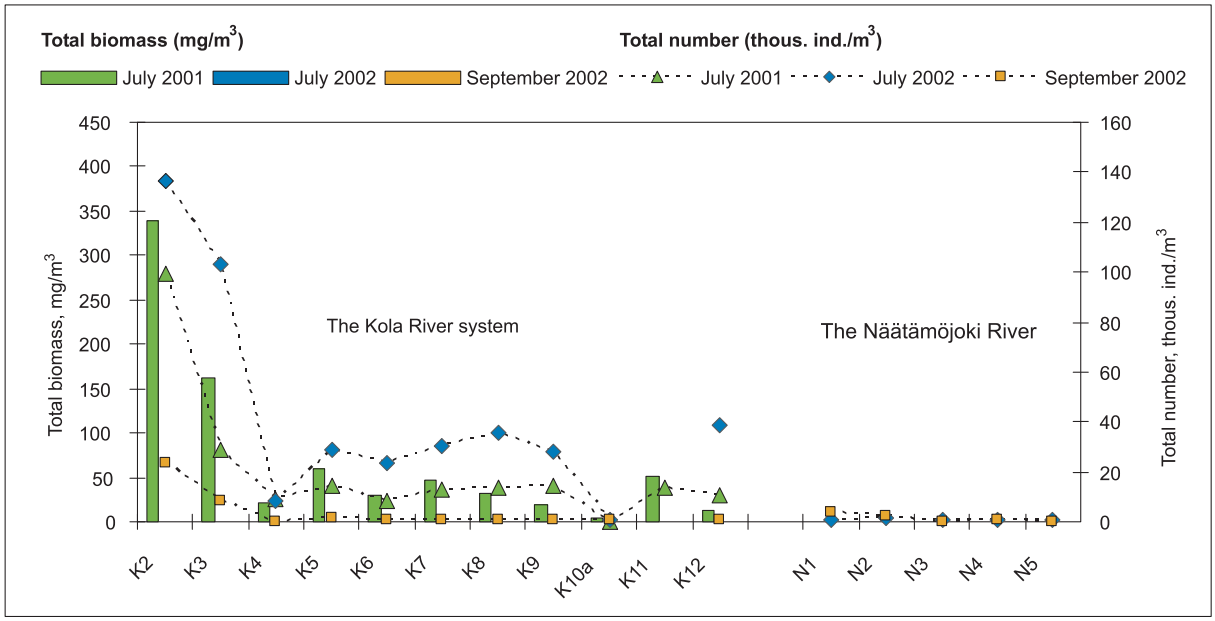

Fig. 55. Zooplankton dynamics in the Kola River system and the Näätämöjoki River.

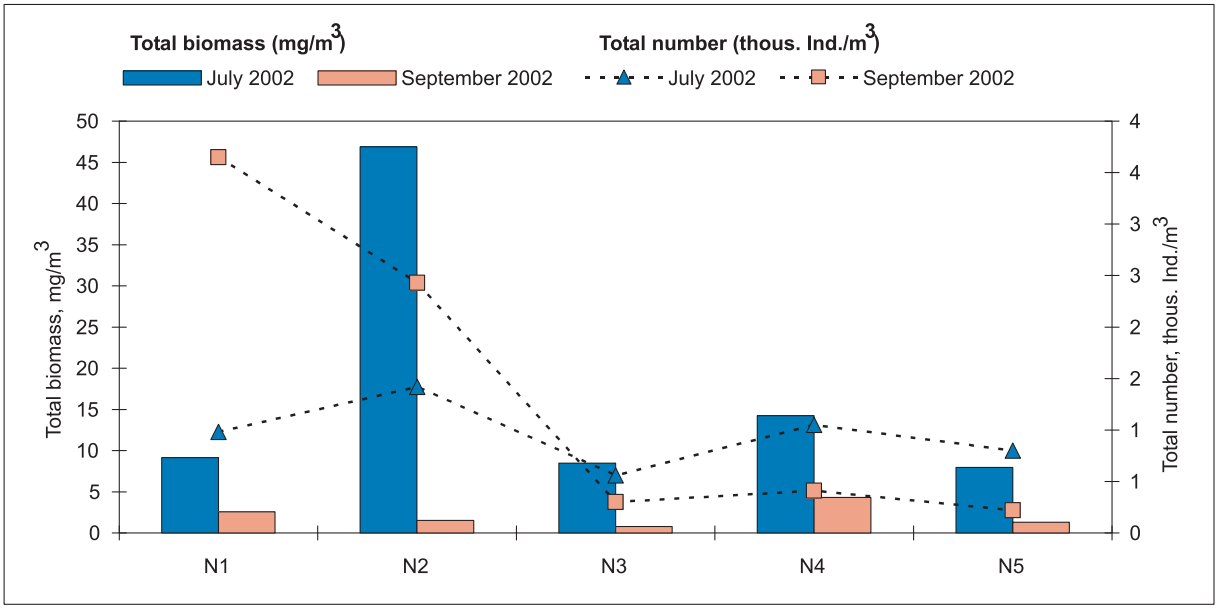

Fig. 56. Quantitative parameters of zooplankton in the Näätämöjoki River.

– 11 and *Copepoda* – 3 (Appendix 20). The total abundance of zooplankton in Näätämöjoki in July varied from 0.56 to 1.42 thous.ind./m^3, and in September from 0.22 to 3.65 thous.ind./m^3. Zooplankton biomass varied from 0.46–46.86 mg/m^3 in July, and from 0.78–4.31 mg/m^3 in September (Fig. 55 and 56). The highest zooplankton abundance was registered on two upper section sites (N1–N2) of the river in September and were caused by of the β-saprobe *Keratella cochlearis*, which made up 92% of total abundance of organisms. The maximum biomass was recorded in July on site N2, caused by the β-saprobe *Bosmina obtusirostris* – 78% of total biomass of organisms.

The total biomass and abundance of zooplankton in the Näätämöjoki River was much lower than in the Kola River, and comparable to those of the Kitsa Creek (K4). The species composition of zooplankton in the Näätämöjoki River, is dominated by clean water indicator species. Out of 27 indicator species, 9 are oligosaprobes, 6 are o-β-saprobes, 7 are β-saprobes, and 3 are β-α saprobes. Lowest values of saprobity index were recorded on sites N3 and N5 in July, indicating clean river water. The saprobity index in September ranged from 1.55–1.84 and correspond to o-β-saprobity (Fig. 57).

Contamination of lower river section nearby the village of Vykhodnoy (K9) was marked by an

increase of biomass and abundance of zooplankton, and the presence of pollution-resistance species. Zooplankton of the Varlamov Creek (K10a) was characterized by low quantitative values, and dominated by *Brachionus urceus*, β-saprobe species. The zooplankton community of the main Kola River is made up by 50% of o-β saprobic species. While β-saprobes dominated the plankton the proportion of clean water indicator organisms varied within 5–30%. The Saprobic index within the whole river basin varied between 1.48–2.06 (Fig. 57). Based on zooplankton parameters the Kola River is moderately polluted.

3.10

Macrozoobenthos

The bentic fauna found on artificial landfill substrate reflect the destructive processes encountered by the benthic community of the Lake Kolozero (K1). Samples at site K1 showed only 3 to 6 taxa. of which *Oligochaeta* the most abundant (42 to 89% of all organisms). In addition, *Bivalvia* (*Mollusca*) – (up to 35.5%) and *Chironomidae* (up to 40%) formed the bulk of the benthic community (Appendix 21). The total abundance of macroinvertebrates at site K1 varied from 1750 to 9085 ind./m^2 in the year 2001 and from 1250 to 267б ind./m^2 in 2002 (Fig. 58). To-

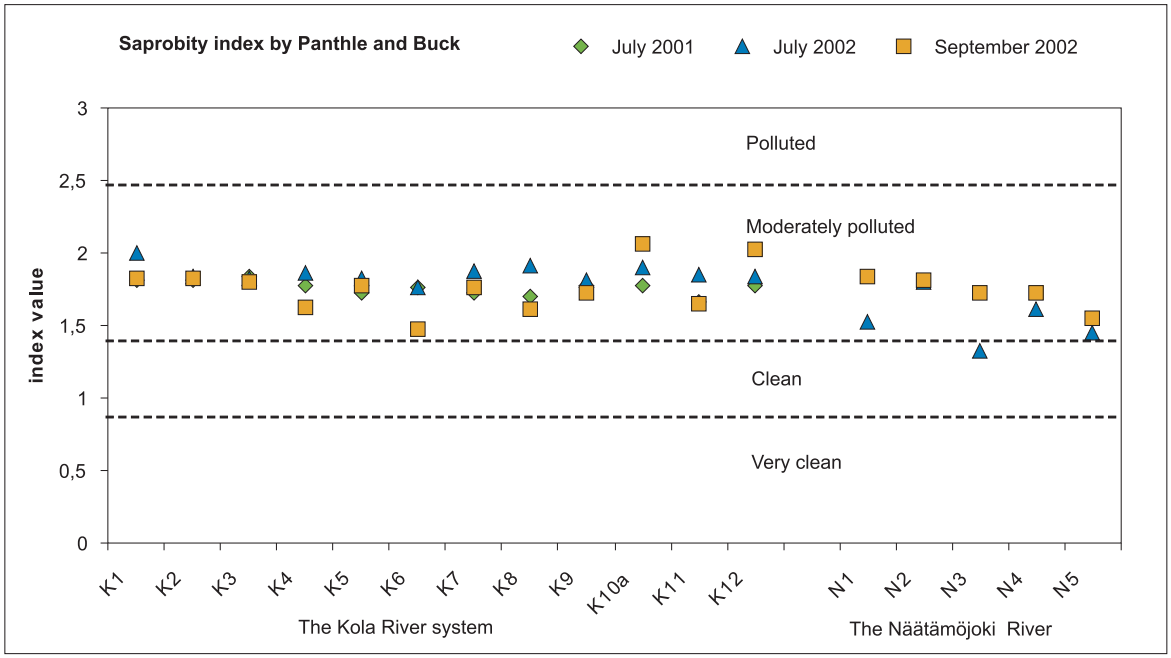

Fig. 57. Water quality according to values of Saprobity Index by Panthle and Buck (Sládeček 1973) for zooplankton in the Kola River system and the Näätämöjoki River.

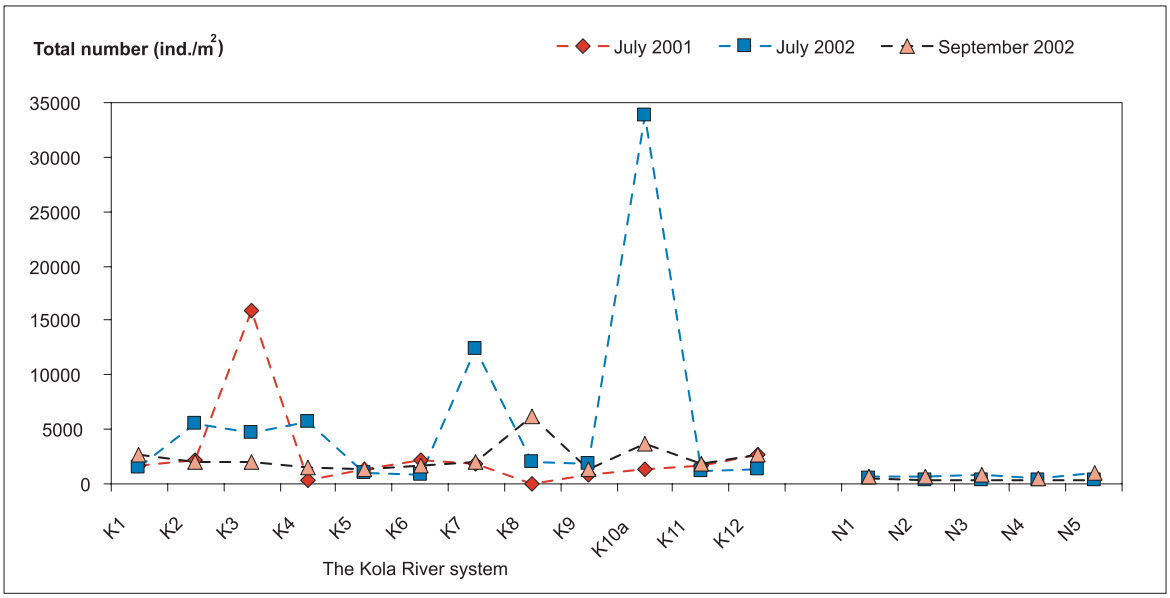

Fig. 58. Total number of macrozoobenthos in the Kola River system and the Näätämöjoki River.

tal biomass fluctuated between 16 and 43 g/m² in 2001 and from 7 to 45 g/m² in 2002 (Fig. 59). Clean water indicator species were absent. Low value of Woudeviss biotic index (2) and high percentage of *Oligochaeta* characterize artificial landfill soils of the Lake Kolozero in the dam area (K1) as polluted (Figures 61–62).

In the Kola River main stem the substrate and habitats differ significantly between sampling sites. Therefore benthic invertebrate composition and abundance varies notably. The total number of zoobenthos ranged between 10 and 15996 ind./m², total biomass between 0.07 and 108.5 g/m² and number of taxa in a sample between 4 and 15 (Fig. 58 and 59). *Chironomidae* dominated up to 74.7% (K7, July 2002) of the total number of organisms in a sample (Appendix 21). All through the Kola River course, excluding slow water section K9, also clean water indicator organisms of the order *Trichoptera* and *Ephemeroptera* were found (Fig. 60). Based on the Woudeviss biotic index the upper and middle sections of the main stem (K2–K7) represent mainly clean water quality (Fig. 61) with the exception of site K6 in September 2002, which indicated polluted water quality. In river sections downstream the Village of Shonguy (K8–K9) index values drop to moderately polluted or polluted class. At lower river parts (K11–K12) index values rise again to clean water quality class. The proportion of *Oligochaeta* varied considerably both between and with-

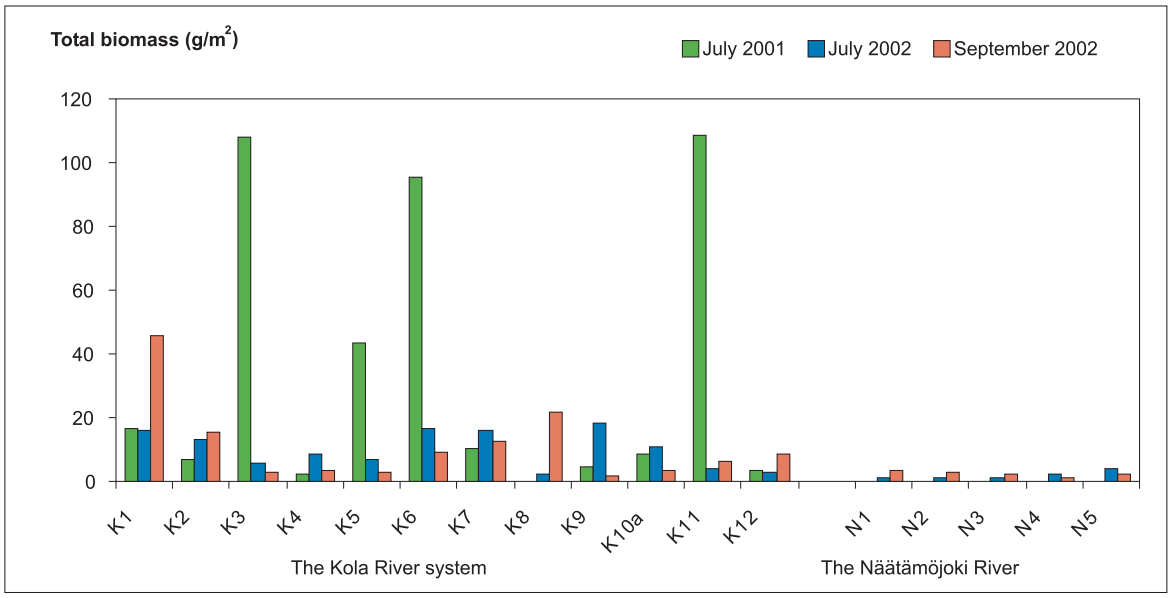

Fig. 59. Total biomass macrozoobenthos in the Kola River system and the Näätämöjoki River.

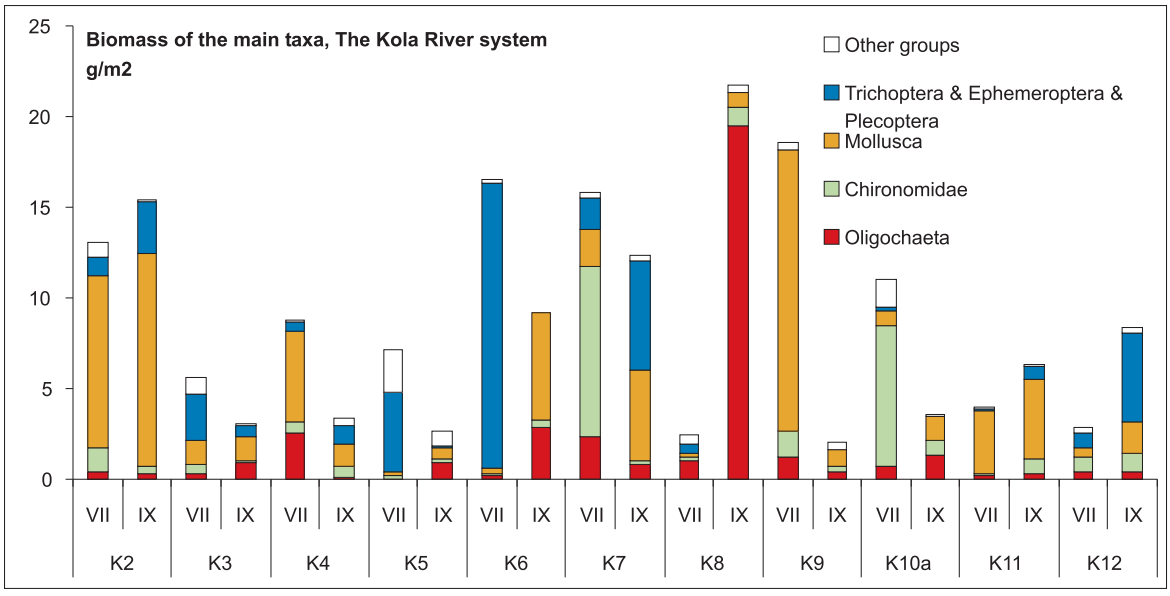

Fig. 60. Biomass of the main taxa of macrozoobenthos in the Kola River system, July and September 2002.

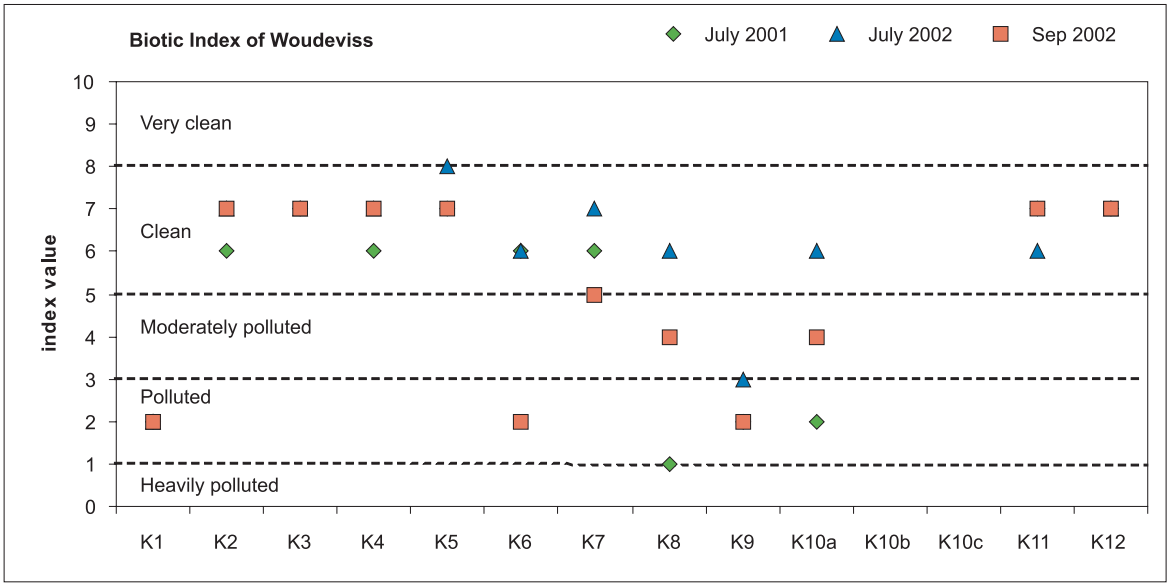

Fig. 61. Water quality according to values of Biotic Index of Woudeviss for macrozoobenthos in the Kola River system.

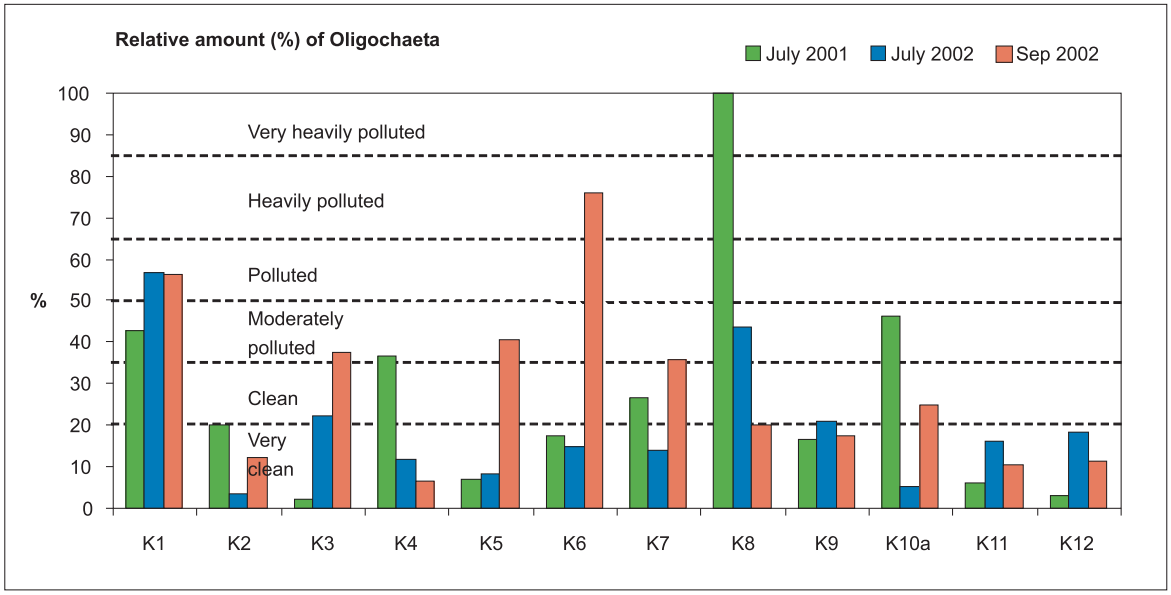

Fig. 62. Classification of water quality based on relative amount of *Oligochaeta* in zoobenthos samples of the Kola River system.

in sampling sites and between different sampling occasions (Fig. 62).

In the Kitsa Creek (K4) 6 to 13 taxa were found per sample. Maximum of quantitative values were 5.67 thous.ind./m^2, biomass – 8.7 g/m^2 (Fig. 58–59). Basis of the bottom biocenosis in K4 included *Oligochaeta*, *Bivalvia* (*Mollusca*) and *Chironomidae* (Fig. 60). Representatives of such taxa as *Trichoptera* – *Molanna angustata* and *Ephemeroptera* – *Heptagenia sulfurea* were common. Based on the Woudeviss Biotic index values (5–7) K4 represents clean water quality (Fig. 61). Varlamov Creeks (K10a) benthic fauna consisted only of *Chironomidae* and *Oligochaeta*. Biomass and abundance were highly variable indicating the great instability. Clean water indicator species occurred sporadically, mainly due to the good aeration of the creek waters. Woudeviss biotic index values varied between 2–6, classifying Varlamov inconsistently to either the clean, moderately polluted or polluted water quality class (Fig. 61).

In the Näätämöjoki River benthos was sampled only from riffle areas. The benthic fauna of the river is diverse in composition, 80 taxa in total. The most abundant group was the *Chironomidae* (from 21 up to 49.5%) (Appendix 21); whereas *Mollusca* dominated the biomass (up to 64%). (Fig. 63). A number of indicator organisms occur in the Näätämöjoki River, including oxiphilic representatives of *Trichoptera*, *Coleoptera* and *Ephemeroptera*. The propor-

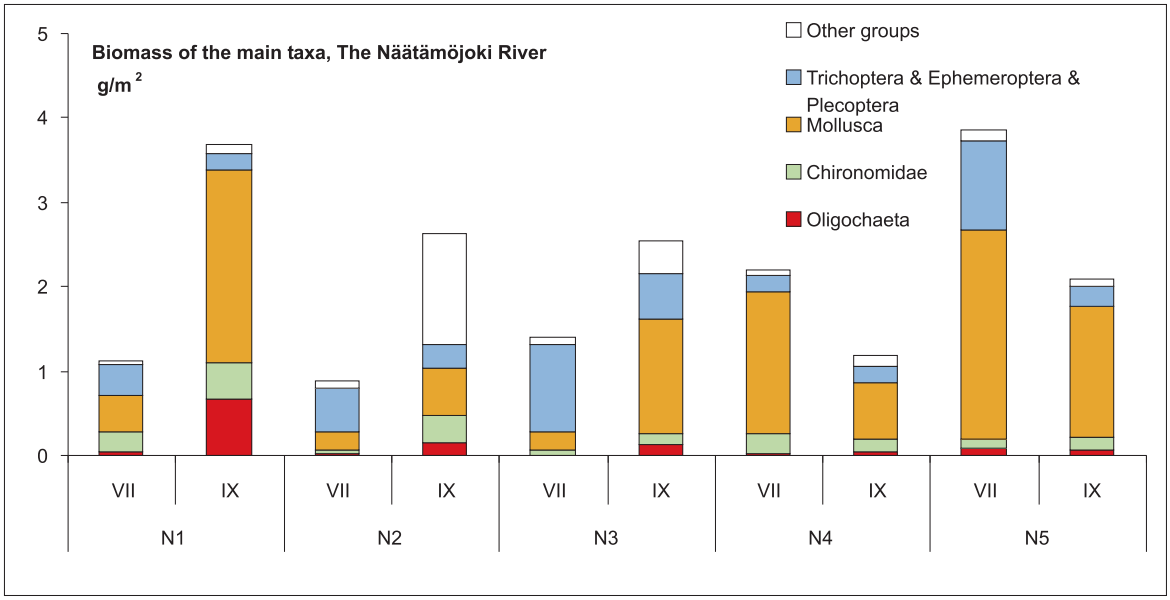

Fig. 63. Biomass of the major taxa of macrozoobenthos in the Näätämöjoki River, July and September 2002.

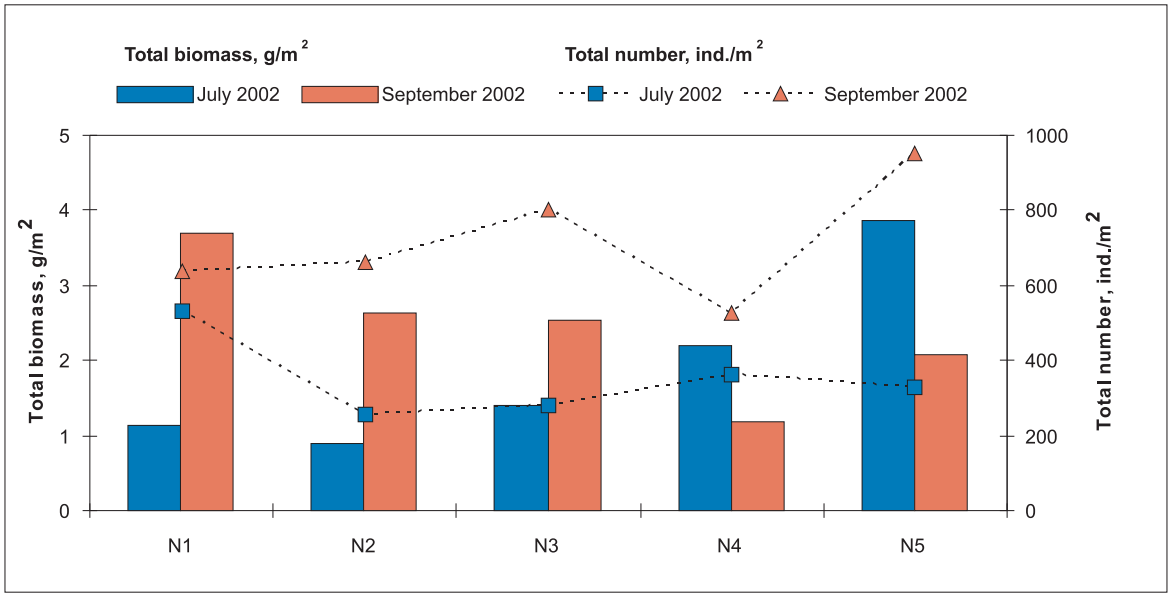

Fig. 64. Quantitative parameters of macrozoobenthos in the Näätämöjoki River.

tion of indicator species varies from 7 up to 17% of the total amount of organisms. The most common species of these groups were *Ephemerella ignita*, *Heptagenia sulfurea*, *Policentrotus flavomaculatus* and *Arctopsyche ladogensis*. The total biomass of the indicator species (*Trichoptera*, *Ephemeroptera*, *Plecoptera*) is relatively low, only 5–10% of the total biomass. Only at N3 in July the indicator species formed 92% of the biomass (Fig. 63). Other taxa, made up 21% of the biomass, and belonged mainly to the *Diptera*. The total abundance of organisms ranged from 255 to 950 ind./m^2, and biomass from 0.88 to 3.69 g/m^2 (Fig. 64). In general, characteristics of the benthic fauna of the Näätämöjoki River reflect natural status and clean water.

3.11

Physical and chemical water quality

Water chemistry indicated that the water quality of the Kola River was rather similar between 2001 and 2002. The oxygen concentration ranged from 9.14 – 10.73 mg/l in year 2001 and 7.24 – 13.98 mg/l in year 2002 (Fig. 65). pH value in the Kola River main stem was 6.26–8.22 in 2001 and 5.63–8.48 in 2002. During years 2001–2002 pH value of the Lake Kolozero (K1) varied between 6.30–9.41. In the Kitsa Creek (K4) pH was 6.10–7.15 and in the Varlamov Creek (K10a) 5.81–7.79. In the creeks Medvegiy (K10b) and Zemlanoy (K10c) pH was 6.91–8.02 and 6.91–8.23 respectively (Fig. 66).

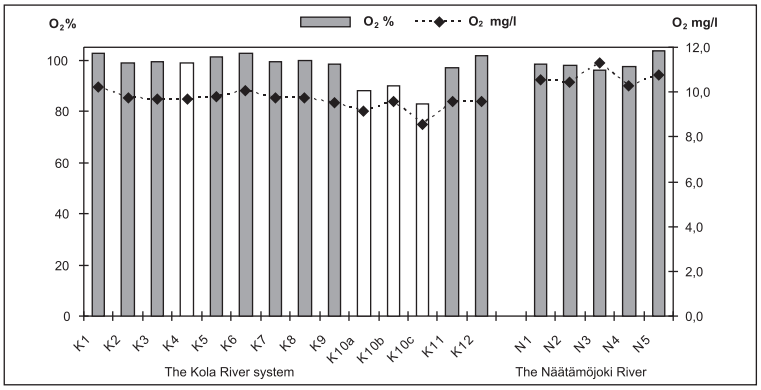

Fig. 65. Average oxygen conditions during ecological studies in the Kola River system (n=3, July 2001, July and September 2002, tributaries in white columns) and the Näätämöjoki River (n=2, July and September 2002).

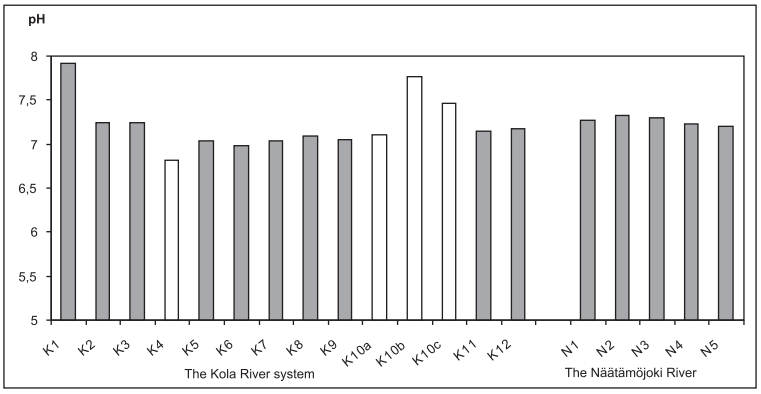

Fig. 66. Average pH during ecological studies in the Kola River system (n=3, July 2001, July and September 2002, tributaries in white columns) and the Näätämöjoki River (n=2, July and September 2002).

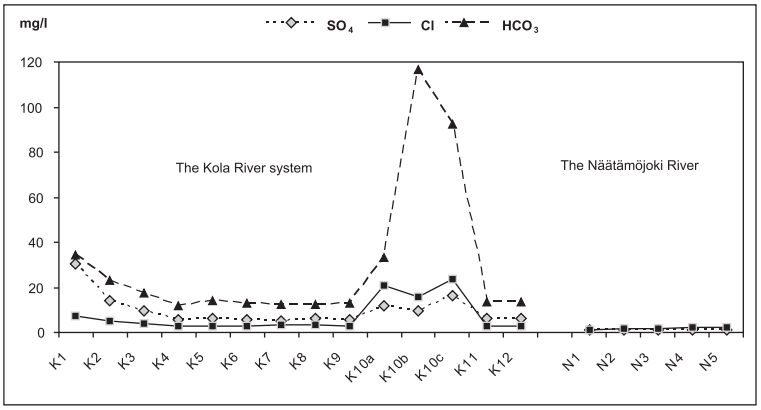

Fig. 67. Average concentrations of sulphate (SO_4), chloride (Cl) and hydrocarbonate (HCO_3) ions during ecological studies in the Kola River system (n=3, July 2001, July and September 2002) and the Näätämöjoki River (n=2, July and September 2002).

In the Näätämöjoki River the water quality was very good. Oxygen concentration varied between 10.3–11.3 mg/l all (Fig. 65). In the springtime, a decrease in the pH was measured, but it seems that these changes are transitory and do not cause disadvantages to the fauna and flora of the river. The pH varied from 7.19 to 7.33 in the sampling period of the year 2002 (Fig. 66).

Water in the Kola River is low mineralized. The average concentration of chloride-ions (Cl) in the main Kola River channel was 2.83–4.83 mg/l (Fig. 67). In the Kitsa Creek (K4) average Cl concentration was 2.83 mg/l, and in the tributaries at the lower river basin (K10a, K10b, K10c) it was between 15.73–23.73 mg/l. In the Lake Kolozero (K1) Cl concentration was on average 7.1 mg/l. The average concentration of sulphate-ions (SO_4) in the river varied from 5.1 up to 14.17 mg/l, at site K4 it was on average 5.7 mg/l and in the creeks K10a–K10c 9.5–16.07 mg/l. In the Lake Kolozero SO_4 reached 30.6 mg/l. Hydrocarbonate-ions (HCO_3) in the main river channel ranged on average from 12.6 to 22.97 mg/l, in site K4 HCO_3 was on average 11.61 mg/l and in the creeks K10a–K10c 33.17–116.67 mg/l. In the Lake Kolozero average concentration of HCO_3 was 31.1 mg/l (Fig. 67). In the Näätämöjoki River all the above mentioned elements showed very low concentrations during the sampling period in 2002 (Fig. 67).

The Kola River waters contain low concentrations of Ca, Mg, Na and K cations, that vary in the main stem on average between 0.67–6.73 mg/l (Fig. 68). In the creeks K10a–K10c concentrations of these elements were much higher, between 2.9–24.73 mg/l, as well as in the Lake Kolozero, on average 5.37–15.2 mg/l. In the Näätämöjoki River level

of Ca, Mg, Na and K was also low, like in the main sections of the Kola. Conductivity follows the same patterns as the main anions and cations (Fig. 69). A major influence on the water quality in the upper parts of the Kola River stems from the Olenegorsk iron ore mine and concentration plant, which wastewaters leak to the Lake Kolozero through the dam. The influence of this could be traced down to the sampling point K3 (Kola River, Taibola village). In the lower part of the river, the major contaminants come from tributaries loaded with organic wastewaters from agricultural farms.

The concentration of nitrogen ammonia (NH_4) in the main channel of the Kola River was not high; on average 0.01–0.1 mg/l (Fig. 70). Increased concentrations of nitrogen-containing substances was typical for the creeks in lower part of the basin, K10a, Varlamov (0.29 mg/l), K10b, Medvegiy (7.93 mg/l) and K10c, Zemlanoy (6.14 mg/l). The average concentration of nitrogen ammonia in the Kola River section located downstream the creeks in the village of Molochny (K11) was 0.06 mg/l. Concentration of nitrite- and nitrate-ions (N_{2+3}) was low all along the main channel of river (0.01–0.14 mg/l). The creeks (K10a–K10c) nitrite- and nitrate-ion concentrations reached 0.26–4.29 mg/l, being highest in K10c, the Zemlanoy Creek. The same pattern as for the nitrogen compounds was seen for phosphate phosphorus (PO_4) (Fig. 70). In the Näätämöjoki River the amount of different nutrients was mainly below detection limits (NH^4 < 0.005 mg/l, NO^{2+3} < 0.002 mg/l, PO^4 < 0.002 mg/l).

Colour of the river water in the Kola was on average 53–73 degree Pt-Co. Humic compounds are present in the river

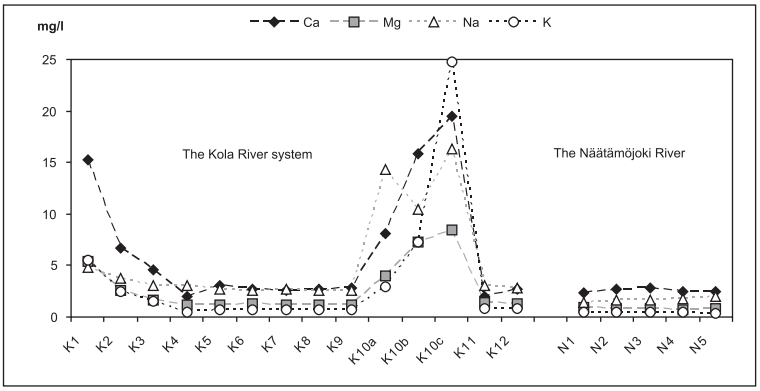

Fig. 68. Average concentrations of Ca, Mg, Na and K during ecological studies in the Kola River system (n=3, July 2001, July and September 2002) and the Näätämöjoki River (n=2, July and September 2002).

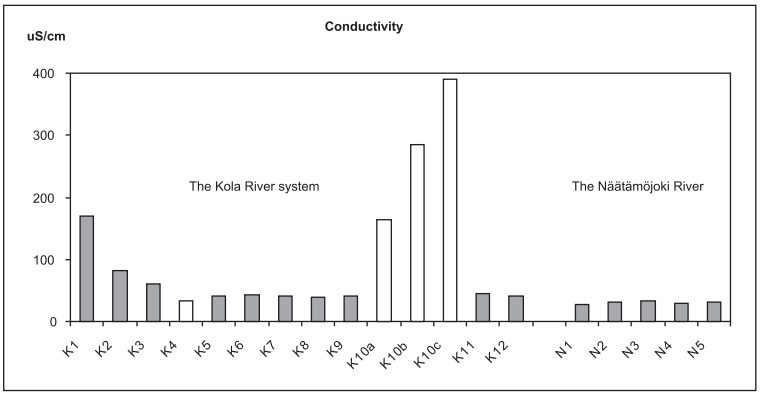

Fig. 69. Average conductivity during ecological studies in the Kola River system (n=3, July 2001, July and September 2002, tributaries in white columns) and the Näätämöjoki River (n=2, July and September 2002).

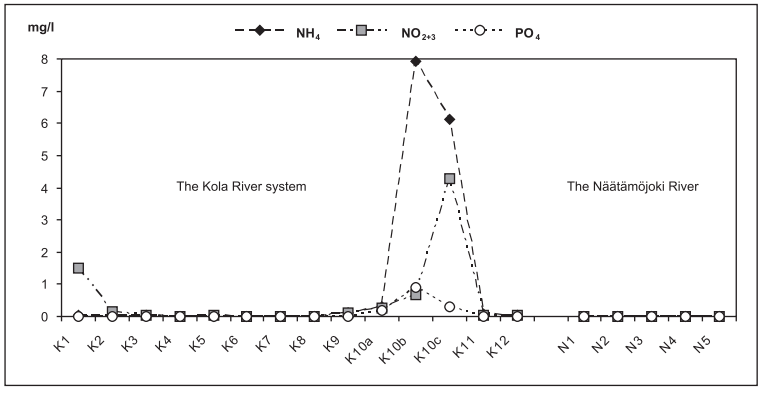

Fig. 70. Average concentration of nitrogen and phosphorus compounds during ecological studies in the Kola River system (n=3, July 2001, July and September 2002) and the Näätämöjoki River (n=2, July and September 2002).

to some degree due to the peatland areas of the drainage basin. In the creeks draining the agricultural areas (K10a–K10c), organic loading was reflected also by the water colour (222–270 degree Pt-Co). In the Näätämöjoki area humus loading is insignificant and the river water is very clear (colour 10–20 mg Pt/l, note the unit difference compared to the Kola!). Suspended susbstances were on rather low level in both the rivers, excluding the tributaries in the lower part of the Kola River basin (Fig. 71).

Concentrations of easily oxidizing organic substances reached 0.71 – 1.42 mg/l on BOD_5 and 10.43–15.6 mg/l on COD_5 in the Kola main stem. In the small tributaries (K10a–K10c), the concentrations exceeded the limit values twice on BOD_5 and 1.5–3 times on COD_5 (Fig 72).

Water flow measurements in the Medvegiy (K10b) and Zemlanoy (K10c) creeks made it possible to calculate the load to the Kola River in July and September 2002. Calculation values showed that major contamination substances in these tributaries were suspended substances and nitrogen-compounds (Table 30).

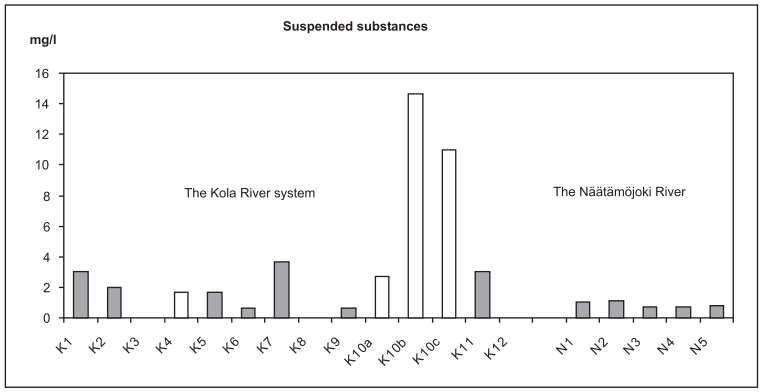

Fig. 71. Average concentration of suspended substances during ecological studies in the Kola River system (n=3, July 2001, July and September 2002) and the Näätämöjoki River (n=2, July and September 2002).

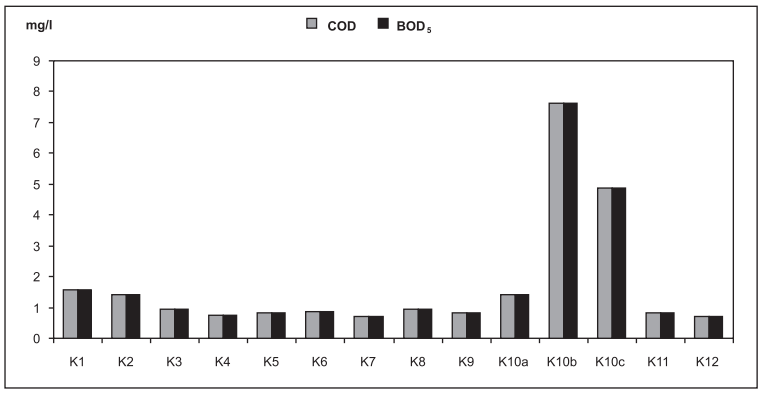

Fig. 72. Chemical (COD) and biological (BOD_5) oxygen demand during ecological studies in the Kola River system (n=3, July 2001, July and September 2002).

Table 30.
Influence of the creeks Medvegiy (K10b) and Zemlanoy (K10c) to the loading of the Kola River.

Water body	Medvegiy creek		Zemlanoy creek	
Time	July 2002	September 2002	July 2002	September 2002
Water flow	0.25 m^3/s	0.19 m^3/s	0.11 m^3/s	0.03 m^3/s
Unit	tons/month	tons/month	tons/month	tons/month
Suspended substances	7.955	4.048	20.088	1.614
BOD_5	2.784	1.417	1.775	0.143
NH_4	2.746	1.397	2.561	0.206
NO_2	0.050	0.025	0.041	0.003
PO_4	0.088	0.045	0.609	0.049
Fe tot.	0.595	0.303	0.626	0.050
Cu	0.002	0.000	0.003	0.000
Zn	0.007	0.000	0.009	0.000
Mn	0.017	0.000	0.072	0.000
Phenols	0.002	0.001	0.002	0.000

4 Discussion

4.1 Macroinvertebrates

4.1.1 BACIPS

BACIPS indicates a positive net effect from the 'before' to the 'after' periods irrespective of either indices or the analysis method used (strict vs. asymmetrical). It is therefore tempting to conclude that the biological treatment stage (BTS) of the waste water treatment plant (WWTP) at Shongui had the desired effect of improving the water quality downstream from the impact sites. There are, however, some factors that have to be considered for the BACIPS data. Firstly, despite initial planning, there is no adequate autumn before data for the Kola River in the BACIPS design. Furthermore, because of the rainy summer in 2001, the autumn flood was extremely high and the sampling at the Näätämöjoki had to be cancelled. Therefore, 'before' data for the Näätämöjoki River is missing. Consequently, the design used to assess the effect of the BTS of the WWTP is either pseudoreplicated (strict approach) or both pseudoreplicated and asymmetrical (asymmetrical approach). Both of these flaws weaken the statistical power of tests, and their influence on the findings themselves is unknown. Secondly, samples were taken by different observers in the 'before' and 'after' periods, possibly introducing between-observer bias to the design. This is especially problematic for samples taken directly downstream (K8) and upstream (K7) of the Shongui WWTP as they were also taken from slightly different locations in the before and after periods. Furthermore, the effects of the violation of the additivity assumption on the outcome of BACIPS tests have to be considered.

The BACIPS designs used here are far from standard, and the obtained results have to be interpreted with caution. The 'strict' approach is inherently pseudoreplicated sensu stricto (Hurlbert 1984), and sampling at the Näätämöjoki River in the before period would have been necessery to obtain a truly symmetric and replicated design. The Näätämöjoki River is in a reference condition, and thus it might seem justified to use the Näätämöjoki River data as a control to impacted sites (see Underwood 1994). However, the use of mere 'after' samples of the Näätämöjoki River sites as a substitute for missing 'before' samples is not permissible since there is no prior knowledge of the interannual persistence of index scores. Similarly, while the asymmetrical approach makes use of September 'after' sampling data, the design is still pseudoreplicated. An efficient use would have required a symmetrical design, that should have included sampling of control (Näätämöjoki) and impact locations in the 'before' period.

While general inter-observer bias is known to be small for the indices used here as the basis of BACIPS analysis (Clarke et al. 2002), the problem introduced through the sampling on slightly different sampling stations is potentially much more serious. Measurements of environmental parameters measured on each sampling site on each sampling date indicate greater than average differences between the two July sampling occasions at the Shongui sites when compared to other sites. It is likely that the habitat characteristics of the Shongui sites were therefore not constant over the course of sampling, which may reflect in different species compositions irrespective of improved water quality.

The NMS ordinations showed that the distances between 'after' and 'before' sampling occasions were larger for impact sites than for control or other sites. This clearly indicates that there is a change in between the sampling periods for the impact sites. However, ordinations are incapable of pinpointing the reason for change and thus the observed change cannot be tied to the BTS of the WWTP. Interestingly, the variables indicating anthropogenic pollution (i.e. K, colour) explain most of the variation in CCA ordinations. However, the interannual differences in the variables explaining the CCA ordinations are not conclusive. While the average potassium content is decreasing in the 'after' period, the average water colour is increasing. Whether or not the changes in these variables are caused by BTS effects or a product of intra-annual variation cannot be discerned since the annual fluctuation for these parameters is not known.

In summary, it cannot be stated with certainty that the BTS at the Shongui WWTP caused the improvement in water quality in the downstream

sites. Alternative explanations may include a recovery from some other detrimental effect on sites downstream of the Shongui WWTP, or type I error (i.e. concluding that there was an effect in the absence of one) due to flaws in the design used to analyse the data. In this context, the observed lack of additivity has, however, probably decreased the risk of a type I error, as tests tend to be overconservative if the additivity assumptions are violated against (see Stewart-Oaten et al. 1992). In conclusion, caution in the interpretation of BACIPS results is advised. Clearly, continuous macroinvertebrate monitoring of sites used in the BACIPS design is recommended in order to ascertain preliminary indications of the data set at hand.

4.1.2

Ecological status assessment

Generally speaking, the main course of the Kola River is in lightly polluted, good, or acceptable condition. While most sites score around 100 for the BMWP index, for Taibola (K3), the BMWP score is consistently lower. Taibola BMWP scores are comparable to those for the Näätämöjoki River site N4, Kallokoski and thus cannot necessarily be interpreted to result from pollution. The Näätämöjoki River is an oligotrophic sub-arctic river with a nutrient limited community. Nutrient limitation is likely to limit the actual number of species harboured by the Näätämöjoki River although it is in pristine condition. While scores of the used macroinvertebrate indices did not differ significantly between the Näätämöjoki River and the Kola River sites, light anthropogenic pollution (i.e. increased nutrient input) may be one reason why sites in the Kola River at times obtain even higher scores when compared to those of the pristine Näätämöjoki River. Thus, taken together, the results for the benthic indices indicate that the Kola River main channel (including K4, Kitsa) is in good condition and for the most part comparable in quality to the Näätämöjoki River. However, the water quality in the tributaries of the Kola River leaves much to be desired. For example, the tributary creeks Varlamov (K10a) and Medvegiy (K10b) receive wastewater from poultry or fur farming, which leaves them heavily polluted and in critical condition. Steps to lessen the pollution load and improve the water quality of Varlamov and Medvegiy and similarly polluted tributaries to the Kola main channel should be taken swiftly, as their future instantaneous impact (e.g. during spring floods) on sites downstream is in all likelihood highly detrimental.

4.2 Fish Communities

4.2.1

Species composition

Both study rivers, Kola and Näätämöjoki, have a low number of fish species. The fish species present in the electrofishing catches represent typical northern fluvial fish communities (cf. Jensen et al. 1997; Erkinaro et al. 2000; Niemelä et al. 2001). All species caught are native. The only non-native fish species present in the occurrence lists of these two rivers (Jenssen et al. 1997; Niemelä et al. 2001) is pink salmon (*Oncorhynchus gorbuscha)*. It has a Pacific origin and has been introduced to the Kola Peninsula area in the 1950´s. Nevertheless, pink salmon has not been met in either of the electrofishing studies referred (Niemelä et al. 2001; Jensen et al. 1997). However, Bjerknes (1977) reported on a successful reproduction of pink salmon in the Näätämöjoki River. In any case, the species can hardly be considered to belong to the permanent fish fauna of these rivers.

Introduced or non-native species pose difficulties in ecological status assessments. Firstly, their presence is clearly a man-made alteration in the fish community with possible serious biological consequences such as competitive exclusion or spreading of diseases. Because of these threats, alien species are generally regarded in ecological assessment approaches as signs of environmental degradation, and they are usually included in fish-based composite assessment indices. On the other hand, some non-native species have such a long history of functional presence in a community that the pristine state of the community in question is hard to determine, and is by no means restorable or even desirable for commercial reasons. Due to their controversial status, non-native species are not included among the biological attributes on which the ecological assessment is based in EUs Water Framework Directive (Directive 2000/60/EC).

The occurrence of sensitive species is a common criterion used in many environmental assessment schemes. The sensitivity of many species to specified impacts makes them usable as an indicator species. Atlantic salmon, brown trout, minnow and burbot have, for example, been used in detecting possible acid-induced effects in the rivers of northern Finland (Erkinaro et al. 2001) In this study, Atlantic salmon, brown trout and minnow were the most frequently met species. Malmquist et al. (2001) refer to the indicative power of these

species especially in connection with two anthropogenic impact types – acidification and habitat alterations. The even distribution of these species in both rivers studied speaks of no major degradation in these impact types.

Electrofishing is the recommended and most widely used method in riverine fish community assessments. It is a cost-, as well as capture-efficient, standardised survey method (EN 14011, 2003). However, it should be kept in mind, that it is a very selective method. In both occurrence and density estimations, one should interpret the results with caution. Field survey practice is usually planned for salmonid monitoring. The size (typically 100–150 m²) and type of a sampling area (riffle) normally satisfy the needs of the density estimations, but larger areas and habitat stratification along the guidelines of EN 14011 (2003) would probably serve better for the diversity purposes of the assessment.

4.2.2

Fish abundance and age structure

The mean densities of juvenile Atlantic salmon differed markedly between the two study rivers. However, large temporal and spatial variations in the juvenile densities and also in the adult run are quite common and may often reflect synchronised processes over large areas (Niemelä et al. 2003). Jensen et al. (1997) conducted three electrofishing surveys in the Kola River between 1994 and 1996 with the main focus of the study on life history comparisons of Atlantic salmon between the Kola River and three reference rivers. Although the density results of these two studies are not comparable because of different sample areas, they help in providing a general picture of the overall occurrence and abundance of salmonids in the whole river length.

Jensen et al. (1997) had a total of 17 sampling stations along the Kola River (13 in the main stem, 4 in the tributaries). The reported mean densities of Atlantic salmon varied between 8.2 and 33.3 individuals per 100 m². In our study, the mean density of Atlantic salmon juveniles in the Kola River was 5.5 ind./ 100 m². This figure is somewhat low in relation to the high annual average catch (41 tons; Niemelä et al. 2003) of adult salmon, especially when compared with the corresponding relation in the Näätämöjoki River (mean parr density 48.0 ind./ 100 m², catch 10 tons; Niemelä et al. 2003). This is, however, consistent with the earlier study by Jensen et al. (1997). They showed that even if the Russian rivers Varzuga and Kola had a clearly larger amount of ascending salmon run and total catches (72 and 25 tonnes versus 13 and 9, respectively) than the Norwegian rivers Alta and Orkla, the abundance of juveniles were constantly lower in the Russian rivers.

There are many possible explanations for this pattern, but in practice, juvenile density is always a result of two factors: the size of the spawning population and the availability and amount of suitable reproduction and rearing areas. Although the Russian rivers had a wider range (in kilometres) for ascending salmon, no comparison was made between the total actual sizes of the production areas in the four study rivers (Jensen et al. 1997). Differences in the sampling areas can also affect the density estimates. However, in the case of the Kola River, the disproportion between adult catches and juvenile density can be partly explained by the continuous salmon stocking, which has surely caused more or less aggregated distribution of parr in the river and a shorter staying time in the river. In addition, the statistics of long-term adult stock variations have shown a strong fall in the adult run entering the river between 1995 and 2000, which has in turn resulted in low juvenile densities (Niemelä et al. 2003).

In contrast to our results, Jensen et al. (1997) found only few brown trout (total annual mean 0–1.0 ind./ 100 m²), and all trout were caught from the three uppermost stations of that study (near to the station K3 in our study). In our study, the mean density of brown trout (6.4 ind./100 m²) was similar to that of salmon. This equal density relation differs from the corresponding results of Jensen et al. (1997) and also from the Näätämöjoki River, where brown trout was clearly outnumbered by salmon over the whole river length except for the two uppermost areas devoid of salmon (table 14, see also Niemelä et al. 2001). The pattern of segregated distribution between these species is also well known from many rivers elsewhere (Erkinaro and Niemelä 1995; Niemelä et al. 1999). Swift-running stretches of the main stem are generally inhabited by juvenile Atlantic salmon, whereas brown trout occupies smaller headwaters and tributary creeks. Segregated distribution is partly caused by different preferences for spawning grounds, but it also has to do with competitive interactions between the species.

Trout is a species with uttermost diversified life-history characteristics. In the case of the Kola River, it is not clear whether the brown trout juveniles caught are of sea- or lake-running origin. Lakes Kolozero, Pulozero, and Murdozero are big enough to sustain lake-migrating populations, which would spawn in the Kola River. Suggestively, all

brown trout in the study of Jensen et al. (1997) were caught between Lakes Murdozero and Pulozero in the outflow area of Lake Pulozero (Taibola).

The density of minnow was clearly higher in the Kola River than in the Näätämöjoki River. This species forms a central component in the northern river communities, but it normally prefers still water. The density differences in this study are thus best explained by differing water velocities at the sampling sites. The catchability of the minnow with electrofishing is lower than that of salmonids (Bohlin et al. 1989), which makes density estimations more unreliable even with three fishing runs.

The age structure did not differ from that expected. Analysis and comparisons are only suggestive because of the defects in the scale material from the Kola River. Visual checks for spawning grounds were made during the survey, and they revealed at least one possible spawning area in the Kola River with suitable habitat characteristics. That station (K5) was indeed dominated by Atlantic salmon fry. However, possible recruitment failures are difficult to prove in the water system because of the massive yearly fish stockings. In the few possible age comparisons, stocking and the resulting growth differences were also reflected in the overlapping sizes between the age groups.

4.2.3

Ecological status assessment based on a composite index (FIX)

The majority of the sampling sites were in both study rivers classified to class 1 (no or minor deviation from the reference values). However, medians of the mean scores for all metrics (1.7 and 2.7) differed clearly between the rivers. So, the FIX index showed distinguishing power to a certain degree. Although in favour to the anticipated reference conditions (the Näätämöjoki River), it is not clear if the difference in the mean scores reflected only different environmental quality or if it is at least partly caused by other factors. The study site selection was not identical in the rivers, sites in the Näätämöjoki River are clear salmon production areas with only few exceptions: the lowermost areas are strongly influenced by tide, whereas the uppermost areas lie outside the range of permanent salmon distribution. In the Kola River, the study sites were not selected from a salmon monitoring perspective. The whole sampling site set revealed only one suitable spawning area (K5) in visual checks. That was also the only area in the whole river dominated by salmon fry.

Interpretation of FIX results should be done with caution. Some metrics turned out to be strongly interrelated. For example, only one fry per area is enough for attaining the highest rankings in both metrics 'salmonid reproduction' and 'acid sensitivity', whereas the catch of even many more bigger salmon parr would result in a remarkably lower assessment status in the same metrics (see Appendix 1.). So, the proximity to the nearest spawning grounds and the stochasticy thereby play perhaps too great a role in the scoring. In the main stem of the Näätämöjoki River, 24 out of 116 riffle stretches surveyed, were classified as reproduction areas suitable for salmon spawning (Erkinaro et al. 2000). In the Kola River, no such classification data is available, but according to Mokrotovarova (2000), the total length of the riffles is 24.5 kilometres divided in eight discrete sections. This whole length can be considered as a possible salmon production area, but the data about the total reproduction potential of the river or the spatial distribution of the actual spawning areas is lacking. Due to the stocking, reproduction of Atlantic salmon is semi-natural in the Kola River in the sense that possible spawning grounds are mostly devoid of river-born fries. Supplemental stocking delivers younglings of differing ages back into the river (Jensen et al. 1997).

Riffle habitats in the northern rivers are characterised by a low number of species and a dominance of salmonids, especially Atlantic salmon. It is curious that latitude does not play any role in the calculation of the FIX index, because the fish fauna of these northern rivers is devoid of many species such like bullheads (*Cottus spp*.), stone loach (*Barbatula barbatula*) and gudgeon (*Gobio gobio*), all commonly met in same kind of riffle habitats further south. It is evident that fish-based assessment indices, such as FIX, need regional adaptations (Malmquist et al. 2001). Regional adaptations are in turn a question of resources with additional reference data and sampling stratification needed.

4.2.4

Fish community status

The abundance and composition of the fish species communities did not show any man-induced alterations in either of the study rivers. Normal age structure of Atlantic salmon, brown trout, and minnow populations revealed no recruitment failures either. The spatial distribution of these three indicator species was also even in the whole study area. However, the results between the rivers are not comparable as such, because the somewhat manipulated semi-natural lifecycle of salmon in the Kola as well as the different choosing criteria for the sampling sites hamper direct comparisons. Anyway, both rivers can be also considered separately.

The European Unions Water Framework Directive (WFD) (Directive 2000/60/EC) has the target of reaching good status in all waters in Europe before year 2015. An establishment of reference conditions for each water type is essential in establishing reliable assessment methods in environmental monitoring. The spatially determined reference conditions used must be of high ecological status. High status of the biological quality element 'fish' is defined in the WFD as follows:

- Species composition and abundance correspond totally or nearly totally to undisturbed conditions
- All the type-specific disturbance-sensitive species are present
- The age structures of the fish communities show little sign of anthropogenic disturbance and are not indicative of a failure in the reproduction or development of any specific species.

As it clearly appears, even the high status criteria of the WFD are easily met in both rivers studied. The only separate study site with reservations is the station K10b, which is heavily impacted by poultry farms located upstream (Pekka and Öhlander 2003). Concentrations of nutrients as well as that of most heavy metals were hundreds of times higher than in the main river. However, any sublethal effect of pollutants on fish population properties is difficult to discriminate from other impacts – fish can always change habitat to a more favourable one. High levels of nutrients do not pose a direct threat in the concentrations reported by Pekka and Öhlander (2003). On the contrary, eutrophication enhances the growth of salmonid juveniles to some extent. According to Jensen et al. (1997) salmon parr from the Kola River showed the highest growth rates in between-river comparisons. Growth is naturally a function of many other factors as well, the heat sum and intraspecific interactions being among the most important. Oxygen depletion is a common consequence of eutrophication. However, oxygen concentrations reported (Pekka and Öhlander 2003) were far from the critical level, even in the nutrient-loaded creeks, but the conditions may aggravate during the long ice-covered period and the critical limits for oxygen deficit (dissolved oxygen < 5 mg/l) may so be achieved (Eklöv et al. 1999). Same reasoning holds for the impacts of acidification, which have been demonstrated to reach the most critical levels during the spring flood in May when the snow melts (de Caritat et al. 1996).

The effect of another anticipated threat on the ecological status, i.e. heavy metals, was even not easy to envisage from the fish perspective. No direct impact can be shown despite the elevated concentrations of Al, Cd, Cu, Ni and Zn in the aquatic bryophytes of the Kola River (see chapter 5.5). Jensen et al. (1997) found Ni and As in concentrations above the detection limit in the fish tissue of Atlantic salmon parr from the Kola River. On the whole, they concluded that the heavy metal concentrations in the Kola River are within the range of concentrations observed in uncontaminated areas.

4.2.5
Future threats to fish stocks

The threats recognised so far in the form of pollution are to be considered seriously also in the future. Air pollution around the Kola Peninsula facilities is still comparable with the most polluted regions of Europe and North America (AMAP 2002). Nickel and copper are the main pollutants from the smelteries affecting the basin of the Kola River. Accumulations of other heavy metals may also become a significant problem, and they form a large potential source of metals to nearby surface waters (AMAP 2002). However, the acidifying effects of sulphur dioxide have decreased during the 1990´s in the Kola Peninsula area (AMAP 2002) and recovery in formerly acid-impacted ecosystems have already been documented in the north-eastern Finland (Tammi et al. 2003).

In addition to some other, more local threats, e.g. increase in fishing pressure or actual poaching, the biggest threats to be expected in the future are large-scale or even global ones. Genetic mixing with wild salmon by aquaculture escapees and spreading of infectious diseases and parasites (e.g. devastating *Gyrodactylus salaris*) are some of the most potential threats, not to mention the uncertain perspectives with the global climate change.

4.3
Diatom community analysis

4.3.1
Water quality and ecological status assessment

Diatom communities react to changes in water quality within a few days – weeks. Therefore they are good indicators both for short and long-term water quality, e.g. nutrient concentrations. Although man-made changes in hydrology and river channel structure may not be evident in the biota

and in the water quality indices similarly like e.g. effects of nutrient load, diatom indices have shown to be one of the most effective tool in evaluating the ecological status of rivers (e.g. Eloranta 1999; Eloranta & Soininen 2002).

According to the diatom community analyses, water quality in the Kola River was basically good or excellent. However, a clear drop in the water quality could be detected in the creeks Varlamov (K10a) and Medvegiy (K10b) and this was also reflected to the water quality of the main flow below the creeks (K11 and K12). The amount of different pollution tolerant diatom species strongly increased at the Kola River lower course. Environmental impacts of organic loading seem to be highest in the estuary section, emphasizing the role of the pollutant loading from the creeks discharging to the area.

Signs of pollutant loading were also noticed at the upper Kola River sections (K2, K3), which showed somewhat elevated trophic conditions. As far as the Näätämöjoki River is concerned, the purpose of representing the reference conditions seem to have been achieved. Water quality is good or excellent at the whole length of the Näätämöjoki River. In the Näätämöjoki River and in the middle section of the Kola River most of the species require oxygen rich conditions and represented N-autotrophic taxa, tolerating very small concentrations of organically bound nitrogen.

The CCA ordinations demonstrated clearly the significance of water chemistry to the diatom species distribution. The ordination diagrams as well as diatom indices and spectrum of ecological characters also pointed out substantial differences in diatom communities between the sampling stations and between the two rivers, Kola and Näätämöjoki. Diatom communities of the small tributaries Varlamov (K10a) and Medvegiy (K10b) differed clearly from those of all the other sites. Main explanation for this are nutrient-rich waste waters flushed from the agricultural enterprises in the area. Decreased water quality is clearly evident by the diatom community structure in these tributaries, e.g. as a great share of eutraphentic and polysaprobe taxa. As a consequence of heavy load of nutrient rich waste waters notable share of diatom taxa of the creeks had also low oxygen demands and represent facultatively N-heterotrophic taxa, which require periodically high concentrations of organically bound nitrogen. With no exception, diatom index scores classified water quality at K10a and K10b as poor or bad, which can be described to be the ecological status of the creeks as well (Fig. 73).

Also the lake outlet sites K2 and K3 on the upper course of the Kola River differ from other parts of the channel, partly explained by natural input of nutrients from the lakes. However, this is not the only reason for the differentiation of these stations. The increased mineral and nutrient content as well as the values of conductivity suggest also some forms of anthropogenic diffuse loading on these lake outflow sites. In the case of Kola springs (K2), this could be, for instance, trace metals and tailings of wastewaters entering the river via Lake Kolozero, originating from the mining industries of Olenegorsk. At the Taibola station (K3), municipal wastewaters that enter Lake Pulozero and fish farming upstream from our sampling site may cause part of the detected eutrophication. However, despite a clear increase in the share of eutraphentic species, the diatom communities in lake outlets showed no remarkable rise in shares of polysaprobes, which would reflect heavy organic loading. The effect of elevated nutrient and mineral compounds at K2 and K3 was observed in the oxygen demands and nitrogen metabolic features of the diatom taxa, but strong changes comparable to those at sites K10a and K10b could not be detected. As a conclusion together with the scores of diatom indices, water quality and ecological status of K2 is moderate, whereas K3 represents good status (Fig. 73).

The middle part of the Kola River was found to represent good or excellent water quality and also the ecological status was assessed to be high in this river section (Fig. 73). The status of the Kitsa River (K4) is near pristine. In the CCA ordinations, the sampling sites in the middle parts of the Kola River grouped close to those of the Näätämöjoki River, which clearly represents natural reference conditions of an oligotrophic arctic river. Grouping of Shongui site K8 (downstream WWTP) in CCA reflects to some extend a little more trophic conditions than the stations upstream. This is possibly due to light pollution effect of municipal wastewaters.

An advantage in assessing water quality using diatom community analysis is the sensitivity of diatom communities in reacting to changes in species specific optimal conditions of e.g. pH, concentarions of nutrients and organic substances (Steinberg & Schiefele 1988; Descy & Coste 1989). Water quality changes are usually reflected fast especially in ecological spectrum of diatom communities better than in diatom index values. This was the case also in our study. Downstream accumulation of all anthropogenic pollution, including influence of organically polluted tributaries, was clearly reflected to the diatom communities of the lower part of the Kola River main channel (K11–K12), which is assessed to be in moderate condition (Fig. 73). Even if this pattern was not evidently seen in water chemistry analyses and in spite of insignificant

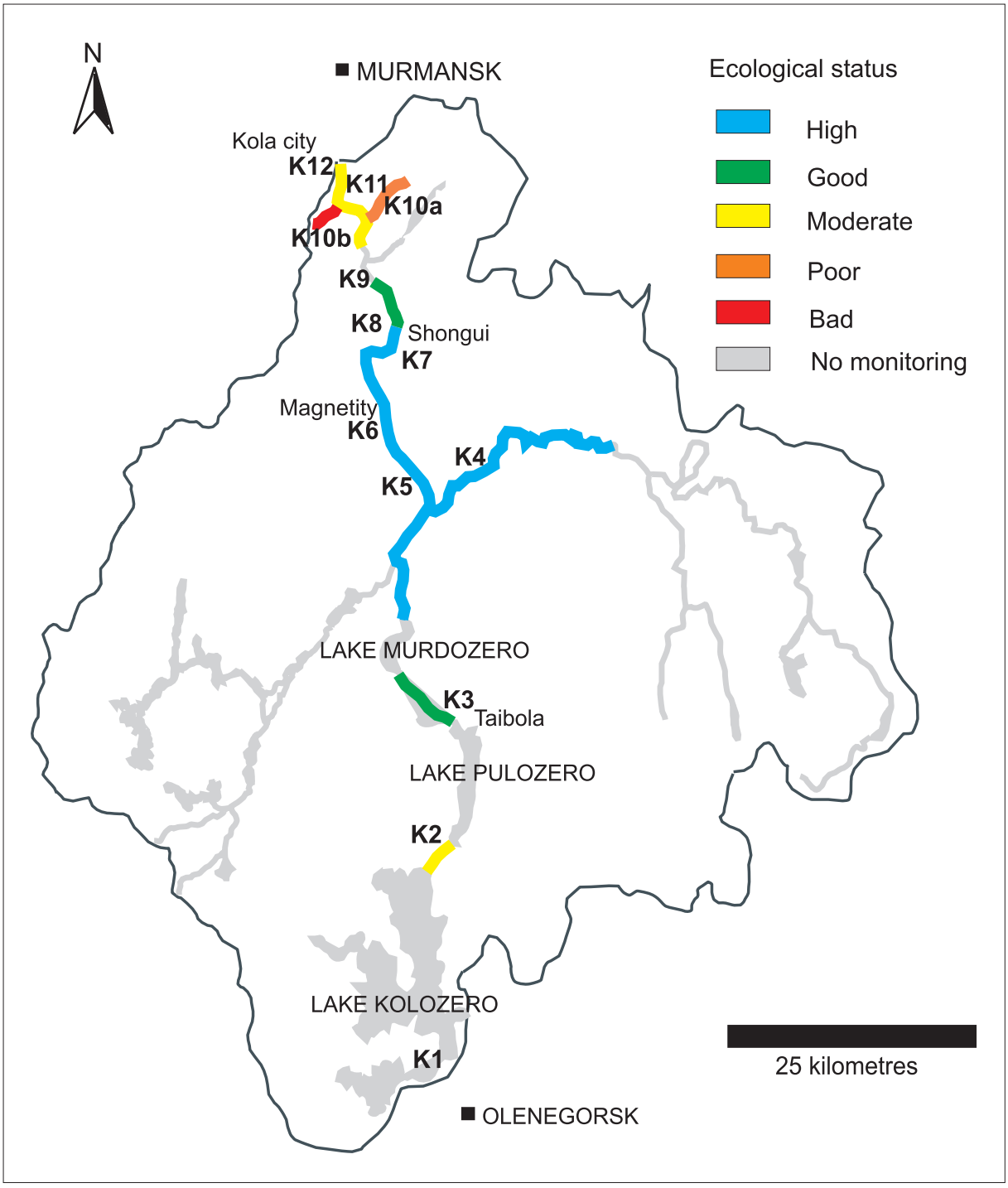

Fig. 73. Assessment of the ecological status in the Kola River and its tributaries according to diatom community studies.

discharge, pollutions of the small tributaries seem to have a definite influence to the ecological status of the Kola River lower course.

4.4

Macrophytes

Ecological quality rate calculations based on all macrophyte species and typical macrophyte species (i.e. species occurring at least in half of the reference rivers) suggested that the Kola River has a high ecological status. When only aquatic and amphibious species were used, the ecological status of the Kola River classified as good. EQR calculations with typical aquatic and amphibious species, indicated moderate ecological status. Using only aquatic species, the ecological status of the Kola River scored lowest but remained in the moderate class. Although the environment of the reference sites at the Näätämöjoki River is pristine,

harsh conditions and other edaphic factors could result in the species richness being lower than in the Kola River and other reference rivers.

At the Kola River, sample area corrected species richness showed a significant negative correlation with the habitat modification score (HMS) (Spearman's rho –0.772, p=0.005) of the River Habitat Survey. This indicates that less plant species are found at sites with increased human influence. Data of the Näätämöjoki River showed significant positive correlation with the species richness of river margins and habitat quality assessment (HQA) of the RHS study (Spearman's rho 0.900, p=0.037). This in turn, indicates higher species richness in places with a more diverse and undisturbed habitat structure.

Comparison of results of the vegetation surveys and the River Habitat Survey (RHS) gives us valuable information about the ecological effects of the habitat alterations and human influence. When combined, these methods are very useful for assessing the ecological status of northern rivers. The calculation of ecological quality rates in some form will be a widely used method when implementing EU's Water Framework Directive (Directive 2000/60/EC). However, the method is still in a development phase and it needs to be further tested. Also choosing the reference areas has to be done carefully in order to truly represent the area and conditions that they are supposed to represent.

4.5

Heavy metals in aquatic bryophytes

The levels of Cu and Ni in bryophytes from the Kola River can be considered elevated from those measured in several kinds of pollutant-free streams (Ukonmaanaho 1991, Alm et al. 1999, Vuori 2002). Most other metal concentrations in bryophytes from the Kola River area seemed to be at the same level as in the Näätämöjoki River, which is relatively free from pollutants and resemble also background concentrations from some other areas (Sudety Mountains and Swiss Alps, Samecka-Cymerman and Kempers 1998). However, in additions to Cu and Ni, the aquatic bryophytes (whole shoots) from the Kola River headwaters (K2), close to the minig areas, concentrations of Ba and Mo that were twice as high as in the Näätämöjoki River. Similarly, Al, Cu, Fe, Ni and Pb were higher in the mosses from the Kola River estuary (K12) than in the Näätämöjoki River. Mosses from the middle part of the Kola River (sites K3–K8) showed generally similar or lower metal levels as the Näätämöjoki River. Heavy metal concentrations in the Varlamov Creek (K10a) however were mostly much higher than in the main stem Kola River or Näätämöjoki River.

The levels of heavy metals in young terminal shoots (*Fontinalis*) found in the Kola River area were also close to or even below the concentrations in the Näätämöjoki River and in non-polluted Swedish streams (Alm et al. 1999), with the exception of Cu and Ni. The concentrations of As, Ba, Cu, Mn, Mo and Ni in young terminal shoots collected within the site K2 are higher than those found at any other sampling site and exceed the levels in the Näätämöjoki River up to 2 times. On the whole, according to the classification of Swedish Environmental Protection Agency for metal concentrations in aquatic bryophytes, the levels of As, Co, Cd, Pb and Zn in mosses (annual growth) of the Kola River are very low, while contents of Cu and Ni are moderately high (Alm et al. 1999).

However, results from the Kola River cannot directly be compared to background results from streams locating in different regions having major differences in water quality and catchment characteristics compared to boreal high-altitude rivers. Furthermore, the single site N5 in the Näätämöjoki River cannot be reliably used as a reference site. Suitable background data for moss metal concentration of the northern boreal or sub-arctic streams exist for the uncontaminated Tenojoki River basin discharging to the Barents Sea about 240 km to the northwest from the Kola River estuary (Hämäläinen et al. 1996) When our results from the Kola River were compared to this reference river, it seemed obvious that both terminal tips and whole shoots of the Kola River mosses had generally elevated concentrations of Al, Cd, Cu, Ni and Zn ($p < 0,05$) (Fig. 74). Cu and Ni concentrations in whole shoots in the Kola River were also higher than in the reference rivers in northern Sweden ($p<0,05$) and in the Näätämöjoki River (Cu, $p<0,05$).

Overall river bed contamination of the Kola River varied spatially and showed a general trend of increase towards the Kola River estuary (K12) for Al, Cd, Co, Fe, Pb and Zn. This suggest pollution load from local sources, such as waste water treatment facilities and agricultural enterprises along the lower course of the river, and air pollutants, e.g. traffic emissions near densely populated and industrialized areas to cause accumulation of these elements. Other group of metals, As, Ba, Cu, Mn, Mo and Ni, showed highest concentrations in the upper river section (K2), relatively low concentrations in the middle parts of the Kola (K3, K5, K6, K8) and enhanced concentrations again in

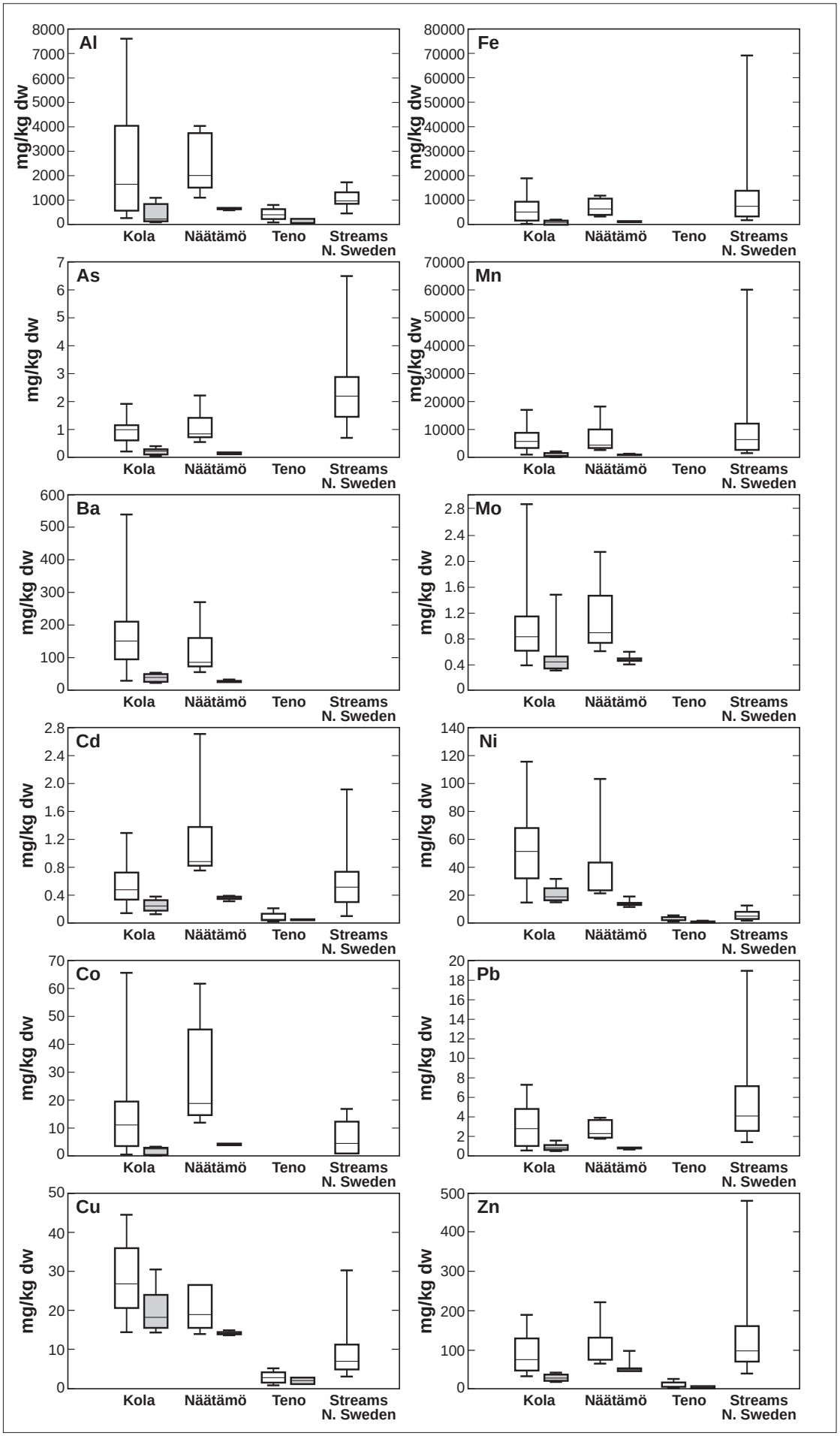

Fig. 74. Median metal concentrations in whole (open boxes) and terminal shoots (filled boxes) of bryophytes in the Kola River and the references sites: the Näätämöjoki River, the Tenojoki River (data from Hämäläinen et al. 1996) and the streams draining woodland in northern Sweden (data from Alm et al. 1999). Boxes represent 25% percentiles and whiskers 5% percentiles.

the lower river section (K11, K12). The sources of these metals in the estuary part are supposed to be much the same as above, but in the headwaters the role of airborn emissions and waste waters from the minig industry can not be neglected (see also Pekka et al. 2007).

Metal concentrations in the Varlamov Creek (K10a) were much higher than in the Kola River and the reference data. The creek contained high concentrations of Al, Ba, Co, Fe, Mn, Ni, Pb and Zn. Also concentrations of many physical and chemical elements (e.g. conductivity, nitrogen and phosphorus compounds) in the Varlamov Creek, loaded with nutrient rich waste waters, were many times higher than in the Kola River itself, which most propably have an affect to metal accumulation rate of the water mosses growing in the creek. However, due to low water discharge of the Varlamov Creek (about 1% of the Kola River discharge), as well the metal concentrations as those of other elements are powerfully dilutated in the main flow.

The increase of metal concentrations in the lower part of the Kola River basin is affected by diverse factors. Location of the site K12 in the city of Kola, close to a road with heavy traffic and a railway line, together with other possible domestic and industrial sources of pollutants, has most likely increased metal contamination in the estuary part of the river. As described by various authors (e.g. Bengtsson and Lithner 1981; Mouvet et al. 1993; Philips and Rainbow 1993; Claveri et al. 1995; Cenci 2000), mosses are found to represent real integrators of element concentrations in water, as high accumulation velocity of moss tissues record every variation, also those between water sampling periods. Elevated metal levels at the estuary may reveal past or present exposure of the mosses to unknown sources of local contamination. Occasional influences from the agriculturally polluted creeks Varlamov (K10a), Medvegiy (K10b) and Zemlanoy (K10c), all flowing to the Kola River upstream site K11, cannot be excluded.

Furthermore, the possible higher bioaccumulation factor of the bryophyte species *Hygrohypnum ochraceum* (sampled at sites K10a, K11 and K12) relative to *Fontinalis* species (K2–K8) may to some extent contribute to the increased metal accumulation at these sites. Specific differences in metal accumulation capacity of these species are not known. Differencies in the morphology of moss leaflets, cell wall composition and ratio of stemm and branch tissue to leaf tissue can affect the metal accumulation capacity of aquatic bryophytes (Glime 1992, Bleuel et al. 2005). Although abilities and sesitivities differ, all the bryophyte taxa are good accumulators of heavy metals (Glime 1992). As single species does not always grow, or is not abundant enough for sampling, throughout the survey area, many pollution surveys with aquatic bryophytes include more than one species (Say et al. 1981, Samecka-Cymerman and Kempers 1998, Vanderpoorten 1999, Nimis et al. 2002, Samecka-Cymerman et al. 2002).

Relatively high values of many metals in the Näätämöjoki River (N5) might indicate potential impact of air pollutants at this site or specific geological features in the area. Sampling site N5 in the Näätämöjoki River is located only about 30–60 km northwest from mining industries in Kirkenes (Norway), Nikel and Zapolarnyj (Russia). However, earlier study on stream waters of this area (de Caritat et al. 1996), did not reveal any major signs of industrial metal contamination close to Näätämöjoki River basin. This, together with the absence of local pollution sources, makes us presume that for instance Al and Mo concentrations of our site N5 are not likely the result of anthropogenic pollution but may rather be attributed to a natural, geogenic source.

In conclusion, the results indicate clear elevation of Cu and Ni concentrations in the riffle habitats of the Kola River as compared with concentrations in aquatic bryophytes in the reference rivers. This corresponds well with the obtained hydrochemical results (Pekka and Öhlander 2003; Pekka et al. 2004) and reflects e.g. airborn emissions of extensive Cu and Ni mining and smelting in the region (Reimann et al. 1998; Dauvalter et al. 2000). Levels of Al, Cd and Zn were also elevated in the Kola River when compared to the Tenojoki River, but were lower or in the same level as in the Näätämöjoki River. No certain conclusion could be drawn on the contamination degree by these elements.

Our data suggests both evaluation methods, measuring heavy metal concentrations in water and in bryophytes to reflect the degree of pollution in the very same scale. Significant correlations between metals in the moss and water samples were found, both for dissolved and suspended phase of elements in water, respectively. However, various authors describe isolated water analyses to be inefficient for the detection of an overall pollution situations over a given period. Peak values from short-term pollution on individual sites can not always be detected by water analyses afterwards (e.g. Bruns et al. 1997). Based on findings of rather tolerable metal contamination situation in the Kola River, further monitoring of the degree of pollution degree in the Kola River may not require constant heavy metal analyses of water, but could

be substituted by temporally widely spaced moss sampling. Accurate sources and reasons for the metal-specific differences between sampling sites as well as possible differencies in metal accumulation rate of various moss species should be clarified in future studies.

4.6

River Habitat Survey (RHS)

Assessment of the hydromorphological states of the Kola River and the Näätämöjoki River is based on the RHS results and Water Framework Directive's (WFD) verbal classification of the ecological state of the river, although there are no precise classifications or definitions for the classes available. However, the high hydromorphological status is determined precisely in WFD: there should be totally or almost totally undisturbed conditions for quality and dynamics of flow including groundwater connectivity, river continuity with free migration of biota and sediments and morphology counting channel pattern, width, depth, flow velocity, substrate, and conditions of the riparian zone (Directive 2000/60/EC). More superficially determined classes of hydromorphological status, good and moderate, are referring to predominant conditions that do not interfere achievement of a given level of biological quality characters, which take into consideration macrophytes, phytobenthos, phytoplankton, benthic invertebrates, and fishes (Directive 2000/60/EC).

The overall hydromorphological state of the Kola River was good. Many survey sites were surrounded by forest and there was variety in flow types, channel vegetation, channel substrates and bank vegetation structure. River continuity was undisturbed in all study sections as well as the groundwater connectivity, except for some reinforced bank sections. Channel depth, width and pattern, and the migration of both biota and sediments were all undisturbed in every section. Flow velocity, quality, and dynamics were also undisturbed. In some of the survey sites, the riparian zone was influenced by human impact because of close settlement or other infrastructure. As the WFD has not defined the extent of the riparian zone so it had to be subjectively estimated by the surveyors.

The hydromorphological state of the Näätämöjoki River was good or even high throughout the whole river length. At all the survey sites, there was variety in the categories of flow types, channel vegetation, channel substrate and trees. In addition, forests surrounded the riparian zones at all the sites. Man-made modifications were almost completely absent from the river. The WFD's required features and factors were all undisturbed: river continuity, groundwater connectivity, channel depth and width, migration of biota and sediments, flow velocity, quality and dynamics and riparian zone. Modest trampling of the river banks was detected, but otherwise the river was undisturbed. There were no major differences between different survey sites.

The Kola River did very well in comparison with the Näätämöjoki River. The states of the rivers were quite equal down to the site K8 in the Kola River. However, human impact along the Kola River was much more substantial than in the reference river. The hydromorphological state of the Kola River declined constantly downstream the river because of more extensive human impact. High hydromorphological status was observed in the upper course and moderate status in the lower course of the river. The sites having moderate status were characterised by reinforced bank sections or settlement close to the river in the riparian zone. Absence or isolated sections of forest along the riparian zone was also typical to the sites with moderate status. Sites with high status had extensive forests along the riparian zone and were free from any man-made modifications.

At the time of the RHS studies, the water level varied within the normal scale in the Kola River, considering the time of year. However, in July 2001, the water level was lower than in July 2002. Raven et al. (1998b) point out that the RHS should not be carried out during high or flood flows because many in-stream features become invisible. A lowered water level can also affect the results, as some features are more visible at the time of the lower water level. Also the boundaries of bankface, bankfull and banktop vary depending on the water level. Therefore, it is reasonable to expect that differences in the water level may have created a bias in the results. The low water level may have affected several HQA categories, whereas influence on the HMS scores is not so obvious. For example, the RHS-study in 2001 reported point bars in the Kola River, whereas in July 2002 no evidence of point bars was found.

Subjective choice of survey sites almost certainly creates bias into the estimation of parameters. Still, the results of the Kola River and the Näätämöjoki River were compared only with each other, not with the whole RHS database. Therefore, the possible bias caused by subjective survey site selection is decreased in the results.

4.6.1

RHS as an assessment method and its applicability to northern rivers

The RHS results can be divided into HQA and HMS scores. The previous is a measure of habitat quality and the latter represents man-made modifications. The RHS results do not directly give an estimation of the hydromorphological state of a river. For example, the HQA scores can be high, indicating good habitat quality, but at same time, the HMS scores can also be high as was the case in the site K11b in the Kola River. Determining the hydromorphological state is based on the RHS results, the EU's Water Framework Directive (Directive 2000/60/EC) and the EU standards for assessing the hydromorphological characteristics of rivers. The hydromorphological estimation of the Kola River was primarily carried out by comparing the results from the Kola River and the Näätämöjoki River. In the second phase, the estimation was specified by joining together two different RHS studies on the Kola River. Doing this removed some of the possible error factors, such as differences in the water level and subjectivity of the surveyors. Altogether, the results from the RHS together with the guidelines of the WFD and the EU standards gave quite a good estimation of the hydromorphological state of the rivers in this study.

The HQA and the HMS calculations were carried out using only a small portion of the available information from the recording forms (Appendix 2). Sections A, B, C, L, N, O, P, and Q were totally neglected from the calculations. In addition, only certain features of some sections were taken into account. For example, three features (broadleaf woodland, moorland, and wetland) out of 13 were included in the calculations in section H. The calculator was designed so that some features, for instance in sections G and K, were joined together in order to simplify the calculations. Too broad generalizations may minimise the creditability of the calculations. The recording form may need simplifying and joining together of different features, whereas the HQA/HMS calculator has perhaps been developed to be too simple.

The RHS system concentrates largely on the existence of forests. Trees and forest are the main contributory factors in the scores in three HQA categories. Sites with extensive woodland along the riverbanks get the best HQA scores. However, treeless environments can also have a high biodiversity, and some species live only in such environments. Therefore, in the question of biodiversity, methods developed to determine diversity in nature should be used along with the RHS method.

A great amount of 'not visible' scores decreases the HQA score. This was also seen in the RSH-study of the year 2001 in the Kola River. In some categories, the HQA score calculator (Environment Agency 1999) punished perhaps too heavily from the 'not visible' scores, for instance in the bank vegetation structure category. The best way to avoid the visibility problems in the HQA scores is to survey both riverbank sides. On the other hand, that would be time-consuming and increase expenses. In this study, the field survey was carried out only from one riverbank at each survey site.

The RHS method has been developed for the rivers in the United Kingdom (Raven et al. 1998b). Due to biogeographical reasons, the northern environment differs greatly from the Central European one. Therefore, it was impossible to use the existing RHS database for comparison. The database has to be adapted to the local conditions so that it is reliable to use it outside the United Kingdom. Hundreds or even thousands of survey sites need to be assessed in order to achieve a database with enough reference material. Hanski (2000) criticizes strongly that the adaptation of the RHS to the northern environment would require a lot of resources and hundreds of field surveys. Extensive field surveys in northern rivers are rather difficult to carry out because of the difficult terrain, long distances and the freezing of rivers in the winter. It is also pointed out that especially in Finland, rivers are divided geographically in different types. Therefore, it would be natural to begin from a system that is based on grouping, since the RHS system does not recognize the grouping of rivers. RHS can be considered more a mapping than an assessing method, as all the information on a river and its surroundings is recorded and database serves also other purposes than only hydromorphological assessment. However, carrying out field surveys in the extent needed for the RHS is quite difficult in northern terrain. Using maps and available geographical information systems (GIS) is rather essential in field surveys.

Certain features in the RHS forms would have to be adapted in order to be suitable for the northern environment. Forests and mires dominate the northern landscape. The land use categories should include a broader selection of different forest types. Also the mire types would need some specification in various sections in order to suit the northern environment. Clear felling and peat mining should also be added to the modification categories. Also ditches and drains, which are characteristic of the northern landscape, are missing from the forms. Moreover, different nuisance

plant species grow in the northern environment than in Central Europe.

The following differences occur when a river assessment method developed in Central Europe is adapted to the northern environmental conditions. First of all, fluvial processes are much slower in the northern environment compared to those in Central Europe. This decreases the scores even in pristine rivers. Secondly, the theory of the river continuum does not quite fit the northern rivers. The third difference is that humic compounds darken the river waters in wide areas in northern Fennoscandia. Visibility suffers greatly from this, and most assessment methods of RHS require good visibility. Another matter is different man-made modification features that are missing from the Central European classification systems. Eutrophication is an example of a common problem in the northern rivers. Freezing of rivers in the winter also creates a problem, when conducting field surveys is limited to a couple of months in a year (Hanski 2000).

Assessing the hydromorphological characteristics of rivers is quite a new task in northern areas. Only a few studies have been carried out in practise. Hanski (2000) has successfully compared different assessment methods, but more practical knowledge is needed in order to choose the most suitable method for the northern environment. Moreover, the WFD obligates to develop and bring into use assessment methods, with which all types of European rivers can be assessed. It is important that the developing work is done in co-operation with the environmental authorities in European countries because the methods have to be comparable. At the moment, the most burning issue is to gather practical information, mostly by field surveys, on different European assessment methods and on different areas so that the most suitable methods for the general use are found.

4.7

Plankton and macrozoobenthos after federal Russian monitoring methods

According to different plankton parameters, the water quality of the Kola River was good in the upper part of the river, varied from good to moderately polluted in the middle section and was moderately polluted in the estuary section. The observed changes are partly consequences of natural phenomena, like for example the effects of the Lake Kolozero to the species composition of the Kola springs (K2). Judging from plankton and macrobenthos grabsamples the species composition varied between sampling points but can generally be characterized to be fairly diverse, but clearly affected by anthropogenic influences. Slight eutrophication of the river area near the Molochny village (K11) is visible by an increase in some quantitative parameters for the microflora and zooplankton, as well as by the dominance of *Cyanophyta, Euglenophyta* and *Chlorophyta* in the phytoplankton. According to results from plankton and macroinvertebrate samples Lake Kolozero can be considered to be moderately polluted. While the plankton community is relativelty stable it is dominated by β-saprobic indicators. The benthic community is dominated by *Oligochaeta* and oxiphilic indicator species are absent

The benthic community is in moderately good condition in the upper parts of the Kola River. Downstream of the village of Shongui (K8) and at the river estuary (K12) human impact is visible, which can be observed in strong changes in the benthic community.

The Kitsa River (K4) water can be considered to be clean and having a high ecological status. Levels of bacterioplankton are low, the community is diverse and typical of that of a natural water body.

The quality of the tributaries, Varlamov (K10a), Medvegiy (K10b) and Zemlanoy (K10c), ranged from moderately polluted to polluted. At these study sites, the total number plankton species was low, but saprophyte bacterioplankton attained high cell counts. The river sections below these heavily polluted tributaries were also dominated with pollution tolerant species. The extensive nutrient loading also triggered mass development of *Chlorophyta* at the Kola River estuary (K12). During this study the obvious adverse effects of the creeks Medvegiy and Zemlanoy on water quality were noticeable only in the immediate vicinity of their confluence to the main river. This is likely to result from the low discharge of these streams to the main river at the time of the study which enabled quick dilution of the organically polluted waters.

The water of the Näätämöjoki River can be considered as clean. The community was characterized by low levels of microflora, and low biomass and abundance of plankton and zoobenthos. This is explained by the oligotrophic conditions of the river which caused low species abundance for all organisms. Oligosaprobic indicator species predominated in the plankton. Due to the high diversity of clean water indicator species the communities of the River Näätämojoki were similar to those of the upper sections of the Kola River water course (especially K2).

5 Conclusions

5.1

Ecological state of the Kola River

The Kola River can be divided into three separate areas according to its ecological status.

1. The ecological status of the Kola springs (K2) and the Kola River, Taibola (K3), ranged from good to moderate. The main problems in these river sections were slightly elevated nutrient concentrations, and metal concentrations both in the water and in the bryophytes. This uppermost section of the drainage basin was affected by the two nearby lakes (Lake Kolozero and Lake Pulozero). The observed changes in water quality are thus at least partly natural, as the lake outlets are usually richer in nutrients than the downstream sections of the same river. However, the lakes also received diffuse pollution loading from their drainage basins, which probably also increased mineral and metal concentrations in their outlets. Most of the wastewaters entering the Lake Kolozero originated, however, from the mining industry of Olenogorsk. Here both the terminal tips and the whole shoots of aquatic bryophytes displayed elevated levels of Cu and Ni, indicating significant metal loading in the area.
2. The ecological status of the mid-section (K4–K8) of the Kola River basin ranged from good to high. The Kitsa River estuary (K4) was assessed to be nearly pristine. No other major human impacts than a slight increase in nutrient concentrations indicated by the diatom community were discernible, and the overall conditions of the mid-section corresponded to those of the reference river. The metal levels in bryophytes in this area were equal to or even below the levels encountered in the Näätämöjoki River.
3. The estuary section (K9–K12) of the Kola River represented the lowest ecological status in the area. The ecological status of the three tributaries (the creeks Varlamov, Medvegiy and Zemlanoy) was poor, and that in the main channel only moderate. By hydrochemical analyses the environmental impacts of nutrient and organic matter loading from poultry, cattle, and fur farms were clearly observed in the tributaries, but only in a small, restricted area in the river main channel. The results of the biological methods, however, indicated that the environmental tolerance of the river biota in the river main channel downstream the tributaries had been exceeded. This detrimental change can pose serious instantaneous problems to the drinking water intake in the future.

There was a gradual increase in the metal concentrations in the river channel from the sampling points K10a towards the estuary. The environmental impacts of the metal loading were quite small in the river headwaters (especially in water quality monitoring), but because of accumulation, however, higher at the mouth and estuary areas of the river.

5.2

Impacts of pollution on the biota

Species composition is the result of the effect of different environmental variables; on large scales regional geographic characteristics set its general boundaries on large scales, whereas on local scales it is determined mainly by the characteristics of the local environment. An important local environmental variable affecting species composition is the pollutant loading. In the Kola River basin its effects can be seen particularly in the upper and estuary sections of the river. On the other hand, the middle section represents the cleanest section of the river. Here unpolluted water from the pristine tributaries flows to the main channel, and the

human impacts are small. Species composition occurring in the middle river section can be supposed to represent largely the natural ecological status of the Kola River.

As a whole, the biota of the Kola River represents typical northern river fauna and flora. The fish, diatom, macrophyte, and macroinvertebrate species found in the river are found also in other northern fluvial communities. The nutrient and organic loading has, however, clear impacts on the composition of the river biota in the river estuary section, especially in the Varlamov, Medvegiy and Zemlanoy creeks. This can be seen as a decreased number of species, mass production of certain algae species, dominance of pollution-tolerating species, and as a lack of benthic macroinvertebrates. The high nutrient loading imposed to the river did not, however, change the biota of the main channel as strongly as expected in this northern river. There was, however, a noticeable decrease in the ecological status of the river main channel.

Even in pristine lotic environments, nutrients tend to increase towards the estuary. In the Kola River, this effect is accelerated by the human impacts at the upper sections of the river basin. Even so, the abundance of species indicating nutrient pollution at the river mouth increased only slightly. An increase in nutrient concentrations is likely to be reflected by an increase in the biodiversity especially in naturally oligotrophic environments. In the Kola River this was observed clearly in the diatom communities, but the macrophytes indicated less plant species at sites with highest anthropogenic nutrient loading. Although no man-induced alterations in the abundance and composition of the fish communities were seen in this study, there is a strong possibility that eutrophication has enhanced the growth of salmonid juveniles to some extent in the river, where salmon parr is reported to have high growth rates in between-river comparisons (Jensen et al. 1997). Oxygen depletion, which is a common consequence of eutrophication, was far from the critical level in the river and even in the creeks loaded highly by nutrients. However, it is probable that the oxygen conditions are weaker during the ice-covered periods in the winter.

5.3 Comparison of the biological methods

In the Kola Water Quality Project, several hydrobiological methods were used to assess the ecological status of the Kola River. The ecological status assessment was carried out using the reference conditions under the Water Framework Directive (WFD) (Directive 2000/60/EC). Plankton and macrozoobenthos were analyzed by standardized methods in Russia within the general water pollution control programme of the Murmansk Areal Department for Hydrometeorology and Environmental Monitoring (MUGMS). The analyses of fish populations, benthic macroinvertebrates, diatoms, and macrophytes, the biological groups recommended for the ecological status assessment of rivers in the WFD, were done by stadardized/generally approved methods in the North Ostrobothnia Regional Environment Centre (NOREC). The aquatic bryophyte studies and the River Habitat Survey were used as special monitoring methods to evaluate the environmental impacts of the metal loading in the area and the hydromorphological status of the river. The scores used for the ecological classification of waterbodies differ between Finland and Russia. In Finland, five classes are commonly used whereas in Russia, the classification of surface waters has six classes. This created slight difficulties when comparing the results.

The work done by the MUGMS's included also methods planned to monitor the special problems identified in the Kola River, such as assessing the oil products, phenolic and sulphuric compounds as well as estimating the general level of pollution, and the work done by the NOREC estimation of the environmental impacts of the long- and short-term metal loading, habitat alterations, acidification, organic matter and nutrient loading.

All the biomonitoring methods showed similar patterns in the ecological status of the Kola River system. Good correlations between the pollutant concentrations in the river water and the results of the different biological methods were also found.

Analyses of aquatic bryophytes, benthic diatoms and macroinvertebrates gave detailed information about the effects of the pollution loading, and the rate of sensitivity of these methods to the changes in water quality was good. Advantages of the MUGMS's zoobenthos and plankton methods were the simplicity of the field sampling (one sample/site) and the taxonomic definitions, which make the methods cost-efficient. The diversity of the species composition in the samples remains, however, low.

Several replicate samples were taken during NOREC's sampling of benthic macroinvertebrates, diatoms and fish. In order to assess the effectivity of these sampling strategies for benthic macroinvertebrates, Meissner (2002) made a species area curve approach for the entire autumn data from the river. The results of this study indicated that eight replicate Surber samples account only for

about 60 ± 5% of the actual number of benthic macroinvertebrate species (Meissner 2002), whereas one Surber sample for only 20 ± 5%. Considering, that the sampling area of one Surber frame is about 3 times larger than that of the grab used by the MUGMS for benthic sampling, the efficiency of the MUGMS sampling strategy, with one sample from a point, is probably even lower. This probably drastically decreases the sensitivity of the method to detect especially the low level changes in macroinvertebrate populations caused by the pollution. Replicate sampling seems to be of paramount importance in biological monitoring, irrespective of the method in question.

The methods standardized in Russia for bacterio-, phyto-, and zooplankton and for zoobenthos are most effective in still waters with soft substratum. In the Kola River, as generally in the riverine environment, especially high flow velocities are problematic for the use of these methods. Also the stony substratum of the Kola River causes difficulties in zoobenthos sampling by the bottom-grab. On the other hand, there in the Kola River are also natural, not pollutant induced, changes in the plankton populations of the area. The effect of these changes on the plankton populations should be studied further. One of these changes is the natural decrease in the species abundance in the plankton downstream from the lake outlets. It is generally known that plankton species caught in drift samples from lake outlets are often mainly of lentic origin, and the density of the really lotic plankton species is low. This causes natural decreases in the species abundance of the plankton downstream from the lake outlets.

5.4

Usability of the different biological methods used in the northern river systems

The results indicate that all the biological methods used in this project are appropriate also in northern rivers even though most of them have been developed in the temperate latitudes. Different levels of nutrient pollution were fairly well recognized, and especially the effects of organic loading were clearly detected.

However, some further development of the methods to the northern environments is still needed. The sensitivity of the MUGMS's zoobenthos method could be drastically increased by taking replicate samples or by using the Surber sampler in riffles. The accuracy of the estimates of plankton species diversity would also greatly benefit by the use of more extensive sampling. There are still also development needs of the monitoring methods to suit better in the northern environment. The use of indices developed e.g. for the temperate regions may lead to misinterpretation when applied directly to the artic conditions. A multitude of northern river systems should be investigated to get better ideas of the variance of the different biotic groups according to the characteristics of the water bodies. It is probable that there are changes in the biogeochemical processes with geographic location, e.g. with latitude. These changes effect species distribution especially in river ecosystems that are dependent on the organic and inorganic matter transport from the soil ecosystems of their drainage basins.

The River Habitat Survey (RHS) is an excellent example of a method that needs further improvement for the northern environment. It has been initially developed for the temperate zone, which differs greatly from the northern boreal and artic. For example, a broader selection of land use categories than is currently included in the RHS would be needed to gain reliable results in the the boreal and arctic environments, where forest and mires are dominating landscapes in the drainage basins. In addition many general forms of land use in the northern environment, like clear cutting and peatland drainage within forestry, and also peat production, are not yet adequately represented in the RHS, and should be included. It can be supposed that the usability the different methods used in the river status assessment improves, when there is knowledge enough to design the survey taking into account the specific features of the target area (Appendix 22).

6 Summary

Ecological state of the Kola River, northwestern Russia, based on extensive biological data gathered in 2001–2002, was assessed by the Kola Water Quality project. One of the main objectives of the project was river status identification. Biological assessment methods conducted by the North Ostrobothnia Regional Environment Centre (NOREC, Finland) included studies on macroninvertebrates, fish, diatoms, hydromorphological state of the river, metal concentrations in aquatic bryophytes and a macrophyte survey. The Murmansk Areal Department for Hydrometeorology and Environmental Monitoring (MUGMS, Russia) carried out studies on bacterio-, phyto- and zooplankton as well as on macrozoobenthos, using methods of federal hydrobiological monitoring in Russia. The Näätämöjoki River in the northernmost Finland and Norway served as a reference area to the Kola River. There were 13 sampling sites at the Kola River basin and 5 at the Näätämöjoki River basin.

The results of the benthic macroinvertebrate survey indicated that the river main channel (including K4, the Kitsa River) is in lightly polluted, acceptable or good condition and for the most part comparable in quality to the oligotrophic Näätämöjoki River, which is in pristine condition. The average site scores for the BMWP index generally indicated good or acceptable state in the river main channel. However, the state of the small creeks at the lower courses of the river was weaker. The Creeks Medvegiy (K10b) and Varlamov (K10a) were classified even as heavily polluted areas. At the river estuary (K12) the macroinvertebrate communities indicated moderate pollution.

Both study rivers, Kola and Näätämöjoki, had a low number of fish species. The fish species present in the electrofishing catches represented typical northern fluvial fish communities. All the species caught were native. The abundance and composition of the fish communities did not show any man-induced alterations. Normal age structure of Atlantic salmon, brown trout, and minnow populations revealed no recruitment failures either. The spatial distribution of these three indicator species was also even in the whole study area.

According to the diatom community analyses, the state of the Kola River was basically good or excellent. However, a clear drop in the state could be seen in the creeks Varlamov (K10a) and Medvegiy (K10b) at the lower part of the river basin, and also in the main channel below these creeks (sites K11 and K12). The amount of different pollution tolerant diatom species strongly increased at the lower courses of the river. Environmental impacts of organic loading seemed to be highest in the estuary section, emphasizing the role of the loading from the polluted creeks to the area. Signs of pollutant loading, somewhat elevated trophic conditions, could also be seen at the upper river sections (K2, K3).

The total number of plant species observed at the Kola River was 173, of which 168 species were found on the river margins and 34 species within the channel. The number of species was lower at the Näätämöjoki River, where the total number of species was 115; 112 species at the river margins and 12 within the channel. One probable reason for the difference between the rivers is that more sites were surveyed in the Kola River than in the Näätämöjoki River. The ecological quality rate calculations based both on all macrophyte species and typical macrophyte species (i.e. species occurring at least in half of the reference rivers) suggested that the Kola River has a high ecological status. But when the macrophyte data was restricted only to the aquatic or amphibious species, the ecological status of the river varied from moderate to good. The EQR values of the Näätämöjoki River were clearly lower than those of the Kola River. This could be mainly due to the naturally harsh climatic and edaphic factors that decrease the species richness in this northern river.

The bryophyte studies indicated clearly elevated Cu and Ni concentrations in the riffles of the Kola River. Most other metal concentrations in the bryophytes from the Kola River were similar to or lower than those in the relatively pollutant-free reference rivers. On the other hand, bryophytes from the headwaters of the Kola River (K2), close to the minig areas, showed also Ba and Mo concentrations that were twice as high as in the Näätämöjoki River. Likewise, Al, Cu, Fe, Ni and Pb concentrations in the mosses from the estuary of the Kola River (K12) were higher than those in the Näätämöjoki River. Levels of Al, Cd and Zn in the Kola River were also elevated when they were compared to the results from the Tenojoki River, but, however, lower or at the same level than those in the Näätämöjoki River. The results indicate that no clear conclusions of the contamination degree

can be drawn on the basis of these elements. In the Varlamov Creek (K10a) the metal concentrations were much higher than in the Kola River and in the reference rivers. The creek contained high concentrations of Al, Ba, Co, Fe, Mn, Ni, Pb and Zn. The results suggested both measuring heavy metal concentrations in water and in bryophytes to reflect the degree of pollution in the very same scale. Significant correlations between the metal concentrations in mosses and water samples were found, both for dissolved and suspended phase of elements in water, respectively.

The overall hydromorphological state of the Kola River was good. Many survey sites were surrounded by forests and there was variety in flow types, channel vegetation, channel substrates and bank vegetation structure. River continuity was undisturbed in all the sections studied, as well as the groundwater connectivity, except for some reinforced bank sections. Channel depth, width and pattern, and the migration of both biota and sediments were all undisturbed in every section. Flow velocity, quality, and dynamics were also undisturbed. In some of the survey sites, the riparian zone showed anthropogenic impacts mainly because of close settlement or other infrastructure. To sum up the results of the Habitat Quality Assessment (HQA) in the River Habitat Survey (RHS) at the Kola River, one could divide the river in two parts. The first part consist of sites at the upper courses of the river (K2–K7), where the HQA scores are high. The second part consists of sites at the lower courses (K8–K12) with in general lower HQA scores. There were almost no anthropogenic impacts at the upper half of the survey sites. In terms of hyrdomorphology, most of the survey sites at the Kola River could be classified as pristine or semi-natural. Only two sites, K11B and K12, were classified as predominantly unmodified. The RHS results differed slightly between the two rivers, Kola and Näätämöjoki. The hydromorphological state of the Kola River was somewhat weaker than that of the Näätämöjoki River. The hydromorphological state of the Näätämöjoki River was good or even high throughout the whole river length. Näätämöjoki flows far away from continuous human disturbances, and man-made modifications on the channel are modest along the hole length of the river.

Bacterio-, phyto- and zooplankton surveys showed the state of the Kola River to be good in the upper river sections, to range from good to moderately polluted in the middle section and to be moderately polluted in the river estuary. According to the different plankton and zoobenthos parameters used in this study the reference area, the Näätämöjoki River, is in a pristine condition. At the Kola River, the species composition varied from a sampling point to another. Slight symptoms of eutrophication, increases in quantitative parameters of microflora and zooplankton as well as dominance of phytoplankton species tolerating trophic conditions, were detected at the site K11. On the whole, based on the results of bacterio-, phyto- and zooplankton studies, no major anthropogenic alterations could be seen in the Kola River main channel. On the other hand, the state of the tributaries, Varlamov (K10a), Medvegiy (K10b) and Zemlanoy (K10c), ranged from moderately polluted to polluted. The total number of plankton species at these sites was low, but saprophytic bacterioplankton attained high cell counts. The river sections below these heavily polluted tributaries were also dominated with pollution tolerant species. Results of the macrozoobenthos studies according to federal Russian monitoring methods indicated the status of benthofauna in the Kola River to be moderately favourable in the upper river sections. The effect of anthropogenic impacts on zoobenthos communities could be seen in the lower Kola River section.

7 Резюме

Экологическое состояние реки Колы (Северо-Западная Россия) было оценено на основании большого количества биологических данных, собранных в 2001-2002 годах. Определение экологического состояния реки было одной из главных целей проекта по изучению качества воды реки Колы в 2000-2004 годах. Биологические методы оценки, применяемые региональным центром окружающей среды Северной Эстерботнии (NOREC, Финляндия), включали исследование макробеспозвоночных, рыб, диатомовых водорослей, гидроморфологического состояния реки, концентрации металлов в гидробриофитах и исследование макрофитов.

Управление по гидрометеорологии и мониторингу окружающей среды Мурманской области (MUGMS, Россия) выполнило исследования бактерио-, фито- и зоопланктона, так же как и макрозообентоса, используя методы, стандартизированные в России. Река Наатамёйоки в северной Финляндии и Норвегии использовалась в качестве фоновой для реки Колы. На реке Коле отбор проб проводился в 13 точках, на реке Наатамёйоки – в 5 точках.

Результаты исследования NOREC бентосных макробеспозвоночных показали, что главное русло реки Колы (включая K4, река Кица) находится в слегка загрязненном, удовлетворительном или хорошем состоянии и, в целом, сопоставимо по качеству с олиготрофной рекой Наатамёйоки, неподверженной прямому антропогенному воздействию. Средние значения индекса BMWP в точках отбора проб указывали, в целом, на хорошее или удовлетворительное качество воды в основном русле реки Колы. Однако качество воды в малых притоках в нижних участках течения оставляет желать лучшего. Притоки Медвежий (K10b) и Варламов (K10a) классифицированы как сильно загрязненные. Сообщества макробеспозвоночных в устье реки Колы (K12) показали умеренное загрязнение вод.

В исследуемых реках, - Кола и Наатамёйоки - обнаружено низкое видовое разнообразие рыб. В уловах, выполненных методом электролова, были представлены типичные для северных речных сообществ виды. Все они принадлежали к числу местных видов. Плотность популяций и состав рыбных сообществ не показали никаких вызванных человеком изменений ни в одной из исследуемых рек. Обычная возрастная структура популяций атлантического лосося, радужной форели и пескаря также указывает на нормальное восстановление популяций. Распределение этих трех индикаторных видов было также равномерным по всей территории исследования.

Согласно анализу сообществ диатомовых водорослей, качество воды в реке Коле было в основном хорошим или отличным. Однако явное ухудшение качества воды наблюдалось в ручьях Варламов (K10a) и Медвежий (K10b) в нижней части речного бассейна. Это также сказалось на качестве воды главного русла ниже места впадения этих притоков (участки K11 и K12). Количество диатомовых водорослей, устойчивых к разным видам загрязнения воды, увеличилось в нижнем течении реки Колы. Наиболее сильное воздействие органического загрязнения на окружающую среду прослеживается в устьевом участке реки, что указывает на попадание загрязняющих веществ в основное русло из притоков.) Признаки загрязнения были также обнаружены в верхних участках реки Колы (K2, K3), где наблюдалась несколько повышенная трофность вод.

На территории бассейна р. Колы было обнаружено 173 вида растений, из которых 168 видов произростают в прибрежной зоне и 34 вида – непосредственно в русле. Число видов растений на территории бассейна реки Наатамёйоки было ниже: из 115 видов 112 было обнаружено в прибрежной зоне и 12 - непосредственно в русле. Большее видовое разнообразие растений на территории бассейна р. Колы объясняется бóльшим числом исследованных участков. Оценка экологического состояния, основанная на подсчёте как всех видов макрофитов, так и типичных видов макрофитов (то есть видов, наблюдаемых по крайней мере в половине фоновых рек) даёт основания предполагать, что река Кола имеет отличное экологическое состояние. Когда в расчёт принимались только водные или наземные виды макрофитов, то состояние реки Колы изменялось от удовлетворительного до хорошего. Значения EQR для реки Наатамёйоки во всех вычислениях были явно ниже, чем для реки Колы. Хотя состояние фоновых участков на реке Наатамёйоки можно считать естественным, суровые условия и другие локальные факторы могли привести к тому, что количество видов там ниже, чем в реке Коле и других фоновых реках.

Результаты аналитических исследований гид-

робриофитов показали явное повышение концентраций меди и никеля на порожистых участках р. Колы по сравнению с концентрациями этих металлов в гидробриофитах фоновых рек. Концентрации других металлов в гидробриофитах реки Колы были такими же или ниже, чем в относительно незагрязнённых фоновых реках. С другой стороны, концентрации бария (Ba) и молибдена (Mo) в гидробриофитах верховья реки Колы (K2), расположенного недалеко от районов горно-перерабатывающего производства, были в два раза выше, чем в гидробриофитах реки Наатамёйоки. Аналогично, концентрации алюминия (Al), меди (Cu), железа (Fe), никеля (Ni) и свинца (Pb) были выше во мхах в устьевом участке реки Колы (K12), чем в реке Наатамёйоки. Уровни содержания алюминия (Al), кадмия (Cd) и цинка (Zn) оказались повышенными в реке Коле также по сравнению с рекой Тана (the Tenojoki River), но были ниже или соответствовали концентрациям в реке Наатамёйоки. Определенного вывода о степени загрязнения этими элементами сделать невозможно. Концентрации металлов в притоке Варламов ручей (K10a) были намного выше, чем в фоновой реке и в реке Коле. В воде ручья отмечались высокие концентрации Al, Ba, кобальта (Co), Fe, марганца (Mn), Ni, Pb и Zn. В рамках данного исследования измерялись концентрации тяжелых металлов как в воде, так и в гидробриофитах для оценки степени загрязнения. Существенная корреляция между концентрациями металлов во мхах и в воде, наблюдалась и по растворенным, и по взвешенным веществам в воде.

Общее гидроморфологическое состояние реки Колы классифицировано как хорошее. Многие участки исследования были окружены лесом, наблюдалось разнообразие типов потоков, растительности водотока, донных отложений и структуры растительности берегов. Непрерывность речного потока сохранилась на всех исследованных участках так же, как и его связь с грунтовыми водами, за исключением некоторых укрепленных участков берега. Глубина, ширина и рельеф русла, а также состояние как биоты, так и донных отложений не были нарушены ни на одном из участков. Скорость течения, динамика русловых процессов были также неизменными. На некоторых из исследуемых участков было обнаружено влияние человеческой деятельности на прибрежную зону вследствие близко расположенных населённых пунктов и других элементов инфраструктуры. По результатам оценки качества среды обитания реку можно разделить на две части: верхнее течение реки (участки K2-K7), где с высоким показателем HQA и нижнее течение (участки K8-K12), где, в целом, показатель HQA ниже. В верхнем течении реки почти не обнаружено антропогенного воздействия Изменения, являющиеся следствием человеческого вмешательства, почти отсутствовали в верхней половине исследованных участков. Большинство исследованных участков на реке Коле было классифицировано как природные или почти неизмененные. Только два участка, K11B и K12, были классифицированы как частично подвергшиеся воздействию. Результаты RHS для рек Колы и Наатамёйоки мало отличались между собой. Гидроморфологическое состояние реки Колы было несколько хуже, чем состояние реки Наатамёйоки. Гидроморфологическое состояние реки Наатамёйоки было хорошим или даже отличным по всей протяженности реки. Наатамёйоки протекает далеко от мест постоянного человеческого вмешательства, и изменения, вызванные человеком, очень невелики на всех участках реки.

Исследования бактерио-, фито- и зоопланктона показали, что качество вод реки Колы хорошее в верхних участках реки, изменяется от хорошего до умеренно загрязненного в среднем участке и является умеренно загрязненным в устье реки. Согласно различным параметрам планктона и зообентоса фоновый район, река Наатамёйоки, находится в незагрязнённом состоянии. В реке Коле видовой состав биоты изменялся в зависимости от места отбора проб. Незначительная эвтрофикация была обнаружена на участке K11. Она выражалась в увеличении количественных параметров микрофлоры и зоопланктона, а также доминировании видов фитопланктона, устойчивых к данным трофическим условиям. В целом, основываясь на данных по бактерио-, фито- и зоопланктону, в главном русле реки Колы не было замечено серьезных изменений антропогенного характера. Качество вод притоков Варламов (K10a), Медвежий (K10b) и Земляной (K10c) изменялось от умеренно загрязненного к загрязненному. На этих участках общее количество видов планктона было низким, но количество клеток сапрофитных бактерий достигало высоких показателей. В речных участках ниже мест впадения этих сильно загрязненных притоков также доминировали виды, устойчивые к сильному загрязнению воды. Результаты исследований макрозообентоса, согласно российским стандартам, показали, что состояние бентофауны в реке Коле является благоприятным в верхнем участке реки. Антропогенное воздействие на донный биоценоз было заметно в сообществах зообентоса в нижнем участке реки Колы.

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Appendix 1

Metric description, status classes and use of different metrics in river status assessment by FIX index (Appelberg et al. 2000).

- Measured values for every metrics are based on the standardised electrofishing results.
- Abundance and biomass are calculated as density or biomass per100 m².
- Altitude (above sea level), flow velocity, stream width at sample site, catchment area and lake proportion are background information needed.
- Only those altitude and flow velocity classes that occurred in this study, are presented below.

1. Number of fish species native to the habitat

Reference value for the metrics (R) is calculated as follows: R = 1.19+0.71 · [log(width)] + 0.419 · [catchment area] + 0.142 · [lake proportion] – 0.0019 · [altitude a.s.l.]. Width and altitude are given in meters. Catchment area and lake proportion classified as below:

Class	Catchment area	Lake proportion
1	< 10 km²	< 1 %
2	< 100 km²	< 5 %
3	< 1000 km²	< 10 %
4	> 1000 km²	> 10 %

Deviation from the reference value is given as measured value divided by reference value.

Final score	Criteria description	Measured value/reference value
1	none, or minor dev. from ref.	≥ 0.85
2	small deviation from ref.	0.70–0.85
3	evident deviation from ref.	0.50–0.70
4	large deviation from ref.	0.50–0.35
5	very large deviation from ref.	< 0.35

2. Biomass (g/100 m²) of fish species native to the habitat

Final score	Criteria description.	0–99 m a.s.l	100–299 m a.s.l
1	none, or minor deviation	≥ 525	≥ 250
2	small deviation	350–525	175–250
3	evident deviation	225–350	100–175
4	large deviation	80–225	35–100
5	very large deviation	< 80	< 35

3. Abundance of fish native to the habitat

Total number of fish log(ind./100 m²); flow regime 0.2 – 0.7 m/s

Final score	Criteria description	0–99 m a.s.l	100–299 m a.s.l
1	no or minor deviation	≥ 1.70	≥ 1.34
2	small deviation	1.50–1.70	1.05–1.34
3	evident deviation	1.24–1.50	0.85–1.05
4	large deviation	0.67–1.24	0.34–0.85
5	very large deviation	< 0.67	< 0.34

4. Proportion biomass of salmonid species in relation to total biomass
Proportion of salmonids (flow velocity 0.2 – 0.7 m/s)

Final score	Criteria description	0–99 m a.s.l	100–299 m a.s.l
1	no or minor deviation	≥ 0.76	≥ 0.62
2	small deviation	0.58–0.76	0.34–0.62
3	evident deviation	0.38–0.58	0.15–0.34
4	large deviation	0.17–0.38	0.05–0.15
5	very large deviation	< 0.17	< 0.05

5. Reproduction of salmonid species native to the habitat
Index can be calculated only at sites where salmonids occur. Number of salmonid species with under-yearlings present is divided by the number of salmonid species without occurrence of under-yearlings.

Final score	Criteria description	Index value
1	none, or minor deviation the reference	1.00
2	small deviation from reference	0.67–1.00
3	evident deviation from reference	0.50–0.67
4	large deviation from reference	0.33–0.50
5	very large deviation from reference	< 0.33

6. Occurrence of acid sensitive fish species and stages

a.) high densities of under-yearlings of brown trout and/or occurrence of under-yearlings of salmon, roach or minnow.
b.) occurrence of cyprinids, gudgeon, stone loach, sturgeon or crayfish and/or occurrence of under-yearlings burbot, grayling or char.
c.) occurrence of bullheads, pike perch, burbot, grayling, char, whitefish, vendace, salmon or eel and/or occurrence of under-yearlings of brown trout or perch.
d.) only occurrence of perch, pike or elder brown trout.
e.) absence of fish species.

Final score	Criteria description	Occurrence of fish species
1	none, or minor deviation from reference	a.)
2	small deviation from reference	b.)
3	evident deviation from reference	c.)
4	large deviation from reference	d.)
5	very large deviation from reference	e.)

7. Proportion biomass of non-native species in relation to total biomass
Index is calculated as biomass proportion of alien species in Sweden to total biomass

Final score	Criteria description	Index value
1	none, or minor deviation the reference	0
2	small deviation from reference	0–0.01
3	evident deviation from reference	0.01–0.02
4	large deviation from reference	0.02–0.05
5	very large deviation from reference	< 0.05

Appendix 2

RIVER HABITAT SURVEY Page 1 of 4

A FIELD SURVEY DETAILS

Site Number : (leave blank) Mid-site Grid Reference/coordinates :

Site Reference :..... Reach Reference :..... River :.....

Date ...../...../20... Time ..... Surveyor name .....

Accredited Surveyor code: .....

Is the site on a river or an artificial channel? River ☐ Artificial ☐

Health and safety assessment completed? Yes ☐

Adverse conditions affecting survey? No ☐ Yes ☐ If yes, state .....

Bed of river visible ? No ☐ partially ☐ entirely ☐ (tick one box)

Duplicate photographs showing general character? Yes ☐ (tick one box)

Site surveyed from : left bank ☐ right bank ☐ channel ☐ (tick as appropriate)

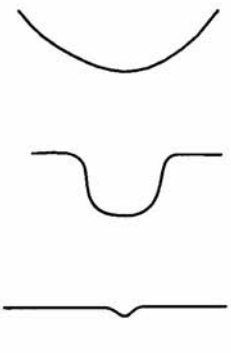
B PREDOMINANT VALLEY FORM (within the horizon limit) (tick one box only)

☐ shallow vee

☐ deep vee

☐ assymetric vee

☐ gorge



☐ concave/bowl

☐ U shape valley

☐ no valley sides obvious

Distinct flat valley bottom? No ☐ Yes ☐ Natural terraces No ☐ Yes ☐ Artificial terraces No ☐ Yes ☐

C NUMBER OF RIFFLES, POOLS AND POINT BARS (indicate total number)

Riffles	Unvegetated point bars
Pools	Vegetated point bars

D ARTIFICIAL FEATURES (indicate total number or tick appropriate box)

None ☐		Major	Intermediate	Minor		Major	Intermediate	Minor
	Weirs				Outfalls			
	Sluices				Fords			
	Culverts				Deflectors/ groynes/croys			
	Bridges				Other (state)			

Is channel realigned? No ☐ Yes, <33% of site ☐ >33% of site ☐

Is water impounded by weir/dam? No ☐ Yes, <33% of site ☐ >33% of site ☐

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RIVER HABITAT SURVEY : TEN SPOT-CHECKS

Spot-check 1 is at : upstream end ☐ downstream end ☐ of site (tick one box)

E PHYSICAL ATTRIBUTES (to be assessed across channel within 1m wide transect)

[1] = one entry only	1	2	3	4	5	6	7	8	9	10	
LEFT BANK	Ring EC or SC if composed of sandy substrate										
Material [1] NV, BE, BO, CO, GS, EA, PE, CL, CC, SP, WP, GA, BR, RR, BW,FA, BI											
Bank modification(s) NK, NO, RS, RI, PC(B), BM, EM											
Marginal feature(s) NV, NO, EC, SC, PB, VP, SB, VS, NB											
CHANNEL	GP- ring either G or P if predominant										
Channel substrate [1] NV, BE, BO, CO, GP, SA, SI, CL, PE, AR											
Flow type [1] FF, CH, BW, UW, CF, RP, UP, SM, NP, DR											
Channel modification(s) NK, NO, CV, RS, RI, DA, FO											
Channel feature(s) NV, NO, RO, MB, VB, MI, TR, VR, EB											
For braided rivers only: number of sub-channels											
RIGHT BANK	Ring EC or SC if composed of sandy substrate										
Material [1] NV, BE, BO, CO, GS, EA, PE, CL, CC, SP, WP, GA, BR, RR, BW,FA,BI											
Bank modification(s) NK, NO, RS, RI, PC(B), BM, EM											
Marginal feature(s) NV, NO, EC, SC, PB, VP, SB, VS,NB											

Enter channel substrates not occurring in spot-checks but present in >1% whole site.

F BANKTOP LAND USE AND VEGETATION STRUCTURE (to be assessed over a 10m wide transect)

Land use : choose one from BL, CP, OR, MH, SC, TH, RP, IG, TL, WL, OW, SU, RS, BP, CW, IL, AW, PG, NK

LAND USE WITHIN 5m OF LEFT BANKTOP										
LEFT BANKTOP (structure within 1m) B/U/S/C/NV										
LEFT BANK FACE (structure) B/U/S/C/NV										
RIGHT BANK FACE (structure) B/U/S/C/NV										
RIGHT BANKTOP (structure within 1m) B/U/S/C/NV										
LAND USE WITHIN 5m OF RIGHT BANKTOP										

G CHANNEL VEGETATION TYPES (to be assessed over a 10m wide transect :use E (≥33% area) or ✓(present) or NV (not visible)

NONE (✓) or Not Visible (NV)											
Liverworts/mosses/lichens											
Emergent broad-leaved herbs											
Emergent reeds/sedges/rushes/grasses											
Floating-leaved (rooted)											
Free-floating											
Amphibious											
Submerged broad-leaved											
Submerged linear-leaved											
Submerged fine-leaved											
Filamentous algae											

Use end column for overall assessment over 500m including types not occurring in spot checks (use E or ✓or NV)

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SITE NO.	RIVER HABITAT SURVEY : 500m SWEEP-UP	Page 3 of 4

H LAND USE WITHIN 50m OF BANKTOP Use E (≥ 33% banklength) or ✓(present)

	L	R		L	R
Broadleaf/mixed woodland semi-natural (BL)			Improved/semi-improved grass (IG)		
Broadleaf/mixed woodland- planted (BP)			Tilled land (TL)		
Coniferous forest semi-natural (CW)			Wetland (eg bog, marsh, fen) (WL)		
Coniferous plantation (CP)			Natural open water (OW)		
Orchard (OR)			Artificial open water (AW)		
Moorland/heath (MH)			Irrigated land (IL)		
Scrub (SC)			Parkland and gardens (PG)		
Tall herbs /rank vegetation (TH)			Suburban/urban development (SU)		
Rough/unimproved grassland/pasture (RP)			Rock, scree and sand dunes (RS)		

I BANK PROFILES Use E (≥ 33% banklength) or ✓(present)

Natural/unmodified	L	R	Artificial/modified	L	R
Vertical/undercut			Resectioned		
Vertical + toe			Reinforced - whole bank		
Steep (>45°)			Reinforced - top only		
Gentle			Reinforced - toe only		
Composite			Artificial berm		
Natural berm			Poached		
			Embanked		
			Set-back embankments		

J EXTENT OF TREES AND ASSOCIATED FEATURES

TREES (tick one box per bank)	Left	Right
None	☐	☐
Isolated/scattered	☐	☐
Regularly spaced, single	☐	☐
Occasional clumps	☐	☐
Semi-continuous	☐	☐
Continuous	☐	☐

ASSOCIATED FEATURES (tick one box per feature)	None	Present	E (≥33%)
Shading of channel	☐	☐	☐
Overhanging boughs	☐	☐	☐
Exposed bankside roots	☐	☐	☐
Underwater tree roots	☐	☐	☐
Fallen trees	☐	☐	☐
Coarse woody debris	☐	☐	☐

K EXTENT OF BANK AND CHANNEL FEATURES (tick one box per feature)

	None	Present	E(≥33%)		None	Present	E (≥33%)
Free fall (Waterfall)	☐	☐	☐	Exposed bedrock	☐	☐	☐
Chute (Cascade)	☐	☐	☐	Exposed boulders	☐	☐	☐
Broken standing waves (Rapid)	☐	☐	☐	Vegetated bedrock	☐	☐	☐
Unbroken standing waves (Riffle)	☐	☐	☐	Unvegetated mid-channel bar(s)	☐	☐	☐
Rippled (Run)	☐	☐	☐	Vegetated mid-channel bar(s)	☐	☐	☐
Upwelling (Boil)	☐	☐	☐	Mature island(s)	☐	☐	☐
Smooth (Glide)	☐	☐	☐	Unvegetated side bar(s)	☐	☐	☐
No perceptible flow (Pool)	☐	☐	☐	Vegetated side bar(s)	☐	☐	☐
No flow (Dry)	☐	☐	☐	Unvegetated point bar(s)	☐	☐	☐
Marginal deadwater	☐	☐	☐	Vegetated point bar(s)	☐	☐	☐
Eroding Cliff	☐	☐	☐	Discrete unvegetated silt deposit(s)	☐	☐	☐
Stable Cliff	☐	☐	☐	Discrete unvegetated sand deposit(s)	☐	☐	☐
				Discrete unvegetated gravel deposit(s)	☐	☐	☐

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RIVER HABITAT SURVEY: DIMENSIONS AND INFLUENCES Page 4 of 4

L CHANNEL DIMENSIONS (to be measured at one location on a straight uniform section, preferably across a riffle)

LEFT BANK		CHANNEL		RIGHT BANK	
Banktop height (m)		Bankfull width (m)		Banktop height (m)	
Is banktop height also bankfull height? (Y or N)		Water width (m)		Is banktop height also bankfull height? (Y or N)	
Embanked height (m)		Water depth (m)		Embanked height (m)	

If trashline is lower than banktop break in slope, indicate: height above water (m) = width (m) =

Bed material at site is: consolidated (compact) ☐ unconsolidated (loose) ☐ unknown ☐

Location of measurement is: riffle ☐ run or glide ☐ other ☐

M FEATURES OF INTEREST use ✓ or E (> 33% length)

None	☐	Leafy debris	☐	Pools	☐	Very large boulders(>1m)	☐
Natural Waterfalls > 5m high	☐	Riffles	☐	Bog	☐	Boulder fields/Boulder berms	☐
Natural Waterfalls < 5m high	☐	Natural Cascades	☐	Carr	☐	Fringing reed-bank	☐
Braided channels	☐	Backwater	☐	Marsh	☐	Floating mat	☐
Side channels	☐	Water meadow	☐	Flush	☐	Sink hole	☐
Debris dams	✓	Fen	☐	Oxbow lakes	☐	Other (state).....	☐

N CHOKED CHANNEL (tick one box)

Is 33% or more of the channel choked with vegetation? No ☐ Yes ☐

O NOTABLE NUISANCE PLANT SPECIES Use ✓ or E (> 33% length)

		bankface/banktop	5-50m banktop		bankface/banktop	5-50m banktop
None ☐	Giant Hogweed	☐	☐	Other (state).....	☐	☐
	Japanese Knotweed	☐	☐	.....	☐	☐
	Himalayan Balsam	☐	☐	.....	☐	☐
	Laurel	☐	☐	.....	☐	☐
	Rhododendron	☐	☐	.....	☐	☐

P OVERALL CHARACTERISTICS (Circle appropriate words, add others as necessary)

Major impacts: landfill - tipping - litter - sewage - pollution - drought - abstraction - mill - dam - road - rail - industry housing - mining - quarrying - overdeepening - afforestation - fisheries management - silting - rice plantation - waterlogging - briglia - sparran - hydroelectric power

Evidence of recent management: dredging - bank-mowing - weed cutting - enhancement - river restoration - rehabilitation - gravel extraction

Animals: otter - mink - water vole - kingfisher - dipper - grey wagtail - sand martin - heron - dragonflies/damselflies

Other significant observations:

Q ALDERS (tick appropriate box(es))

Alders? None ☐ Present ☐ Extensive ☐ Diseased Alders? None ☐ Present ☐ Extensive ☐

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RIVER HABITAT SURVEY: SPOT-CHECK KEY

PHYSICAL ATTRIBUTES (SECTION E)

BANKS

Predominant bank material

NV = not visible

BE = bedrock
BO = boulder
CO = cobble
GS = gravel/sand
EA = earth (crumbly)
PE = peat
CL = sticky clay

CC = concrete
SP = sheet piling
WP = wood piling
GA = gabion
BR = brick/laid stone
RR = rip-rap
BW = builders' waste
FA =fabric
BI = Bio-engineering materials

Bank modifications

NK = not known
NO = none

RS = resectioned
RI = reinforced
PC = poached
PC(B) = poached (bare)
BM = artificial berm
EM = embanked

Bank features

NV = not visible (eg far bank)
NO = none

EC = eroding cliff (ring if sandy substrate)
SC = stable cliff (ring if sandy substrate)

PB = unvegetated point bar
VP = vegetated point bar

SB = unvegetated side bar
VS = vegetated side bar
NB = natural berm

CHANNEL

Predominant substrate

NV = not visible

BE = bedrock
BO = boulder
CO = cobble
GP = gravel/pebble (ring G or P if predominant)
SA = sand
SI = silt/mud
CL = clay
PE = peat
AR = artificial

Predominant flow-type (see below)

FF = freefall
CH = chute
BW = broken standing waves (white-water)
UW = unbroken standing wave
CF = chaotic flow
RP = rippled
UP = upwelling
SM = smooth
NP = no perceptible flow
NO = no flow (dry)

Channel modifications

NK = not known
NO = none

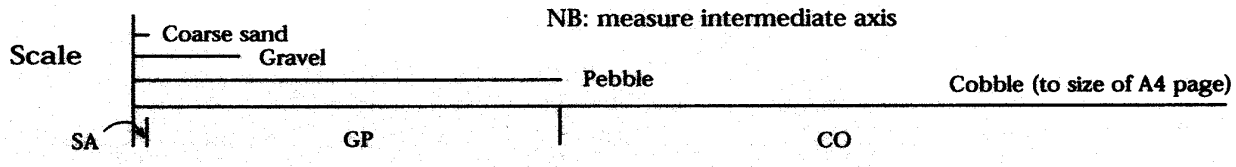
CV = culverted
RS = resectioned
RI = reinforced
DA = dam/weir
FO = ford (man-made)

Channel features

NV = not visible
NO = none

EB = exposed bedrock
RO = exposed boulders
MB = unvegetated mid-channel bar
VB = vegetated mid-channel bar
MI = mature island
TR = urban debris (trash)
VR = vegetated rock

FLOW TYPES	DESCRIPTION
FF: Free fall	clearly separates from back-wall of vertical feature ~ associated with waterfalls
CH: Chute	low curving fall in contact with substrate
BW: Broken standing waves	white-water tumbling wave must be present ~ associated with rapids
UW: Unbroken standing waves	upstream facing wavelets which are not broken ~ associated with riffles
CF: Chaotic flow	a mixture of 3 or more 'rough' flow types on no organised pattern
RP: Rippled	no waves, but general flow direction is downstream with disturbed rippled surface ~ associated with runs
UP: Upwelling	heaving water as upwellings break the surface ~ associated with boils.
SM: Smooth	preceptible downstream movement is smooth (no eddies) ~ associated with glides
NP: No perceptible flow	no net downstream flow ~ associated with pools, ponded reaches and marginal deadwater
NO: No flow	dry



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RIVER HABITAT SURVEY: SPOT-CHECK KEY

LAND USE WITHIN 5m OF BANKTOP (SECTION F)

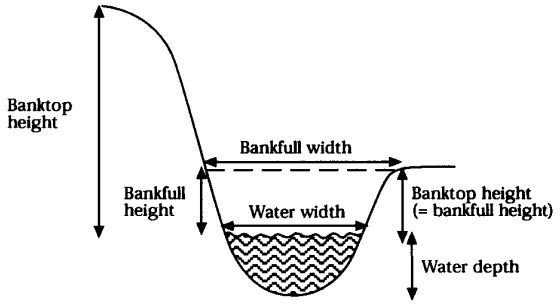
BL =	Broadleaf/mixed woodland(semi natural)	SC =	Scrub	TL =	Tilled land
BP =	Broadleaf/mixed plantation	TH =	Tall herbs	MH =	Moorland/heath
CW =	Coniferous forest (semi natural)	RP =	Rough unimproved grassland/pasture	RS =	Rock & scree & sandunes
CP =	Coniferous/forest (planted)				
WL =	Wetland	SU =	Suburban/urban	NV=	Not visible
OR =	Orchard	AW =	Artificial open water		
IL =	Irrigated land	OW =	Natural open water		
IG =	Improved grass	PG =	Parkland and gardens		

BANKTOP AND BANKFACE VEGETATION STRUCTURE To be assessed within a 10m wide transect (SECTION F)

bare	B	bare earth/rock etc.	vegetation types
uniform 	U	predominantly one type (no scrub or trees)	bryophytes short herbs/ creeping grasses
simple 	S	two or three vegetation types	tall herbs/ grasses scrub/brambles etc.
complex 	C	four or more types	saplings and trees 

Channel dimensions guidance (Section L)

- Select location on uniform section.
- If riffle is present, measure there. If not, measure at straightest and shallowest point.
- Banktop = first major break in slope above which cultivation or development is possible.
- Bankfull = point where river first spills onto floodplain.



WORKING ALONE: CHECKLIST

- PREPARATION
- IMPLEMENT REPORTING-IN PROCEDURE
- WEAR PROTECTIVE CLOTHING
- DO NOT RUSH
- NEVER ENTER CONFINED SPACES
- OBSERVE HYGIENE RULES
- WATCH FOR CHANGING CONDITIONS ESPECIALLY HEAVY RAIN OR RISING WATER LEVELS

WEIL'S DISEASE

INSTRUCTION TO CARD HOLDERS

1. As infection may enter through breaks in the skin ensure that any cut, scratch or abrasion is thoroughly cleansed and covered with a waterproof plaster.
2. Avoid rubbing your eyes, nose and mouth during work.
3. Clean protective clothing, footwear and equipment etc, after use.
4. Report all accidents and/or injuries however slight.
5. Keep your card with you at all times.

ENVIRONMENT AGENCY

EMERGENCY HOTLINE 0800 80 70 60

24 hour free emergency telephone line for reporting all environmental incidents relating to air, land and water.

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Appendix 3

Macroinvertebrate taxa and total number of individuals (eight Surber samples per site) in July 2001 in the Kola River system. (Individual Surber samples were not pooled in analyses.)

TAXON	K2	K3	K4	K5	K6	K7	K8	K10b	K11	K12	TOTAL
MOLLUSCA											
Lymnaea spp.	45	50	1	3	1	-	-	1	555	1	**1269**
Pisidium spp.	2	206	27	45	7	4	1	-	3	-	**588**
Planorbidae spp.	-	29	7	1	-	-	-	-	-	-	**74**
Valvata sibirica	4	251	-	-	-	-	-	-	6	-	**518**
OLIGOCHAETA	38	72	61	50	41	24	13	13	25	18	**672**
Glossiphonia complanata	-	4	-	-	-	-	-	-	2	-	**12**
HYDRACHNELLAE	4	37	10	9	37	28	1	1	81	23	**458**
EPHEMEROPTERA											
Ameletus inopinatus	-	-	-	-	-	-	-	4	-	-	**8**
Metretopus borealis	-	-	-	-	-	3	-	-	-	-	**6**
Procloeon bifidum	-	1	1	-	2	6	2	-	4	-	**32**
Baetis spp.	-	-	1	2	7	58	1	185	-	-	**508**
Baetis fuscatus	20	-	9	101	25	165	11	1399	267	561	**5096**
Baetis lapponicus	-	-	-	5	-	1	3	-	-	-	**18**
Baetis macani	-	-	-	-	-	-	-	46	-	-	**92**
Baetis muticus	1	1	3	-	2	1	-	2	1	-	**21**
Baetis niger	-	-	-	-	-	-	-	5	-	-	**10**
Baetis rhodani	9	10	11	2	19	1	-	66	7	6	**253**
Baetis subalpinus	215	11	10	84	5	77	7	1696	197	151	**4691**
Baetis vernus	-	-	-	-	-	-	-	-	5	1	**12**
Heptagenia dalecarlica	9	-	7	17	115	15	11	-	3	4	**353**
Heptagenia sulphurea	13	-	-	-	-	-	-	-	-	-	**13**
Heptagenia joernensis	-	-	3	6	9	29	8	-	12	15	**164**
Paraleptophlebia spp.	-	-	1	-	-	-	-	2	4	-	**14**
Caenis rivulorum	6	4	-	2	2	1	-	-	3	-	**30**
Ephemerella aurivillii	11	3	15	101	11	25	2	80	40	1	**567**
Ephemerella ignita	16	9	51	9	5	-	-	-	12	-	**188**
Ephemerella mucronata	-	36	1	-	-	1	-	1	-	-	**78**
PLECOPTERA											
Taeniopteryx nebulosa	12	-	4	7	1	2	1	-	22	-	**86**
Amphinemura borealis	-	-	6	-	1	-	-	-	-	-	**14**
Amphinemura sulcicollis	-	-	-	-	-	-	-	189	14	-	**406**
Leuctra fusca	-	1	84	47	10	24	11	20	54	4	**510**
Leuctra nigra	-	-	-	-	-	-	-	2	-	-	**4**
Arcynopteryx compacta	1	-	-	-	1	1	2	-	-	-	**9**
Diura nanseni	-	-	42	13	22	19	15	-	49	-	**320**
Isoperla difformis	-	-	-	-	-	-	-	-	2	-	**4**
Xanthoperla apicalis	-	-	-	-	-	-	1	-	-	-	**2**
TRICHOPTERA											
Rhyacophila nubila	42	6	15	15	30	30	1	244	31	120	**1026**
Rhyacophila obliterata	1	-	-	-	-	-	-	4	-	-	**9**
Polycentropus flavomaculatus	35	-	-	-	-	2	-	-	-	-	**39**
Neureclipsis bimaculata	1	-	-	-	-	-	-	-	-	-	**1**

TAXON	K2	K3	K4	K5	K6	K7	K8	K10b	K11	K12	TOTAL
Hydropsyche pellucidula	8	-	-	-	-	-	-	-	-	-	**8**
Cheumatopsyche nevae	6	10	-	8	3	2	2	-	-	-	**56**
Arctopsyche ladogensis	-	-	-	2	-	1	1	-	-	-	**8**
Hydroptila spp.	1	-	1	1	-	-	-	-	-	-	**5**
Oxyethira spp.	-	-	7	-	-	-	-	-	-	-	**14**
Ithytrichia spp.	-	-	2	-	-	-	-	-	-	-	**4**
Apatania spp.	-	-	-	-	1	-	-	2	-	-	**6**
Apatania stigmatella	1	-	-	1	-	-	-	-	-	-	**3**
Chaetopteryx spp.	-	-	-	-	-	-	-	-	-	1	**2**
Ceraclea spp.	2	-	1	2	-	-	-	-	-	-	**8**
Ceraclea annulicornis	3	-	1	-	-	6	-	-	2	-	**21**
Ceraclea nigronervosa	1	-	2	-	-	-	-	-	3	-	**11**
Ceraclea dissimilis	2	23	-	-	-	-	-	-	1	-	**50**
Athripsodes spp.	-	-	-	1	1	2	4	-	5	4	**34**
Lepidostoma hirtum	-	-	1	2	-	1	-	-	-	-	**8**
Brachycentrus subnubilus	-	-	-	-	-	2	-	4	-	-	**12**
Sericostoma personatum	-	-	-	-	-	1	-	-	-	-	**2**
Glossosoma ssp.	-	-	-	1	-	-	-	-	-	-	**2**
Agapetus ochripes	-	-	-	-	-	2	7	-	-	-	**18**
Psychomyia pusilla	-	-	-	7	22	4	7	-	-	-	**80**
DIPTERA											
Chironomidae	40542	78102	416	39577	39261	345	51	41184	85638	42158	**694006**
Simulidae		387	36088	48	152	38725	56	23	39	15781	**-**
Ceratopogonidae	-	-	1	-	-	-	1	-	1	-	**6**
Empididae	5	14	6	5	5	2	-	3	1	10	**97**
Tipula spp.	-	-	1	-	-	-	-	-	-	-	**2**
Dicranota spp.	-	-	-	-	-	-	-	25	3	1	**58**
Eloeophila spp.	-	-	-	5	-	-	6	1	-	-	**24**
Pedicia spp.	-	-	1	-	-	-	-	-	-	-	**2**
Pericoma spp.	-	-	-	-	-	-	-	1	-	-	**2**
Atherix ibis	1	-	31	35	1	5	-	-	11	-	**167**
COLEOPTERA											
Oreodytes spp.	-	-	-	-	-	1	-	-	-	1	**4**
Ilybius spp.	-	-	-	-	-	-	-	1	-	-	**2**
Elmis aenea	8	173	95	36	219	253	2	2	8	7	**1598**
Limnius volckmari	-	-	-	3	-	1	-	1	-	-	**10**
Oulimnius tuberculatus	1	-	31	21	101	34	2	-	12	7	**417**

Appendix 4

Macroinvertebrate taxa and total number of individuals (eight Surber samples per site) in July 2002 in the Kola River system. (Individual Surber samples were not pooled in analyses.)

TAXON	K2	K3	K4	K5	K6	K7	K8	K10a	K10b	K11	K12	TOTAL
MOLLUSCA												
Lymnaea spp.	89	105	3	3	2	8	74	-	-	4	21	**529**
Pisidium spp.	18	113	19	2	2	5	1	-	-	1	1	**306**
Planorbidae	1	52	12	-	-	-	2	-	-	1	3	**141**
Valvata sibirica	5	241	-	-	-	-	-	-	-	-	-	**487**
OLIGOCHAETA	269	202	116	11	27	12	5	12	39	31	5	**1189**
HIRUDINEA												
Glossiphonia complanata	3	5	-	-	-	-	-	-	-	1	-	**15**
HYDRACHNELLAE	5	3	-	1	2	-	3	-	-	12	11	**69**
EPHEMEROPTERA												
Ameletus inopinatus	-	-	-	-	-	-	-	5	-	-	-	**10**
Metretopus borealis	-	-	-	-	-	-	-	1	-	-	-	**2**
Procloeon bifidum	-	-	-	-	-	-	-	-	-	9	1	**20**
Baetis spp.	4	-	1	20	17	1	1	2	2	5	-	**102**
Baetis fuscatus	179	4	50	201	90	109	202	360	-	392	1205	**5405**
Baetis lapponicus	-	-	-	-	-	2	-	-	-	-	-	**4**
Baetis macani	-	-	-	-	-	-	-	14	6	-	-	**40**
Baetis muticus	1	-	2	-	-	-	1	11	-	1	-	**31**
Baetis niger	-	-	-	-	-	-	-	3	-	-	-	**6**
Baetis rhodani	11	-	2	-	4	-	-	68	9	-	-	**177**
Baetis subalpinus	975	67	41	136	38	53	62	1093	1	464	363	**5611**
Baetis vernus	2	-	-	-	-	-	-	48	-	-	2	**102**
Heptagenia dalecarlica	36	-	4	33	31	15	22	-	-	22	11	**312**
Heptagenia sulphurea	11	-	-	-	-	-	-	-	-	-	-	**11**
Heptagenia joernensis	33	-	-	2	12	9	27	-	-	17	46	**259**
Paraleptophlebia spp.	-	-	-	-	-	-	-	2	-	-	-	**4**
Caenis rivulorum	20	1	-	2	-	-	-	-	-	4	1	**36**
Ephemerella aurivillii	22	-	3	57	392	10	45	15	-	101	5	**1278**
Ephemerella ignita	38	1	5	1	8	-	3	-	-	15	1	**106**
Ephemerella mucronata	1	-	-	-	-	-	-	-	-	-	-	**1**
PLECOPTERA												
Taeniopteryx nebulosa	13	4	5	2	97	-	8	-	-	700	5	**1655**
Nemoura cinerea	-	-	-	-	-	-	-	-	1	-	-	**2**
Amphinemura borealis	-	1	1	-	-	-	1	-	-	-	-	**6**
Amphinemura sulcicollis	1	-	-	-	-	-	-	92	5	3	-	**201**
Leuctra fusca	23	-	23	36	26	17	7	77	-	30	5	**465**
Arcynopteryx compacta	16	-	2	6	6	7	6	-	-	7	3	**90**
Diura nanseni	1	-	12	6	10	3	2	1	-	37	7	**157**
Isoperla spp.	-	-	-	-	-	-	-	-	-	1	-	**2**
Isoperla obscura	3	-	-	-	-	-	-	-	-	-	-	**3**
Isogenus nubecula	-	-	-	-	-	-	1	-	-	-	-	**2**
TRICHOPTERA												
Rhyacophila nubila	125	4	15	21	9	21	21	190	-	68	76	**975**
Rhyacophila obliterata	6	-	-	-	-	-	-	5	-	-	-	**16**

TAXON	K2	K3	K4	K5	K6	K7	K8	K10a	K10b	K11	K12	TOTAL
Polycentropus flavomaculatus	13	-	-	-	-	-	-	-	-	-	-	**13**
Hydropsyche contuberalis	-	-	-	-	-	-	1	-	-	-	-	**2**
Hydropsyche pellucidula	5	-	-	-	-	-	-	-	-	-	-	**5**
Cheumatopsyche nevae	5	-	1	5	2	-	1	-	-	1	1	**27**
Arctopsyche ladogensis	-	-	5	4	-	15	5	-	-	-	-	**58**
Hydroptila spp.	1	-	-	-	1	-	2	-	-	1	-	**9**
Apatania stigmatella	4	-	-	-	1	-	-	4	-	-	1	**16**
Chaetopteryx spp.	-	-	-	-	-	-	-	-	-	3	8	**22**
Ceraclea annulicornis	6	-	1	-	-	-	-	-	-	-	-	**8**
Ceraclea nigronervosa	-	-	-	-	-	-	-	-	-	1	-	**2**
Ceraclea dissimilis	30	37	-	-	-	-	-	-	-	-	-	**104**
Athripsodes spp.	-	-	-	2	1	-	-	-	-	-	1	**8**
Brachycentrus subnubilus	-	-	-	-	-	-	-	14	-	-	-	**28**
Psychomyia pusilla	-	-	-	5	-	-	1	-	-	-	-	**12**
DIPTERA												
Chironomidae	4625	743	339	247	720	33	2427	2041	11059	7006	445	**54745**
Simulidae	8609	64493	135	46	128	27	1	53	22	86	3	**138597**
Ceratopogonidae	-	1	-	-	-	-	1	-	-	-	-	**4**
Empididae	1	-	6	2	1	1	-	1	1	1	2	**31**
Tipula spp.	1	-	1	-	1	-	-	-	1	-	-	**7**
Dicranota spp.	-	-	1	1	-	-	-	10	32	4	2	**100**
Eloeophila spp.	-	-	-	2	1	1	-	3	-	1	-	**16**
Psychoda spp.	-	-	-	-	-	-	-	-	1	-	-	**2**
Atherix ibis	2	-	-	3	-	-	-	-	-	-	-	**8**
COLEOPTERA												
Platambus maculatus	-	-	-	-	-	-	-	-	-	3	-	**6**
Hydraena spp.	-	-	-	-	-	-	-	-	1	-	-	**2**
Elmis aenea	4	-	8	9	12	3	38	6	-	5	9	**184**
Limnius volckmari	-	-	-	-	1	-	-	1	-	-	-	**4**
Oulimnius tuberculatus	-	-	4	4	-	1	8	-	-	6	3	**52**
TOTAL	15217	66077	817	870	1642	353	2979	4132	11180	9044	2247	**213899**

Appendix 5

Macroinvertebrate taxa and total number of individuals (eight Surber samples per site) in September 2002 in the Kola River system. (Individual Surber samples were not pooled in analyses.)

TAXON	K2	K3	K4	K5	K6	K7	K8	K10a	K10b	K11	K12	TOTAL
MOLLUSCA												
Lymnaea spp.	27	74	2	26	2	12	-	-	-	9	55	**387**
Pisidium spp.	3	175	4	62	-	1	1	1	-	1	1	**495**
Planorbidae	4	38	-	2	3	-	-	1	-	2	11	**118**
Valvata sibirica	3	111	-	-	-	-	-	-	-	-	-	**225**
OLIGOCHAETA	184	33	13	41	27	13	18	2	12	43	131	**850**
HIRUDINEA												
Glossiphonia complanata	-	13	-	-	-	-	-	-	-	1	-	**28**
HYDRACHNELLAE	3	2	-	1	1	-	-	-	-	7	-	**25**
EPHEMEROPTERA												
Ameletus inopinatus	-	-	-	6	6	22	6	1	-	4	-	**90**
Baetis spp.	-	-	1	-	-	1	1	7	1	-	-	**22**
Baetis fuscatus	-	-	-	3	-	-	-	1	-	-	-	**8**
Baetis muticus	75	1	9	24	25	40	7	-	-	126	1	**541**
Baetis niger	-	-	4	-	8	5	1	3	-	30	1	**104**
Baetis rhodani	85	15	7	51	56	30	5	22	-	2	-	**461**
Heptagenia dalecarlica	147	-	3	23	7	12	11	-	-	22	5	**313**
Heptagenia sulphurea	6	-	-	-	-	-	-	-	-	-	-	**6**
Heptagenia joernensis	1	-	-	-	-	-	-	-	-	-	-	**1**
Paraleptophlebia spp.	19	-	-	-	-	-	-	1	-	3	-	**27**
Caenis rivulorum	11	1	-	3	7	11	7	-	-	6	2	**85**
Ephemerella aurivillii	14	-	19	51	82	7	11	57	-	117	7	**716**
Ephemerella ignita	-	1	-	-	-	-	-	-	-	-	-	**2**
Ephemerella mucronata	-	10	-	-	-	-	4	-	-	3	-	**34**
PLECOPTERA												
Taeniopteryx nebulosa	46	424	108	5	72	4	5	73	-	1789	87	**5180**
Nemoura spp.	-	-	-	-	-	-	-	17	3	-	1	**42**
Nemoura cinerea	1	-	-	-	-	-	-	-	-	2	-	**5**
Amphinemura spp.	-	-	-	-	-	-	-	-	-	1	-	**2**
Amphinemura standfussi	-	-	-	-	-	-	-	1	-	-	-	**2**
Protonemura meyeri	-	-	-	-	1	-	-	-	-	-	-	**2**
Protonemura intricata	-	8	9	-	-	-	-	-	-	10	1	**56**
Leuctra spp.	-	-	1	-	-	-	-	-	-	8	-	**18**
Leuctra fusca	-	-	-	-	-	-	-	4	-	-	1	**10**
Capnia spp.	-	-	-	43	24	214	670	1	-	2	2	**1912**
Capnopsis schilleri	-	-	-	-	-	-	-	-	-	1	-	**2**
Arcynopteryx compacta	25	-	-	4	-	1	2	-	-	7	2	**57**
Diura nanseni	3	-	10	9	6	7	20	1	-	46	7	**215**
Isoperla obscura	4	50	5	1	5	2	-	3	-	33	2	**206**
Isoperla grammatica	-	-	-	1	2	-	5	-	-	9	-	**34**
Siphonoperla burmeisteri	-	-	-	1	-	-	5	-	-	-	-	**12**
Xanthoperla apicalis	-	-	-	-	-	2	22	-	-	-	-	**48**
TRICHOPTERA												
Rhyacophila nubila	23	7	6	4	3	6	2	62	-	51	49	**403**

TAXON	K2	K3	K4	K5	K6	K7	K8	K10a	K10b	K11	K12	TOTAL
Polycentropus flavomaculatus	176	-	-	-	1	2	-	-	-	1	1	**186**
Neureclipsis bimaculata	17	-	-	-	-	-	-	-	-	-	-	**17**
Hydropsyche contuberalis	-	-	-	-	-	-	101	-	-	-	-	**202**
Hydropsyche pellucidula	64	7	-	-	-	-	-	-	-	-	-	**78**
Cheumatopsyche nevae	316	798	3	118	3	47	107	1	-	1	4	**2480**
Arctopsyche ladogensis	2	49	-	8	-	1	1	-	-	3	-	**126**
Hydroptila spp.	-	-	-	-	-	-	-	-	-	1	-	**2**
Agraylea spp.	-	1	-	-	-	-	-	-	-	-	-	**2**
Apatania spp.	-	-	-	-	-	-	-	3	-	-	-	**6**
Apatania wallengreni	4	-	-	-	1	-	-	1	-	1	-	**10**
Ceraclea annulicornis	13	-	-	-	-	-	-	-	-	-	-	**13**
Ceraclea nigronervosa	-	-	-	-	-	-	-	-	-	2	-	**4**
Ceraclea dissimilis	7	5	-	-	-	-	-	-	-	-	-	**17**
Athripsodes spp.	-	-	-	1	-	2	20	-	-	-	-	**46**
Brachycentrus subnubilus	-	-	-	-	-	-	1	2	-	-	-	**6**
Sericostoma personatum	-	-	-	-	-	1	-	-	-	-	-	**2**
Glossosoma spp.	-	-	1	2	1	-	-	-	-	15	1	**40**
Micrasema	-	-	1	18	77	1	-	-	-	18	6	**242**
Agapetus ochripes	-	-	-	1	-	-	9	-	-	-	-	**20**
Psychomyia pusilla	-	-	-	4	2	-	-	-	-	2	2	**20**
DIPTERA												
Chironomidae	894	1567	61	73	79	17	44	106	3260	577	366	**13194**
Simulidae	6	27	17	3	-	-	-	5	52	-	-	**214**
Ceratopogonidae	-	-	-	-	-	-	-	1	-	-	-	**2**
Empididae	4	71	-	1	-	1	1	3	5	13	8	**210**
Tipula spp.	2	-	-	1	-	-	-	1	-	1	-	**8**
Dicranota spp.	4	-	3	5	-	13	6	6	-	2	2	**78**
Eloeophila spp.	-	-	-	-	1	2	17	-	-	-	1	**42**
Psychoda spp.	-	-	1	-	-	-	-	-	-	-	-	**2**
Atherix ibis	4	-	7	17	-	-	1	-	-	3	-	**60**
COLEOPTERA												
Platambus maculatus	-	-	-	-	-	-	-	2	-	1	-	**6**
Hydraena spp.	-	-	-	-	-	-	-	-	1	-	-	**2**
Helophorus spp.	-	-	-	-	-	-	-	1	-	-	-	**2**
Elmis aenea	4	10	35	3	57	6	1	-	-	6	10	**260**
Oulimnius tuberculatus	2	-	13	1	10	8	-	-	-	7	3	**86**
TOTAL	2203	3498	343	617	569	491	1112	390	3334	2989	770	**30429**

Appendix 6

Macroinvertebrate taxa and total number of individuals (eight Surber samples per site) in July 2002 in the Näätämöjoki River. (Individual Surber samples were not pooled in analyses.)

TAXON	N1	N2	N3	N4	N5	TOTAL
MOLLUSCA						
Lymnaea spp.	31	13	-	-	17	**91**
Pisidium spp.	18	113	4	-	5	**262**
Planorbidae	2	5	3	-	2	**22**
OLIGOCHAETA	120	77	37	50	50	**548**
HYDRACHNELLAE	1	1	-	1	2	**9**
EPHEMEROPTERA						
Metretopus borealis	-	-	-	3	-	**6**
Procloeon bifidum	-	-	-	1	-	**2**
Centroptilum luteolum	-	1	-	-	-	**2**
Baetis spp.	9	51	4	2	8	**139**
Baetis digitatus	-	-	-	-	1	**2**
Baetis fuscatus	62	9	5	-	5	**100**
Baetis muticus	-	2	-	-	8	**20**
Baetis niger	-	1	-	-	-	**2**
Baetis rhodani	-	1	-	-	-	**2**
Baetis subalpinus	37	5	-	9	35	**135**
Heptagenia dalecarlica	20	92	56	10	30	**396**
Heptagenia joernensis	-	12	7	-	-	**38**
Paraleptophlebia strandii	1	1	-	-	-	**3**
Ephemerella aurivillii	21	175	6	6	131	**657**
Ephemerella mucronata	-	-	-	-	15	**30**
PLECOPTERA						
Taeniopteryx nebulosa	3	15	1	6	225	**497**
Amphinemura borealis	-	3	-	-	-	**6**
Protonemura meyeri	3	-	-	-	8	**19**
Leuctra fusca	13	19	5	2	-	**65**
Arcynopteryx compacta	2	-	-	-	-	**2**
Diura nanseni	10	19	5	16	9	**108**
Isoperla spp.	4	9	-	7	5	**46**
TRICHOPTERA						
Rhyacophila nubila	13	62	9	7	34	**237**
Polycentropus flavomaculatus	15	-	3	-	1	**23**
Hydropsyche pellucidula	9	1	-	-	-	**11**
Cheumatopsyche nevae	2	-	19	1	4	**50**
Arctopsyche ladogensis	27	-	13	5	8	**79**
Hydroptila spp.	20	6	2	-	-	**36**
Apatania stigmatella	1	-	-	-	-	**1**
Ceraclea annulicornis	-	-	-	-	2	**4**
Ceraclea nigronervosa	-	4	2	-	-	**12**
Lepidostoma hirtum	-	-	1	-	1	**4**
DIPTERA						
Chironomidae	1528	787	219	197	403	**4740**
Simulidae	86	21	9	48	79	**400**

TAXON	N1	N2	N3	N4	N5	TOTAL
Ceratopogonidae	1	-	-	-	-	**1**
Empididae	38	-	3	1	7	**60**
Tipula spp.	1	-	-	-	-	**1**
Atherix ibis	-	-	-	-	2	**4**
COLEOPTERA						
Elmis aenea	39	1	-	-	164	**369**
Limnius volckmari	-	-	1	-	-	**2**
Oulimnius tuberculatus	-	-	-	-	15	**30**
TOTAL	2137	1506	414	372	1276	**9273**

Appendix 7

Macroinvertebrate taxa and total number of individuals (eight Surber samples per site) in September 2002 in the Näätämöjoki River. (Individual Surber samples were not pooled in analyses.)

TAXON	N1	N2	N3	N4	N5	TOTAL
MOLLUSCA						
Lymnaea spp.	7	237	4	6	22	**545**
Pisidium spp.	4	304	16	-	-	**644**
Planorbidae	-	4	5	-	3	**24**
OLIGOCHAETA	17	29	13	9	22	**163**
HIRUDINEA						
HYDRACHNELLAE	-	-	-	-	1	**2**
EPHEMEROPTERA						
Ameletus inopinatus	3	10	39	2	4	**113**
Baetis spp.	-	-	2	-	-	**4**
Baetis digitatus	6	90	2	4	2	**202**
Baetis muticus	23	14	23	4	11	**127**
Baetis rhodani	170	26	17	8	43	**358**
Heptagenia dalecarlica	-	72	81	3	17	**346**
Paraleptophlebia spp.	-	1	-	-	-	**2**
Ephemerella aurivillii	24	60	5	-	44	**242**
Ephemerella mucronata	-	1	2	-	80	**166**
PLECOPTERA						
Taeniopteryx nebulosa	2	12	-	1	8	**44**
Nemoura spp.	1	-	-	-	-	**1**
Protonemura meyeri	-	-	-	-	5	**10**
Leuctra spp.	2	-	5	-	-	**12**
Capnia spp.	-	1	-	-	-	**2**
Capnia pygmaea	-	-	101	1	9	**222**
Diura nanseni	1	8	9	-	1	**37**
Isoperla spp.	-	1	-	-	-	**2**
Isoperla obscura	4	23	1	-	14	**80**
Siphonoperla burmeisteri	-	-	7	-	-	**14**
TRICHOPTERA						
Rhyacophila nubila	2	5	-	1	10	**34**
Polycentropus flavomaculatus	6	6	5	-	1	**30**
Hydropsyche pellucidula	1	1	-	-	-	**3**
Cheumatopsyche nevae	-	-	13	-	3	**32**
Hydroptila spp.	3	2	1	-	-	**9**
Apatania wallengreni	-	5	2	-	-	**14**
Ceraclea annulicornis	-	3	1	-	1	**10**
Ceraclea nigronervosa	-	24	-	1	-	**50**
Ceraclea dissimilis	-	1	-	-	-	**2**
Athripsodes spp.	-	1	-	-	-	**2**
Lepidostoma hirtum	1	1	-	-	-	**3**
DIPTERA						
Chironomidae	419	313	111	235	220	**2177**
Simulidae	5	2	-	2	15	**43**
Ceratopogonidae	-	-	1	-	1	**4**

TAXON	N1	N2	N3	N4	N5	TOTAL
Empididae	28	-	1	1	4	**40**
Tipula spp.	-	-	1	-	-	**2**
Dicranota spp.	1	1	-	1	1	**7**
Eloeophila spp.	-	-	-	2	2	**8**
COLEOPTERA						
Elmis aenea	1	-	-	1	21	**45**
Oulimnius tuberculatus	-	-	5	-	3	**16**
Callicorixa spp.	-	-	-	1	-	**2**
TOTAL	731	1258	473	283	568	**5895**

Appendix 8

Total abundance of diatom taxa (three replicate samples per site) in the Kola River system in July 2001. (Individual samples were not pooled in analyses.)

TAXON	K2	K3	K4	K5	K6	K7	K8	K10a	K11	K12	TOTAL
Aulacoseira ambigua (Grun.) Simonsen	7	0	0	0	0	0	0	0	0	0	**7**
Achnanthes bioreti Germain (=Psammothidium)	1	39	0	0	0	7	4	3	10	10	**74**
Anomoeoneis brachysira (Breb.) Grunow var.zellensis (Grunov) Krammer	1	0	0	0	0	0	0	0	0	0	**1**
Achnanthes calcar Cleve	1	0	0	0	0	0	0	0	0	0	**1**
Achnanthes chlidanos Hohn & Hellerman	0	0	0	2	0	1	0	0	3	0	**6**
ACHNANTHES J.B.M.Bory de St. Vincent	0	0	0	0	0	0	0	0	3	0	**3**
Achnanthes didyma Hustedt	0	0	2	0	0	1	1	1	2	0	**7**
Achnanthes flexella (Kutzing) Brun var. flexella	0	36	0	0	1	0	0	0	1	0	**38**
Asterionella formosa Hassall	15	42	2	2	4	0	0	0	0	0	**65**
Achnanthes helvetica (Hustedt) Lange-Bertalot	0	0	0	0	0	3	1	0	0	2	**6**
Achnanthes holstii Cleve	0	0	0	0	0	0	0	1	0	0	**1**
Achnanthes impexiformis Lange-Bertalot	0	0	0	1	0	0	0	0	1	0	**2**
Achnanthes kriegeri Krasske	0	0	3	0	0	0	0	0	0	0	**3**
Achnanthes kryophila Petersen	0	0	0	0	0	0	0	0	2	0	**2**
Achnanthes lanceolata (Breb.) Grunow var. lanceolata Grunow	1	10	0	0	0	0	0	263	26	0	**300**
Achnanthes laterostrata Hustedt	0	18	0	0	3	1	0	3	4	0	**29**
Auricula levis	0	0	0	0	0	0	5	0	0	0	**5**
Achnanthes laevis Oestrup var. austriaca (Hustedt) Lange-Bertalot	0	2	0	0	0	0	0	0	0	0	**2**
Achnanthes levanderi Hustedt	1	7	0	4	1	1	0	0	2	0	**16**
Achnanthes laevis Oestrup var. laevis Oestrup	0	21	1	1	20	13	16	0	5	0	**77**
Amphora fogediana Krammer	1	0	0	0	0	0	0	0	0	0	**1**
Achnanthes minutissima Kutzing v.minutissima Kutzing (Achnanthidium)	759	709	95	451	668	650	725	29	428	435	**4949**
Anomoeoneis brachysira (Brebisson in Rabenhorst) Grunow in Cleve	0	0	2	3	1	1	1	0	0	0	**8**
Achnanthes nodosa A.Cleve	0	0	0	0	0	0	3	0	0	0	**3**
Achnanthes oblongella Oestrup	0	0	0	0	0	0	0	6	0	2	**8**
Amphora ovalis (Kutzing) Kutzing	1	0	0	0	0	0	0	1	0	0	**2**

TAXON	K2	K3	K4	K5	K6	K7	K8	K10a	K11	K12	TOTAL
Amphora pediculus (Kutzing) Grunow	66	9	0	0	0	0	0	0	10	4	**89**
Achnanthes petersenii Hustedt KLB91p67f37/	0	0	1	6	2	3	0	1	6	0	**19**
Achnanthes pusilla (Grunow) De Toni	3	160	113	76	11	58	31	0	16	11	**479**
Achnanthes rossii Hustedt	0	0	1	0	3	0	0	0	0	1	**5**
Achnanthes subatomoides (Hustedt) Lange-Bertalot et Archibald	4	21	0	2	1	1	3	15	20	1	**68**
Achnanthes saccula Carter in Carter & Bailey-Watts	0	0	0	0	0	5	0	0	4	3	**12**
Achnanthes stolida (Krasske) Krasske	0	0	0	2	0	0	0	0	0	0	**2**
Anomoeoneis styriaca (Grunow) Hustedt	0	0	0	0	0	0	0	0	1	0	**1**
Achnanthes suchlandtii Hustedt	1	10	0	3	1	0	2	1	7	4	**29**
Aulacoseira crenulata (Ehrenberg) Thwaites	0	2	0	0	0	0	0	0	0	0	**2**
Aulacoseira distans (Ehr.) Simonsen	0	0	2	0	0	0	0	0	0	0	**2**
Aulacoseira islandica (O.Muller) Simonsen	1	0	0	0	0	0	0	0	0	0	**1**
Aulacoseira italica (Ehr.)Simonsen	1	0	1	0	0	0	0	0	0	0	**2**
AULACOSEIRA G.H.K.Thwaites	0	0	1	1	0	0	0	0	1	2	**5**
Aulacoseira lacustris (Grunow) Krammer	0	0	0	0	0	1	0	0	0	0	**1**
Aulacoseira subarctica (O.Muller) Haworth	4	18	2	3	0	1	1	0	4	0	**33**
Anomoeoneis vitrea (Grunow) Ross	1	13	56	17	13	17	35	0	8	2	**162**
Achnanthes ventralis (Krasske) Lange-Bertalot	0	0	1	0	3	0	0	0	0	0	**4**
Cymbella affinis Kutzing	0	17	0	0	0	0	0	0	0	0	**17**
Caloneis tenuis (Gregory) Krammer	0	0	5	5	0	0	2	0	0	1	**13**
Cymbella caespitosa (Kutzing) Brun (Encyonema)	1	0	0	0	0	0	0	0	0	0	**1**
Cymbella descripta (Hustedt) Krammer et Lange-Bertalot	6	0	20	0	1	7	6	0	2	1	**43**
Cymbella gracilis (Ehr.) Kutzing	0	0	6	2	1	4	2	0	2	0	**17**
Cyclotella iris Brun & Heribaud	0	0	0	0	0	1	0	0	0	0	**1**
Cymbella mesiana Cholnoky (Encyonema)	3	0	1	0	0	0	0	0	0	0	**4**
Cymbella microcephala Grunow	0	0	1	0	1	0	0	0	0	0	**2**
Cymbella minuta Hilse ex Rabenhorst (Encyonema)	44	14	1	11	6	14	7	17	54	16	**184**
Cyclotella ocellata Pantocsek	0	0	0	0	0	1	0	0	0	0	**1**

TAXON	K2	K3	K4	K5	K6	K7	K8	K10a	K11	K12	TOTAL
Cocconeis placentula Ehrenberg var. placentula	40	0	0	0	0	0	0	1	31	59	**131**
Cyclotella praetermissa Lund	0	19	0	0	0	0	0	0	0	0	**19**
Cymbella prostrata (Berkeley) Grunow (Encyonema)	1	0	0	0	0	0	0	0	0	0	**1**
Cymbella proxima Reimer	0	0	1	0	0	0	0	0	0	0	**1**
Cyclotella rossii Hakansson	0	23	0	0	0	0	0	0	0	0	**23**
Cymbella sinuata Gregory	15	50	0	5	2	6	1	2	175	185	**441**
Cymbella silesiaca Bleisch in Rabenhorst (Encyonema)	3	20	3	12	0	3	8	5	15	2	**71**
Cyclotella stelligera Cleve et Grun in Van Heurck	22	9	0	8	0	0	1	0	5	2	**47**
Cymbella tumida (Brebisson) Van Heurck	1	15	0	3	0	0	1	0	0	0	**20**
CYCLOTELLA F.T. Kützing ex A de Brébisson	0	4	0	0	0	0	0	0	0	0	**4**
CYMBELLA C.Agardh 1830	0	0	3	0	0	0	0	0	0	0	**3**
Didymosphenia geminata (Lyngbye) W.M.Schmidt	0	13	0	24	1	1	1	0	1	7	**48**
DIPLONEIS C.G.Ehrenberg ex P.T. Cleve	0	0	0	0	0	0	1	0	0	0	**1**
Diatoma tenuis Agardh	142	139	8	3	9	5	12	15	0	0	**333**
Diatoma mesodon (Ehrenberg) Kutzing	0	0	0	0	0	0	0	17	1	0	**18**
Diatoma moniliformis Kutzing	0	0	0	0	3	0	0	0	0	0	**3**
Diploneis parma Cleve	1	0	0	0	0	0	0	0	0	0	**1**
Denticula tenuis Kutzing	0	0	0	11	0	0	0	0	0	0	**11**
Epithemia adnata (Kutzing) Brebisson	0	0	1	1	1	3	0	0	1	0	**7**
Eunotia arcus Ehrenberg var. arcus	0	0	0	0	1	1	2	0	1	0	**5**
Eunotia bilunaris (Ehr.) Mills var. biluna	0	0	7	0	1	0	5	0	3	0	**16**
Eunotia circumborealis Nörpel & Lange-Bertalot	0	0	0	0	0	1	3	0	0	0	**4**
Eunotia faba Grunow	0	0	2	1	0	1	1	0	0	0	**5**
Eunotia flexuosa (Brebisson) Kutzing	0	0	7	0	1	0	0	0	3	0	**11**
Eunotia formica Ehrenberg	0	0	0	0	1	0	0	0	0	0	**1**
Eunotia implicata Nörpel, Lange-Bertalot & Alles	0	0	2	4	8	17	12	0	7	1	**51**
Eunotia incisa Gregory var. incisa	0	0	25	14	4	7	2	0	9	0	**61**
Eunotia pectinalis (Dyllwyn) Rabenhorst var. pectinalis	0	6	0	0	0	0	1	0	0	0	**7**
Eunotia pirla Carter & Flower	0	44	2	0	0	0	0	0	0	0	**46**
Eunotia rhynchocephala Hustedt var. satelles Norpel & Lange-Bertalot	0	0	1	0	0	0	0	0	0	0	**1**
Eunotia serra Ehrenberg var. serra	0	0	5	0	0	0	1	0	0	0	**6**

TAXON	K2	K3	K4	K5	K6	K7	K8	K10a	K11	K12	TOTAL
Eunotia soleirolii (Kutzing) Rabenhorst	0	0	0	0	1	0	0	0	0	0	**1**
EUNOTIA C.G.Ehrenberg	0	39	18	1	13	76	27	1	17	0	**192**
Fragilaria arcus (Ehrenberg) Cleve var. arcus	2	5	6	22	9	13	3	3	6	6	**75**
Fragilaria brevistriata Grunow (Pseudostaurosira)	0	0	1	1	1	0	0	0	1	0	**4**
Fragilaria capucina Desmazieres var.capucina	0	0	0	0	2	0	0	0	1	0	**3**
Fragilaria capucina Desmazieres var.gracilis (Destrup) Hustedt	15	16	29	34	18	21	26	0	9	5	**173**
Fragilaria capucina Desmazieres var.mesolepta (Rabenhorst) Rabenhorst	0	13	0	1	10	0	1	0	0	0	**25**
Fragilaria construens (Ehr.) Grunow f.construes (Staurosira)	8	58	15	14	1	7	13	0	25	9	**150**
Fragilaria capucina Desmazieres var.radian	6	65	0	0	2	0	2	3	0	0	**78**
Fragilaria crotonensis Kitton	3	0	0	0	0	0	0	0	0	0	**3**
Fragilaria capucina Desmazieres ssp. rumpens (Kutzing) Lange-Bertalot	4	193	4	12	5	1	3	22	15	7	**266**
Fragilaria capucina Desmazieres var.vaucheriae (Kutzing) Lange-Bertalot	4	12	10	16	3	1	4	15	2	2	**69**
Fragilaria exigua Grunow	0	0	0	1	0	0	0	0	0	0	**1**
Fragilaria nanana Lange-Bertalot	0	0	6	0	10	3	10	0	2	4	**35**
Fragilaria parasitica (W.Sm.) Grun. var. paracitica	0	0	0	0	1	0	0	0	0	0	**1**
Fragilaria pinnata Ehrenberg var. pinnata (Starosirella)	0	0	1	0	0	0	0	0	2	0	**3**
FRAGILARIA H.C. Lyngbye	0	0	0	0	1	0	0	2	3	0	**6**
Frustulia rhomboides (Ehr.) De Toni	0	0	10	3	1	1	0	0	0	0	**15**
Fragilaria tenera (W.Smith) Lange-Bertalot	68	44	8	27	28	18	41	0	11	0	**245**
Fragilaria ulna (Nitzsch.) Lange-Bertalot var. ulna	39	81	20	23	23	11	18	39	21	6	**281**
Fragilaria virescens Ralfs	0	0	1	0	0	0	0	0	0	0	**1**
Gomphonema acuminatum Ehrenberg	1	87	5	3	1	3	3	0	2	2	**107**
Gomphonema angustatum (Kutzing) Rabenhorst	8	94	0	0	0	0	0	16	5	0	**123**
Gomphonema angustum Agardh	2	18	1	1	3	0	0	4	4	0	**33**
Gomphonema clavatum Ehr.	1	22	3	20	6	3	3	0	1	0	**59**
Gomphonema gracile Ehrenberg	0	10	5	1	3	0	0	0	0	0	**19**
Gomphonema grovei M.Schmidt	1	0	0	0	0	0	0	0	0	0	**1**

TAXON	K2	K3	K4	K5	K6	K7	K8	K10a	K11	K12	TOTAL
Gomphonema minutum (Ag.) Agardh f. minutum	0	0	0	0	0	0	0	2	0	0	**2**
Gomphonema olivaceum (Hornemann) Brébisson var. olivaceum	38	32	0	0	2	1	0	2	0	0	**75**
GOMPHONEMA C.G.Ehrenberg	0	0	0	0	0	2	1	3	4	0	**10**
Gomphonema parvulum Kutzing var. parvulum F. parvulum	0	5	0	5	2	0	0	2	12	12	**38**
Gomphonema truncatum Ehr.	3	36	0	1	1	0	1	0	1	0	**43**
HANTZSCHIA A. Grunow	0	0	1	0	0	0	0	5	0	0	**6**
Hantzschia elongata (Hantzsch.) Grunow	0	0	0	0	0	0	0	1	0	0	**1**
Meridion circulare (Greville) Agardh var. costrictum (Ralfs)	0	0	0	3	0	0	0	0	0	0	**3**
Meridion circulare (Greville) C.A.Agardh var. circulare	16	106	0	4	4	2	4	20	44	1	**201**
Melosira lineata (Dillwyn) Agardh	0	0	0	0	0	0	0	3	0	0	**3**
Navicula angusta Grunow	0	0	0	0	0	0	0	4	0	0	**4**
Navicula accomoda Hustedt	0	0	0	0	0	0	0	0	1	0	**1**
Nitzschia accommodata Hustedt	0	0	0	0	0	0	0	3	1	0	**4**
Navicula atomus (Kutz.) Grunow	0	0	0	0	0	0	0	14	0	0	**14**
NAVICULA J.B.M. Bory de St. Vincent	0	0	0	1	0	0	0	0	0	0	**1**
Neidium bisulcatum (Lagerstedt) Cleve	0	0	0	0	1	0	0	0	0	0	**1**
Navicula capitata Ehrenberg (=Hippodonta)	0	0	0	1	0	0	0	1	0	0	**2**
Navicula cari Ehrenberg	0	7	1	0	0	0	0	0	0	0	**8**
Navicula cincta (Ehr.) Ralfs in Pritchard	0	0	0	5	0	0	0	0	0	0	**5**
Navicula cocconeiformis Gregory ex Greville	1	5	1	0	0	0	0	0	0	0	**7**
Nitzschia capitellata Hustedt in A.Schmidt	0	0	0	0	0	0	0	0	3	0	**3**
Navicula capitatoradiata Germain	1	0	0	0	0	0	0	0	0	0	**1**
Navicula cryptocephala Kutzing	1	0	2	2	0	0	1	1	5	0	**12**
Navicula cryptotenella Lange-Bertalot	0	0	0	0	0	0	0	0	1	0	**1**
Navicula cuspidata Kutzing	0	0	0	0	0	0	0	1	0	0	**1**
Navicula difficillima Hustedt	0	0	0	0	0	0	1	0	0	0	**1**
Nitzschia fontikola Grunow in Cleve et Möller	0	0	1	0	0	0	6	1	10	0	**18**
Navicula gracilis Ehrenberg	0	147	0	1	0	0	0	0	0	0	**148**
Nitzschia homburgiensis Lange-Bertalot	0	0	0	0	0	0	0	6	0	0	**6**
Nitzschia angustata Grunow	1	39	2	2	3	1	7	0	1	0	**56**

TAXON	K2	K3	K4	K5	K6	K7	K8	K10a	K11	K12	TOTAL
Nitzschia bryophila Hustedt	2	0	0	0	0	0	0	0	0	0	**2**
Nitzschia frustulum (Kutzing) Grunow var.frustulum	1	0	0	0	0	0	0	0	0	0	**1**
Nitzschia gracilis Hantzsch	22	0	0	0	2	0	0	1	4	1	**30**
Nitzschia perminuta (Grunow) M.Peragallo	7	641	0	8	2	2	11	33	16	9	**729**
NITZSCHIA A.H. Hassall	3	57	2	2	0	0	0	14	5	3	**86**
Navicula jaernefeltii Hustedt	0	0	0	1	0	0	0	0	0	0	**1**
Nitzschia linearis (Agardh) W.M.Smith var.linearis	9	0	0	1	0	0	1	0	8	0	**19**
Navicula leptostriata Jorgensen	0	0	0	0	0	1	1	0	2	0	**4**
Nitzschia laevissima Grunow	0	0	0	0	0	0	1	0	0	0	**1**
Navicula medioconvexa Hustedt 1961	0	0	0	0	0	0	0	0	1	0	**1**
Nitzschia microcephala Grunow in Cleve & Möller	0	0	0	0	0	0	0	0	4	0	**4**
Navicula minima Grunow	0	0	0	0	0	0	0	77	6	0	**83**
Navicula minuscula Grunow in van Heurck 1880	0	0	0	2	0	0	0	0	0	0	**2**
Nitzschia paleacea Grunow fo.acicularioides Coste & Ricard	0	0	0	0	0	0	0	19	0	0	**19**
Nitzschia palea (Kutzing) W.Smith	0	17	1	3	0	1	2	10	7	0	**41**
Navicula phyllepta Kutzing	0	0	0	0	0	0	1	0	0	0	**1**
Navicula porifera Hustedt	1	0	0	0	0	0	0	0	0	0	**1**
Navicula peregrina (Ehr.) Kutzing	0	0	0	0	0	0	0	0	1	0	**1**
Navicula pseudoscutiformis Hustedt	0	0	0	0	1	0	0	0	0	0	**1**
Navicula pupula Kutzing	0	0	1	0	0	1	0	0	1	0	**3**
Navicula pygmaea Kutzing	0	0	0	0	0	0	0	2	1	0	**3**
Navicula radiosa Kützing	0	0	2	2	0	0	1	0	1	1	**7**
Nitzschia recta Hantzsch ex Rabenhorst	0	0	0	2	0	0	0	34	3	0	**39**
Navicula rhynchocephala Kutzing	0	0	0	0	0	0	0	3	0	0	**3**
Navicula riparia Hustedt	0	0	0	0	0	0	0	93	0	0	**93**
Navicula salinarum Grunow in Cleve et Grunow	0	0	0	0	0	0	0	12	0	0	**12**
Nitzschia sublinearis Hustedt	1	2	2	2	0	0	0	0	0	0	**7**
Navicula seminulum Grunow	0	0	0	0	0	0	0	1	2	0	**3**
Navicula soehrensis Krasske var.hassiaca (Krasske) Lange-Bertalot	0	0	3	1	1	0	0	0	1	0	**6**
Navicula soehrensis Krasske	0	2	0	1	0	0	0	0	0	0	**3**
Navicula subtilissima Cleve	0	0	0	1	0	0	0	0	0	0	**1**
Nitzschia tubicola Grunow	0	0	1	0	0	1	0	11	0	0	**13**
Navicula veneta Kutzing	0	0	0	2	0	0	0	0	0	0	**2**

TAXON	K2	K3	K4	K5	K6	K7	K8	K10a	K11	K12	TOTAL
Navicula viridula (Kutzing) Ehrenberg	0	26	0	0	0	0	0	363	2	0	**391**
Navicula viridula (Kutz.) Ehr. var.rostell	0	0	0	0	0	0	0	1	0	0	**1**
Nitzschia alpina Hustedt	0	0	1	0	0	0	0	4	0	0	**5**
Pinnularia borealis Ehrenberg var. borealis	0	0	0	0	0	0	0	1	1	0	**2**
Pinnularia gibba Ehrenberg	0	8	0	0	0	0	0	0	0	0	**8**
Pinnularia interrupta W.M.Smith	0	0	0	0	0	0	0	1	1	0	**2**
PINNULARIA C.G.Ehrenberg	0	0	3	1	0	1	0	0	0	1	**6**
Pinnularia maior (Kutzing) Rabenhorst	0	0	0	0	0	0	0	0	1	0	**1**
Pinnularia stomatophora (Grunow) Cleve var. stomatophora	0	0	1	0	0	0	0	0	0	0	**1**
Pinnularia viridis (Nitzsch) Ehrenberg	0	0	2	0	0	0	0	0	0	0	**2**
Stephanodiscus alpinus Hustedt in Huber-Pestalozzi	6	0	0	0	0	0	0	0	0	0	**6**
Surirella angusta Kutzing	0	0	0	0	0	0	0	1	0	0	**1**
Surirella brightwellii W.Smith var.baltica (Schumann) Krammer	0	0	0	0	0	0	0	0	1	0	**1**
Surirella brebissonii Krammer & Lange-Bertalot var. brebissonii	0	0	0	0	0	0	0	11	0	0	**11**
Stephanodiscus hantzschii Grunow in Cl. & Grun. 1880	1	0	0	0	0	0	0	0	0	0	**1**
Stauroneis anceps Ehrenberg	0	0	1	0	0	0	0	0	0	0	**1**
STAURONEIS C.G.Ehrenberg	0	0	0	0	0	0	0	0	1	0	**1**
STEPHANODISCUS C.G.Ehrenberg	0	2	0	0	0	0	0	0	0	0	**2**
SURIRELLA P. J.F.Turpin	0	0	0	0	0	0	0	0	1	0	**1**
Tabellaria fenestrata (Lyngbye) Kutzing	2	22	20	5	20	16	12	0	24	2	**123**
Tabellaria flocculosa (Roth) Kutzing	4	195	291	248	330	237	359	1	94	8	**1767**
Tetracyclus glans (Ehrenb.) Mills	0	0	0	0	1	0	1	1	0	0	**3**
TOTAL	1430	3596	866	1165	1285	1260	1462	1249	1273	830	**14416**

Appendix 9

Total abundance of diatom taxa (three replicate samples per site) in the Kola River system in July 2002. (Individual samples were not pooled in analyses.)

TAXON	K2	K3	K4	K5	K6	K7	K8	K10a	K10b	K11	K12	TOTAL
Achnanthes alpestris Lange-Bertalot & Metz	1	0	0	0	0	0	0	0	0	0	0	**1**
Achnanthes altaica (Poretzky) Cleve Euler	0	0	1	0	0	0	0	0	0	0	1	**2**
Aulacoseira ambigua (Grun.) Simonsen	3	0	0	0	0	0	0	0	0	0	0	**3**
Achnanthes biasolettiana Grunow var. biasolettiana Grunow in Cleve & Grun.	0	1	0	0	0	2	42	0	0	48	37	**130**
Achnanthes calcar Cleve	0	0	0	0	0	0	0	0	0	0	1	**1**
Achnanthes carissima Lange-Bertalot	0	1	0	0	0	0	1	0	0	0	0	**2**
Achnanthes chlidanos Hohn & Hellerman	0	1	0	0	0	0	0	0	0	0	0	**1**
ACHNANTHES J.B.M. Bory de St. Vincent	1	3	4	6	2	0	4	3	0	4	6	**33**
Achnanthes curtissima Carter	0	4	1	0	0	0	1	0	0	2	1	**9**
Achnanthes daonensis Lange-Bertalot	0	53	0	2	0	7	1	5	0	18	4	**90**
Achnanthes didyma Hustedt	0	0	6	2	0	1	3	0	0	0	1	**13**
Achnanthes flexella (Kutzing)Brun var. flexella	0	0	0	0	0	0	0	0	0	0	0	**0**
Achnanthes helvetica (Hustedt) Lange-Bertalot	6	1	1	0	0	1	3	0	0	0	1	**13**
Amphora inariensis Krammer	0	3	0	0	0	0	0	0	0	0	0	**3**
Achnanthes impexiformis Lange-Bertalot	0	0	0	0	0	0	0	0	0	1	0	**1**
Amphipleura kriegeriana (Krasske) Hustedt	0	0	2	0	0	0	0	0	0	0	0	**2**
Achnanthes lanceolata (Breb.) Grunow var. lanceolata Grunow	1	1	1	0	0	0	0	258	88	21	7	**377**
Achnanthes laterostrata Hustedt	2	4	0	2	1	0	0	2	0	3	4	**18**
Achnanthes linearis (W.Sm.) Grunow	0	0	1	2	1	0	2	0	0	5	8	**19**
Achnanthes levanderi Hustedt	0	0	2	0	0	0	3	0	0	0	1	**6**
Achnanthes laevis Oestrup var. laevis Oestrup	2	12	0	0	9	9	10	0	0	4	7	**53**
Achnanthes minutissima Kutzing v.minutissima Kutzing (Achnanthidium)	831	772	144	979	1116	1057	998	2	1	570	410	**6880**
AMPHORA C.G. Ehrenberg ex F.T. Kützing	1	1	0	0	0	0	0	0	0	0	1	**3**

TAXON	K2	K3	K4	K5	K6	K7	K8	K10a	K10b	K11	K12	TOTAL
Anomoeoneis brachysira (Brebisson in Rabenhorst) Grunow in Cleve	0	0	6	6	2	0	3	0	0	2	2	**21**
Achnanthes nodosa A.Cleve	0	0	4	1	0	0	0	0	0	0	1	**6**
Achnanthes oblongella Oestrup	3	0	0	0	0	0	0	0	0	0	0	**3**
Amphora ovalis (Kutzing) Kutzing	0	1	0	0	0	0	1	0	0	0	0	**2**
Amphora pediculus (Kutzing) Grunow	124	5	0	1	0	0	0	0	0	0	0	**130**
Achnanthes peragalli Brun & Héribaud in Héribaud	0	0	1	0	0	0	0	0	0	0	0	**1**
Achnanthes pusilla (Grunow) De Toni	2	20	264	45	16	35	6	0	1	7	17	**413**
Achnanthes subatomoides (Hustedt) Lange-Bertalot et Archibald	1	0	4	0	1	2	2	1	0	4	1	**16**
Achnanthes saccula Carter in Carter & Bailey-Watts	0	62	4	2	4	2	44	0	0	59	10	**187**
Achnanthes suchlandtii Hustedt	2	0	1	0	0	0	0	1	0	3	4	**11**
Aulacoseira distans (Ehr.) Simonsen	0	0	10	0	0	0	0	1	1	1	1	**14**
Aulacoseira islandica (O.Muller) Simonsen	1	0	0	0	0	0	0	0	0	0	0	**1**
Aulacoseira italica (Ehr.) Simonsen	3	1	2	0	1	0	0	0	0	1	0	**8**
AULACOSEIRA G.H.K.Thwaites	1	0	0	1	0	0	0	0	0	0	0	**2**
Anomoeoneis vitrea (Grunow) Ross	2	1	81	36	16	9	7	0	0	2	9	**163**
Achnanthes ventralis (Krasske) Lange-Bertalot	0	0	0	0	0	2	0	0	0	1	0	**3**
Brachysira procera Lange-Bertalot & Moser	0	0	9	7	1	1	2	0	0	1	0	**21**
Cymbella affinis Kutzing	6	6	1	2	1	0	0	0	0	0	0	**16**
Cymbella angustata (W.M.Smith) Cleve	0	0	0	0	0	0	0	0	0	2	1	**3**
Cymbella aspera (Ehr.) Cleve	0	1	0	0	0	0	0	0	0	0	0	**1**

TAXON	K2	K3	K4	K5	K6	K7	K8	K10a	K10b	K11	K12	TOTAL
Caloneis tenuis (Gregory) Krammer	0	1	18	4	0	0	0	0	0	1	1	**25**
Cymbella caespitosa (Kutzing) Brun (Encyonema)	3	0	0	0	0	0	0	0	0	0	0	**3**
Cymbella cesatii (Rabh.) Grunow	0	1	0	0	0	0	0	0	0	0	0	**1**
Cymbella cistula (Ehrenberg) Kirchner	0	0	0	0	0	0	0	0	0	1	1	**2**
Cyclotella comta (Ehr.) Kutzing	0	0	0	0	0	0	0	0	0	1	0	**1**
Cymbella descripta (Hustedt) Krammer et Lange-Bertalot	0	0	0	1	0	1	1	0	0	0	0	**3**
Cymbella gracilis (Ehr.) Kutzing	0	0	9	2	0	3	1	0	0	5	2	**22**
Craticula halophila (Grunow ex Van Heurck)	1	0	0	0	0	0	0	0	0	0	0	**1**
Cymbella helvetica Kutzing	2	1	0	0	0	0	0	0	0	0	0	**3**
Chamaepinnularia mediocris (Krasske) Lange-Bertalot	0	0	0	3	0	0	2	0	0	0	0	**5**
Chamaepinnularia soehrensis (Krass.) Lange-Bertalot & Krammer	0	0	1	0	0	0	0	0	0	0	0	**1**
Cyclotella meneghiniana Kutzing	0	0	0	0	0	0	0	0	0	0	1	**1**
Cymbella mesiana Cholnoky (Encyonema)	2	1	1	0	0	0	0	0	0	0	0	**4**
Cymbella microcephala Grunow	20	1	34	23	2	0	0	0	0	1	0	**81**
Cymbella minuta Hilse ex Rabenhorst (Encyonema)	85	1	0	2	0	0	3	10	2	20	18	**141**
COCCONEIS C.G.Ehrenberg 1837	0	0	0	0	0	0	0	0	0	0	1	**1**
Cocconeis pediculus Ehrenberg	6	0	0	0	0	0	0	0	0	0	0	**6**
Cymbella perpusilla A.Cleve	0	0	1	0	0	0	0	0	0	0	0	**1**
Cocconeis placentula Ehrenberg var. placentula	6	1	0	0	0	0	1	0	0	7	81	**96**
Cyclotella pseudostelligera Hustedt	7	2	0	1	0	0	1	0	0	0	5	**16**

TAXON	K2	K3	K4	K5	K6	K7	K8	K10a	K10b	K11	K12	TOTAL
Craticula accomoda (Hustedt) Mann	0	0	0	0	0	0	0	0	17	0	0	**17**
Craticula minusculoides (Hustedt) Lange-Bertalot	0	0	0	0	0	0	0	0	0	2	0	**2**
Cyclotella rossii Hakansson	1	0	0	1	0	0	0	0	0	0	0	**2**
Caloneis silicula (Ehr.) Cleve	1	0	0	0	0	0	0	0	0	0	0	**1**
Cymbella sinuata Gregory	3	6	0	1	3	20	2	0	0	97	365	**497**
Cymbella silesiaca Bleisch in Rabenhorst (Encyonema)	16	17	2	6	3	5	5	4	0	8	48	**114**
Cavinula mollicula (Hust.) Lange-Bertalot	0	0	0	0	0	0	1	0	0	0	0	**1**
CYCLOTELLA F.T.Kützing ex A de Brébisson	1	0	0	0	0	0	0	0	0	0	1	**2**
CYMBELLA C.Agardh 1830	2	1	2	0	0	0	0	0	0	0	1	**6**
Didymosphenia geminata (Lyngbye) W.M.Schmidt	2	1	0	2	0	0	9	0	0	2	0	**16**
Diatoma tenuis Agardh	47	31	9	10	15	11	8	17	0	10	4	**162**
Diatoma mesodon (Ehrenberg) Kutzing	0	0	0	0	1	0	0	13	0	0	0	**14**
Diatoma moniliformis Kutzing	0	0	0	0	0	0	0	3	0	2	1	**6**
Denticula tenuis Kutzing	3	2	0	0	0	0	0	0	0	0	0	**5**
Diatoma vulgaris Bory 1824	0	0	0	0	0	0	0	5	0	0	0	**5**
Epithemia adnata (Kutzing) Brebisson	0	0	0	2	0	0	0	0	0	0	0	**2**
Eunotia arcus Ehrenberg var. arcus	0	0	11	9	3	3	0	0	0	0	0	**26**
Eunotia bilunaris (Ehr.) Mills var. biluna	0	0	1	0	0	0	1	0	0	0	0	**2**
Eunotia botuliformis Wild Norpel & Lange-Bertalot	0	0	0	0	0	0	1	0	0	0	0	**1**
Eunotia exacta (Cl.-Euler) Norpel-Schempp & Lange-Bertalot	0	0	1	0	0	0	0	0	0	0	0	**1**

TAXON	K2	K3	K4	K5	K6	K7	K8	K10a	K10b	K11	K12	TOTAL
Eunotia flexuosa (Brebisson) Kutzing	0	0	0	0	0	0	1	0	0	0	0	**1**
Eunotia implicata Nörpel, Lange-Bertalot & Alles	0	0	28	16	26	25	0	0	1	3	6	**105**
Eunotia incisa Gregory var. incisa	0	1	193	6	3	2	2	0	0	4	5	**216**
Eunotia meisteri Hustedt	0	0	1	0	0	0	0	0	0	0	0	**1**
Eunotia minor (Kutzing) Grunow in van Heurck	0	0	4	3	4	2	0	0	0	2	1	**16**
Eunotia muscicola Krasske var. muscicola	0	0	1	0	0	0	0	0	0	0	0	**1**
Eunotia naegeli Migula	0	0	1	0	0	0	0	0	0	0	0	**1**
Eunotia pectinalis (Dyllwyn) Rabenhorst var. pectinalis	0	1	1	0	0	0	0	0	0	0	0	**2**
Eunotia praerupta Ehrenberg var. excelsa Krasske	0	0	1	0	0	0	0	0	0	0	0	**1**
Eunotia serra Ehrenberg var.serra	0	0	2	0	0	0	0	0	0	0	0	**2**
Eunotia sudetica O.Muller	0	0	18	0	0	1	1	0	0	0	0	**20**
Eunotia tenella (Grunow) Hustedt	0	0	0	0	0	0	0	0	0	1	0	**1**
Eunotia intermedia (Krasske ex Hustedt) Nörpel&Lange-Bertalot	0	0	1	0	0	0	0	0	0	0	0	**1**
EUNOTIA C.G.Ehrenberg	1	0	5	2	0	0	1	0	0	1	0	**10**
Fragilaria arcus (Ehrenberg) Cleve var. arcus	0	2	5	11	7	7	6	11	0	1	5	**55**
Fragilaria brevistriata Grunow (Pseudostaurosira)	6	2	4	0	0	0	0	0	1	1	5	**19**
Fragilaria capucina Desmazieres var.capucina	3	0	13	9	0	2	5	1	0	1	9	**43**
Fragilaria capucina Desmazieres var.distans (Krunow) Lange-Bertalot	0	0	0	2	0	0	0	0	0	0	0	**2**
Fragilaria capucina Desmazieres var.gracilis (Destrup) Hustedt	5	1	80	26	29	52	36	4	0	20	25	**278**
Fragilaria capucina Desmazieres var.mesolepta (Rabenhorst) Rabenhorst	0	2	0	1	2	3	1	1	0	0	0	**10**

TAXON	K2	K3	K4	K5	K6	K7	K8	K10a	K10b	K11	K12	TOTAL
Fragilaria construens (Ehr.) Grunow f.construes (Staurosira)	18	12	27	5	1	0	6	0	1	14	17	**101**
Fragilaria crotonensis Kitton	14	0	0	0	0	0	0	0	0	0	0	**14**
Fragilaria capucina Desmazieres ssp. rumpens (Kutzing) Lange-Bertalot	0	10	0	2	3	0	19	52	13	76	23	**198**
Fragilaria capucina Desmazieres var.vaucheriae (Kutzing) Lange-Bertalot	5	10	23	11	7	5	6	25	43	24	12	**171**
Fragilaria exigua Grunow	0	0	2	3	1	0	5	0	0	1	0	**12**
Fallacia maceria (Schimanski) Lange-Bertalot	0	0	1	0	0	0	0	0	0	0	0	**1**
Fragilaria oldenburgiana Hustedt	1	0	0	0	0	0	0	0	0	0	0	**1**
Fragilaria parasitica (W.Sm.) Grun. var. paracitica	0	0	0	1	0	0	0	0	0	0	0	**1**
Fragilaria pinnata Ehrenberg var. pinnata	2	1	4	0	1	0	0	0	3	2	2	**15**
FRAGILARIA H.C.Lyngbye	0	2	4	1	0	2	3	2	0	5	6	**25**
Frustulia rhomboides (Ehr.) De Toni var. crassinervia (Brebisson) Ross	0	0	10	0	0	0	1	0	0	0	0	**11**
Frustulia rhomboides (Ehr.) De Toni	0	0	1	0	0	0	1	0	0	0	1	**3**
Frustulia rhomboides (Ehr.) De Toni var. saxonica (Rabenhorst) De Toni	0	0	31	1	0	0	0	0	0	0	0	**32**
Fragilaria tenera (W.Smith) Lange-Bertalot	12	1	0	1	1	3	5	0	0	2	5	**30**
Fragilaria ulna (Nitzsch.) Lange-Bertalot var. acus (Kutz) Lange-Bertalot	0	0	3	3	0	1	4	0	0	0	0	**11**
Fragilaria ulna (Nitzsch.) Lange-Bertalot var. ulna	1	5	1	4	7	1	4	6	0	9	3	**41**
Gomphonema acuminatum Ehrenberg var.coronata (Ehr.) W. Smith	0	0	3	1	0	0	0	0	0	0	0	**4**
Gomphonema angustatum (Kutzing) Rabenhorst	0	3	1	1	0	0	1	0	1	7	25	**39**
Gomphonema angustum Agardh	3	2	0	0	2	1	3	2	2	3	3	**21**
Gomphonema clavatum Ehr.	0	3	1	0	2	0	1	0	0	0	0	**7**

TAXON	K2	K3	K4	K5	K6	K7	K8	K10a	K10b	K11	K12	TOTAL
Gomphonema exilissimum (Grun.) Lange-Bertalot & Reichardt	0	0	0	0	1	0	1	0	0	2	1	**5**
Gomphonema gracile Ehrenberg	0	0	0	0	1	0	0	0	0	0	0	**1**
Gomphonema grovei M.Schmidt	0	1	0	0	0	0	0	0	0	0	0	**1**
Gomphonema olivaceum (Hornemann) Brébisson var. olivaceum	18	12	0	5	0	0	2	0	0	1	0	**38**
GOMPHONEMA C.G.Ehrenberg	1	1	0	0	0	0	1	2	0	1	2	**8**
Gomphonema parvulum Kutzing var. parvulum F. parvulum	0	0	0	0	0	0	0	0	41	21	8	**70**
Gomphonema truncatum Ehr.	3	1	1	1	1	0	0	0	0	2	0	**9**
Gomphonema ventricosum Gregory	0	0	0	0	0	0	7	0	0	0	0	**7**
Hippodonta capitata (Ehr.) Lange-Bert.Metzeltin & Witkowski	1	0	0	0	0	0	0	0	0	0	0	**1**
Mayamaea atomus (Kutzing) Lange-Bertalot	0	0	0	0	0	0	0	0	1	0	0	**1**
Mayamaea atomus var. permitis (Hustedt) Lange-Bertalot	0	0	0	0	0	0	0	172	740	10	5	**927**
Meridion circulare (Greville) C.A.Agardh var. circulare	6	200	1	5	2	1	18	21	42	19	12	**327**
Melosira varians Agardh	0	0	0	0	0	0	0	1	0	0	0	**1**
Navicula angusta Grunow	0	0	2	1	0	0	0	0	0	0	0	**3**
Nitzschia acidoclinata Lange-Bertalot	0	0	2	0	0	0	0	0	0	0	0	**2**
Neidium alpinum Hustedt	0	1	0	0	0	0	0	0	0	0	0	**1**
Nitzschia amphibia Grunow f.amphibia	2	0	1	2	1	0	0	0	0	0	0	**6**
NAVICULA J.B.M.Bory de St. Vincent	1	0	0	0	0	0	0	1	0	5	2	**9**
Navicula bryophila Boye Petersen	0	0	1	0	0	0	0	0	0	0	0	**1**
Navicula cincta (Ehr.) Ralfs in Pritchard	0	3	0	0	0	0	0	0	0	0	0	**3**
Navicula cocconeiformis Gregory ex Greville	0	0	1	0	0	0	0	0	0	0	0	**1**

TAXON	K2	K3	K4	K5	K6	K7	K8	K10a	K10b	K11	K12	TOTAL
Nitzschia capitellata Hustedt in A.Schmidt & al.	2	0	0	0	0	0	0	0	0	0	0	**2**
Navicula cryptocephala Kutzing	0	1	0	0	0	1	1	0	2	4	11	**20**
Navicula cryptotenella Lange-Bertalot	3	1	1	2	0	0	0	0	0	0	1	**8**
Naviculadicta hambergii Hustedt	0	0	0	0	0	0	0	0	1	1	0	**2**
Nitzschia dissipata (Kutzing) Grunow var. dissipata	2	5	0	0	0	1	4	29	0	7	8	**56**
Neidium ampliatum (Ehrenberg) Krammer	0	0	1	0	0	0	0	0	0	0	0	**1**
NEIDIUM E.Pfitzer	0	0	0	0	0	0	0	0	1	0	0	**1**
Navicula elginensis (Gregory) Ralfs in Pritchard	1	0	0	0	0	0	0	0	0	0	0	**1**
Nitzschia flexa Schumann	0	0	0	0	0	0	0	0	0	0	1	**1**
Nitzschia flexoides Geitler	1	2	0	0	0	0	0	0	0	4	1	**8**
Nitzschia fontikola Grunow in Cleve et Möller	21	2	0	1	1	1	1	2	0	2	0	**31**
Navicula gregaria Donkin	0	0	0	0	0	0	0	142	2	0	0	**144**
Nitzschia hantzschiana Rabenhorst	1	0	0	3	1	1	4	6	0	8	2	**26**
Nitzschia homburgiensis Lange-Bertalot	0	0	0	0	0	0	0	0	0	1	0	**1**
Nitzschia angustata Grunow	1	0	3	0	2	0	1	0	0	1	0	**8**
Nitzschia bryophila Hustedt	7	6	1	3	2	2	0	0	0	6	5	**32**
Nitzschia rustulum (Kutzing) Grunow var. frustulum	0	0	0	0	0	0	0	1	0	0	0	**1**
Nitzschia gracilis Hantzsch	0	0	0	0	0	0	2	0	0	8	0	**10**
Nitzschia inconspicua Grunow	1	1	0	0	0	0	0	1	1	0	0	**4**
Nitzschia perminuta (Grunow) M.Peragallo	1	4	4	2	1	1	0	6	1	3	1	**24**
Nitzschia pura Hustedt	0	0	0	0	0	0	0	0	0	5	0	**5**
Nitzschia pusilla (Kutzing) Grunow	0	0	0	0	0	0	0	0	1	1	0	**2**

TAXON	K2	K3	K4	K5	K6	K7	K8	K10a	K10b	K11	K12	TOTAL
NITZSCHIA A.H.Hassall	6	2	5	4	1	0	2	7	6	17	14	**64**
Navicula lanceolata (Agardh) Ehrenberg	0	0	0	0	0	0	0	197	1	0	0	**198**
Nitzschia linearis (Agardh) W.M.Smith var.linearis	16	0	0	0	0	0	0	0	0	0	1	**17**
Navicula mediocris Krasske	0	0	2	0	0	0	0	0	0	0	0	**2**
Navicula minima Grunow	0	0	0	0	0	0	0	240	238	28	7	**513**
Navicula molestiformis Hustedt	0	0	0	0	0	0	0	0	40	0	0	**40**
Nitzschia palea (Kutzing) W.Smith	1	0	1	0	0	0	0	12	24	27	2	**67**
Navicula pseudoscutiformis Hustedt	0	0	3	0	0	0	1	0	0	0	0	**4**
Navicula pupula Kutzing	0	0	0	1	0	0	0	0	0	0	0	**1**
Navicula radiosa Kützing	1	1	2	1	1	0	1	0	0	1	0	**8**
Nitzschia recta Hantzsch ex Rabenhorst	0	0	1	1	0	0	0	0	0	0	1	**3**
Navicula rhynchocephala Kutzing	0	0	0	0	0	0	1	0	0	0	0	**1**
Navicula saprophila Lange-Bertalot & Bonik	0	0	0	0	0	0	0	0	6	0	0	**6**
Nitzschia sublinearis Hustedt	12	0	0	0	0	0	0	0	0	0	0	**12**
Navicula subminuscula Manguin	0	0	0	0	0	0	0	0	8	0	0	**8**
Navicula seminulum Grunow	0	0	0	0	0	0	0	14	3	1	0	**18**
Navicula slesvicensis Grunow	0	0	0	0	0	0	0	14	0	3	1	**18**
Navicula schmassmanii Hustedt	0	5	1	0	1	0	0	1	0	0	2	**10**
Nitzschia sociabilis Hustedt	1	0	0	0	0	0	0	0	0	0	0	**1**
Navicula stankovici Hustedt	0	1	0	0	0	0	0	0	0	0	0	**1**
Navicula subtilissima Cleve	1	0	1	0	0	0	0	0	0	0	1	**3**

TAXON	K2	K3	K4	K5	K6	K7	K8	K10a	K10b	K11	K12	TOTAL
Navicula suchlandtii Hustedt	0	0	0	1	0	20	2	0	0	0	0	**23**
Navicula trivialis Lange-Bertalot var. trivialis	0	0	0	1	0	0	0	0	0	0	0	**1**
Nitzschia tubicola Grunow	0	0	0	0	0	0	0	20	0	0	0	**20**
Navicula umbra Hohn & Hellerman	0	0	0	0	0	1	0	0	0	0	0	**1**
Navicula viridula (Kutz.) Ehr. var.rostellata (Kutz.) Cleve	0	0	0	0	0	0	0	1	0	0	0	**1**
Nitzschia supralitorea Lange-Bertalot	1	0	0	0	0	0	0	15	0	0	0	**16**
Pinnularia borealis Ehrenberg var. borealis	0	0	0	1	0	0	0	0	0	0	0	**1**
Pinnularia gibba Ehrenberg	0	0	1	0	0	0	0	0	0	0	0	**1**
Pinnularia interrupta W.M.Smith	0	0	1	0	0	0	1	0	0	0	0	**2**
PINNULARIA C.G.Ehrenberg	0	0	0	0	0	1	0	0	0	0	0	**1**
Pinnularia microstauron (Ehr.) Cleve	0	0	0	0	0	0	0	0	2	0	0	**2**
Rhopalodia gibba (Ehr.) O.Muller var.gibba	0	0	2	2	0	0	0	0	0	0	0	**4**
Surirella angusta Kutzing	0	0	0	0	0	0	0	2	1	0	0	**3**
Surirella brebissonii Krammer & Lange-Bertalot var. brebissonii	0	0	0	0	0	0	0	16	0	0	1	**17**
Stauroneis phoenicenteron (Nitzsch.) Ehrenberg	0	0	1	0	1	0	0	0	0	0	0	**2**
Sellaphora pupula (Kutzing) Mereschkowksy	0	0	0	1	0	0	0	0	1	1	0	**3**
STEPHANODISCUS C.G.Ehrenberg	1	1	0	0	0	0	0	0	0	0	0	**2**
Tabellaria fenestrata (Lyngbye) Kutzing	0	0	1	0	0	0	0	0	0	0	0	**1**
Tabellaria flocculosa (Roth) Kutzing	6	24	140	24	47	11	13	3	0	23	25	**316**
Tetracyclus glans (Ehrenb.) Mills	0	0	2	0	0	0	1	0	0	0	0	**3**
TOTAL	1391	1354	1293	1333	1358	1319	1345	1355	1338	1306	1334	**14726**

Appendix 10

Total abundance of diatom taxa (three replicate samples per site) in the Kola River system in September 2002. (Individual samples were not pooled in analyses.)

TAXON	K2	K3	K4	K5	K6	K7	K8	K10a	K10b	K11	K12	TOTAL
Achnanthes alpestris Lange-Bertalot & Metz	0	0	0	0	0	0	1	0	0	0	0	**1**
Aulacoseira ambigua (Grun.) Simonsen	1	0	3	0	0	0	0	0	0	0	0	**4**
Achnanthes biasolettiana Grunow var. biasolettiana Grunow in Cleve & Grun.	0	0	0	1	1	0	1	1	0	51	36	**91**
Achnanthes bioreti Germain (=Psammothidium)	0	0	0	0	1	0	0	0	0	0	0	**1**
Achnanthes carissima Lange-Bertalot	0	0	0	0	0	0	0	0	0	1	0	**1**
ACHNANTHES J.B.M.Bory de St. Vincent	1	6	8	2	0	1	0	0	0	3	0	**21**
Achnanthes clevei Grunow var. clevei (=Karayevia)	0	0	0	3	0	0	0	0	0	0	0	**3**
Achnanthes curtissima Carter	0	4	0	0	0	1	0	0	0	0	0	**5**
Achnanthes daonensis Lange-Bertalot	0	20	0	0	0	0	0	0	1	2	2	**25**
Achnanthes didyma Hustedt	0	0	4	0	1	0	1	0	0	0	1	**7**
Achnanthes flexella (Kutzing) Brun var. flexella	0	0	0	0	0	0	1	0	0	0	0	**1**
Asterionella formosa Hassall	0	4	0	0	0	0	0	0	0	0	1	**5**
Achnanthes helvetica (Hustedt) Lange-Bertalot	0	0	0	0	0	0	4	0	0	0	0	**4**
Amphora inariensis Krammer	0	2	0	0	0	0	0	0	0	0	0	**2**
Achnanthes impexiformis Lange-Bertalot	0	0	0	1	0	0	0	0	0	0	0	**1**
Achnanthes lanceolata (Breb.) Grunow var. lanceolata Grunow	1	4	0	0	0	0	0	158	76	5	0	**244**
Achnanthes laterostrata Hustedt	1	1	2	0	0	0	1	1	3	4	0	**13**
Achnanthes linearis (W.Sm.) Grunow	0	2	11	0	1	0	3	0	0	10	6	**33**

TAXON	K2	K3	K4	K5	K6	K7	K8	K10a	K10b	K11	K12	TOTAL
Aulacoseira lirata (Ehr.) Ross in Hartley	0	0	0	1	1	0	0	0	0	0	0	**2**
Achnanthes levanderi Hustedt	0	0	4	0	1	1	1	0	0	1	1	**9**
Achnanthes laevis Oestrup var. laevis Oestrup	0	3	0	2	3	2	2	0	1	1	2	**16**
Achnanthes minutissima Kutzing v.minutissima Kutzing (Achnanthidium)	891	409	315	900	809	997	701	9	2	922	509	**6464**
Anomoeoneis brachysira (Brebisson in Rabenhorst) Grunow in Cleve	0	0	11	10	3	4	1	0	1	2	1	**33**
Achnanthes nodosa A.Cleve	0	0	0	0	0	1	0	0	0	0	0	**1**
Achnanthes oblongella Oestrup	0	4	0	0	0	0	0	0	0	0	0	**4**
Achnanthes oestrupii (Cleve-Euler) Hustedt var. oestrupii Hustedt	0	0	0	1	0	0	0	0	0	0	0	**1**
Amphora ovalis (Kutzing) Kutzing	0	0	0	1	0	0	0	0	0	1	0	**2**
Amphora pediculus (Kutzing) Grunow	17	10	0	0	0	0	0	0	0	0	0	**27**
Achnanthes pusilla (Grunow) De Toni	0	21	130	13	14	14	42	0	0	4	1	**239**
Achnanthes rossii Hustedt	0	0	1	0	1	0	0	0	0	1	0	**3**
Achnanthes subatomoides (Hustedt) Lange-Bertalot et Archibald	0	0	4	1	2	1	1	0	1	1	0	**11**
Achnanthes saccula Carter in Carter & Bailey-Watts	0	32	13	3	2	2	0	0	0	39	36	**127**
Achnanthes scotica Flower & Jones	0	0	0	0	0	0	0	0	0	0	1	**1**
Achnanthes stewartii Patrick	0	1	0	0	0	0	1	0	0	0	0	**2**
Achnanthes suchlandtii Hustedt	0	0	0	0	0	0	1	0	0	1	1	**3**
Aulacoseira distans (Ehr.) Simonsen	0	1	2	0	0	0	1	0	0	0	0	**4**
Aulacoseira italica (Ehr.) Simonsen	0	0	2	1	2	1	1	0	0	0	0	**7**
AULACOSEIRA G.H.K.Thwaites	2	1	0	0	0	0	0	0	0	0	0	**3**

TAXON	K2	K3	K4	K5	K6	K7	K8	K10a	K10b	K11	K12	TOTAL
Aulacoseira valida (Grunow) Krammer	0	0	2	0	0	0	0	0	0	0	0	**2**
Anomoeoneis vitrea (Grunow) Ross	0	4	80	68	59	23	71	0	0	4	1	**310**
Achnanthes ventralis (Krasske) Lange-Bertalot	0	0	2	0	0	0	1	0	0	0	0	**3**
Brachysira procera Lange-Bertalot & Moser	0	0	4	6	2	2	2	0	0	1	0	**17**
Cymbella affinis Kutzing	5	4	0	0	1	0	1	0	0	0	0	**11**
CALONEIS	1	1	0	0	0	0	0	0	0	0	1	**3**
Caloneis tenuis (Gregory) Krammer	0	1	3	0	2	1	0	0	1	0	0	**8**
Cymbella caespitosa (Kutzing) Brun (Encyonema)	3	0	0	0	0	0	0	0	0	0	0	**3**
Cymbella cesatii (Rabh.) Grunow	0	0	0	1	2	2	2	0	0	6	0	**13**
Cymbella cistula (Ehrenberg) Kirchner	0	1	0	1	0	0	0	0	0	0	0	**2**
Cyclostephanos dubius (Fricke) Round	1	2	0	0	0	0	0	0	0	0	0	**3**
Cymbella gaeumannii Meister	0	1	0	0	0	0	0	0	0	0	0	**1**
Cymbella gracilis (Ehr.) Kutzing	0	0	14	2	1	0	6	0	0	1	1	**25**
Cymbella helvetica Kutzing	0	0	0	1	1	0	1	0	0	0	0	**3**
Cyclotella meneghiniana Kutzing	0	0	0	0	0	0	0	0	3	0	0	**3**
Cymbella microcephala Grunow	8	3	18	24	12	7	28	0	0	1	2	**103**
Cymbella minuta Hilse ex Rabenhorst (Encyonema)	84	6	1	3	0	0	3	66	2	27	19	**211**
Cyclotella ocellata Pantocsek	0	2	0	0	0	0	0	0	0	0	0	**2**
Cymbella perpusilla A.Cleve	0	0	1	0	0	0	0	0	0	0	0	**1**
Cocconeis placentula Ehrenberg var. placentula	21	0	0	0	1	0	0	2	0	5	16	**45**

TAXON	K2	K3	K4	K5	K6	K7	K8	K10a	K10b	K11	K12	TOTAL
Cyclotella pseudostelligera Hustedt	2	3	0	1	1	0	2	0	0	1	3	**13**
Craticula accomoda (Hustedt) Mann	0	0	0	0	0	0	0	1	0	0	0	**1**
Craticula minusculoides (Hustedt) Lange-Bertalot	0	0	0	0	0	0	0	0	1	0	0	**1**
Cyclotella rossii Hakansson	0	1	0	0	0	0	0	0	0	0	0	**1**
Cymbella sinuata Gregory	1	4	0	0	2	1	0	0	2	7	8	**25**
Cymbella silesiaca Bleisch in Rabenhorst (Encyonema)	23	4	0	2	3	2	7	6	1	7	58	**113**
CYMBELLA C.Agardh 1830	2	0	0	2	0	0	0	1	0	1	0	**6**
Didymosphenia geminata (Lyngbye) W.M.Schmidt	0	0	0	0	0	1	0	0	0	0	0	**1**
Diatoma tenuis Agardh	77	24	16	27	22	17	25	1	0	5	4	**218**
Diatoma moniliformis Kutzing	0	0	0	3	0	0	1	3	0	1	3	**11**
Denticula tenuis Kutzing	1	1	0	0	0	0	0	0	0	0	0	**2**
Diatoma vulgaris Bory 1824	0	0	0	0	0	0	0	1	0	0	0	**1**
Eunotia arcus Ehrenberg var. arcus	0	0	1	11	2	6	3	1	0	0	0	**24**
Eunotia bilunaris (Ehr.) Mills var. bilunaris	0	0	3	1	0	0	0	0	0	0	0	**4**
Eunotia botuliformis Wild Norpel & Lange-Bertalot	0	0	1	0	0	0	0	0	0	0	0	**1**
Eunotia exigua (Breb.) Rabenhorst	0	0	0	0	0	1	0	0	0	0	0	**1**
Eunotia glacialis Meister	0	0	0	0	0	0	1	0	0	0	0	**1**
Eunotia implicata Nörpel, Lange-Bertalot & Alles	0	2	44	10	37	20	9	0	0	0	2	**124**
Eunotia incisa Gregory var. incisa	0	0	69	3	5	6	1	0	1	0	5	**90**
Eunotia minor (Kutzing) Grunow in Van Heurck	0	1	3	0	4	0	1	1	2	0	0	**12**

TAXON	K2	K3	K4	K5	K6	K7	K8	K10a	K10b	K11	K12	TOTAL
Eunotia naegeli Migula	0	0	1	0	0	0	0	0	0	0	0	**1**
Eunotia praerupta Ehrenberg var. praerupta	0	0	1	0	0	0	0	0	1	0	0	**2**
Eunotia rhomboidea Hustedt	0	0	0	0	0	1	1	0	0	0	0	**2**
Eunotia intermedia (Krasske ex Hustedt) Nörpel & Lange-Bertalot	0	0	1	0	0	0	0	0	0	0	0	**1**
EUNOTIA C.G.Ehrenberg	0	0	3	0	2	0	0	1	0	0	0	**6**
Fragilaria arcus (Ehrenberg) Cleve var. arcus	0	0	0	2	0	2	1	0	0	1	8	**14**
Fragilaria brevistriata Grunow (Pseudostaurosira)	0	0	0	1	3	0	0	0	0	2	0	**6**
Fragilaria capucina Desmazieres var.capucina	0	1	10	6	1	0	1	0	0	2	1	**22**
Fragilaria capucina Desmazieres var.gracilis (Destrup) Hustedt	27	3	54	33	36	61	92	1	0	14	16	**337**
Fragilaria capucina Desmazieres var.mesolepta (Rabenhorst) Rabenhorst	4	1	1	2	1	0	2	1	0	3	6	**21**
Fragilaria construens (Ehr.) Grunow f.construes (Staurosira)	3	23	24	9	8	3	10	0	0	4	4	**88**
Fragilaria capucina Desmazieres ssp. rumpens (Kutzing) Lange-Bertalot	90	3	1	2	0	0	1	15	1	30	56	**199**
Fragilaria capucina Desmazieres var.vaucheriae (Kutzing) Lange-Bertalot	14	20	8	14	10	4	12	9	2	13	6	**112**
Fragilaria exigua Grunow	0	1	9	0	2	1	2	0	0	1	1	**17**
Fragilaria lapponica Grunow in van Heurck	0	0	1	0	0	0	2	0	0	0	0	**3**
Fragilaria leptostauron (Ehr.) Hustedt var. leptostauron	0	0	0	0	0	1	0	0	0	0	0	**1**
Fallacia maceria (Schimanski) Lange-Bertalot	0	0	0	0	0	1	0	0	0	0	0	**1**
Fragilaria nanana Lange-Bertalot	0	0	0	0	0	0	1	0	0	0	0	**1**
Fragilaria pinnata Ehrenberg var. pinnata	0	4	4	2	1	0	2	0				**13**
FRAGILARIA H.C.Lyngbye	0	2	6	6	3	2	1	0	0	2	0	**22**

TAXON	K2	K3	K4	K5	K6	K7	K8	K10a	K10b	K11	K12	TOTAL
Frustulia rhomboides (Ehr.) De Toni var. crassinervia (Brebisson) Ross	0	0	2	0	0	0	0	0	0	0	2	**4**
Frustulia rhomboides (Ehr.) De Toni	0	0	1	0	0	0	0	0	0	0	0	**1**
Frustulia rhomboides (Ehr.) De Toni var. saxonica (Rabenhorst) De Toni	0	0	11	0	0	0	2	0	0	0	0	**13**
Fistulifera saprophila (Lange-Bertalot & Bonik) Lange-Bertalot	0	0	0	0	0	0	0	10	1	1	0	**12**
Fragilaria tenera (W.Smith) Lange-Bertalot	2	1	0	2	0	16	21	0	16	2	0	**60**
Fragilaria ulna (Nitzsch.) Lange-Bertalot var. acus (Kutz) Lange-Bertalot	0	0	0	2	1	0	0	0	0	1	0	**4**
Fragilaria ulna (Nitzsch.) Lange-Bertalot var. ulna	39	3	1	6	4	2	2	2	0	0	0	**59**
Gomphonema acuminatum Ehrenberg var.coronata (Ehr.) W.Smith	0	0	1	1	1	0	2	0	1	1	2	**9**
Gomphonema angustatum (Kutzing) Rabenhorst	0	1	0	0	0	1	2	0				**4**
Gomphonema angustum Agardh	4	2	0	9	4	4	1	5	0	0	1	**30**
Gomphonema clavatum Ehr.	0	2	0	3	2	0	0	0	8	3	30	**48**
Gomphonema exilissimum (Grun.) Lange-Bertalot & Reichardt	0	0	1	1	1	0	1	0	0	4	1	**9**
Gomphonema hebridense Gregory	0	0	0	0	0	1	0	0	0	1	0	**2**
Gomphonema insigne Gregory	0	0	0	0	0	0	0	0	0	0	0	**0**
Gomphonema olivaceum (Hornemann) Brébisson var. olivaceum	6	1	1	0	0	0	0	0	0	0	0	**8**
GOMPHONEMA C.G.Ehrenberg	2	0	2	0	1	0	0	0	0	0	1	**6**
Gomphonema parvulum Kutzing var. parvulum f. parvulum	0	0	0	0	0	0	0	0	0	1	0	**1**
Gomphonema truncatum Ehr.	2	0	0	1	2	0	1	0	1	1	0	**8**
Gomphonema ventricosum Gregory	0	1	0	0	0	0	0	0	10	7	12	**30**

TAXON	K2	K3	K4	K5	K6	K7	K8	K10a	K10b	K11	K12	TOTAL
Hippodonta capitata (Ehr.) Lange-Bert.Metzeltin & Witkowski	0	0	0	0	0	0	0	0	0	4	0	**4**
Mayamaea atomus var. permitis (Hustedt) Lange-Bertalot	0	0	0	0	0	0	0	122	0	2	0	**124**
Meridion circulare (Greville) C.A.Agardh var. circulare	2	122	1	2	1	0	0	3	0	2	0	**133**
Melosira varians Agardh	0	0	0	0	0	0	0	1	320	2	0	**323**
Navicula angusta Grunow	0	0	3	0	0	0	0	0	5	4	1	**13**
Nitzschia acula Hantzsch	0	0	0	0	0	0	1	0	0	2	0	**3**
NAVICULADICTA Lange-Bertalot	0	0	0	0	0	0	1	0	0	0	0	**1**
Navicula agrestis Hustedt	0	0	0	0	0	0	0	1	0	0	0	**1**
Nitzschia amphibia Grunow f.amphibia	0	0	2	0	2	0	4	0	0	0	2	**10**
NAVICULA J.B.M.Bory de St. Vincent	0	1	2	0	0	0	1	0	1	0	0	**5**
Navicula cincta (Ehr.) Ralfs in Pritchard	0	10	0	0	0	0	0	0	0	0	0	**10**
Navicula clementis Grunow	0	0	0	0	0	0	0	2	2	0	0	**4**
Navicula cocconeiformis Gregory ex Greville	0	0	0	0	0	0	1	0	1	0	0	**2**
Navicula cryptocephala Kutzing	0	2	3	1	0	1	0	2	0	0	0	**9**
Navicula cryptotenella Lange-Bertalot	0	0	0	0	0	0	1	0	0	0	0	**1**
Nitzschia dissipata (Kutzing) Grunow var.dissipata	0	2	0	0	0	0	0	14	2	4	1	**23**
Nitzschia flexoides Geitler	5	2	0	2	0	2	10	0	0	0	1	**22**
Nitzschia fontikola Grunow in Cleve et Möller	6	5	0	0	0	2	7	4	1	4	1	**30**
Navicula gregaria Donkin	0	0	0	0	0	0	0	90	0	0	3	**93**
Nitzschia hantzschiana Rabenhorst	0	1	3	2	0	0	1	6	1	25	6	**45**
Navicula heimansioides Lange-Bertalot	0	0	2	0	0	0	3	0	0	0	0	**5**

TAXON	K2	K3	K4	K5	K6	K7	K8	K10a	K10b	K11	K12	TOTAL
Navicula heimansii Van Dam et Kooyman	0	0	0	0	0	0	2	0	0	2	7	**11**
Nitzschia homburgiensis Lange-Bertalot	0	0	0	0	0	0	0	1	0	0	0	**1**
Nitzschia angustata Grunow	0	0	1	5	4	4	4	0	0	1	0	**19**
Nitzschia bryophila Hustedt	0	1	1	1	2	0	1	0	0	0	2	**8**
Nitzschia frustulum (Kutzing) Grunow var.fru	0	0	0	0	0	0	1	9	0	1	1	**12**
Nitzschia gracilis Hantzsch	0	0	1	0	0	0	0	0	0	8	4	**13**
Nitzschia perminuta (Grunow) M.Peragallo	0	1	4	1	0	1	4	5	0	0	0	**16**
Nitzschia pura Hustedt	2	0	0	0	0	0	1	1	0	5	2	**11**
Nitzschia pusilla (Kutzing) Grunow	0	0	0	0	0	0	0	0	0	8	2	**10**
NITZSCHIA A.H.Hassall	0	3	0	3	1	0	0	17	0	0	0	**24**
Navicula lanceolata (Agardh) Ehrenberg	0	0	0	0	0	0	0	48	0	1	0	**49**
Navicula minima Grunow	0	1	4	0	0	0	1	614	2	2	1	**625**
Navicula molestiformis Hustedt	0	0	0	0	0	0	0	8	0	0	0	**8**
Nitzschia palea (Kutzing) W.Smith	0	2	0	0	0	0	0	13	807	11	5	**838**
Navicula pseudoscutiformis Hustedt	0	0	1	0	0	0	0	0	10	0	0	**11**
Navicula pupula Kutzing	0	0	0	0	0	0	1	0	10	8	1	**20**
Navicula radiosa Kützing	0	3	2	0	0	0	1	0	0	1	1	**8**
Nitzschia recta Hantzsch ex Rabenhorst	0	0	1	0	1	0	1	2	0	0	0	**5**
Navicula rhynchocephala Kutzing	0	0	1	0	0	0	0	0	0	0	0	**1**
Navicula subminuscula Manguin	0	0	0	0	0	0	0	0	0	0	0	**0**
Navicula seminulum Grunow	0	0	0	0	0	0	1	7	0	0	0	**8**

TAXON	K2	K3	K4	K5	K6	K7	K8	K10a	K10b	K11	K12	TOTAL
Navicula slesvicensis Grunow	0	0	0	0	0	0	0	4	2	0	0	**6**
Navicula schmassmanii Hustedt	0	4	0	0	0	0	1	0	7	0	0	**12**
Nitzschia sociabilis Hustedt	0	0	0	0	0	1	0	0	1	0	0	**2**
Navicula soehrensis Krasske	0	1	0	0	0	0	0	0	0	0	0	**1**
Navicula suchlandtii Hustedt	0	0	0	0	0	4	0	0	0	0	0	**4**
Navicula tenelloides Hustedt	0	1	0	0	0	0	0	0	0	0	0	**1**
Nitzschia tubicola Grunow	0	0	0	0	0	0	0	1	0	0	1	**2**
Navicula umbra Hohn & Hellerman	0	0	1	0	0	0	0	0	0	0	0	**1**
Nitzschia supralitorea Lange-Bertalot	0	0	0	0	0	0	0	44	0	0	0	**44**
Pinnularia ignobilis (Krasske) Cleve-Euler	0	0	0	0	0	0	0	1	0	0	0	**1**
PINNULARIA C.G.Ehrenberg	0	0	0	0	0	0	0	0	0	0	0	**0**
Pinnularia microstauron (Ehr.) Cleve	0	0	0	0	0	0	0	0	0	0	0	**0**
Pinnularia nodosa (Ehrenberg) W.Smith	0	0	0	0	0	0	0	0	0	0	1	**1**
Pinnularia subcapitata Gregory var. subcapitata	0	0	0	0	0	0	0	1	1	0	0	**2**
Surirella brebissonii Krammer & Lange-Bertalot var. brebissonii	0	0	0	0	0	0	0	7	1	0	0	**8**
Sellaphora pupula (Kutzing) Mereschkowksy	0	0	0	0	0	0	0	1	3	0	0	**4**
STENOPTEROBIA A. de Brébisson ex H. Van Heurck	0	0	1	0	0	0	0	0	0	0	1	**2**
Stauroneis kriegeri Patrick	0	0	0	0	0	0	0	0	0	1	0	**1**
SURIRELLA P. J.F.Turpin	0	0	0	0	0	0	0	1	0	0	0	**1**
Tabellaria flocculosa (Roth) Kutzing	3	32	385	95	235	74	175	0	2	0	0	**1001**
Tetracyclus glans (Ehrenb.) Mills	0	0	1	1	0	0	0	0	0	0	0	**2**
Tabellaria quadriseptata Knudson	0	0	0	0	1	0	1	0	0	22	16	**40**
TOTAL	1354	853	1336	1321	1329	1303	1314	1326	1318	1330	928	**13712**

Appendix 11

Total abundance of diatom taxa (three replicate samples per site) in the Näätämöjoki River in July 2002. (Individual samples were not pooled in analyses.)

TAXON	N1	N2	N3	N4	N5	TOTAL
Achnanthes altaica (Poretzky) Cleve Euler	0	0	0	2	0	**2**
Aulacoseira ambigua (Grun.) Simonsen	0	1	0	0	0	**1**
Anomoeoneis brachysira (Breb.) Grunow var.zellensis (Grunov) Krammer	10	3	0	12	2	**27**
ACHNANTHES J.B.M. Bory de St. Vincent	2	7	0	0	0	**9**
Achnanthes didyma Hustedt	0	2	0	0	0	**2**
Achnanthes flexella (Kutzing) Brun var. flexella	3	1	3	12	6	**25**
Achnanthes helvetica (Hustedt) Lange-Bertalot	0	4	2	2	0	**8**
Achnanthes laterostrata Hustedt	0	1	0	0	1	**2**
Achnanthes linearis (W.Sm.) Grunow	2	2	1	0	0	**5**
Achnanthes levanderi Hustedt	2	6	3	1	0	**12**
Achnanthes laevis Oestrup var. laevis Oestrup	1	2	5	0	10	**18**
Achnanthes marginulata Grunow in Cleve & Grun.	0	1	0	0	0	**1**
Achnanthes minutissima Kutzing v.minutissima Kutzing (Achnanthidium)	512	518	396	376	753	**2555**
Anomoeoneis brachysira (Brebisson in Rabenhorst) Grunow in Cleve	27	3	2	4	0	**36**
Achnanthes nodosa A.Cleve	0	1	4	4	0	**9**
Achnanthes oblongella Oestrup	0	0	1	0	0	**1**
Amphora ovalis (Kutzing) Kutzing	0	1	0	1	0	**2**
Achnanthes petersenii Hustedt KLB91p67f37/	0	2	1	0	0	**3**
Achnanthes pusilla (Grunow) De Toni	38	33	22	39	35	**167**
Achnanthes rosenstockii Lange-Bertalot var. rosenstockii	1	0	0	0	0	**1**
Achnanthes subatomoides (Hustedt) Lange-Bertalot et Archibald	2	0	0	2	1	**5**
Anomoeoneis styriaca (Grunow) Hustedt	3	0	0	3	0	**6**
Aulacoseira distans (Ehr.) Simonsen	0	1	0	1	0	**2**
Aulacoseira islandica (O.Muller) Simonsen	0	1	0	0	0	**1**
Aulacoseira italica (Ehr.) Simonsen	0	2	0	0	0	**2**
AULACOSEIRA G.H.K. Thwaites	1	0	0	1	0	**2**
Anomoeoneis vitrea (Grunow) Ross	79	41	121	174	12	**427**
Achnanthes ventralis (Krasske) Lange-Bertalot	0	1	0	0	0	**1**
Brachysira procera Lange-Bertalot & Moser	11	6	16	45	3	**81**
Brachysira zellensis (Grunow) Round & Mann Lange-Bertalot	2	0	0	0	0	**2**
Cymbella affinis Kutzing	37	7	7	6	1	**58**
CALONEIS	0	1	0	1	0	**2**
Cymbella angustata (W.M.Smith) Cleve	0	1	0	2	0	**3**
Caloneis tenuis (Gregory) Krammer	11	4	7	2	1	**25**
Cymbella caespitosa (Kutzing) Brun (Encyonema)	0	0	0	0	1	**1**
Cymbella cesatii (Rabh.)Grunow	13	5	30	40	3	**91**
Cymbella cymbiformis Agardh var.nonpunctata Fontell	2	0	0	0	0	**2**
Cyclotella comta (Ehr.) Kutzing	0	3	0	1	0	**4**
Cymbella cymbiformis Agardh	2	0	0	0	0	**2**
Cymbella descripta (Hustedt) Krammer et Lange-Bertalot	2	1	0	4	1	**8**
Cymbella gracilis (Ehr.) Kutzing	3	5	0	2	2	**12**
CHAMAEPINNULARIA Lange-Bertalot & Krammer	0	1	0	0	0	**1**
Cymbella helvetica Kutzing	6	0	4	1	0	**11**
Cymbella mesiana Cholnoky (Encyonema)	3	0	0	1	0	**4**

TAXON	N1	N2	N3	N4	N5	TOTAL
Cymbella microcephala Grunow	92	39	41	40	16	**228**
Cymbella naviculiformis Auerswald	0	1	0	1	0	**2**
Cyclotella ocellata Pantocsek	1	0	0	3	0	**4**
Cymbella perpusilla A.Cleve	0	0	1	0	0	**1**
Cymbella prostrate (Berkeley) Grunow (Encyonema)	1	0	0	0	0	**1**
Cymbella proxima Reimer	1	0	0	0	0	**1**
Cymbella pseudocuspidata Tynni	0	0	1	0	0	**1**
Cyclotella pseudostelligera Hustedt	1	7	3	2	0	**13**
Caloneis pulchra Messikommer	2	0	1	0	0	**3**
Cyclotella rossii Hakansson	4	2	0	0	0	**6**
Cymbella subcuspidata Krammer	0	1	0	0	0	**1**
Caloneis silicula (Ehr.) Cleve	0	1	0	0	0	**1**
Cymbella silesiaca Bleisch in Rabenhorst (Encyonema)	5	2	3	0	2	**12**
CYCLOTELLA F.T. Kützing ex A de Brébisson	1	0	1	1	0	**3**
CYMBELLA C.Agardh 1830	5	0	0	1	1	**7**
Didymosphenia geminata (Lyngbye) W.M.Schmidt	3	0	1	0	0	**4**
Diatoma tenuis Agardh	7	18	10	3	7	**45**
Diatoma mesodon (Ehrenberg) Kutzing	0	0	0	0	1	**1**
Denticula tenuis Kutzing	6	3	1	1	0	**11**
Epithemia adnata (Kutzing) Brebisson	0	0	0	0	6	**6**
Eunotia arcus Ehrenberg var. arcus	1	0	6	18	0	**25**
Eunotia bilunaris (Ehr.) Mills var. biluna	1	1	0	1	0	**3**
Eunotia faba Grunow	0	0	3	3	0	**6**
Eunotia flexuosa (Brebisson) Kutzing	1	0	0	0	0	**1**
Eunotia implicata Nörpel, Lange-Bertalot & Alles	4	2	104	13	24	**147**
Eunotia incisa Gregory var.incisa	1	4	0	2	1	**8**
Eunotia minor (Kutzing) Grunow in van Heurck	5	0	0	0	1	**6**
Eunotia pectinalis (Dyllwyn) Rabenhorst var. pectinalis	1	3	0	0	0	**4**
EPITHEMIA F.T. Kützing	0	1	0	0	0	**1**
Eunotia rhomboidea Hustedt	1	1	7	0	1	**10**
Eunotia rostellata Hustedt ex Patrick	0	0	1	0	0	**1**
Eunotia sudetica O.Muller	0	0	19	5	7	**31**
EUNOTIA C.G. Ehrenberg	0	1	11	6	2	**20**
Eunotia veneris (Kutzing) De Toni	0	0	0	0	5	**5**
Fragilaria arcus (Ehrenberg) Cleve var. arcus	8	11	2	1	3	**25**
Fragilaria capucina Desmazieres var.capucina	19	2	2	9	6	**38**
Fragilaria capucina Desmazieres var.distans (Krunow)Lange-Bertalot	0	2	2	9	3	**16**
Fragilaria capucina Desmazieres var.gracilis (Destrup) Hustedt	3	48	31	15	75	**172**
Fragilaria construens (Ehr.) Grunow f.construes (Staurosira)	12	23	4	6	1	**46**
Fragilaria capucina Desmazieres var.vaucheriae (Kutzing) Lange-Bertalot	69	35	29	21	13	**167**
Fragilaria exigua Grunow	0	4	7	13	4	**28**
Fragilaria lapponica Grunow in van Heurck	0	0	0	1	0	**1**
Fragilaria pinnata Ehrenberg var. pinnata	1	4	2	3	0	**10**
FRAGILARIA H.C. Lyngbye	2	4	1	3	1	**11**
Frustulia rhomboides (Ehr.) De Toni var. crassinervia (Brebisson) Ross	0	0	1	0	0	**1**
Frustulia rhomboides (Ehr.) De Toni var. saxonica (Rabenhorst) De Toni	2	2	11	14	2	**31**
Fragilaria tenera (W.Smith) Lange-Bertalot	12	8	14	14	12	**60**
Fragilaria ulna (Nitzsch.) Lange-Bertalot var. acus (Kutz) Lange-Bertalot	0	0	0	0	3	**3**

TAXON	N1	N2	N3	N4	N5	TOTAL
Fragilaria ulna (Nitzsch.) Lange-Bertalot var. ulna	7	14	17	3	16	**57**
Gomphonema acuminatum Ehrenberg var.coronata (Ehr.) W. SMith	1	0	2	1	0	**4**
Gomphonema acuminatum Ehrenberg	1	0	0	1	0	**2**
Gomphonema angustatum (Kutzing) Rabenhorst	0	0	1	0	0	**1**
Gomphonema angustum Agardh	15	7	118	10	4	**154**
Gomphonema clavatum Ehr.	7	0	0	0	0	**7**
GOMPHONEMA C.G. Ehrenberg	5	0	4	0	0	**9**
Gomphonema vibrio Ehrenberg	1	0	2	0	0	**3**
Navicula angusta Grunow	2	0	0	1	1	**4**
Neidium affine (Ehrenberg) Pfitzer var.longiceps (Gregory) Cleve	0	0	0	1	0	**1**
Nitzschia amphibia Grunow f.amphibia	4	2	1	3	0	**10**
NAVICULA J.B.M. Bory de St. Vincent	0	1	0	0	1	**2**
Navicula bryophila Boye Petersen	1	1	2	1	0	**5**
Navicula concentrica Carter et Bailey-Watts	1	0	0	0	0	**1**
Navicula cocconeiformis Gregory ex Greville fo. elliptica Hustedt	0	0	0	1	0	**1**
Navicula cocconeiformis Gregory ex Greville	3	1	0	0	0	**4**
Nitzschia capitellata Hustedt in A.Schmidt	0	1	0	0	0	**1**
Navicula cryptocephala Kutzing	2	4	1	0	0	**7**
Navicula cryptotenella Lange-Bertalot	4	1	1	0	1	**7**
Nitzschia dissipata (Kutzing) Grunow var. dissipata	0	2	1	1	0	**4**
Nitzschia fontikola Grunow in Cleve et Möller	1	7	1	2	0	**11**
Nitzschia angustata Grunow	12	2	6	13	1	**34**
Nitzschia bryophila Hustedt	1	3	1	2	1	**8**
Nitzschia gracilis Hantzsch	0	0	0	0	2	**2**
Nitzschia hungarica Grunow	1	3	1	0	0	**5**
Nitzschia intermedia Hantzsch ex Cleve & Grunow	0	0	2	2	0	**4**
Nitzschia perminuta (Grunow) M.Peragallo	2	4	1	4	0	**11**
Nitzschia pura Hustedt	0	0	1	0	0	**1**
NITZSCHIA A.H. Hassall	1	0	2	3	2	**8**
Nitzschia linearis (Agardh) W.M.Smith var.linearis	0	0	1	0	0	**1**
Navicula mediocris Krasske	0	3	1	1	0	**5**
Navicula minima Grunow	1	0	0	1	0	**2**
Navicula pseudoscutiformis Hustedt	0	1	0	0	0	**1**
Navicula radiosa Kützing	4	6	2	1	0	**13**
Navicula rhynchocephala Kutzing	1	0	0	0	0	**1**
Navicula subtilissima Cleve	0	0	0	4	0	**4**
Nitzschia tubicola Grunow	0	1	0	0	0	**1**
Pinnularia borealis Ehrenberg var. borealis	1	0	2	0	0	**3**
Peronia fibula (Breb.ex Kutz.)Ross	0	1	2	7	0	**10**
Pinnularia interrupta W.M.Smith	0	2	0	1	0	**3**
PINNULARIA C.G. Ehrenberg	0	0	0	0	1	**1**
Pinnularia julma Krammer & Metzeltin	0	1	0	0	0	**1**
Pinnularia microstauron (Ehr.) Cleve	0	0	0	1	0	**1**
Pinnularia subcapitata Gregory var. subcapitata	1	0	0	0	0	**1**
Pinnularia stomatophora (Grunow) Cleve var. stomatophora	0	0	0	1	0	**1**
Pinnularia viridis (Nitzsch) Ehrenberg	1	0	0	0	0	**1**
Rhopalodia gibba (Ehr.) O.Muller var.gibba	1	1	1	1	1	**5**
Rhopalodia rupestris (W.Smith) Krammer	0	1	0	0	0	**1**

TAXON	N1	N2	N3	N4	N5	TOTAL
Surirella linearis W.M.Smith	0	1	0	0	0	**1**
Stauroneis phoenicenteron (Nitzsch.)Ehrenberg	0	0	1	0	0	**1**
Stauroneis anceps Ehrenberg	0	2	0	0	0	**2**
STAURONEIS C.G. Ehrenberg	0	1	0	0	0	**1**
Stenopterobia curvula (W.Smith) Krammer	0	0	0	0	1	**1**
Stauroneis kriegeri Patrick	0	1	0	0	0	**1**
Tabellaria fenestrate (Lyngbye) Kutzing	0	0	1	1	0	**2**
Tabellaria flocculosa (Roth) Kutzing	171	332	167	282	251	**1203**
TOTAL	1300	1305	1288	1298	1312	**6503**

Appendix 12

Total abundance of diatom taxa (three replicate samples per site) in the Näätämöjoki River in Sep-tember 2002. (Individual samples were not pooled in analyses.)

TAXON	N1	N2	N3	N4	N5	TOTAL
Achnanthes altaica (Poretzky) Cleve Euler	0	2	0	0	0	**2**
Achnanthes carissima Lange-Bertalot	0	2	0	0	0	**2**
ACHNANTHES J.B.M. Bory de St. Vincent	2	1	2	2	1	**8**
Achnanthes daonensis Lange-Bertalot	0	0	0	4	0	**4**
Achnanthes flexella (Kutzing) Brun var. flexella	0	1	0	1	0	**2**
Asterionella formosa Hassall	0	1	0	0	0	**1**
Achnanthes helvetica (Hustedt) Lange-Bertalot	1	4	0	1	0	**6**
Amphipleura kriegeriana (Krasske)Hustedt	1	0	1	3	0	**5**
Achnanthes linearis (W.Sm.) Grunow	0	2	0	0	0	**2**
Achnanthes levanderi Hustedt	0	5	0	1	0	**6**
Achnanthes laevis Oestrup var. laevis Oestrup	0	1	1	2	3	**7**
Achnanthes minutissima Kutzing v.minutissima Kutzing (Achnanthidium)	667	339	208	328	101	**1643**
AMPHORA C.G. Ehrenberg ex F.T. Kützing	0	1	0	0	0	**1**
Anomoeoneis brachysira (Brebisson in Rabenhorst) Grunow in Cleve	6	8	2	5	0	**21**
Achnanthes nodosa A.Cleve	3	7	2	4	2	**18**
Achnanthes petersenii Hustedt KLB91p67f37/	4	9	0	1	0	**14**
Achnanthes pusilla (Grunow) De Toni	33	48	12	61	23	**177**
Achnanthes subatomoides (Hustedt) Lange-Bertalot et Archibald	1	2	1	0	0	**4**
Achnanthes saccula Carter in Carter & Bail	1	0	0	1	0	**2**
Achnanthes stewartii Patrick	1	0	0	0	0	**1**
Aulacoseira distans (Ehr.) Simonsen	1	2	2	4	2	**11**
Aulacoseira islandica (O.Muller) Simonsen	0	3	0	1	0	**4**
Aulacoseira italica (Ehr.) Simonsen	0	2	0	1	0	**3**
AULACOSEIRA G.H.K. Thwaites	2	0	0	0	0	**2**
Anomoeoneis vitrea (Grunow) Ross	74	52	73	118	12	**329**
Achnanthes ventralis (Krasske) Lange-Bertalot	2	1	0	1	1	**5**
Brachysira procera Lange-Bertalot & Moser	20	7	40	63	4	**134**
Brachysira zellensis (Grunow) Round & Mann Lange-Bertalot	1	8	4	15	0	**28**
Cymbella affinis Kutzing	10	5	8	4	0	**27**
Cymbella angustata (W.M.Smith) Cleve	0	1	0	0	0	**1**
Cymbella amphioxys (Kutzing) Cleve	0	3	2	1	0	**6**
Caloneis tenuis (Gregory) Krammer	3	6	3	12	2	**26**
Cyclotella antiqua W.Smith	0	0	0	1	0	**1**
Cymbella cesatii (Rabh.)Grunow	5	13	16	41	1	**76**
Cymbella cistula (Ehrenberg) Kirchner	0	2	2	2	0	**6**
Cymbella delicatula Kutzing	1	2	0	0	0	**3**
Cymbella descripta (Hustedt) Krammer et Lange-Bertalot	1	5	1	4	1	**12**
Cymbella gaeumannii Meister	1	1	0	2	0	**4**
Cymbella gracilis (Ehr.) Kutzing	8	7	4	7	3	**29**
Cymbella helvetica Kutzing	2	2	1	0	0	**5**
Cymbella incerta (Grunow) Cleve	0	1	1	0	0	**2**
Cyclotella michiganiana Skvortzow 1937	0	0	0	1	0	**1**
Cymbella mesiana Cholnoky (Encyonema)	1	0	0	0	0	**1**
Cymbella microcephala Grunow	57	70	54	77	20	**278**
Cymbella minuta Hilse ex Rabenhorst (Encyonema)	1	1	1	0	0	**3**

TAXON	N1	N2	N3	N4	N5	TOTAL
Cymbella naviculiformis Auerswald	0	0	0	1	0	**1**
Cymbella naviculacea Grunow	2	0	0	0	0	**2**
Cyclotella ocellata Pantocsek	3	1	5	5	2	**16**
Cyclotella pseudostelligera Hustedt	40	44	9	10	0	**103**
Caloneis pulchra Messikommer	0	0	0	0	1	**1**
Cyclotella rossii Hakansson	2	3	2	2	2	**11**
Cymbella subaequalis Grunow	0	1	0	0	0	**1**
Cymbella silesiaca Bleisch in Rabenhorst (Encyonema)	5	1	1	1	2	**10**
Cyclotella stelligera Cleve et Grun in Van Heurck	0	1	0	0	1	**2**
Caloneis undulata (Gregory) Krammer	0	1	0	0	0	**1**
CYCLOTELLA F.T. Kützing ex A de Brébisson	1	0	0	4	0	**5**
CYMBELLA C.Agardh 1830	0	0	2	1	0	**3**
Didymosphenia geminata (Lyngbye) W.M.Schmidt	1	0	0	1	0	**2**
Diatoma tenuis Agardh	5	13	19	3	2	**42**
Denticula tenuis Kutzing	4	8	1	3	0	**16**
Epithemia adnata (Kutzing) Brebisson	0	0	0	0	10	**10**
Eunotia arcus Ehrenberg var. arcus	2	1	6	8	0	**17**
Eunotia bilunaris (Ehr.) Mills var. bilunaris	1	1	2	3	0	**7**
Eunotia faba Grunow	0	0	0	1	0	**1**
Eunotia implicata Nörpel, Lange-Bertalot & Alles	24	5	31	7	1	**68**
Eunotia incisa Gregory var.incisa	2	4	6	2	3	**17**
Eunotia minor (Kutzing) Grunow in van Heurck	2	0	1	0	1	**4**
EPITHEMIA F.T. Kützing	0	1	0	0	0	**1**
Eunotia praerupta Ehrenberg var. praerupta	0	1	1	0	0	**2**
Eunotia rhomboidea Hustedt	0	0	0	1	0	**1**
EUNOTIA C.G. Ehrenberg	1	0	0	0	1	**2**
Fragilaria arcus (Ehrenberg) Cleve var. arcus	1	3	4	0	1	**9**
Fragilaria brevistriata Grunow (Pseudostaurosira)	0	0	0	1	0	**1**
Fragilaria capucina Desmazieres var.capucina	0	2	3	3	1	**9**
Fragilaria capucina Desmazieres var.distans (Krunow)Lange-Bertalot	12	19	13	4	0	**48**
Fragilaria capucina Desmazieres var.gracilis (Destrup) Hustedt	24	85	88	29	9	**235**
Fragilaria construens (Ehr.) Grunow f.construes (Staurosira)	16	23	13	14	4	**70**
Fragilaria capucina Desmazieres var.vaucheriae (Kutzing) Lange-Bertalot	55	27	14	37	4	**137**
Fragilaria exigua Grunow	4	9	3	7	0	**23**
Fragilaria lapponica Grunow in van Heurck	1	1	0	2	0	**4**
Fallacia maceria (Schimanski) Lange-Bertalot	0	0	0	1	0	**1**
Fragilaria nanana Lange-Bertalot	3	5	0	4	1	**13**
Fragilaria pinnata Ehrenberg var. pinnata	5	1	0	1	0	**7**
FRAGILARIA H.C. Lyngbye	3	6	3	2	0	**14**
Frustulia rhomboides (Ehr.)De Toni var. crassinervia (Brebisson)Ross	0	0	3	0	0	**3**
Frustulia rhomboides (Ehr.)De Toni	0	1	0	0	0	**1**
Frustulia rhomboides (Ehr.)De Toni var. saxonica (Rabenhorst) De Toni	0	4	15	8	1	**28**
Fragilaria tenera (W.Smith) Lange-Bertalot	14	22	42	27	3	**108**
Fragilaria ulna (Nitzsch.) Lange-Bertalot var. ulna	1	10	5	3	4	**23**
Gomphonema acuminatum Ehrenberg var.coronata (Ehr.)W. SMith	1	2	0	0	0	**3**
Gomphonema angustum Agardh	10	4	28	2	1	**45**
Gomphonema clavatum Ehr.	0	1	1	0	0	**2**
Gomphonema exilissimum (Grun.) Lange-Bertalot & Reichardt	0	0	0	0	1	**1**

TAXON	N1	N2	N3	N4	N5	TOTAL
Gomphonema gracile Ehrenberg	0	1	0	0	0	**1**
Gomphonema hebridense Gregory	0	1	0	0	1	**2**
Gomphonema olivaceum (Hornemann) Brébisson var. olivaceum	3	1	1	1	0	**6**
GOMPHONEMA C.G. Ehrenberg	2	0	0	0	0	**2**
Gomphonema truncatum Ehr.	0	0	2	0	1	**3**
Navicula angusta Grunow	1	1	1	2	0	**5**
Nitzschia acula Hantzsch	0	2	0	1	0	**3**
NAVICULADICTA Lange-Bertalot	2	2	0	1	0	**5**
Nitzschia amphibia Grunow f.amphibia	0	2	0	3	0	**5**
NAVICULA J.B.M. Bory de St. Vincent	2	4	0	0	0	**6**
Navicula bryophila Boye Petersen	1	4	2	1	0	**8**
Navicula cocconeiformis Gregory ex Greville	1	2	0	0	0	**3**
Navicula capitatoradiata Germain	1	0	0	0	0	**1**
Navicula cryptocephala Kutzing	0	2	0	3	2	**7**
Navicula cryptotenella Lange-Bertalot	2	1	0	0	0	**3**
Nitzschia dissipata (Kutzing) Grunow var. dissipata	0	1	0	0	0	**1**
Naviculadicta witkowskii Lange-Bertalot&Metzeltin	0	3	0	0	0	**3**
Navicula festiva Krasske	0	1	0	0	0	**1**
Nitzschia flexa Schumann	0	1	0	0	0	**1**
Nitzschia flexoides Geitler	1	7	2	3	2	**15**
Nitzschia fontikola Grunow in Cleve et Möller	0	3	1	0	0	**4**
Nitzschia hantzschiana Rabenhorst	0	1	0	1	1	**3**
Navicula heimansii Van Dam et Kooyman	0	3	0	2	0	**5**
Nitzschia angustata Grunow	0	6	5	7	1	**19**
Nitzschia bryophila Hustedt	1	0	0	0	0	**1**
Nitzschia gracilis Hantzsch	0	2	1	1	0	**4**
Nitzschia intermedia Hantzsch ex Cleve & Grunow	0	2	1	4	0	**7**
Nitzschia perminuta (Grunow) M.Peragallo	5	13	2	3	0	**23**
NITZSCHIA A.H. Hassall	5	6	0	6	1	**18**
Navicula mediocris Krasske	0	2	0	2	0	**4**
Navicula pseudoscutiformis Hustedt	0	3	0	0	0	**3**
Navicula radiosa Kützing	2	3	0	2	1	**8**
Nitzschia sinuata (Thwaites) Grunow var.delognei (Grunow) Lange-Bertalot	0	0	0	1	0	**1**
Nitzschia sociabilis Hustedt	0	0	1	1	0	**2**
Navicula soehrensis Krasske	0	1	0	0	0	**1**
Navicula suchlandtii Hustedt	0	0	0	0	1	**1**
Pinnularia brebissonii (Kutz.) Rabenhorst	0	0	0	3	0	**3**
Peronia fibula (Breb.ex Kutz.)Ross	1	1	0	2	0	**4**
Pinnularia gibba Ehrenberg	0	1	0	0	0	**1**
PINNULARIA C.G. Ehrenberg	0	0	0	1	0	**1**
Pinnularia microstauron (Ehr.) Cleve	1	1	1	1	0	**4**
Rhopalodia gibba (Ehr.) O.Muller var.gibba	3	2	0	0	0	**5**
Stauroneis phoenicenteron (Nitzsch.)Ehrenberg	0	1	0	0	0	**1**
Sellaphora pupula (Kutzing) Mereschkowksy	0	5	2	1	0	**8**
Stauroneis anceps Ehrenberg	0	0	0	2	0	**2**
Stenopterobia curvula (W.Smith) Krammer	0	2	1	1	0	**4**
Tabellaria flocculosa (Roth) Kutzing	134	227	500	283	192	**1336**
TOTAL	1323	1259	1285	1306	435	**5608**

Appendix 13

Abbreviations of diatom taxa in multivariate analyses.

Abbreviation	Taxon
Aamb	Aulacoseira ambigua
abia	Achnanthes biasolettiana Grunow var.subato
abio	Achnanthes bioreti Germain(=Psammothidium)
abze	Anomoeoneis brachysira(Breb.) Grunow var.zellensis (Grunov) Krammer
ACHN	ACHNANTHES J.B.M. Bory de St. Vincent
adao	Achnanthes daonensis Lange-Bertalot
afle	Achnanthes flexella (Kutzing)Brun var. fle
afor	Asterionella formosa Hassall
ahel	Achnanthes helvetica (Hustedt) Lange-Berta
alan	Achnanthes lanceolata(Breb.)Grunow var. la
alin	Achnanthes linearis (W.Sm.) Grunow
alvs	Achnanthes laevis Oestrup var. laevis Oestrup
anbr	Anomoeoneis brachysira(Brebisson in Rabenh
aped	Amphora pediculus (Kutzing) Grunow
apus	Achnanthes pusilla (Grunow)De Toni
asat	Achnanthes subatomoides (Hustedt) Lange-Be
ascl	Achnanthes saccula Carter in Carter & Bailey-Watts
asuc	Achnanthes suchlandtii Hustedt
AULA	AULACOSEIRA G.H.K. Thwaites
avit	Anomoeoneis vitrea (Grunow) Ross
bpro	Brachysira procera Lange-Bertalot & Moser
bzel	Brachysira zellensis (Grunow) Round & Mann
caff	Cymbella affinis Kutzing
cate	Caloneis tenuis (Gregory) Krammer
cces	Cymbella cesatii (Rabh.)Grunow
cdes	Cymbella descripta(Hustedt)Krammer et Lang
cgra	Cymbella gracilis(Ehr.)Kutzing
cmic	Cymbella microcephala Grunow
cmin	Cymbella minuta Hilse ex Rabenhorst (Ency
cped	Cocconeis pediculus Ehrenberg
cpla	Cocconeis placentula Ehrenberg var. placen
cpst	Cyclotella pseudostelligera Hustedt
crac	Craticula accomoda (Hustedt) Mann
crmi	Craticula minusculoides (Hustedt) Lange-Bertalot
csin	Cymbella sinuata Gregory
csle	Cymbella silesiaca Bleisch in Rabenhorst (Encyonema)
cste	Cyclotella stelligera Cleve et Grun in Van Heurck
dgem	Didymosphenia geminata (Lyngbye) W.M.Schmi
dite	Diatoma tenuis Agardh
dmes	Diatoma mesodon (Ehrenberg) Kutzing
dten	Denticula tenuis Kutzing
eadn	Epithemia adnata (Kutzing) Brebisson
earc	Eunotia arcus Ehrenberg var. arcus
eimp	Eunotia implicata Nörpel, Lange-Bertalot &
einc	Eunotia incisa Gregory var.incisa

Abbreviation	Taxon
epir	Eunotia pirla Carter & Flower
esud	Eunotia sudetica O.Muller
EUNO	EUNOTIA C.G. Ehrenberg
farc	Fragilaria arcus (Ehrenberg) Cleve var. ar
fbre	Fragilaria brevistriata Grunow (Pseudostau
fcap	Fragilaria capucina Desmazieres ssp. rumpens (Kutzing) Lange-Bertalot
fcdi	Fragilaria capucina Desmazieres var.distans (Krunow)Lange-Bertalot
fcgr	Fragilaria capucina Desmazieres var.gracil
fcme	Fragilaria capucina Desmazieres var.mesole
fcon	Fragilaria construens (Ehr.) Grunow f.cons
fcra	Fragilaria capucina Desmazieres var.radians (Kutzing) Lange-Bertalot
fcro	Fragilaria crotonensis Kitton
fcru	Fragilaria capucina Desmazieres ssp. rumpe
fcva	Fragilaria capucina Desmazieres var.vauche
fexi	Fragilaria exigua Grunow
fnan	Fragilaria nanana Lange-Bertalot
FRAG	FRAGILARIA H.C. Lyngbye
frho	Frustulia rhomboides(Ehr.)De Toni
frsa	Frustulia rhomboides(Ehr.)De Toni var.saxo
fsap	Fistulifera saprophila (Lange-Bertalot & Bonik) Lange-Bertalot
ften	Fragilaria tenera (W.Smith) Lange-Bertalot
fuac	Fragilaria ulna (Nitzsch.) Lange-Bertalot var. acus(Kutz)Lange-Bertalot
fuln	Fragilaria ulna (Nitzsch.) Lange-Bertalot
gacu	Gomphonema acuminatum Ehrenberg
gang	Gomphonema angustatum (Kutzing) Rabenhorst
gant	Gomphonema angustum Agardh
gcla	Gomphonema clavatum Ehr.
goli	Gomphonema olivaceum (Hornemann) Brébisson
gpar	Gomphonema parvulum Kutzing var. parvulum
gtru	Gomphonema truncatum Ehr.
gven	Gomphonema ventricosum Gregory
mape	Mayamaea atomus var. permitis (Hustedt) Lange-Bertalot
mcir	Meridion circulare (Greville) C.A.Agardh v
nato	Navicula atomus (Kutz.) Grunow
ncin	Navicula cincta (Ehr.) Ralfs in Pritchard
ncry	Navicula cryptocephala Kutzing
ndis	Nitzschia dissipata (Kutzing) Grunow var. dissipata
nflx	Nitzschia flexoides Geitler
nfon	Nitzschia fontikola Grunow in Cleve et Möller
ngra	Navicula gracilis Ehrenberg
ngre	Navicula gregaria Donkin
nhan	Nitzschia hantzschiana Rabenhorst
nian	Nitzschia angustata Grunow
nibr	Nitzschia bryophila Hustedt
nigr	Nitzschia gracilis Hantzsch
nimp	Navicula impexa Hustedt
NITZ	NITZSCHIA A.H. Hassall
nlan	Navicula lanceolata (Agardh) Ehrenberg

Abbreviation	Taxon
nlin	Nitzschia linearis(Agardh) W.M.Smith var.linearis
nmin	Navicula minima Grunow
npac	Nitzschia paleacea Grunow fo.acicularioides Coste & Ricard
npal	Nitzschia palea (Kutzing) W.Smith
nrec	Nitzschia recta Hantzsch ex Rabenhorst
nrip	Navicula riparia Hustedt
nsbl	Nitzschia sublinearis Hustedt
nsem	Navicula seminulum Grunow
nsle	Navicula slesvicensis Grunow
nsuc	Navicula suchlandtii Hustedt
ntub	Nitzschia tubicola Grunow
nvir	Navicula viridula (Kutz.) Ehr. var.rostellata (Kutz.) Cleve
nzsu	Nitzschia supralitorea Lange-Bertalot
sbre	Surirella brebissonii Krammer & Lange-Bertalot var. brebissonii
tfen	Tabellaria fenestrata(Lyngbye)Kutzing
tflo	Tabellaria flocculosa(Roth)Kutzing

Appendix 14

Vegetation data of the Kola River and the Näätämöjoki River. Data for river margins is recorded as presence/absence, channel vegetation is recorded as abundance scale with 7 classes.

	River margin vegetation																Channel vegetation														
	K2	K3	K4	K5	K6	K7	K8	K9	K11A	K11B	K12	N1	N2	N3	N4	N5	K2	K3	K4	K5	K6	K7	K8	K9	K11A	K11B	K12	N1	N2	N3	N4	N5
Achillea millefolium			1		1	1	1	1	1	1	1			1													2					
Achillea ptarmica				1		1		1																								
Agrostis capillaris			1						1					1	1	1																
Agrostis mertensii					1	1						1		1	1	1																
Agrostis sp.															1																	
Agrostis stolonifera													1																			
Alchemilla sp.		1	1			1	1						1			1															
Allium schoenoprasum	1	1	1	1	1	1	1							1																		
Alnus incana		1	1		1									1		1																
Alopecurus aequalis				1																												
Alopecurus pratensis									1																							
Andromeda polifolia					1							1	1	1		1																
Angelica archangelica				1	1		1	1	1	1	1				1																	
Angelica sylvestris			1					1																								
Anthoxanthum odoratum		1	1		1								1	1		1																
Anthriscus silvestris							1		1	1	1																					
Antennaria dioica			1	1									1	1	1	1																
Astragalus alpinus			1	1	1	1	1	1	1						1																	
Astragalus frigidus			1		1									1		1																
Barbarea stricta											1																					
Barbarea vulgaris																										2						
Bartsia alpina			1	1	1	1		1				1	1	1		1																
Betula nana	1											1	1																			

	River margin vegetation																Channel vegetation														
	K2	K3	K4	K5	K6	K7	K8	K9	K11A	K11B	K12	N1	N2	N3	N4	N5	K2	K3	K4	K5	K6	K7	K8	K9	K11A	K11B	K12	N1	N2	N3	N4	N5
Betula pubescens	1	1	1	1	1			1		1		1	1	1	1																	
Brassica rapa											1																					
Calamagrostis canescens	1	1			1			1	1							1																
Calamagrostis purpurea	1	1			1				1	1		1				1	2															
Calamagrostis stricta			1	1	1	1	1	1		1		1	1	1	1	1																
Callitriche palustris																		1				2		3								
Calluna vulgaris	1		1		1								1	1	1	1																
Caltha palustris	1	1	1	1		1	1	1					1			1	1	3	1	2		2							2			3
Campanula patula					1							1	1	1																		
Campanula rotundifolia															1	1																
Capsella bursa-pastoris				1							1																					
Cardamine pratensis		1	1		1		1	1	1	1															2							
Carex acuta								1	1	1														6	4	1						
Carex aquatilis	1	1	1	1	1	1	1	1	1	1			1	1		1		4	1	2		4	5	6	4	4			6	1		4
Carex buxbaumii												1	1																			
Carex canescens	1			1	1	1		1							1	1																
Carex dioica												1	1		1	1																
Carex flava												1			1																	
Carex magellanica												1	1																			
Carex nigra			1									1	1	1	1	1													6			
Carex nigra ssp. juncella		1	1		1		1									1	3	2														
Carex panicea												1	1	1	1	1																
Carex rostrata	1											1	1				3											2				
Carex rotundata												1																				
Carex vaginata		1																														

	River margin vegetation																Channel vegetation														
	K2	K3	K4	K5	K6	K7	K8	K9	K11A	K11B	K12	N1	N2	N3	N4	N5	K2	K3	K4	K5	K6	K7	K8	K9	K11A	K11B	K12	N1	N2	N3	N4	N5
Cerastium fontanum		1	1	1		1		1	1	1	1																					
Cirsium helenioides		1	1		1	1		1	1							1																
Cornus suecica	1	1	1	1	1			1				1			1	1																
Dactylorhiza maculata			1					1																								
Deschampsia cespitosa	1	1	1	1	1	1	1	1	1	1	1			1	1	1							3				4				2	
Deschampsia flexuosa	1			1	1									1	1	1																
Dianthus superbus					1		1																									
Dryopteris carthusiana		1																														
Elymus caninus								1	1																							
Elymus mutabilis															1																	
Elymus repens				1			1				1																2					
Empetrum nigrum	1	1		1	1							1		1	1																	
Epilobium angustifolium	1		1	1	1	1	1	1		1	1																4					
Equisetum arvense	1	1	1	1		1	1	1	1		1		1	1		1				2			2				2					1
Equisetum fluviatile	1	1						1	1	1		1				1	3	2	1			3		1	6	3		3				
Equisetum palustre											1		1														2					
Equisetum scirpoides													1																			
Equisetum sylvaticum	1	1	1		1					1				1		1																
Equisetun variegatum													1		1																	
Eriophorum angustifolium	1											1	1																		2	
Eriophorum scheuzeri					1																											
Euphrasia frigida			1	1	1							1	1	1	1	1																
Festuca ovina				1	1		1	1				1	1	1	1	1																
Festuca rubra				1	1	1		1		1	1																					
Filipendula ulmaria	1	1	1			1	1	1	1	1		1	1																			

	River margin vegetation																Channel vegetation															
	K2	K3	K4	K5	K6	K7	K8	K9	K11A	K11B	K12	N1	N2	N3	N4	N5	K2	K3	K4	K5	K6	K7	K8	K9	K11A	K11B	K12	N1	N2	N3	N4	N5
Galium boreale									1																							
Galium palustre							1																									
Galium uliginosum	1	1	1	1	1	1	1	1				1	1			1																
Geranium sylvaticum	1	1	1	1	1	1	1	1	1	1				1		1																
Geum rivale	1	1																														
Gnaphalium uliginosum			1																													
Gymnadea conopsea													1																			
Gymnocarpium dryopteris	1				1											1																
Hieracium rigida								1	1	1	1			1																		
Hieracium umbellata															1																	
Hieracium sylvaticum					1								1																			
Hieracium vulgata				1		1		1						1	1	1																
Hierochloe hirta						1	1	1																								
Hippuris vulgaris						1																										
Juncus alpinoarticulatus													1	1	1	1																
Juncus filiformis	1	1	1	1	1	1	1	1	1			1		1	1	1							4									
Juniperus communis	1	1			1								1	1		1																
Ledum palustre	1	1		1																												
Leontodon autumnalis											1																					
Leucanthemum vulgare											1																					
Linnea borealis					1																											
Luzula sudetica			1	1									1	1		1																
Lychnis alpina					1									1																		
Lysimachia thyrsiflora																	1															
Melampyrum pratense	1		1													1																

	River margin vegetation																Channel vegetation															
	K2	K3	K4	K5	K6	K7	K8	K9	K11A	K11B	K12	N1	N2	N3	N4	N5	K2	K3	K4	K5	K6	K7	K8	K9	K11A	K11B	K12	N1	N2	N3	N4	N5
Melampyrum sylvaticum			1		1																											
Melica nutans		1											1																			
Menyanthes trifoliata	1																															
Molinia caerulea			1	1	1		1					1	1	1	1	1																
Monesus uniflora								1																								
Myosotis laxa				1		1	1	1	1	1													5									
Myriophyllum alterniflorum																														1		2
Myriophyllum sibiricum						1																										
Nardus stricta																1																
Oxalis acetosella							1																									
Oxyria digyna												1			1																	
Oxytropis campestris				1	1									1	1																	
Parnassia palustris			1		1	1						1	1	1	1	1																
Pedicularis lapponum														1																		
Pedicularis palustris		1			1																											
Pedicularis sceptrum-carolinum			1	1	1	1		1					1	1		1																
Phalaris arundinacea		1				1	1	1										4														
Phleum alpinum			1	1	1	1		1								1																
Phleum pratense									1																							
Picea abies	1																															
Pilosella peleteriana				1																												
Pinguicula vulgaris			1	1	1			1				1	1	1	1	1																
Pinus sylvestris		1	1		1																											
Plantago major										1																						
Poa alpigena						1																										

	River margin vegetation																Channel vegetation															
	K2	K3	K4	K5	K6	K7	K8	K9	K11A	K11B	K12	N1	N2	N3	N4	N5	K2	K3	K4	K5	K6	K7	K8	K9	K11A	K11B	K12	N1	N2	N3	N4	N5
Poa annua						1			1	1	1																3					
Poa nemoralis		1			1			1		1																						
Poa palustris		1					1		1	1	1		1																			
Poa pratensis						1		1	1	1																						
Poa subcaerulea	1	1		1		1					1						1															
Polemonium caeruleum											1																					
Polygonum viviparum	1		1	1	1	1	1	1	1			1	1	1	1	1																
Populus tremula											1																					
Potamogeton gramineus																	3				2		4	4	4					1		
Potamogeton perfoliatus																								5								
Potentilla erecta		1	1										1	1																		
Potentilla cranzii															1																	
Potentilla palustris	1	1			1	1	1		1			1	1		1	1																
Primula stricta												1			1																	
Prunus padus		1																														
Pyrola minor	1	1	1		1			1																								
Pyrola rotundifollia											4																					
Ranunculus acris		1	1	1		1	1	1		1	1																					
Ranunculus auricomus		1																														
Ranunculus repens			1	1		1		1	1		1											1	4	5	3						
Ranunculus reptans					1			1					1						1		2	3	3	5						1		2
Rhinanthus minor			1	1		1	1	1								1																
Ribes spicatum		1																														
Rorippa palustris		1							1	1	1																4					
Rosa majalis		1																														
Rubus arcticus	1	1		1							1	1			1																	

	River margin vegetation																Channel vegetation															
	K2	K3	K4	K5	K6	K7	K8	K9	K11A	K11B	K12	N1	N2	N3	N4	N5	K2	K3	K4	K5	K6	K7	K8	K9	K11A	K11B	K12	N1	N2	N3	N4	N5
Rubus chamaemorus	1	1																														
Rubus idaeus							1																									
Rubus saxatilis		1			1			1				1			1	1																
Rumex acetosa							1																									
Rumex acetosella				1		1		1		1	1																					
Rumex aquaticus							1		1		1												1									
Rumex longifolius				1					1		1																					
Salix borealis	1	1				1		1		1	1																					
Salix caprea				1																												
Salix glauca			1	1	1			1	1		1	1		1	1																	
Salix hastata														1																		
Salix lanata																1																
Salix lapponum	1	1	1		1				1			1	1	1	1	1	1								1							
Salix myrsinites												1																				
Salix phylicifolia	1	1	1	1	1			1	1	1	1	1		1	1	1	1															
Salix polaris					1																											
Saussurea alpina		1	1	1		1		1				1	1	1		1																
Saxifraga aizoides												1	1	1	1																	
Scutellaria galericulata		1																														
Silene dioica											1																					
Solidago virgaurea		1	1	1	1	1	1	1	1	1		1	1	1	1	1																
Sorbus aucubaria	1	1	1		1			1							1	1																
Sparganium angustifolium								1														3		6	4	2				1		2
Stellaria media				1					1	1	1																					
Stellaria palustris				1		1	1	1	1																							
Taraxacum sp.		1	1	1		1		1	1	1	1	1															3					
Thalictrum alpinum												1	1	1	1																	

	River margin vegetation																Channel vegetation															
	K2	K3	K4	K5	K6	K7	K8	K9	K11A	K11B	K12	N1	N2	N3	N4	N5	K2	K3	K4	K5	K6	K7	K8	K9	K11A	K11B	K12	N1	N2	N3	N4	N5
Thalictrum flavum							1																									
Thelypteris phegopteris		1													1																	
Tofieldia pusilla			1		1								1	1	1																	
Trichophorum alpinum												1	1	1	1																	
Trichophorum cespitosum					1							1	1	1	1	1																
Trientalis europaea	1	1	1		1											1																
Trifolium pratense				1		1	1	1	1		1																					
Trifolium repens			1					1	1																							
Triglochin palustre													1																			
Tripleurospermim maritimum											1																					
Trollius europeus	1	1	1	1	1	1	1	1				1	1	1	1	1																
Tussilago farfara						1			1	1	1																					
Urtica dioida				1			1	1	1	1	1																3					
Vaccinium myrtillus	1		1		1											1																
Vaccinium uliginosum	1	1	1	1	1								1	1	1																	
Vaccinium vitis-idaea	1	1		1	1			1							1																	
Valeriana sambucifolia							1	1	1							1																
Veronica longifolia		1		1	1	1	1		1	1			1		1	1																
Veronica serpyllifolia			1																													
Vicia cracca											1																					
Vicia sepium			1				1			1																						
Viola canina ssp. montana				1		1	1								1																	
Viola epipsila		1			1								1		1	1																
Viola sp.											1																					
Viola palustris	1						1			1	1	1	1	1		1											1					

Appendix 15

Phytoplankton taxa in the Kola River system (samplings in 2001 and 2002). Saprobic index values by Panthle and Buch (Abakumov 1992), Saprobic zones by Sladechek (Kozina 1977).
+ = present, - = not present.

Taxon	Saprobic index	Saprobic zone	2001	2002
BACILLARIOPHYTA-DIATOMAE				
Asterionella formosa	1.40	oβ	+	+
Asterionella gracillima	1.20	o	+	+
Achnanthes minutissima	1.45	oβ	+	+
Cyclotella comta	1.15	o	+	+
Cyclotella sp			+	-
Cymbella sp.			-	+
Ceratoneis arcus	0.40	xo	+	+
Ceratoneis arcus v. amphioxus	0.70	xo	+	+
Diatoma vulgare	1.85	oβ	+	+
Diatoma elongatum	1.50	oβ	+	+
Didymosphenia geminata	0.10	x	+	-
Fragilaria capucina	1.60	oβ	+	+
Fragilaria crotonensis	1.40	oβ	+	+
Fragilaria sp			+	-
Gomphonema sp.			-	+
Gomphonema acuminatum	1.70	β	+	+
Gomphonema acuminatum v. coronatum	2.20	β	+	+
Gomphonema olivaceum	1.85	β	+	+
Melosira sp.			+	-
Melosira ambigua	1.50	oβ	+	-
Melosira distans	0.50	xo	+	+
Melosira islandica			+	-
Melosira islandica f.helvetica	2.00	β	+	+
Melosira italica	1.60	oβ	+	+
Melosira italica v.subarctica			+	+
Melosira varians	1.85	oβ	+	+
Meridion circulare	0.65	xo	+	+
Navicula sp			+	-
Nitzschia sp.			+	+
Nitzschia holsatica	2.00	β	+	-
Nitzschia acicularis	2.70	α	+	+
Rhizosolenia longiseta	1.20	o	+	+
Rhizosolenia eriensis			+	-
Rhopalodia gibba	1.00	o	+	-
Stephanodiscus hantzschii	2.70	α	+	-
Surirella ovata	1.85	β	-	-
Synedra sp.			+	-
Synedra actinastroides	1.50	oβ	+	-
Synedra acus	1.85	β	+	+
Synedra acus v. angustissima	1.00	o	-	-
Synedra ulna	1.95	xα	+	+
Synedra ulna v. danica	1.20	o	+	+

Taxon	Saprobic index	Saprobic zone	2001	2002
Synedra berolinensis	1.90	β	+	+
Tabellaria fenestrata	1.40	oβ	+	+
Tabellaria fenest. intermedia	1.40	oβ	+	+
Tabellaria flocculosa	0.60	ox	+	+
SUM			**42**	**31**
CYANOPHYCEAE				
Anabaena sp.			+	-
Anabaena scheremetievi			+	+
Anabaena spiroides	1.35	oβ	+	+
Anabaena flos-aquae	2.00	β	-	+
Anabaena lemmermannii	2.00	β	-	+
Aphanothece clathrata	1.70	β	-	+
Aphanizomenon flos-aquae	1.70	β	+	+
Microcystis aeruginosa	1.75	β	-	+
Microcystis wesenbergii	2.00	β	+	-
Gomphosphaeria lacustris f. compacta	2.00	β	-	-
Gomphosphaeria lacustris	1.50	oβ	+	-
Coelosphaerium kuetzingianum	1.60	βo	+	+
Oscillatoria tenuis	2.85	β	-	+
Oscillatoria limosa	2.35	βα	-	+
Oscillatoria sp.			+	+
Lyngbya limnetica	2.00	β	-	+
Merismopedia sp.			+	-
Gomphosphaeria sp.			-	+
Microcystis sp.			+	+
Gloeocapsa sanguinea	1.00	o	+	-
Gloeotrichia sp.			+	-
Anabaenopsis sp			+	-
Gloeocapsa sp.			-	+
SUM			**13**	**15**
CHRYSOPHYCEAE				
Chrysococcus rufescens	1.40	oβ	+	+
Mallomonas sp.			+	+
Dinobryon sp.			+	+
Dinobryon divergens	1.85	β	+	+
Dinobryon suecicum	1.00	o	+	+
Dinobryon stipitatum	1.20	o	+	+
Dinobryon borgei			+	+
Dinobryon cylindricum			-	+
Synura petersenii	2.25	β	-	+
Dinobryon sertularia	1.30	o	+	+
Uroglenopsis americana	1.00	o	-	+
Mallomonas elegans	1.40	oβ	+	+
SUM			**9**	**12**

Taxon	Saprobic index	Saprobic zone	2001	2002
PYRROPHYTA				
Ceratium hirundinella	1.15	o	+	+
Peridinium cinctum	1.00	o	+	+
Peridinium bipes	1.00	o	+	+
Peridinium sp.			+	+
Gymnodinium sp			+	+
Cryptomonas sp.			-	+
SUM			**5**	**6**
EUGLENOPHYCEAE				
Euglena sp.			+	+
Trachelomonas volvocina	2.00	β	-	+
Trachelomonas hispida	2.00	β	+	+
Trachelomonas planctonica	1.65	βo	+	+
Phacus sp.			-	+
Trachelomonas sp.			+	-
Trachelomonas cylindrica			-	+
Phacus caudatus	2.20	β	-	+
SUM			**4**	**7**
CHLOROPHYTA				
Ankistrodesmus longissimus			+	+
Ankistrodesmus acicularis	2.00	β	+	+
Ankistrodesmus falcatus	2.35	βα	+	+
Chlorella sp.			-	+
Coelastrum sphaericum			-	+
Coelastrum microporum	2.00	β	-	+
Dictyosphaerium pulchellum	2.15	βα	+	+
Dictyosphaerium pulchellum v. ovatum			+	-
Micractinium pussilum	2.00	β	+	+
Pediastrum tetras	1.75	β	+	+
Pediastrum boryanum	1.85	β	+	+
Pediastrum duplex	1.70	β	+	+
Scenedesmus obliguus	2.30	β	+	-
Scenedesmus acuminatus	2.20	β	+	+
Scenedesmus denticulatus	2.00	β	+	-
Scenedesmus quadricauda	2.00	β	+	+
Scenedesmus opoliensis	2.00	β	+	-
Chlamydomonas sp.			+	+
Eudorina elegans	1.80	β	+	-
Spirogyra sp.			+	+
Scenedesmus sp.			+	+
Pleurococcus viridis	1.55	oβ	+	+
Ankistrodesmus sp.			+	+
Pandorina morum	2.00	β	+	-
Closterium sp.			+	+
Cosmarium sp.			+	+
Gloeococcus schroeteri	1.00	o	-	+

Taxon	Saprobic index	Saprobic zone	2001	2002
Rhizoclonium hieroglyphicum	1.60	oβ	+	+
Pediastrum sp.			+	+
Staurastrum gracile	1.50	oβ	-	+
Desmidium sp.			+	-
Eurastrum elegans	1.00	o	+	-
Closterium kuetzingii	1.00	o	+	-
Volvox sp.			-	+
Cosmarium formulosum	1.80	β	-	+
Staurastrum sp.			+	+
Micrasterias radiata	1.00	o	+	+
Pleurotaenium trabecula	1.20	o	+	-
Euastrum sp.			+	+
Gloeotila sp.			-	+
SUM			**32**	**30**
TOTAL NUMBER OF SPECIES			**105**	**101**

Appendix 16

Phytoplankton taxa in the Näätämöjoki River (samplings in July and September 2002). Saprobic index values by Panthle and Buch (Abakumov 1992), Saprobic zones by Sladechek (Kozina 1977). Total number of species in each group in brackets.

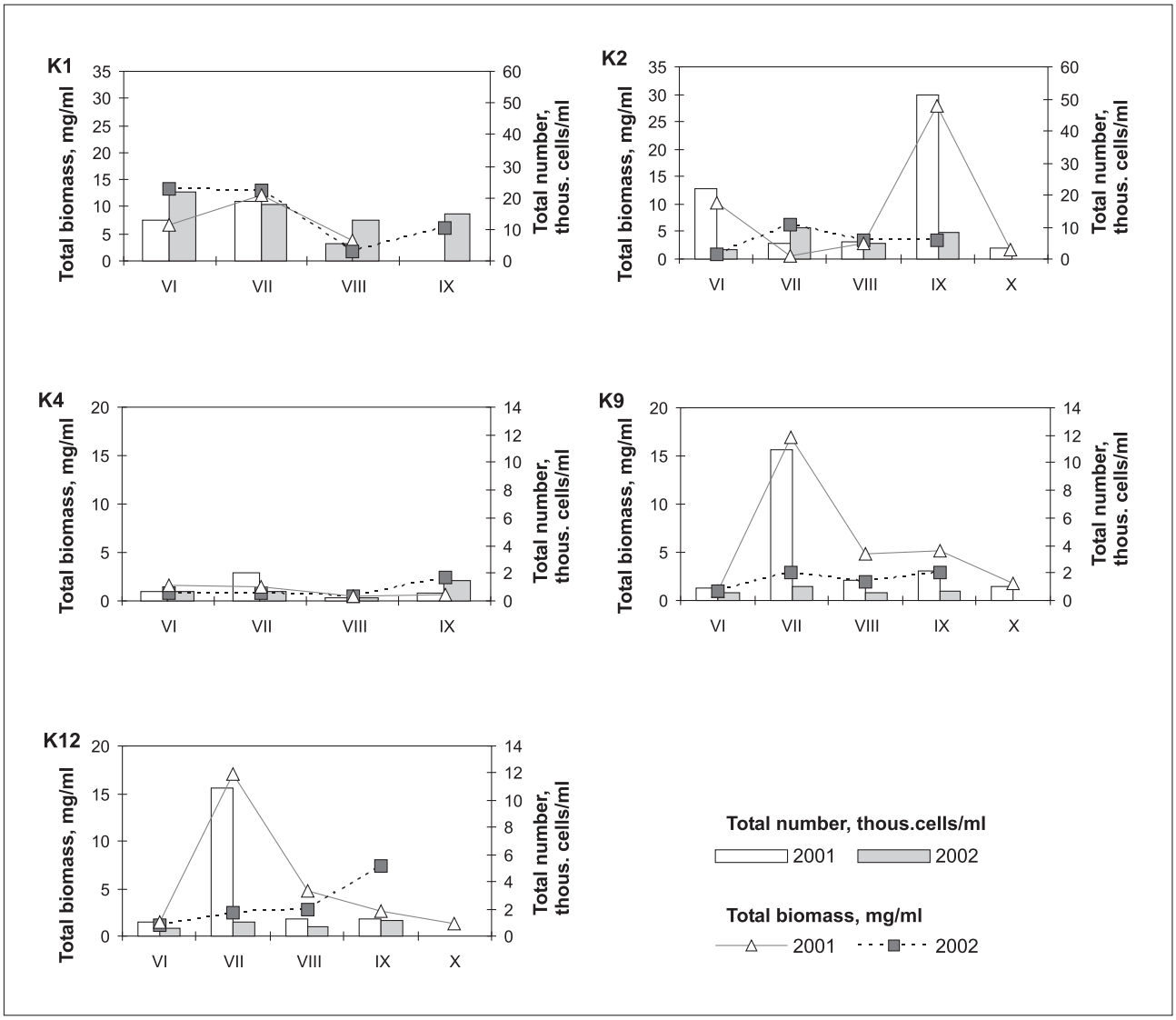
Taxon	Saprobic index	Saprobic zone
BACILLARIOPHYTA-DIATOMAE (40)		
Asterionella formosa	1.40	oβ
Asterionella gracillima	1.20	o
Achnanthes minutissima	1.45	oβ
Achnanthes sp.		
Amphora ovalis	1.65	xα
Amphora ovalis v.gracilis	1.40	oβ
Cyclotella sp.		
Cyclotella kuetzingiana	2.00	β
Cyclotella planctonica		
Cyclotella comta	1.15	o
Cymbella sp.		
Ceratoneis arcus	0.40	xo
Diatoma elongatum	1.50	oβ
Diatoma hiemale v.mesodon	0.20	x
Didymosphenia geminata	0.10	x
Fragilaria crotonensis	1.40	oβ
Gomphonema olivaceum	1.85	β
Gomphonema acuminatum v. coronatum	2.20	β
Gomphonema acuminatum	1.70	β
Melosira ambigua	1.50	oβ
Melosira distans	0.50	xo
Melosira italica	1.60	oβ
Melosira italica v.tenuissima	2.10	β
Melosira italica v.subarctica		
Melosira islandica		
Melosira islandica f.helvetica	2.00	β
Melosira varians	1.85	oβ
Navicula sp.		
Rhopalodia gibba	1.00	o
Synedra acus	1.85	β
Synedra ulna	1.95	xα
Synedra ulna v. danica	1.20	o
Synedra actinastroides	1.50	oβ
Synedra nana		
Synedra sp.		
Tabellaria fenestrata	1.40	o β
Tabellaria fenest. intermedia	1.40	o β
Tabel. fenest. asterionelloides		
Tabellaria flocculosa	0.60	ox
Tetracyclus rupestris	0.10	x

Taxon	Saprobic index	Saprobic zone
CYANOPHYCEAE (23)		
Aphanothece clathrata	1.70	βo
Aphanothece microspora		
Aphanocapsa grevillei		
Anabaena solitaria	1.60	βo
Anabaena planctonica		
Anabaena spiroides	1.35	oβ
Anabaenopsis sp.		
Coelosphaerium kuetzingianum	1.60	βo
Coelosphaerium minutissimus		
Dactylococcopsis Elenkinii		
Gloeocapsa limnetica	1.40	oβ
Gloeocapsa minutus		
Gloeocapsa turgida	1.30	oβ
Gloeocapsa sanguinea	1.00	o
Gomphosphaeria lacustris	1.50	oβ
Merismopedia sp.		
Merismopedia tenuissima	2.45	βα
Merismopedia minima		
Microcystis sp.		
Microcystis aeruginosa	1.75	β
Microcystis elabens		
Microcystis wesenbergii	2.00	β
Oscillatoria sp.		
CHRYSOPHYCEAE (10)		
Dinobryon divergens	1.85	β
Dinobryon suecicum	1.00	o
Dinobryon stipitatum	1.20	o
Dinobryon cylindricum		
Dinobryon sertularia	1.30	o
Hyalobryon sp.		
Dinobryon sp.		
Chrysococcus sp.		
Mallomonas sp.		
Hydrurus sp.		
PYRROPHYTA (8)		
Ceratium hirundinella	1.15	o
Gymnodinium sp		
Peridinium cinctum	1.00	o
Peridinium bipes v. tabulatum	1.00	o
Peridinium sp.		
Peridinium palatinum	1.20	o
Peridinium inconspicuum		
Glenodinium sp.		

Taxon	Saprobic index	Saprobic zone
EUGLENOPHYCEAE (3)		
Euglena sp		
Trachelomonas planctonica	1.65	βo
Trachelomonas cilindrica		
XANTHOPHYCEAE (1)		
Chlorobotrys regularis	1.20	o
CHLOROPHYTA (36)		
Ankistrodesmus acicularis	2.00	β
Ankistrodesmus angustus		
Cosmarium humile	1.0	o
Cosmarium pygmaeum		
Cosmarium bioculatum		
Cosmarium margaritiferum		
Cosmarium blyttii		
Cosmarium formulosum	1.80	β
Cosmarium turpini	1.00	o
Crucigenia tetrapedia	1.75	oα
Closterium sp.		
Dictyosphaerium pulchellum	2.15	βα
Dictyosphaerium subsolitarium		
Dictyosphaerium elegans		
Eurastrum elegans	1.00	o
Euastrum denticulatum	1.00	o
Euastrum sp.		
Gonatozygon sp		
Gloeotila sp.		
Gloeococcus schroeteri	1.00	o
Mougeotia div. sp.	1.00	o
Nephrocytium agardhianum		
Oocystis sp.		
Oocystis solitaria		
Pediastrum boryanum	1.85	β
Pediastrum tetras	1.75	β
Pediastrum biradiatum	1.00	o
Rhizoclonium hieroglyphicum	1.60	oβ
Spondylosium sp.		
Scenedesmus biqugatus	2.00	β
Staurodesmus sp.		
Staurastrum sp.		
Staurastrum arachne		
Staurastrum teliferum	1.00	o
Quadrigula pfitzeri		
Xanthidium antilopeum		

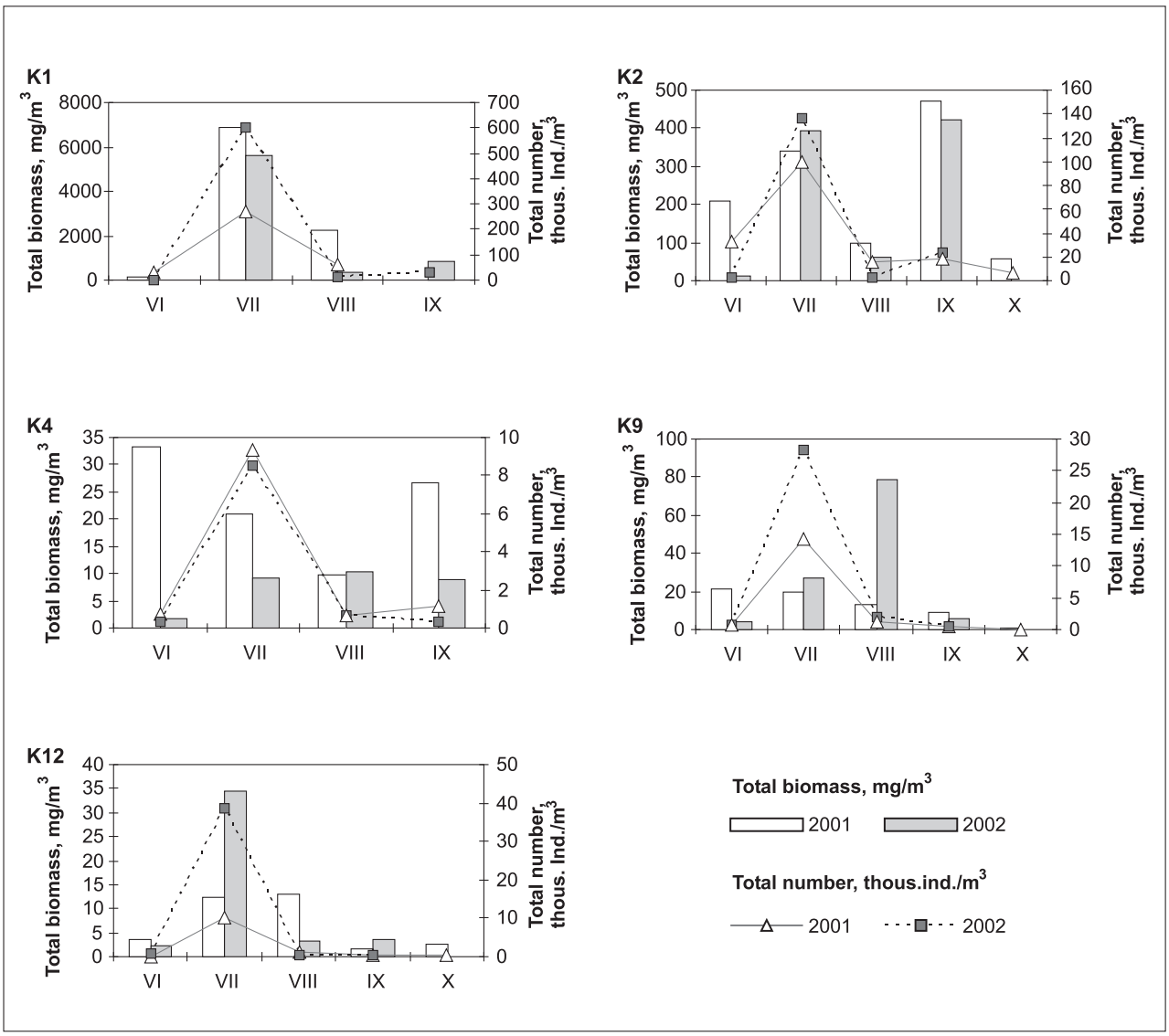
Appendix 17

Quantitative parameters of phytoplankton in the Kola River system, sampling sites K1,K2, K4, K9 and K12.



Appendix 18

Quantitative parameters of zooplankton in the Kola River system, sampling sites K1, K2, K4, K9 and K12.



Appendix 19

Zooplankton taxa occurred (+) in the Kola River system. Saprobic index values by Panthle and Buck (Sládeček 1973; Abakumov 1992), Saprobic zones by Sládeček (Kozina 1977).

Taxon	Saprobic index	Saprobic zone	2001	2002
ROTATORIA				
Asplanchna priodonta	1.90	β	+	+
Bipalpus hudsoni	1.70	β -o	+	+
Brahionus angularis	2.50	β	+	-
Euchlanis deflexa	1.50	o- β	+	-
Euchlanis dilatata	1.50	o- β	+	+
Filinia longiseta longiseta	3.10	α	+	+
Kellicottia longispina	1.70	β -o	+	+
Keratella cochlearis	1.90	β	+	+
Keratella qudrata	2.20	β	+	+
Lecane luna	1.55	o- β	+	+
Lecane cornuta	1.50	o- β	+	+
Notolca acuminata	1.20	o	+	+
Polyarthra maior	2.00	β	+	+
Polyarthra vulgaris	1.85	β	+	+
Ploesoma hudsoni	-	-	+	+
Synchaeta pectinata	1.65	β	+	+
Synchaeta stylata	1.00	o	+	+
Trichocerca longiseta	1.20	o	+	+
Euchlanis triquetra	1.20	o	+	+
Trichotria pocillum	1.10	o	+	+
Notommata tripis	1.00	o	+	-
CLADOCERA				
Acroperus harpae	1.40	o	+	+
Alona affinis	1.20	o	+	+
Alonella nana	1.40	o	+	-
Alona quadrangularis	1.40	o	+	+
Alonopsis elongata	0.80	o	+	+
Bosmina longirostris	2.20	β	-	+
Bosmina obtusirostris	1.90	β	+	+
Bosmina longispina	1.50	o- β	-	+
Ceriodaphnia quadrangula	1.15	o	+	-
Chidorus sphaericus	2.20	β	+	+
Daphnia longispina	2.05	β	+	+
Daphnia cristata	1.70	β -o	+	+
Graptoleberis testudinaria	1.50	o- β	+	-
Holopedium gibberum	1.20	o	+	+
Limnosida frontosa	2.00	β	-	+
Ophryoxus gracilis	-	-	+	-
Peracanta truncata	1.30	o	+	-
Pleuroxus striatus	1.50	o- β	+	+
Polyphemus pediculus	1.30	o	+	-

Taxon	**Saprobic index**	Saprobic zone	**2001**	**2002**
Simocephalus vetulus	1.50	o- β	-	+
Cyclopoida				
Cyclops strenuus	2.50	β - α	+	+
Eucyclops serrulatus	1.85	β	+	+
Mesocyclops oithonoides	1.90	β	-	+
CALANOIDA				
Diaptomus graciloides	1.65	β -o	+	+
Total number of species			40	36

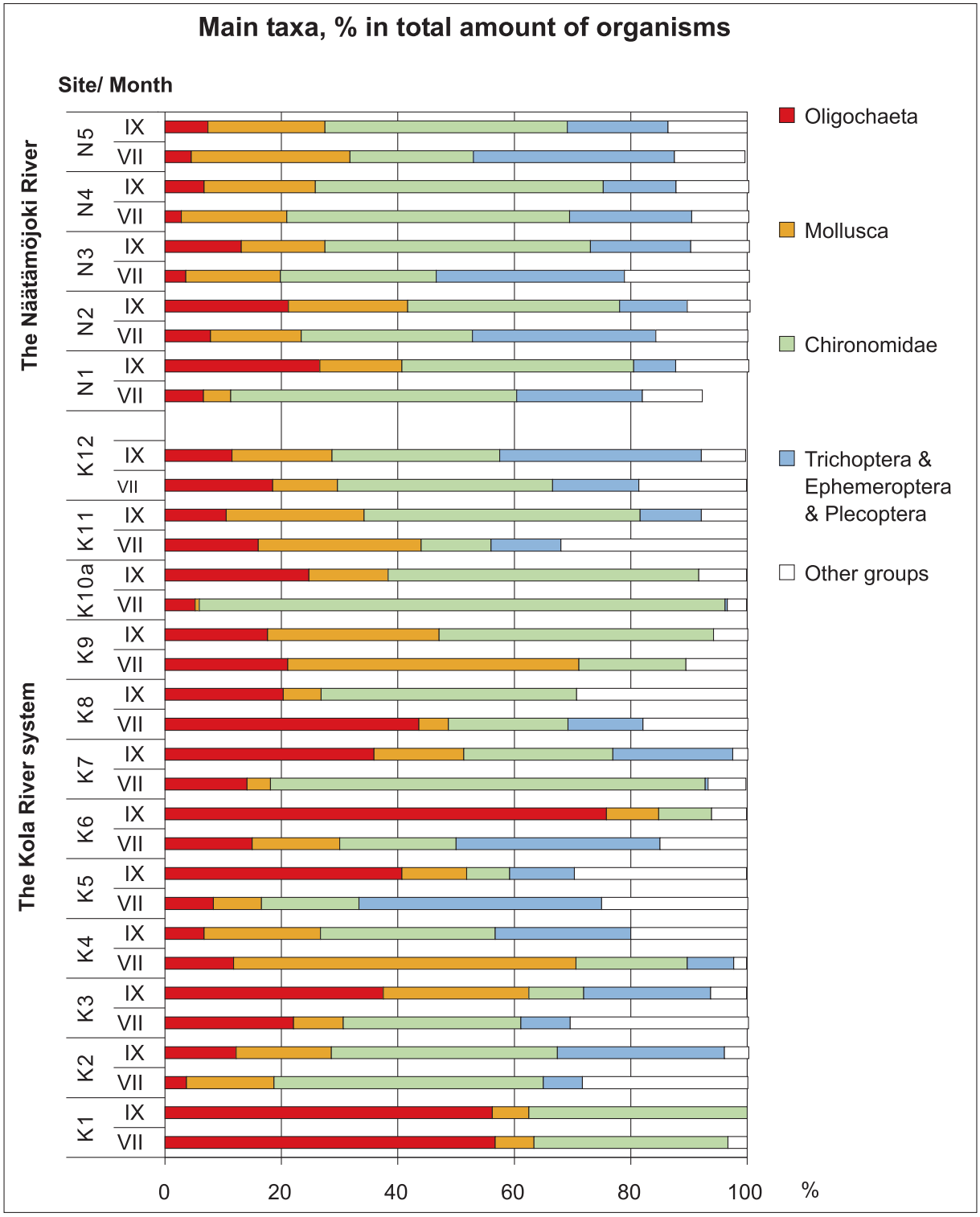
Appendix 20

Zooplankton taxa in the Näätämöjoki River. Saprobic index values by Panthle and Buck (Sládeček 1973; Abakumov 1992), Saprobic zones by Sládeček (Kozina 1977).

Taxon	Saprobic index	Saprobic zone
ROTATORIA		
Bipalpus hudsoni	1.70	β - o
Cephalodella gracilis	1.50	o - β
Euchlanis deflexa	1.50	o - β
Euchlanis dilatata	1.50	o - β
Kellicottia longispina	1.70	β - o
Keratella cochlearis	1.90	β
Lecane luna	1.55	o - β
Lecane cornuta	1.50	o - β
Polyarthra maior	2.00	β
Ploesoma hudsoni	-	-
Synchaeta stylata	1.00	o
Trichocerca longiseta	1.20	o
Euchlanis triquetra	1.20	o
Trichotria pocillum	1.10	o
Notommata tripis	1.00	o
CLADOCERA		
Acroperus harpae	1.40	o
Alona affinis	1.10	o
Alona quadrangularis	1.40	o
Alonopsis elongata	0.80	o
Bosmina coregoni	2.00	β
Bosmina obtusirostris	1.90	β
Ceriodafnia quadrangula	1.15	o
Chidorus sphaericus	2.20	β
Daphnia longispina	2.05	β
Pleuroxus striatus	1.50	o - β
Ophryoxus gracilis	-	-
CYCLOPOIDA		
Cyclops strenuus	2.50	β -α
Cyclops scutifer	2.50	β -α
Calanoida		
Diaptomus graciloides	1.65	β - o

Appendix 21

Main zoobenthos taxa (%) in the Kola River system and in the Näätämöjoki River, samplings in July and September 2002.



Appendix 22

Items to be taken into account for adequate, cost effective biological monitoring of a river system.

	In planning	In practice
Biota	• A priori measurements of different variables; acidification, habitat alterations, nutrients, organic compounds, toxic compounds, metal loading • Calculations of statistical power • Long and short term measurements • Usability in different areas of the river; riverbank, main channel, substratum or body of water, hard or loose substratum, running or quiet waters	• To know the geographical and local environmental features • Identify the main human impacts in the area
Sampling	• The biota • Different areas of the river: rapids, riffles, runs, glides, quiet waters, lake inlets and outlets, bonds • Different substratum; boulders, cobbles, pebbles, gravel, sand, clay • Number of replicate sampling	• To use the right sampling in different circumstances and for different biotas • Enough replicate samples from the right area, in right time whit clean and operational sampler • Transportation • Storage
Identification	• Necessary know-how	• Proper equipments and literature
Analyses and parameters	• Basic information about the species composition in the samples; number of species, species diversity, biomass, density, abundance, • Measurements of different variables; eutrophication, saprobia, toxic contamination, concentration of oxygen, • Multivariate analyses	• The necessary know-how to use different analyses • The discussion of the results
Results	• The aim of the research (hypotheses)	• Reliable conclusions

Proposal for biological monitoring in the Kola River.

Sampling site	Problem	Density	Date	Methods
The Kola springs, K2	• nutrient loading • metal loading	• annually, twice per year	1) summer, about 4–6 weeks after spring flood 2) early autumn, during the low water	• aquatic bryophytes • diatoms
Magnetity village, K6	• possible metal loading	• interval, every 2–4 years	• early autumn, during the low water	• aquatic bryophytes • fish community analyses
Varlamov creek, K10a Medvegiy creek, K10b Zemlanoy creek, K10c	• heavy nutrient loading • organic loading • metal loading • low oxygen concentration • bacterium	• annually	• early autumn, during the low water	• saprophyte bacteria • diatoms, phytoplankton, zooplankton or zoobenthos (one method is enough) • aquatic bryophytes
Molochny village, K11	• nutrient loading • metal loading	• annually, twice per year	1) summer, about 4–6 weeks after spring flood 2) early autumn, during the low water	• saprophyte bacteria • diatoms, phytoplankton, zooplankton or zoobenthos (one method is enough) • aquatic bryophytes
The Kola River estuary, K12	• nutrient loading • metal loading	• annually	• early autumn, during the low water	• phytoplankton, zooplankton or zoobenthos (one method is enough) • aquatic bryophytes

DOCUMENTATION PAGE

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Author(s)	Hanna Halmeenpää, Pirjo Niemelä, Janne Alahuhta, Natalya Dvornikova, Heikki Erkinaro, Kaisa Heikkinen, Sergey Kotov, Natalya Masyk, Kristian Meissner, Juha Riihimäki, Kari-Matti Vuori and Marina Zueva			
Title of publication	**Ecological State of the Kola River, Northwestern Russia – The Kola Water Quality -project**			
Publication series and number	The Finnish Environment			
Theme of publication	Environmental protection			
Parts of publication/ other project publications				
Abstract	The Kola River is situated in Northwestern Russia, Kola Peninsula, which is an area with about 70 year long history of copper and nickel mining and smelting. However, environmental effects on the Kola River, caused by industry and other human activities, are not studied thoroughly. Area of the Kola River basin is 3850 km^2. The river flows 83 km from south to north and enters the Kola Bay of the Barents Sea in front of the Kola City. The Kola River is vital for the reproduction of salmon and it is also an important source of drinking water for about half a million people in the city of Murmansk and in the surrounding settlements. In the Kola Water Quality -project in years 2001–2004 one the main objectives was to define the ecological status of the Kola River. The Näätämöjoki River in northern Finland and Norway was surveyed as a reference area. This publication includes ecological studies carried out by North Ostrobothnia Regional Environment Centre (NOREC, Finland) and The Murmansk Areal Department for Hydrometeorology and Environmental Monitoring (MUGMS, Russia). Chapters concerning macroinvertebrate studies were written by Kristian Meissner (NOREC/ SYKE). Studies on macrozoobenthos after federal Russian hydrobiological monitoring methods are grouped in separate chapters and were reported by Sergey Kotov (MUGMS). Chapters concerning fish communities were written by Heikki Erkinaro (NOREC, Finnish Game and Fisheries Research Institute). Diatom community analyses were reported by Hanna Halmeenpää and Pirjo Niemelä (NOREC). Chapters concerning hydromorphological state of the river (River Habitat Survey) were written by Janne Alahuhta (NOREC) and chapters on macrophyte survey by Juha Riihimäki (Finnish Environment Institute). Studies on metal concentrations in aquatic bryophytes were reported by Hanna Halmeenpää (NOREC) and Kari-Matti Vuori (Finnish Environment Institute). Chapters concerning bacterioplankton and phytoplankton were written by Natalya Masuk (MUGMS), chapters on zooplankton by Natalya Dvornikova (MUGMS). Chapters concerning physical and chemical water quality of the rivers Kola and Näätämöjoki were written by Marina Zueva (MUGMS) and Hanna Halmeenpää (NOREC). Hanna Halmeenpää and Pirjo Niemelä (NOREC) took the responsibility of editing the report and writing of common chapters. On grounds of the ecological studies, the Kola River can be divided into three separate areas. At the upper river sections (K2-K3) the ecological status ranged from good to moderate. Signs on nutrient and metal (copper, nickel) loading could be detected both in water quality and in aquatic organisms. The ecological status of the mid-section (K4-K8) of the Kola River basin ranged from good to high. No major human impact could be seen. The estuary section (K9-K12) of the Kola River represented the moderate ecological status. This was probably caused by small, heavily polluted tributaries (Varlamov, Medvegiy and Zemlanoy) draining organic load and nutrient rich waters into main flow and also by other anthropogenic loading along the lower river section. The ecological status of the reference river Näätämöjoki was high on grounds of all the biological parameters used in this study.			
Keywords	hydrobiology, macrozoobenthos, diatoms, fish, River Habitat Survey, aquatic bryophytes, bacterioplankton, phytoplankton, zooplankton, water quality, Kola River, Näätämöjoki River			
Financier/ commissioner	EU/ INCO-Copernicus programme (ICA2-CT-2000-10051), the Finnish Ministry of the Environment, Finnish Environment Institute, North Ostrobothnia Regional Environment Centre			
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KUVAILULEHTI

Julkaisija	Pohjois-Pohjanmaan ympäristökeskus			*Julkaisuaika* Elokuu 2007
Tekijä(t)	Hanna Halmeenpää, Pirjo Niemelä, Janne Alahuhta, Natalya Dvornikova, Heikki Erkinaro, Kaisa Heikkinen, Sergey Kotov, Natalya Masyk, Kristian Meissner, Juha Riihimäki, Kari-Matti Vuori and Marina Zueva			
Julkaisun nimi	**Ecological State of the Kola River, Northwestern Russia – The Kola Water Quality –project** (Kuolajoen ekologinen tila, Luoteis-Venäjä – Kola Water Quality -projekti)			
Julkaisusarjan nimi ja numero	Suomen ympäristö			
Julkaisun teema	Ympäristönsuojelu			
Julkaisun osat/ muut saman projektin tuottamat julkaisut				
Tiivistelmä	Kuolajoki sijaitsee Luoteis-Venäjällä, Kuolan niemimaalla, jossa kaivosteollisuudella on pitkä historia mm. kuparin ja nikkelin hyödyntämisessä. Teollisuuden ja muun ihmistoiminnan aiheuttamia riskejä Kuolajoen tilaan on kuitenkin tutkittu melko vähän. Kuolajoen valuma-alueen pinta-ala on 3850 km^2. Joki virtaa 83 km etelästä pohjoiseen ja laskee Kolan kaupungin edustalla Kuolavuonon kautta Barentsinmereen. Kuolajoki on merkittävä lohijoki ja tärkeä raakavesilähde noin 500 000 Murmanskin kaupungin ja sen ympäristön asukkaalle. Vuosien 2001–2004 aikana toteutetun Kola Water Quality -projektin päätavoitteisiin kuului Kuolajoen ekologisen tilan selvittäminen. Vertailukohteena tutkittiin myös Pohjois-Suomen ja Pohjois-Norjan alueilla virtaavan Näätämöjoen ekologista tilaa. Julkaisuun on koottu Pohjois-Pohjanmaan ympäristökeskuksen (PPO) ja Murmanskin hydrometeorologian ja ympäristöseurannan laitoksen hallinto (MUGMS) johdolla tehdyt ekologiset tutkimukset. Pohjaelämiä koskevat kappaleet on kirjoittanut Kristian Meissner (PPO). Venäjän valtiollisen ympäristöseurannan menetelmiin perustuvat pohjaeläintutkimukset, jotka on eritelty omiin kappaleisiinsa, on kirjoittanut Sergey Kotov (MUGMS). Kalastotutkimusten kappaleet on kirjoittanut Heikki Erkinaro (PPO, Riistan- ja kalatalouden tutkimuskeskus). Piilevätutkimukset ovat raportoineet Hanna Halmeenpää ja Pirjo Niemelä (PPO). Joen hydromorfologista tilaa käsittelevät River Habitat Survey -kappaleet on kirjoittanut Janne Alahuhta (PPO) ja kasvillisuusslevitystä koskevat kappaleet Juha Riihimäki (Suomen ympäristökeskus). Vesisammalten metallispitoisuustutkimukset ovat raportoineet Hanna Halmeenpää (PPO) ja Kari-Matti Vuori (Suomen ympäristökeskus). Bakteeri- ja kasviplanktonkappaleet on kirjoittanut Natalya Masuk (MUGMS), eläinplanktonkappaleet Natalya Dvornikova (MUGMS). Kuolajoen ja Näätämöjoen veden fysikaalis-kemiallista laatua koskevat kappaleet ovat kirjoittaneet Marina Zueva (MUGMS) ja Hanna Halmeenpää (PPO). Raporttikoosteen toimituksesta sekä yhteisten osioiden kirjoituksesta ovat vastanneet Hanna Halmeenpää ja Pirjo Niemelä (PPO). Tehtyjen ekologisten selvitysten perusteella Kuolajoki voidaan jakaa kolmeen osa-alueeseen. Joen yläjuoksulla (K2-K3) ekologinen tila vaihtelee hyvästä tyydyttävään, merkkejä ravinne- ja metallikuormituksesta (kupari, nikkeli) havaittiin sekä veden laadussa että eliöstössä. Joen keskijuoksulla (K45-K8) ekologinen tila on hyvä tai erinomainen, merkittävää ihmisvaikutusta ei ollut havaittavissa. Joen alajuoksulla (K9-K12) ekologinen tila on tyydyttävä, johtuen voimakkaan ravinnekuormituksen likaamaa vettä tuovista pienistä sivu-uomista (Varlamov, Medvegiy ja Zemlanoy) ja ihmistoiminnan läheisyydestä itse pääuoman varrella. Vertailukohteena olleen Näätämöjoen ekologinen tila on erinomainen kaikkien tehtyjen selvitysten perusteella.			
Asiasanat	hydrobiologia, pohjaeläimistö, piilevät, kalasto, River Habitat Survey, vesisammalet, bakteeriplankton, kasviplankton, eläinplankton, vedenlaatu, Kuolajoki, Näätämöjoki			
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ЛИСТ ОПИСАНИЯ ПУБЛИКАЦИИ

<table>
<tr><td>Издатель</td><td colspan="2">Региональный Центр окружающей среды Северной Эстерботнии</td><td>Время публикации
Август 2007</td></tr>
<tr><td>Автор(ы)</td><td colspan="3">Ханна Халмеенпаа, Пирьё Ниэмеля, Янне Алахухта, Натальей Дворниковой, Хейкки Эркинаро, Кайса Хейккинен, Сергеем Котовым, Натальей Масюк, Кристианом Меисснером, Юхой Риихимяки, Кари-Матти Вуори, Мариной Зуевой</td></tr>
<tr><td>Название публикации</td><td colspan="3">Ecological State of the Kola River, Northwestern Russia – The Kola Water Quality -project
(Проект «Экологическое состояние реки Кола на Северо-Западе России»)</td></tr>
<tr><td>Название и номер серии публикаций</td><td colspan="3">Окружающая среда Финляндии</td></tr>
<tr><td>Тематика публикации</td><td colspan="3">Охрана окружающей среды</td></tr>
<tr><td>Резюме</td><td colspan="3">Река Кола протекает по Северо-Западной части Кольского полуострова, региона с 70-летней историей добычи и выплавки меди и никеля. Однако воздействие антропогенных факторов на экосистему р.Колы изучено недостаточно. Площадь бассейна реки 3850 км2, протяжённость реки 83 км. Река Кола несёт свои воды в направлениис юга на север и впадает в Кольский залив Баренцева моря в районе города Колы. Река Кола имеет важное значение для воспроизводства популяции лосося, а также является источником питьевого водоснабжения для полумиллионного населения города Мурманска и его окрестностей.
В проекте по изучению качества воды реки Колы в 2001-2004 годах одной из главных целей было определение экологического состояния данного водоёма. Река Наатамёйоки (Näätämöjoki River) в северной Финляндии и Норвегии использовалась в качестве фонового участка. Данная публикация знакомит с экологическими исследованиями, выполненными Управлением по гидрометеорологии и мониторингу окружающей среды Мурманской области (MUGMS, Россия) и региональным центром окружающей среды Северной Эстерботнии (NOREC, Финляндия). Главы, касающиеся исследований макробеспозвоночных, написаны Кристианом Меисснером (Kristian Meissner, NOREC). Исследования макрозообентоса проведены согласно российским стандартам государственного мониторинга. Их результаты, представленные Сергеем Котовым (MUGMS), сгруппированы в отдельных главах. Разделы, посвященные изучению сообществ рыб, написаны Хейкки Эркинаро (Heikki Erkinaro, NOREC, Институт исследования охотничьего и рыбного хозяйства). Исследования сообществ диатомовых водорослей описаны Ханной Халмеенпаа (Hanna Halmeenpää, NOREC) и Пирьё Ниэмеля (Pirjo Niemelä, NOREC). Главы, по исследованию гидроморфологического состояния реки (среды обитания реки), написаны Янне Алахухта (Janne Alahuhta, NOREC), по исследованию макрофитов - Юхой Риихимяки (Juha Riihimäki, Институт окружающей среды Финляндии). Результаты исследования концентраций металлов в гидробриофитах предоставлены Ханной Халмеенпаа (Hanna Halmeenpää, NOREC) и Кари-Матти Вуори (Kari-Matti Vuori, Институт окружающей среды Финляндии). Разделы о бактериопланктоне и фитопланктоне написаны Натальей Масюк (MUGMS), о зоопланктоне - Натальей Дворниковой (MUGMS). Гидрохимический состав воды рек Кола и Наатамёйоки (Näätämöjoki) описаны Мариной Зуевой (MUGMS) и Ханной Халмеенпаа (Hanna Halmeenpää, NOREC). Ханна Халмеенпаа и Пирьё Ниэмеля (NOREC) отвечали за редакцию отчёта и написание глав общего характера.
На основании результатов экологических исследований река Кола может быть разделена на три отдельных зоны. В верхних участках реки (K2-K3) экологическое состояние варьирует от хорошего до удовлетворительного. Признаки загрязнения биогенами и металлами (медь, никель) обнаружены и в воде, и в речных организмах. Экологическое состояние среднего участка (K4-K8) бассейна реки Колы варьирует от хорошего до отличного. Значительного антропогенного воздействия здесь замечено не было. Состояние устьевого участка (K9-K12) реки удовлетворительное. Это, вероятно, обусловлено наличием небольших, сильно загрязненных притоков (ручьёв Варламов, Медвежий и Земляной), откуда в главное русло реки Колы попадают воды с большим содержанием органических и биогенных веществ). Экологическое состояние фоновой реки Наатамёйоки (Näätämöjoki) было отличным по всем биологическим параметрам, использованным в этом исследовании.</td></tr>
<tr><td>Ключевые слова</td><td colspan="3">гидробиология, макрозообентос, диатомовые водоросли, рыба, исследование среды обитания реки, гидробриофиты, бактериопланктон, фитопланктон, зоопланктон, качество воды, река Кола, река Наатамёйоки (Näätämöjoki)</td></tr>
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</table>

The river is vital for the reproduction of salmon in this region and an important source of drinking water for 500 000 people of the city of Murmansk and the surrounding settlements. Industrial development, especially the large iron ore mine and concentration plant at Olenegorsk and the Cu-Ni smelter at Monchegorsk, has increased the risk of metal pollution in the river. No comprehensive assessment of the pollution status of this important river basin has been made, however.

The Kola River (69° N, 33° E) located on the Kola Peninsula, in northern Russia, is a large northern boreal or sub-arctic river draining into the Barents Sea.

What is the state of the Kola River, northwestern Russia, at present? The answer is given in this report, prepared as a part of the EU/ INCO-Copernicus programme (ICA2-CT-2000-10051) in the Kola Water Quality Project during years 2000-2004. The report includes data on water quality, bacterio-, phyto- and zooplankton, diatoms, aquatic bryophytes, macrophytes, macroinvertebrates and fish, as well as on the hydromorphological state of the river. Also data on the Näätämöjoki River in the northernmost Finland and Norway, which served as a reference area to the Kola River, have been presented. The ecological status assessment was carried out in co-operation by the North Ostrobothnia Regional Environment Centre (NOREC, Finland) and the Murmansk Areal Department for Hydrometeorology and Environmental Monitoring (MUGMS, Russia).

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