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forskningsrapport

Pollution impact on freshwater communities in the border region between Russia and Norway

II. Baseline study 1990-1992

Arnfinn Langeland (Editor)

NINA

NORSK INSTITUTT FOR NATURFORSKNING

Corrections

Langeland, A (Editor) 1993. Pollution impact on freshwater communities in the border region between Russia and Norway. II. Baseline study 1990-1992. - NINA Scientific report 44: 1-53.

Corrections on pages 14, 26, 27, 28:

The concentration of metal given as g should be µg.

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Abstract

Langeland, A (Editor) 1993. Pollution impact on freshwater communities in the border region between Russia and Norway. II. Baseline study 1990-1992. - NINA Scientific report 44: 1-53.

The aim of this baseline study carried out between 1990 and 1992, was to assess the ecological state of freshwater communities in Russian and Norwegian territories. Water chemistry, phytoplankton, aquatic mosses, zooplankton, zoobenthos and fish were sampled in different lakes and streams in border areas.

Severe pollution impacts upon freshwater communities has been recorded near factories in Nikel and Zapolyarny. Moderate adverse impact on the Norwegian side, and on areas at longer distances from the factories on the Russian side, are related to these pollution sources.

Heavy metal accumulation, pathological anomalies in fish and a low diversity of invertebrates were observed. Indications of acidification impact were only recorded within restricted areas at highest altitudes in the Jarfjord region.

This study provides a satisfactory background for further evaluation of ecological changes following the planned reconstruction of air purification systems at the factories. A monitoring program restricted to annual investigations in six localities in the border areas is recommended.

Key words: freshwater communities - pollution - border area Russia and Norway.

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РЕЗЮМЕ

Лангеланд А. (редактор), Влияние загрязнения на пресноводные сообщества в приграничном районе России и Норвегии. II. Основное изучение 1990 - 1992. НИНА, Научный отчёт 44.

Целью этих исследований, сделанных в течение 1990 - 1992 годов было определение экологического состояния пресноводных сообществ как на русской, так и на норвежской территориях. В приграничных районах, из разных озёр, ручьёв были взяты пробы воды, фитопланктона, водного мха, зоопланктона, зообентоса и рыб.

Сильное воздействие загрязнения на пресноводые сообщества было зарегистрировано вблизи фабрик в Никеле и Заполярном. Умеренное негативное воздействие на норвежской стороне и в районах, находящихся в большом расстоянии от фабрик на русской стороне,связано с этими источниками загрязнения.

Замечено накопление тяжёлых металлов, патологии у рыб и небольшое видовое разнообразие среди беспозвоночных. Признаки воздействия закисления озёр были зарегистрированы только на большой высоте, в районе Ярфьорда.

Эти исследования являются хорошей основой для дальнейшей оценки экологических изменений в связи с запланированной на фабриках реконструкцией систем очистки воздуха. Предлагается мониторинг, предусматривающий проведение исследований в шести приграничных районах.

Ключевые слова: пресноводные сообщества, загрязнение, приграничный район России и Норвегии.

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Preface

The impact of pollution on the environment of the Kola Peninsula has increased during recent decades due to activities at several mining factories and metallurgical industries. As a consequence a bilateral agreement between Russia and Norway on environmental problems between Russia and Norway was established in 1988. According to this agreement, a cooperative study of freshwater communities in the border areas was initiated in 1990.

Participating institutions were:
Norwegian Institute for Nature Research (NINA), Trondheim - Norway.
Institute of the North Industrial Ecology Problems Kola Science Centre (INEP), Academy of Science of Russia, Apatity - Russia.
County governor of Finmark, Vadsø - Norway
Department of Forestry, Finnmark - Norway (field assistances).
Akvaplan-NIVA, Tromsø-Norway.

This report present the results of field investigations in 1990, 1991 and 1992.

The following persons have contributed to the report (in alphabetical order):
H. M. Berger, field work and fish
J. H. Halleraker, aquatic mosses
H. Huru, zoobenthos
N. Kashulin, field work and fish
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1 Introduction

During recent years increasing attention has been paid to environmental impact of pollution in the border areas between Russia and Norway caused by industrial activities (Kryuchkova & Makarova 1989, Frisvoll & Flatberg 1990, Hagen et al. 1990, Sivertsen 1990, Year Book ...1990, Traaen et al. 1991).

The Pechenga nickel factories located in the Russian towns Nikel and Zapolyarny, are the main sources of pollutants which affect the environment in the border area between Russia and Norway. Emissions mainly contain sulphuric gases, heavy metals and dust (Sivertsen et al. 1991). As a result of the long-term pollutant impact in that area, damage to terrestrial and water ecosystems is obvious. High concentrations of pollutants in the atmosphere and effects on vegetation are observed even in border areas of Norway.

Information about fish and invertebrates is available from Sør-Varanger area (Norway) concerning phytoplankton and zooplankton (Sæther 1970), zoobenthos (Økland, K.A. 1969, Tobias 1973 Økland, J. 1990,) and fish (Huitfeldt-Kaas 1918, Berg 1964, Kristoffersen & Sterud 1985). Strong acidification impact on fish and invertebrates is well known from the southern part of Norway (Drabløs & Tollan 1980, Berger et al. 1992). Recent studies of water quality, zoobenthos and fish populations in Finnmark county indicate acidification impact ((SFT 1987, 1988, 1990, Traaen 1987, 1991, Karlsen 1988, Henriksen et al. 1990, Traaen et al. 1990). Impact of acidification on freshwater in Finnish Lapland have also been documented (Kinnunen 1990). Information of diseases on freshwater biota caused by heavy metal contamination is scarce. Accumulation of heavy metals has been recorded in bottom sediments and fish from the Pasvik River (Nordheim et al. 1985, Rognerud & Fjeld 1990, Rognerud 1990). Earlier studies on freshwater communities from the Pechenga area are scarce (Kruglova 1983, Year Book .... 1990, Yakovlev 1991).

The aim of this study was to assess the state of freshwater communities in Russian and Norwegian areas. Results from studies in 1990 have been presented in a previous report (Nøst et al. 1991). This report presents results for the baseline study period 1990, 1991 and 1992. The investigation presents results on species composition, abundances and biomass of phytoplankton, aquatic mosses as bioindicators of heavy metals, zooplankton, zoobenthos and fish communities, pathological state and heavy metal accumulation in fish. The results are also related to other studies on geology and chemical analyses of water and precipitation.

A monitoring program aimed to reveal the changes following the process of reconstruction of the air purification systems of the factories will continue the investigations in the border area between Russia and Norway. A sampling program on suitable parameters will be carried out annually in a few selected lakes and streams.

2 Study area

The investigated area located at latitude 69-70° N and longitude 29-31° E, was divided into five regions; 1) Nikel Region, 2) Pechenga River System, 3) Pasvik River system including Lake Kuetsyarvi, 4) Jarfjord Region and 5) Russian-Finnish Border (**Figure 1**). Regions 1 and 2 are later denoted as the Pechenga area.

The geology is complex and consists of hard bedrock predominating in the Jarfjord Region and more soluble and richer bedrock (more Ca and Na) in the Pechenga area and the Pasvik River system (Sigmond et al. 1984, Atlas.. 1971).

The climate is influenced by warm air streams from the Northern Atlantic and by cold ones from the Arctic (Yakovlev 1991). The annual mean temperature in the border area is low, e.g. in Pasvik, Sør-Varanger -0.3°C. Minimum and maximum monthly mean temperatures are -13.5°C and +14.0°C, respectively. The annual precipitation in Pasvik is low, 358 mm (Bøyum 1970, NVE 1987). Surface water systems drain into the Barents Sea. Mean annual runoff in the Pechenga area is in the range of 600-800 mm.

3 Load of pollutants

The load of pollutants from the Pechenga nickel factories consists mainly of nickel (Ni), copper (Cu), sulphurdioxide (SO_2) and dust (Hagen et al. 1990, Sivertsen 1990). As heavy metals are deposited near the sources, the gases may be transported longer distances and then precipitate as acid deposits. Dusts emitted into the atmosphere are composed of nickel (3.13 %), copper (1.91 %), cobolt (0.114 %) and sulphur as S_2 (8.67 %) (Pechenga Nickel Company data). The annual levels of nickel and copper in dust emissions are about 500 tonne Ni and 300 tonne Cu. Annual sulphurdioxide (SO_2) emission from the factories (300 000 tonne) is about three times higher than the total Norwegian emission of sulphur. Anthropogenic sulphur fallout on the territory near the main sources is 30 g m^{-2} $year^{-1}$. The minimum pH of precipitation in the Pechenga area is 3.4 (Krychkov & Makarova 1989).

The load of pollutants is different in the study regions. The Pasvik River systems drains the Nikel town area through Lake Kuetsyarvi. In the other regions pollutants are only transported through air, except some streams near Zapolyarny and in the Pechenga River System. Thus the load of pollutants is determined by the distance from emission sources and wind direction. The surroundings of the factories receive the largest amounts of pollutants as gases and dust. Dominating wind directions from the factories are mostly north-east, partly north and north-west. This means that the north-eastern parts of Norway including the Jarfjord Region also receives air transported pollutants (Scholdager et al. 1983). However, the load in this area is reduced as compared to the areas near the sources.

Figure 1
The study areas near the Norwegian-Russian border defined in five different regions.

4 Sampling methods

4.1. Water chemistry

Water samples were collected from 107 localities (**Appendix 1**) and analyzed for a maximum of 25 chemical parametres at NINA's laboratory using standard methods (**Appendix 2**).

4.2 Phytoplankton

Water samples of 100 ml were taken from 6 localities in 1991 and 1992 and fixed with Lugols fixation for determination of phytoplankton abundances and species composition. The phytoplankton samples have been analysed by Øivind Løvstad, Limnoconsult - Norway.

4.3. Aquatic mosses

In 1991, tip-samples of two species of river-mosses, (*Fontinalis antipyretica* Hedw. and *Fontinalis dalecarlica* B., S & G.) were collected from several streams in four regions as shown in **figure 5**. *Fontinalis* spp. were sampled from 33 localities in the periode between June 25th and July 19th, 1991 (**Appendix 1**).

The 2 cm tip-samples of these two river mosses species were rinsed in the river water, air dried and than frozen for later analyses of heavy metal accumulation. The contents of 9 heavy metals in the mosses were analysed using an atomic absorption spectrofotometer. For a detailed description of the metods see **appendix 2** and Halleraker (1992) .

At each sampling site the environments were characterized regarding substrate structure, water surface speed and temperature. Additional water samples were taken for chemical analyses from most of the localities (**Appendix 3**).

4.4 Zooplankton

Zooplankton samples were taken in 6 lakes in the Nickel region, 3 lakes in the Pechenga River System, 5 localities in the Pasvik River system, 13 lakes in the Jarfjord region and 2 lakes located on the Russian-Finnish border (**Appendix 1**). Samples were made in three periods, June-July, July-August and August-September in all years 1990-1992. In Lake Kuetsyarvi sampling was carried out at 5 stations.

Quantitative zooplankton samples were taken with a 5 l tube sampler, 1 m in length. The water was sieved through a net of mesh size 45 m. Depending on lake depth, mixed samples were made from depths of 0-5 m, 5-10 m, 10-15 m and 15-20 m. Additional qualitative samples were obtained from each lake using vertical net hauls from bottom to the surface (net area 660 cm^2 and mesh size 90 m). All samples were fixed in Lugols fixation.

Calculations of biomass (dry weight) was based on the relationships between body weight (W) and body length (L) according to Bottrell et al. (1976) and Langeland (1982).

4.5 Zoobenthos

Zoobenthos samples were carried out in different habitats (littoral and profundal zones of lakes, lake outlet/inlet, streams) and substrate. Total samples are available from 178 stations; 75 from the Pechenga area, 19 from the Pasvik River system and 84 from the Jarfjord Region (**Appendix 1**).

In the profundal zone, zoobenthos was collected with an Ekman dredge (213 cm^2). 3-5 dredge samples were taken from each station. All samples were sieved through a net with mesh size 250 m. Samples from the littoral zones of lakes and from running waters were made by the kicking sampling method described by Frost et al. (1971), using a net with mesh size 500 m. All animals were picked out and preserved in 70 % ethanol.

Biomass of zoobenthos was based on fresh weight.

4.6 Fish

Electrofishing was performed in streams and inshore areas in lakes in August/September. A total of 89 stations were sampled; 30 in Pechenga area, 3 in the Russian side of the Pasvik River system and 56 in the Jarfjord Region (**Appendix 1**). Additionally 8 localities in the border area between Russia and Finland were electrofished in 1992. Natural tip lengths of all fish were measured. Some of the fish were collected for heavy metal analyses. Fish caught near Nikel were preserved in 70 % ethanol.

Fish were caught with standard gillnet series, consisting of 8 fleets 10-45 mm bar mesh size (Rosseland et al. 1979) in 10 localities on the Russian side and 21 in Norwegian territory in August/September (**Appendix 1**). In 9 of the Jarfjord lakes, test-fishing was also done in July. For comparison, test-fishing was also carried out in Lake Kocheyavr and Lake Virtuovoshyavr situated 150 km and 100 km south of Nikel near the Russian-Finnish border, respectively.

All fish were analysed for body length and weight, Fultons condition coefficient, sex, gonad maturity, fat content of intestine and stomach fullness. The stomach contents of a selected number of fish were collected for food habits and preserved in 70 % ethanol. The stomach content was determined to prey group or species composition and weight according to the point method described by Hynes (1950). Pathological and morphological examination were made of the fish and symptoms of diseases and parasitic infection were recorded visually. Scales, otoliths, shoulder- and opercular bones were collected for age determination according to standard methods (Jonsson 1976, L'Abèe-Lund 1985). Determination of different morphs of whitefish was made according to a standard systematic method (Reschetnikov 1980).

Heavy metal contents of tissues and organs were determined for the samples of brown trout (*Salmo trutta*), Arctic char (*Salvelinus alpinus*), perch (*Perea fluviatilis*)and pike (*Esox lucius*) collected in 1990 and 1991 at INEP. Subsamples for each individual fish were collected from the gills, liver, kidneys, muscle and skeleton. Samples were placed in plastic bags and quickly frozen in liquid nitrogen for further determination at the laboratory according to methods given in **Appendix 2**. These samples were dried to constant weight at 105°C. Organic matter was removed using concentrated nitric acid (HNO_3). In organs and tissues, contents of nickel, copper, zinc, cobolt, manganese and mercury were determined using the atomic absorbtion method (AAS - 30 Karl-Zeiss-Jena).

Heavy metal content was examined for samples collected in 1991 and 1992 by NINA using a similar method (**Appendix 2**).

5 Results

5.1 Water chemistry

All values are included in **Appendix 3** while averages, minimum and maximum values for some chosen localities are shown in **figure 2** and **figure 3**. Localities in the border-area between Russia and Finland are used as reference-localities.

In general higher values were found in the Russian localities for most of the chemical parametres. The range in pH was between 4.55 and 7.58 (**Appendix 3**) with highest values in the Nikel Region and in the Pasvik River System. Low pH-values were measured in the Jarfjord localities: F. Høgfjellsvatn, A. Høgfjellsvatn, Limgambergtjern, Dalvatn and the tarns Jarfjord 2 - Jarfjord 7. Concerning alkalinity and calcium-concentration (Ca), high values were found in three localities near Nikel (189 - 728 µekv/l, respectively 11.98 - 49.87 mg Ca/l) as well as in the Russian part of the Pasvik River System (189 - 393 µekv/l and 9.09 - 13.03 mg Ca/l, respectively). Concentrations of Ca in the Jarfjord Region were, with some few exceptions, lower than 2 mg/l.

Sulphate (SO_4) varied between 3.02 and 212.12 mg/l concerning the whole investigated area. As for Ca, high values of SO_4 were found in the localities near Nikel and in Lake Kuetsyarvi.

High values of nitrogen (Tot-N) and phosphorus (Tot-P) were measured in localities draining the town of Nikel (Lake Kuetsyarvi). In Lake Nikel 1, near Nikel, a maximum of 381 µg tot-N/l was obtained. The number of measurements was however higher for nitrate (NO_3), which ranged from 2 to 767 µg/l (**Figure 2**).

Contents of metals were in general highest in the Nikel Region and in the Russian part of the Pasvik River System (**Figure 3**). Concentrations of cadmium (Cd) were lower than the detection limits of 2 ppb (1990), respectively 0.10 ppb (1991-92) most of the time. Highest values were measured in Kolosyoki but did not exceed 2 ppb. High values of copper (Cu) were obtained in Kolosyoki, the Nikel lakes, Lake Maayarvi and Lake Kuetsyarvi with a maximum of 125 ppb in Lake Nikel 2. The manganese-concentrations (Mn) were high in Lake Kuetsyarvi, with averages between 55 and 82 ppb and a maximum of 292 ppb on station Ku-2. High values of Mn was also obtained in F. Høgfjellsvatn (46 - 62 ppb). Contents of nickel (Ni) in the Nikel Region ranged from below the detection limits to 485 ppb. Highest values were obtained in Kolosyoki. Concentrations of Ni in Lake Kuetsyarvi

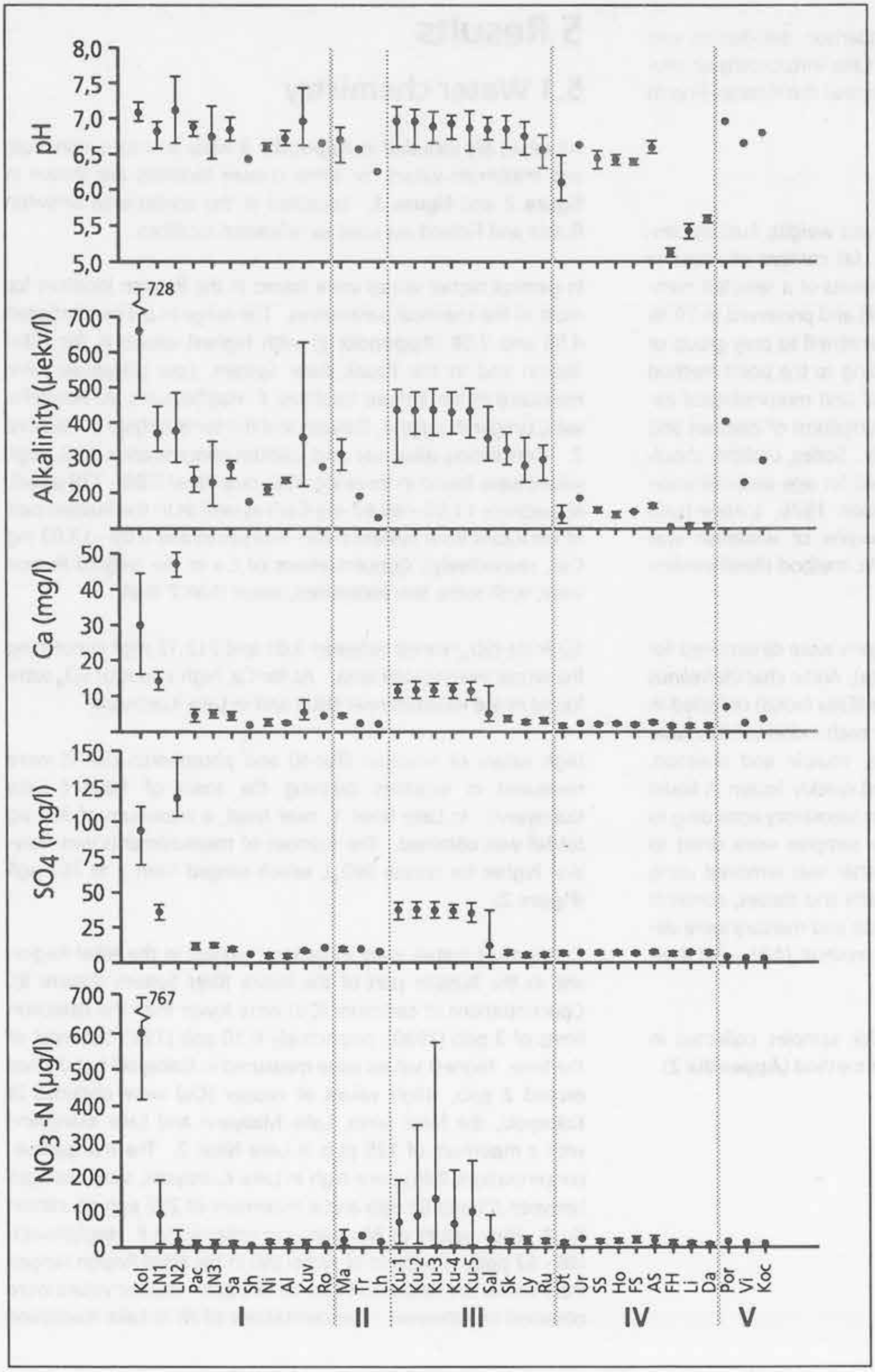

Figure 2

Mean, minimum and maximum values of NO_3, SO_4, Ca, alkalinity and pH in the water in different localities. I = Nikel Region, II = Pechenga River System, III = Pasvik River System, IV = Jarfjord Region, V = Russian-Finnish Border.

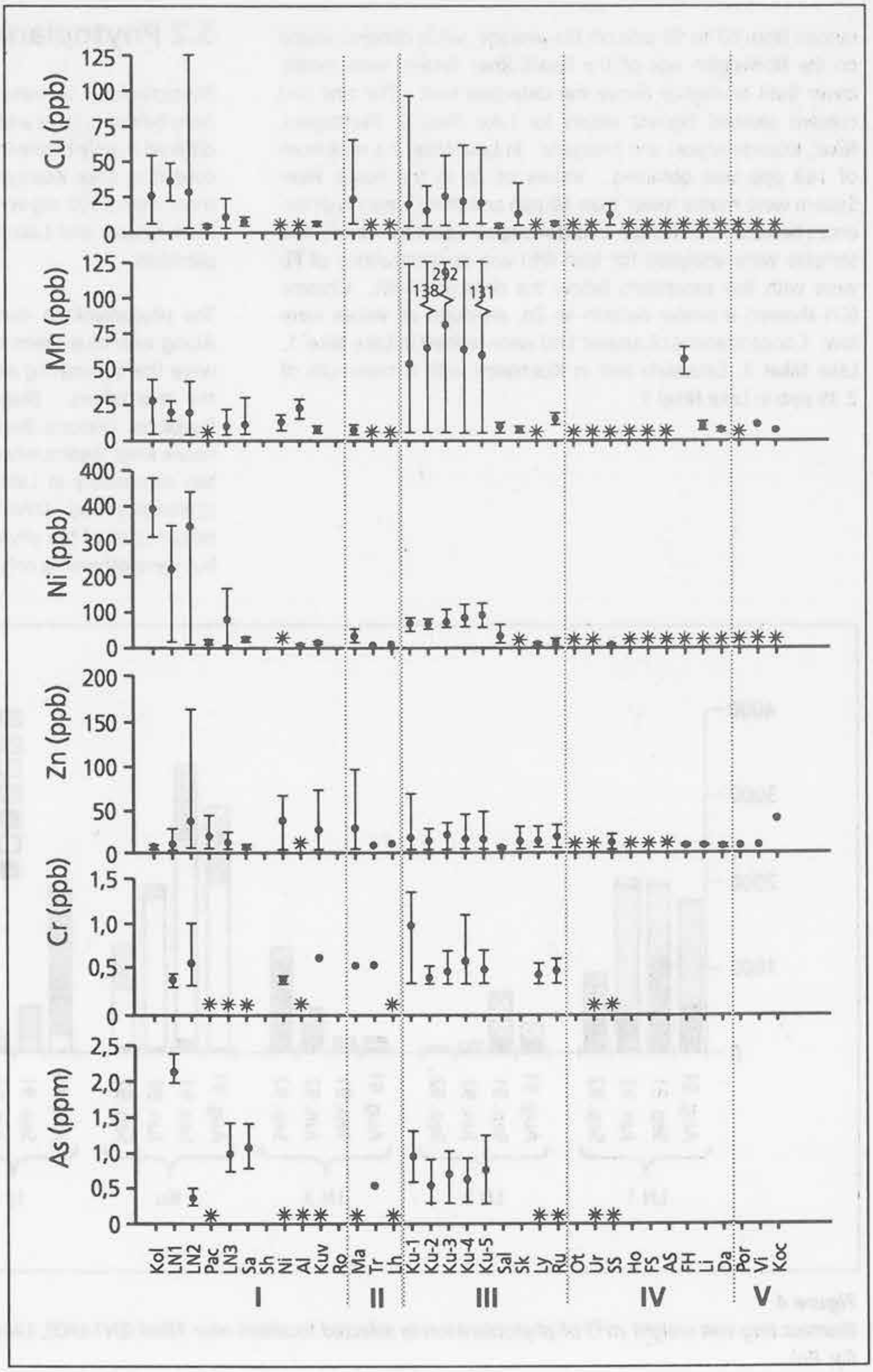

Figure 3

Mean, minimum and maximum values of As, Cr, Zn, Ni, Mn and Cu in the water in different localities. Symbols as in figure 2. Asterix indicate values below detection limits. Detection limits in ppb: Cu: 5; Mn: 5; Ni: 20; (1990/91), 5 (1992); Zn: 5; Cr: 0,3; As:0,3.

ranged from 67 to 94 ppb on the average, while concentrations on the Norwegian side of the Pasvik River System were mostly lower than or slightly above the detection limit. The zinc (Zn) content showed highest values for Lake Nikel 2, Pachtayoki, Nikel, Kuvernerinyoki and Maayarvi. In Lake Nikel 2 a maximum of 163 ppb was obtained. Values of Zn in the Pasvik River System were mostly lower than 40 ppb and there were no differences between the Russian and Norwegian localities. Only a few samples were analyzed for lead (Pb) and concentrations of Pb were with few exceptions below the detection limit. Chrome (Cr) showed a similar pattern to Zn, although all values were low. Concentrations of arsenic (As) were highest in Lake Nikel 1, Lake Nikel 3, Sarasslaki and in Kuetsyarvi with a maximum of 2.39 ppb in Lake Nikel 1.

5.2 Phytoplankton

Phytoplankton biomass (wet weight m^{-3}) showed great variations between lakes and between dates while algae composition differed mainly between lakes (**Figure 4**). High biomass was recorded in Lake Kuetsyarvi, especially in September 1991 with more than 3000 mg ww. m^{-3}, but also other parts of the Pasvik River System and Lake Nikel 1 showed high biomass of phytoplankton.

The phytoplankton diversity was low in all of the Nikel lakes. Along with blue-green bacteria (Cyanophyceae), Chrysophyceae were the dominating algae in Lake Nikel 1 and small µ-algae in the two others. Blue-green bacteria were also common in Ruskvatn. Diatoms (Bacillariophyceae) were only obtained in the Pasvik River System where this group dominated the phytoplankton community in Lake Kuetsyarvi together with green algae (Chlorophyceae). Dinoflagellates (Dinophyceae) made up a significant part of the phytoplankton in Lyngbukta in August 1991, but were otherwise only seldom registered.

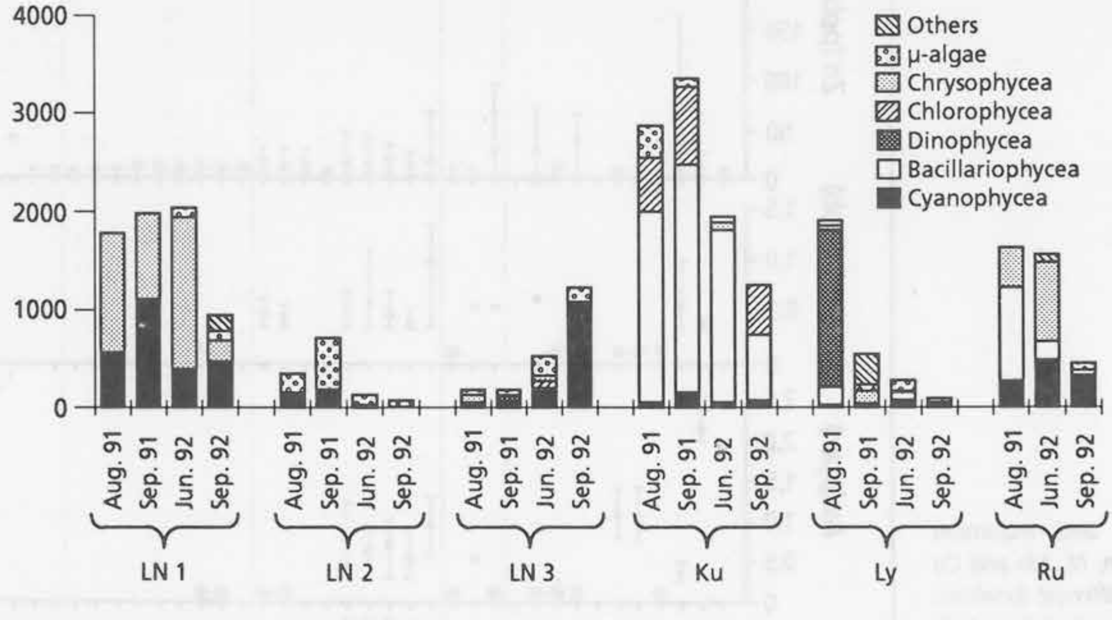

Figure 4
Biomass (mg wet weight m^{-3}) of phytoplankton in selected localities near Nikel (LN1-LN3), Lake Kuetsyarvi (Ku) an Pasvik River System (Ly, Ru).

5.3 Aquatic mosses

The river mosses *F. antipyretica* and *F. dalecarlica* were widely distributed in the border area between Norway and Russia except at higher altitudes in the Jarfjord Region. These mosses were found in a wide range of water habitats, and the typical sampling localities were brooks on bottom substrates between 15-50 cm stone size and stream surface velocity 0,2-0,5 m/s (Halleraker 1992).

The *Fontinalis spp*. were examined for the trace elements As, Cd, Cr, Cu, Hg, Ni, Pb, Se and Zn. Except for Cd and Pb all values were above the detection limit for the specific element.

Figures 5 and 6 show a wide range in the concentration (C) and accumulation factor $Cf=C/C_o$ of Ni, Cu, Cr and As in *Fontinalis spp.*. The lowest values were from the upper part of the Pasvik River system, and the concentration (C_o) in Ellenelva (Va-s) was used as the background level.

The Ni-content was highest on the Russian side. In the Pechenga area, the Ni concentration varied between 117 to 443 ppm (µg/g dry weight), and the maximum in *F. antipyretica* from the outlet of Salmiyarvi (Pasvik River system) was 907 ppm. On the Norwegian side, the Ni-content were between 8 (Ellenelva) to 373 ppm. The highest concentration on this side was from the localities nearest the border in the North-East direction from the Pechenga-nickel factories, and the Ni-concentrations decreased with distance from the factories.

Partly the same distribution was found in the As-content of *Fontinalis* spp. (**Figures 5, 6**). The As-concentrations varied; in Pechenga area 1.3 - 59.3 ppm, in the Pasvik River System 0.5 - 4.0 ppm and in the Jarfjord region 0.4 - 10.2 ppm.

Cr and Cu showed a different distribution in the Pechenga area than the previous metals (**Figure 5**). Certain localities showed very high contents in this area as well as the southern part of the Jarfjord region. For most of the other metals, Cd, Hg, Pb, Se and Zn, the accumulation factor (C_f) was lower than 6, except for a few localities.

Significant correlations were found between the concentrations of Ni in *F. antipyretica* and Cr, Zn, Pb and Cd but not for Cu. Skogheim (1993) also found no correlation between Ni and Cu in berries from the Norwegian side. The concentrations of Ni in the same moss species were also found to be significant correlated to the chemical parametre SO_4, Ca, pH, conductivity, alkalinity and Ni in the water (Halleraker 1992).

5.4 Zooplankton

A total of 10 species of Cladocera and 7 species of Copepoda were recorded in the investigated lakes (**Appendix 4**). *Bosmina longispina* and *Cyclops scutifer*, the most frequently occuring species, were recorded in all but 2 and 3 lakes, respectively. Other common species were *Holopedium gibberum*, *Heterocope appendiculata* and *Eudiaptomus graciloides*. The highest numbers of species were found in the Pasvik River system (**Figure 7**). However, great differences existed within the different regions. In the lakes near Nikel only one species, the copepod *E. graciloides*, was recorded in two of the lakes. Noteworthy is the lack of daphnids and diaptomids in some lakes in the Jarfjord Region. *Daphnia cristata*, *Bosmina longirostris* and *Eudiaptomus gracilis* were only recorded in the Pasvik River System and the Nikel Region.

Most of the rotatorian species were found in all regions, but the number of species and their relative importance differed within each region (Nøst et al. 1991). Usually *Polyarthra vulgaris* was the most common species, except in the Jarfjord Region where *Kellicottia longispina* predominated in all lakes, apart from F. Høgfjellsvatn.

Biomass calculations (dry weight m^{-2}) showed great variation within the different regions concerning individual lakes and between years (**Figure 8**). Exceptionally high biomass was recorded in Lake Kuetsyarvi in 1990. However, in 1991 and 1992 the biomass was reduced to ca. 500 mg m^{-2} similar to the general level recorded in most lakes. This was due to much lower numbers of B. longirostris and D. cristata in the last years. Despite that only one species was recorded in two lakes near Nikel (LN1 and LN3), the biomass was quite high especially in LN1 in 1992. Very low biomass was recorded in some lakes in the Jarfjord Region and at the Svanvik locality in the Pasvik River System.

5.5 Zoobenthos

In the Pechenga area several groups that are sensitive to pollution, were lacking or sparse, especially Ephemeroptera, Plecoptera, Hirudinae, Amphipoda and Mollusca. The zoobenthos of the lakes in this area were characterized by low species diversity and low densities. Chironomids, water bugs and water beetles dominated. The share of groups sensitive to pollution, was very low in streams and lakes surrounding Nikel and Zapolyarny (**Table 1**). However, relatively high abundances of the most tolerant groups Chironomidae, Trichoptera, Coleoptera

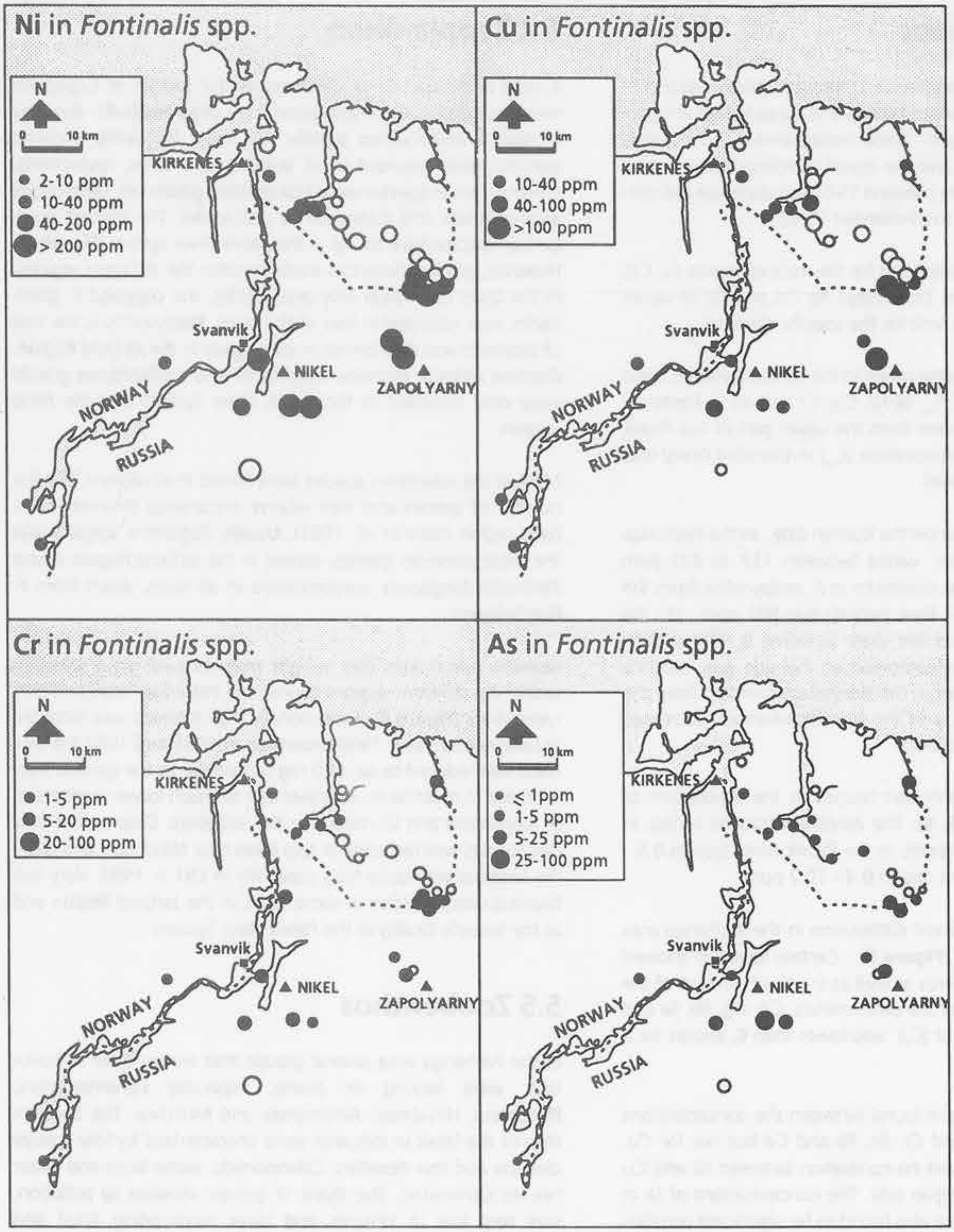

Figure 5
Concentration (g/g dry weight) of Ni, Cu, Cr and As in aquatic mosses from the investigated areas in 1991.

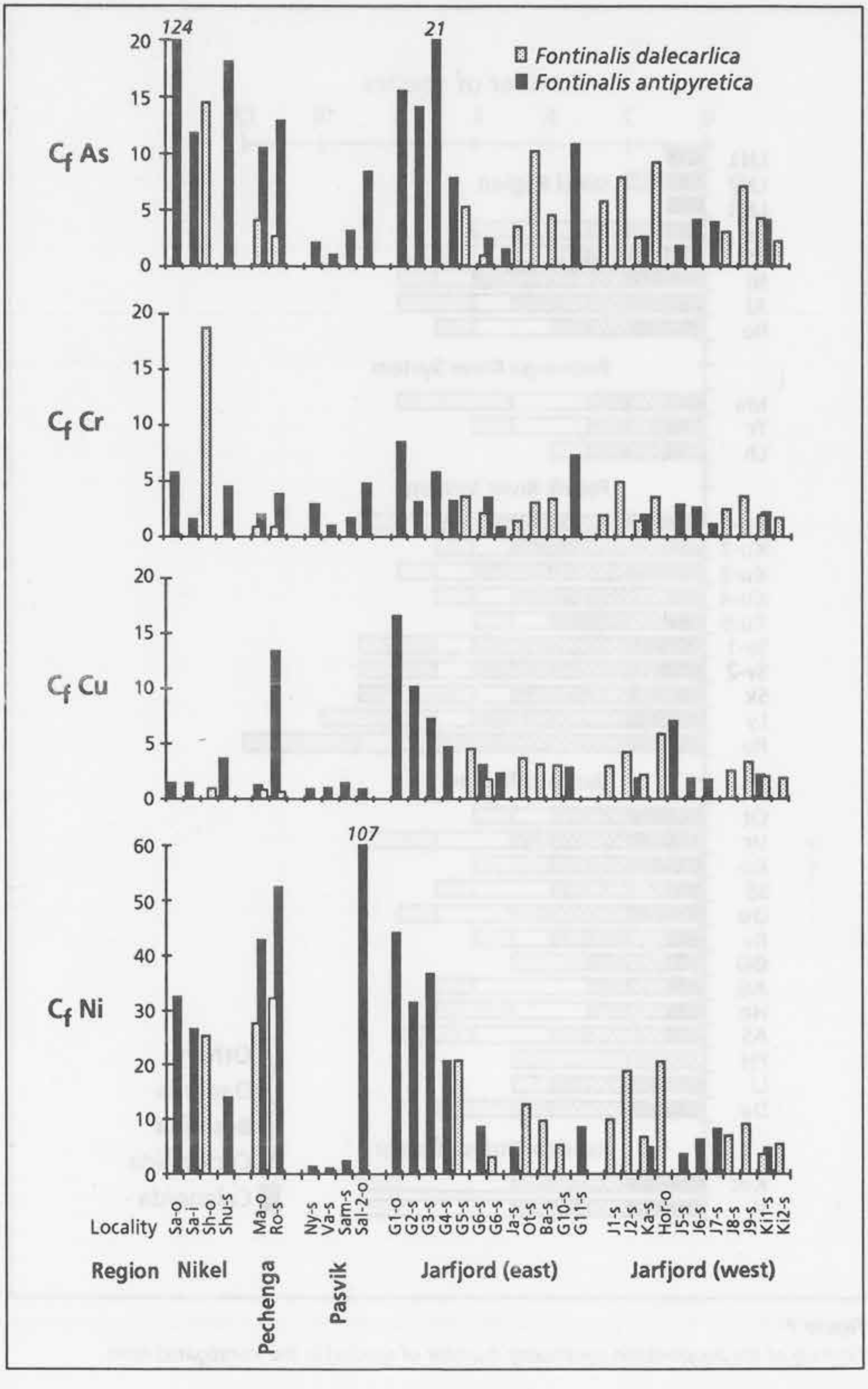

Figure 6
Accumulation factor (C_f) of As, Cr, Cu and Ni in aquatic mosses in the investigated areas in 1991.

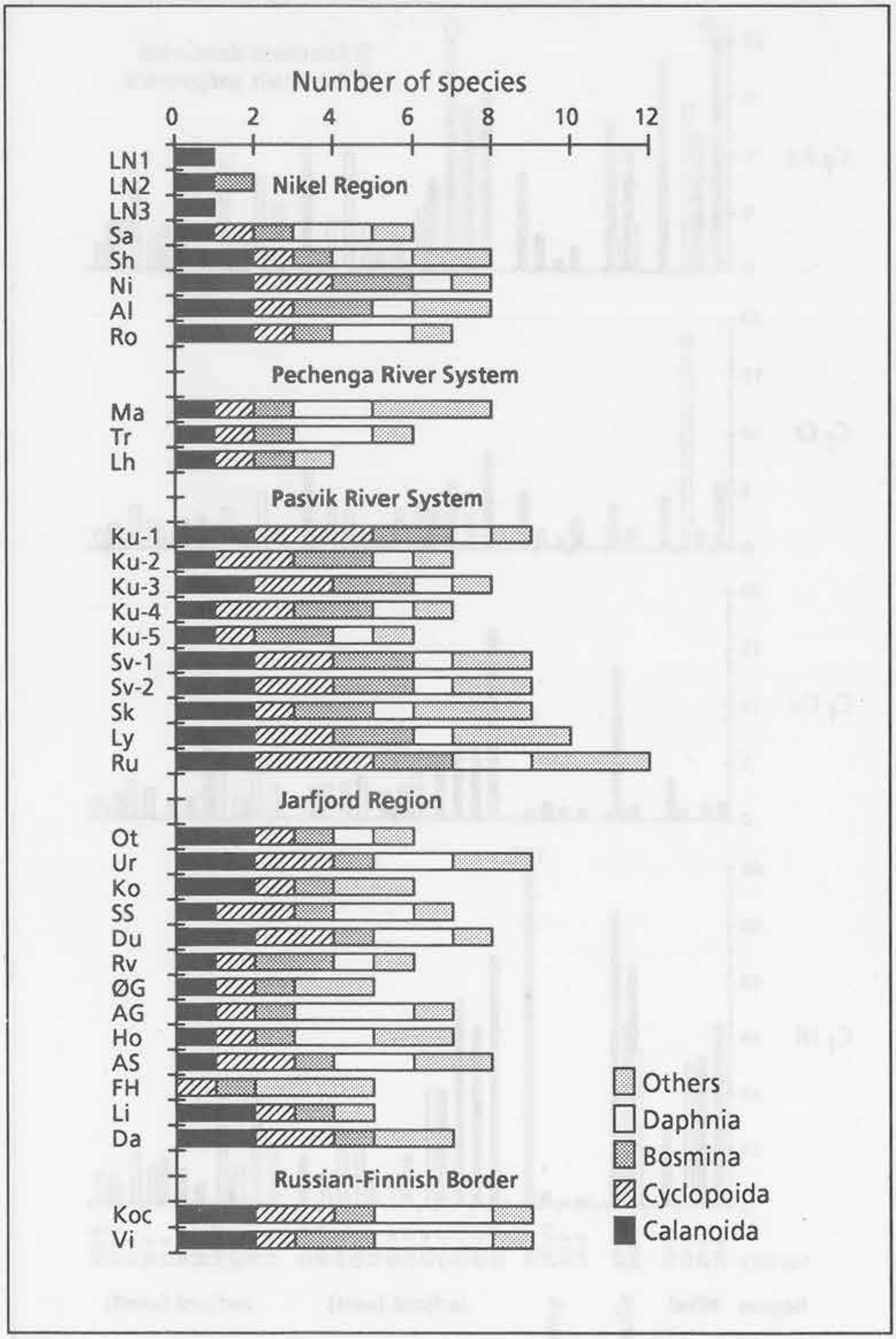

Figure 7
Diversity of the zooplankton community (number of species) in the investigated lakes.

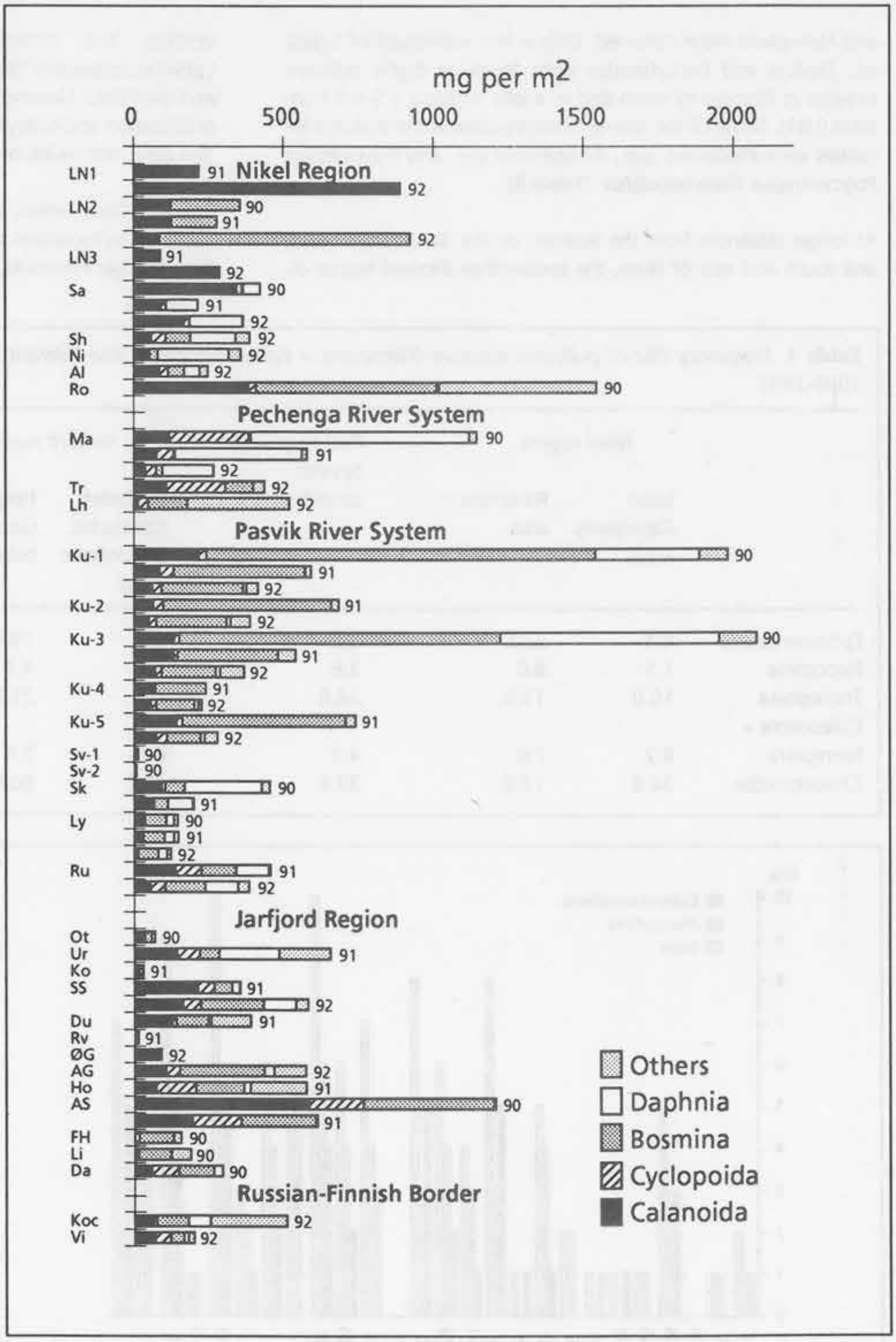

Figure 8
Biomass (mg dry weight m^{-2}) of zooplankton in the investigated lakes.

and Hemiptera were obtained. Only a few individuals of *Sigara* sp., Diptera and Enchytraedae were found in highly polluted streams in Zapolyarny town and in a lake situated 1.5 km from Nikel (LN1). Some of the tolerant species observed in polluted localities were *Procladius* spp., *Ablabesmya* spp. and the caddisfly *Polycentropus flavomaculatus* (**Table 2**).

At longer distances from the sources, on the Barents sea coast, and south and east of Nikel, the zoobenthos showed higher diversities and densities. Groups sensitive to pollution, Ephemeroptera and Plecoptera, showed slightly higher densities and diversities. However, the zoobenthos reflected the impact of acidification and heavy metal contamination, especially in mountain areas northwest of Liinakhmari settlement.

In the Jarfjord region, acidification effects on zoobenthos were observed in mountain areas (**Figure 9**). In a few small lakes on the Varanger Peninsula, the zoobenthos also showed indications

Table 1. *Frequency (%) of pullution sensitive (Plecoptera + Ephemeeroptera) and tolerant zoobenthos taxa in the study areas in 1990-1992.*

	Nikel region		Pechenga River System	Jarfjord region		Pasvik River System	
	Nikel Zapolyarny areas	Prirechnyi area	Liinakhmari	Urdfjellet Korpfjellet S.Skardvatn areas	Høgfjellsvatn Guokkolob-balatv areas	Svanvik Skrukke-bukta	Kuetsyarvi
Ephemeroptera	4.4	23.5	5.8	5.2	18.0	10.5	1.6
Plecoptera	1.5	8.0	3.6	3.8	4.2	1.0	0.6
Trichoptera	16.9	13.8	24.0	7.6	21.6	12.0	11.3
Coleoptera + Hemiptera	8.2	7.0	4.2	8.7	2.9	7.0	8.8
Chironomidae	34.8	13.8	33.6	40.2	50.6	36.2	58.4

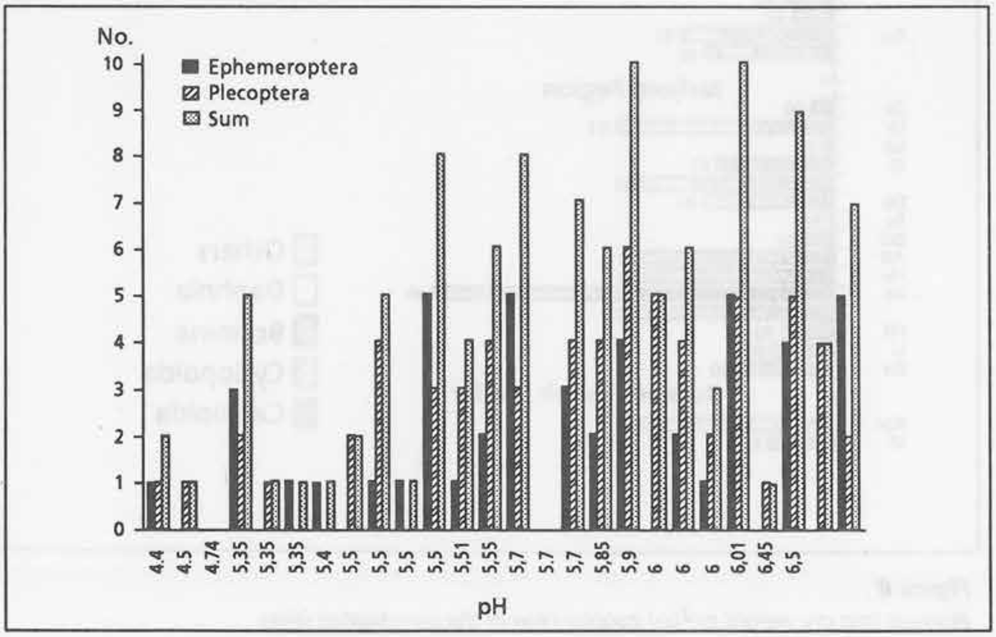

Figure 9
Number of species of Ephemeroptera and Plecoptera related to pH in lakes and rivers in the Jarfjord Region.

Table 2. *Frequency (%) and contribution in abundance (%) of the six most common species or taxas of zoobenthos in the shallow water (lakes littoral and streams) and deeper part of lakes (profundal).*

Species	Frequency (%)	Average share in number (%)
Jarfjord region		
	Shallow zones of water	
Arctopelopia spp	48.8	13.8
Psectrocladius (P.) sordidellus gr.	48.0	7.0
Paratanytarsus spp.	41.0	4.3
Enchytraeidae spp.	41.0	3.6
Polycentropus flavomaculatus Pict.	30.8	6.7
Plectronemia conspersa Curt.	30.8	3.1
	Profundal lake zones	
Procladius (Holotanypus)spp.	90.0	15.6
Pisidium spp.	80.0	6.9
Paratanytarsus spp.	60.0	7.6
Psectrocladius (P.) sordidellus gr.	60.0	5.1
Heterotrissocladius marcidus gr.	40.0	6.2
Heterotrissocladius suppilosus gr.	30.0	12.0
Pechenga area		
	Shallow zones of water	
Polycentropus flavomaculatus Pict.	25.9	7.0
Conchapelopia spp.	24.3	4.3
Lumbriculus variegatus	24.1	4.2
Ablabesmyia spp.	23.8	3.4
Cricotopus (Cricotopus) spp.	24.4	8.1
Micropsectra spp.	19.0	1.9
	Profundal lake zones	
Procladius (Holotanypus) spp.	57.6	22.5
Ablabesmyia spp.	39.4	6.1
Sergentia (Sergentia) coracina	24.2	3.1
Conchapelopia spp.	21.2	3.5
Psectrocladius (P.) sordidellus gr.	21.2	3.1
Parakiefferiella triquetra	18.2	4.0

of being affected by acidification. In most of the mountain lakes and streams in the Jarfjord region, low abundances were recorded (**Table 3**). Lowest densities and diversities were recorded in the smallest mountain lakes and streams with rare occurrences of Ephemeroptera and Plecoptera. Chironomids and caddisflies larvae predominated, mainly represented by *Arctopelopia* spp., *Procaldius* spp.,*Psectrocladius* spp., *Paratanytarsus* spp. and *Polycentropus flavomaculatus* and *Plectrocnemia conspersa* (**Table 1,2**). The acid sensitive crustacean *Gammarus lacustris* was found in low numbers in two localities, Andre Skardvatn and Urdfjellsvatn.

Extremely high densities and biomass of zoobenthos, especially chironomids, were recorded in Lake Kuetsyarvi (**Table 3**). In the profundal zone, chironomids made up 60-80 % of zoobenthos number and biomass. High accumulation of heavy metals in bottom animals was recorded in Lake Kuetsyarvi and in Lake LN1.

High diversity and abundance of zoobenthos were observed in the upper part of the Pasvik River System, in Ruskvatn and Lyngbukta (**Table 3**). Chironomidae, Mollusca and Oligochaetae occurred in high densities. In the lower part of the river, the diversity and density were lower.

Table 3. *Mean abundance =N (ind m $^{-2)}$ and biomass =B (g fresh weight m $^{-2)}$ of zoobenthos in the different regions in 1990-1992 using Ekman grab. Calculated as mean for all lakes sampled in the certain regions.*

Taxa	Pechenga Area		Jarfjord Region		Lake Kuetsyarvi		Pasvik River System Lyngbukta and Ruskvatn		Svanvik	
	N	B	N	B	N	B	N	B	N	B
Oligochaeta	17.6	0.14	4.7	0.01	802.0	0.77	199.0	0.14	325.5	0.61
Mollusca	9.9	0.02	38.3	0.10	56.4	0.36	431.5	1.80	75.8	0.13
Trichoptera	3.9	0.04	0	0	16.4	0.51	15.4	0.10	14.5	0.02
Chironomidae	360.1	0.41	638.0	0.91	1306.1	7.06	1250.9	3.0	793.3	0.86
Other groups	20.8	0.11	27.5	0.19	30.8	0.25	83.2	1.28	110.5	0.05
Total	412.3	0.72	708.5	1.21	2211.7	8.95	1980.0	6.32	1319.6	1.67

5.6 Fish

5.6.1 Fish communities

A higher number of fish species was recorded in the Pasvik River System than in other regions (**Appendix 5**). However, only 8 species of a total of 12 earlier reported from the Pasvik River System, were recorded in Lake Kuetsyarvi (Kristoffersen & Sterud 1985). The most frequently occurring species was brown trout (*Salmo trutta*). No fish species were recorded in the three lakes located near Nikel. The lakes in the Jarfjord Region were inhabited by brown trout, Arctic char (*Salvelinus alpinus)*and three-spined stickleback (*Gasteresteus aculeatus*); most frequently by brown trout. Population structure of perch (Perea fluviatilis) and pike (Esox lucius) was presented by Nøst et al. (1991).

Population structures (age and length) and catches of brown trout and Arctic char in lakes and streams are presented in the **figures 10-13**. The population structure (age and length distribution) and catches of trout varied greatly between lakes from very few older fish e.g. F. Høgfjellsvatn to a more normal expected population state e.g. in F. Skardvatn.

In Kuetsyarvi the catches were dominated by whitefish (*Coregonus lavaretus*). The catch per unit effort (CPUE) and echosounder recordings indicated a very dense population of whitefish in this lake. The results indicated that the whitefish may exhibit ecological polymorphism as two forms could be distinguised; one slowgrowing with early maturation with many gill rackers feeding on zooplankton, and a fast growing form maturing at an higher age with few gill rackers feeding on benthic invertebrates. The growth rate of perch from different lakes was similar and did not differ significantly between populations. In general, all populations of whitefish, perch and pike consisted of young individuals up to an age of 5 years, indicating high mortality after attained maturity. The fish community in Lake Kuetsyarvi has been more thoroghly considered by Amundsen & Stallvik (1993).

The diet of brown trout and Arctic char was in general dominated by terrestrial insects probably caught at the lake surface and larvae of aquatic living insects (**Table 4**). *Eurycercus lamellatus* and *Gammarus lacustris* were of substantial importance for the same fish species in some lakes in the Jarfjord Region. Zooplankton was of great importance for Arctic char in 5 lakes in the Jarfjord Region. Piscivorous brown trout and Arctic char were recorded in all regions totally in 7 lakes. Prey fish species recorded were three-spined stickleback.

The main food items of perch were fish (minnows, *Phoxinus Phoxinus*), daphnids and *E. lamellatus*. Gastropoda and *E. lamellatus* were the main prey for whitefish in Lake Kuetsyarvi.

5.6.2 Heavy metal accumulation

Heavy metal accumulation in fish have been investigated for the elements nickel, copper, manganese and zinc. Detailed describtions of the heavy metal content of fish in the Pasvik River System including Lake Kuetsyarvi, are given in Nøst et al. (1991) and Amundsen & Stallvik (1993). The levels and distribution varied between organs, species and lakes (**Figure 14,15**). Accumulation in muscles was in general considerably lower than that found in other organs and tissues. Nickel was mainly accu-

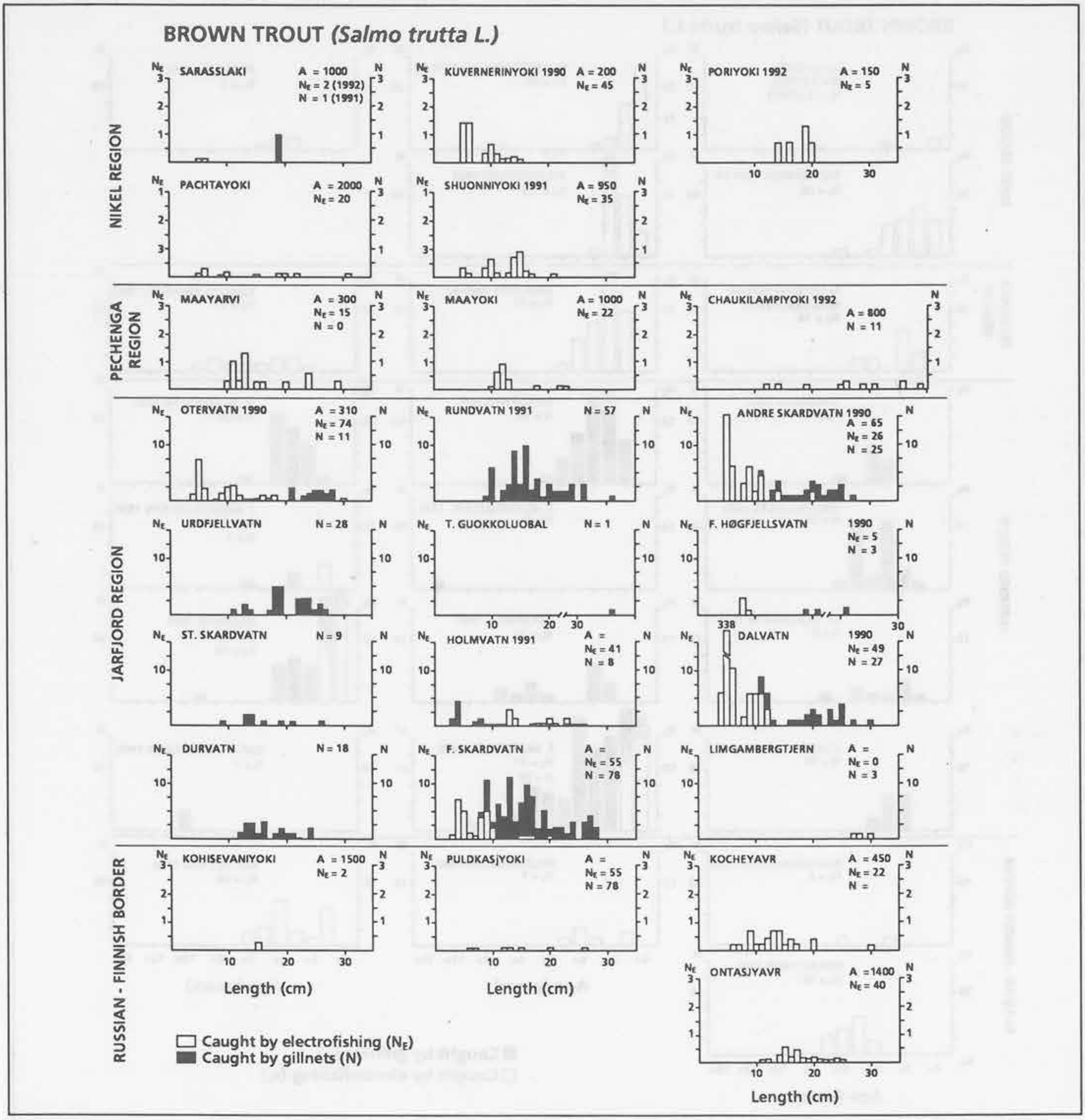

Figure 10

Length distribution (%) of brown trout (Salmo trutta L.) in streams and lakes caught by electrofishing and gillnets in the different localities. A= area sampled, N= number caught by gillnets, N_E= number caught by electrofishing.

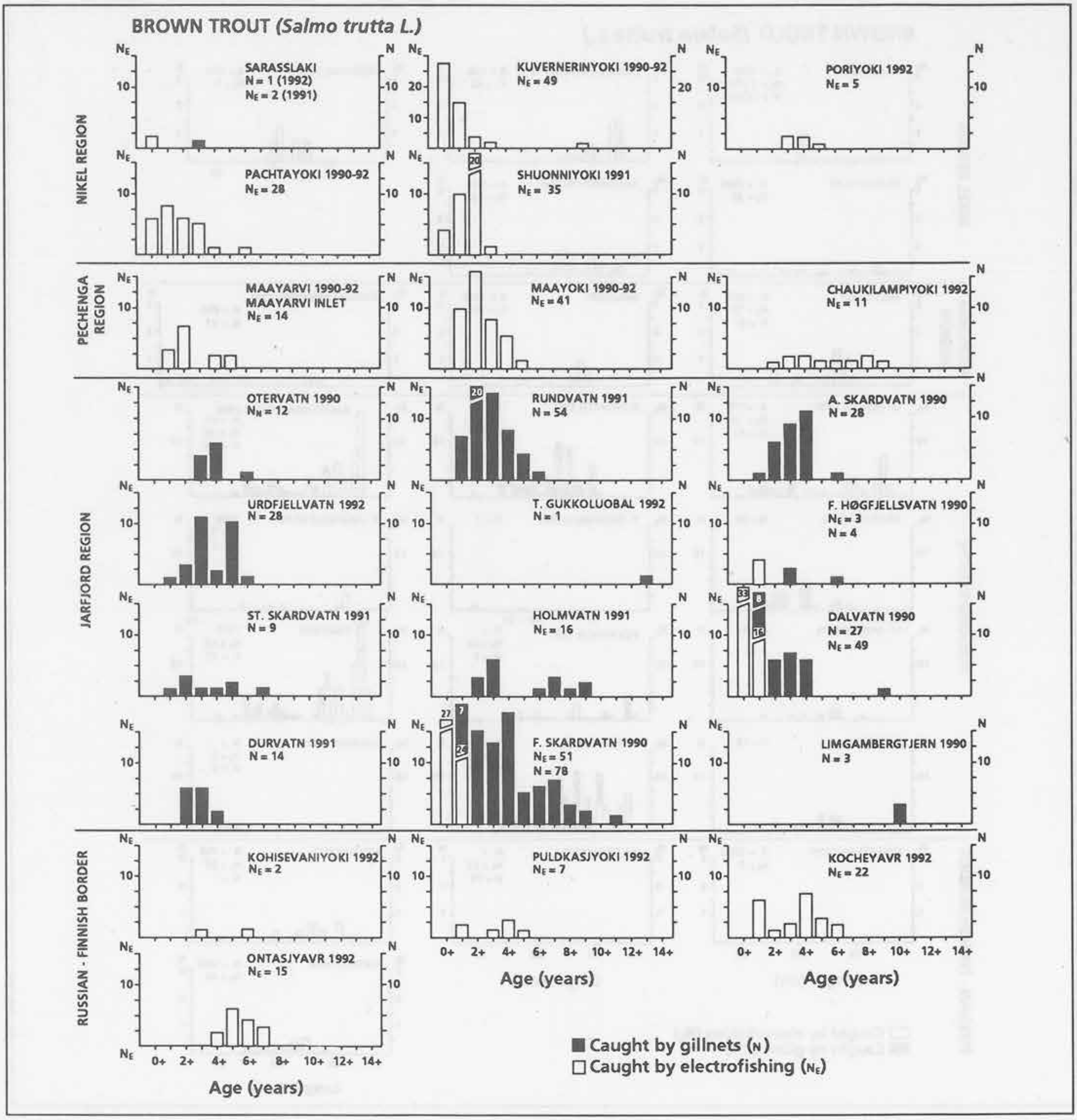

Figure 11
Age distribution (%) of brown trout (Salmo trutta L.) in streams and lakes caught by electrofishing and gillnets in the different localities. Symbols as in figure 10.

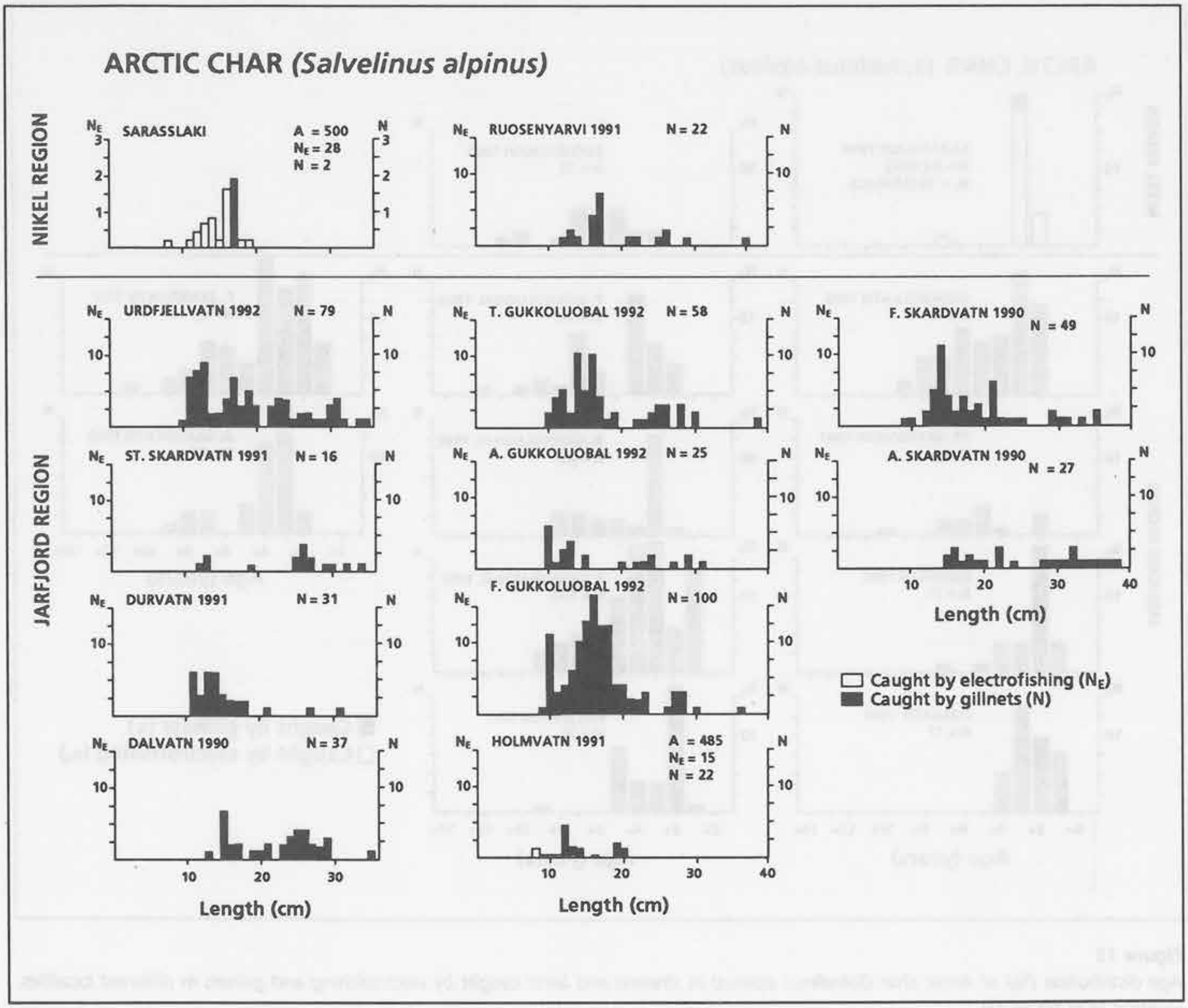

Figure 12
Length distribution (%) of Arctic char (Salvelinus alpinus) in streams and lakes caught by electrofishing and gillnets in different localities. Symbols as in figure 10.

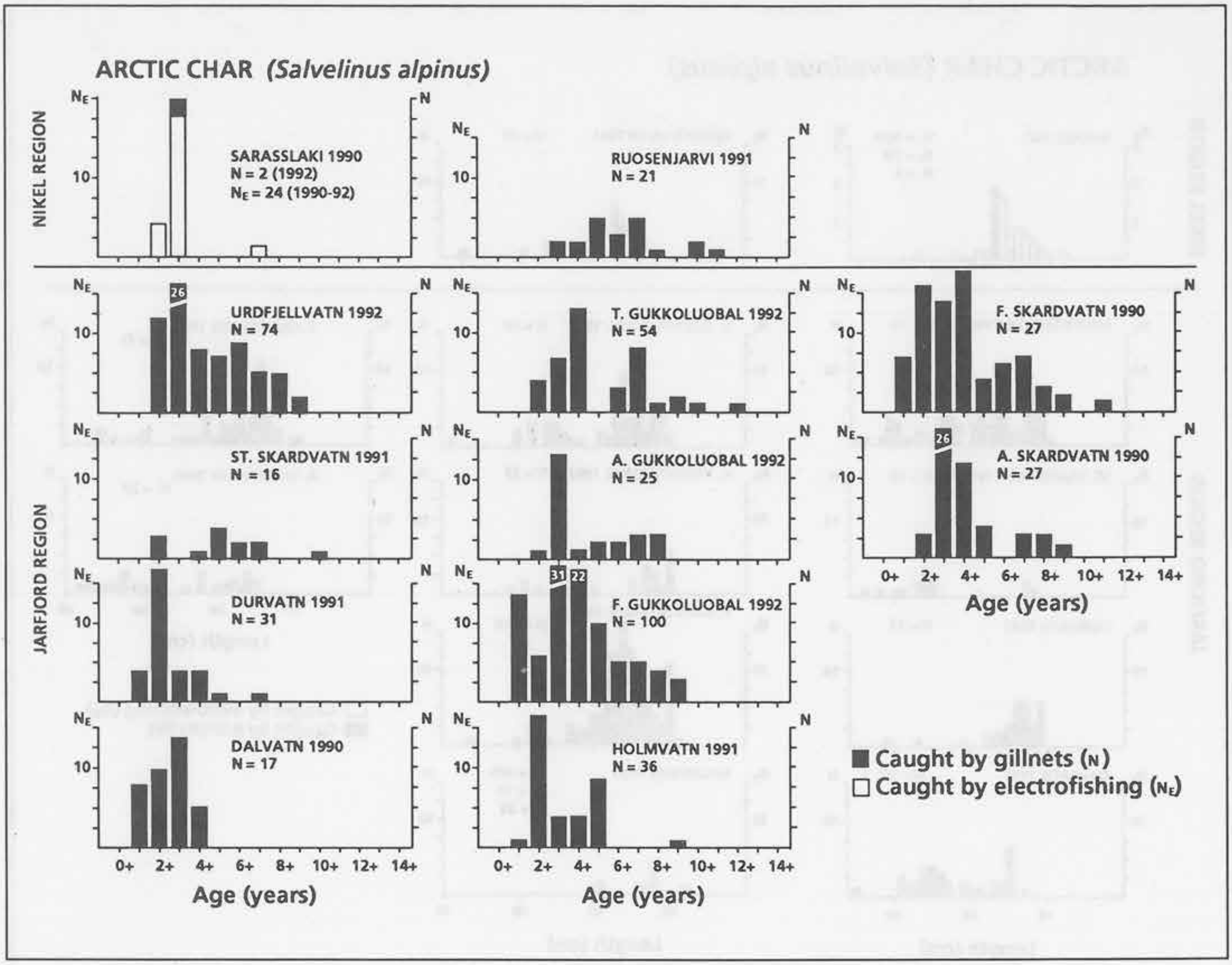

Figure 13

Age distribution (%) of Arctic char (Salvelinus alpinus) in streams and lakes caught by electrofishing and gillnets in different localities. Symbols as in figure 10.

***Table 4.** Food items (volume %) in stomachs of Arctic char (A), brown trout (B), perch (P) and whitefish (W) in lakes and streams in August/September 1990-1992.*

Region	Loc.	Year	Species	Number of stomachs	Terrestrial insects	Aquatic insects	Gastropoda/ Mollusca	Eurycercus	Gammarus	Zooplankton	Fish
Nikel Region											
	Sa	91	A	3	16,7	83,3	0	0	0	0	0
	Sai	90	A	11	62,7	37,3	0	0	0	0	0
	Shu	91	B	18	28,4	68,3	3,3	0	0	0	0
	Kuv	90	B	24	17,8	82,2	0	0	0	0	0
	Ro	91	A	10	10	0	10	10	0	20	50
Pechenga River System											
	Ma	90	P	12	0	8,3	0	0	0	71	20,4
	Mai	90	B	6	26,5	49,3	7,5	0	0	0	16,7
Pasvik River System											
	Ku-1	90	W	10	11,3	10,9	33,7	31,3	0	12,8	0
	Ku-2	90	P	3	0	0	0	0	0	0	100
	Ku-1	90	B	1	0	0	0	0	0	0	100
	Ku-3	90	W	25	14,3	2,9	37,5	36	0	9,3	0
	Ku-3	90	P	21	1,7	0,8	0	22,6	0	22,4	52,5
Jarfjord Region											
	Ot	90	B	5	31,6	27	21,4	0	0	0	20
	SS	91	A	11	0	2,7	24,9	6,4	0	66	0
	SS	91	B	9	11,1	83,9	2,2	0	2,8	0	0
	Du	91	A	20	3,2	21,2	3,5	29,5	0	37,4	5,2
	Du	91	B	15	30,2	65,3	4,5	0	0	0	0
	Rv	91	B	20	36,5	18	33,3	0	0	0	12,2
	FG	92	A	20	21	0,7	10	14	0	54,3	0
	Ho	91	A	20	7,5	23,4	6,3	34,3	0	28,5	0
	Ho	91	B	6	16,7	78,3	5	0	0	0	0
	AS	90	A	20	52,1	5,8	0	18,3	15,6	0	0
	AS	90	B	8	33,9	28,8	0	16,5	24,8	0	0
	FH	90	B	3	76,7	23,3	0	0	0	0	0
	Li	90	B	2	99,9	0,1	0	0	0	0	0
	Da	90	A	4	48	17,7	0	0	0	34,3	0
Russian -Finnish Border											
	Koc	92	P	9	3,3	10	0	0	0	0	86,7
	Koc	92	W	16	0	99,1	0,9	0	0	0	0
	Vi	92	W	17	0	11,8	17,7	20,9	6,1	43,5	0
	On	92	B	10	69	31	0	0	0	0	0

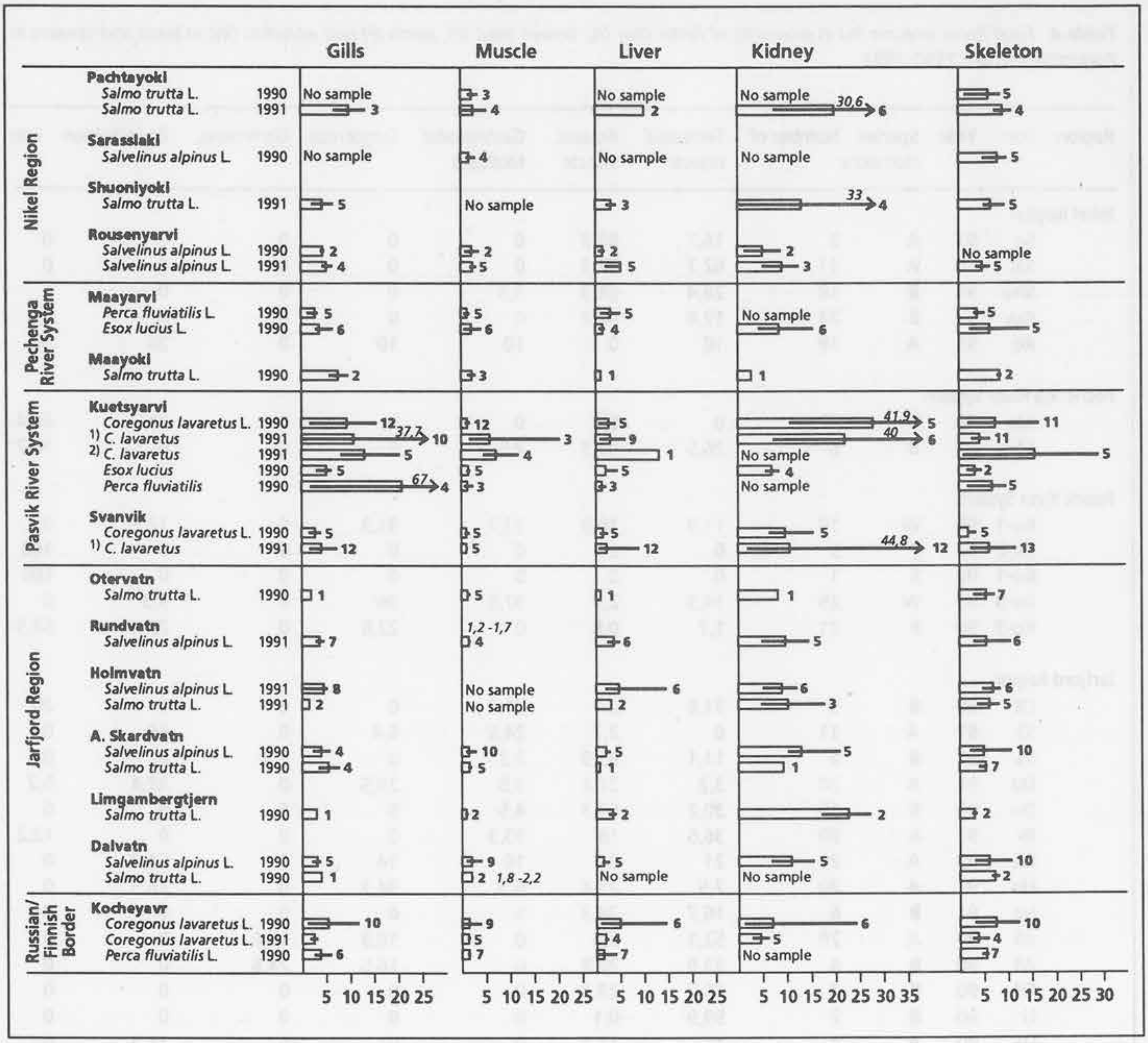

Figure 14

Concentration of nickel (g Ni g dry weight^{-1}) in organs and tissues of fish.

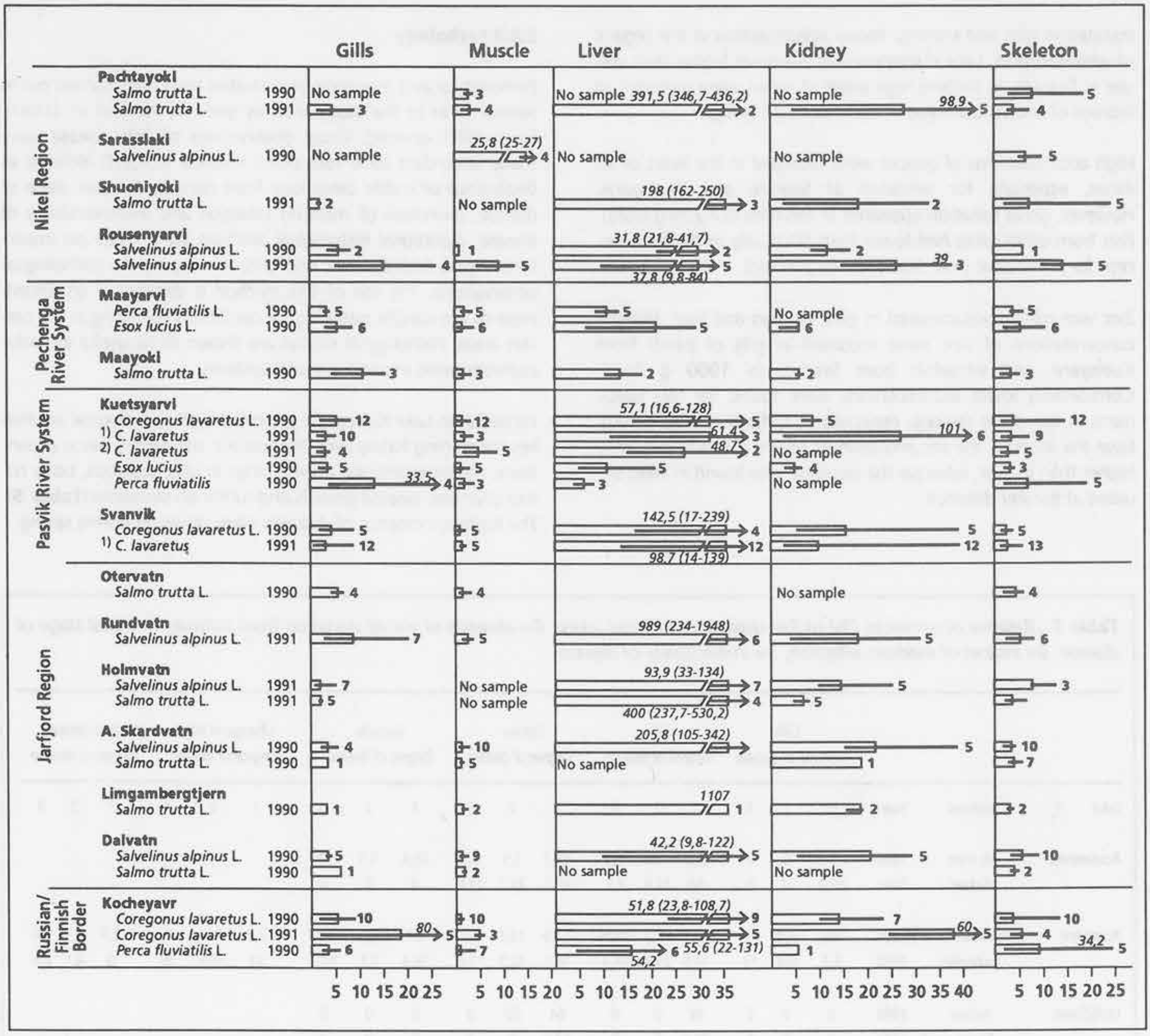

Figure 15

Concentration of copper (g Cu g dry weight^{-1}) in organs and tissues of fish.

mulated in gills and kidneys. Nickel accumulation in the organs of whitefish from Lake Kuetsyarvi was 2-3 times higher than values at Svanvik. In Jarfjord high levels of nickel were recorded in kidneys of brown trout and Arctic char (8-22 gNi/g).

High accumulations of copper were recorded in the livers of all fishes, especially for whitefish at Svanvik and Kuetsyarvi. However, great variation appeared in this area (17-239 g Cu/g). Fish from other lakes had lower than 50 gCu/g in the liver, except for Arctic char in A. Skardvatn (> 200 g/g).

Zinc was mainly accumulated in gills, kidneys and liver. Highest concentrations of zinc were recorded in gills of perch from Kuetsyarvi and whitefish from Svanvik (> 1000 g Zn/g). Considerably lower accumulations were found for fish specimens in the other regions, especially in Jarfjord (< 250 gZn/g). Near the sources, the accumulation of zinc in gills was generally higher than in liver, whereas the opposite was found in lakes situated at greater distance.

5.6.3 Pathology

Pathological and morphological studies have been carried out in several lakes in the study area as given by Nøst et al. (1991). From 1991 onward, visual observations of fish disease were made according to a four-point method (0,1,2,3) defined as 0=absence of visible deviations from normal, 1=initial stage of disease, 2=indices of medium infection and 3=irreversibility of disease. Additional histological analyses were made on important organs (kidney, liver and gills) to support the pathological observations. The use of this method is dependent on knowledge of the specific pathological conditions prevailing in the certain areas. Pathological studies are shown to be useful to reveal anthropogenic impacts in water systems.

Whitefish in Lake Kuetsyarvi exhibited high pathological anomalies concerning flabby liver, liver colour, connective tissue expansions, nephrocaleitoses, anemic rings in gills, scoleosis, body colour changes, twisted gonads and tumor on stomachs (**Table 5**). The highest incidence of diseases were observed during spring.

Table 5. *Relative occurrences (%) of fish disease in selected lakes. 0= absence of visible deviation from normal, 1= initial stage of disease, 2= indices of medium affection, 3= irreversibility of disease.*

			Gills Degree of disease			Liver Degree of disease			Kidney Degree of disease			Gonads Degree of disease			Change of color Degree of disease			Nephrocalcitosis Degree of disease		
Lake	Species	Year	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Rousenyarvi	A. charr	1990	0	0	0	9,8	7,8	7,8	15,7	5,9	1,9	21,6	5,9	0						
	A.charr	1991	68,2	0	0	50	31,8	4,5	45,5	22,7	13,6	0	0	0						
Kuetsyarvi	whitefish	1991	8,5	2,8	1,2	32,8	23,2	25,9	12,9	10,2	2,8	6,7	5,6	0,6	2,8	0,6	0	2,3	1,1	0,6
	whitefish	1992	5,7	0,8	13	11,5	23,8	34,4	18,1	10,7	15,6	16,4	4,1	12,3	23	36,9	59	0	4,1	6,6
Urdfjellvatn	A.charr	1992	0	0	0	92	0	0	64	32	0	0	0	0						
	brown trout	1992	0	0	0	84,6	0	0	84,6	0	0	0	0	0						
St. Skardvatn	A.charr	1992	42,9	0	0	71,4	3,6	0	21,4	75	0	3,6	0	0						
T. Guokkolobbalat	A.charr	1992	0	0	0	66,7	3,3	0	76,7	18,3	1,7	1,7	0	0						
A. Guokkolobbalat	A.charr	1992	0	0	0	87,5	12,5	0	95,8	4,2	0	4,2	0	0						
F. Guokkolobbalat	A.charr	1992	47,8	0	0	73,9	21,7	0	100	0	0	8,7	0	0						

Indications of disease were also observed in pike from Lake Kutsyarvi and Lake Maayarvi. Anomalies like blue and greenish colour of fins, blueish and greenish colour of the back skin and blue and green colour of the muscles, were observed in a large number of pike.

No observations of disease in brown trout were found in Dalvatn and Otervatn in the Jarfjord Region. However, some indications of disease (pale colour of liver, connective tissue expansions of kidney, anemic rings on gills) were observed in trout from Urdfjellvatn and Rousenyarvi.

Arctic char from the lakes Dalvatn, Sarasslaki and A. Skardvatn, showed no visual indications of pathological anomalies. Observations of abnormal gills, liver and kidney, on the other hand, were observed on Arctic char from Rousenyarvi, Urdfjellvatn, F.,T. and A. Guokkolobbalat and Store Skardvatn.

In perch from Lake Kuetsyarvi and Lake Kocheyarv indications of disease were only observed in kidneys and gonads.

The pathological indications of disease could be verified by histological analyses of gills, liver and kidney. Fish from polluted areas had discomplexity of gill lamelles (slits), swollen respiratory epitelium, defect liver structure (hepatocytes fat dystrophy) and cytomorphological changes of kidney.

6 Discussion

Our study in 1990-1992 showed that the composition of freshwater communities mainly consisted of widely distributed species within the Palearctic region (Lakes..1974, Biological prod..1975 and Illies 1978). The most severe anthropogenic impact upon freshwater communities was recorded in Russian localities near the smelters in Nikel and Zapolyarny, probably related to heavy metal contamination. The low diversity recorded was mainly caused by lack of several pollution sensitive taxas, especially Mayflies (Ephemeroptera), Stoneflies (Plecoptera), Cladocera and salmonids. This is supported by the state of freshwater communities observed in the highly heavy metal polluted Lake Imandra on the Kola Peninsula (Moiseenko & Yakovlev 1990).

Near the Pechenga nickel factories and settlements, surface waters are polluted by sewage, containing substantial amounts of heavy metals, sulphates, chlorides, oil products, mineral suspended particles and other matters. Heavy metals and sulphates are assumed to have the most detrimental influence on freshwater communities (Drabløs & Tollan 1980, Sandøy & Nilssen 1987, Morling & Pejler 1990 and Muniz & Aagaard 1990). However, acid-sensitive species like daphnids (Davis & Ozburn 1969, Almer et al. 1974), molluscs (Økland, J. 1990) stoneflies and mayflies (Raddum 1980) and salmonids were recorded in the Pechenga area. This fact is due to the specific bedrock, composed of crystalline rocks of basic and ultrabasic composition making the buffer capacity very high near the factories (Traaen et al.1991). Alkalic dusts and other pollutants from fallout increase the water mineralization and acid neutralization capacity, (ANC of surface waters > 200 eq l^{-1}) (Traaen et al. 1991). At larger distances (20-30 km) from the factories ANC is reduced to a critical level, < 20 eq l^{-1}.

The concentrations of nickel and copper in water in the Russian areas were generally above limits assumed to cause severe effects on freshwater organisms (Lithner 1989, SFT 1989, Year book.. 1990). Extremely high contents of nickel were recorded in River Kolosyoki (> 300 µg Ni/l) and in the Nikel lakes LN1 - LN3 (> 100 µg Ni/l). The same pattern could be seen by Ni-contents > 200 ppm in the aquatic mosses from the localities at the Russian side also recorded by Lithner (1989). The highest Ni-concentrations in mosses were found near and in the northeast direction of the factories. Concerning Cu in *Fontinalis spp.* this pattern was less pronounced. Part of this low accumulation seems to be related to the generally high alkalinity on the Russian side (Livonen et al. 1992, Say & Whitton 1983). This could also affect the Cr- and Zn-content. Studies in Finnish headwater lakes showed that bioaccumulation of several trace metals in plants, insects and fish increased with increasing acidity and decreasing ANC in water, aquatic plants being the best indicator (Livonen et al. 1992).

In general the concentrations and the narrow range of Cd, Hg, Pb, Se and Zn in river mosses were low and similar to other surveys (Lithner 1989). The concentrations of Ni in mosses were significantly correlated to several chemical parametres in the water. A decrease in the Ni-content in river mosses was recorded with increased distance from the pollution sources. The calculated pollution index or accumulation factor (C_f) was also high for As, Cr and Cu in several samples, indicating a pollution state as considered by similar investigations (Klein et al.1991, Goncalves et al. 1992,). Our investigation showed much higher contents of Ni in tips of aquatic mosses than in the fish tissues from the same regions. Whole moss samples would probably have shown higher levels of bioaccumulation (Dallinger & Kautzky 1985). The easily detectable metal content in aquatic mosses in addition to time-integrated picture of the metal condition in a locality, in contrast to the static state of water samples, makes *Fontinalis spp*. to a useful pollution indicator for trace metals (Klein et al. 1991, Say & Whitton 1983). The concentration of heavy metals in river mosses is considered a useful indicator of pollution in the investigated area, especially in localities of pH>6 and low humic content (TOC) in the water (Halleraker 1992).

The phytoplankton communities in Nikel lakes showed low diversity; diatoms, dinoflagellates and green algae were entirely missing in LN1 and LN2. High biomass of phytoplankton in Kuetsyarvi compared to the Norwegian localities in the Pasvik River System are in accordance with higher concentrations of NO_x and PO_4 on the Russian side.

Low diversities of zooplankton were found in the lakes LN1 - LN3 which are located within the most pronounced wind-direction, at a distance of 1.5 - 12 km from Nikel. Low diversities of zoobenthos and high abundances of chironomids were obtained in the most polluted localities: Kolosyoki, Semiaki, Chaukilampiyoki and in LN1. However, the composition of zoobenthos on the Russian side was highly variable.

The benthic invertebrates showed high sensitivity to water pollution by metals and acidification. The tolerant Chironomidae larvae were the most abundant group in the polluted waters within the Pechenga area. Acidification and pollution seem to have altered the composition and structure of the benthos fauna in the investigated area. Expected natural fauna were recorded in localities east and south of Nikel and in forest areas in the Jarfjord region. North-west of the Pechenga River estuary, the bottom fauna is affected by acidification and heavy metals. The zoobenthos diversity and relative share of different sensitive groups to pollution, were lower than recorded by Järnfeldt in 1929 in Pechenga (Petsamo) area (Järnfeldt 1934). The high abundances of zoobenthos recorded in the upper part of Pasvik River System are probably caused by organic matter from submerged vegetation and allochthoneous material from the surroundings as well as suitable habitats in shallow creeks.

Negative impacts upon the population structure of fish were recorded in all studied localities in Russian areas, especially in the lakes Kuetsyarvi, Rousenyarvi, Sarasslaki and Maayarvi. No fish species were recorded in the three small lakes located near Nikel probably due to contamination effects. In the other lakes in the Pechenga area electrofishing revealed the presence of mainly young brown trout in inlet and outlet streams (**Figure 10**). However, no catch of brown trout in the lakes, indicated low survival characterized as juvenilization. In localities near the factories, several taxa of e.g. salmonids, gastropoda and daphnids were still present. Likewise, in Lake Kuetsyarvi high densities and biomass of zooplankton appeared. In 1990 the abundance of zooplankton in Lake Kuetsyarvi was at least 4-6 times higher than in the Norwegian localities in the Pasvik River System. Effluents of nutrients (i.e. NOx and PO_4) into Lake Kuetsyarvi are assumed to enhance the phytoplankton food base for zooplankton. The very high abundances of zoobenthos, especially chironomids also indicated eutrophication in Lake Kuetsyarvi.

In the Pechenga area bioaccumulation of the heavy metals, Ni, Cu and Zn, was documented in fish organs, especially in liver, kidney, gills and skeleton. The concentrations in muscles were in general considerably lower than in other organs and tissues.

High concentrations of heavy metals were also found in chironomids and caddisflies larvae from Lake Kuetsyarvi and a small nearby lake. However, in these localities heavy metal contamination is assumed to have sublethal effects. Abnormal structure and symptoms of diseases in the whitefish and pike populations and juvenilization in brown trout populations of the stream Pachtayoki and Lake Sarasslaki within the Nikel Region, supported this assumption.

Several factors influence the concentrations of heavy metals in organs and tissues of fish, such as the levels and distribution of pollutants in water bodies, physiological characteristics of fish and biochemical properties of metals. The accumulation of heavy metals thus is determined by a balance between the intake rate through the gills and the food, and the capability of the fish to release an excess of elements not necessary for the maintenance of basic metabolism. Concentrations of metals in fish organs, especially in soft tissues were inconsistent. The most stable levels were in skeletons reflecting the total load of the whole lifespan, whereas the more variable levels in the soft tissues reflect the seasonal fluctuation of hydrochemical conditions and diet. In some localities high concentrations of other chemical elements may have a reducing effect upon heavy metal contamination in organisms. As stated by Alabaster & Lloyd (1982), the lethal and sublethal effects of heavy metal contamination in freshwater organisms may decrease with increasing concentrations of calcium. In the Russian area high levels of nickel and copper correspond with high values of calcium. However, the lethal and sublethal effects observed upon freshwater organisms did not decrease toward the highest calcium concentrations.

Indications of acidification effects upon freshwater communities similar to other affected areas (Acidic Deposition 1990) were only recorded within the Jarfjord Region. Geological differences within this region are reflected in differences regarding water quality and freshwater communities. Impact due to acidification was recorded in gneissic/granitic areas with low buffering capacity (Alkalinity ≈ 0), including Limgambergtjern, F. and A. Høgfjellsvatn as well as Dalvatn. Several acid-sensitive taxa of zoobenthos were absent or recorded in very low numbers, also stated by Bækken & Aanes (1990). A similar state was also found for daphnids. Skogheim (1993) recorded higher concentrations of Ni and Co in samples of cloudberry and bilberry from the Jarfjord Region compared with the reference localities. Despite great efforts of electrofishing in inlet and outlet streams and fishing in the lakes, only a few older trout were caught in five lakes at high elevations (Limgambergtjern, F. Høgfjellsvatn and 1-3 Guokkolobbalat). The absence of young fish indicated irregular yearly recruitment (senescence) probably due to acicification effects. This corresponds with analyses of pH of minimums 4.55-5.08 which are below critical limits for recruitment for brown trout. Senescence in the brown trout populations in Limgambergtjern and F. Høgfjellsvatn are considered as adverse effects of acidification (Bravington et al. 1990). The presence of the acid sensitive crustacean *Gammarus lacustris* in stomachs of brown trout and Arctic char and daphnids in lakes at lower elevation, indicated that acidification impacts are locally restricted to higher elevations in gneissic/granitic areas with low buffering capacity. Lack of young fish in St. Skardvatn may be due to restricted spawning areas or heavy metal impact (**Figure 10**). The population structure of brown trout and Arctic char in Dalvatn are considered as normal (**Figure 10**).

In order to evaluate the environmental impact of pollutants, it is also necessary to consider biotic interactions within freshwater communities. Previously it has been shown that the fish community is capable to structure the zooplankton community by selective predation (Nilsson & Pejler 1973). Distributions of small cladoceran species like *D.cristata* and *B. longirostris* and the copepod *E. gracilis*, were assosiated with coregonids (whitefish and cisco). Diversity of species and number of trophic levels differed between the regions and the complexity seemed more pronounced in the Pasvik River System. The variability in abundance and species dominance of zooplankton between years in Lake Kuetsyarvi may be due to both changes in fish predation pressure and nutrient conditions. The drastic decline of daphnids from 1990 to 1992 indicate changes in predation pressure from fish. The fish studies showed that the density of plantivorous fish was exteremely high in Kuetsyarvi (Amundsen & Stallvik 1993). No such changes of cladocerans were recorded in the reference localities Lyngbukta and Ruskvatn in the Pasvik River System. However, in these localities bluegreen algae were observed supposedly due to indirecte effects of high fish density. The special occurrence of *Anabena spp.* in Ruskvatn may be caused by temporary nitrogen limitation (Løvstad pers. med.). Also in these localities a high density of planktivorous fish was recorded including the first record of cisco (*Coregonus albula*) in Sør-Varanger (Amundsen & Stallvik 1993). Lower fish diversity and large individual size of daphnids in lakes in the Pechenga area, indicated very low predation pressure.

Conclusion:

Heavy metal impacts

- Negative impacts upon population structure of fish were recorded in all studied localities in Russian areas. No fish species were recorded in three small lakes near Nikel. The presence of only young brown trout in inlet and outlet streams indicated low survival with age (juvenalization).

- In the same area bioaccumulation of Ni, Cu, Cr and As was documented in 2 cm tips of the river mosses *F. antipyretica* and *F. dalecarlica*. The concentration of Ni and As was generally more than 10 times, in some localities more than 100 times, higher on the Russian side compared to the upper part of the Pasvik River System. The Ni-content in aquatic mosses decreased with distance from the Pechenga nickel factories.

- Severe pathological anomalies and diseases were observed in fish near Nikel: curvature of spine (scoleosis), kidney disease (nephrocalcitosis), abnormal colour of body and flesh, pale gonads, anemic and pale gills with fluorescence and anemic rings, enlarged gall-bladder with abnormal colour of the bile, high frequency of parasites and adipose heart.
- Less pronounced pathological anomalies and diseases were observed in the Norwegian localities (at Svanvik and Jarfjord).
- A low diversity of zoobenthos and zooplankton was recorded in the most polluted localities in the Pechenga area.

Acidification impacts

- Senescence and no recruitment in brown trout populations, and absence or low numbers of acid sensitive invertebrates (daphnids and ephemeropterans) were recorded within the Jarfjord Region, in the Limgambergtjern and F.Høgfjellsvatn area.

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Appendix 1-5

Appendix 1. Localities and sampling in the different regions and periods. I= June/July, II= July/August and III= August/September. For phytoplankton and mosses cfr. Figure 4, 5 and 6.

	loc.	Water sampling									Zooplankton sampling									Fish sampling									Zoobenthos sampling								
		1990			1991			1992			1990			1991			1992			1990			1991			1992			1990			1991			1992		
		I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
Nikel Region																																					
Kolosyoki stream	Kol-s			x	x	x	x															x							x		x	x	x	x	x		x
Lake Nikel 1	LN1					x	x	x	x	x				x	x	x	x	x	x										x		x	x	x	x	x	x	
Lake Nikel 1 outlet	LN1-o				x																	x										x	x	x	x	x	
Lake Nikel 2	LN2			x	x	x	x	x	x	x			x	x	x	x	x	x	x												x	x	x	x	x	x	
Lake Nikel 2 inlet	LN2-i			x																		x									x	x	x				
Lake Nikel 2 stream	LN2-s			x																		x														x	
Pachtayoki stream	Pac-s			x	x		x			x												x															
Pachta stream	Pa-s			x																		x			x			x			x	x		x	x	x	
Tarn 1 Nikel-Zapolyarny	NZ1			x																																	
Tarn 2 Nikel-Zapolyarny	NZ2			x																																	
Lake Nikel 3	LN3				x	x	x	x	x	x				x	x	x	x	x	x			x			x							x	x	x	x	x	
Lake Sarasslaki	Sa					x	x						x	x	x	x	x	x	x									x			x	x	x	x	x	x	
Lake Sarasslaki inlet	Sa-i			x	x		x															x			x			x			x	x	x	x	x	x	
Lake Sarasslaki outlet	Sa-o			x	x			x		x												x			x			x			x	x	x	x	x	x	
Shuoniyoki stream	Shu-s			x	x		x	x														x			x			x			x	x		x	x	x	
Lake Shuoniyavr	Sh				x												x	x	x						x			x				x			x	x	
Upper Pechenga stream	UPe-s									x																		x								x	
Lake Nicoyarvi	Ni							x		x							x	x	x									x							x		
Lake Allaakkayarvi	Al							x		x							x	x	x																		
Kuvernerinyoki stream	Kuv-s			x	x		x			x												x			x			x			x			x	x	x	
Lake Rousenyarvi	Ro				x														x			x			x			x									
Pechenga River System																																					
Lake Big Maayarvi	BMa							x																			x								x		
Lake Maayarvi	Ma					x	x						x	x	x	x		x	x			x	x								x	x	x	x		x	
Lake Maayarvi inlet	Ma-i			x	x		x															x			x			x			x	x	x	x		x	
Lake Maayarvi outlet	Ma-o			x	x					x												x									x	x	x	x		x	
Maayoki stream	May-s			x						x												x			x			x			x					x	
Anatoliyoki stream	Ana-s									x																		x									
Naamiyoki stream	Na-s				x																							x	x								
Arvaldejm stream	Ar-s				x																											x					
Chaukilampiyoki stream	Ch-s									x																		x	x								
Lake Chaukilampiyarv	Ch																												x								
L. Chaukilampiyarv outl.	Ch-o																												x								
Semiaki stream	Se-s																												x								
Lake Trifonayarvi	Tr							x									x	x	x									x	x						x	x	
Lake Trifonayarvi outlet	Tr-o																			I								x							x	x	
Lake NW Liinakhmari	Lh							x									x	x										x	x						x	x	
L. NW Liinakhmari outlet	Lh-o																																		x	x	

	loc.	Water sampling									Zooplankton sampling									Fish sampling									Zoobenthos sampling								
		1990			1991			1992			1990			1991			1992			1990			1991			1992			1990			1991			1992		
		I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
Pasvik River System																																					
Lake Kuetsyarvi 1	Ku-1			x	x	x	x	x	x	x			x	x	x	x	x	x	x														x	x	x	x	
Lake Kuetsyarvi 2	Ku-2				x	x	x	x	x	x				x	x	x	x	x	x			x	x								x	x	x	x	x	x	
Lake Kuetsyarvi 3	Ku-3			x	x	x	x	x	x	x			x	x	x	x	x	x	x			x	x									x	x	x	x	x	
Lake Kuetsyarvi 4	Ku-4				x	x	x	x	x	x				x	x	x	x	x	x													x	x	x	x	x	
Lake Kuetsyarvi 5	Ku-5				x	x	x	x	x	x				x	x	x	x	x	x			x	x									x	x	x	x	x	
Lake Kuetsyarvi 6	Ku-6					x																											x				
Lake Salmiyarvi	Sal			x		x	x																								x	x			x	x	
Lake Salmiyarvi 1	Sal-1				x																											x		x	x		
Lake Salmiyarvi 2	Sal-2				x																											x		x	x		
Lake Svanvik 1	Sv-1												x																		x			x			
Lake Svanvik 2	Sv-2			x									x																		x						
Lake Skrukkebukt	Sk			x		x	x						x			x															x			x			
Lake Lyngbukta	Ly			x		x	x	x	x	x			x	x	x	x	x	x	x												x			x	x		
Lake Ruskvatn	Ru				x	x	x	x	x	x				x	x	x	x	x	x												x			x	x		
Vaggetem stream	Va-s				x																																
Sameti stream	Sam-s				x																																
Nyrud stream	Ny-s				x																																
Jarfjord Region																																					
Lake Otertjern inlet	On-i			x																		x															
Lake Otertjern outlet	On-o	x		x																		x															
Lake Otervatn	Ot				x						x	x	x							x		x							x		x						
Lake Otervatn outlet	Ot-o	x		x																		x							x		x			x			
Oterbekken stream	Ot-s																																	x	x	x	x
Lake Urdfjellvatn	Ur									x							x	x	x							x		x							x		
Lake Urdfjellvatn inlet	Ur-i																																		x		
Lake Urdfjellvatn outlet	Ur-o																																		x		
Lake Korpvatn	Ko				x	x								x	x								x														
Lake Store Skardvatn	SS				x		x	x	x	x				x	x	x	x	x	x						x	x								x	x		
L. Store Skardvatn inlet	SS-i																																	x	x		
L. Store Skardvatn outlet	SS-o																																	x	x		
Banebekken stream	Ba-s				x																																
Lake Durvatn	Du				x		x							x	x	x									x									x			
Lake Rundvatn	Rv				x		x							x	x	x									x									x			
Karpelva stream	Ka-s				x																													x			
Jakobselva stream	Ja-s				x																																
Lake Ø. Guokkolobbalat	ØG									x							x	x	x							x									x		x
Lake T. Guokkolobbalat	TG																									x									x		x
Lake A. Guokkolobbalat	AG									x							x	x	x							x									x		x
L. A. Guokkolobbalat inl.	AG-i									x																									x		x
Lake F. Guokkolobbalat	FG																									x		x							x		x
Lake Jarfjord 1	Jar1					x																						x									
Lake Jarfjord 2	Jar2					x																						x									
Lake Jarfjord 3	Jar3					x																						x									
Lake Jarfjord 4	Jar4					x																						x									

	loc.	Water sampling									Zooplankton sampling									Fish sampling									Zoobenthos sampling								
		1990			1991			1992			1990			1991			1992			1990			1991			1992			1990			1991			1992		
		I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
Lake Jarfjord 5	Jar5					x																						x									
Lake Jarfjord 6	Jar6					x																						x									
Lake Jarfjord 7	Jar7					x																						x									
Lake Holmvatn	Ho				x									x	x	x									x			x						x			
Lake Holmvatn inlet	Ho-i			x			x															x			x			x					x	x			
Lake Holmvatn outlet	Ho-o			x						x												x			x			x									
Lake Holmvatn stream 2	Ho-s2			x						x												x			x			x									
Lake Holmvatn stream 3	Ho-s3			x			x			x												x			x			x									
Lake Holmvatn stream 4	Ho-s4			x			x			x												x			x			x									
Lake Holmvatn stream 5	Ho-s5			x																		x			x			x									
Lake F. Skardvatn inlet	FS-i			x						x												x			x			x					x				
L. F. Skardvatn outlet	FS-o			x			x			x												x			x			x									
L. F. Skardvatn stream	FS-s			x																		x													x		
Lake Andre Skardvatn	AS				x								x	x	x	x						x												x	x		x
L. A. skardvatn outlet	AS-o			x			x			x												x			x			x						x	x		x
L. A.Skardvatn stream	AS-s			x																		x												x	x		x
L.F.Høgfjellsvatn	FH										x	x	x									x							x		x	x		x	x		x
L. F. Høgfjellsvatn inl.	FH-i	x					x			x												x			x			x				x					x
L. F. Høgfjellsvatn outl.	FH-o	x		x			x			x												x			x			x	x		x	x			x		x
L. A.Høgfjellsvatn outl	AH-o			x																		x										x			x		x
Lake Hornholmvatn inlet	Hor-i				x																														x		
Lake Kobbholmvatn	Kob				x																																
Lake Limgambertjern	Li	x									x	x	x							x		x							x		x	x			x		
L. Limgambergtjern inl.	Li-i	x		x																		x															
L. Limgambergtjern outl.	Li-o	x		x																		x							x		x						
Limgambergtjern str.	Li-s	x																				x															
Tarn 1 Limgambertjern	Li-t1	x		x																		x															
Tarn 2 Limgambertjern	Li-t2	x		x																		x															
Tarn 3 Limgambergtjern	Li-t3	x		x																		x															
Tarn 4 Limgambertjern	Li-t4	x																				x															
Lake Dalvatn	Da										x	x	x							x		x							x		x						
Lake Dalvatn inlet	Da-i	x																				x															
Lake Dalvatn outlet	Da-o	x		x																		x							x		x						
Lake Dalvatn stream	Da-s	x																				x							x		x	x					
Russian - Finnish Border																																					
Lake Poriyarvi outlet	Po-o									x																		x									
Kohisevaniyoki stream	Koh-s									x																		x									
Puldkasjyoki stream	Pul-s									x																		x									
Lake Virtuovoshyavr	Vi									x									x						x			x									
Lake Kocheyarv	Koc									x									x						x			x									
Lake Kocheyarv inlet	Koc-i									x																		x									
Madsasjyoki stream	Mad-s									x																		x									
Lake Ontasjyavr outlet	Ont-o									x																		x									

Appendix 2. Methods used in the analyses of chemical parametres and bioaccumulation of heavy metals.

Turb: Turbidity was measured nephelometrically with a HACH model 2100A Turbidimeter after Norwegian Standards (NS 4723) modified by Blakar & Odden (1986).

Col: The watercolour was analysed in accordance with NS 4722 using a Shimadzu UV-160 and calculated after Hongve (1984).

Cond: Conductivity was measured after NS 4721 using a Radiometer model CDM 80 with a platina-electrode.

pH: pH was analysed in accordance with NS 4720 using a Radiometer model PHM 84 pH meter equipped with separated glass- and calomel-electrodes.

Alk: Alkalinity was determined after NS 4754 using a Radiometer model TTT 80 Titrator, Radiometer model ABU 80 Autobyrette and a Radiometer model PHM 84 pH meter and the values are adjusted in accordance with Henriksen (1982).

Ca, Mg, Na, K: Cations were determined by atomic absorption spectrophotometry (Perkin-Elmer model 1100 B) after NS 4775 and NS 4776.

Cl, NO3, Si: Cloride, nitrate and silisium were determined by cholometry (FIA Star model 5020 Analyzer) after Tecator application note ASN 63-03/83, ASN 62-01/83 and ASTN 5/84 (modified), respectively.

SO4: Sulphate was determined by the formula: SO4 = SSS - (Cl + NO3) where SSS (sum of strong acids anions) was analysed, after passing through a cation exchange resin (Dowex, 50 mesh, H+), by conductivimetry using a Radiometer model CDM 80 connected to the FIA Star model 5020 Analyzer.

Tot-N, Tot-P, PO4: Nitrogen, phosphorus and phosphate were measured on an Unicam model PU 8600 Spectrophotometer after NS 4743, NS 4725 and NS 4724, respectively.

Trace metals:

Cd, Cu, Mn, Ni, Zn, Pb, Cr, As: Trace elements in water (0,04 M Suprapure HNO3-solution) were determined by atomic absorption spectrophotometry (Perkin-Elmer model 1100 B) in comparison with NIST Standard reference material 1643C.

Analytical Procedure for heavy metal analysis in biological material

The biological material analysed at NINA laboratory was aquatic mosses and fish tissues.

Freeze-drying process

The samples were freeze-dried for approximately 24 hours to a final pressure of 0.05mbar at -53C in CHRIST LDC-equipment.

Digestion Procedure

Approximately 0.4 g freeze-dried material was weighed in, and 4-5 ml cons. HNO3 Supra Pure grade was added. The digestion-program in a Microwave-ovn Milestone MLS 1200, with bombs SV 140 made of PFA with max. pressure 10 bar, was applied for 10 minutes.

Analytical procedure

Perkin Elmer model 1100B, equipped with high sensitivity nebulizer, graphite furnace HGA 700 with autosampler AS 70, and Hydride system FIAS 200 were used as the analytic equipment for heavy metals in the biolobical material.

The elements Zn, Cu, Cd (high levels >0.4ppm) Pb (high levels > 2.5ppm), Mn, Ni, Co were analysed using flame-mode. Standard wavelengths were used for all elements, and background correction was used for Zn, Pb, Ni, Cd.

The elements Cd, Pb (low levels, see flame), Se, As, Cr were analysed using graphite-furnace. Tubes used was pyrolytical with plattform for all elements except for Cr (pyrolytical without plattform). STPF technique according to Perkin Elmers manual for graphite furnace was used for all elements except Cr (not plattform). Modifier used: Palladium approximately. 5µg /sample was used for Se-As-Cd and Pb. For Cr approximately 1µg/samples with Mg(NO3)2 was used. Peak area was used for all elements except for selenium, due to overcompensation-problems.

Hg was analysed using FIAS 200 with NaBH4 as reducing agent.

Referance material used to verify the results:
Achieved sertified values of As, Cd, Cu, Pb and Zn in Pine needles (PN) 1575 and Peach leaves (PL) 1547.
Hg: achieved approx. 65 % of PL and approx. 50 % of unsertified PN-values.
Cr: achieved approx. 40 % of PN.
Ni: achieved 90 % of unsertified PN-values.
Se: Not verified on vegetable material, but correct values achieved in animal materials.

Appendix 3. *Water chemistry of the different localities. Locality name in accordance with Appendix 1.*

Locality	Depth	Date	FTU Turb.	mg Pt/l Col.	µS/cm Cond	pH	µekv/l Alk	mg/l Ca	mg/l Mg	mg/l Na	mg/l K	mg/l Fe	µekv/l SSS	mg/l SO4
Nikel Region														
Kol-s	0,2	30-08-90	8,10	10	743,0	7,08	728	44,27	4,50	17,00	8,63		2619	108,77
Kol-s	0,2	27-06-91	15,00	12	235,0	7,07	373	16,66	8,79	9,80	1,79		1654	70,58
Kol-s	0,2	02-08-91			292,0	6,97	527	27,03	9,00	13,66	2,10		1980	84,48
Kol-s	0,2	04-09-91	5,30	8	449,0	7,21	645	33,19	14,80	5,50	4,93		2475	106,40
LN1	1,0	01-08-91												
LN1	1,0	04-09-91	2,40	9	137,5	6,93	343	15,38	2,40	3,54	0,66		845	35,52
LN1	0,2	30-06-92	2,60	9	119,6	6,82	224	14,19	2,25	3,52	0,65		819	34,12
LN1	0,2	29-07-92	1,40	14	127,5	6,60	230	13,90	2,33	3,51	0,62		849	35,33
LN1	0,2	02-09-92	1,50	15	137,3	6,90	262	16,47	2,63	3,90	0,69		937	39,54
LN1-o	0,2	27-06-91	2,90	6	120,2	6,93	269	11,98	2,18	3,09	0,63		765	32,18
LN2	0,2	01-09-90	0,63	9	386,0	7,13	312	49,87	11,09	4,40	0,73	44	3118	145,85
LN2	0,2	27-06-91	0,95	6	363,0	7,09	242	46,98	10,80	3,95	0,80		2534	117,46
LN2	1,0	02-08-91			377,0	7,40	379	48,52	10,80	4,61	1,01		2409	110,62
LN2	5,0	02-08-91			373,0	7,58	336	48,18	10,20	4,52	0,70		2410	111,35
LN2	1,0	04-09-91	0,58	7	356,0	7,05	281	44,34	10,40	4,19	0,70		2438	112,49
LN2	0,2	30-06-92	0,42	8	355,0	6,82	189	44,79	7,15	4,09	0,74		2569	119,19
LN2	0,2	29-07-92	0,38	15	351,0	6,67	209	43,27	10,28	4,39	0,64		2268	104,74
LN2	0,2	02-09-92	0,53	11	372,0	7,00	229	47,62	8,65	4,82	0,69		2366	109,41
LN2-i	0,2	01-09-90	0,34	21	79,1	6,75	300	7,60	2,28	2,94	0,12		401	14,97
LN2-s	0,2	01-09-90	0,48	7	323,0	6,94	235	34,77	14,49	4,03	0,72	35	4487	212,12
Pac-s	0,2	01-09-90	0,81	6	56,2	6,95	170	5,93	1,31	1,99	0,25		318	12,38
Pac-s	0,2	27-06-91	0,54	10	41,2	6,80	107	3,11	0,88	1,52	0,28		245	9,19
Pac-s	0,2	04-09-91	0,60	10	57,4	6,84	138	5,16	1,31	2,05	0,36		343	12,97
Pac-s	0,2	30-08-92	2,80	5	53,6	6,86	138	5,52	1,27	1,93	0,24		311	11,99
Pa-s	0,2	01-09-90	0,34	9	78,6	6,89	258	7,88	1,98	2,57	0,23		436	17,01
NZ1	0,2	01-09-90	0,39	4	55,1	6,53	82	4,80	0,85	2,29	0,31		347	11,76
NZ2	0,2	02-09-90	0,45	21	55,0	6,21	49	4,16	1,40	2,39	0,18		388	14,34
LN3	0,2	27-06-91	0,71	2	48,8	6,61	89	4,47	0,82	2,13	0,27		320	10,55
LN3	1,0	02-08-91			62,5	6,92	182	4,87	0,97	2,72	0,35		369	12,58
LN3	5,0	02-08-91			67,7	7,42	238	4,66	0,90	2,70	0,35		339	11,14
LN3	1,0	04-09-91	2,00	1	50,4	6,46	65	4,32	0,82	2,21	0,29		358	12,40
LN3	0,2	30-06-92	0,58	0	53,3	6,53	96	5,26	0,93	2,50	0,36		351	11,38
LN3	0,2	29-07-92	0,77	2	55,1	6,52	112	5,80	0,94	2,42	0,27		359	11,75
LN3	0,2	01-09-92	1,50	3	57,6	6,74	123	5,96	0,93	2,46	0,26		356	11,70
Sa	1,0	01-08-91												
Sa	1,0	04-09-91	0,46	8	50,8	7,01	185	4,78	1,02	2,02	0,34		254	9,09
Sa-i	0,2	31-08-90	0,48	9	70,9	7,08	288	7,03	1,30	2,52	0,36		298	11,22
Sa-i	0,2	25-06-91	0,62	16	45,5	6,85	160	3,71	0,92	1,83	0,25		242	9,04
Sa-i	0,2	04-09-91	0,25	12	63,4	6,97	214	6,20	1,28	2,32	0,36		336	12,76
Sa-o	0,2	31-08-90	0,62	10	52,0	6,79	185	5,08	1,00	2,08	0,34		258	9,19
Sa-o	0,2	25-06-91	0,86	12	48,2	6,97	187	3,85	1,00	1,97	0,34		244	8,64
Sa-o	0,2	30-06-92	0,62	9	46,9	6,70	158	4,69	1,02	2,10	0,77		241	8,43
Sa-o	0,2	30-08-92	1,40	11	45,4	6,81	145	4,71	0,96	1,94	0,25		241	8,57
Shu-s	0,2	30-08-90	1,80	22	91,7	7,05	397	8,83	2,07	3,23	1,27	60	394	14,34

mg/l Cl	µg/l Tot-N	µg/l NO3-N	µg/l Tot-P	µg/l PO4-P	µg/l Si	ppb Cd	ppb Cu	ppb Mn	ppb Ni	ppb Zn	ppb Pb	ppb Cr	ppb As
11,10		586			6,36	< 2,00	9	< 5	485	6			
5,47		428			2,43	0,14	55	42	384	9	3,3		
5,90		767			3,39		14	41	321	5			
7,64		634			4,82								
							37	16	255	10			
3,71		10			0,64		25	15	238	6			
3,64	357	83	13	4	1,38	< 0,10	32	26	237	8		0,41	2,01
3,56		178			1,62		50		24	29		< 0,30	2,39
3,55	381	189	10	6	1,89		34	21	350	10		0,34	1,99
3,32		17			0,91	< 0,10	41	23	238	5	0,6		
2,91		6			3,58	< 2,00	5	< 5	403	11			
3,13		19			3,27	< 0,10	7	41	402	8	0,5		
3,72		25			3,56		42	17	443	38			
3,24		11			3,63		125	16	423	163			
3,40		8			3,61		11	16	357	16			
3,08	72	22	5	1	3,00	< 0,10	9	29	367	13		0,99	0,50
3,10		6			3,38		18		17	31		0,32	< 0,30
3,03	152	49	7	4	3,63		11	8	386	12		< 0,30	< 0,30
3,15		8			4,97	< 2,00	6	< 5	33	5			
2,52		17			6,08	< 2,00	10	26	261	13			
2,12		10			2,86	< 2,00	< 5	< 5	20	< 5			
1,89		4			1,69	< 0,10	6	< 5	16	< 5	< 0,5		
2,58		8			2,56								
2,14		16			2,87		< 5	< 5	21	53		< 0,30	< 0,30
2,88		3			3,86	< 2,00	< 5	< 5	33	< 5			
3,62		3			0,13	< 2,00	< 5	< 5	76	< 5			
3,16		6			0,89	< 2,00	8	< 5	53	< 5			
3,55		4			0,17	< 0,10	9	16	83	< 5	< 0,5		
3,79		8			0,53		22	< 5	125	21			
3,75		12			0,70		23	< 5	171	15			
3,54		3			0,18		12	10	90	9			
3,99	150	15	9	1	0,44	< 0,10	7	20	69	6		< 0,30	1,40
4,02		19			0,44		10		12	24		< 0,30	0,84
3,93	152	19	8	4	0,52		< 5	< 5	51	5		< 0,30	0,77
							10	< 5	29	5			
2,29		3			1,63		10	5	25	< 5			
2,28		6			4,41	< 2,00	< 5	< 5	< 20	< 5			
1,88		3			2,67	< 0,10	6	5	13	< 5	< 0,5		
2,49		3			3,98								
2,33		8			1,93	< 2,00	6	< 5	32	< 5			
2,27		3			1,89	< 0,10	11	18	26	< 5	0,7		
2,28	107	15	9	5	1,94	< 0,10	9	28	31	7		< 0,30	1,40
2,18		17			1,96		6	< 5	29	10		< 0,30	0,80
3,03		145			3,20	< 2,00	33	5	36	31			

Locality	Depth	Date	FTU Turb.	mg Pt/l Col.	µS/cm Cond	pH	µekv/l Alk	mg/l Ca	mg/l Mg	mg/l Na	mg/l K	mg/l Fe	µekv/l SSS	mg/l SO4
Shu-s	0,2	27-06-91	1,80	48	57,7	6,91	230	4,66	1,44	2,09	0,43		291	10,45
Shu-s	0,2	04-09-91	0,45	22	67,1	7,27	408	7,18	1,58	2,43	0,62		243	7,72
Shu-s	0,2	30-06-92	0,22	13	28,4	6,56	70	2,15	0,70	1,67	0,57		162	5,25
Sh	0,2	27-06-91	0,44	17	29,4	6,45	76	1,89	0,69	1,56	0,42		168	5,54
UPe-s	0,2	04-09-92	0,41	19	27,2	6,62	78	2,18	0,69	1,54	0,40		156	4,90
Ni	0,2	30-06-92	0,40	31	31,4	6,63	123	2,65	0,87	1,77	0,42		174	4,62
Ni	0,2	04-09-92	0,85	58	25,7	6,55	101	2,18	0,83	1,44	0,37		131	3,74
Al	0,2	30-06-92	0,46	28	29,9	6,63	135	2,46	1,00	1,58	0,48		128	3,98
Al	0,2	04-09-92	0,91	37	29,1	6,81	140	2,54	0,98	1,47	0,43		126	3,91
Kuv-s	0,2	29-08-90	0,42	20	64,0	6,93	239	5,07	1,35	3,23	0,54	40	286	8,32
Kuv-s	0,2	26-06-91	0,52	30	47,1	6,64	111	3,63	1,12	2,79	0,38		292	9,08
Kuv-s	0,2	06-09-91	0,46	18	90,0	7,40	522	8,77	2,16	3,67	0,82		325	9,82
Kuv-s	0,2	02-09-92	0,52	31	51,2	6,87	156	4,23	1,28	3,04	0,63		286	8,32
Ro	0,2	29-06-91	1,00	52	57,4	6,66	173	4,50	1,38	3,33	0,60		341	10,27
Pechenga River System														
BMa	0,2	30-06-92	0,48	27	41,8	6,53	98	2,94	1,14	2,84	0,31		256	7,20
Ma	1,0	02-08-91			61,3	6,65	272	4,75	1,33	3,23	0,36		269	7,91
Ma	10,0	02-08-91			61,2	6,39	253	4,71	1,29	3,14	0,36		280	8,33
Ma	1,0	06-09-91	0,88	22	56,6	6,80	197	4,63	1,31	2,88	0,34		297	8,97
Ma	10,0	06-09-91	0,98	22	56,5	6,58	196	4,61	1,31	2,90	0,35		299	8,98
Ma-i	0,2	01-09-90	0,76	16	81,6	7,05	409	9,78	1,51	3,04	0,33		367	12,22
Ma-i	0,2	27-06-91	4,00	24	75,8	6,92	316	8,31	1,51	2,87	0,34		373	12,79
Ma-i	0,2	06-09-91	1,20	22	84,0	7,06	369	9,24	1,59	3,10	0,35		385	12,67
Ma-o	0,2	01-09-90	0,44	21	56,2	6,80	191	4,77	1,26	2,87	0,36		298	9,14
Ma-o	0,2	27-06-91	1,50	22	50,8	6,85	177	4,40	1,22	2,64	0,36		279	8,80
Ma-o	0,2	02-09-92	0,74	39	50,9	6,77	164	4,53	1,33	2,80	0,28		284	8,51
May-s	0,2	01-09-90	0,83	22	56,2	6,91	201	4,58	1,36	3,10	0,40	26	291	8,39
May-s	0,2	01-09-92	0,55	19	82,5	7,08	304	10,16	1,53	2,95	0,33		430	14,27
Ana-s	0,2	02-09-92	0,42	22	56,8	6,83	133	3,99	1,59	3,60	0,68		349	10,49
Na-s	0,2	27-06-91	0,72	15	68,6	6,93	207	5,22	1,74	2,73	0,36		407	14,93
Ar-s	0,2	27-06-91	1,70	9	315,0	6,89	281	23,71	13,00	7,17	1,47		2359	101,17
Ch-s	0,2	01-09-92	0,86	24	72,9	6,81	185	7,19	2,00	2,87	0,33		448	16,90
Tr	0,2	30-06-92	2,30	5	67,4	6,57	90	2,47	1,56	7,05	0,74		487	8,11
Lh	0,2	30-06-92	0,26	5	50,8	6,24	30	2,03	1,11	4,95	0,41		381	7,18
Pasvik River System														
Ku-1	0,2	29-08-90	1,70	15	143,5	6,73	342	12,06	4,10	6,94	1,40	29	887	35,98
Ku-1	0,2	26-06-91	3,20	17	158,3	7,16	381	9,91	4,75	8,39	1,65		996	39,88
Ku-1	20,0	26-06-91	2,50	17	161,9	7,02	393	10,30	5,11	8,63	1,64		1027	41,14
Ku-1	1,0	30-07-91	1,50	15	152,6	7,05	360	12,60	4,50	7,89	1,59		896	36,10
Ku-1	15,0	30-07-91	2,00	16	153,7	6,92	357	12,60	4,47	7,99	1,57		900	35,96
Ku-1	1,0	03-09-91	2,90	15	152,3	7,02	366	11,37	4,33	7,76	1,53		943	38,52
Ku-1	15,0	03-09-91	3,30	16	152,9	7,03	375	11,51	4,44	7,90	1,54		955	39,16
Ku-1	0,2	30-06-92	1,30	18	136,4	6,93	293	11,25	4,02	7,31	1,35		902	36,92
Ku-1	0,2	27-07-92	1,10	21	125,5	6,61	189	9,65	3,60	6,07	1,09		860	31,23
Ku-1	0,2	01-09-92	2,10	27	117,6	6,96	283	10,58	3,56	5,57	0,99		754	30,72

mg/l Cl	µg/l Tot-N	µg/l NO3-N	µg/l Tot-P	µg/l PO4-P	µg/l Si	ppb Cd	ppb Cu	ppb Mn	ppb Ni	ppb Zn	ppb Pb	ppb Cr	ppb As
2,39		86			2,17	< 0,10	5	10	15	< 5	< 0,5		
2,52		151			3,19								
1,82	92	18	2	1	1,32	< 0,10	< 5	< 5	< 5	< 5		< 0,30	0,37
1,85		3			1,17								
1,86		19			1,26		< 5	< 5	< 5	29		0,61	< 0,30
2,71	190	17	7	4	2,74	< 0,10	< 5	7	< 5	5		0,39	< 0,30
1,84		13			1,65		< 5	16	< 5	66		0,32	< 0,30
1,58	153	10	7	1	1,84	< 0,10	< 5	27	< 5	< 5		< 0,30	< 0,30
1,56		15			1,50		< 5	16	8	5		< 0,30	< 0,30
3,97		4			2,93	< 2,00	5	< 5	< 20	< 5			
3,63		11			1,96	< 0,10	7	8	18	< 5	< 0,5		
4,27		3			3,47								
3,97		14			2,85		5	8	18	72		0,60	< 0,30
4,49		4			1,39								
3,73	252	16	8	2	1,50	< 0,10	9	6	28	13		0,69	0,53
3,66		20			1,49		31	5	32	25			
3,70		30					65	9	52	47			
3,88		7			1,29		19	9	25	12			
3,96		5			2,21		16	10	25	9			
3,89		38			0,98	< 2,00	9	< 5	22	6			
3,77		8			1,45	< 0,10	11	< 5	32	< 5	< 0,5		
4,19		42			1,35								
3,80		6			1,46	< 2,00	7	< 5	27	< 5			
3,37		9			1,78	< 0,10	10	5	20	< 5	1,5		
3,68		40			1,86		8	6	35	96		0,51	< 0,30
4,10		9			2,05	< 2,00	6	< 5	27	< 5			
3,75		376			2,18		< 5	< 5	26	< 5		< 0,30	0,35
4,59	180	13	5	4	3,49		< 5	< 5	< 5	7		< 0,30	< 0,30
3,39		3			1,87	< 0,10	7	9	42	< 5	< 0,5		
4,84		1640			1,99	< 0,10	7	67	116	13	< 0,5		
3,37		14			2,37		7	< 5	63	< 5		< 0,30	0,51
11,20	83	27	20	6	0,95	< 0,10	< 5	< 5	7	7		0,51	0,53
8,17	63	11	1	< 1	0,88	< 0,10	< 5	< 5	9	10		< 0,30	< 0,30
4,69		86											
5,49		149			1,12	< 2,00	7	57	58	< 5			
5,58		185			0,97	< 0,10	6	46	68	5	0,8		
5,01		46			2,03	< 0,10	6	123	83	< 5	0,9		
5,17		80			0,10		13	36	63	12			
4,99		11			0,07		94	59	77	66			
4,93		13			0,04		9	75	56	< 5			
4,71	245	10			0,07		12	68	58	5			
4,26			34	7	1,00	< 0,10	18	24	77	18		1,21	0,90
4,03	166	10			0,80		16		63	12		1,33	1,27

Locality	Depth	Date	FTU Turb.	mg Pt/l Col.	µS/cm Cond	pH	µekv/l Alk	mg/l Ca	mg/l Mg	mg/l Na	mg/l K	mg/l Fe	µekv/l SSS	mg/l SO4
Ku-2	15,0	26-06-91												
Ku-2	1,0	30-07-91	1,60	17	153,6	6,93	357	12,79	4,43	7,93	1,56		920	36,84
Ku-2	15,0	30-07-91	1,80	16	154,8	6,55	349	13,02	4,61	7,99	1,58		929	36,68
Ku-2	1,0	03-09-91	3,20	17	153,3	7,00	373	11,51	4,42	7,97	1,56		941	38,49
Ku-2	15,0	03-09-91	2,50	16	153,0	7,06	366	11,55	4,34	7,79	1,51		959	39,51
Ku-2	0,2	30-06-92	1,60	19	135,5	7,05	288	11,19	4,06	7,24	1,45		919	37,25
Ku-2	0,2	28-07-92	1,80	23	124,0	6,82	273	9,74	3,61	6,13	1,11		789	31,90
Ku-2	0,2	01-09-92	1,60	29	118,5	6,96	283	10,75	3,64	5,55	0,99		761	31,25
Ku-2	0,2	26-06-91	3,70	19	161,1	7,11	377	9,81	5,01	8,55	1,66		1022	41,73
Ku-3	0,2	30-08-90	3,00	20	153,8	6,66	388	12,80	4,19	7,43	2,18		959	36,95
Ku-3	1,0	30-07-91	1,50	19	152,1	6,98	354	12,89	4,47	7,79	1,52		899	36,60
Ku-3	15,0	30-07-91	3,70	18	152,3	6,75	349	12,93	4,59	7,73	1,55		910	36,63
Ku-3	1,0	03-09-91	2,90	17	155,7	7,08	378	11,57	4,45	7,98	1,51		973	40,05
Ku-3	15,0	03-09-91	10,00	17	154,8	7,00	367	11,71	4,45	8,03	1,55		981	40,48
Ku-3	0,2	30-06-92	1,80	19	132,3	6,82	269	11,00	3,98	6,95	1,26		885	36,39
Ku-3	0,2	28-07-92	3,20	28	121,6	6,87	266	9,82	3,58	5,77	1,04		782	31,27
Ku-3	0,2	02-09-92	2,20	32	119,8	7,00	286	10,81	3,72	5,49	0,96		774	31,93
Ku-4	0,2	26-06-91												
Ku-4	15,0	26-06-91												
Ku-4	1,0	31-07-91	2,60	19	152,0	6,72	358	12,84	4,56	7,79	1,51		904	36,28
Ku-4	1,0	03-09-91	2,80	18	156,1	7,02	379	11,69	4,52	7,96	1,53		958	39,41
Ku-4	15,0	03-09-91	1,80	18	156,0	7,02	379	11,72	4,54	8,07	1,58		978	40,32
Ku-4	0,2	30-06-92	2,20	20	131,7	6,82	271	10,94	3,91	6,81	1,23		897	36,95
Ku-4	0,2	28-07-92	2,40	27	122,1	6,89	274	9,76	3,60	5,90	1,04		772	31,38
Ku-4	0,2	02-09-92	2,60	32	120,1	7,03	293	10,93	3,71	5,58	0,97		780	32,28
Ku-5	0,2	26-06-91	3,50	23	148,2	7,08	334	9,09	4,50	7,56	1,48		943	39,15
Ku-5	15,0	26-06-91												
Ku-5	1,0	31-07-91	2,30	20	150,1	6,89	350	13,03	4,40	7,58	1,47		901	36,20
Ku-5	15,0	31-07-91	4,80	21	148,0	6,56	355	12,01	4,38	7,57	1,44		870	35,30
Ku-5	1,0	03-09-91	3,30	19	157,3	7,02	389	11,87	4,58	7,91	1,54		988	40,76
Ku-5	15,0	03-09-91	4,00	19	157,0	6,96	385	11,75	4,44	7,95	1,53		989	40,53
Ku-5	0,2	30-06-92	1,80	23	123,9	6,87	261	10,36	3,69	6,45	1,15		855	34,46
Ku-5	0,2	28-07-92	2,80	37	112,0	6,85	263	9,47	3,26	5,07	0,94		704	28,52
Ku-5	0,2	02-09-92	1,90	36	122,6	6,98	295	11,20	3,87	5,51	0,97		799	33,12
Ku-6	1,0	31-07-91	2,40	20	154,0	6,89	358	12,48	4,52	7,96	1,50		921	37,35
Sal	0,2	29-08-90	1,60	18	146,5	6,90	342	12,10	4,08	7,09	1,42		907	36,91
Sal	1,0	02-08-91			44,0	6,72	251	3,48	1,11	2,23	0,50		147	5,06
Sal	10,0	02-08-91			43,6	6,72	264	3,21	1,02	2,11	0,48		132	4,44
Sal	1,0	05-09-91	1,60	16	35,4	6,98	198	2,91	1,03	1,64	0,50		136	4,80
Sal	5,0	05-09-91	1,50	15	34,0	6,92	194	2,75	0,98	1,54	0,46		122	4,06
Sal-1	15,0	28-06-91	3,80	21	95,4	6,98	273	5,84	2,79	4,82	1,04		564	22,05
Sal-2	0,2	28-06-91	4,60	23	157,5	7,07	360	9,25	4,88	8,36	1,64		1013	40,58
Sv-2	0,2	04-09-90	3,80	14	32,2	6,78	181	2,77	0,92	1,47	0,44		114	3,94
Sk	0,2	04-09-90	9,30	16	37,9	6,57	182	3,26	1,07	1,79	0,51	26	161	5,73
Sk	0,2	01-07-91	1,40	16	43,1	6,97	199	2,87	1,23	2,07	0,56		195	6,98
Sk	1,0	03-08-91			47,9	7,01	269	3,72	1,26	2,51	0,57		174	6,13
Sk	20,0	03-08-91			52,1	6,78	266	3,82	1,31	2,65	0,61		187	6,47

mg/l Cl	µg/l Tot-N	µg/l NO3-N	µg/l Tot-P	µg/l PO4-P	µg/l Si	ppb Cd	ppb Cu	ppb Mn	ppb Ni	ppb Zn	ppb Pb	ppb Cr	ppb As
			18	5	1,13		5	< 5	67	< 5		< 0,30	0,60
5,00		163				< 0,10	5	63	77	< 5	< 0,5		
5,01		339			0,05		21	50	66	15			
4,89		21			0,28		25	138	78	17			
4,83		8			0,08		10	86	58	< 5			
5,03	272	22			0,04		10	86	58	< 5			
4,28		65	48	8	1,05	< 0,10	31	39	80	26		0,49	0,90
3,91	170	10			0,73		23		57	27		< 0,30	0,34
5,29		60	13	7	1,22		< 5	< 5	77	< 5		< 0,30	< 0,30
5,30		568			0,78	< 0,10	5	47	72	< 5	< 0,5		
4,85		4			1,01	< 2,00	11	< 5	79	30			
4,84		158			0,04		25	44	72	15			
4,89		24			0,55		13	292	88	8			
4,85		20			0,05		53	92	65	36			
4,48	284	22			0,11		12	90	60	< 5			
4,03		243	33	9	1,08	< 0,10	34	43	85	32		0,66	1,00
3,84	179	10			0,99		42		103	28		0,37	0,87
			17	8	1,30		< 5	7	82	< 5		< 0,30	< 0,30
						< 0,10	7	42	76	< 5	< 0,5		
4,75		214				< 0,10	10	125	106	10	2,4		
4,87		3			0,04		20	75	77	13			
4,85		29			0,06		12	77	61	< 5			
4,34	306	70			0,04		10	75	61	5			
4,09		49	35	16	1,19	< 0,10	41	48	96	35		1,06	0,90
3,81	231	12			0,97		60		120	41		0,36	0,68
4,52		3	26	10	1,34		< 5	< 5	82	< 5		< 0,30	< 0,30
					1,9	< 0,10	19	39	112	12	1,4		
4,63		238				< 0,10	18	92	122	13	0,8		
4,63		64			1,71		16	43	104	9			
4,76		71			0,19		11	131	84	6			
4,82		130			0,05		8	70	68	< 5			
4,67	325	78			0,06		15	71	80	9			
3,67		99	37	17	1,33	< 0,10	58	42	117	46		0,65	0,80
3,73	240	57			1,35		23		65	32		0,46	1,22
4,76		128	27	17	1,70		< 5	< 5	96	5		< 0,30	< 0,30
4,72		84			0,06		15	53	80	7			
1,45		5			0,95	< 2,00	6	< 5	62	< 5			
1,40		5			1,79		< 5	8	< 20	< 5			
1,28		2			1,95		< 5	7	< 20	< 5			
1,33		7			1,58		5	10	< 20	6			
3,44		116			1,67								
5,25		287			1,07								
1,13		6			0,52	< 0,10	8	36	73	< 5	0,8		
1,47		7			1,66	< 2,00	< 5	< 5	< 20	< 5			
1,74		12			1,52	< 2,00	< 5	< 5	< 20	< 5			
1,62		10			1,67								
1,81		12			1,59		< 5	6	< 20	6			

Locality	Depth	Date	FTU Turb.	mg Pt/l Col.	µS/cm Cond	pH	µekv/l Alk	mg/l Ca	mg/l Mg	mg/l Na	mg/l K	mg/l Fe	µekv/l SSS	mg/l SO4
Sk	1,0	08-09-91	0,85	16	41,4	6,93	200	3,35	1,19	1,94	0,53		178	6,15
Sk	10,0	08-09-91												
Ly	0,2	02-09-90	0,70	17	32,4	6,70	177	2,66	0,92	1,43	0,42		109	3,71
Ly	1,0	03-08-91			41,1	6,86	251	2,69	0,90	2,00	0,48		128	4,25
Ly	5,0	03-08-91			35,8	6,86	220	2,66	0,92	1,97	0,49		121	3,72
Ly	1,0	08-09-91												
Ly	0,2	30-06-92	0,93	17	28,5	6,69	140	2,60	0,86	1,54	0,64		113	3,51
Ly	0,2	01-08-92	1,40	25	28,4	6,61	133	2,34	0,78	1,46	0,45		112	3,31
Ly	0,2	05-09-92	1,80	30	28,0	6,72	137	2,31	0,79	1,52	0,47		115	3,42
Ru	0,2	30-06-91	2,10	14	32,6	6,83	177	2,21	0,97	1,71	0,53		133	4,01
Ru	1,0	03-08-91			40,1	6,42	250	2,86	1,04	2,26	0,63		124	3,68
Ru	5,0	03-08-91			37,4	6,13	220	2,65	0,99	2,19	0,55		122	3,48
Ru	1,0	08-09-91	4,60	15	33,5	6,43	167	2,44	0,97	1,77	0,54		131	4,04
Ru	0,2	30-06-92	0,82	16	33,1	6,59	173	2,71	1,04	1,95	0,55		127	3,84
Ru	0,2	01-08-92	2,10	20	34,1	6,69	180	3,11	0,96	1,80	0,56		128	3,80
Ru	0,2	05-09-92	2,40	30	32,0	6,77	172	2,59	0,99	1,71	0,50		125	3,68
Va-s	0,2	30-06-91	0,79	23	25,2	6,65	99	2,01	0,67	1,49	0,46		134	5,03
Sam-s	0,2	30-06-91	1,00	52	35,1	6,62	144	3,14	0,82	2,22	0,41		179	4,74
Ny-s	0,2	30-06-91	0,74	114	29,6	6,11	119	2,52	0,97	1,77	0,42		155	4,84
Jarfjord Region														
On-i	0,2	04-09-90	0,48	17	44,4	6,49	96	2,43	1,22	3,12	0,27	34	275	7,87
On-o	0,2	27-06-90	0,84	26	28,6	6,01	46	1,41	0,71	2,17	0,18	78	180	4,62
On-o	0,2	04-09-90	0,58	20	41,9	6,55	90	2,30	1,19	3,05	0,24	31	266	7,53
Ot	0,2	01-07-91	0,54	27	31,8	6,46	57	1,66	0,85	2,37	0,18		212	5,72
Ot-o	0,2	27-06-90	0,52	12	26,3	6,01	28	1,20	0,64	1,93	0,18	31	175	4,49
Ot-o	0,2	04-09-90	0,46	12	30,7	5,82	15	1,33	0,77	2,20	0,20		222	6,26
Ur	0,2	06-09-92	0,43	11	36,2	6,63	82	2,09	0,94	2,88	0,32		227	5,49
Ko	0,2	01-07-91	0,74	23	32,2	6,52	71	1,84	0,85	2,51	0,23		212	5,17
Ko	1,0	04-08-91			50,9	6,65	166	2,09	1,09	3,36	0,31		247	6,10
SS	0,2	02-07-91	0,46	8	36,0	6,52	53	1,69	0,91	2,85	0,33		248	5,88
SS	1,0	10-09-91	3,40	9	37,4	6,52	50	1,65	0,91	2,91	0,35		250	5,95
SS	0,2	30-06-92	0,31	8	36,9	6,40	51	1,72	0,98	3,14	0,39		248	5,76
SS	0,2	02-08-92	1,00	11	36,7	6,29	48	1,63	0,88	2,92	0,29		246	5,72
SS	0,2	06-09-92	0,32	11	36,3	6,50	51	1,77	0,96	3,01	0,32		248	5,93
Ba-s	0,2	02-07-91	0,44	26	34,6	6,55	78	1,79	0,88	2,70	0,19		226	5,60
Du	0,2	02-07-91	0,42	13	34,5	6,72	80	1,85	0,84	2,68	0,33		221	5,27
Du	1,0	10-09-91	0,55	14	38,4	6,70	86	1,87	0,94	2,98	0,35		232	5,48
Rv	0,2	02-07-91	0,64	11	35,7	6,30	34	1,59	0,84	3,04	0,31		262	5,60
Rv	1,0	10-09-91	0,86	12	38,5	6,33	40	1,57	0,89	3,22	0,31		267	5,81
Ka-s	0,2	01-07-91	0,66	28	42,1	6,75	101	2,66	1,06	3,05	0,38		269	6,87
Ja-s	0,2	01-07-91	0,49	22	36,9	6,58	69	2,05	1,01	2,60	0,30		245	6,66
ØG	0,2	07-09-92	0,40	7	34,1	5,75	11	1,31	0,83	3,04	0,20		258	5,62
AG	0,2	07-09-92	0,34	4	35,8	6,32	40	1,68	0,86	3,01	0,26		255	5,97
AG-i	0,2	07-09-92	0,25	3	31,7	6,05	17	1,49	0,73	2,67	0,20		236	5,94
Jar1	0,2	01-08-91	0,26	6	39,1	6,45	49	1,75	0,90	3,18	0,24		268	5,70
Jar2	0,2	01-08-91	0,23	3	35,5	5,17	0	1,20	0,71	2,84	0,24		263	5,87

mg/l Cl	µg/l Tot-N	µg/l NO3-N	µg/l Tot-P	µg/l PO4-P	µg/l Si	ppb Cd	ppb Cu	ppb Mn	ppb Ni	ppb Zn	ppb Pb	ppb Cr	ppb As
1,76		8			2,17								
					1,43		< 5	7	< 20	< 5			
1,12		6					35	5	< 20	28			
1,39		5			1,78	< 2,00	< 5	< 5	< 20	< 5			
1,51		13			1,65		5	< 5	< 20	6			
					1,48								
1,38	97	21					< 5	5	< 20	< 5			
1,48		15	6	1	1,58	< 0,10	< 5	5	< 5	< 5		0,53	< 0,30
1,52		18			1,56		< 5		7	23		0,31	< 0,30
1,75		3			1,77		< 5	< 5	< 5	28		0,33	< 0,30
1,67		11			1,08								
1,72		14			1,09		< 5	16	< 20	< 5			
1,66		6			1,19								
1,66	244	10			1,07								
1,71		13	17	5	1,22	< 0,10	7	11	< 5	8		0,56	< 0,30
1,69		12			1,09		< 5		21	26		0,45	< 0,30
1,02		3			1,11		< 5	12	< 5	29		< 0,30	< 0,30
2,81		9			1,11								
1,89		7			1,32								
					2,11								
3,94		3											
2,95		4			2,68	< 2,00	< 5	< 5	< 20	< 5			
3,85		3			1,42	< 2,00	< 5	< 5	< 20	< 5			
3,26		11			2,24	< 2,00	< 5	< 5	< 20	< 5			
2,87		5			1,31								
3,25		3			0,84	< 2,00	< 5	< 5	< 20	< 5			
3,95		15			0,24	< 2,00	< 5	< 5	< 20	< 5			
3,67		3			1,59		< 5	< 5	7	< 5		< 0,30	< 0,30
4,22		7			1,09								
4,43		11			1,16		15	< 5	79	15			
4,44		6			1,41								
4,49	31	18			1,42		10	< 5	< 20	9			
4,45		12	5	1	1,52	< 0,10	18	< 5	7	19		< 0,30	< 0,30
4,38		18			1,64		12		< 5	12		< 0,30	< 0,30
3,86		4			1,57		< 5	< 5	6	5		< 0,30	< 0,30
3,93		7			2,07								
4,16		3			1,59								
5,13		3			1,71		17	< 5	< 20	13			
5,16		7			0,80								
4,45		12			0,61		8	8	< 20	10			
3,76		9			1,55								
4,98		10			1,62								
4,59		14			0,58		< 5	< 5	< 5	5		< 0,30	< 0,30
3,92		19			1,19		< 5	< 5	< 5	38		< 0,30	< 0,30
5,29		6			1,11		< 5	< 5	< 20	7		< 0,30	< 0,30
4,97		4			0,73								

Locality	Depth	Date	FTU Turb.	mg Pt/l Col.	µS/cm Cond	pH	µekv/l Alk	mg/l Ca	mg/l Mg	mg/l Na	mg/l K	mg/l Fe	µekv/l SSS	mg/l SO4
Jar3	0,2	01-08-91	0,26	2	33,5	5,36	0	1,08	0,70	2,71	0,25		244	5,32
Jar4	0,2	24-07-91	0,38	2	34,0	5,27	0	1,08	0,75	2,67	0,23		251	5,81
Jar5	0,2	24-07-91	0,42	2	34,3	4,70	0	0,75	0,58	2,47	0,18		233	5,02
Jar6	0,2	24-07-91	0,25	2	38,1	5,53	0	1,32	0,85	3,05	0,35		284	6,57
Jar7	0,2	23-07-91	0,16	2	34,6	5,51	0	1,24	0,75	2,75	0,24		254	5,97
Ho	0,2	02-07-91	0,36	2	41,2	6,47	42	1,93	0,98	3,26	0,43		302	6,60
Ho-i	0,2	06-09-90	0,22	5	41,1	6,42	47	1,75	0,97	3,35	0,33		284	6,19
Ho-i	0,2	09-09-91												
Ho-i	0,2	07-09-92	0,46	9	39,0	6,38	40	1,64	0,97	3,36	0,29		280	5,61
Ho-o	0,2	06-09-90	0,22	5	41,6	6,35	33	1,90	0,96	3,23	0,33		296	6,67
Ho-o	0,2	07-09-92	0,25	5	40,4	6,38	42	1,87	0,99	3,28	0,30		292	6,04
Ho-s2	0,2	06-09-90	0,28	5	46,2	6,53	54	1,98	1,15	3,82	0,45		320	7,02
Ho-s2	0,2	07-09-92	0,32	7	44,9	6,56	56	1,86	1,21	3,80	0,39		317	6,47
Ho-s3	0,2	06-09-90	0,16	8	50,6	6,81	120	3,19	1,20	3,34	0,39		308	8,49
Ho-s3	0,2	09-09-91												
Ho-s3	0,2	07-09-92	0,36	7	38,9	6,41	41	2,21	0,88	2,97	0,26		270	6,96
Ho-s4	0,2	06-09-90	0,33	4	38,7	6,13	24	1,85	1,04	2,90	0,33		274	7,57
Ho-s4	0,2	09-09-91	0,30	4	39,3	6,37	35	1,75	0,85	2,98	0,31		267	6,10
Ho-s4	0,2	07-09-92	3,00	4	38,4	5,69	33	1,97	0,87	3,03	0,28		278	6,92
Ho-s5	0,2	06-09-90	0,19	4	38,2	6,36	38	1,78	0,85	2,93	0,29		263	6,29
FS-i	0,2	05-09-90	0,22	6	42,6	6,47	52	1,94	0,95	3,46	0,36		286	6,39
FS-i	0,2	07-09-92	0,34	5	37,2	6,13	21	1,44	0,88	3,26	0,26		282	5,79
FS-o	0,2	05-09-90	0,30	6	40,9	6,40	45	1,77	0,96	3,30	0,34		276	6,05
FS-o	0,2	09-09-91												
FS-o	0,2	07-09-92	0,26	8	38,9	6,36	42	1,62	0,96	3,35	0,29		279	5,54
FS-s	0,2	06-09-90	0,26	12	41,8	6,43	63	1,74	1,13	3,32	0,35		277	6,19
AS	0,2	02-07-91	0,32	4	44,0	6,65	61	2,37	1,04	3,40	0,38		309	6,93
AS-o	0,2	05-09-90	0,22	5	43,8	6,53	59	2,27	1,01	3,39	0,37		299	6,87
AS-o	0,2	09-09-91												
AS-o	0,2	07-09-92	0,32	6	43,6	6,55	63	2,17	1,06	3,46	0,34		303	6,38
AS-s	0,2	05-09-90	0,38	17	41,7	6,42	76	1,94	1,09	3,35	0,24	64	270	5,98
FH-i	0,2	28-06-90	0,36	5	35,6	5,21	0	1,13	0,72	2,98	0,23		259	5,50
FH-i	0,2	09-09-91												
FH-i	0,2	07-09-92	0,26	5	35,2	5,35	0	1,21	0,74	3,09	0,19		266	5,21
FH-o	0,2	28-06-90	0,36	2	35,2	5,11	0	0,95	0,71	2,92	0,23		253	5,41
FH-o	0,2	05-09-90	0,40	2	35,5	5,08	0	1,00	0,71	2,88	0,24		258	5,53
FH-o	0,2	09-09-91												
FH-o	0,2	07-09-92	0,20	1	35,1	5,17	0	1,02	0,76	3,06	0,21		263	5,12
AH-o	0,2	05-09-90	0,44	5	36,5	5,22	0	1,96	0,76	2,98	0,24		267	5,71
Hor-i	0,2	02-07-91	0,43	8	35,0	6,37	38	1,58	0,85	2,87	0,32		251	5,66
Kob	0,2	02-07-91	0,60	2	37,3	6,17	25	1,65	0,85	3,00	0,35		276	6,07
Li	0,2	27-06-90	0,49	7	34,3	5,51	6	1,26	0,75	2,85	0,23		249	5,43
Li-i	0,2	27-06-90	1,40	37	38,5	5,54	18	1,52	0,85	3,22	0,16	66	271	5,89
Li-i	0,2	03-09-90	7,80	27	42,1	5,35	0	1,66	0,95	3,48	0,13	34	311	7,10
Li-o	0,2	27-06-90	0,46	7	34,6	5,43	1	1,26	0,74	2,84	0,24		252	5,50
Li-o	0,2	03-09-90	5,30	8	36,0	5,34	0	1,29	0,76	2,83	0,24		262	5,84
Li-s	0,2	27-06-90	0,80	11	33,8	5,37	5	1,24	0,74	2,87	0,21		243	5,24

mg/l Cl	µg/l Tot-N	µg/l NO3-N	µg/l Tot-P	µg/l PO4-P	µg/l Si	ppb Cd	ppb Cu	ppb Mn	ppb Ni	ppb Zn	ppb Pb	ppb Cr	ppb As
4,69		5			0,87								
4,59		5			0,30								
4,54		4			0,75								
5,19		3			0,15								
4,59		6			0,47								
5,78		13			0,66								
5,48		7			0,96								
					0,97	< 2,00	< 5	< 5	< 20	< 5			
5,76		9					< 5	< 5	< 20	< 5			
5,57		3			0,98								
5,83		18			0,98	< 2,00	< 5	< 5	< 20	< 5			
6,14		4			0,99								
6,43		8			1,20	< 2,00	< 5	< 5	< 20	< 5			
4,64		7			1,21								
					1,98	< 2,00	< 5	< 5	< 20	8			
4,37		19					< 5	< 5	< 20	12			
4,13		4			1,49								
4,97		2			1,34	< 2,00	< 5	< 5	< 20	9			
3,70		15			1,05		< 5	< 5	< 20	< 5			
4,66		8			1,38								
5,42		3			1,24	< 2,00	< 5	< 5	< 20	< 5			
5,66		26			1,15	< 2,00	< 5	< 5	< 20	< 5			
5,31		6			0,91								
					0,95	< 2,00	< 5	< 5	< 20	< 5			
5,74		21					< 5	< 5	< 20	< 5			
5,24		3			0,97								
5,83		3			0,82	< 2,00	< 5	< 5	< 20	< 5			
5,49		7			0,99								
					1,06	< 2,00	< 5	< 5	< 20	< 5			
5,96		22					< 5	< 5	< 20	< 5			
5,14		4			1,09								
5,10		2			1,66	< 2,00	< 5	< 5	< 20	< 5			
					0,52	< 2,00	< 5	15	< 20	8			
5,57		7					< 5	11	< 20	< 5			
4,97		3			0,63								
5,05		0			0,47	< 2,00	< 5	62	< 20	7			
					0,43	< 2,00	< 5	57	< 20	6			
5,53		8					< 5	46	< 20	5			
5,23		6			0,48								
4,69		9			0,48	< 2,00	< 5	15	< 20	6			
5,15		51			1,07								
4,81		5			0,96								
5,23		3			0,39	< 2,00	< 5	8	< 20	5			
5,77		6			0,17	< 2,00	< 5	7	< 20	6			
4,87		5			0,11	< 2,00	< 5	8	< 20	6			
4,96		3			0,36	< 2,00	< 5	9	< 20	6			
4,71		5			0,20	< 2,00	< 5	6	< 20	6			

Locality	Depth	Date	FTU Turb.	mg Pt/l Col.	µS/cm Cond	pH	µekv/l Alk	mg/l Ca	mg/l Mg	mg/l Na	mg/l K	mg/l Fe	µekv/l SSS	mg/l SO4
Li-t1	0,2	27-06-90	1,50	16	32,1	5,48	10	1,18	0,71	2,76	0,15		230	5,14
Li-t1	0,2	03-09-90	0,68	6	34,1	4,74	0	0,82	0,68	2,49	0,18		239	5,32
Li-t2	0,2	27-06-90	0,45	2	36,6	4,67	0	0,75	0,63	2,42	0,21		236	5,49
Li-t2	0,2	03-09-90	0,56	4	37,3	4,72	0	0,81	0,70	2,56	0,21		251	5,69
Li-t3	0,2	27-06-90	0,96	3	33,2	4,91	0	0,94	0,66	2,51	0,20		227	4,88
Li-t3	0,2	03-09-90	0,80	3	41,1	4,55	0	0,73	0,65	2,49	0,22		259	6,22
Li-t4	0,2	27-06-90	0,64	4	31,6	4,90	0	0,84	0,61	2,39	0,20		210	4,40
Da-i	0,2	27-06-90	0,33	8	34,6	5,53	3	1,34	0,74	2,88	0,22		251	5,49
Da-o	0,2	27-06-90	0,56	7	35,3	5,59	6	1,31	0,79	2,91	0,26		258	5,64
Da-o	0,2	04-09-90	2,80	7	35,7	5,55	0	1,30	0,80	2,89	0,26		262	5,73
Da-s	0,2	27-06-90	4,20	13	56,4	6,15	215	5,78	0,76	3,08	0,75		258	6,12
Russian-Finnish Border														
Por-o	0,2	29-08-92	39,00	19	55,1	6,96	301	6,57	1,03	1,94	0,61		202	6,32
Koh-s	0,2	29-08-92	0,74	39	30,8	6,85	180	3,07	0,87	1,50	0,55		105	3,02
Pul-s	0,2	27-08-92	0,52	22	28,3	6,76	152	2,51	0,95	1,28	0,40		102	3,26
Vi	0,2	29-08-92	1,40	34	26,3	6,65	125	2,07	1,05	1,29	0,34		108	3,45
Koc	0,2	25-08-92	0,76	26	31,6	6,78	190	3,10	1,05	1,33	0,41		101	3,52
Koc-i	0,2	27-08-92	0,30	39	32,0	6,79	185	3,28	0,94	1,57	0,37		115	3,72
Mad-s	0,2	26-08-92	0,72	35	30,0	6,70	173	2,83	1,06	1,33	0,39		103	3,24
Ont-o	0,2	26-08-92	0,34	33	29,1	6,73	160	2,48	0,99	1,53	0,36		104	3,35

mg/l Cl	µg/l Tot-N	µg/l NO3-N	µg/l Tot-P	µg/l PO4-P	µg/l Si	ppb Cd	ppb Cu	ppb Mn	ppb Ni	ppb Zn	ppb Pb	ppb Cr	ppb As
4,33		4			0,31	< 2,00	< 5	7	< 20	5			
4,51		4			0,33	< 2,00	< 5	< 5	< 20	5			
4,30		2			0,06	< 2,00	< 5	11	21	6			
4,69		2			0,09	< 2,00	< 5	19	< 20	9			
4,42		4			0,06	< 2,00	< 5	13	< 20	6			
4,59		3			0,31	< 2,00	< 5	14	< 20	6			
4,18		0			0,06	< 2,00	< 5	18	< 20	7			
4,85		3			0,18	< 2,00	< 5	10	< 20	6			
4,97		4			0,21	< 2,00	< 5	6	< 20	< 5			
5,07		0			0,69	< 2,00	< 5	6	< 20	7			
4,56		29			0,74	< 2,00	< 5	< 5	< 20	5			
					2,85	< 2,00	7	< 5	< 20	27			
2,44		15			1,56		< 5	< 5	< 5	6		< 0,30	< 0,30
1,46		14			2,63		< 5	5	< 5	6		< 0,30	< 0,30
1,19		12			1,83		< 5	10	< 5	5		< 0,30	< 0,30
1,26		10			1,93		< 5	10	< 5	5		< 0,30	< 0,30
0,96		10			2,06		< 5	6	< 5	36		0,32	< 0,30
1,31		13			3,96		< 5	< 5	< 5	7		0,38	< 0,30
1,24		10			2,58		< 4	6	< 5	6		0,34	< 0,30
1,19		10			4,09		< 5	< 5	< 5	8		0,44	< 0,30

Appendix 4. *Zooplankton species present in the lakes 1990-1992.*

For Copepoda: E.g.= Eudiaptomus gracilis, E.go.=Eudiaptomus graciloides,
A.t.= Acanthodiaptomus tibetanus, H.a.= Heterocope appendiculata, C. C.a= Cyclops abyssorum, M.l.= Mesocyclops leuckarti.
For Cladocera: H.g.= Holopedium gibberum, B.ls.= Bosmina longispina,
B.lr.= Bosmina longirostris, D.c.= Daphnia cristata, D.lr.= Daphnia longiremis,
D.ls. =Daphnia longispina, D.g.= Daphnia galeata, C.q.= Ceriodaphnia quadrangula, B.lm.= Bythotrephes longimanus,
L.k.=Leptodora kindti.

			COPEPODA							CLADOCERA									
Region	Loc	Year	E.g	E.go.	A.t.	H.a.	C.s.	C.a.	M.l.	H.g.	B.ls.	B.lr.	D.c.	D.lr.	D.ls.	D.g.	C.q.	B.lm.	L.k.
Nikel Region																			
	LN1	91.92		x															
	LN2	90.91.92		x							x								
	LN3	91.92		x															
	Sa	90.91.92		x			x				x				x	x		x	
	Sh	92	x			x	x			x	x				x	x		x	
	Ni	92	x			x	x	x		x	x	x	x						
	Al	92	x			x	x			x	x	x	x					x	
	Ro	92		x		x	x			x	x			x		x			
Pechenga River System																			
	Ma	90.91.92		x			x			x	x				x	x		x	x
	Tr	92		x			x			x	x				x	x			
	Lh	92		x			x			x	x								
Pasvik River System																			
	Ku-1	90.91.92	x			x	x	x	x		x	x	x						x
	Ku-2	91.92	x				x		x		x	x	x						x
	Ku-3	90.91.92	x			x	x		x		x	x	x						x
	Ku-4	91.92	x				x	x			x	x	x						x
	Ku-5	91.92	x				x				x	x	x						x
	Sv-1	90	x			x	x		x	x	x	x	x				x		
	Sv-2	90	x			x	x		x	x	x	x	x				x		
	Sk	90.91	x			x	x			x	x	x	x				x		x
	Ly	90.91.92	x			x	x		x	x	x	x	x				x		x
	Ru	91.92	x			x	x	x	x	x	x	x	x		x		x		x
Jarfjord Region																			
	Ot	90		x		x	x			x	x			x					
	Ur	92		x	x		x	x		x	x				x	x		x	
	Ko	91		x		x	x			x	x							x	
	SS	91.92		x			x	x		x	x				x	x			
	Du	91		x		x	x	x		x	x				x	x			
	Rv	91		x			x			x	x	x		x					
	ØG	92		x			x			x	x							x	
	AG	92		x			x			x	x			x	x	x			
	Ho	91		x			x			x	x				x	x		x	
	AS	90.91		x			x	x		x	x				x	x		x	
	FH	90					x			x	x							x	x
	Li	90		x		x	x			x	x								
	Da	90		x		x	x		x	x	x							x	
Russian-Finnish Border																			
	Koc	92		x		x	x		x	x	x			x	x	x			
	Vi	92	x			x	x			x	x	x		x	x	x			

Appendix 5. *Fish species present in the different lakes and streams 1990-1992.*

localities\species	Salmo trutta	Salvelinus alpinus	Coregonus lavaretus	Coregonus albula	Thymallys thymallus	Perca fluviatilis	Phoxinus phoxinus	Esox lucius	Lampetra fluviatilis	Lota lota	Gastrosteus aquleatus	Pungitus pungitus
Nikel Region												
Kolosyoki							x					
Pachtayoki	x											x
Sarasslaki	x	x										
Shuoniyoki	x						x	x		x	x	
Kuvernerinyoki	x						x					
Rousenyarvi	x	x									x	
Pechenga Riv. Sys.												
Maayarvi	x					x	x	x		x		
Naamiyoki	x											
Chaukilampiyoki	x							x			x	
Trifonayarvi												
Pasvik Riv. Sys.												
Kuetsyarvi	x		x		x	x	x	x		x	x	x
Lyngbukta/Ruskvatn	x		x	x	x	x	x	x	x	x	x	x
Jarfjord Region												
Otervatn	x										x	
Urdfjellvatn	x	x										
St.Skardvatn	x	x										
Durvatn	x	x										
Rundvatn	x											
T. Guokkolobbalat	x	x										
A. Guokkolobbalat		x										
F. Guokkolobbalat		x										
Lake Jarfjord 1-7	x	x										
Holmvatn	x	x										
F. Skardvatn	x	x										
A. Skardvatn	x	x										
F. Høgfjellsvatn	x											
Limgambergtjern	x										x	
Dalvatn	x	x									x	
Rus.-Fin. Border												
Poriyarvi	x							x				
Kohisevaniyoki	x						x					
Puldkasjyoki	x						x					
Virtuovoshyavr			x			x	x	x		x		
Kocheyarv	x		x		x	x	x	x		x		x
Madsasjyoki	x						x			x		
Ontasjyavr	x						x	x				

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