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forskningsrapport

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## I. Preliminary study in 1990

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NINA

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# Abstract

Nøst, T., Yakovlev, V., Berger, H.M., Kashulin, N., Langeland, A., Lukin, A. & Muladal, H. 1991. Impacts of pollution on freshwater communities in the border area between Russia and Norway. I. Preliminary study in 1990. - NINA Scientific report 26: 1-41.

The aim of this preliminary study during 1990 was to assess the present state of freshwater communities both on Russian and Norwegian territories. Zooplankton, zoobenthos and fish were sampled in different localities in the border areas.

Severe impacts upon freshwater communities have been documented, especially near the factories in Nikel and Zapolyarny. Negative impacts on the Norwegian side, and on areas at longer distances from the Russian side are related to this pollution.

Heavy metal accumulation and pathological anomalies in fish and a low diversity of invertebrates were observed. Indications of acidification impacts were only recorded within the Jarfjord Region.

More intensive studies in the border areas are necessary to quantify the impacts of pollutants, especially with respect to heavy metal contamination and sublethal effects on fish and invertebrates.


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

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# Резюме

Ност Т., Яковлев В., Бергер Х.М., Кашулин Н., Лангеланд А., Лукин А., и Муладал Х. 1991. Влияние загрязнения на пресноводные сообщества в приграничном районе СССР и Норвегии.
1. Предварительное изучение в 1990 г. - НИНА, Научный отчет 26: 1-41.

Целью данного предварительного изучения в 1990 году было выявление современного состояния пресноводных сообществ как на советской, так и на норвежской территориях. В приграничном районе из разных мест были собраны пробы зоопланктона, зообентоса и рыб.

Некоторые воздействия на пресноводные сообщества, особенно в районе Никеля и Заполярного были зафиксированы. Негативные влияния на норвежской стороне, а также в районах на большом расстоянии от источников на советской стороне связаны также с загрязнением.

Отмечалось накопление тяжелых металлов и патологические аномалии у рыб, а также низкое разнообразие беспозвоночных. Показатели влияния закисления (ацидофикации) отмечено только в районе Ярвфиорда.

Необходимы более интенсивные исследования в пограничных районах с тем, чтобы охарактеризовать количественно влияние загрязнителей, особенно в связи с воздействием тяжелых металлов и сублетальное воздействие на рыб и беспозвоночных.


Ключевые слова: пресноводные сообщества, загрязнение, пограничный район, СССР и Норвегия.

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# Preface

The impact of pollution on the environment of the Kola Peninsula has increased during the last decades due to several mining factories and metallurgical industries. Recently there has been a considerable focus on the effects of pollutants on the environment and human health. As a consequence a bilateral agreement on environmental problems between the USSR and Norway was established in 1988. In accordance with this agreement, a cooperative study on freshwater communities in the border areas was started in 1990. Participitating institutions were:

Norwegian Institute for Nature Research (NINA), Trondheim - Norway.
Akvaplan-Niva, Tromsø - Norway
Institute of the North Industrial Ecology Problems Kola Science Centre, (INEP), Academy of Sciences of the USSR, Apatity - Russia.

This report present the results of field investigations in 1990 in two periods; June 25 - July 14, and August 27 - September 7.

In addition to the authors several persons have contributed to this study:

| | |
|---|---|
| N. Yakovleva | INEP, Russia |
| B.M. Larsen | NINA, Norway |
| S. Lierhagen | NINA, Norway |
| J.B. Breistein | NINA, Norway |
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Trondheim, Desember 1991

# Contents



# 1 Introduction

In the border area between the Russia and Norway, the Pechenga nickel factories in the Russian towns Nikel and Zapolyarny are the main sources of pollutants. Emissions mainly contain sulphuric gases, heavy metals and dust. As a result of the long-term pollutants impact on the Pechenga area of Murmansk Region, damage to the terrestrial and water ecosystems is obvious. Elevated concentrations of pollutants in the atmosphere and effects on vegetation are observed even in the border areas of Norway.

The aim of this first joint study was to assess the present state of freshwater communities both on Russian and Norwegian territories. This report presents species composition, abundance and biomass of the invertebrate and fish communities, pathological state and levels of heavy metal accumulation in the fish. The object of this assessment program will continue: 1) in 1991-1992 to determine the impact of pollution from the Pechenga nickel factories on freshwater biota both on Russian and Norwegian territories, and later on 2) to assess the causes in the freshwater biota following the process of reconstruction of the air purification systems of the factories.

# 2 Study area

The investigated area, divided into four regions, 1) Nikel Region, 2) Pechenga and 3) Pasvik River Systems and 4) Jarfjord Region (**Figure 1**), is located at latitude 69-70° N and longitude 29-31°E.

The geology is complex and consists of hard bedrock predominating in the Jarfjord Region and more soluble and richer (more Ca and Na) bedrock in the Nikel-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 1991a). The annual mean temperature in the border area is low ( 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 to the Baltic Sea. Mean annual runoff on the Pechenga area remains within the limits of 600-800 mm.

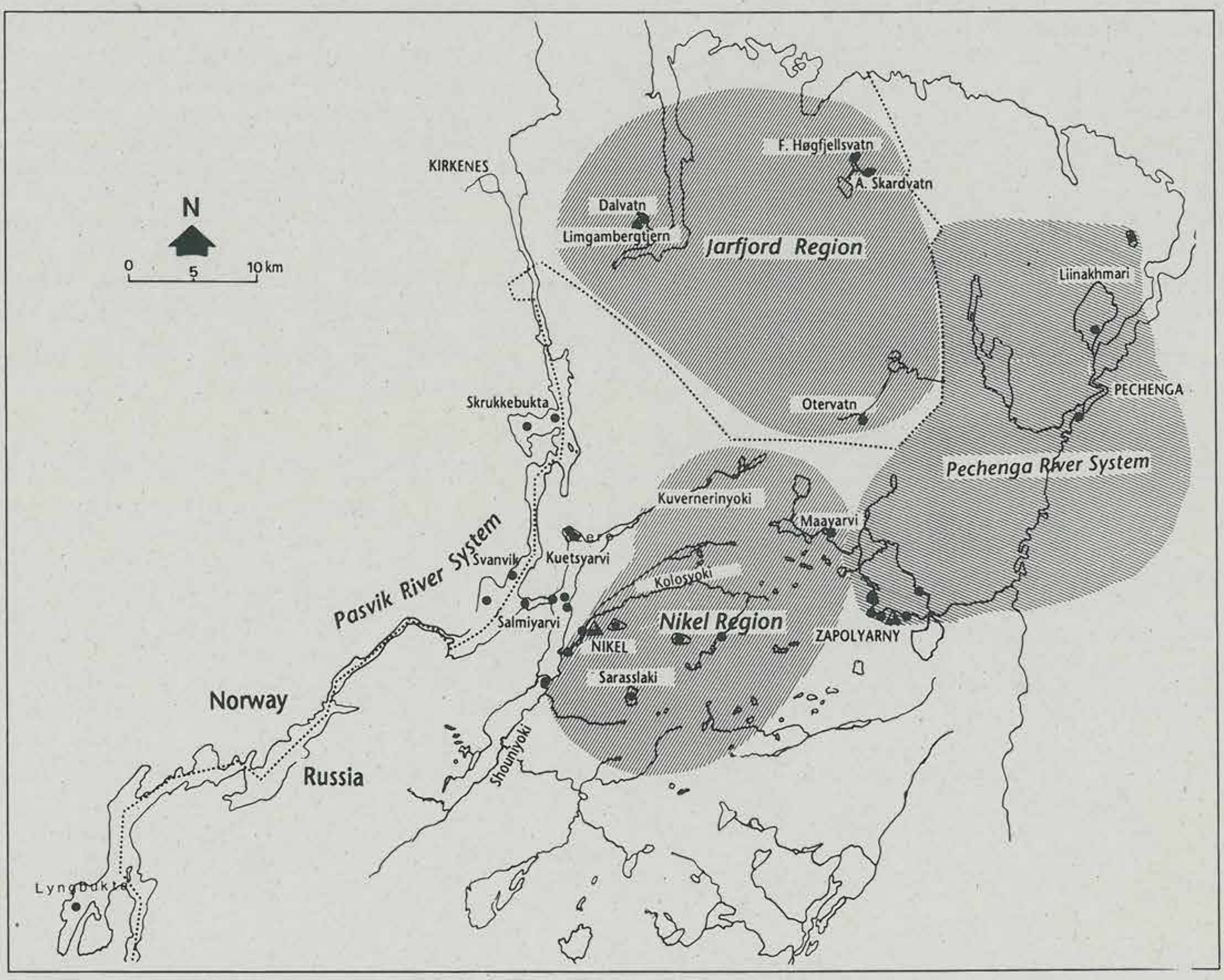


***Figure 1***
*The study areas near the Norwegian-Russian border (Nikel Region, Pechenga River System, Pasvik River System and Jarfjord Region).*

# 3 Load of pollutants

The load of pollution from the Pechenga nickel factories consist mainly of nickel (Ni), copper (Cu), sulphurdioxide ($SO_2$) and dusts (Hagen et al. 1990, Sivertsen 1990). As heavy metals are mostly deposited near their source, the gases may be transported longer distances and then precipitate as acid deposits. Dust ejected into the atmosphere is composed of nickel (3.13 %), copper (1.91 %), cobalt (0.114 %), sulphur ($S_2$) (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 $gm^{-2}$ $year^{-1}$. The minimum pH of precipitation in the Pechenga area is 3.4 (Kryuchkov & Makarova 1989).

The load of pollutants is different in the four study regions. The Pasvik River System drains the Nikel town area through Kuetsyarvi. In the three other regions pollutants are only transported through the air, except some streams near Zapolyarny and the Pechenga River. 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 gasses and dust. Dominating wind directions from the factories are mostly north-east, partly north and north-west. This means that the northeastern parts of Norway (incl. 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.

# 4 Sampling methods

## 4.1. Water chemistry

Water-samples were collected from 49 localities and analysed for 21 chemical parameters at NINA's laboratoryy by standard methods. Anions, kations and heavy metals were tested to sertificated standard solutions (**Appendix 1**).

## 4.2 Zooplankton

Zooplankton samples were taken in 3 lakes in the Pechenga nickel area, 6 localities in the Pasvik River System and 5 lakes in the Jarfjord Region during August/September 1990 (**Appendix 1**). In four of the Jarfjord lakes samples were also taken in late June.

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

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

## 4.3 Zoobenthos

Zoobenthos was sampled in different habitats (littoral and profundal zones of lakes, lake outlet/inlet, streams) and substrate, a total of 44 stations: 23 from the Pechenga nickel area, 12 from the Pasvik River System and 9 from the Jarfjord Region (**Appendix 1**).

In the profundal zones zoobenthos was collected with an Ekmann dredge (213 $cm^2$). Samples from the littoral zone and running waters were made by a kicking technique described by Frost et al.(1971). All samples were sieved through a net with mesh size 250 µm, and the animals were separated from the mud sample and preserved in 70 % ethanol.

Some biological indexes were obtained: Information theory diversity index (Shannon 1948), Biological Monitoring Working

Party; Score index (BMWP 1978) and ISO's Long Score Index (1983).

## 4.4 Fish

Electrofishing was performed in streams and inshore areas in lakes in August/September. In total 39 stations were sampled; 11 in the Pechenga nickel area, 1 in the russian side of the Pasvik River System and 27 in the Jarfjord Region (**Appendix 1**). Natural tip lengths of all fish captured were measured. Fish caught near Nikel were preserved in 70 % ethanol.

Fish were caught with a standard gillnet series, consisting of 8 fleets 10-45 mm (Rosseland et al. 1979) in 4 localities on Russian and 5 on Norwegian territory in August/September (**Appendix 1**). In four of the Jarfjord lakes test-fishing was also performed in July. For a comparison, test fishing was performed in Lake Kocheyavr situated 150 km south of Nikel near the Russia-Finland border.

The fish were analysed for: body length, weight, sex, gonad maturity, colour of flesh, fat content of intestine, and stomach fullness. For fish condition analysis, pathological and morphological examinations were performed and symptoms of diseases and parasitic infection were also examined for visually.

Heavy metal contents of tissues and organs were determined for the following fish species: brown trout, Arctic char, perch and pike. Subsamples for each species were collected from the gills, liver, kidneys, muscle and skeleton. Samples were placed in plastic bags and frozen quickly in liquid nitrogen for further examination at the laboratory. These samples were dryed to constant weight at 105 °C. Organic matter was removed using consentrated nitric acid ($HNO_3$). In organs and tissues, contents of nickel, copper, zinc, cobalt and manganese were determined by the atomic absorbtion method (AAS - 30 Karl-Zeiss-Jena). Scales, otoliths, shoulder- and opercular bones were collected for age determination in accordance to standard methods (Jonsson 1976, L`Abee-Lund 1985). Determination of different morphs of whitefish was performed according to a standard systematic method (Reschetnikov 1980). 10-20 fish from each species and locality were analysed for food habits. The stomach samples were preserved in 70 % ethanol.

# 5 Results

## 5.1. Water chemistry

In general higher values were found in Russian localities for most of the chemical parameters (**Appendix 2**). The range in pH was between pH 4.55 and 7.13 (**Figure 2**). The lower pH and the larger variation in the Jarfjord Region (4.55-6.55) reflects the more sensibility of acidification due to specific geological conditions. The lowest pH was measured at higher elevation with little or no soil and vegetation cover.

Levels for sulphate ($SO_4$) mainly ranged between 4 and 35 $mgSO_4$/l. The values on the Norwegian side never exceeded 8 $mgSO_4$/l (**Figure 2**). Extreme high values for sulphate were obtained in a few localities near Nikel, > 100 $mgSO_4$/l. Concentrations of calcium were lower than 3 mgCa/l in Norwegian lakes, except in the Pasvik River System (**Figure 2**). However, the values on Russian side in the Pasvik River System were 4 times higher than on the Norwegian side. High values for calcium (40-50 mgCa/l) were obtained in the localities near Nikel, similar to the sulphate measurements.

Due to the fact that the sampling bottles were not acid-washed before sampling, the values obtained for heavy metals (**Figure 2**) should be considered as minimium values. Contents of Ni in the Russian part of the Pasvik River System were between 50-80 µgNi/l and in the Pechenga nickel area 20-485 µgNi/l. On the Norwegian side the concentrations were less than 20 µgNi/l. The contents of copper were mostly less or slight above the detection limits, < 5 µgCu/l. One exception was the stream Shuoniyoki near Nikel, 33 µgCu/l. The zinc contents were less than 30 µgZn/l and minor differences between the regions were found. Generally the concentrations for manganese were lower than 5-10 µgMn/l, but values as high as 57 µgMn/l were found in Kuetsyarvi and F.Høgfjellsvatn (**Appendix 2**).

Concentrations for nitrate were in general lower than 10-20 $\mu gNO_3$/l (**Appendix 2**). In localities draining the town of Nikel, the contents of $NO_3$ (85-585 $\mu gNO_3$/l) were 10-100 times higher than in other localities.

## 5.2 Zooplankton

Zooplankton species composition is given in **Table 1**. Representatives of Rotatoria, Cladocera and Copepoda were recorded in all lakes, a total of 22 species (7 Rotatoria, 10

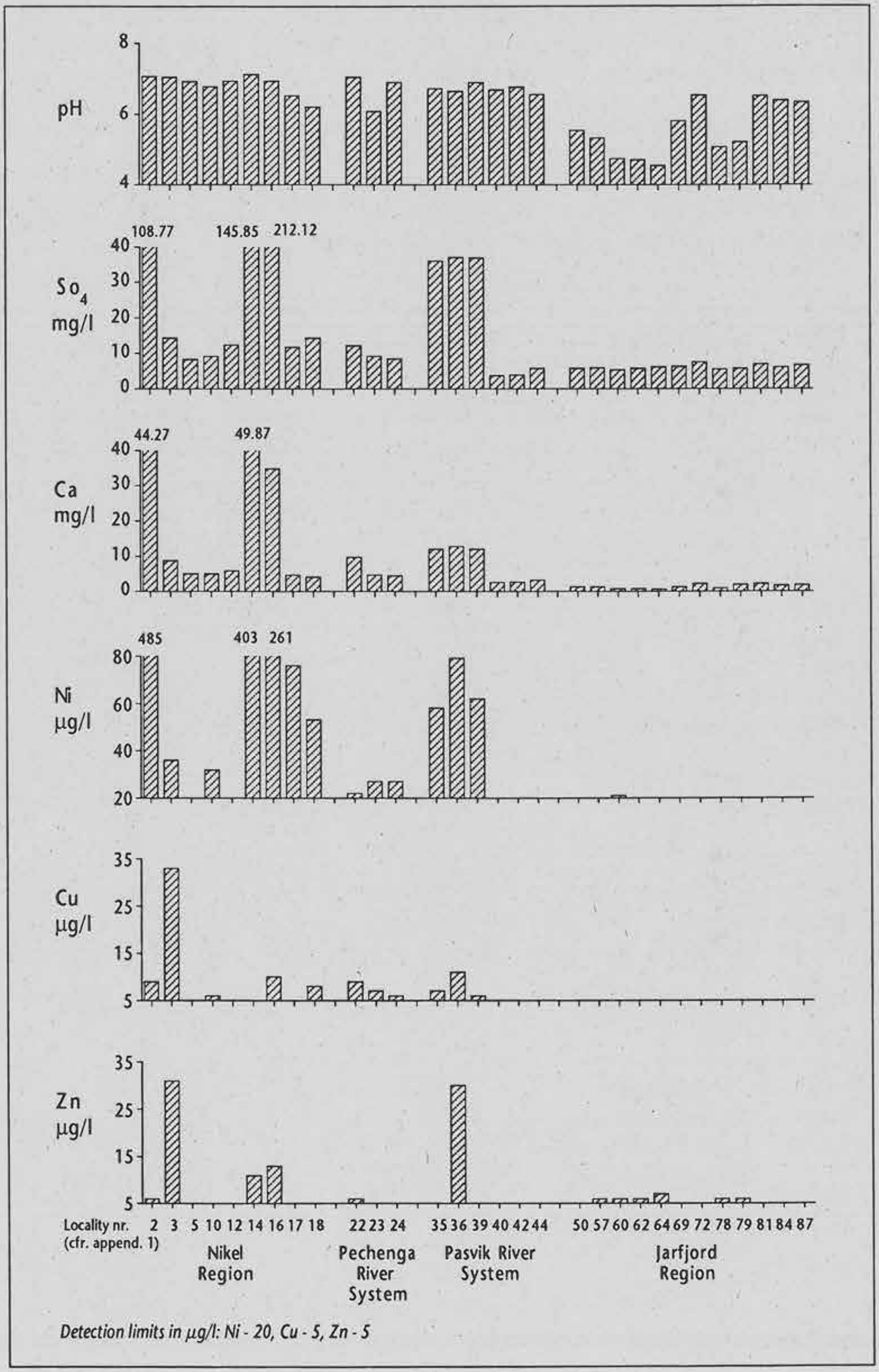


***Figure 2***
*Levels of some chemical parameters in water from different localities in August/September 1990.*

Cladocera and 5 Copepoda) was found. The lake situated near Nikel (LN2) differed from the others; only 3 species of rotifers and one species of Cladocera and Copepoda were found.

Most of the rotatorian species were found in all regions, but the number of species and their relative importance differed within each region (**Table 1**). Usually *Polyarthra vulgaris* was the most common species, except in the Jarfjord Region where *Kellicottia longispina* predominated in all lakes, except in F.Høgfjellsvatn.

The highest number of species of Cladocera and Copepoda were found in the Pasvik River System (**Figure 3**). Noteworthy is the lack of daphnids and diaptomids in some localities in the Nikel and Jarfjord Regions. *Daphnia cristata*, *Bosmina longirostris* and *Eudiaptomus gracilis* were restricted to the Pasvik River System.

***Table 1.*** *Zooplankton species present in the lakes.*
*Nikel Region: Sa1 = Sarasslaki, LN2 = Lake Nikel - NE 10 km*
*Pechenga River System: Ma 1 = Maayarvi*
*Pasvik River System: Ku1 and Ku3 = Kuetsyarvi, Ly = Lyngbukta, Sv1 and Sv2 = Svanvik, Sk1 = Skrukkebukta*
*Jarfjord Region: Da = Dalvatn, Li = Limgambergtjern, Ot = Otervatn, FH = F. Høgfjellsvatn, AS = A. Skardvatn*

| | Nikel Region | | Pechenga River System | Pasvik River System | | | | | | Jarfjord Region | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sa1 | LN2 | Ma1 | Ku1 | Ku3 | Ly | Sv1 | Sv2 | Sk1 | Da | Li | Ot | FH | AS |
| *Rotatoria* | | | | | | | | | | | | | | |
| Kellicottia longispina | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| Keratella cochlearis | | x | x | x | x | x | x | x | x | x | | x | x | |
| Keratella hiemalis | | | x | x | x | | | | | x | | x | x | x |
| Conochilus unicornis | x | | x | x | x | x | x | x | x | | x | x | | x |
| Asplanchna priodonta | | | | x | x | x | x | x | x | x | x | x | | |
| Polyarthra vulgaris | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| Synchaeta sp. | | | | x | x | | | | | | | | | |
| Rotatoria indet. | x | | x | x | x | x | x | x | x | | | x | | |
| *Cladocera* | | | | | | | | | | | | | | |
| Holopedium gibberum | | | x | | | x | x | x | x | x | x | x | x | x |
| Bosmina longispina | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| Bosmina longirostris | | | | x | x | x | x | x | x | | | | | |
| Daphnia cristata | | | | x | x | x | x | x | x | | | | | |
| Daphnia longiremis | | | | | | | | | | | | x | | |
| Daphnia longispina | x | | | | | | | | | | | | | x |
| Daphnia galeata | x | | x | | | | | | | | | | | |
| Ceriodaphnia quadrangula | | | | | | x | x | x | | | | | | |
| Bythotrephes longimanus | x | | x | | | | | | | x | | | x | |
| Leptodora kindti | | | x | x | x | x | | | x | | | | x | |
| *Copepoda* | | | | | | | | | | | | | | |
| Eudiaptomus graciloides | x | x | x | | | | | | | x | x | x | | x |
| Eudiaptomus gracilis | | | | x | x | x | x | x | x | | | | | |
| Heterocope appendiculata | | | | x | x | x | x | x | x | x | x | x | | |
| Cyclops scutifer | x | | x | x | x | x | x | x | x | x | x | x | x | x |
| Mesocyclops leuckarti | | | | x | x | x | x | x | | x | | | | |

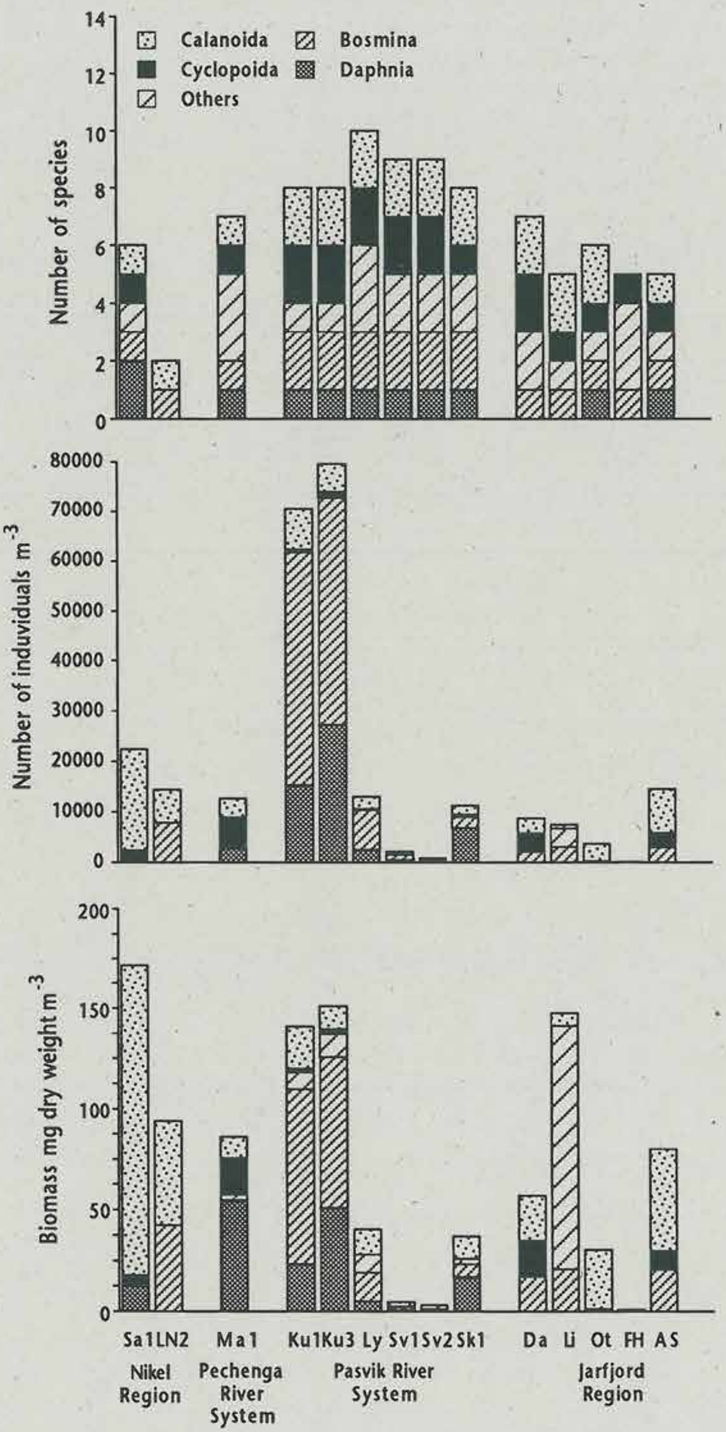


**Figure 3**

*Zooplankton communities in the lakes; number of species present, abundances (ind. $m^{-3}$) and biomasses (mg dry weight $m^{-3}$).*

Very high zooplankton numbers and biomass were recorded in Kuetsyarvi (**Figure 3**), with *Bosmina longirostris* the dominating species. In general, these levels were low in the other localities, especially at the Svanvik locality and lake F.Høyfjellsvatn. In the lakes Limgambergtjern and Sarasslaki the recorded biomasses of 147 and 171 mg $m^{-3}$ respectively, were similar or even higher. This was due to high individual size of the cladocerans. Minimum sizes of eggbearing females and maximum size of the cladocerans were highest in these two lakes and in Maayarvi. However, the clutch size in these lakes was rather small (3-5 eggs per female).

## 5.3. Zoobenthos

Most of the zoobenthos belong to the taxa Chironomidae (**Table 2**). In general, Ephemeroptera, Plecoptera and Trichoptera showed highest diversity in the littoral zone, while Chironomidae dominated in the profundal zone of lakes. Running waters were inhabited mainly by phytophilic and lythophilic specimens.

### 5.3.1. Lakes

Kuetsyarvi showed the highest diversity of all the water bodies studied (**Table 2, Figure 4**). The number of species recorded

**Table 2.** *Zoobenthos present in different localities. Number of species of the main taxa. Locality description is given in Appendix 1.*

| | Nikel Region | | | | | | | Pechenga River System | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Taxa | Kol | Shu | Kuv | Sa | PaS | LN1 | LN2 | Ma | ChL | ChO | Chs | SS | NS | Pr | LL | TrL |
| Oligochaeta | 1 | 1 | 1 | 3 | 0 | 0 | 3 | 1 | 2 | 0 | 0 | 1 | 2 | 0 | 5 | 0 |
| Mollusca | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 2 | 2 | 1 | 1 |
| Ephemeroptera | 0 | 5 | 4 | 1 | 0 | 0 | 0 | 3 | 0 | 1 | 0 | 0 | 6 | 1 | 1 | 0 |
| Plecoptera | 0 | 5 | 5 | 2 | 2 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 6 | 2 | 2 | 0 |
| Trichoptera | 3 | 9 | 2 | 4 | 2 | 0 | 0 | 7 | 1 | 6 | 0 | 0 | 2 | 1 | 6 | 3 |
| Chironomidae | 12 | 4 | 9 | 22 | 1 | 1 | 2 | 17 | 6 | 3 | 7 | 2 | 15 | 11 | 10 | 8 |
| Other taxa | 6 | 0 | 2 | 2 | 0 | 2 | 2 | 5 | 1 | 3 | 2 | 0 | 6 | 1 | 2 | 3 |
| Tot. number of species | 22 | 24 | 23 | 34 | 5 | 3 | 7 | 38 | 10 | 13 | 9 | 3 | 39 | 18 | 27 | 15 |

| | Pasvik River System | | | | Jarfjord Region | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Taxa | Ku | Sal | Sv | SK | Da | DaO | Li | LiO | Ot | OtO | FH | FHO |
| Oligochaeta | 4 | 0 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 |
| Mollusca | 6 | 2 | 2 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 |
| Ephemeroptera | 0 | 0 | 2 | 0 | 1 | 1 | 1 | 0 | 1 | 5 | 1 | 0 |
| Plecoptera | 2 | 0 | 1 | 0 | 1 | 4 | 2 | 1 | 1 | 6 | 2 | 1 |
| Trichoptera | 9 | 5 | 6 | 1 | 2 | 3 | 1 | 3 | 1 | 1 | 2 | 1 |
| Chironomidae | 48 | 15 | 24 | 7 | 5 | 3 | 3 | 1 | 4 | 1 | 3 | 2 |
| Other taxa | 4 | 1 | 1 | 0 | 5 | 4 | 4 | 2 | 5 | 3 | 2 | 3 |
| Tot. number of species | 73 | 23 | 38 | 11 | 15 | 16 | 12 | 8 | 14 | 17 | 11 | 8 |

from the littoral zone in Kuetsyarvi exceeded 20, dominant genera and species were: *Cricotopus* spp., *Procladius* spp. *Psectrocladius* spp.(Chironomidae), *Limnophilus* spp., *Oxyethira distinctella* (Trichoptera) and *Pisidium* spp. (Mollusca).

In the profundal zone of this lake the proportion of chironomids was 80-90 % of the total zoobenthos number and biomass (**Figure 5**). Maximum densities and biomass of zoobenthos in Kuetsyarvi were 4633 ind. $m^{-2}$ and 21.12 g $m^{-2}$ at the depth of 15 m, respectively (**Table 3**). Similar zoobenthos communities were also found in other parts of the Pasvik River System. However, Ephemeroptera and Plecoptera nymphs were not recorded in Salmiyarvi, where chironomids (mainly the phytophil larvae of *Orthocladiinae* and *Chironomini*) dominated. In biomass the mollusc *Lymnaea ovata* was the dominating species.

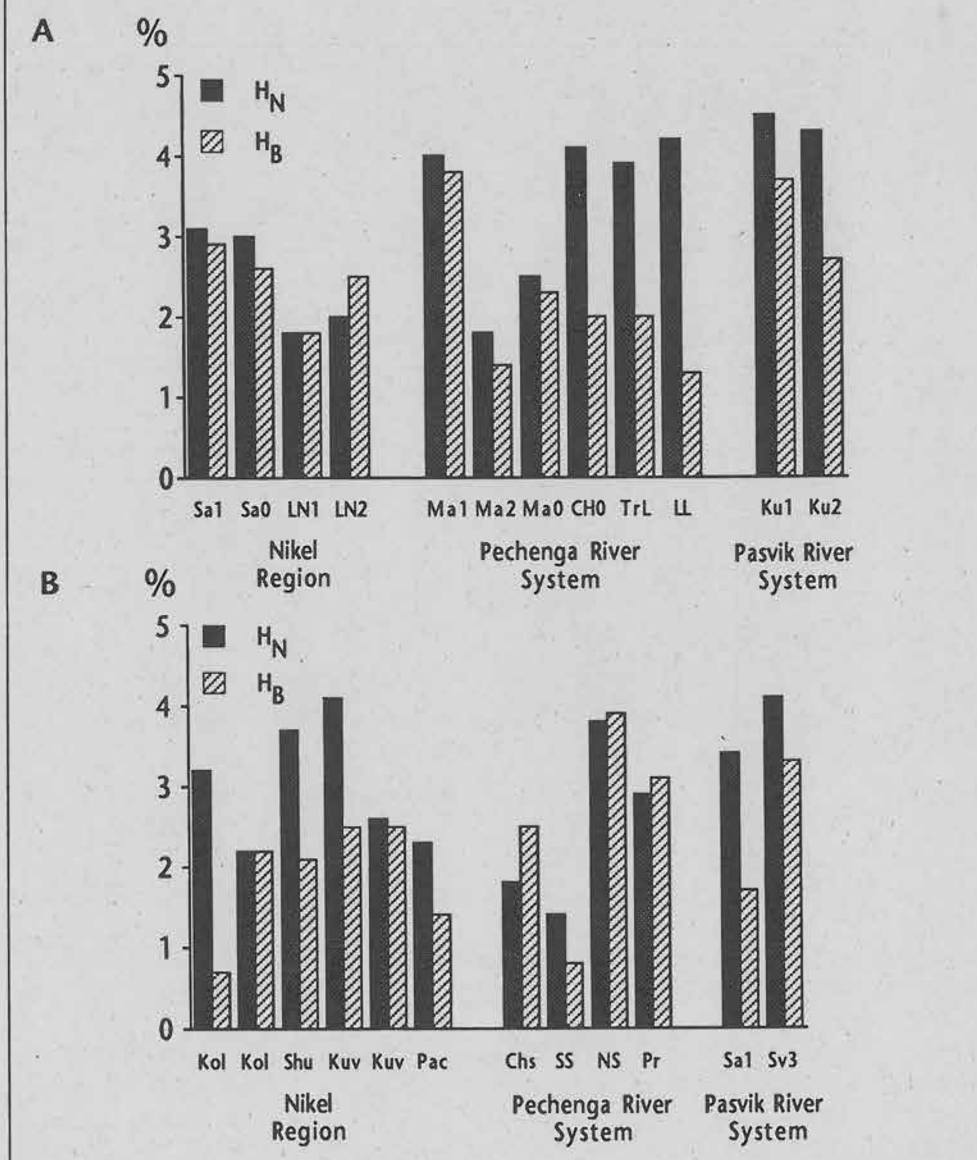


***Figure 4***
*The distribution of Shannon diversity index value. A- lakes and outlets, B- streams and rivers.*

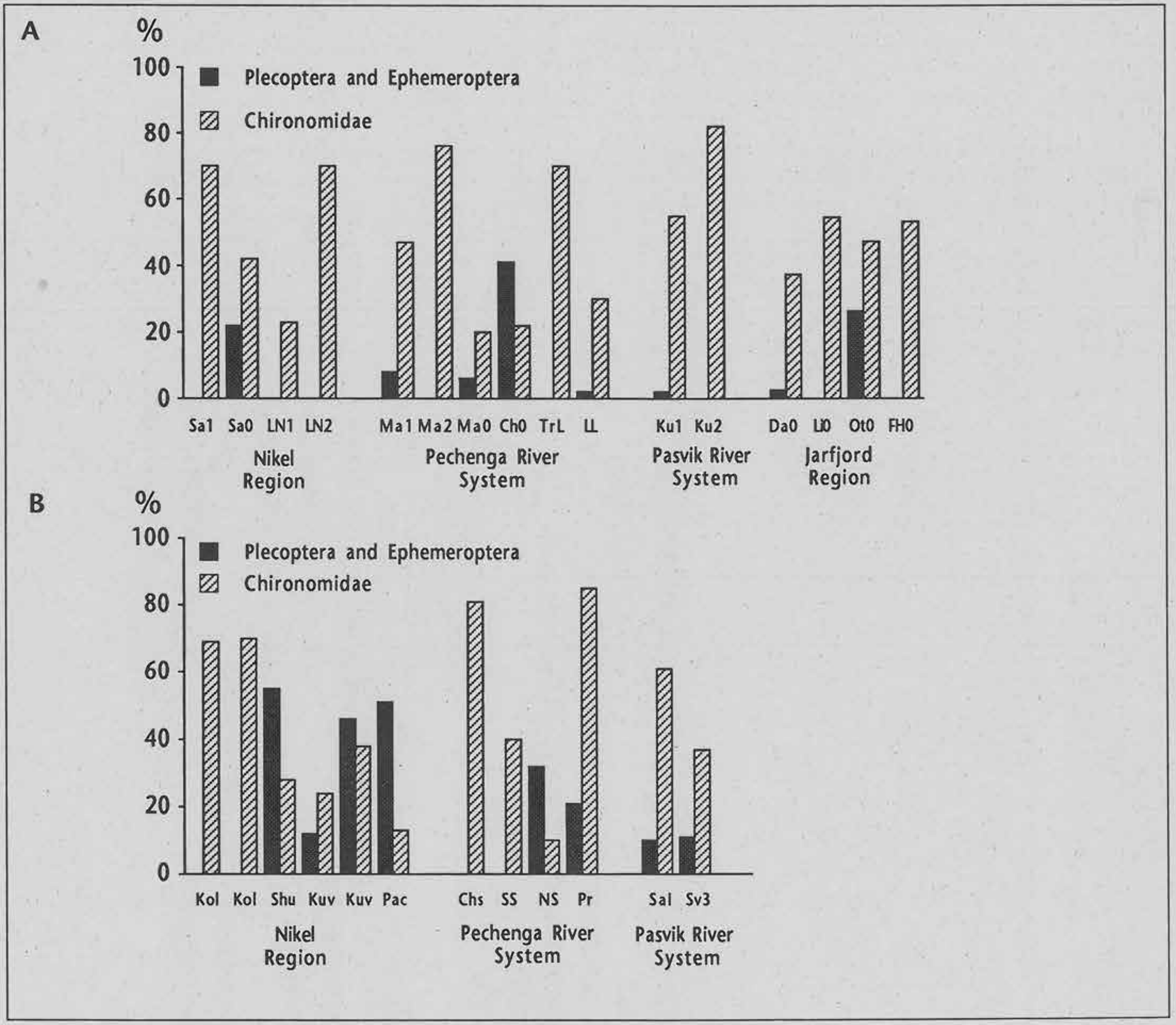


***Figure 5***

*Frequency (%) of pollution sensitive (Plecoptera and Ephemeroptera) and tolerant (Chironomidae) zoobenthos taxa in studied areas. A- lakes and outlets, B- streams and rivers.*

Along the shore at Svanvik the dominant species were: *Lumbriculus variegatus*, *Caenis* sp, *Tanypodinae* spp., *Sialis* sp. The Shannon index of species diversity had a very high value - 4.09 (by number) (**Figure 4**). With increasing depths the number of chironomids increased. In Skrukkebukta the zoobenthos diversity was low.

In the Nikel Region a low abundance was recorded in Sarasslaki (mean biomass for the profundal 0.49 g $m^{-2}$). Trichoptera made the greatest contribution. A similar low abundance was obtained for the zoobenthos in Maayarvi.

*Table 3. Abundance (ind. $m^{-2}$) and biomass (g fresh weight $m^{-2}$) of zoobenthos in the lakes in June - September 1990 using Ekman grab. Biomass values in parenthesis. Lake description is given in Appendix 1.*

| | 6 | 7 | 14 | 20 | 25 | 33 | 36 | 37 | 38 | 41 | 42 | 44 | 45 | 46 | 47 | 52 | 53 | 66 | 67 | 73 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lake | Sa1 | Sa2 | LN 2 | Ma1 | ChL | Ku2 | Ku3 | Ku4 | Ku5 | Sv1 | Sv2 | Sk1 | Sk2 | Da | Da | Li | Li | Ot | Ot | FH |
| Depth m | 1 | 1 | 8 | 10 | 1 | 15 | 14 | 6 | 1 | 3 | 4 | 15 | 18 | 9 | 9 | 4 | 4 | 3 | 3 | 25 |
| Oligochaeta | 16 | 0 | 23 | 23 | 47 | 78 | 0 | 0 | 469 | 62 | 438 | 16 | 16 | 0 | | 15 | | | | 74 |
| | (0.08) | (0) | (0.18) | (0.01) | (0.04) | (0.53) | (0) | (0) | (1.62) | (0.16) | (3.05) | (0.01) | (0.04) | | | | | | | |
| Mollusca | 0 | 0 | 0 | 0 | 0 | 31 | 16 | 94 | 47 | 16 | 0 | 16 | 47 | 0 | | | | | | |
| | (0) | (0) | (0) | (0) | (0) | (0.12) | (0.55) | (0.39) | (0.42) | (0.18) | (0) | (0.10) | (0.04) | | | | | | | |
| Chironomidae | 16 | 94 | 23 | 234 | 203 | 4508 | 469 | 499 | 795 | 313 | 594 | 172 | 109 | 1259 | 622 | 251 | 325 | 59 | 148 | 59 |
| | (0.01) | (0.05) | (0.08) | (1.46) | (0.16) | (20.39) | | (2.33) | (0.86) | (8.26) | (0.81) | (1.12) | (0.33) | (0.22) | | | | | | |
| Other groups | 140 | 94 | 48 | 0 | 46 | 16 | 0 | 0 | 187 | 93 | 93 | 0 | 125 | 0 | | | | | | |
| | (0.40) | (0.09) | (2.27) | (0) | (0.12) | (0.08) | (0) | (0) | (7,66) | (0.06) | (0.13) | (0) | (0.24) | | | | | | | |
| Total | 172 | 188 | 94 | 257 | 296 | 4633 | 485 | 593 | 1498 | 484 | 1125 | 204 | 297 | 1259 | 622 | 266 | 325 | 59 | 148 | 133 |
| | (0.49) | (0.14) | (2.53) | (1.47) | (0.32) | (21.12) | | (2.88) | (1.25) | (17.96) | | (1.21) | (4.30) | (0.44) | (0.54) | | | | | |

The zoobenthos of lakes in the Pechenga area close to Zapolyarny were characterized by low species diversity. Chironomidae, Hemiptera and Coleoptera dominated, while few species of Ephemeroptera and Plecoptera were found. At longer distance from the sources near Liinakhmari the zoobenthos showed higher diversities and abundances.

In most of the Jarfjord lakes low diversities and densities were recorded (**Table 2**). Highest numbers were found in Dalvatnet, especially in June (**Table 3**).

### 5.3.2. Streams

In Kolosyoki, draining the factory and Nikel town, the zoobenthos mainly consisted of chironomids. In other streams of the Nikel Region the nymphs of Ephemeroptera, Plecoptera and Trichoptera had wide distribution (**Figure 5**). Only a few individuals of *Sigara* sp., Tabanidae and Enchytraeidae were found in the highly polluted streams Chaukilampiyoki and Semiaki near Zapolyarny. In the moderately polluted and larger rivers Naamiyoki and Pechenga species richness and their abundances were considerable higher.

In the outlets of the Jarfjord lakes low abundances were found, and Chironomidae and Trichoptera predominated. The highest diversity was recorded in the Otervatn outlet, where the pollution sensitive taxas Plecoptera and Ephemeroptera had high frequences (**Figure 5**). Lowest diversity was found in the outlets of Limgambergtjern and F.Høgfjellsvatn.

## 5.4. Biological indication of water quality

The BMWP and LSI indexes for zoobenthos communities in the littoral zones of the lakes were lower than for the streams (**Figure 6**). In Kolosyoki, Semiaki, Chaukilampiyoki and other polluted streams the indexes did not exceed the value of 4. The highest indexes were observed in the streams Pachta, Shuoniyoki and Kuvernerinyoki. Correlation analyses between biological indexes and some water quality parameters, gave only significant correlation between number of chironomids (*Orthocladiinae* and *Tanytarsini*) and most chemical parameters, $p < 0.01$ (**Table 4**).

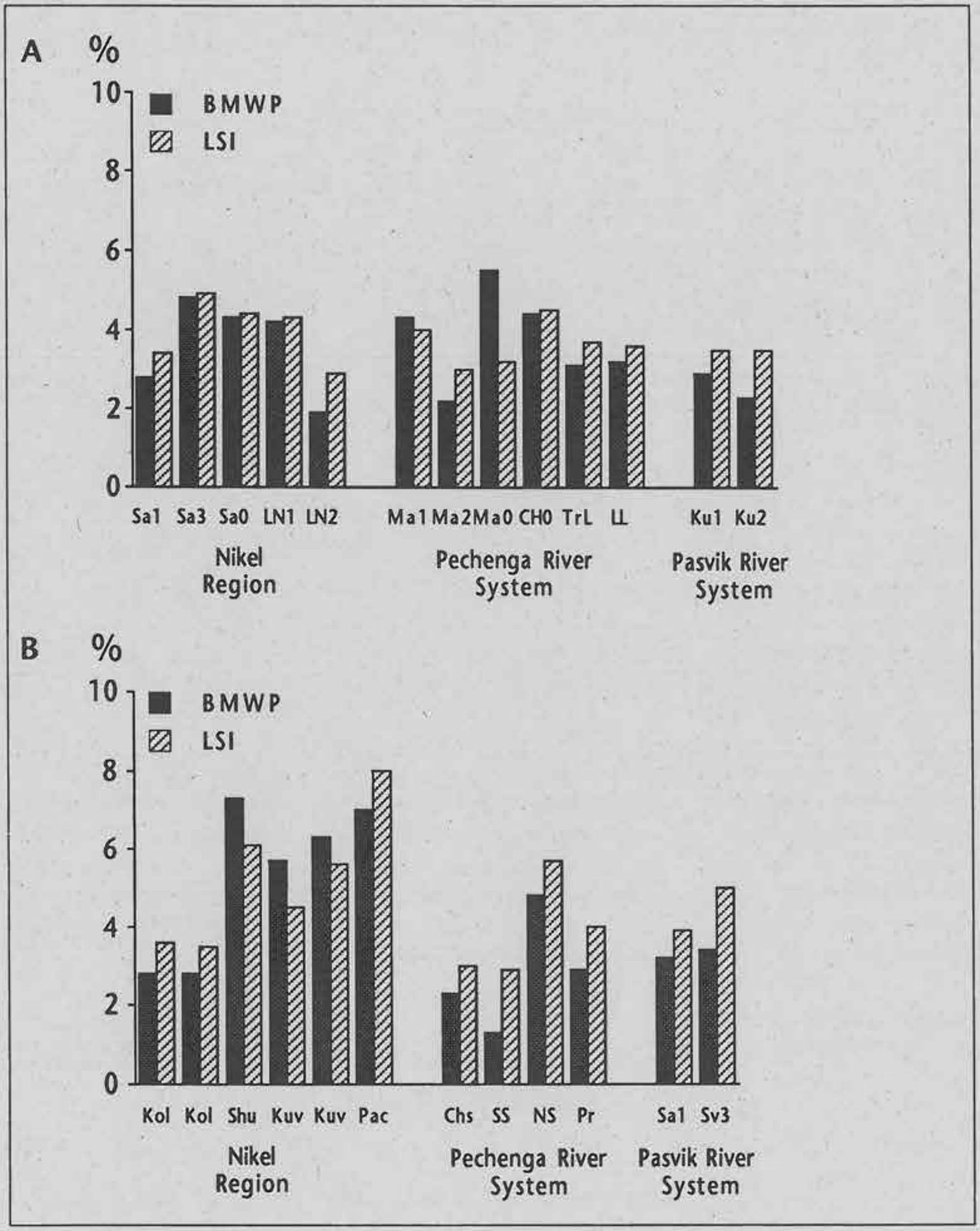


***Figure 6***
*BMWP and LSI indexes of zoobenthos. A- lakes and outlets, B- streams and rivers.*

## 5.5. Fish communities

In the Pasvik River System higher number of fish species were found than in the other regions (**Table 5**). However only 8 species of a total of 12 earlier reported from the Pasvik River System were recorded in Kuetsyarvi (Kristoffersen & Sterud 1985). Length distribution for the fish species are shown in **Figure 7**.

### 5.5.1. Lakes

In Kuetsyarvi (Ku1 and Ku3) the catches were dominated by whitefish (*Coregonus lavaretus* L.), perch (*Perca fluviatilis*) and pike (*Esox lucius*). Whitefish was the most numerous species in Kuetsyarvi (Ku1), while perch predominated in Kuetsyarvi (Ku3). The catch per unit effort and echosounder results indicated a very dense population of whitefish in Kuetsyarvi. The whitefish

***Table 4**. Multiple regression analyses between benthic invertebrates (n = 13) and environmental parameters. * - p < 0.05, ** - p < 0.01, *** - p < 0.001.*

| | Turb | pH | Alk | SSS | Cond | SO4 | Cl | NO3 | Cu | Ni | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|
| HN | 0.09 | -0.39 | 0.04 - | 0.32 | -0.36 - | 0.33 - | 0.13 | 0.15 | 0.19 - | 0.43 | 0.30 |
| HB | 0.10 | 0.04 | 0.11 - | 0.22 | -0.17 | -0.22 - | 0.14 | 0.01 | 0.40 - | 0.19 | 0.29 |
| No.tot. | 0.52 | -0.07 | 0.44 | 0.24 | 0.41 | 0.19 | 0.52 | 0.40 | 0.06 | 0.36 | -0.08 |
| No.EP | -0.18 | 0.20 | -0.12 | -0.42 | -0.33 | -0.41 | -0.34 - | 0.21 | 0.73** | -0.32 | 0.41 |
| No.OT | 0.82 *** | 0.03 | 0.81 *** | 0.61 * | 0.77 *** | 0.53 | 0.88 *** | 0.86 *** | -0.03 | 0.69** | 0.04 |
| BMWP | -0.38 | 0.13 | -0.24 | -0.56 * | -0.40 | -0.56*- | 0.25 | -0.36 | 0.26 | -0.42 | 0.01 |
| LSI | -0.23 | 0.05 | -0.18 | -0.46 | -0.34 | -0.46 | -0.25 | -0.25 | 0.19 | -0.35 | 0.04 |

HN - diversity index (Shannon, 1948) by numbers of species. HB - diversity index (Shannon, HB - 1948) by biomass of species. No.tot - total numbers of bottom fauna. No.EP - No. of Ephemeroptera and Plecoptera. No.OT - No. of chironomidae Orthocladiinae and Tanytarsini. BMWP - Biological Monitoring Working Party, Score index (1978). LSI - ISO's Long Score index (1984).

***Table 5**. Fish species present in lakes and streams in the Nikel Region, the Pechenga River and Pasvik River Systems and the Jarfjord Region. RF = Russia - Finland Border Area. Locality description in Appendix 1.*

| Region | Nikel Region | | | | | | Pechenga River System | | | | Pasvik River System | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Locality nr / Fish species | 2 | 3 | 5 | 9 | 12 | 19 | 20 | 22 | 23 | 24 | 35 | 36 | 40 | 42 |
| Salmo trutta L. | | | x | | x | x | | x | | x | | x | x | |
| Salvelinus alpinus L. | | | | x | | x | | | | | | | x | |
| Coregonus lavaretus L. | | | | | | | | | | | x | x | x | x |
| Coregonus albula | | | | | | | | | | | | | x | |
| Thymallus thymallus | | | | | | | | | | | x | | x | |
| Perca fluviatilis L. | | | | | | | x | | | | x | x | x | x |
| Phoxinus phoxinus L. | x | x | x | | | | x | x | x | x | x | x | x | |
| Esox lucius L. | | | | | | | x | | | | x | x | x | x |
| Anguilla anguilla | | | | | | | | | | | | | x | |
| Lota lota L. | x | x | | | | | x | | | | x | x | x | |
| Gasterosteus aquleatus | | | | | | | | | | | x | x | x | |
| Pungitus pungitus | | | | | x | x | | | | | | | x | |
| Total number of fish species caught | 2 | 2 | 2 | 1 | 2 | 3 | 4 | 2 | 1 | 2 | 7 | 7 | 12* | 3 |

| Region | Jarfjord Region | | | | | | | | | | | | | | | | | | | | | | | | | | RF |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Locality nr / Fish species | 46 | 47 | 48 | 49 | 50 | 52 | 53 | 54 | 66 | 67 | 68 | 69 | 70 | 72 | 74 | 76 | 80 | 81 | 83 | 84 | 85 | 86 | 87 | 89 | 90 | 91 | 92 |
| Salmo trutta L. | x | x | | x | x | x | x | | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | | x | x |
| Salvelinus alpinus L. | x | x | x | | | | | | | | | | | | | | x | | x | x | | | | x | x | x | |
| Coregonus lavaretus L. | | | | | | | | | | | | | | | | | | | | | | | | | | | x |
| Coregonus albula | | | | | | | | | | | | | | | | | | | | | | | | | | x | |
| Thymallus thymallus | | | | | | | | | | | | | | | | | | | | | | | | | | | x |
| Perca fluviatilis L. | | | | | | | | | | | | | | | | | | | | | | | | | | | x |
| Phoxinus phoxinus L. | | | | | | | | | | | | | | | | | | | | | | | | | | | x |
| Esox lucius L. | | | | | | | | | | | | | | | | | | | | | | | | | | | x |
| Anguilla anguilla | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Lota lota L. | | | | | | | | | | | | | | | | | | | | | | | | | | | x |
| Gasterosteus aquleatus | x | x | | | | | | x | | | x | x | | | | | | | | | | | | | | | |
| Pungitus pungitus | | | | | | | | | | | | | | | | | | | | | | | | | | | x |
| Total number of fish species caught | 3 | 3 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 1 | 1 | 1 | 1 | 2 | 1 | 2 | 2 | 1 | 1 | 1 | 2 | 1 | 2 | 8 |

*after Kristofffersen & Sterud (1985)

in locality 10, 15 and 16 in the Nikel Region no fish were present

in locality 51, 56, 57, 58, 60, 62, 64, 73, 78, 79, 82 and 88 in the Jarfjord Region no fish were present

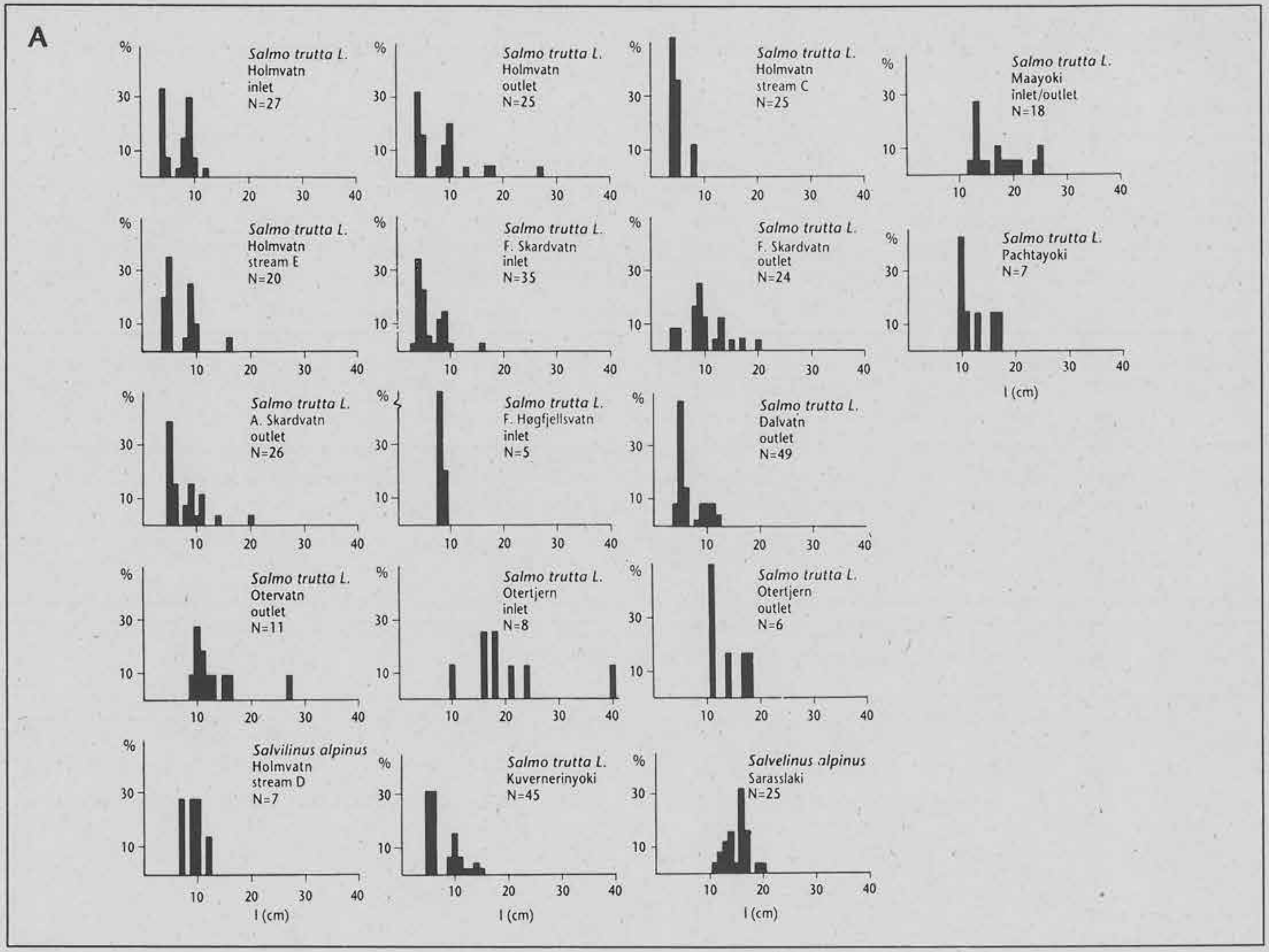


***Figure 7***

*Length distribution (%) of brown trout (*Salmo trutta L.*) and Arctic char* (Salvelinus alpinus) *in the streams (A), and brown trout, Arctic char, whitefish* (Coregonus lavaretus), *perch* (Perca fluviatilis) *and pike* (Esox lucius) *in the lakes (B).*

may be divided into two ecologigal groups, slow- and fastgrowing. The slow growing group mature at the age of three (2+) and four (3+) and the mean length 14.5 and 21.7 cm, respectively. The fast growing group was distinguished by higher age at maturity (ages 5-6+) and larger maximum sizes (**Appendix 3**). The two whitefish populations did not differ in systematic signs; i.e. the number of gillrakers was 23-32, numbers of scales along sideline were 83-93 and along vertebrae 61-63. In Kocheyavr whitefish and perch were also dominant, but only the fast growing whitefish group was recorded. Perch and pike were the dominant species in Maayarvi. The growth rate of perch from different lakes was similar and did not differ significantly between populations. In general, the populations of whitefish, perch and pike consisted of young individuals, ages 2+ and 3+, and no individuals older than age 5+ were found (**Appendix 3**).

Few specimens of other species were caught in the Russian lakes. Ruosenjarvi in the Nikel Region contained a dense population of Arctic char (*Salvelinus alpinus* L.) and a sparse popula-

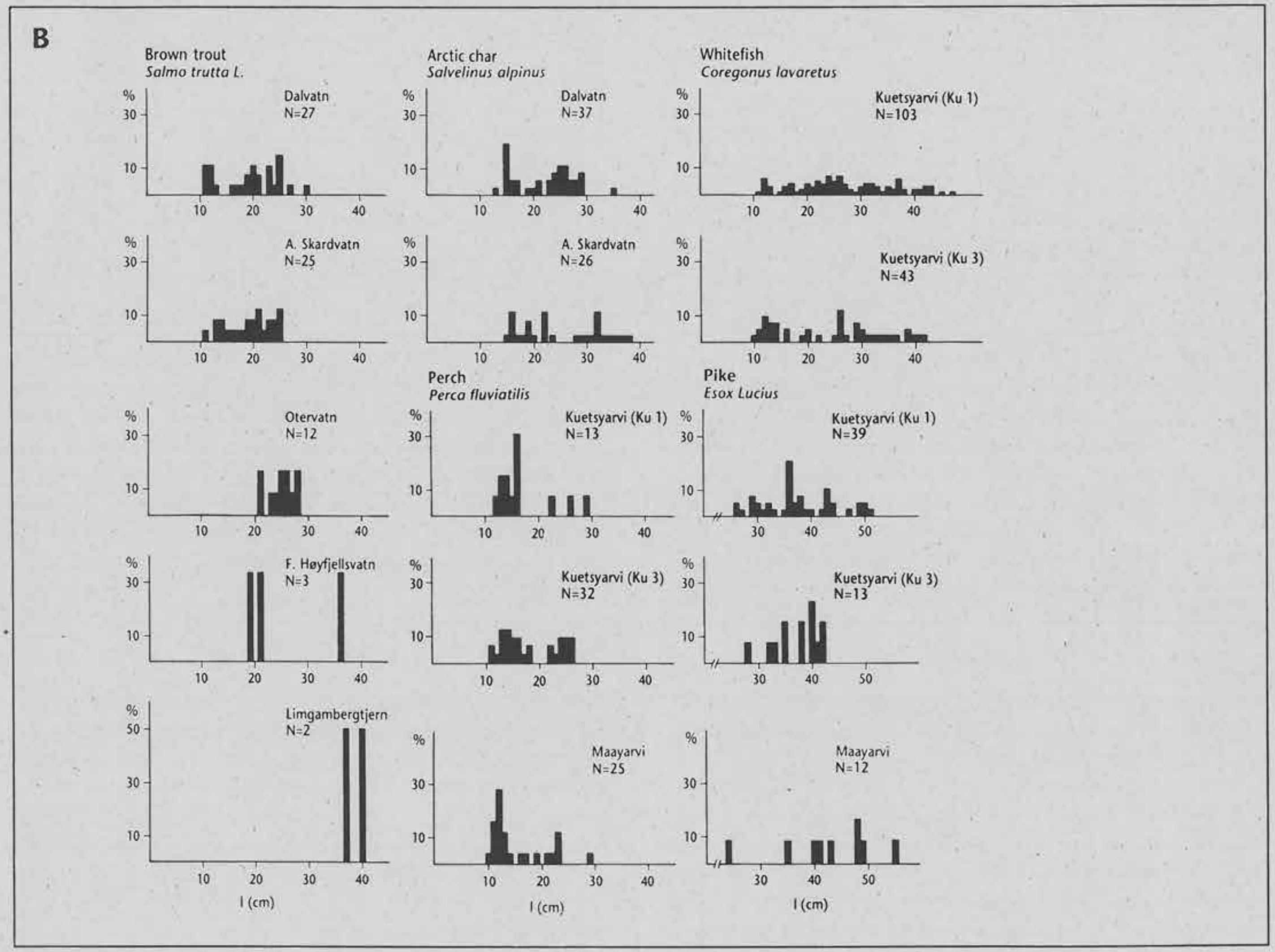


***Figure 7***
*Forts.*

tion of brown trout (*Salmo trutta*). These two species were also caught in four of the Jarfjord lakes indicating dense populations, especially of arctic char, except in F.Høgfjellsvatn (**Appendix 3**). Arctic char was represented by various age groups up to 4-6+. However, the early age at first maturity (2+) was characteristic for all populations. Similar age and maturity structure for trout and char populations were recorded in Ruosenyarvi. Sparse populations of brown trout inhabited the other lakes, and in Limgambergtjern only old individuals (age > 8+) appeared.

### 5.5.2. Streams

Brown trout was the most widely distributed species in the streams, except in some high polluted localities of the Nikel Region and the most acid streams in Jarfjord, where no or only a few individuals of other species were recorded (**Table 5**). The highest densities of brown trout were found within the Jarfjord Region, especially in Dalvatn outlet. The more polluted stream Kolosyoki contained a moderately dense population of *Phoxinus phoxinus*. A dwarf population of Arctic char with a predominance of females over males (5:1), was found in the nearby inlet of Sarasslaki.

### 5.5.3. Pathology

**Whitefish**

In Kuetsyarvi (Ku1) a few specimens (1 %) had abnormal body colour, curvature of the spine (scoleosis) and cranium decolaration. The incidence of a pathological degeneration of several organs was surprisingly high. Pale colour and a flabby liver were observed in 14 % of whitefish. Kidney anomaly was frequently observed; 18 % had expanded kidneys due to connective tissue, and 10 % had kidney disease (nephrocalcitosis). In Kuetsyarvi (Ku1) 10 % of whitefish had twisted gonadae, and most of the specimens had anemic and pale gills, fluorescence, and anemic rings were observed. At Kuetsyarvi (Ku3) 16 % of the whitefish deviated from normal state, and 4 % had nephrocalcitosis. The few individuals caught in the Pasvik River System on the Norwegian side (at Svanvik) showed only the beginning of kidney diseases. About 80 % of the specimens from Kocheyavr had pale mosaic liver, and 98 % had expansions caused by connective tissue. "Granular" kidneys was found in 2 %, twisted gonads in 17 % and "jelly-like" pale gonads for 6 %, respectively. Adipose heart was recorded in more than 50 % of the whitefish populations.

**Pike**

In Kuetsyarvi and Maayarvi the pike displayed remarkable variation in the colour of skin and fins. Abdomen, abdominal, thoracic and caudal fins were blue and greenish for 86 %, 100 % and 50 % respectively. Dissection revealed deviations from the normal state of functionally important organs such as liver, kidneys and gonads. Liver colour was blue-green for more than 70 % of pike from Maayarvi and Kuetsyarvi (Ku1) and for all specimens from Kuetsyarvi (Ku3). Common for these pikes were enlargements of gall-bladder, whose content were dark-green, with clots of blood. In Kuetsyarvi (Ku1) "granular" kidneys and expansions caused by connective tissue were observed in 22 % and 28 % respectively. Similar pathological signs and diseases were not observed in Kuetsyarvi (Ku3) and Maayarvi. However, gonadae anomalies were recorded in Kuetsyarvi (Ku1) and Maayarvi.

**Perch, Arctic char and brown trout** did not generally reveal anomalies. An exception was the Arctic char and brown trout in Ruosenyarvi, where pale, mosaic liver, kidneys expansion and anemic rings on gills were common. The frequency of parasites and signs of diseases were more pronounced in fish species from Kuetsyarvi, Maayarvi and Ruosenyarvi than in the other lakes. The infection by parasites was high especially in the liver and heart of whitefish in Kuetsyarvi (Ku1 and Ku3), and on liver, heart, stomach walls, bowels and swim bladder of Arctic char in Ruosenyarvi. Parasites on the swimming bladder of Arctic char was frequently observed in A.Skardvatn and Dalvatn, and in addition on hearts in A.Skardvatn.

### 5.5.4 Food composition

The diet of brown trout and Arctic char was in general dominated by terrestrial and aquatic insects (**Table 6**). In A.Skardvatn *Gammarus lacustris* and *Eurycercus lamellatus* also formed an important part of the diet. *Bosmina longispina* was important as a food item for Artic char in Dalvatn. Gastropoda and *Gastrosteus aquelatus* made up 40 % of the diet for brown trout in Otervatn. The main food objects for perch in Kuetsyarvi and Maayarvi were minnows and daphnids. Gastropoda and *Eurycercus lamellatus* were the main food items for whitefish in Kuetsyarvi. Among the two whitefish groups, the diet of the slow growing group was more planktonic.

### 5.5.5 Heavy metal accumulation

Heavy metal accumulation in fish was mainly related to the elements nickel, copper and zinc (**Figures 8,9,10**). The levels and distribution varied between organs, species and lakes (**Table 7, Figure 11**). Accumulation in muscles was in general considerably lower than found in other organs and tissues. Species differences of metal accumulation are clearly shown in the examples of fishes from Kuetsyarvi (see also **Figure 12**):

| | Ni | Cu | Zn |
|---|---|---|---|
| Gills: | pe>wh>pi | pe>wh>pi | pe>wh>pi |
| Muscles: | pe>pi>wh | pe>wh>pi | pe>wh>pi |
| Liver: | wh>pi>pe | wh>pi>pe | pi>wh>pe |
| Kidney: | wh>pi>pe | wh>pi | |
| Skeleton: | wh>pe>pi | pe>wh>pi | wh>pi>pe |

pe = perch, pi = pike, wh = whitefish

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

*Table 6. Food items (volume %) in stomachs of Arctic char (A), Brown trout (B), Perch (P) and Whitefish (W) in the lakes in August/September 1990.*

| Region | Localtiy | Species | Number of stomachs | Terrestrial insects | Aquatic insects | Gastropoda/ Mollusca | Eurycercus | Gammarus | Zooplankton | Fish |
|---|---|---|---|---|---|---|---|---|---|---|
| N | Kuvernerinyoki | B | 24 | 17,8 | 82,2 | 0 | 0 | 0 | 0 | 0 |
| N | Sarasslaki Inl | A | 11 | 62,7 | 37,3 | 0 | 0 | 0 | 0 | 0 |
| Pe | Maayarvi | P | 12 | 0 | 8,3 | 0 | 0 | 0 | 71 | 20,4 1) |
| Pe | Maayarvi Inl | B | 6 | 26,5 | 49,3 | 7,5 | 0 | 0 | 0 | 16,7 1) |
| Pa | Kuetsyarvi 1 | W | 10 | 11,3 | 10,9 | 33,7 | 31,3 | 0 | 12,8 | 0 |
| Pa | Kuetsyarvi 1 | P | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 100 2) |
| Pa | Kuetsyarvi 1 | B | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 100 1) |
| Pa | Kuetsyarvi 3 | W | 25 | 14,3 | 2,9 | 37,5 | 36,0 | 0 | 9,3 | 0 |
| Pa | Kuetsyarvi 3 | P | 21 | 1,7 | 0,8 | 0 | 22,6 | 0 | 22,4 | 52,5 2) |
| J | Dalvatn | A | 4 | 48 | 17,7 | 0 | 0 | 0 | 34,3 | 0 |
| J | Limgambergtjern | B | 2 | 99,9 | 0,1 | 0 | 0 | 0 | 0 | 0 |
| J | Otervatn | B | 5 | 31,6 | 27,0 | 21,4 | 0 | 0 | 0 | 20 3) |
| J | F. Høgfjellsvatn | B | 3 | 76,7 | 23,3 | 0 | 0 | 0 | 0 | 0 |
| J | A. Skardvatn | B | 8 | 33,9 | 28,8 | 0 | 16,5 | 24,8 | 0 | 0 |
| J | A. Skardvatn | A | 20 | 52,1 | 5,8 | 0 | 18,3 | 15,6 | 0 | 0 |

1) Minnows, 2) Minnows and sticklebacks, 3) Sticklebacks. N = Nikel Region, Pe = Pechenga River System, Pa = Pasvik River System, J = Jarfjord Region.

*Table 7. Maximum concentrations of Ni, Cu and Zn (µg/g dry weight) in fish organs from different species and localities.*

| | Ni | | | Cu | | | Zn | | |
|---|---|---|---|---|---|---|---|---|---|
| GILLS | 20.8 | - perch | Kuetsyarvi | 13.8 | - perch | Kuetsyarvi | 1071.8 | - whitefish - | Svanvik |
| | 11.5 | - brown trout | Maayoki | | | | | | |
| MUSCLE | 2.4 | - pike | Maayarvi | 25.8 | - Arctic char | Sarasslaki inlet | 44.0 | - brown trout | Pachtayoki |
| LIVER | 4.8 | - whitefish | Kocheyavr | 205.8 | - Arctic char | A. Skardvatn | 298.6 | - whitefish | Kocheyavr |
| KIDNEY | 28.0 | - whitefish | Kuetsyarvi | 22.0 | - Arctic char | A. Skardvatn | 467.0 | - whitefish | Svanvik |
| | | | | 20.8 | - Arctic char | Dalvatn | | | |
| SKELETON | 7.9 | - Arctic char | Sarasslaki inlet | 7.9 | - Arctic char | Sarasslaki inlet | 221.0 | - whitefish | Kuetsyarvi |
| | 7.5 | - whitefish | Kuetsyarvi | 7.4 | - perch | Kuetsyarvi | | | |
| | 7.2 | - whitefish | Kocheyavr | | | | | | |

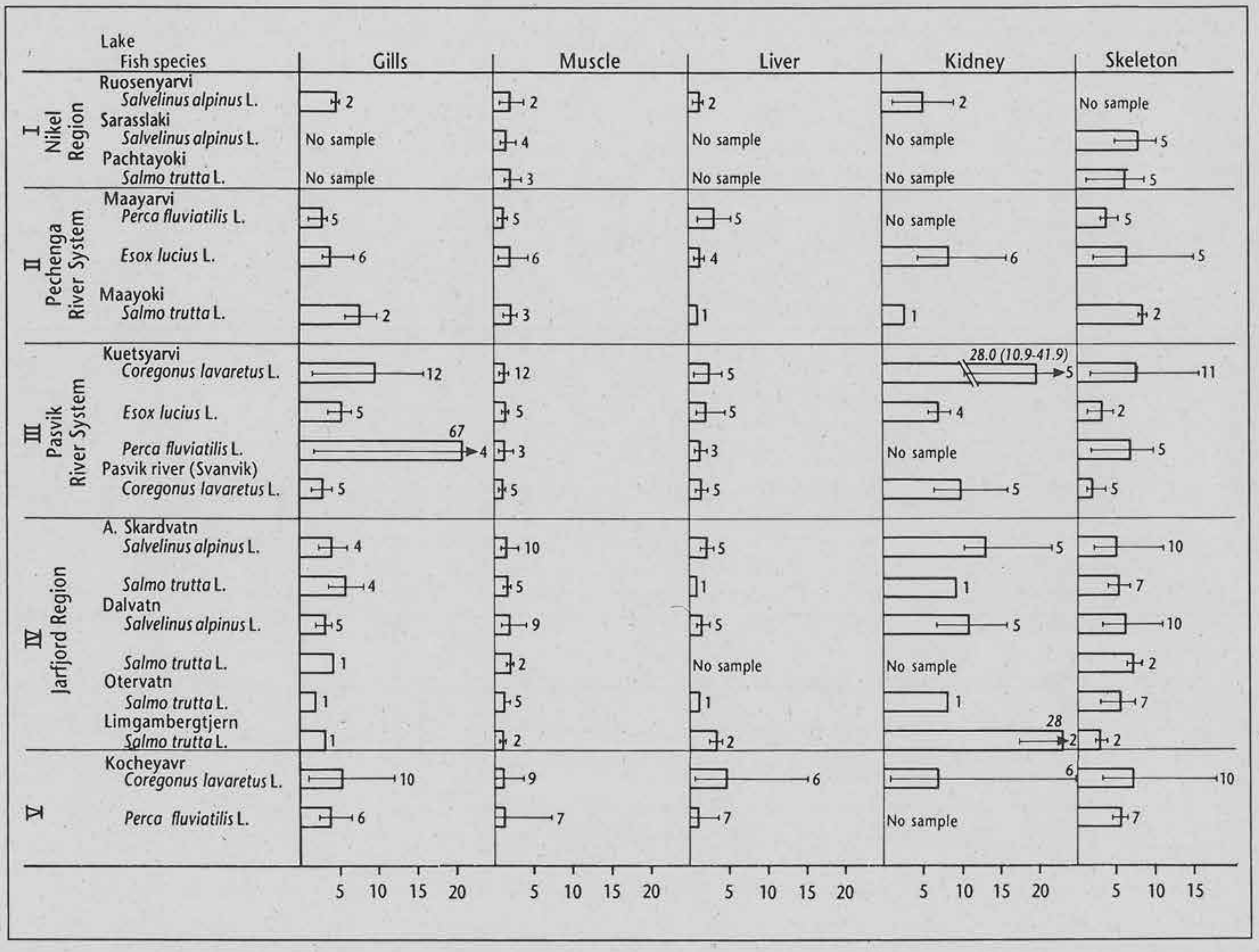


**Figure 8**

*Concentration of nickel (µgNi/g dry weight) in organs and tissues of fish.*

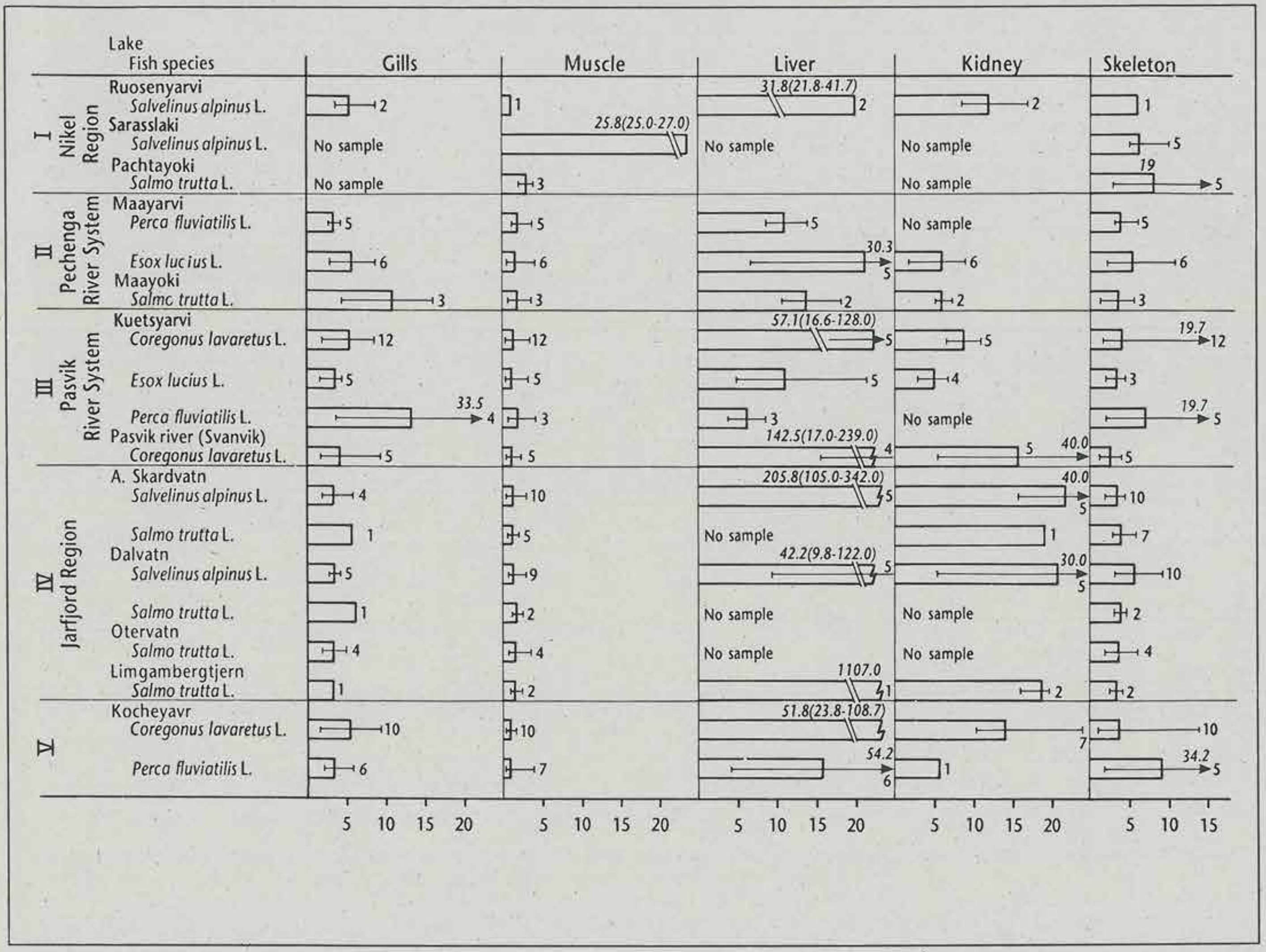


**Figure 9**
*Concentration of copper (µgCu/g dry weight) in organs and tissues of fish.*

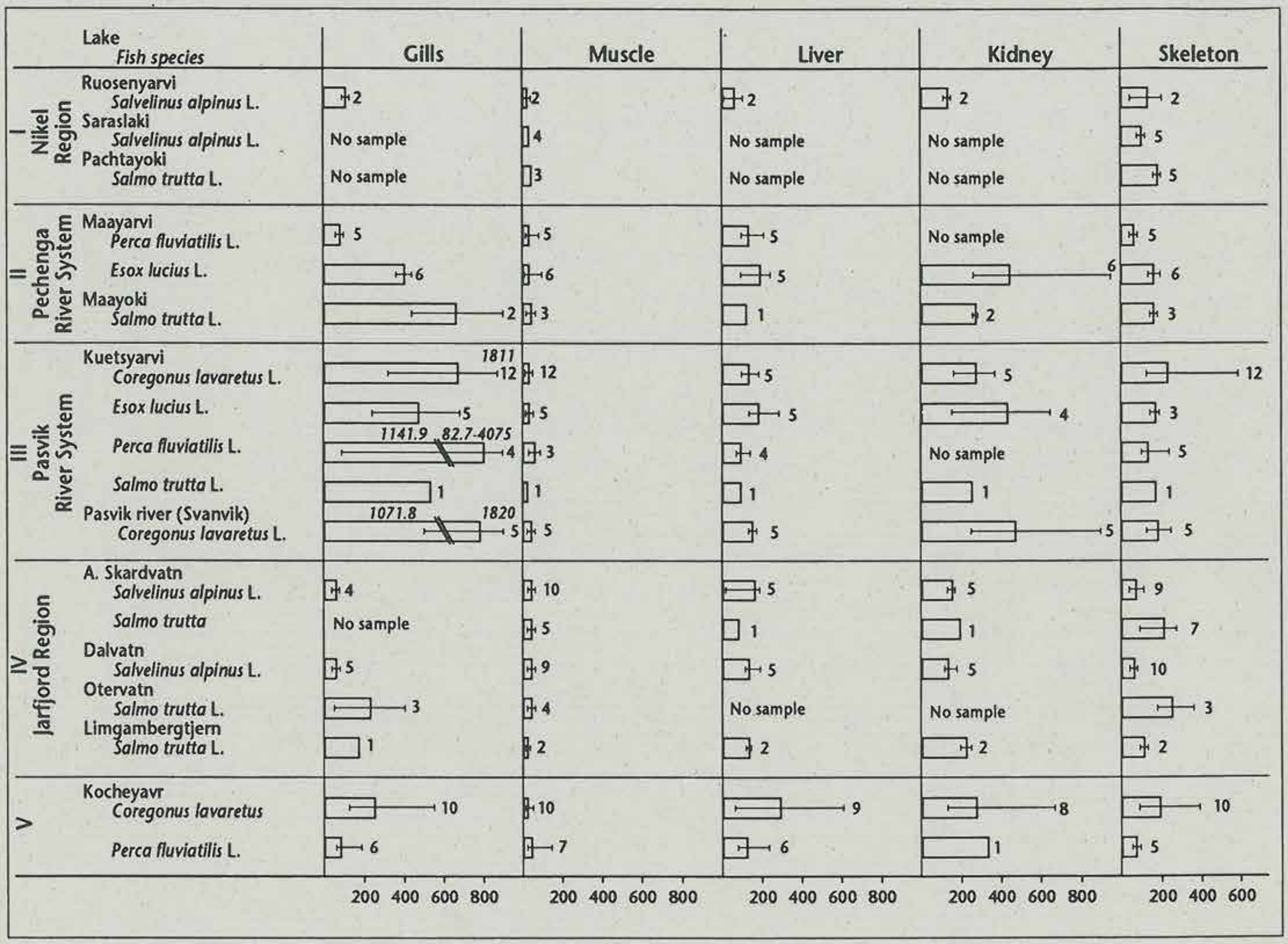


*Figure 10*
*Concentration of zinc (µgZn/g dry weight) in organs and tissues of fish.*

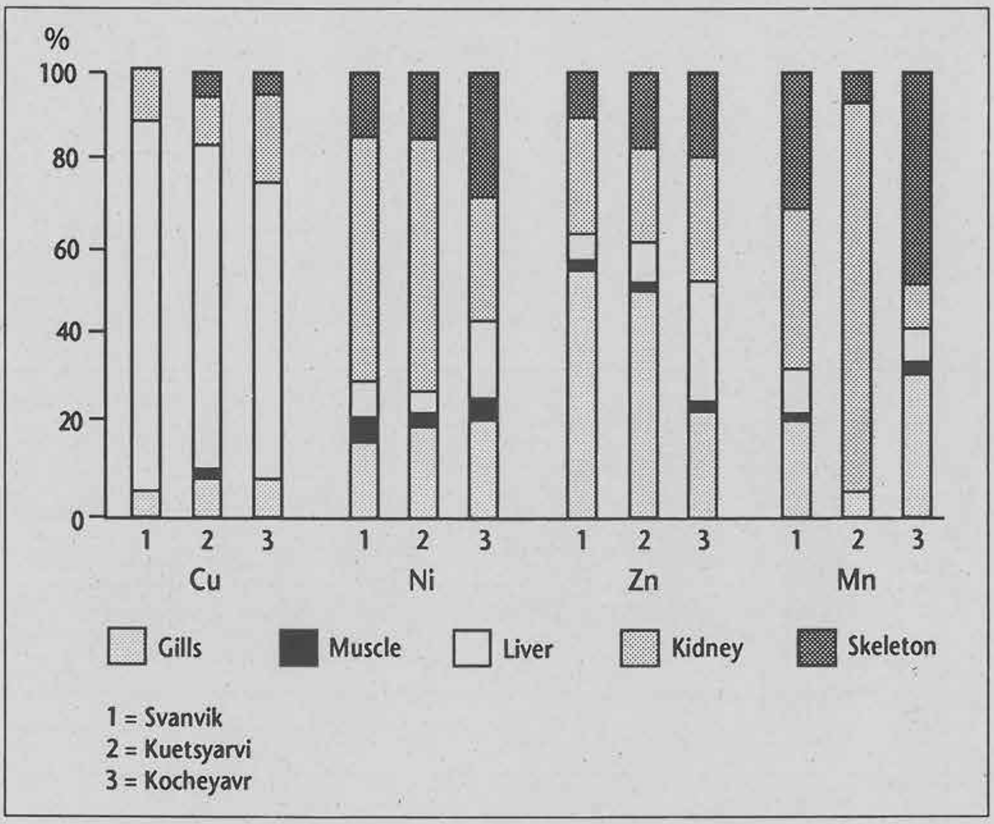


***Figure 11***
*Distribution (%) of copper, nickel, zinc and manganese in organs of whitefish at Svanvik, Kuetsyarvi and Kocheyavr.*

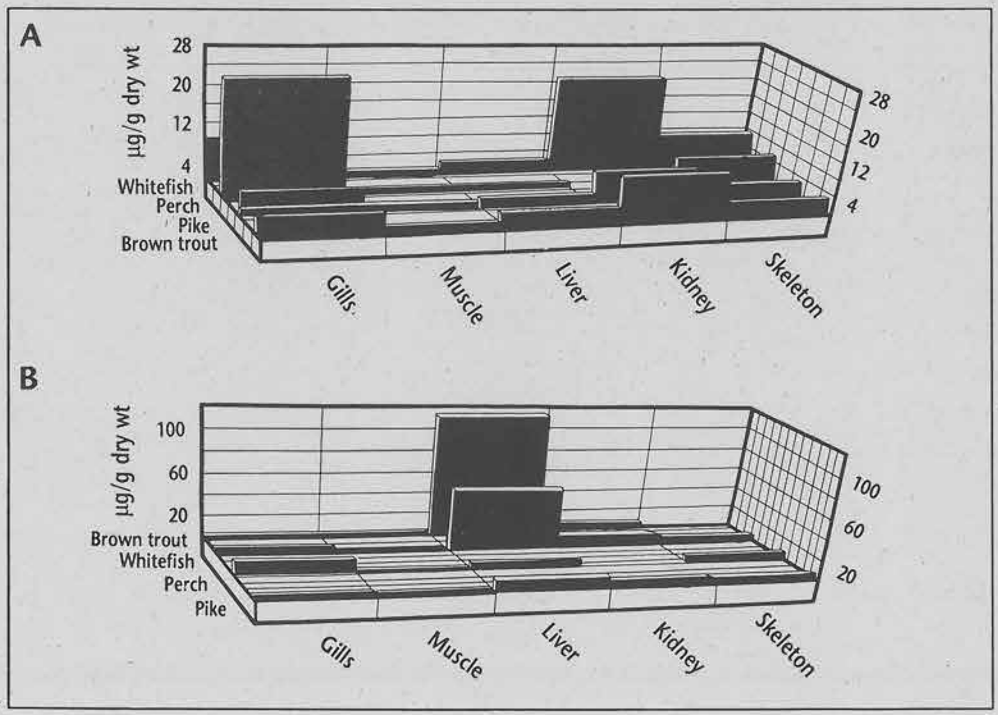


***Figure 12***
*Concentration (µg/g dry weight) of nickel (A) and copper (B) in organs of fish from Kuetsyarvi.*

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 µgCu/g). Fish from other lakes had lower than 50 µgCu/g in liver, except for Arctic char in A.Skardvatn (> 200 µg/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 µgZn/g). Considerably lower accumulations were found for fish specimens in the other regions, especially in Jarfjord (< 250 µgZn/g). Near the sources the accumulation of zinc in gills was generally higher than in liver, whereas the opposite were found in lakes situated at longer distance (**Figure 13**).

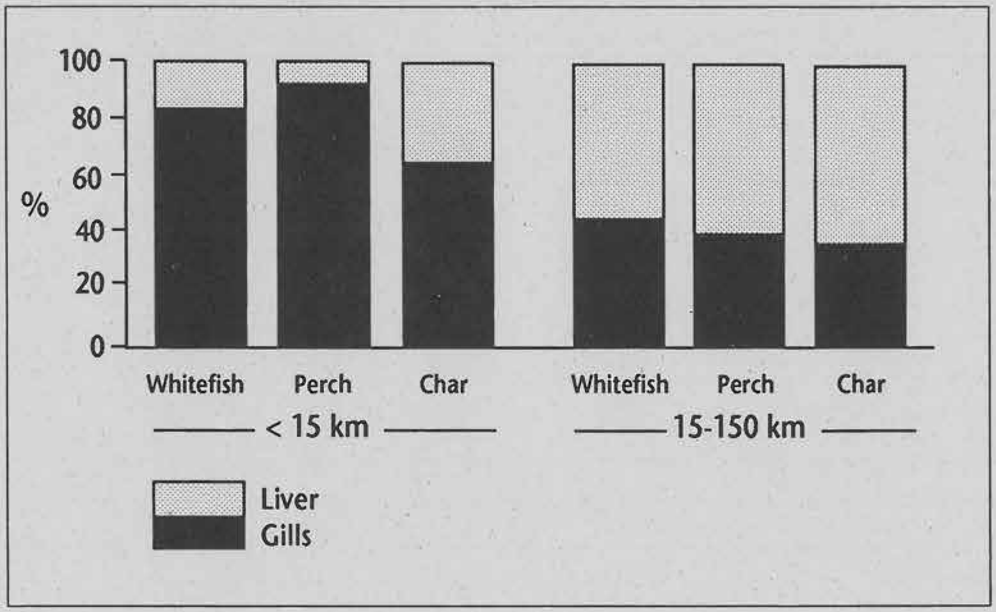


***Figure 13***
*Relative distribution of zinc in gills and liver from lakes near and at longer distances from the source.*

# 6. Discussion

During the last years there has been an increase in the attention paid to the environmental impacts of pollution due to the industrial activities in the border areas between Russia and Norway (Kryuchkov & Makarova 1989, Frisvoll & Flatberg 1990, Hagen et al. 1990, Sivertsen 1990, Year Book.. 1990, Traaen et. al 1991).

A lot of information about freshwater communities exists from Sør-Varanger (Norway), which is mainly concerned with species distribution (Huitfeldt-Kaas 1918, Berg 1964, Økland, K.A. 1969, Sæther 1970, Tobias 1973, Kristoffersen & Sterud 1985, Økland, J. 1990). The impacts of pollution upon the freshwater communities is poorly known, but recent studies on water quality, zoobenthos and fish populations in Finnmark county indicated effects supposedly caused by acidification (SFT 1987, 1988, 1990, Traaen 1987, 1990, Karlsen 1988, Henriksen et al.1990, Traaen et al. 1990). Impacts of acidification in freshwaters in Finnish Lapland have also been documented (Kinnunen 1990). Information on fish diseases caused by heavy metal contamination is scarce. Accumulation of heavy metals have been recorded in bottom sediments and in fish from the Pasvik River (Norheim et al. 1985, Rognerud & Fjeld 1990, Rognerud 1990). Earlier publications about freshwater communities from the Pechenga nickel area are scarce (Kruglova 1983, Year book.. 1990, Yakovlev 1991b).

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 supposed 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 nickel 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 the fallouts increase the water mineralization and acid neutralization capacity, ( ANC of surface waters > 200 $\mu eq\ l^{-1}$) (Traaen et al. 1991). At larger distances (20-30 km) from the factories ANC is reduced to a critical level, < 20 $\mu eq\ l^{-1}$.

Generally the concentrations of nickel and copper in water in Russian areas were above limits assumed to cause severe effects on freshwater organisms (Lithner 1989, SFT 1989, Year book.. 1990). In Kolosyoki and in a lake near Nikel the content of nickel was extremely high (> 100 µgNi/l).

Our study in 1990 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 impacts upon freshwater communities in Russian localities were supposedly due to the heavy metals. The low diversity recorded was mainly caused by lack of occurrance of several taxas, especially Ephemeroptera, Plecoptera, Cladocera, Copepoda and Salmonidae. This is supported by the state of freshwater communities observed in the highly heavy metal polluted Imandra lake on the Kola Peninsula (Moiseenko & Yakovlev 1990).

A low diversity of zooplankton was found in a lake 10 km northeast of Nikel (LN2). High abundances of chironomids were obtained in the most polluted localities: Kolosyoki, Semiaki, Chaukilampiyoki and in a lake 1.5 km east of Nikel. However, the composition of zoobenthos on the Russian side was very variable.

Negative impacts upon the population structure of fish were recorded in all studied localities in Russian areas, especially in Kuetsyarvi, Rousenyarvi and Maayarvi. In other localities near the factories, several taxa of, for example salmonids, gastropoda and daphnids were still present. Likewise, in Kuetsyarvi high densities and biomass of zooplankton appeared. The abundance of zooplankton in 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 POx) into Kuestsyarvi are assumed to enhance the phytoplankton food base for zooplankton. The very high abundances of zoobenthos, especially chironomids also indicated euthrophication in Kuetsyarvi. 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 juvenilisation in brown trout populations within the Nikel Region supported this assumption.

Several factors influence the concentrations of heavy metals in organs and tissues in 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 matabolism. Concentrations of metals in fish organs, especially in soft tissues were inconsistant. The most stable levels were in skeleton 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 towards 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, in gneissic/granitic areas with low buffering capacity (Alkalinity = 0). Several pH-sensitive taxa of zoobenthos were absent or recorded in very low numbers, also stated by Baekken & Aanes (1990). A similar state was also found for daphnids. In the localities with lowest pH (< 5.0) no fish were present. Senescence in brown trout population in Limgambergtjern also indicated adverse effects of acidification (Bravington et al. 1990).

In order to evaluate the environmental impacts of pollutants, it is also necessary to consider biotic interactions within the freshwater communities. Diversity of species and number of trophic levels differ between the regions and the complexity seems more pronounced in the Pasvik River System. Higher diversity of planktivore and carnivore fish species, and the size and fecundity of certain zooplankton species indicate hard predation pressure in the Pasvik River System. Lower fish diversity and large individual size of daphnids and *H.gibberum* indicate very low predation pressure, especially in the Pechenga nickel area.

## Concluding remarks

### Heavy metal impacts

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

- Severe pathological anomalies and diseases were observed in fish near Nikel: curvature of spine (scoleosis), kidney disease (nephrocalcitosis), abnormal colour of body, 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 Norwegian localities (at Svanvik and Jarfjord).
- A low diversity of invertebrates was recorded in the Pechenga nickel 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.

More intensive studies in the border areas are necessary to quantify the effects of pollutants, especially with respect to heavy metal contamination and sublethal effects on fish and invertebrates. This knowledge is necessary for evaluating the biological benefits of the purification process of the factories on freshwater communities. Unlike other impacted areas in Scandinavia and Northern-Europe, the local emissions totally dominate the distribution of pollutants in the border region between Russia and Norway. This fact makes the area unique in studying the effects of pollutants and the recovery of freshwater communities through a purification process of the main emission sources.

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# Appendix

***Appendix 1**. Localities, dates and sampling in the different regions.*
*N = Nikel Region, Pe = Pechenga River System, Pa = Pasvik River System, J = Jarfjord Region and RF = Russia-Finland border area. Sampling: W = water samples, Zp = zooplankton samples, Zb = zoobenthos samples, F = fish samples.*

| Nr. | Locality | Region | Date | Sampling | | | |
|---|---|---|---|---|---|---|---|
| 1 | Kolosyoki (Kol) | N | 13.07.90 | | | Zb | |
| 2 | Kolosyoki (Kol) | N | 30.08.90 | W | | Zb | F |
| 3 | Shuoniyoki (Shu) | N | 30.08.90 | W | | Zb | F |
| 4 | Kuvernerinyoki (Kuv) | N | 26.08.90 | | | Zb | |
| 5 | Kuvernerinyoki (Kuv) | N | 29.08.90 | W | | Zb | F |
| 6 | Sarasslaki 1 (Sa1) | N | 31.08.90 | | Zp | Zb | |
| 7 | Sarasslaki 2 (Sa2) | N | 31.08.90 | | | Zb | |
| 8 | Sarasslaki 3 (Sa3) | N | 31.08.90 | | | Zb | |
| 9 | Sarasslaki Inl.(SaI) | N | 31.08.90 | W | | Zb | F |
| 10 | Sarasslaki Outl.(SaO) | N | 31.08.90 | W | | Zb | F |
| 11 | Pachta Stream (PaS) | N | 01.09.90 | W | | Zb | |
| 12 | Pachtayoki (Pac) | N | 01.09.90 | W | | | F |
| 13 | Lake Nikel-NE 1.5km (LN1) | N | 13.07.90 | | | Zb | |
| 14 | Lake Nikel-NE 10km (LN2) | N | 01.09.90 | W | Zp | Zb | |
| 15 | Lake Nikel-NE 10km Inl.(LN2i) | N | 01.09.90 | W | | | F |
| 16 | Lake Nikel-NE 10km Str.(LN2s) | N | 01.09.90 | W | | | |
| 17 | Tarn 1 Nikel-Zapolyarny (ZN1) | N | 01.09.90 | W | | | |
| 18 | Tarn 2 Nikel-Zapolyarny (ZN2) | N | 02.09.90 | W | | | |
| 19 | Rousenyarvi (Ro) | N | 04.09.90 | | | | F |
| 20 | Maayarvi 1 (Ma1) | Pe | 01.90.90 | | Zp | Zb | F |
| 21 | Maayarvi 2 (Ma2) | Pe | 01.09.90 | | | Zb | |
| 22 | Maayarvi inlet (MaI) | Pe | 01.09.90 | W | | Zb | F |
| 23 | Maayarvi outlet (MaO) | Pe | 01.09.90 | W | | Zb | F |
| 24 | Maayoki (May) | Pe | 01.09.90 | W | | | F |
| 25 | Lake below Chaukilampi (ChL) | Pe | 11.07.90 | | | Zb | |
| 26 | L.bel.Chaukilampi Outl.(ChO) | Pe | 11.07.90 | | | Zb | |
| 27 | Chaukilampiyoki Stream (ChS) | Pe | 11.07.90 | | | Zb | |
| 28 | Semiaki Stream (SS) | Pe | 11.07.90 | | | Zb | |
| 29 | Naamiyoki Stream (NS) | Pe | 11.07.90 | | | Zb | |
| 30 | Pechenga River (PR) | Pe | 12.07.90 | | | Zb | |
| 31 | Lake NW Liinakhmari (LL) | Pe | 12.07.90 | | | Zb | |
| 32 | Lake Trifonayarvi (TrL) | Pe | 14.07.90 | | | Zb | |
| 33 | Kuetsyarvi 2 (Ku2) | Pa | 13.07.90 | | | Zb | |
| 34 | Kuetsyarvi 1 (Ku1) | Pa | 26.08.90 | | | Zb | |
| 35 | Kuetsyarvi 1 (Ku1) | Pa | 29.08.90 | W | Zp | Zb | F |
| 36 | Kuetsyarvi 3 (Ku3) | Pa | 30.08.90 | W | Zp | Zb | F |

*forts.*

***Appendix 1**. Forts.*

| Nr. | Locality | Region | Date | Sampling | | | |
|---|---|---|---|---|---|---|---|
| 37 | Kuetsyarvi 4 (Ku4) | Pa | 30.08.90 | | | Zb | |
| 38 | Kuetsyarvi 5 (Ku5) | Pa | 30.08.90 | | | Zb | |
| 39 | Salmiyarvi (Sal) | Pa | 29.08.90 | W | | Zb | |
| 40 | Lyngbukta (Ly) | Pa | 02.09.90 | W | Zp | Zb | |
| 41 | Svanvik 1 (Sv1) | Pa | 04.09.90 | | Zp | Zb | |
| 42 | Svanvik 2 (Sv2) | Pa | 04.09.90 | W | Zp | Zb | F |
| 43 | Svanvik 3 (Sv3) | Pa | 04.09.90 | | | Zb | |
| 44 | Skrukkebukta 1 (Sk1) | Pa | 04.09.90 | W | Zp | Zb | |
| 45 | Skrukkebukta 2 (Sk2) | Pa | 04.09.90 | | | Zb | |
| 46 | Dalvatn (Da) | J | 27.06.90 | | Zp | Zb | F |
| 47 | Dalvatn (Da) | J | 04.09.90 | | Zp | Zb | F |
| 48 | Dalvatn inlet (DaI) | J | 27.06.90 | W | | | F |
| 49 | Dalvatn outlet (DaO) | J | 27.06.90 | W | | Zb | F |
| 50 | Dalvatn outlet (DaO) | J | 04.09.90 | W | | Zb | F |
| 51 | Dalvatn stream (DaS) | J | 27.06.90 | W | | Zb | F |
| 52 | Limgambergtjern (Li) | J | 27.06.90 | W | Zp | Zb | F |
| 53 | Limgambergtjern (Li) | J | 03.09.90 | | Zp | Zb | F |
| 54 | Limgambergtjern inlet (LiI) | J | 27.06.90 | W | | | F |
| 55 | Limgambergtjern inlet (LiI) | J | 03.09.90 | W | | | |
| 56 | Limgambergtjern outlet (LiO) | J | 27.06.90 | W | | Zb | F |
| 57 | Limgambergtjern outlet (LiO) | J | 03.09.90 | W | | Zb | F |
| 58 | Limgambergtjern Stream (LSA) | J | 27.06.90 | W | | | F |
| 59 | Limgamberg Tarn A (LiA) | J | 27.06.90 | W | | | |
| 60 | Limgamberg Tarn A (LiA) | J | 03.09.90 | W | | | F |
| 61 | Limgamberg Tarn B (LiB) | J | 27.06.90 | W | | | |
| 62 | Limgamberg Tarn B (LiB) | J | 03.09.90 | W | | | F |
| 63 | Limgamberg Tarn C (LiC) | J | 27.06.90 | W | | | |
| 64 | Limgamberg Tarn C (LiC) | J | 03.09.90 | W | | | F |
| 65 | Limgamberg Tarn D (LiD) | J | 27.06.90 | W | | | |
| 66 | Otervatn (Ot) | J | 27.06.90 | | Zp | Zb | F |
| 67 | Otervatn (Ot) | J | 04.09.90 | | Zp | Zb | F |
| 68 | Otervatn outlet (OtO) | J | 27.06.90 | W | | Zb | F |
| 69 | Otervatn outlet (OtO) | J | 04.09.90 | W | | Zb | F |
| 70 | Otertjern inlet (OnI) | J | 04.09.90 | W | | | F |
| 71 | Otertjern outlet (OnO) | J | 27.06.90 | W | | | |
| 72 | Otertjern outlet (OnO) | J | 04.09.90 | W | | | F |
| 73 | F.Høgfjellsvatn (FH) | J | 28.06.90 | | Zp | Zb | F |
| 74 | F.Høgfjellsvatn (FH) | J | 05.09.90 | | Zp | Zb | F |
| 75 | F.Høgfjellsvatn inlet (FHI) | J | 28.06.90 | W | | | |
| 76 | F.Høgfjellsvatn inlet (FHI) | J | 05.09.90 | | | | F |
| 77 | F.Høgfjellsvatn outlet (FHO) | J | 28.06.90 | W | | Zb | F |
| 78 | F.Høgfjellsvatn outlet (FHO) | J | 05.09.90 | W | | Zb | F |
| 79 | A.Høgfjellsvatn outlet (AHO) | J | 05.09.90 | W | | | F |

*forts.*

***Appendix 1**. Forts.*

| Nr. | Locality | Region | Date | Sampling | | |
|---|---|---|---|---|---|---|
| 80 | A.Skardvatn (AS) | J | 05.09.90 | | Zp | F |
| 81 | A.Skardvatn outlet (ASO) | J | 05.09.90 | W | | F |
| 82 | A.Skardvatn Stream (ASA) | J | 05.09.90 | W | | F |
| 83 | F.Skardvatn inlet (FSI) | J | 05.09.90 | W | | F |
| 84 | F.Skardvatn outlet (FSO) | J | 05.09.90 | W | | F |
| 85 | F.Skardvatn Stream (FSA) | J | 06.09.90 | W | | F |
| 86 | Holmvatn inlet (HoI) | J | 06.09.90 | W | | F |
| 87 | Holmvatn outlet (HoO) | J | 06.09.90 | W | | F |
| 88 | Holmvatn Stream B (HSB) | J | 06.09.90 | W | | F |
| 89 | Holmvatn Stream C (HSC) | J | 06.09.90 | W | | F |
| 90 | Holmvatn Stream D (HSD) | J | 06.09.90 | W | | F |
| 91 | Holmvatn Stream E (HSE) | J | 06.09.90 | W | | F |
| 92 | Kocheyavr (Koc) | RF | 04.07.90 | | | F |

***Appendix 2.*** *Water chemistry of the different localities. Locality numbers are in accordance with Appendix 1.*

| Locality | | FTU | mg Pt/l | µS/cm | | µekv/l | µekv/l | mg/l | mg/l | mg/l | mg/l | mg/l | uu | mg/l | mg/l | µg/l | µg/l | µg/l | µg/l | µg/l | µg/l | µg/l |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| nr | Date | Turb. | Col. | Kond | pH | Alk 4.5 | Alk | Ca | Mg | Na | K | Fe | SSS | $SO_4$ | Cl | $NO_3$ | Si | Cd | Cu | Mn | Ni | Zn |
| 2 | 30-Aug-9 | 8.1 | 10 | 743 | 7.08 | 742 | 728 | 44.27 | 4.50 | 17.00 | 8.63 | | 2619 | 108.77 | 11.1 | 586 | 6.36 | <2 | 9 | <5 | 485 | 6 |
| 3 | 30-Aug-90 | 1.8 | 22 | 91.7 | 7.05 | 416 | 397 | 8.83 | 2.07 | 3.23 | 1.27 | 60 | 394 | 14.34 | 3.03 | 145 | 3.2 | <2 | 33 | 5 | 36 | 31 |
| 5 | 29-Aug-90 | 0.42 | 20 | 64 | 6.93 | 261 | 239 | 5.07 | 1.35 | 3.23 | 0.54 | 40 | 286 | 8.32 | 3.97 | 4 | 2.93 | <2 | 5 | <5 | <20 | <5 |
| 9 | 31-Aug-90 | 0.48 | 9 | 70.9 | 7.08 | 309 | 288 | 7.03 | 1.30 | 2.52 | 0.36 | | 298 | 11.22 | 2.28 | 6 | 4.41 | <2 | <5 | <5 | <20 | <5 |
| 10 | 31-Aug-90 | 0.62 | 10 | 52 | 6.79 | 208 | 185 | 5.08 | 1.00 | 2.08 | 0.34 | | 258 | 9.19 | 2.33 | 8 | 1.93 | <2 | 6 | <5 | 32 | <5 |
| 11 | 01-Sep-90 | 0.34 | 9 | 78.6 | 6.89 | 279 | 258 | 7.88 | 1.98 | 2.57 | 0.23 | | 436 | 17.01 | 2.88 | 3 | 3.86 | <2 | <5 | <5 | 33 | <5 |
| 12 | 01-Sep-90 | 0.81 | 6 | 56.2 | 6.95 | 193 | 170 | 5.93 | 1.31 | 1.99 | 0.25 | | 318 | 12.38 | 2.12 | 10 | 2.86 | <2 | <5 | <5 | 20 | <5 |
| 14 | 01-Sep-90 | 0.63 | 9 | 386 | 7.13 | 332 | 312 | 49.87 | 11.09 | 4.4 | 0.73 | 44 | 3118 | 145.85 | 2.91 | 6 | 3.58 | <2 | 5 | <5 | 403 | 11 |
| 15 | 01-Sep-90 | 0.34 | 21 | 79.1 | 6.75 | 321 | 300 | 7.60 | 2.28 | 2.94 | 0.12 | | 401 | 14.97 | 3.15 | 8 | 4.97 | <2 | 6 | <5 | 33 | 5 |
| 16 | 01-Sep-90 | 0.48 | 7 | 323 | 6.94 | 257 | 235 | 34.77 | 14.49 | 4.03 | 0.72 | 35 | 4487 | 212.12 | 2.52 | 17 | 6.08 | <2 | 10 | 26 | 261 | 13 |
| 17 | 01-Sep-90 | 0.39 | 4 | 55.1 | 6.53 | 108 | 82 | 4.80 | 0.85 | 2.29 | 0.31 | | 347 | 11.76 | 3.62 | 3 | 0.13 | <2 | <5 | <5 | 76 | <5 |
| 18 | 02-Sep-90 | 0.45 | 21 | 55 | 6.21 | 76 | 49 | 4.16 | 1.40 | 2.39 | 0.18 | | 388 | 14.34 | 3.16 | 6 | 0.89 | <2 | 8 | <5 | 53 | <5 |
| 22 | 01-Sep-90 | 0.76 | 16 | 81.6 | 7.05 | 428 | 409 | 9.78 | 1.51 | 3.04 | 0.33 | | 367 | 12.22 | 3.89 | 38 | 0.98 | <2 | 9 | <5 | 22 | 6 |
| 23 | 01-Sep-90 | 0.44 | 21 | 56.2 | 6.8 | 214 | 191 | 4.77 | 1.26 | 2.87 | 0.36 | | 298 | 9.14 | 3.8 | 6 | 1.46 | <2 | 7 | <5 | 27 | <5 |
| 24 | 01-Sep-90 | 0.83 | 22 | 56.2 | 6.91 | 224 | 201 | 4.58 | 1.36 | 3.10 | 0.4 | 26 | 291 | 8.39 | 4.1 | 9 | 2.05 | <2 | 6 | <5 | 27 | <5 |
| 35 | 29-Aug-90 | 1.7 | 15 | 143.5 | 6.73 | 362 | 342 | 12.06 | 4.10 | 6.94 | 1.40 | 29 | 887 | 35.98 | 4.69 | 86 | 1.12 | <2 | 7 | 57 | 58 | <5 |
| 36 | 30-Aug-90 | 3 | 20 | 153.8 | 6.66 | 407 | 388 | 12.80 | 4.19 | 7.43 | 2.18 | | 959 | 36.95 | 5.3 | 568 | 1.01 | <2 | 11 | <5 | 79 | 30 |
| 39 | 29-Aug-90 | 1.6 | 18 | 146.5 | 6.9 | 362 | 342 | 12.10 | 4.08 | 7.09 | 1.42 | | 907 | 36.91 | 4.72 | 84 | 0.95 | <2 | 6 | <5 | 62 | <5 |
| 40 | 02-Sep-90 | 0.7 | 17 | 32.4 | 6.7 | 200 | 177 | 2.66 | 0.92 | 1.43 | 0.42 | | 109 | 3.71 | 1.12 | 6 | 1.78 | <2 | <5 | <5 | <20 | <5 |
| 42 | 04-Sep-90 | 3.8 | 14 | 32.2 | 6.78 | 204 | 181 | 2.77 | 0.92 | 1.47 | 0.44 | | 114 | 3.94 | 1.13 | 6 | 1.66 | <2 | <5 | <5 | <20 | <5 |
| 44 | 04-Sep-90 | 9.3 | 16 | 37.9 | 6.57 | 205 | 182 | 3.26 | 1.07 | 1.79 | 0.51 | 26 | 161 | 5.73 | 1.47 | 7 | 1.52 | <2 | <5 | <5 | <20 | <5 |
| 48 | 27-Jun-90 | 0.33 | 8 | 34.6 | 5.53 | 34 | 3 | 1.34 | 0.74 | 2.88 | 0.22 | | 251 | 5.49 | 4.85 | 3 | 0.21 | <2 | <5 | 6 | <20 | <5 |
| 49 | 27-Jun-90 | 0.56 | 7 | 35.3 | 5.59 | 36 | 6 | 1.31 | 0.79 | 2.91 | 0.26 | | 258 | 5.64 | 4.97 | 4 | 0.69 | <2 | <5 | 6 | <20 | 7 |
| 50 | 04-Sep-90 | 2.8 | 7 | 35.7 | 5.55 | 31 | 0 | 1.30 | 0.80 | 2.89 | 0.26 | | 262 | 5.73 | 5.07 | 0 | 0.74 | <2 | <5 | <5 | <20 | 5 |
| 51 | 27-Jun-90 | 4.2 | 13 | 56.4 | 6.15 | 237 | 215 | 5.78 | 0.76 | 3.08 | 0.75 | | 258 | 6.12 | 4.56 | 29 | 2.85 | <2 | 7 | <5 | <20 | 27 |
| 52 | 27-Jun-90 | 0.49 | 7 | 34.3 | 5.51 | 36 | 6 | 1.26 | 0.75 | 2.85 | 0.23 | | 249 | 5.43 | 4.81 | 5 | 0.39 | <2 | <5 | 8 | <20 | 5 |
| 54 | 27-Jun-90 | 1.4 | 37 | 38.5 | 5.54 | 47 | 18 | 1.52 | 0.85 | 3.22 | 0.16 | 66 | 271 | 5.89 | 5.23 | 3 | 0.17 | <2 | <5 | 7 | <20 | 6 |
| 55 | 03-Sep-90 | 7.8 | 27 | 42.1 | 5.35 | 31 | 0 | 1.66 | 0.95 | 3.48 | 0.13 | 34 | 311 | 7.10 | 5.77 | 6 | 0.11 | <2 | <5 | 8 | <20 | 6 |
| 56 | 27-Jun-90 | 0.46 | 7 | 34.6 | 5.43 | 32 | 1 | 1.26 | 0.74 | 2.84 | 0.24 | | 252 | 5.50 | 4.87 | 5 | 0.36 | <2 | <5 | 9 | <20 | 6 |
| 57 | 03-Sep-90 | 5.3 | 8 | 36 | 5.34 | 28 | 0 | 1.29 | 0.76 | 2.83 | 0.24 | | 262 | 5.84 | 4.96 | 3 | 0.2 | <2 | <5 | 6 | <20 | 6 |
| 58 | 27-Jun-90 | 0.8 | 11 | 33.8 | 5.37 | 35 | 5 | 1.24 | 0.74 | 2.87 | 0.21 | | 243 | 5.24 | 4.71 | 5 | 0.31 | <2 | <5 | 7 | <20 | 5 |
| 59 | 27-Jun-90 | 1.5 | 16 | 32.1 | 5.48 | 40 | 10 | 1.18 | 0.71 | 2.76 | 0.15 | | 230 | 5.14 | 4.33 | 4 | 0.33 | <2 | <5 | <5 | <20 | 5 |
| 60 | 03-Sep-90 | 0.68 | 6 | 34.1 | 4.74 | 11 | 0 | 0.82 | 0.68 | 2.49 | 0.18 | | 239 | 5.32 | 4.51 | 4 | 0.06 | <2 | <5 | 11 | 21 | 6 |
| 61 | 27-Jun-90 | 0.45 | 2 | 36.6 | 4.67 | 8 | 0 | 0.75 | 0.63 | 2.42 | 0.21 | | 236 | 5.49 | 4.30 | 2 | 0.09 | <2 | <5 | 19 | <20 | 9 |
| 62 | 03-Sep-90 | 0.56 | 4 | 37.3 | 4.72 | 8 | 0 | 0.81 | 0.70 | 2.56 | 0.21 | | 251 | 5.69 | 4.69 | 2 | 0.06 | <2 | <5 | 13 | <20 | 6 |
| 63 | 27-Jun-90 | 0.96 | 3 | 33.2 | 4.91 | 20 | 0 | 0.94 | 0.66 | 2.51 | 0.20 | | 227 | 4.88 | 4.42 | 4 | 0.31 | <2 | <5 | 14 | <20 | 6 |
| 64 | 03-Sep-90 | 0.8 | 3 | 41.1 | 4.55 | 1 | 0 | 0.73 | 0.65 | 2.49 | 0.22 | | 259 | 6.22 | 4.59 | 3 | 0.06 | <2 | <5 | 18 | <20 | 7 |
| 65 | 27-Jun-90 | 0.64 | 4 | 31.6 | 4.9 | 22 | 0 | 0.84 | 0.61 | 2.39 | 0.20 | | 210 | 4.40 | 4.18 | 0 | 0.18 | <2 | <5 | 10 | <20 | 6 |
| 68 | 27-Jun-90 | 0.52 | 12 | 26.3 | 6.01 | 56 | 28 | 1.20 | 0.64 | 1.93 | 0.18 | 31 | 175 | 4.49 | 2.87 | 5 | 0.84 | <2 | <5 | <5 | <20 | <5 |
| 69 | 04-Sep-90 | 0.46 | 12 | 30.7 | 5.82 | 44 | 15 | 1.33 | 0.77 | 2.20 | 0.20 | | 222 | 6.26 | 3.25 | 3 | 0.24 | <2 | <5 | <5 | <20 | <5 |
| 70 | 04-Sep-90 | 0.48 | 17 | 44.4 | 6.49 | 121 | 96 | 2.43 | 1.22 | 3.12 | 0.27 | 34 | 275 | 7.87 | 3.94 | 3 | 2.68 | <2 | <5 | <5 | <20 | <5 |

*forts.*

***Appendix 2.** Forts.*

| Locality nr | Date | FTU Turb. | mg Pt/l Col. | µS/cm Kond | pH | µekv/l Alk 4.5 | µekv/l Alk | mg/l Ca | mg/l Mg | mg/l Na | mg/l K | mg/l Fe | uu SSS | mg/l $SO_4$ | mg/l Cl | µg/l $NO_3$ | µg/l Si | µg/l Cd | µg/l Cu | µg/l Mn | µg/l Ni | µg/l Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 71 | 27-Jun-90 | 0.84 | 26 | 28.6 | 6.01 | 73 | 46 | 1.41 | 0.71 | 2.17 | 0.18 | 78 | 180 | 4.62 | 2.95 | 4 | 1.42 | <2 | <5 | <5 | <20 | <5 |
| 72 | 04-Sep-90 | 0.58 | 20 | 41.9 | 6.55 | 116 | 90 | 2.30 | 1.19 | 3.05 | 0.24 | 31 | 266 | 7.53 | 3.85 | 3 | 2.24 | <2 | <5 | <5 | <20 | <5 |
| 75 | 28-Jun-90 | 0.36 | 5 | 35.6 | 5.21 | 25 | 0 | 1.13 | 0.72 | 2.98 | 0.23 | | 259 | 5.50 | 5.10 | 2 | 0.52 | <2 | <5 | 15 | <20 | 8 |
| 77 | 28-Jun-90 | 0.36 | 2 | 35.2 | 5.11 | 23 | 0 | 0.95 | 0.71 | 2.92 | 0.23 | | 253 | 5.41 | 4.97 | 3 | 0.47 | <2 | <5 | 62 | <20 | 7 |
| 78 | 05-Sep-90 | 0.4 | 2 | 35.5 | 5.08 | 22 | 0 | 1.00 | 0.71 | 2.88 | 0.24 | | 258 | 5.53 | 5.05 | 0 | 0.43 | <2 | <5 | 57 | <20 | 6 |
| 79 | 05-Sep-90 | 0.44 | 5 | 36.5 | 5.22 | 25 | 0 | 1.96 | 0.76 | 2.98 | 0.24 | | 267 | 5.71 | 5.23 | 6 | 0.48 | <2 | <5 | 15 | <20 | 6 |
| 81 | 05-Sep-90 | 0.22 | 5 | 43.8 | 6.53 | 86 | 59 | 2.27 | 1.01 | 3.39 | 0.37 | | 299 | 6.87 | 5.49 | 7 | 1.06 | <2 | <5 | <5 | <20 | <5 |
| 82 | 05-Sep-90 | 0.38 | 17 | 41.7 | 6.42 | 102 | 76 | 1.94 | 1.09 | 3.35 | 0.24 | 64 | 270 | 5.98 | 5.14 | 4 | 1.66 | <2 | <5 | <5 | <20 | <5 |
| 83 | 05-Sep-90 | 0.22 | 6 | 42.6 | 6.47 | 79 | 52 | 1.94 | 0.95 | 3.46 | 0.36 | | 286 | 6.39 | 5.42 | 3 | 1.15 | <2 | <5 | <5 | <20 | <5 |
| 84 | 05-Sep-90 | 0.3 | 6 | 40.9 | 6.4 | 72 | 45 | 1.77 | 0.96 | 3.30 | 0.34 | | 276 | 6.05 | 5.31 | 6 | 0.95 | <2 | <5 | <5 | <20 | <5 |
| 85 | 06-Sep-90 | 0.26 | 12 | 41.8 | 6.43 | 90 | 63 | 1.74 | 1.13 | 3.32 | 0.35 | | 277 | 6.19 | 5.24 | 3 | 0.82 | <2 | <5 | <5 | <20 | <5 |
| 86 | 06-Sep-90 | 0.22 | 5 | 41.1 | 6.42 | 74 | 47 | 1.75 | 0.97 | 3.35 | 0.33 | | 284 | 6.19 | 5.48 | 7 | 0.97 | <2 | <5 | <5 | <20 | <5 |
| 87 | 06-Sep-90 | 0.22 | 5 | 41.6 | 6.35 | 61 | 33 | 1.90 | 0.96 | 3.23 | 0.33 | | 296 | 6.67 | 5.57 | 3 | 0.98 | <2 | <5 | <5 | <20 | <5 |
| 88 | 06-Sep-90 | 0.28 | 5 | 46.2 | 6.53 | 81 | 54 | 1.98 | 1.15 | 3.82 | 0.45 | | 320 | 7.02 | 6.14 | 4 | 1.2 | <2 | <5 | <5 | <20 | <5 |
| 89 | 06-Sep-90 | 0.16 | 8 | 50.6 | 6.81 | 145 | 120 | 3.19 | 1.20 | 3.34 | 0.39 | | 308 | 8.49 | 4.64 | 7 | 1.98 | <2 | <5 | <5 | <20 | 8 |
| 90 | 06-Sep-90 | 0.33 | 4 | 38.7 | 6.13 | 53 | 24 | 1.85 | 1.04 | 2.90 | 0.33 | | 274 | 7.57 | 4.13 | 4 | 1.34 | <2 | <5 | <5 | <20 | 9 |
| 91 | 06-Sep-90 | 0.19 | 4 | 38.2 | 6.36 | 66 | 38 | 1.78 | 0.85 | 2.93 | 0.29 | | 263 | 6.29 | 4.66 | 8 | 1.24 | <2 | <5 | <5 | <20 | <5 |

***Appendix 3.*** *Population parameters of A) whitefish (*Coregonus lavaretus*), B) pike (*Esox lucius*), C) perch (*Perca fluviatilis*), D) brown trout (*Salmo trutta L.*), E) Arctic char (*Salvelinus alpinus*). J = juvenile, F = female, M = male.*

A. Whitefish

1 - Kuetsyarvi (Ku1); 2 - Kuetsyarvi (Ku3); 3 - Kocheyavr (Koc); 4 - Svanvik (Sv2).

1

| AGE | 1+ | | 2+ | | | 3+ | | 4+ | | 5+ | | 6+ | | 7+ | | 8+ | | 9+ | 10+ | mean | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SEX | J | F | J | M | F | M | F | M | F | M | F | M | F | M | F | M | F | F | M | J | M | F |
| Sample size | 1 | 1 | 4 | 1 | 4 | 12 | 8 | 10 | 13 | 9 | 14 | 1 | 9 | 3 | 4 | 1 | 2 | 3 | 1 | 1 | 38 | 58 |
| Weight, g | | 25. | | | 65. | 101.7 | 115.8 | 153.5 | 180.4 | 288.3 | 347.6 | 1000. | 484.4 | 701. | 756.5 | 750. | 762.5 | 1025. | 1300. | | 283.9 | 351.9 |
| range | | | | | 20-110 | 30-160 | 75-225 | 80-200 | 100-370 | 110-475 | 150-600 | | 325-600 | 350-900 | 626-850 | | 525-1000 | 1000-1050 | | | | |
| Length AC,cm | 12. | 12.5 | 13. | 12.2 | 16.2 | 19.4 | 20.5 | 22.2 | 23.7 | 27.1 | 29.2 | 39. | 32.3 | 36.4 | 37.4 | 37. | 37.2 | 39.8 | 46.5 | 12.4 | 24.8 | 27.3 |
| range | | | 12-15.5 | | 12-21 | 13.6-23 | 18-27 | 17-25 | 19.5-29.5 | 20-33 | 24-34 | | 28-35 | 29.5-40 | 34.5-38.5 | | 34-40.5 | 39.5-40 | | | | |
| male:female | | | 1 : 4 | | | 1.5 : 1 | | 1 : 1.3 | | 1 : 1.6 | | 1 : 9 | | 1 : 1.3 | | 1 : 2 | | | | 1 : 1.53 | | |

2

| AGE | 1+ | 2+ | | 3+ | | 4+ | | 5+ | | 6+ | | 7+ | mean | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SEX | J | M | F | M | F | M | M | M | F | M | F | F | J | M | F |
| Sample size | 1 | 3 | 7 | 6 | 1 | 3 | 4 | 4 | 4 | 6 | 2 | 4 | 1 | 22 | 22 |
| Weight, g | 13. | 13.7 | 13.7 | 43.5 | 16. | 143.7 | 205. | 184.5 | 267. | 410.3 | 372.5 | 763.8 | 13. | 178.8 | 263.6 |
| range | | 11-19 | 8-23 | 13-140 | | 81-263 | 28-351 | 77-331 | 182-426 | 161-642 | 166-579 | 728-852 | | | |
| Length AC,cm | 11.2 | 11.5 | 10.8 | 15.5 | 11.7 | 22. | 23.2 | 24.4 | 26.9 | 30.8 | 28.2 | 37.8 | 11.2 | 21.6 | 22.5 |
| range | | 10.5-13 | 9.5-13 | 10.3-27.2 | | 19.5-26.5 | 13.9-28 | 19-30 | 24-31.5 | 24-36 | 23-33.3 | 36.7-39 | | | |
| male:female | | 1 : 4 | | 6 : 1 | | 1 : 1.3 | | 1 : 1 | | 3 : 1 | | | 1 : 1 | | |

\- 2

3

| AGE | 1 + | 2 + | | 3 + | | 4 + | | 5 + | | 6 + | 7 + | | 8 + | mean | . |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SEX | M | M | F | M | F | M | F | M | F | F | M | F | F | M | F |
| Sample size | 1 | 11 | 2 | 4 | 9 | 3 | 6 | 1 | 4 | 4 | 2 | 4 | 1 | 22 | 30 |
| Weight, g | 13. | 110.9 | 95. | 160. | 142.2 | 300. | 221.7 | 350. | 332.5 | 495. | 547.5 | 571.2 | 700. | 195.2 | 303.2 |
| range | | 50-180 | 60-130 | 110-220 | 90-190 | 120-490 | 90-380 | | 300-380 | 400-575. | 520-575.5 | 320-740 | | | |
| Length AC,cm | 11.2 | 21.5 | 21.3 | 24.7 | 23. | 38.3 | 26.9 | 31.5 | 31.1 | 33.8 | 35.9 | 36.1 | 36. | 24.7 | 28.4 |
| range | | 17.5-24 | 20-22.5 | 22.27.3 | 20-25.8 | 22-33 | 21-32.2 | | 30-32.2 | 31-36.5 | 35-36.5 | 31-39 | | | |
| male:female | | 5.5 : 1 | | 1 : 2.25 | | 1 : 2 | | 1 : 4 | | | 1 : 2 | | | 1 : 1.4 | |

4

| AGE | 3 + | 4 + | 5 + | 7 + | | mean | . |
|---|---|---|---|---|---|---|---|
| SEX | F | M | M | M | F | M | F |
| Sample size | 1 | 2 | 2 | 2 | 2 | 6 | 3 |
| Weight, g | 144. | 254.5 | 342.5 | 630. | 752. | 409. | 549.3 |
| range | | 217-292 | 320-365 | 590-670 | 727-777 | | |
| Length AC,cm | 24. | 28. | 30.8 | 35.8 | 38.7 | 31.5 | 33.8 |
| range | | 26.5-29.5 | 30.2-31.4 | 35.5-36 | 38-39.4 | | |
| male:female | | | | | | 2 : 1 | |

***Appendix 3.*** *Forts.*

B. Pike (Esox lucius)

1 - Kuetsyarvi (Ku1); 2 - Kuetsyarvi (Ku3); 3-Maayarvi (Ma1).

1

| AGE | 2+ | 3+ | | 4+ | | 5+ | | 6+ | | mean | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| SEX | F | M | F | M | F | M | F | M | F | M | F |
| Sample size | 4 | 6 | 5 | 2 | 5 | 4 | 1 | 2 | 5 | 16 | 20 |
| Weight, g | 207.5<br>110-450 | 280.<br>200-425 | 359.<br>200-525 | 325.<br>275-375 | 505.<br>375-750 | 623.8<br>450-750 | 850 | 600.<br>350-850 | 750.<br>600-1000 | 492.2 | 487.5 |
| Length AC,cm | | 33.8<br>31-36.5 | 31.5 | 36.5 | 35.8<br>35.5-36 | 43.3<br>43-43.5 | 50. | 49.5 | 46.8<br>42.5-51 | 41.2 | 41.1 |
| male:female | | 1.2 : 1 | | 1 : 2.5 | | 4 : 1 | | 1 : 2.5 | | 1 : 1.25 | |

2

| AGE | 2 + | 3 + | | 4 + | 5 + | mean | |
|---|---|---|---|---|---|---|---|
| SEX | F | M | F | M | F | M | F |
| Sample size | 2 | 4 | 5 | 2 | 1 | 6 | 8 |
| Weight, g | 191.5<br>132-251 | 400.5<br>255-474 | 397.8<br>254-561 | 559.<br>539-579 | 707. | 453.3 | 384.9 |
| Length AC,cm | 31.5<br>28-35 | 37.5<br>32-40 | 37.7<br>32-42 | 40.8<br>40-41.5 | 44. | 38.6 | 37. |
| male:female | | 1 : 1.25 | | | | 1 : 1.33 | |

3

| AGE | 2 + | 3 + | 4 + | | 6 + | mean | |
|---|---|---|---|---|---|---|---|
| SEX | F | F | M | F | M | M | F |
| Sample size | 1 | 4 | 1 | 2 | 2 | 3 | 7 |
| Weight, g | 83. | 224.<br>198-261 | 429. | 403.<br>345-461 | 696.<br>684-708 | 607. | 255. |
| Length AC,cm | 24. | 33.5<br>31-35 | 40. | 41.8 | 48. | 45.3 | 41.2 |
| male:female | | | 1 : 2 | | | 1 : 2.33 | |

## *Appendix 3.* Forts.

C. Perch (Perca fluviatilis)

1 - Kuetsyarvi (Ku1); 2 - Kuetsyarvi (Ku3); 3 - Maayarvi (Ma1); 4 - Kocheyavr (Koc).

1

| AGE | 2+ | | | 3+ | | 4+ | | mean | | |
|---|---|---|---|---|---|---|---|---|---|---|
| SEX | J | M | F | M | F | M | F | J | M | F |
| Sample size | 5 | 1 | 4 | 1 | - | 1 | 1 | 5 | 3 | 5 |
| Weight, g | - | 55. | 43.8<br>21-85 | 158. | | 300. | 385. | - | 171. | 112. |
| Length AC,cm | 14.2<br>12.2-16.2 | 16.1 | 14.0 | 22.5 | | 22.5 | 27. | 14.2 | 21.4 | 16.9 |
| male:female | 1 : 4 | | | | | 1 : 1 | | 1 : 1.67 | | |

2

| AGE | 1 + | 2 + | | 3 + | | mean | | |
|---|---|---|---|---|---|---|---|---|
| SEX | J | M | F | M | F | J | M | F |
| Sample size | 3 | 6 | 11 | 7 | 5 | 3 | 13 | 16 |
| Weight, g | 23.5<br>18.5-31 | 74.3<br>37-190 | 42.3<br>20-81 | 202.9<br>72-280 | 284.8<br>217-311 | 23.5 | 143.5 | 118.1 |
| Length AC,cm | 11.7<br>11.-13. | 16.5<br>14.-25.5 | 15.2<br>12.-25 | 22.9<br>17.5-25.5 | 25.1<br>23.5-26 | 11.7 | 19.9 | 18.3 |
| male:female | | 1 : 1.83 | | 1.4 : 1 | | 1 : 1.23 | | |

3

| AGE | 1 + | | 2 + | | | 3 + | | 4 + | mean | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| SEX | J | F | J | M | F | M | F | M | J | M | F |
| Sample size | 3 | 2 | 2 | 4 | 10 | 4 | 5 | 1 | 5 | 8 | 18 |
| Weight, g | 15.7<br>21-10 | 14.2<br>11-17.5 | 12.0 | 39.2<br>19-93 | 23.5<br>11-56 | 118.5<br>14-180 | 81.2<br>14-180 | 367. | 14.2 | 78.9 | 57.6 |
| Length AC,cm | 11.8<br>10.5-12.9 | 11.8 | 10.5 | 12. | 12.6<br>9.6-17.2 | 19.2<br>11.2-23 | 16.3<br>11-23 | 29.1 | 11.8 | 15.6 | 14.8 |
| male:female | | | 1 : 2.5 | | | 1 : 1.25 | | | 1 : 2.25 | | |

4

| AGE | 1 + | | 2 + | | 3 + | | 4 + | 5 + | mean | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| SEX | J | F | M | F | M | F | F | F | J | M | F |
| Sample size | 5 | 1 | 4 | 3 | 4 | 3 | 2 | 3 | 5 | 8 | 14 |
| Weight, g | 20.0 | 160 | 165<br>110-220 | 183.3<br>160-230 | 302.5<br>260-350 | 333.3<br>300-380 | 335.<br>330-340 | 315.3<br>226-380 | 20.0 | 233.8 | 286. |
| Length AC,cm | 13.1<br>13.-13.5 | 22.5 | 23.2<br>22-25 | 24.<br>23-26 | 28.2<br>27-30 | 29.<br>28.5-29.5 | 28.5 | 28.7 | 13.1 | 25.8 | 27.4 |
| male:female | | | 1.33 : 1 | | 1.33 : 1 | | | | 1 : 1.75 | | |

***Appendix 3.*** *Forts.*

D. Brown trout (Salmo trutta L.)

1 - Ruosenyarvi (Ro); 2 - A. Skardvatn (AS); 3 - Dalvatn (Da); 4 - Maayoki (May); 5 - Pachtayoki (Pac); 6 - Otervatn (Ot)

1

| AGE | 2+ | 4+ |
|---|---|---|
| SEX | F | F |
| Sample size. | 1 | 1 |
| Weight, g | 120. | 220. |
| Length AC,cm | 22.5 | 17.5 |

4

| AGE | 1+ | 2+ | 3+ | | 4+ | 5+ | mean | |
|---|---|---|---|---|---|---|---|---|
| SEX | F | F | M | F | F | M | M | F |
| Sample size | 2 | 5 | 2 | 5 | 3 | 1 | 3 | 15 |
| Weight, g | 20.5 | 25.2<br>20-29 | 67.<br>55-79 | 91.<br>40-169 | 128.3<br>63-163 | 370. | 168. | 67.1 |
| Length AC,cm | 12.9 | 13.1<br>12.1-14 | 18.1<br>17.2-19 | 19.2<br>15-24.8 | 21.9<br>17.2-25 | 30. | 22.1 | 17. |
| male:female | | | 1 : 2.5 | | | | 1 : 5 | |

2

| AGE | 1+ | 2+ | | 3+ | | 4+ | | 6+ | mean | |
|---|---|---|---|---|---|---|---|---|---|---|
| SEX | M | M | F | M | F | M | F | F | M | F |
| Sample size | 1 | 4 | 2 | 3 | 6 | 7 | 4 | 1 | 15 | 13 |
| Weight, g | 13. | 29.<br>22-38 | 26.<br>18-34 | 78.3<br>77-80 | 64.<br>43-83 | 125.<br>74-155 | 132.5<br>106-159 | 500. | 82.6 | 112.8 |
| Length AC,cm | 10.8 | 14.3<br>12.8-15.8 | 14.3<br>12.8-15.8 | 19.2<br>18.5-20.2 | 18.2<br>16.1-19.9 | 22.1<br>19-24.5 | 23.4<br>21.5-25.9 | 34.9 | 18.6 | 20.5 |
| male:female | | 2 : 1 | | 1 : 2 | | 1.7 : 1 | | | 1.15 : 1 | |

3

| AGE | 1+ | | 2+ | | 3+ | | 4+ | | mean | |
|---|---|---|---|---|---|---|---|---|---|---|
| SEX | M | F | M | F | M | F | M | F | M | F |
| Sample size | 1 | 6 | 3 | 3 | 2 | 5 | 2 | 5 | 8 | 19 |
| Weight, g | 15. | 13.5<br>12-15 | 50.<br>42-56 | 56.7<br>37-76 | 85<br>77-93 | 109.8<br>72-132 | 210.<br>180-240 | 152.4<br>170-134 | 94.4 | 82.2 |
| Length AC,cm | 12.2 | 11.6<br>10.8-12.5 | 18.<br>16.8-19.4 | 18.1<br>16-20 | 20.5<br>20-21 | 22.<br>20-23 | 28.4<br>27.2-29.6 | 25.<br>25.4-23.8 | 20.5 | 18.9 |
| male:female | 1 : 6 | | 1 : 1 | | 1 : 2.5 | | 1 : 2.5 | | 1 : 2.38 | |

5

| AGE | 1+ | 2+ | 3+ | | mean | |
|---|---|---|---|---|---|---|
| SEX | F | F | M | F | M | F |
| Sample size | 2 | 2 | 2 | 1 | 2 | 5 |
| Weight, g | 12. | 11.5 | 42. | 29. | 42. | 15.2 |
| Length AC,cm | 10.2 | 9.9 | 16.4 | 12.5 | 16.4 | 10.5 |
| male:female | | | 2 : 1 | | 1 : 2.5 | |

6

| AGE | 3+ | 4+ | | 6+ | mean | |
|---|---|---|---|---|---|---|
| SEX | F | M | F | F | M | F |
| Sample size | 4 | 3 | 3 | 1 | 3 | 9 |
| Weight, g | 94.<br>73-130 | 156.<br>128-188 | 189.<br>149-264 | 459. | 156. | 176.8 |
| Length AC,cm | 20.8<br>19.6-22.3 | 24.1<br>13.2-25.6 | 25.5<br>24.2-27.4 | 34.2 | 24.1 | 24.4 |
| male:female | | 1 : 1 | | | 1 : 3 | |

## *Appendix 3.* Forts.

E. Arctic Char (Salvelinus alpinus)

1 - Ruosenyarvi (Ro); 2 - Sarasslaki (Sa); 3 - Dalvatn (Da); 4 - A. Skardvatn (As).

1

| AGE | 1+ | 2+ | | | 3+ | | 4+ | | 5+ | | mean | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SEX | J | J | M | F | M | F | M | F | M | F | J | M | F |
| Sample size | 3 | 1 | 6 | 3 | 10 | 7 | 7 | 8 | 1 | 3 | 4 | 24 | 21 |
| Weight, g | | | 40. | 90. | 92.5<br>75-120 | 68.8<br>40-100 | 75. | 122.5<br>85-160 | - | 190. | | 75 | 110. |
| Length AC,cm | 13.3<br>11.8-14.9 | 12.4 | 13.4<br>11.-15.4 | 15.8<br>11.9-19.9 | 17.7<br>14.7-21.8 | 15.6<br>12.8-19.8 | 15.5<br>12.3-18.6 | 18.2<br>15.5-24 | 17.2 | 22.1<br>17-25.3 | 13.3 | 16. | 17.5 |
| male:female | | 2 : 1 | | | 1.4 : 1 | | 1 : 1.1 | | 1 : 3 | | 1 : 0.88 | | |

2

| AGE | 1+ | 2+ | 3+ | 4+ | | mean | |
|---|---|---|---|---|---|---|---|
| SEX | F | F | F | M | F | M | F |
| Sample size | 3 | 6 | 8 | 4 | 4 | 4 | 21 |
| Weight, g | 25.3<br>22-29 | 27.5<br>12-46 | 37.1<br>22-52 | 63.8<br>49-98 | 53.9<br>40.5-76 | 63.8 | 35.9 |
| Length AC,cm | 12.6<br>12-13.8 | 13.2<br>10.9-15.6 | 14.5<br>12.5-16.2 | 16.6<br>15-19.5 | 16.<br>15.2-17.5 | 16.6 | 14.1 |
| male:female | | | | 1 : 1 | | 1 : 5.25 | |

3

| AGE | 1+ | | 2+ | | 3+ | | 4+ | | mean | |
|---|---|---|---|---|---|---|---|---|---|---|
| SEX | M | F | M | F | M | F | M | F | M | F |
| Sample size | 5 | 3 | 5 | 5 | 5 | 9 | 1 | 4 | 16 | 21 |
| Weight, g | 25.2<br>23-29 | 23.7<br>16-28 | 102.6<br>13-193 | 68.4<br>23-119 | 90.6<br>42-164 | 148.8<br>25-222 | 149. | 229.2<br>153-381 | 77.6 | 127.1 |
| Length AC,cm | 14.1<br>13.5-15.2 | 13.8<br>11.5-15.3 | 21.2<br>14.4-27.3 | 18.7<br>13.5-23.5 | 20.3<br>15.6-25.8 | 24.7<br>22.5-27.3 | 24.2 | 25.<br>17.2-33 | 18.9 | 21.8 |
| male:female | 1.66 : 1 | | 1 : 1 | | 1 : 1.8 | | 1 : 4 | | 1 : 1.33 | |

4

| AGE | 1+ | 2+ | | 3+ | | 4+ | 5+ | | 6+ | | mean | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SEX | M | M | F | M | F | M | M | F | M | F | M | F |
| Sample size | 1 | 5 | 1 | 3 | 1 | 2 | 5 | 2 | 1 | 3 | 17 | 9 |
| Weight, g | 22. | 45.2<br>31-68 | 37. | 85.<br>82-87 | 707. | 167.5 | 348.6<br>227-431 | 325. | 510. | 325.<br>326-359 | 181. | 217.6 |
| Length AC,cm | 13.7 | 16.6<br>14.6-18.9 | 15.6 | 20.4<br>20-20.7 | 44. | 27.4 | 31.3<br>27.4-33.9 | 31.7 | 35.3 | 30.1<br>29.4-30.8 | 23.8 | 24.9 |
| male:female | | 5 : 1 | | 3 : 1 | | | 2.5 : 1 | | 1 : 3 | | 1.89 : 1 | |

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