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Institute of North Industrial Ecology Problems,
INEP, Apatity
in cooperation with
Norwegian Institute For Water Research,
NIVA, Oslo

Pasvik River Watercourse, Barents Region:
Pollution Impacts and Ecological Responses

Investigations in 1993

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Abstract:

For the Pasvik River watercourse two major ecological problems are encountered: 1) Effects of heavy metals. This prosess is observed espesially in Kuetsyarv and to a lesser extent in the lower part of Pasvik River. This is caused by the Ni and Cu input with waste water from smelters and pits of the "Pechenganickel" company. Very high content of heavy metals (especially Ni) in water, lake sediment, macrophytes and fish is documented in Kuetsyarv. Extensive toxic effects were documented on the fish-population in the lake. The toxic effects are less than expected from the concentrations of heavy metals. This is due to high calsiumcontent, organic matter and eutrophication. 2) Eutrophication. This prosess is caused by domestic sewage from the settlements situated within the water catchment. According to phosphorus concentrations, diatoms in sediments and composition of the planctonic and benthic communities, Kuetsyarv is eutrophic and the Pasvik River is oligotrophic to oligo-mesotrophic.

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PREFACE

The maintainance of the Pasvik River ecosystem is a primary object for both countries involved in the project: Russia and Norway. Within the frame of a joint project between INEP and NIVA supported by Norwegian Ministry of Environment, multidisciplinary investigations of the Pasvik River were carried out in 1993. A joint scientist group of INEP (Russia) and NIVA (Norway) have prepared the report.

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Morten Meslo (Fjelltjenesten, Finnmark) and Juriy Tereshko (INEP) assisted in field works. The water chemistry and heavy metals in fish have been analysed by the laboratory of INEP, whilst the laboratory of NIVA has analysed heavy metals in macrophytes. Calculations and design are partly done by S. Vasilyeva (INEP).

We are indebted to Hanne Edvardsen, Bodø, for her material and lists of species from the upper parts of the Pasvik River. Reidar Elven (The Museum of Botany, Oslo) has kindly given us his list of species from the Tana Watercourse. The material of *Sagittaria sagittifolia* x *natans* has been determined by Stefan Ericsson, Umeå, whilst Kari Martinsson, Uppsala, helped us determining the diverging species of *Ranunculus peltatus*. Anders Langangen (Oslo "Katedralskole") has determined the charophytes.

Tatyana Makarova was kind to share her data on sulphur and heavy metals deposition in the Pasvik River watercourse. In the work we also used some water chemistry data from Lapland Water and Environment District (Finland).

Tatjana Moiseenko (INEP) has been the project leader, whilst Tor Erik Brandrud (NIVA) has been the leader for the Norwegian part of the project.

The author group is highly greatful to the Ministry of Environment and personally to Jan Thompson for his brilliant idea and support.

Picture at front page: Tangenfoss, upper parts of the Pasvik River. Foto: Steinar Wikan

CONTENTS

SUMMARY

For the Pasvik River watercourse two major ecological problems are pronounced: 1) Effects of heavy metals. This process is observed especially in Kuetsyarvi and to a lesser extent in the lower part of the Pasvik River. This is caused by the Ni and Cu input with waste water from smelters and pits of the "Pechenganickel" company. Very high content of heavy metals (especially Ni) in water, lake sediment, macrophytes and fish is documented in Kuetsyarvi. Extensive toxic effects were documented on the fish-population in the lake. The toxic effects are less than expected from the concentrations of heavy metals. This is due to high calsium content, organic matter and eutrophication.
2) Eutrophication. This process is caused by domestic sewage from the settlements situated within the water catchment. At present Kuetsyarvi has eutrophic status, whilst the lower parts of the Pasvik River has oligo-mesotrophic status according to phosphorus concentrations, and the composition of the planctonic and benthic communities. Due to increased and stabilized water level from HEP-regulations, increased abundances of macrophytes and zoobenthos in shallow areas also have occurred.

The river receives a complex anthropogenic load from: Air pollution of the catchment by the "Pechenganickel" smelter emissions, runoff from smelter and mine wastes and domestic sewage from the Russian and Norwegian settlements. The Pasvik River is also strongly regulated for hydroelectric power production (HEP).

Assessment of pollution from the Russian side (25% of water catchment) shows that the major amount of pollutants enters the Pasvik River from Kuetsyarvi (Ni 36 tons/years). Water chemistry of the river is stable upstream the runoff from Kuetsyarvi. In the lower parts of the river a clear increase of Ni (from <1 to 4 µg/l), SO4 (from 2.5 to 3.5 mg/l) and totP (from 7.2-9.2 µg/) were detected. It results from influence of the heavily polluted Kuetsyarvi.

Analysis of heavy metal accumulation in the sediments did not show any distinct influence of smelters atmospheric emissions above the inlet from Kuetsyarvi. No increase in accumulation, with the exception of Hg, were observed in the upper part. According to the index of Håkanson this part had a moderate degree of contamination (C_d), mainly due to the presence of Hg (C_d=10.9, C_f^{Hg}=5.0). The lower part of the Pasvik River system had a moderately high C_d value and moderate to high contamination factors (C_f) (C_d=22.1, C_f^{Ni}=7.8, C_f^{Cu}=4.2, C_f^{Hg}=4.0), whilst the sediments in Kuetsyarvi were heavily contaminated with a very high C_d value (C_d=58.7).

According to diatom analysis in the sediments, the oligotrophic waters of the Pasvik River watercourse have been somewhat eutrophicated during the last 30 years. The trophic status in the upper river part changed only little during this period according to the indexes used, but eutrophication and organic pollution increased in the lower part of the river. The changes in the diatom flora in Kuetsyarvi indicate an intensive water eutrophication during the last 30 years, corresponding to an increasing load of phosphorus and organic substances to the lake.

The phytoplankton communities did not show any pollution effects in the Pasvik River. In spite of some increased volume and some changes in the diversity at Bjørnevatn compared with Langvatn, both localities were still in the oligotrophic range. The phytoplankton in Kuetsyarvi reflects eutrophic-hypertrophic conditions.

The luxuriant macrophytic vegetation at Svanvik and Skrotnes with massive stands of the eutrophic species *Lemna trisulca* and *Polygonum amphibium*, respectively, seem to reflect some eutrophication in Svanevatn due to the influence from Kuetsyarvi. The vegetation in Gjøkbukta and at Perslåtta seem to be due to some eutrophication from great amounts of swans and from the HEP-regulations, respectively. Otherwise, the vegetation in the Pasvik River reflects the stable water level throughout

the year combined with the relatively warm and continental summer climate. The macrophytic vegetation in Kuetsyarvi, dominated by large stands of *Potamogeton perfoliatus* and *Polygonum amphibium*, seems to reflect eutrophic conditions.

The concentration of Ni in macrophytes was somewhat increased in the lower part of the Pasvik River compared with the upper part, but within the intervals for unpolluted areas. A Ni-content of 103 µg/g in plant material in Kuetsyarvi is very high also compared with other polluted areas. Some specimens of *Potamogeton perfoliatus* in the south-eastern part of Kuetsyarvi seemed to have somewhat lower vitality, perhaps because of the pollution of heavy metal or sulphur from Nikel.

The zooplankton species composition and abundance in the Pasvik River watercourse did not show a clear influence of toxic pollutants, and the communities recorded (except at Kuetsyarvi) did neither indicate any eutrophication effect.

The abundance of zoobenthos was higher in the upper compared with the lower part of the main river. The high abundance recorded in the upper part seems to be caused by a high content of organic matter and nutrients coming from the surroundings and from the presence of submerged vegetation. The extremly high abundance of pollution tolerant taxa in Kuetsyarvi is likely due to antropogenic eutrophication.

Under current conditions the fish community of the Pasvik river experiences some stress caused by heavy metal pollution and water eutrophication in the lower part. Several toxic effects are detected, reaching maximum occurrence in Kuetsyavri. The effects are characterized by pathologies of functionally important organs and tissues, i. e. skin depigmentation, liver adipose depletion, nephrocalcitosis, gill petal and small petal hyperaemia, scoliosis, and at the population level length change indices, fish juvenation and disorder of mature terms. High levels of nickel and copper are accumulated mainly in the kidneys and in the liver of fish from Kuetsyarvi, and is probably the major cause for the above mentioned pathology.

1. INTRODUCTION

The Pasvik River is one of the largest rivers in the Northern Fennoscandia. The main river constitutes the border between Norway and Russia. Therefore, maintaining stable ecological conditions are important for both countries. Anthropogenic load over the Pasvik River water catchment is caused by smoke emissions and the "Pechenganikel" industrial wastes and also, consumer wastes from the settlements placed on its water catchment.

A number of investigations on some aspects of the river ecological state has been carried out within the frame of Russian - Norwegian commission for environmental cooperation (Traaen et al. 1990, 1991, 1993; Nøst et al., 1991; Langeland et al., 1993; Rognerud et al., 1993; Amundsen et al., 1993). However, the total assessment of the river load and ecological state has not been performed up to now.

Within the frame of the joint project between INEP and NIVA approved by Norwegian Ministry of Environment, multidisciplinary investigations of the Pasvik River watercourse were carried out in 1993. The aim of the work is to give a comprehensive assessment of the load and current ecological state of the Pasvik River ecosystem, to discover the prior effluents and unfavourable processes in the ecosystem and to propose measures for ecosystem recovery.

One year of investigations appeared to be insufficient for the work. The complex nature of the Pasvik River will need further attention to get more complete understanding of the structure and function of the ecosystem.

The following subjects were investigated: Precipitations and polluted run off, water chemistry, lake sediments, diatoms analysis, phytoplankton, macrophytes, zooplankton, zoobenthos and fish.

2. SITE DESCRIPTION

The Pasvik River is 166.6 km long (120 km from the Finnish border). The fall from Lake Inari to its outlet at Kirkenes is aproximately 70 m. Its total catchment is 20890 km^2, of which 69.8% belong to Finland, 25.2% to Russia and 5% to Norway (Holtan & Brettum 1976). The upper part of the catchment mainly includes the Inari Lake in Finland, while the catchment on Russia side is dominated by the Kuetsyarvi Lake with the largest tributary, Shuoniyoki River, coming from the South-east (Fig. 2.1).

The river represents the boundary between Russia and Norway from Grensefoss North to Boris Gleb. The tides influence the river up to Skoltefoss (Boris Gleb) ca. 4 km from sea (Holtan & Brettum 1976).

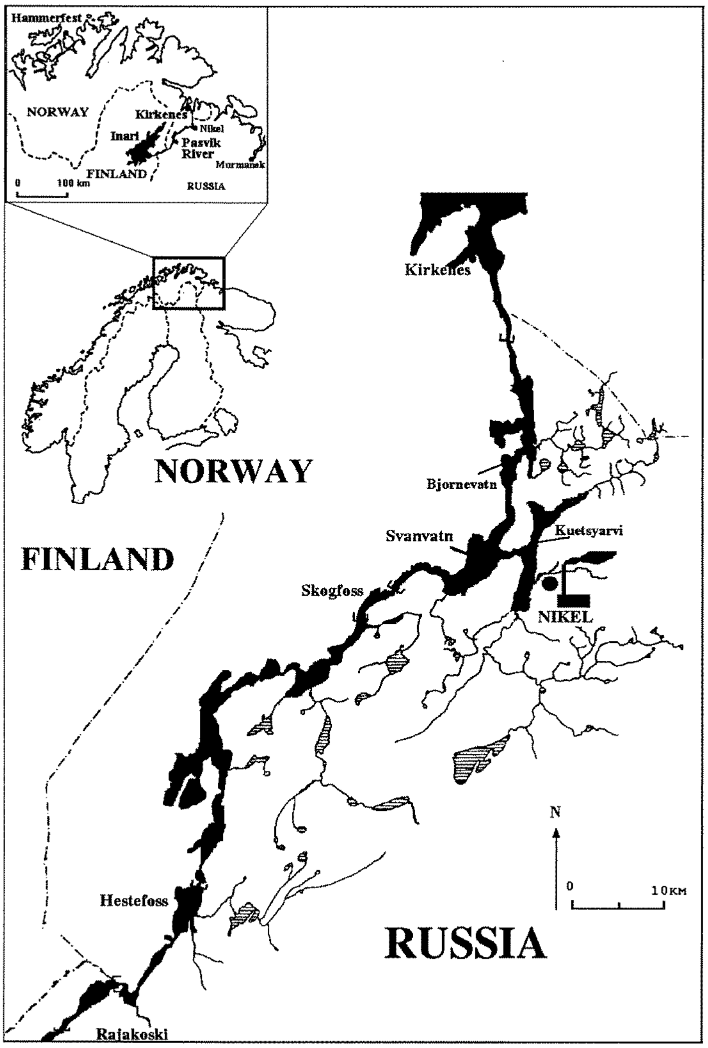

Figure 2.1. *Pasvik River watercourse*

Hydroelectric power (HEP) - regulations

The Pasvik River is strongly regulated. During the period from 1951 - 1978 altogether seven HEP constructions in the river were established south of Grensefoss in the Russian part of the river, three dams were constructed over 1951 - 1959 period. Along the Russian-Norwegian border the following

HEP installations are present: Boris Gleb (Skoltefoss, 1963, Russia), Melkefoss (1978, Norwegian), Skogfoss (1964, Norwegian) and Hestefoss (1970 Russia) (Edvardsen, in prep.). The Inari Lake in Finland is also regulated. In addition, three installations are placed in the uppermost part of the river, in the Russian part (Wikan 1980).

The Pasvik River is wide and gently flowing with many lakes: total length of the lake area is 61.7 km. The average discharge (1989 - 1993) is estimated to 196 m^3/s at Skogfoss (Sameiet Skogfoss kraftverk A/S).

Many HEP installations in the river and especially the regulation of the Inari Lake has contributed to a reduced variation in the discharge during the year. The fluctuations in the water level at Vaggatem during the last five years (Fig. 2.2) are assumed to reflect the general fluctuations in the Pasvik River. An average annual water level at Vaggatem is calculated to 51.71 m a.s.l., while the summer and winter medium level is at 51.75 m a.s.l., and 51.67 m a.s.l., that is a negligible variation of 10 cm.

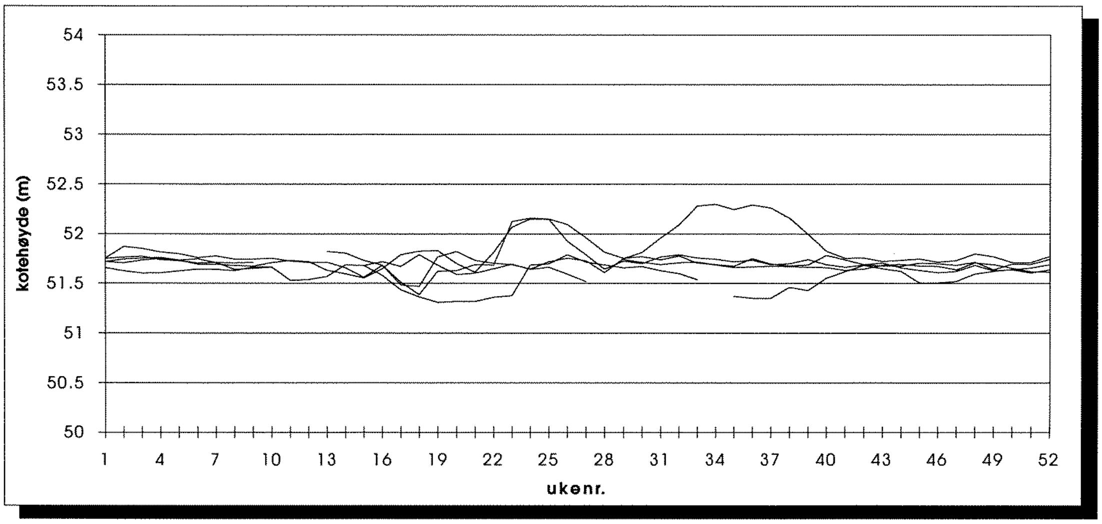

Figure 2.2. *The water level at Vaggatem during the period 1989-1993. Based on 7-days means. Data received from Sameiet Skogfoss kraftverk A/S.*

Climate

According to Alm (1991) the inner parts of Finnmark have a continental climate, with cold winters, fairly high summer temperatures and low annual precipitation. An average annual precipitation (1961 - 1990) was 391 mm for Upper Pasvik River, being a little higher at Bjørnevatn (438mm), Nickel (463mm) and Kirkenes (430mm). The year average temperature for the area is - 1.1°C and -0.6°C for Upper Pasvik River and Kirkenes, respectively. An average temperature for July is 13.7°C and 12.0°C for the two stations, while the corresponding temperatures for January/February are - 15.4°C and - 11.6°C. Average values of meteorological parameters for "Nikel" area are given in Tab.2.1.

Table 2.1. *Average values of meteorological parameters from the "Nikel" station (1936 - 1980) (Data from HYDROMET).*

Temperature in air °C	Relative humidity %	Wind velocity m/sek	Cloudness total/low	Precipitation mm	Total days with snow cover
-0.1 (-40°-+34°)	76	3.8	7.7 6.0	463	203

Geology

The central part of the study area (Pechenga - area) includes the so-called Petsamo-formation, consisting of eruptive and sedimentary rocks which are easily weathered and more nutrient/calcium - rich than the much harder and infertile gneissic and granitic bedrock that dominates to the south and north (Lieungh, 1990). The calcium-rich bedrocks cover large areas southeast of Nikel, then occur along the east and south side of the Kuetsyarvii and crosses the Pasvik River at Langevatn. Small areas with lime - rich bedrocks can be found also in the uppermost part of the Pasvik River valley.

Much of the area is covered by morainic till, with the thickest depositions south and north of the Petsamo mountains (thickness 1-20 m), near the cost the till cover is thin and patchy (thickness ca 0-2m). The Shuoniyoki River valley south of Nikel includes large glacifluvial deposits with gravel and sand. The morainic soil in the area is more or less locally derived, and is fairly calcium-rich (Lieungh, 1990).

Vegetation and soils

The major part of the Pasvik River catchment is forest-covered, sometimes heavily bogged, hilly country (m a.s.l. 120 - 450 m). The upper part has pine forest of *Vaccinium* or lichen-dominated type. Those ecosystems are stretching to the lower part (Holmfoss, Boris Gleb) where they gradually are replaced by birch forests of *Vaccinium* or gras/herb rich type.

The soils normally are podzolic illuvial-humus (podzolic Al-Fe-humus), thin-solum soils, their thickness in the upper part of water catchment does not exceed 50 cm. The soil profile in the birch ecosystems of the lower part of the catchment does not exceed 30 cm. On the hills with rock outcrops the thickness of soil profile is 3-5 cm.

3. MATERIAL and METHODS

Water chemistry. During maximum vegetation from August 5 through 10 there has been carried out water sampling along the Pasvik River: from Yaniskoski to Bjørnevatn at six stations (stations I -VI, see Fig. 3.3A and Appendix 3.1). At four stations (II, IV, V and VI) there has been measured temperature and oxygen concentrations along the depth profiles.

At the three stations Skogfoss, Bjørnevatn and Kuetsyarvi (IV, V and VI) water sampling has been made regularly during open water period: 12.06, 16.07, 11.08, 22.09 (Fig. 3.3A, stations II, IV, V and VII).

With an objective to estimate the matter input from the water catchment into the Pasvik River during a year (3 - 4 times) there have been made water samples from its main tributary rivers in Russian territory (stations 1-12, see Fig. 3.3A and Appendix 3.1). Detailed monitoring of water chemistry has been conducted in the Kolosjoki Stream where the wastes from smelters, tailing dumps and municipal system of the Nikel town come in. The samples have been analyzed according to standard procedures. The analytical program included the following components: pH, conductivity, calcium (Ca), potassium (K), magnesium (Mg), sodium (Na), chloride (Cl), sulphate (SO_4), nitrate (NO_3), alkalinity, total organic carbon (TOC), total phosphorus (TotP), aluminium (Al) and heavy metals (Ni, Cu, Zn, Cr, Mn, Fe).

Sediment samples were collected from Kuetsyarvi, Bjørnevatn and Skogfoss with a ordinary gravity sediment corer as described by Skogheim (1979). Sediment cores from Skogfoss (IV) (6 cm long) and Bjørnevatn (V) (11 cm long) were collected in September 21, 1993 (see Appendix 3.1), and vertically extruded and sectioned in 1 cm layers for analysis. Sediment sampling from Kuetsyarvi (VI) was performed in September 1991 from 9 stations (Appendix 3.1). The uppest (0-1 cm) and deepest (24-25 cm) layers from each core were taken for analyses. The additional core from the VI-station was collected, and upper 10-cm layer was sectioned in 2-cm intervals. Values of water content (W), loss of ignition as indirect index of organic content (LOI) were determined in the samples, as well as the metals Ni, Cu, Co, Zn, Cd, Pb, Sr, Mn, Fe, Ca, Mg, Na, K and Al (analysed with atomic-absorption spectrophotometry).

To determine an anthropogenic influence on lake ecosystems, of heavy metals contamination factor (C_f) values for each metal (Ni, Cu, Co, Zn, Pb, Cd, Hg) were calculated as the quotient of concentrations from uppest to deepest layers according to method suggested by Håkanson (1980, 1984). Degree of contamination (C_d) values were defined as the sum of all contamination factors for given lake.

Diatom analysis of the sediment cores from the Skogfoss (IV), Bjørnevatn (V) and Kuetsyarvi (VI) has been performed (Appendix 3.1). Subsamples of these sediment sections were prepared for diatom analyses by boiling in 30% H_2O_2 with addition of $N_4P_2O_7$ to remove organic matter. Subsamples of 17x17 mm were taken under 40- and 100-fold increasing. 400 to 1000 valves at the prepared subsamples were counted to determine of the relative frequencies (%) of valves. Dominating diatom species and species diversity have been determined. Diatom taxa were classified into pH groups (alkaliphilous and alkalobiontic, acidofilous and acidobiontic, circumneutral) according to their ecological preference (Hustedt, 1939). Diatom concentrations (number/g sediment d.w.) have been calculated, as well as the following values:
1) index of trophic classification-A/C: of the *Araphineae* to the *Centrical* groups of diatoms in the plankton, according to Stockner (1971);
2) saprobity index for assessment of water quality using method by Pantle Buck (Sladecek, 1973; Unificiated methods, 1975). Waters have been classified according to the Kolkwitz and Marsson system, modified by Sladecek (1973).

Phytoplankton. Through the growing season 1993 quantitative samples for phytoplankton analysis were sampled from three localities in the Pasvik River watercourse. The samples were taken from 1 m depth over the deeper parts in the lakes Langvatn (Skogfoss), Bjørnevatn and Kuetsyarvi (Fig. 3.3A, Appendix 3.1), ones a month, in June, July, August and September. The samples were fixed and preserved with Lugol's solution added acetic acid.

Analysis of the phytoplankton were carried out according to Utermöhl (1958) and Rott (1981). Both 10 and 50 ml chambers were used for the sedimentation procedure, and 2 or 4 transects were examined and the number of individuals of each species in the transects recorded. An Leitz Fluovert Fs inverted microscope with phase contrast was used for the examination. A number of cells of each species were measured and the mean cell volume calculated using simple geometric figures (Rott 1981). Phytoplankton volumes as volume of each species, the main groups (green algae, diatoms etc.) and the total volume in each samples were then calculated.

Aquatic macrophytes. The field work took place 24-27 August 1993, covering 19 localities; 16 in the Pasvik river and 3 in Lake Kuetsyarvi (Fig. 3.3B and Appendix 3.1). The plants were recorded using a water tube and collected by dredging from the boat. The abundance of the species is scored by a semi-quantitative scale, where 1 = rare, 2 = scattered, 3 = common, 4 = locally dominant and 5 = dominant. All depths given relate to the current water level in the period of field work. The nomenclature for the macrophytes (except *Myriophyllum sibiricum*) is according to Lid (1985), and for aquatic mosses according to Corley et al. (1981) and Grolle (1983). The names of the charophytes follow Langangen (1992).

To determine nickel and copper in macrophytes *Sparganium angustifolium* were used, a species which is widely distributed throughout the watercourse. Because this species has nutrient-uptake from the water, it probably reflects the concentrations of copper and nickel in the water. Species from loc. 9 (Fuglebukta), loc. 12 (Kuetsyarvi by the outlet) and loc. 19 (Skrukkebukta at Bratli) were examined for the heavy metals copper and nickel. We also collected specimens of *Sparganium angustifolium* from 7 more localities and specimens of *Potamogeton perfoliatus* from 4 localities. These collections will be stored at NIVA. For the heavy metal analysis we used the growth of the year, it means the whole plant of *Sparganium angustifolium* and a 10 cm tip-sample of *Potamogeton perfoliatus*.

Zooplankton. Qualitative zooplankton samples were obtained using a plankton net of 40 μm mesh size in July 1993. Three samples (two replicates) were taken in Skogfoss and Bjørnevatn localities (Fig.3.3A, Appendix 3.1) from 0-3 m, 0-5 m and 0-15 m. All samples were fixed in Lugol`s fixation. Number and biomass (wet weight) were calculated.

Zoobenthos. Benthic invertebrates were sampled in littoral, deep parts and stretches of the Pasvik River watercourse (Skogfoss, Svanevatn, Bjørnevatn), and Kuetsyarvi in beginning of August 1993 (Fig. 3.3A, Appendix 3.1). In deep zones zoobenthos was collected with an Ekman dredge (213 cm^2) Samples from the littoral zone were made by kicking technique described by Frost et al. (1971). 2-5 samples were collected from each localities. All samples were sieved through a net with mesh size of 250 μm, and the animals were separated from the mud material and preserved in 70% ethanol. For comparison there were used data of our earlier study of the Pasvik River watercourse (Langeland et al. 1993). Biomass of zoobenthos was based on fresh weight.

Fish. Research of fish in the Pasvik River were conducted in August 1993. The short time of work did not allow us to investigate all sites of the River. Therefore we used results of our previous research being conducted in a period 1991-1992 with the colleagues from University of Tromsø and Institue of Evolutionary Ecology and Morphology Russian Academy of Science, Moscow (Amundsen et al., 1993).

During the whole period there were investigated Kuetsyarvi (VI), Svanvatn - Bjørnevatn (V) and upper reaches (II-III) (Appendix 3.1). Fish were caught with standard gillnet series, consisting of 8 fleets 10-45 mm bar mesh size (Rosseland et al. 1979). All fish were analysed for body length and weight, sex gonad maturity, fat content of intestine and stomach fullness. Fish pathological and morphological examination was made and symptoms of diseases and parasitic infection were recorded visually (Lukin & Kashulin 1991, Kashulin & Lukin 1992, Langeland et al. 1993). Scales of fish were collected for age determination by standard methods (Pravdin, 1960). Haemotologic fish parameters, morphology and pathology of blood cells were defined by Krylov's method.

Heavy metal contents of tissues and organs were determined for the samples of whitefish from 4 sites of the river. Subsamples from 5 individual fish from every point were collected from the gills, liver, kidney, muscle, and skeleton. Samples were placed in plastic bags and quickly frozen in liquid nitrogen for further determination at the laboratory. These samples were dried to constant weight at 105^{o}C. Organic matter was removed with concentrated nitric acid (HNO_3). In organs and tissues, contents of Ni, Cu, Zn, Co, Mn, Al, Sr were determined with the atomic absorption method using flame-mode with Perkin Elmer model 460.

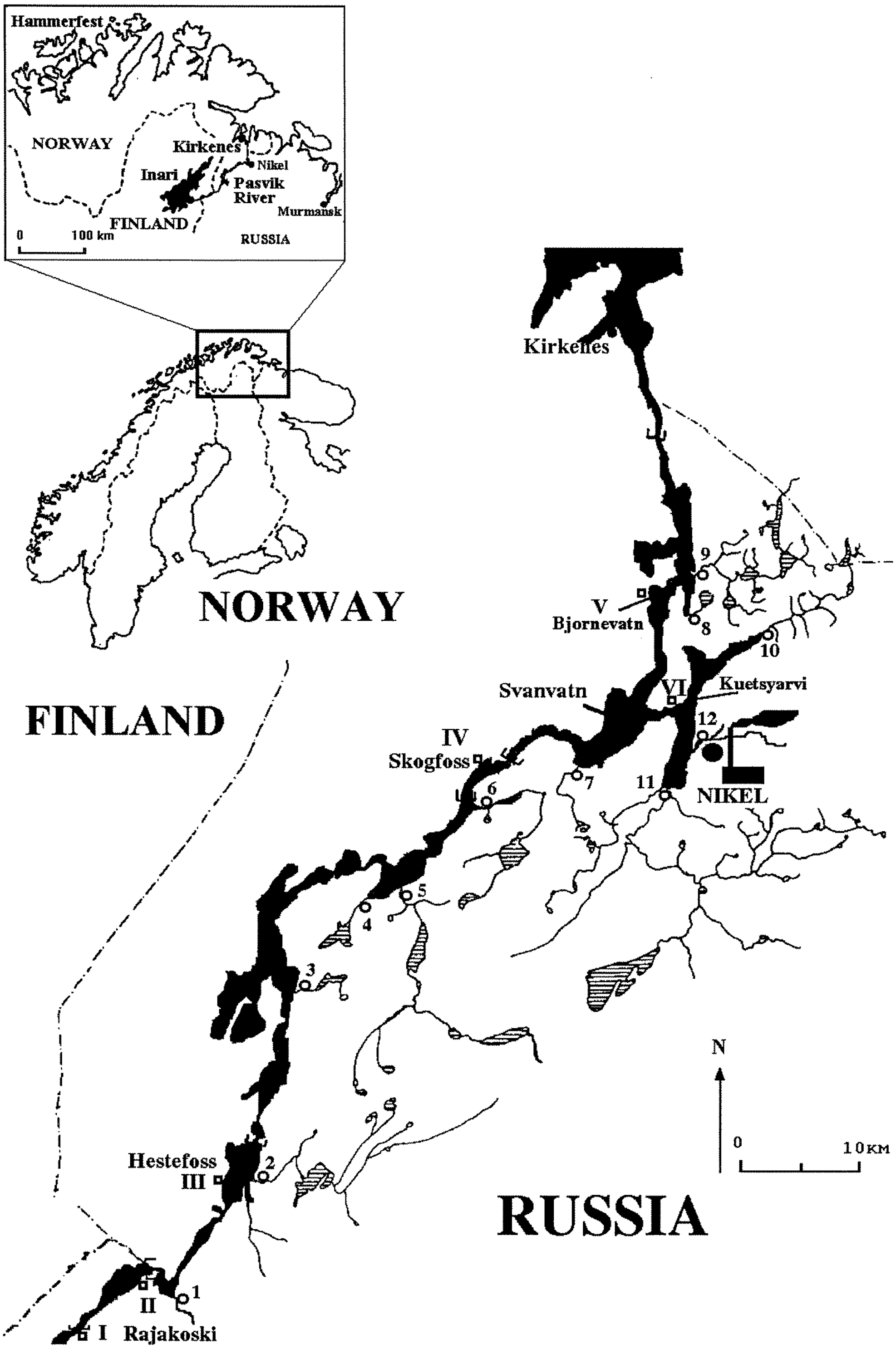

Figure 3.3A. *The studied area and sampling stations. 1 - 12: water samples in tributaries, I - VI: samples of water chemistry, zoobenthos and fish (August 1993), IV, V, VI: monitoring of water chemistry, phytoplankton and zooplankton (June -September 1993) and chemistry and diatom analysis of sediments.*

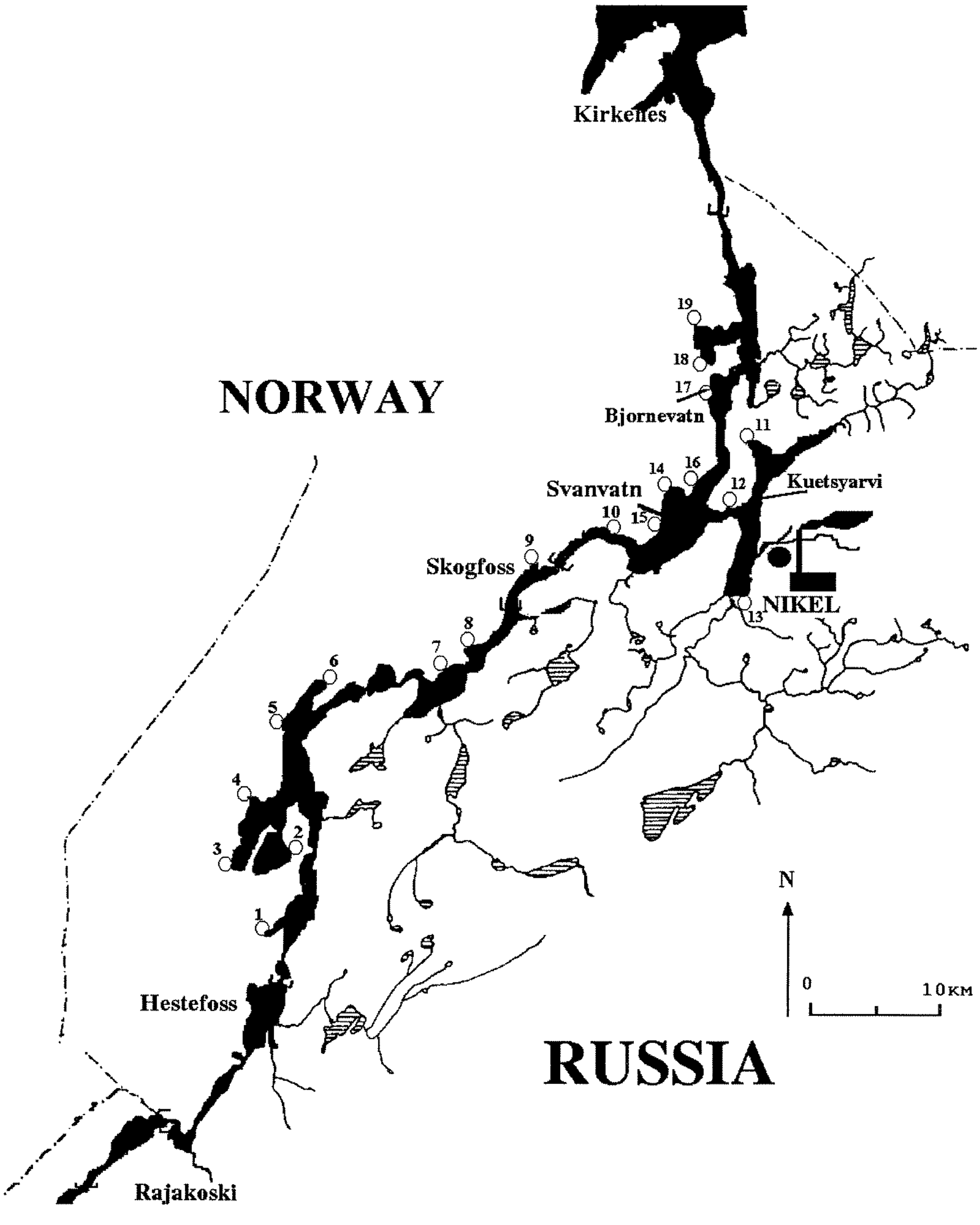

Figure 3.3B. The studied area and localities for macrophytes in august 1993.

4. POLLUTION SOURCES

Airborne pollution

The main pollution source in the catchment is the "Pechenganikel" smelter, operating since 1946. Prior to the "Pechenganikel" company the Finns operated the smelter a few years before and during 2. world war. From 1971 Norilsk high-sulphur copper-nickel ore, containing 30% of sulphur was used. Sharp increase of sulphur emissions in 1974 (+150 000 t/year) is caused by increased use of the Norilsk ore. Yearly emissions account for 512 tons nickel, 308 tons copper and 20 tons cobalt. Airborne pollution load to the Pasvik River catchment is mainly from local air pollution by the "Pechenganickel" smelter emissions, but also, to less extent, longrange transboundary airborne pollution. The prior pollutant to the water catchment is anthropogenic sulphur. It is shown that pollution by Ni, Co, Cu, Sr, Mg, Ca and S compounds are mainly a result of smelter emissions (Makarova and Radkin 1991). The water catchment of Kuetsyarvi has the highest depositions of pollutants. The annual Ni deposition here ranges from 30 to 160 mg/m^2 and anthropogenic sulphur from 600 to 1700 mg/m^2. On the major part of the Pasvik River catchment the annual nickel precipitation is less than 100 mg/m^2 and anthropogenic sulfur 300 - 700 mg/m^2.

Waste water

Waste water from the smelter and pits run into the Kolosjoki Stream, then into Kuetsyarvi and through a channel into the Salmijavri (Svanevatn, Pasvik River). Total bulk of wastes (average for the last five years) accounted for 12041 ths. m^3/year including Ni (6.4 tons/year) and Cu (0.13 tons/year).

The pollution of heavy metals from the smelter and the pits represents only a small part of the total load of Ni (ca 50 tons) to Kolosjoki. Resent unpublished investigations by INEP/HYDROMET/NIVA show that most of the load of Ni and Cu runs into Kolosjoki above the factory area. The sources are not yet identified, but it is reasonable to assume that weathering of waste rock dumps is a major source.

According to HYDROMET data (1990-1992) the river Kolosjoki is also polluted by toxic organic matters, e.g. phenols - 3 -14 μg/l, hexachloroethane - 0.002 - 0.53 μg/l, lindan 0.003 - 0.69 μg/l and oil products 26 - 360 μg/l.

In addition to industrial wastes the Kolosjoki Stream and Kuetsyarvi also receive domestic sewage from the Nikel town (30 000 inhabitants). On the bank of the Pasvik River there also are situated a number of small Russian and Norwegian settlements with municipal wastes containing nutrients accelerating the process of eutrophication.

Estimating total input of pollution into the Pasvik River from Russian territory

To discover the basic pollution sources and pollution loads from the water catchment the largest tributaries of the Pasvik River from Russian side were studied (Appendix 4.1).

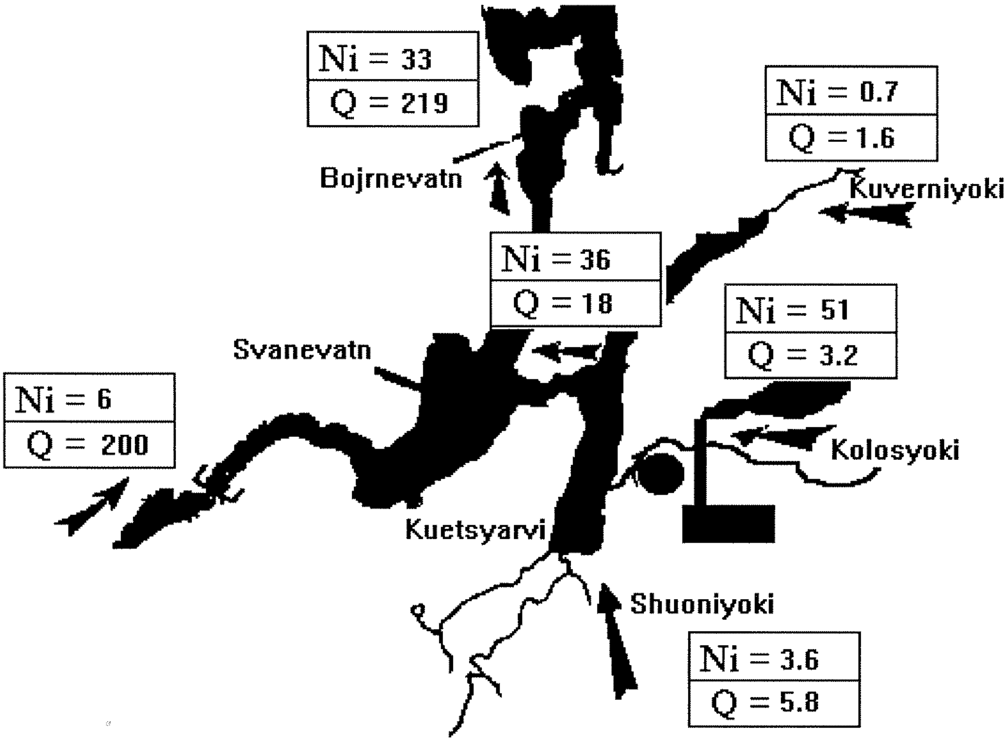

Figure 4.1 *Transport values of Ni (ton/year) and water flow (Q, m^3/s) in Pasvik River System in 1993.*

The main load of pollutants (Ni, Cu, SO_4) come with the Kolosjoki Stream into Kuetsyarvi. Further, Shuonijoki River receives runoff from the Kuorpukas Mountain. This mountain is situated southward from the smelter and is heavily polluted by smoke emissions. Total input of pollutants into the Kuetsyarvi are approximately : **Ni - 55 ton, Cu - 4 ton and sulphates -24000 tons (Appendix 4.2)**. Only parts of the total inputs of P and N are determined. It should be noted that 1993 compared with 1992 were characterized by abnormally high precipitation level that caused run off increase almost by two-fold in comparition with average values. Long-term average run-off for 1950-1990 from the Kuetsyarvi lake (data from HYDROMET) was 8.6 m^3/s. In 1992 and 1993 it was much higher - about 18.3 m^3/s.

Kuetsyarvi serves as a sink for pollutats into the Pasvik River. Significant amounts of the nickel and copper accumulates in the lake sediments before the water runs into Pasvik River (Appendix 4.1). The loads to Pasvik River from Kuetsyarvi are approximately: Ni - 36 tons, Cu - 3 tons, P_{tot} - 7 tons and N - 3700 tons. The contribution of nickel from the other tributaries are very small compared to the outlet of Kuetsyarvi, while the contributions of P, N and Cu are smaller but in the same order of magnitude as from Kuetsyarvi (Appendix 4.2). In Fig. 4.1 transport values of Ni in the lower part of Pasvik River are shown.

5. WATER CHEMISTRY

Water chemistry parameters along the Pasvik River was studied extensively during one week (4.-10. august 1993) in the growth season (Appendix 5.1).

The temperature of the water surface layer was in the range of 14.5 - 16.0°C at all stations. At most stations there were only minor temperature stratification. At 17 - 20 m depth the temperature was in the range 10.5 - 14.5°C. Oxygen saturation was good along the whole depth profile. Lowered concentration (5.4 mgO/l) were only observed close to the bottom of Kuetsyarvi. Thus, oxygen regime of the Pasvik River seems to be favourable for the biota in all parts.

The content of main ions are about 3 times higher in Kuetsyarvi than in Pasvik River. However, due to dilution, the influence of Kuetsyavri on the basic chemistry of Pasvik River is small (Fig. 5.1).

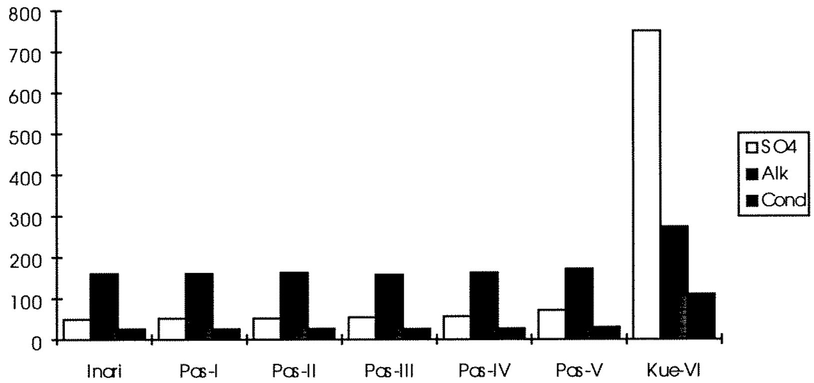

Figure 5.1. *Alkalinity, sulphate (µeq/l), and conductivity (µS/cm) in Pasvik River catchment.*

In the vegetation period the content of nutrient elements N, P, Si, Fe and organic matter are relatively high along the whole river (Appendix 5.1). The values for P and N were particularly high in august 1993 (Fig. 5.2). Earlier measurements in 1980 and 1990 (Traaen 1991) did not show such high values (about 6-8 µgP/l). The seasonal variation in 1993 might therefore not be typical for Pasvik River.

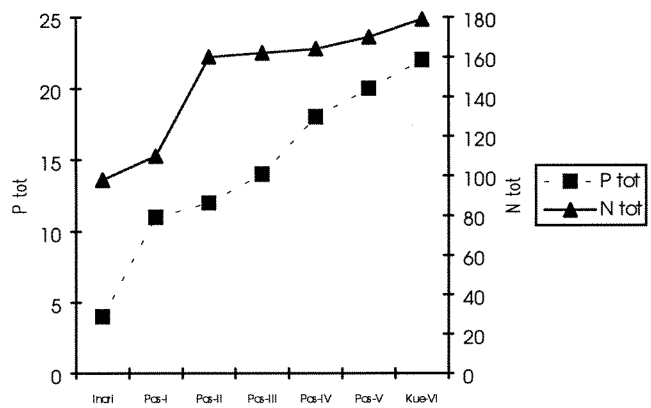

Figure 5.2. *TotP and totN (µg/l) in Pasvik River catchment, August 1993.*

The average increase of ca 2 µgP/l (7.5 - 9.3) from Skogfoss (Pas-IV) to Bjørnevatn (Pas-V) is in good agreement with the measurements in 1980 and 1990, but the mean values were ca 3 µgP/l higher at both stations in 1993. The main reason for the difference in mean values is that the high august values has a strong influence on the mean value when the sample number is low.

Analysis of the season dynamics of nutrients shows maximum P content and minimum ammonium-ion and nitrates in August. The major part of N is in organic form (Fig. 5.3, Appendix 5.2).

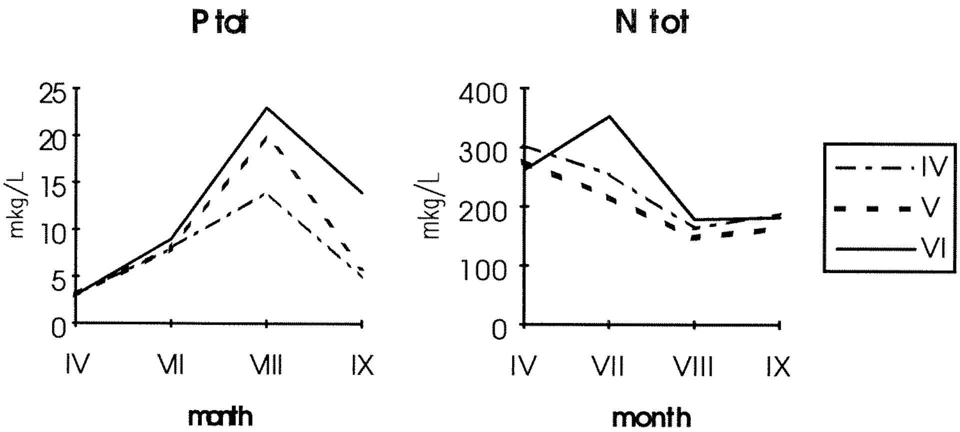

Figure 5.3. *Sesonal variations of totP and totN at 3 sampling points in the Pasvik River catchment.*

When estimating trophic status of the Pasvik River we used the trophic index of R.E. Carlson (1977). Juged by hydrochemical parameters (concentration of total N, P and dissolved organic carbon) the Pasvik River appears to be on the border between oligo- and -mesotrophic state. The Kuetsyarvi is characterized as an eutrophic lake. Earlier measurements in 1991 and 1992 (Langeland et al. 1993) of totP near the outlet of Kuetsyarvi showed higher values (from 17 to 35 µgP/l) than recorded in 1993 (from 3 to 22 µgP/l). Due to the great variations of totP measured in Kuetsyarvi, more frequent sampling is necessary to obtain a reliable average figure for the consentration and transport of totP.

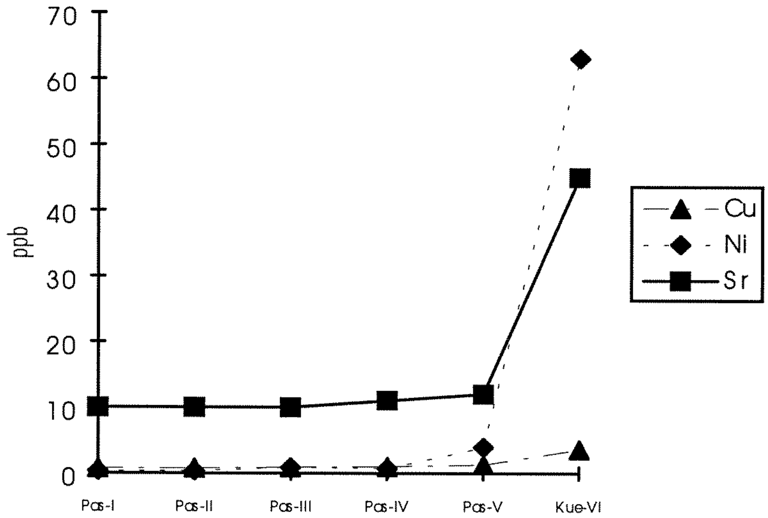

Figure 5.4. *Cu, Ni, and Sr in water (August 1993)*

The Kuetsyarvi is heavily polluted by Ni (70 µg/l) and to a lesser extent Cu (5µg/l). This affects the Pasvik River in its lower part, where Ni concentration was 7 µg/l and Cu 2 µg/l in 1993. In the upper part of the Pasvik River Ni and Cu content was about 1 µg/l and sometimes less (Fig. 5.4). Therefore, heavy metal pollution has no significant effect on the water quality of the upper part of Pasvik River. The result from 1993 are in reasonable good agreement with the measurements in 1990, when average Ni concentrations at Skogfoss and Bjørnevatn were <1 and 5 µg/l respectively, and Cu values were 1 and 4 µg/l.

6. HEAVY METALS IN SEDIMENTS

Investigations of heavy metal concentrations in surface sediments enable us to reveal the extent of contamination and the pollution history of the Pasvik River catchment, including Kuetsyarvi.

No significant changes in the vertical distribution of Ni, Cu, Co, Zn and Pb concentrations in the sediments of Skogfoss were noticed (Fig. 6.1, Appendix 6.1). This is in good agreement with investigations at Vaggatem, situated close to Skogfoss, by Rognerud (1990). However, Rognerud found a considerable increase of Hg and Cd concentrations in the surface sediments of Vaggatem relative to the background values in the deep sediments. This increase was probably not connected with the activity of the "Pechenganikel" company, because this part of the Pasvik River watershed is not heavily exposed to factory emissions.

Maximum content of heavy metals in Bjørnevatn sediments were observed in the upper 1-cm layer. An exception was Pb, which had slightly decreased concentrations towards the top layer (Fig. 6.1, Appendix 6.2). A considerable increase of heavy metal concentrations in the sediment interval of 3-4 cm relative to background values was found at Bjørnevatn. According to the diatom analysis (chapter 7) one must assume that sediments below 3-4cm were marine sediments. This probably means that accumulation of freshwater sediments at the sampling point might have startet only ca. 30 years ago when the water level was increased due to the construction of the dam at Boris Gleb. However, the content of Ni and copper in the deeper sediment layers at Bjørnevatn were very similar to values at Skogfoss. Organic content increased significantly from 3 cm sediment depth towards to surface. Maximum contents of Al, Ca, Mg and K were found in the intervals of 3-7 cm.

Maximum background values of heavy metals were observed in sediments of Kuetsyarvi, that is connected with geochemical and morphometrical peculiarities of the watershed area and the lake itself. Background concentrations of Ni and Cu in Kuetsyarvi sediments were 2 times higher and other metals 1.2-1.5 times higher than in Bjørnevatn and Skogfoss.

In the vertical distribution of heavy metal contents in the Kuetsyarvi sediments, maximum of Ni, Cu, Co and Zn concentrations were measured at 2-6 cm depth (Fig. 6.1, Appendix 6.3). A similar vertical distribution was found in sediments of the Russjanjarvi Lake located 17 km north-northeast from the "Pechehganikel" smelter (Rognerud et al., 1993). The reduced concentrations in the upper 2 cm is probably connected with changes of physical and chemical conditions in the lakes and watershed areas, as well as with decrease of atmospheric heavy metal emissions by the smelters (Baklanov & Makarova, 1992). Maximum of Al, Ca and Mg contents were recorded at the same sediment depths. These metals, as well as heavy metals, enter the lake with waste waters and atmospheric emissions. The sedimentation rate in the Kuetsyarvi on indirect determinations was approximately 3 mm/yr , based on the contamination of sediments down to a depth of ca 15 cm (Dauvalter, 1992).

Maximum values of the contamination factor (C_f) for heavy metals, with the exception of Pb and Cd, were found for the Kuetsyarvi sediments (Fig. 6.2, Appendix 6.4). The Kuetsyarvi has very high C_f values for Ni, Cu and Hg according to Håkanson classification (1980), moderate value- for Co and low values- for other metals. The Bjørnevatn Lake has very high C_f value for Ni, considerable high for Cu and Hg and moderate- for other metals. The Skogfoss station has a considerable C_f value only for Hg. Other metals have low C_f values.

The Kuetsyarvi has maximum value of degree of contamination (C_d), which according to Håkanson classification (1980) is considered to be a very high value (Fig. 6.2, Appendix 6.4). The Bjørnevatn has considerable C_d value, the Skogfoss moderate C_d value.

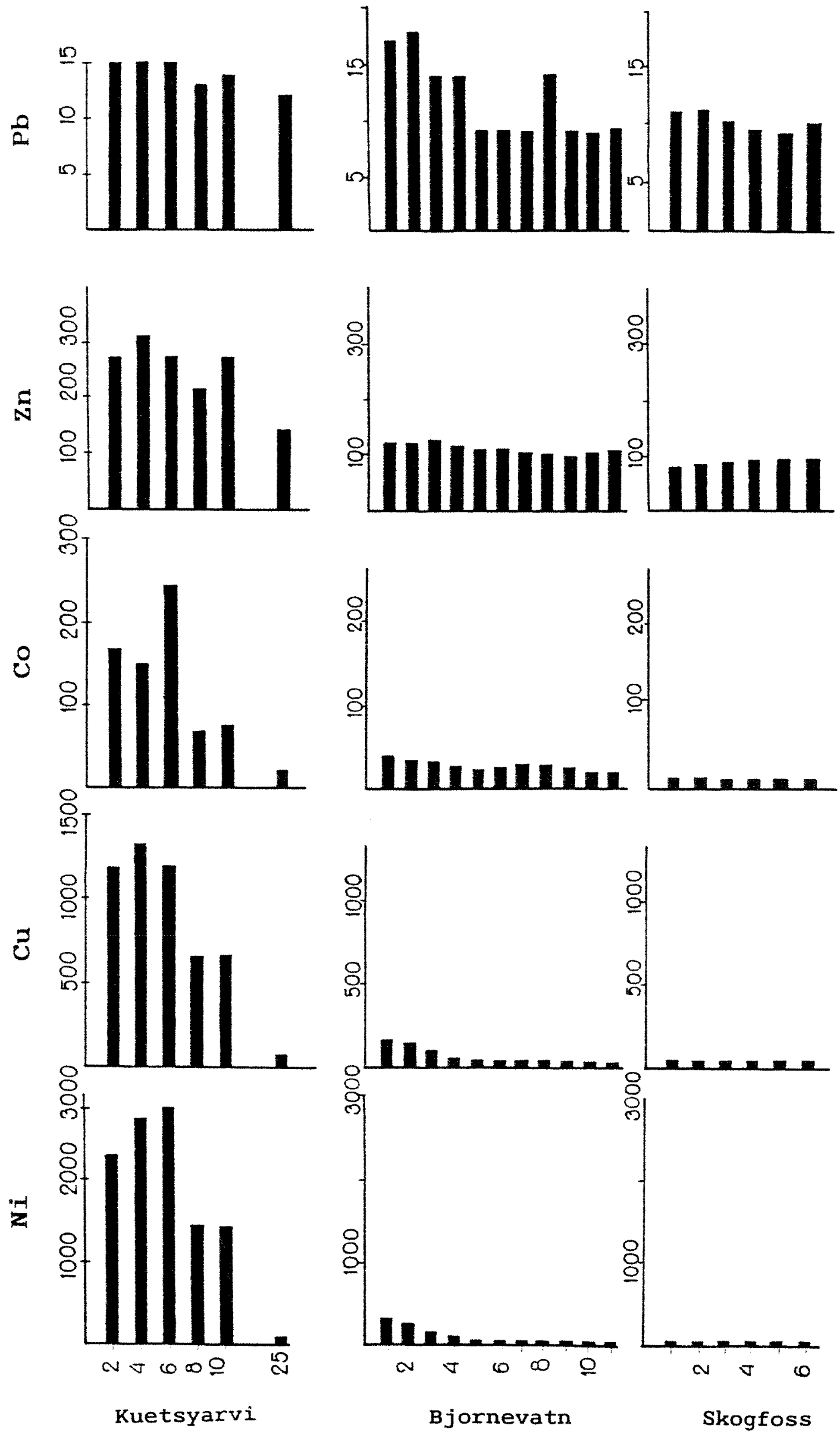

Figure 6.1 *Vertical distribution of heavy metals (Ni, Cu, Co, Zn, Pb) concentrations (µg/g dry substance) in the sediment cores of the Kuetsyarvi, Bjørnevatn and Skogfoss Lakes.*

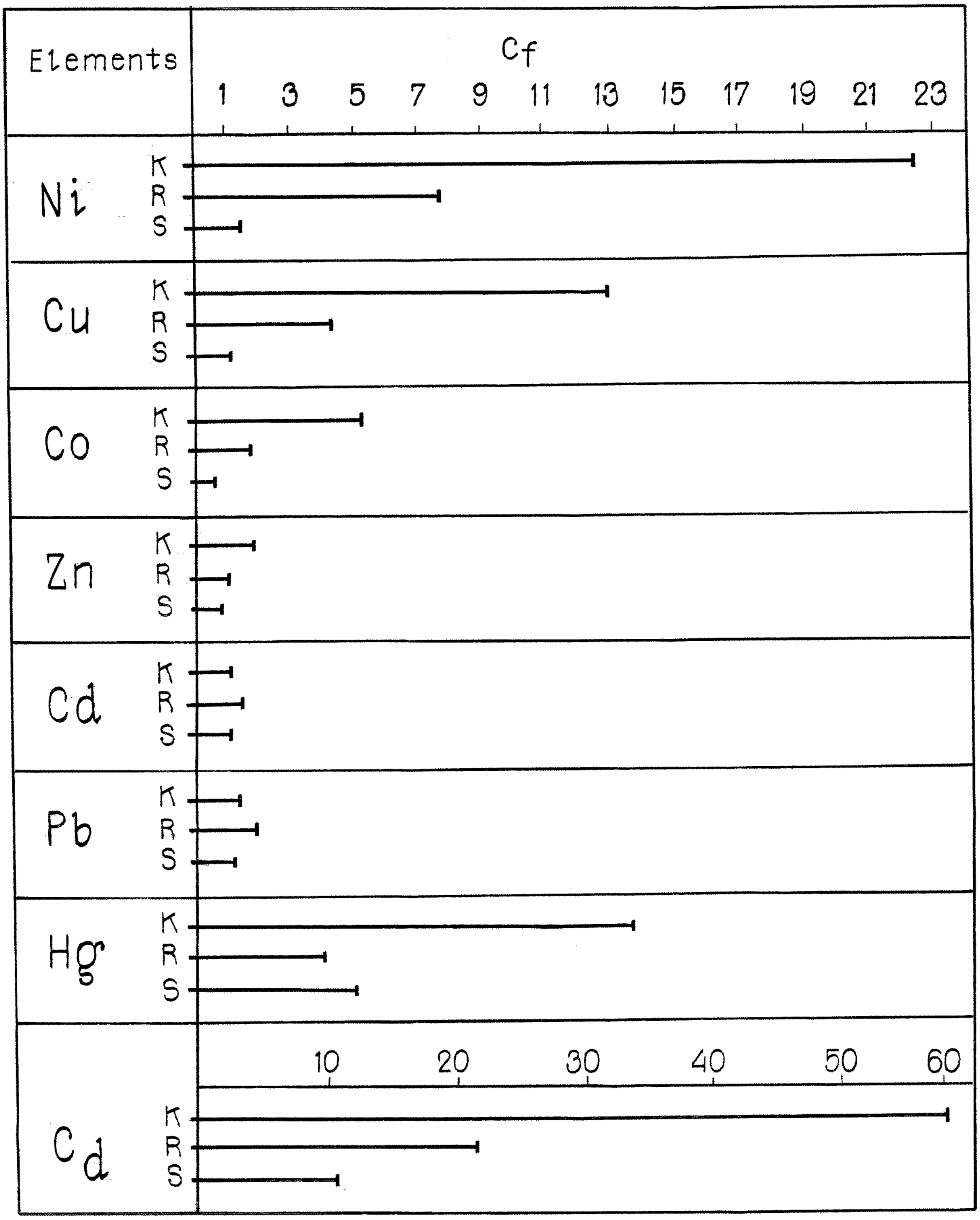

Figure 6.2. *Contamination factor (C_f) and contamination degree (C_d) values according to Håkanson (1980) classification in the Kuetsyarvi (K), Bjørnevatn (B) and Skogfoss (S) Lakes sediments.*

7. DIATOMS IN SEDIMENTS

Diatom analysis performed for three stations of the Pasvik River allows us to reconstruct the trophic status dynamic and intensivity of water eutrophication.

Sediments of the most clean middle part of the Pasvik River (Skogfoss) have been subdivided into two parts based on the abundance of dominating diatom species (Fig. 7.1):

1) The deeper layer of 3-5 cm had medium-grained sand and poorly decomposed organic substance. Periphytons and bottom diatoms such as the acidophilous *Pinnularia viridis var. sudetica* 19%, circumneutral *Pinnularia subcapita* s.lat. (19%) dominated. Among the subdominants were planktonic, circumneutral species *Cyclotella kutzingiana* (7%). Diatom concentration was low (140-250 ths valves/g). River water at this period (30-50 years ago) was classified to a xenobiotic stage according to terminology by Sladecek (1973), and oligotrophic according to terminology by Stockner (1971). Stockner index was equal 0.2-0.5 and saprobity index 0.75. Water quality was extremely good.

2) The upper layer (0-3 cm) was characterised by a different community. Planktonic species such as circumneutral *Cyclotella kutzingiana* (9%), alkaliphilous *Aulacoseira italica s.lat.* (12%) and *Aulacoseira ambigua* (12%) dominated in the grey-brown silt. The relative abundance of alkaliphilous species in the sediment profile of Skogfoss increased from deeper to upper layers from 10 to 50%. Stockner index remained at the level of 0.2-0.5. Diatom concentration increased up to 1.5-2 mln valves/g, and saprobity index was also increased (Appendix 7.1). This changes indicate a slight increase in water trophy level during the last 50 years (see Appendix 7.1).

The Bjørnevatn sediments have been subdivided into three parts (Fig. 7.2):

1) The deeper layer (2-8 cm) was characterised by a number of marine species (*Paralia sulcata, Ishmia nervosa* etc.) in yellow-grey silt with gravel. Marine species disappeared abrubly at the core depth of 2 cm. The sediment core in Bjørnevatn thus seem to be sampled in an area which had very little sedimentation before the construction of the dam at Boris Gleb. The layer below 2cm must be derived from this old, postglacial marine sediment.

2) The middle layer (1-2 cm) was had yellow-grey silt with gravel and pebbles. The planktonic, alkaliphilous species *Aulacoseira alpigena* (7%), *A. valida, A. subarctica* (11%) dominated. The relative frequency of alkaliphilous species was high (47%). The saprobity and Stockner indexes were indicated for oligotrophic waters (Appendix 7.2).

3) The upper layer (0-1 cm) was dominated by periphyton diatoms such as *Tabellaria flocculosa* (15%) and *Fragilaria construens* (21%). Stockner index increased from 0.2 to 2.8 in this case towards sediment surface. Saprobity index for plankton and periphyton was almost identical (1.64 and 1.63, respectively). This corresponds to slightly polluted water (Appendix 7.1). However, the increase of Stockner index, diatom concentration (from 0.112 to 3 mln/g) as well as species diversity in the surface layer indicate elevation of trophic level. According to diatom analysis this river part is assessed as mesotrophic.

The Kuetsyarvi sediments have been subdivided into four parts (Fig. 7.3):

1) The deeper layer (50-60 cm) had a dominance of planktonic, alkaliphilous species such as *A. alpigena* (37%) and *Aulacoseira islandica* (16%) in yellow-grey alevrite substratum. The lake at this developmental stage was oligotrophic according to the indexes applied (Appendix 7.2).

2) The next layer (50-10 cm) was dominated by the planktonic, alkaliphilous species *A. alpigena* (up to 50%) and *A. islandica* (22%), and from 20-10 cm also of the acidofilous periphyton species *Tabellaria flocculosa* (Appendix 7.2). Diatom concentration in the sediment profile is here at minimum (15-20 mln valves/g), but relatively high as compared with other investigated Pasvik River parts. Stockner index (0.03) and saprobity index (0.3) were minimum in the 20-30 cm interval. The waters in this sedimentation period (about 100 years ago) were xenobiotic, and very clean.

3) The 8-10 cm interval was dominated by alkaliphilous species such as *Aulacoseira alpigena* (up to 63%), and the lake trophic level began to increase. Abundance of acidophilous periphyton species *Tabellaria flocculosa* was reduced considerably (Appendix 7.2).

4) In the upper layer (0-8 cm) the dominating diatoms changed considerably towards predominance of more eutrophic taxa such as planktonic alkaliphilous species: *Diatoma tenuis* (42%), *Asterionella formosa* + *Asterionella gracillima* (22%), *Stephanodiscus minutulus* and *Stephanodiscus hantzschi* (17%). The subdominants were *Fragilaria capucina* (10%) and *A. islandica* (8%). The peak of diatom concentration (up to 170 mln/g), and maximum Stockner index values (3.6) and the highest trophy level according to the indexes used were observed in the 4-6 cm interval (Appendix 7.2). This interval corresponds to period of 1960-1970.

The Kuetsyarvi trophic level seems to have changed in the investigated period (200 years according to preliminary data): From oligotrophic to eutrophic stage owing to anthropogenic pollution (10-0 cm interval).

Conclusively, according to diatom analysis, the formerly oligotrophic waters of the Pasvik River watercourse has experienced some eutrophication, probably owing to domestic sewage, HEP regulation and industrial activity in the watershed during last 50 years. The trophic status in the upper river part has changed insignificantly, but saprobity was increased. Processes of eutrophication and organic pollution in the lower river part were increased. This fact was connected with increasing of total phosphorus flow and organic substances from the Kuëtsyarvi, where intensive water eutrophication has occured.

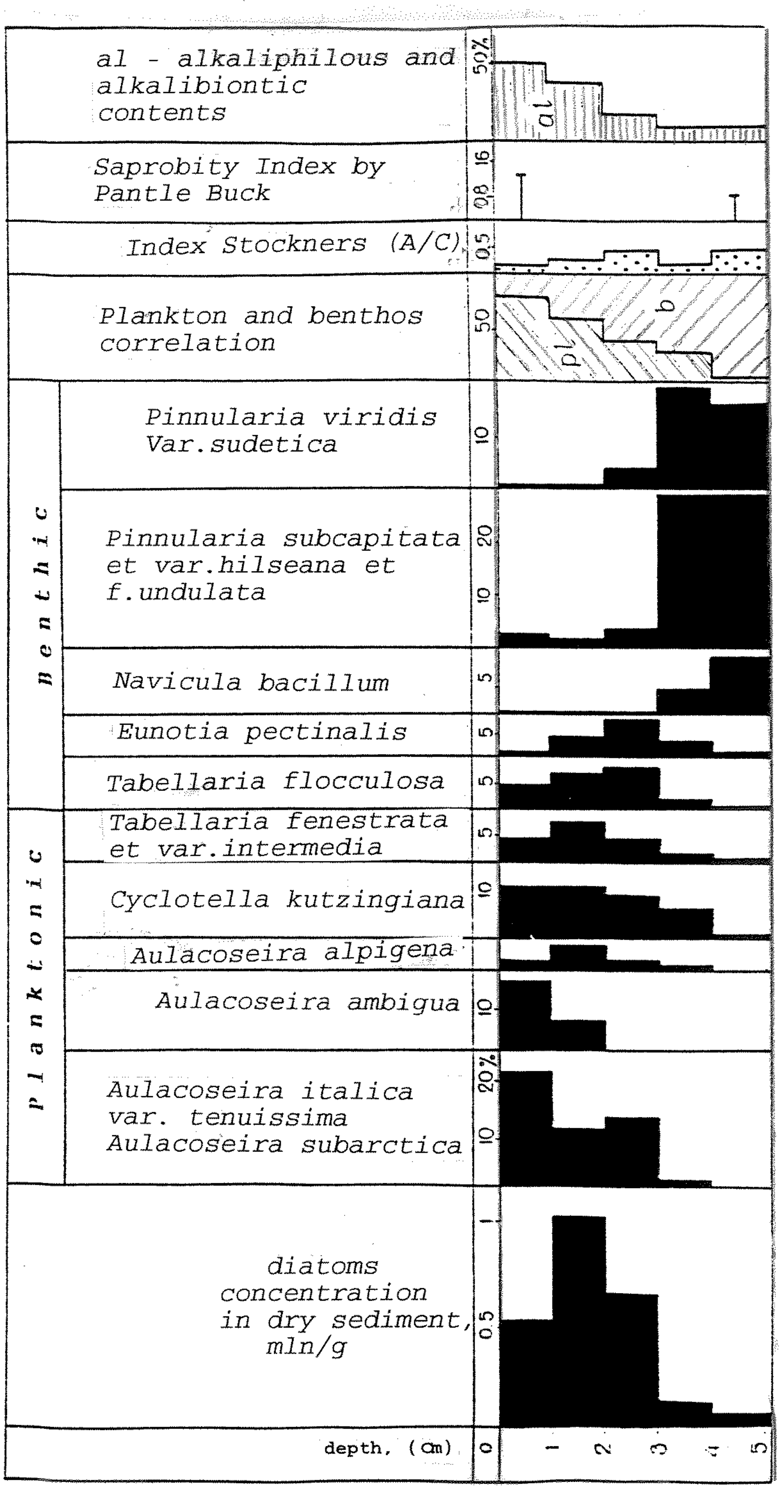

Figure 7.1. Diatom diagrams of the sediments (Skogfoss).

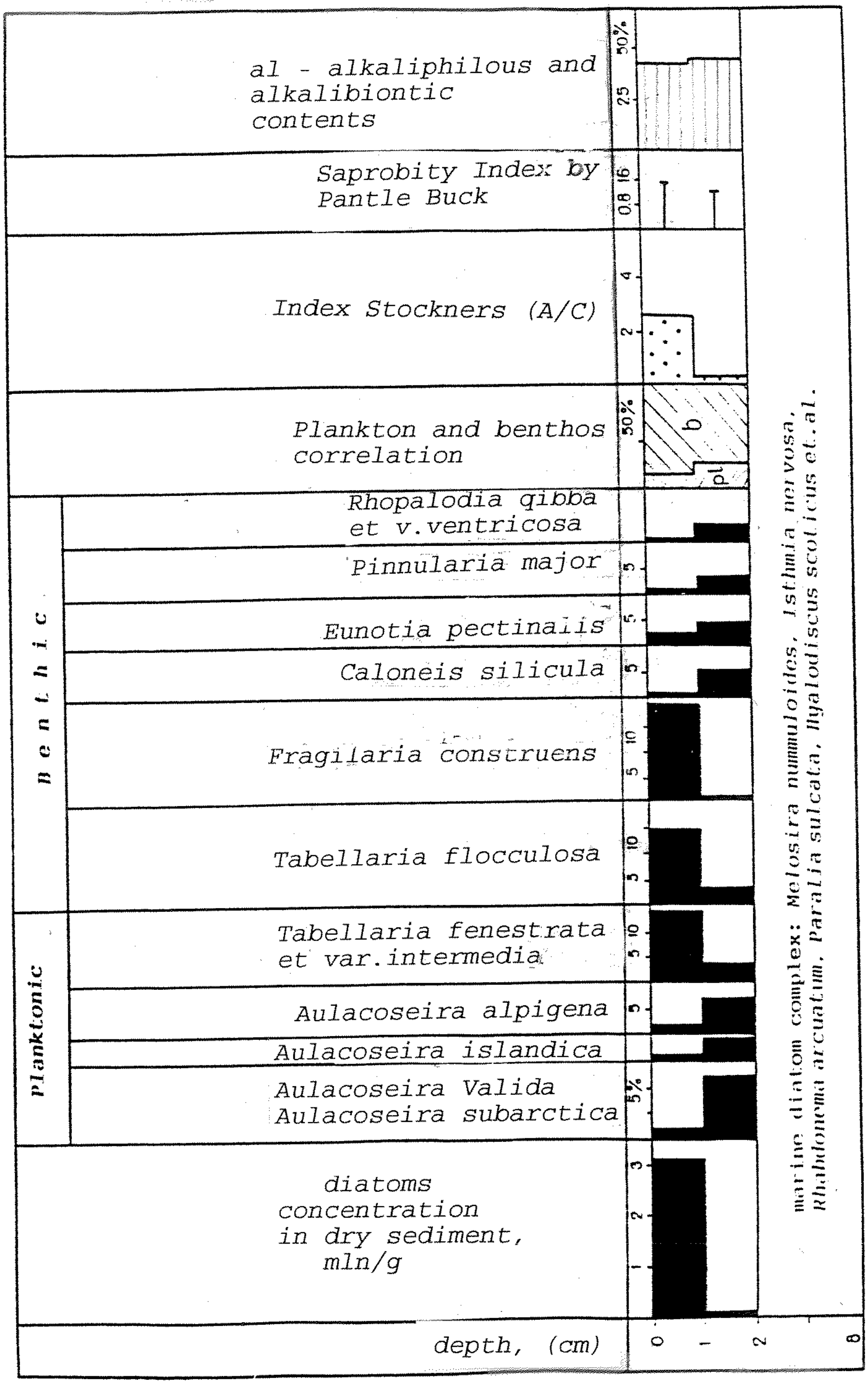

Figure 7.2. Diatom diagrams of the sediments (Bjørnevatn)

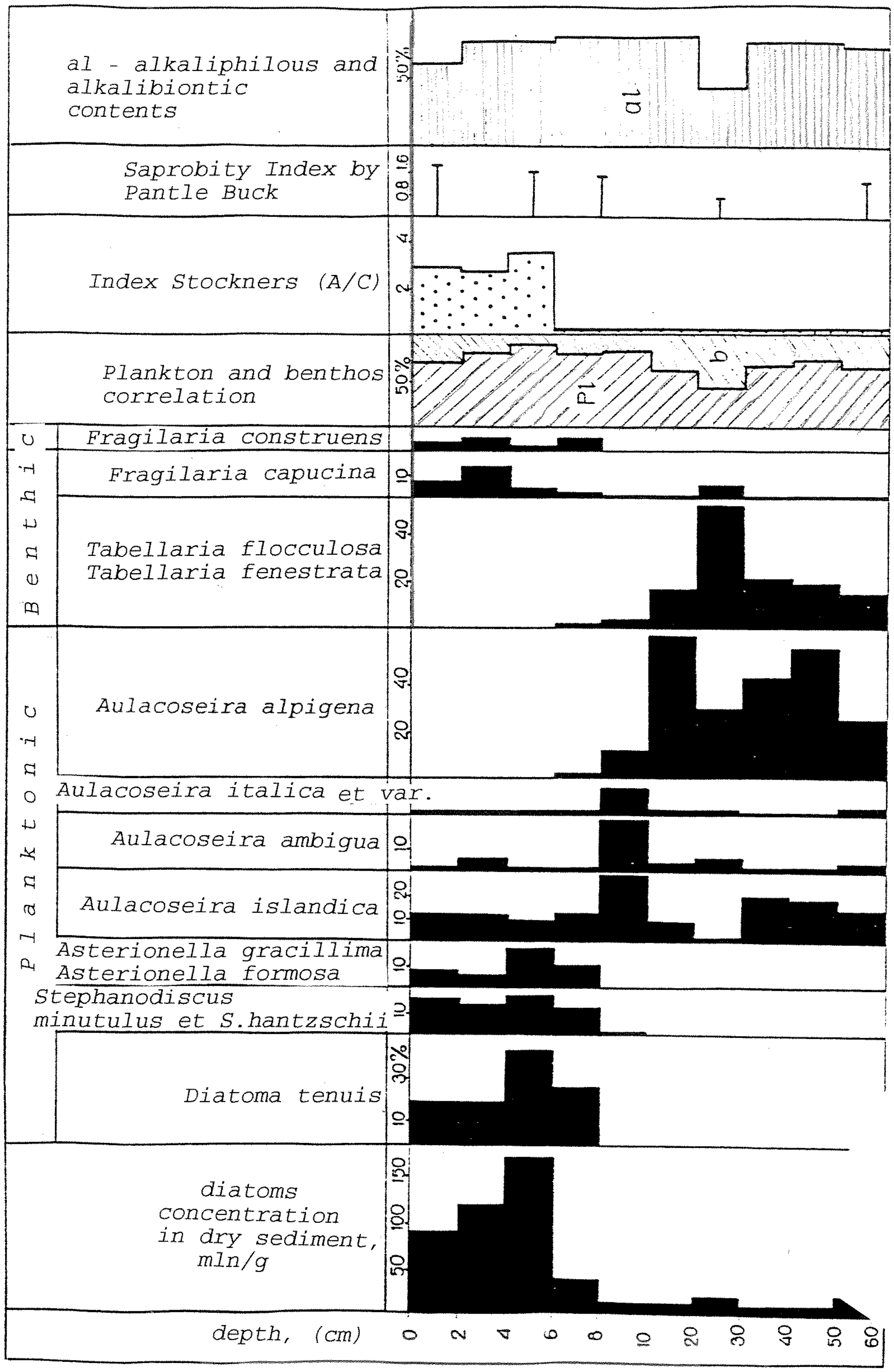

***Figure 7.3.** Diatom diagrams of the sediments (Kuetsyarvi)*

8. PHYTOPLANKTON

The volumes calculated are the basis for the valuation of the water quality at each locality. In the valuation of the water quality the volumes are compared with the classification system for trophic levels given by Brettum (1989). This system is based on maximum total phytoplankton volume registered in the samples of a locality throughout the growth season, and the mean value of the total volume in the same period. According to Brettum (1989) the values of total volumes of different trophic levels are:

Volumes in mm^3/m^3

Trophic level	Ultra-oligotrophic	Oligotrophic	Oligo-mesotrophic	Mesotrophic	Eutrophic	Poly-eutrophic	Hyper-eutrophic
Max-volume	0-200	200-700	700-1200	1200-3000	3000-5000	5000-10000	10000 →
Mean-volume	0-120	120-400	400-600	600-1500	1500-2500	2500-5000	5000 →

Increasing content of nutrients
--->

The total volumes recorded in Langvatn were rather small throughout the growth season (Fig 8.1, Appendix 8.1). Maximum was 236 mm^3/m^3 and the mean value approximately 190 mm^3/m^3. According to Brettum (1989) the water is classified as oligotrophic, with a low phytoplankton growth potential. This means that the water quality in this lake is very good.

As is normal for this type of water, there was no dominance of any group of phytoplankton, even though species of the Chrysophyceae (golden algae) were more marked in the samples than species of other groups. The most frequent species were chrysomonads of different sizes. The Bacillariophyceae (diatoms) were of relatively little importance in the phytoplankton composition, while different species of the group Cryptophyceae (cryptomonads), especially such as *Rhodomonas lacustris* and different species of the genus *Cryptomonas*, periodically were periodically of some importance.

Very high values of total phytoplankton volumes were recorded in Kuetsyarvi (Fig. 8.1, Appendix 8.2). Especially in July the totale volume was extremely high with more than 17000 mm^3/m^3. The group Bacillariophyceae (diatoms) dominated almost completely in the phytoplankton community, even though different species of other groups were recorded. The diatoms made up a share of about 80-90 % of the total volume. A considerable part of the diatom biomass of July was the species *Fragilaria capucina* (6232 mm^3/m^3). This species produce long ribbons of cells, and is usually counted as a littoral form more than a real planktonic form. Even if we subtract the volume of *F. capucina* from the total phytoplankton volume in July, about 12000 mm^3/m^3 is left, which is still a very high amount of phytoplankton.

The maximum value of phytoplankton registered in the lake Kuetsyarvi, either with or without *F. capucina*, shows that the water masses in this lake have to be characterized as *hypertrophic* according to the scale of trophic levels proposed by Brettum (1989). The most important species of diatoms in this lake throughout the growth season, besides *F. capucina*, were *Asterionella formosa*, *Cyclotella catenata*, *Diatoma tenuis* and *Synedra* spp.

The Bjørnevatn showed very low total volumes of phytoplankton throughout the season. Maximum was 295 mm^3/m^3 and the mean value of the four samples from this locality was 245 mm^3/m^3, which characterizes the water masses in this lake as oligotrophic. No group dominated at any time of the season (Fig.8.1, Appendix 8.3). The group Bacillariophyceae (diatoms) had a somewhat higher part of the total phytoplankton in this lake than in Langvatn. This phytoplankton composition is probably not directly derived from the influx water from Kuetsyarvi, because most of the diatoms in Bjørnevatn were species not found in Kuetsyarvi.

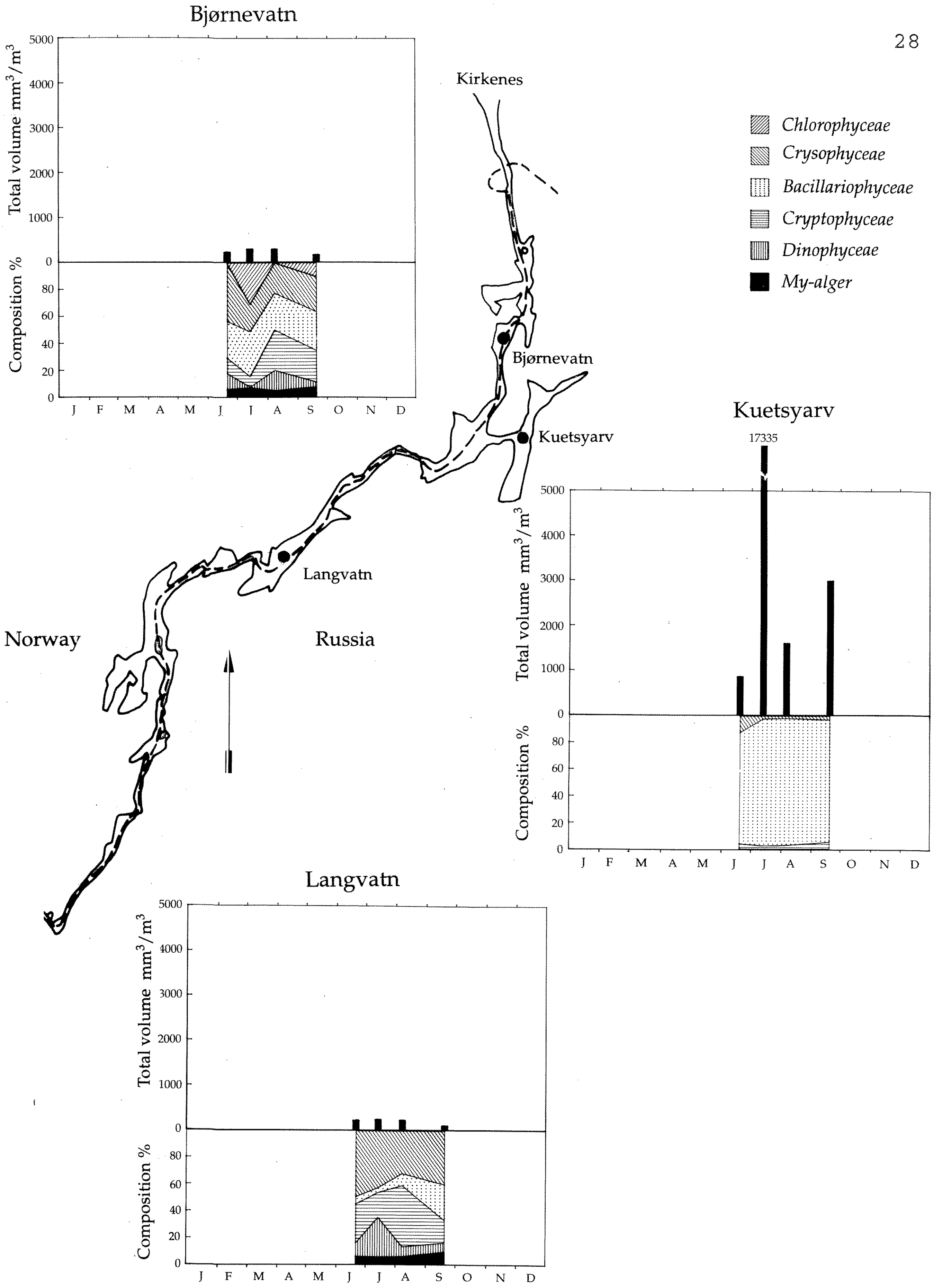

***Figure 8.1** Variations in total volume and composition of phytoplankton in the lakes Langvatn, Kuetsyarvi and Bjørnevatn in 1993.*

9. AQUATIC MACROPHYTES

The aquatic macrophytes can be divided into growth-habit groups: helophytes (semi-aquatic plants with main part of the photosynthetic organs above the water most of the time and well developed roots), isoetids (small submerged, rosette-plants with well developed roots), elodeids (elongated and submerged plants, poorly rooted), nymphaeids (plants with floating leaves) and lemnids (free floating plants). In this report, the last four groups, together with aquatic mosses and charophytes, will be termed aquatic vegetation. The most characteristic vegetation in Norwegian oligotrophic lakes is the isoetide-vegetation. The plants use CO_2 and macro-nutrients from the sediments. Some of the small annual isoetids is partly amphibious with alternative carbon sources. As a carbon-source the elodeids use HCO_3 (or CO_2) from the water, while they take the macro-nutrients partly from water and partly from the sediment. The elodeids are often the dominating element in more eutrophic lakes. The nymphaeids use CO_2 from the air and nutrients from the sediment, while the lemnids use CO_2 from the air and nutrients from the water (Rørslett 1985). The charophytes is a quite homogeneous group of long-lived macro-algae, and occur in fresh and brackish water. The plants are attached to the sediments by rhizoides (Langangen 1974). See Appendix 9.1 for general description of the macrophytes and description of the rare and interesting species. Detailed descriptions of the localities are given in Appendix 9.3

The aquatic vegetation in the Pasvik river is rich in species and we recorded a total of 29, including 7 isoetids, 16 eloeides, 4 nymphaeids, 1 lemnide and 1 charophyte. Including earlier registrations the number of species in the Pasvik river is 35 (Tab. 9.1).

The most common species in the Pasvik river was *Sparganium angustifolium* (recorded at all 19 localities), *Potamogeton perfoliatus* (16 localities), *Myriophyllum alterniflorum* (15 localities), *Subularia aquatica* (14 localities) and *Isoetes setacea* (13 localities) which are all very common in Fennoscandia and without any specific nutrient requirements.

The most species-rich localities were Gjøkbukta (loc.1), Fuglebukta (loc.9) and Svanevatn at Svanvik (loc.14) (see Fig. 9.1). These localities are little exposed coves, possibly with some nutrient increase. Fuglebukta is a shallow and circular cove with limited connection to the river. It is remarkable that the cove is not overgrown with vegetation and one could believe that the cove dries out during the winter, which keeps especially the elodeids at low levels. In a part with a little deeper water at the outlet of the cove, the elodeids built massive stands.

The average diversity in the upper and lower part of the Pasvik river is approximately equal. Lake Kuetsyarvi has somewhat lower diversity, in spite of the calcium-rich water.

Table 9.1. The aquatic vegetation in the Pasvik River, including some additional earlier records: [1]: Dahl (1934), [2]: Kaasa 1958, [3]: Økland (1962), [4]: Økland (1970), [5]: Edvardsen (in prep.)

Growth groups/Latin names	English names	Comments
ISOETIDS		
Alopecurus aequalis [5]		
Elatine hydropiper		
Eleocharis acicularis	Needle Spike-rush	
Isoetes lacustris	Common Quillwort	
Isoetes setacea	Spring Quillwort	
Limosella aquatica		
Ranunculus reptans		
Subularia aquatica	Awlwort	
ELODEIDS		
Callitriche hamulata	Intermediate Water-starwort	
Callitriche hermaphroditica	Autumnal Starwort	
Callitriche cf. palustris		
Hippuris tetraphylla [1]		Elvenes (brachish water)
Hippuris vulgaris	Mare's tail	
Myriophyllum alterniflorum	Alternate-flowered Water-milfoil	
Myriophyllum sibiricum		
Myriophyllum verticillatum [3,5]	Whorled Water-milfoil	
Potamogeton alpinus	Red Pondweed	
Potamogeton berchtoldi	Small Pondweed	
Potamogeton filiformis	Slender-leaved Pondweed	
Potamogeton gramineus	Various-leaved Pondweed	
Potamogeton x nitens [1,5]	Pondweed-hybrid	P. gramineus x perfoliatus
Potamogeton perfoliatus	Perfoliate Pondweed	
Potamogeton praelongus	Long-stalked Pondweed	
Potamogeton x sparganifolius	Pondweed-hybrid	P. gramineus x natans
Ranunculus confervoides		
Ranunculus peltatus	Water Crowfoot	
Utricularia intermedia [1,5]	Intermediate Bladderwort	Svanvik
Utricularia vulgaris	Greater Bladderwort	
Zannichellia Walustris [1]	Horned Pondweed	Elvenes (brachish water)
NYMPHAEIDS		
Nuphar pumila	Least Water-lily	
Polygonum amphibium	Amphibious Bistort	
Sagittaria sagittifolia x natans	Arrowhead-hydrid	
Sparganium angustifolium	Floating Bur-reed	
LEMNIDS		
Lemna trisulca	Ivy-leaved Duckweed	
CHAROPHYTES		
Nitella flexilis/opaca	-	

In addition Edvardsen (in prep.) recorded *Nuphar lutea* in the lower part of the Brook Ødevannsbekken, *U. ochroleucha* in a brook east of the small lakes Kiletjernene, and *U. minor*, *Sparganium hyperboreum*, *S. minimum*, *S. emersum* (uncertain material) and *Potamogeton natans* in the area, but probably not in the Pasvik river.

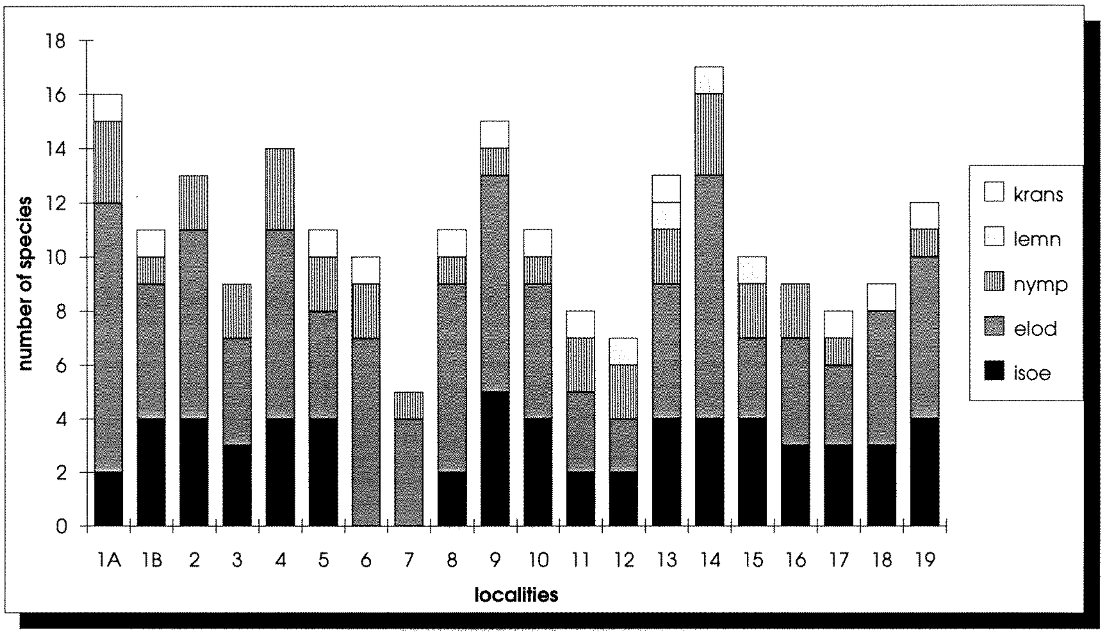

Figure 9.1. The Pasvik River and Lake Kuetsyarvi 1993. The richness of species at the different localities.

The diversity of aquatic macrophytes in the Pasvik River is remarkable, taking into consideration the geographical situation and the length of the river (number of ecological niches). A total amount of 33 freshwater plants, including one charophyte, is recorded in the river (Tab. 9.1). Most of the species has a widely distribution in Fennoscandia, whilst 2 species have northern distribution and 3 southern distribution.

The species, which have a southern distribution (according to Samuelsson 1934), are *Elatine hydropiper*, *Myriophyllum verticillatum* and *Lemna trisulca*. These species have their main distribution in the southern parts of the Nordic countries, but are also distributed northwards from the Gulf of Bottnia and some reaching the East of Finnmark. In addition, the southern *Nuphar lutea* was found in Brook Ødevannsbekken in 1984 (Edvardsen, in prep.). These southern distributed plants stands out as a thermophilous element of the vegetation in Finnmark.

Some of the widely distributed species in Fennoscandia have their main distribution in the southern parts of the countries, whilst the distribution in the northern parts are scattered. In the Pasvik River this group contain *Polygonum amphibium*, *Potamogeton natans*, *Myriophyllum alterniflorum* and *Utricularia vulgaris* (Hultèn 1971, Edvardsen, in prep.). *Polygonum amphibium* is according to Samuelsson (1934) regarded as an ubiquist species, whilst Edvardsen (in prep.) included it to the south-eastern group. The species is widely distributed in the Nordic countries. The main distribution, however, is clearly associated to the southern parts, and the distribution in the middle and northern parts are scattered (Hultèn 1971). The species also occurs in coast-areas in the south of Norway (plus a few finds in coast-areas in northern Nordland) and therefore it does not seem to belong to the south-eastern species. We choose to report *Polygonum amphibium* as a southern species or an ubiquist with southern trend according to the classification in Bendiksen & Schumacher 1982.

The richness of species and the luxuriance of the vegetation in the river make a contrast to the poorer boreal-alpine terrestrial vegetation in the upper parts of the Pasvik valley and to the rest of eastern Finnmark (Edvardsen, in prep., Dahl 1934). Then, in spite of the harsh climate in the northern part of the country, lower valleys can be favourable, with luxuriant aquatic vegetation.

The Pasvik River can be reckoned as one of the most species-rich rivers in Norway. Only the river Glåma (Hedmark), the largest river in Norway and 5 times as long as Pasvik River, contain a greater number of species (Fig. 9.2). Regarding to the richness of species, the Pasvik River seems to have a unique position compared other large rivers in Finnmark, such as the Alta-Kautokeino River and the Tana River.

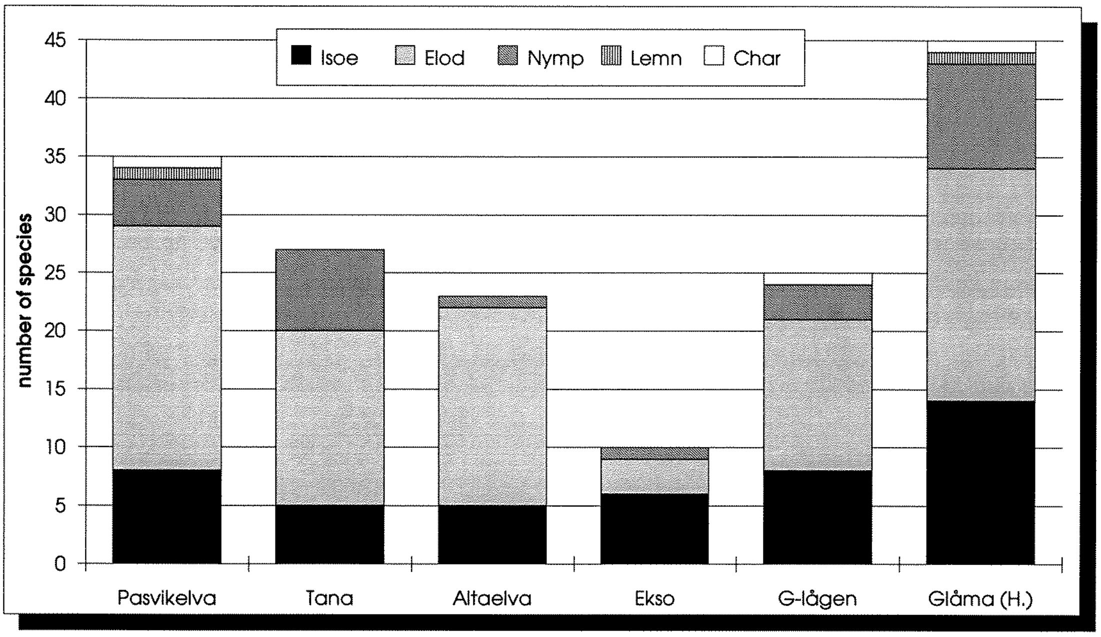

Figure 9.2. *Richness of aquatic species in some of the largest rivers in Norway. Isoe=isoetids, elod=elodeids, nymp=nymphaeids, lemn=lemnids and char=charophytes. The data from the river Alta-Kautokeino is according to Traaen et al. (1983) and Sivertsen (1978), from the river Tana according to R. Elven (pers. comm.), from the river Gudbrandsdalslågen according to Kjellberg et al. (1988), from the river Glåma (in Hedmark) according to Rørslett et al. (1982) and from the river Eksingedalselva according to Brandrud et al. (1992).*

The rich and interesting flora in the Alta-Kautokeino River is well known (Sivertsen 1978), with 23 species recorded in the aquatic vegetation (Traaen et al. 1983) and, equivalent to the Pasvik River, including some southern species. The flat parts of the Kautokeino River (Gædgejavre - Virdnejavre) are situated at altitudes between 200-400 m.a.s., whilst the altitudes in the Pasvik River are lower than 70 m.a.s.. Therefore, the differences in the amount of species between the rivers could be due to the differences in altitudes (presence/absence of marine sediments and some differences in the climate). However, the southern species *Lemna trisulca* and *Ceratophyllum demersum* are recorded at altitudes of 305 (Kautokeino) and 391 m.a.s. (Lake Lille Holmvatn), respectively. The latter species is probably a relict from the climatic optimum after the last glaciation (Samuelsson 1934). In addition, the southern helophytes *Butomus umbellatus* and *Cicuta virosa* are recorded several places in the Kautokeino River. Considering the distributions of these thermophilous species, it is likely that the differences in altitudes do not explain the differences in the vegetation.

In the Tana watercourse (including the rivers Anarjohka, Karasjohka and several small rivers) 27 aquatic species were recorded (Elven, pers. comm.), but in the main river Tana, only 18 species were recorded. The aquatic vegetation in both Pasvik and Alta-Kautokeino Rivers contain species with south-south-east distributions in Fennoscandia, which seems to be missing in the Tana River. However, such species are, as in the other watercourses, recorded in the terrestrial vegetation (Traaen et al. 1992). Lakes and more slow flowing parts of the river are nearly missing in Tana River, and the river is known for the large amount of drifting ice in the spring. The conditions for the vegetation, both regarding the richness of species and the luxuriance, seem less suitable than in the other rivers.

On the other hand, the Pasvik River can be characterised as a continuous series of lakes, and with very stable water level throughout the year partly due to the HEP-regulations (Chapt. 2). Thus the aquatic vegetation avoids periods with stress, suchs as periods with heavily increased water level in the spring or early summer, or lowered water level with draining and freezing in the winter. The stable water level seems to be one of the main reasons to the richness of species and the luxuriant vegetation.

Effects of pollution

The major parts of the Pasvik River can be characterised as a calcium-poor and oligotrophic river, with low content of phosphor and nitrogen. However, some areas, such as Svanevatn and Gjøkbukta, seem to have some local pollution.

Mesotrophic and slightly eutrophic localities with moderate to high calcium-contents generally have the highest species-richness of macrophytes (Rørslett 1991). On the other hand, increased pollution generally leads to a decrease in species diversity. However, up to some threshold level of pollution, tolerant species can be favoured and make luxuriant stands. Increased pollution with phosphorus and nitrogen do not necessarily lead to a community dominated of eutrophic species. Which species that will dominate in more polluted (eutrophic water) are depending on the species and diaspores that occur in the watercourse. Eutrophication (from a oligotrophic state to a more eutrophic state) often lead to increased luxuriance of the vegetation and, if presence, semi-eutrophic and eutrophic species can make large stands.

According to Linkola (1933) (refered in Nordiska Ministerrådet 1984) and adjusted to Norwegian conditions, the main part of the aquatic plants in the Pasvik River can be characterised as oligotrophic or indifferent. Eight species (25%) can be characterised as eutrophic or semi-eutrophic, and these are *Callitriche hermaphroditica*, *Myriophyllum sibiricum*, *M. verticillatum*, *Potamogeton praelongus*, *Ranunculus confervoides*, *Polygonum amphibium*, *Sagittaria sagittifolia x natans* and *Lemna trisulca*.

Svanevatn seems to be the most nutrient-rich locality in the river, where 40% of the species at Svanvik are eutrophic or semi-eutrophic. The luxuriant vegetation at Svanvik and Skrotnes, with mass stands of the eutrophic species *Lemna trisulca* and *Polygonum amphibium*, respectively, also reflect the high nutrient-content in Svanevatn (Fig. 9.3). This again probably reflects the influence from Lake Kuetsyarvi, which has high concentrations of phosphor. Gjøkbukta in the upper part of the River, has a luxuriant vegetation with comparatively high amount of eutrophic species. The Fjørvatn area, including Gjøkbukta, is known for the large quantities of swans. In the spring 150 swans have been recorded in the area. The birds sometimes stay for several months in the spring and autumn (Wikan, pers.comm.). Whether the luxuriant vegetation is due to eutrophication from the swans or not is uncertain.

Although the species-richness and the luxuriance of the vegetation in Svanevatn and Gjøkbukta seem partly to be due to some eutrophication, this can not explain the rich vegetation in most of the river (see previous pages). At other localities, for instance at Perslåtta (loc.10), both the helophytes and the submerged vegetation are very luxuriant, dominated by *Equisetum fluviatile* and *Ranunculus peltatus* (Fig. 9.4). This is probably due to the HEP-regulations. The river parts downstream the outlet from the powerplant often get luxuriant vegetation because of the increased water level and water temperature in winter (Rørslett et al. 1989).

The luxuriant vegetation of *Potamogeton perfoliatus* and *Polygonum amphibium* in the southern part and of *Lemna trisulca* in the southernmost part of the Lake Kuetsyarvi seem to be due to the nutrient-rich water. The Lake Kuetsyarvi is an eutrophic lake and with comparatively high content of calcium. Therefore, we did not expect any acidification effects on the aquatic vegetation. In spite of the luxuriant vegetation in the southern parts of the lake, few species dominated. These were *Potamogeton perfoliatus*, *Polygonum amphibium* and locally *Sparganium angustifolium*. The elodeid, *Myriophyllum alterniflorum*, which occurred at most of the localities in the Pasvik River and is regarded as one of the most common species in Norway, including Finnmark, was rare and only recorded as drifting specimens in Lake Kuetsyarvi. *Myriophyllum alterniflorum* seems to disappear from acidificated areas in the south of Norway (Brandrud and Mjelde 1993). Whether the very rare occurrence in Kuetsyarvi is due to the acid pollution or heavy metal pollution from Nikel or just a coincidence, is difficult to determine.

It does not seem to be any changes in the diversity of species in the lower parts of the Pasvik River after the inclusion of the more eutrophic water from Lake Kuetsyarvi. The luxuriance of the vegetation varies between the localities, and the somewhat less luxuriance in the lower parts is probably due to a less amount of suitable localities.

The concentrations of nickel and copper in macrophytes

The concentrations of heavy metals in aquatic plant vary between species and in the different parts of the plant, and with the seasons. The literature data sometimes are incomplete concerning these factors, and comparisons can be difficult. Aulio and Salin (1982) analysed the content of heavy metals in different species of *Potamogeton*, and concluded that species with floating leaves generally had less content of copper than the submerged ones. Investigations analysing *Sparganium angustifolium* are not known to the present authors. According to Aulio and Salin (1982) the concentrations of copper and nickel in *Sparganium angustifolium* are probably lower than in the elodeids, for instance *Potamogeton perfoliatus*.

The concentration of nickel in the plants reflected the pollution in Kuetsyarvi (Tab. 9.2), and was markedly higher than known from unpolluted areas, and from polluted areas, as well (Outridge & Noller 1991, see Tab. 9.3). Compared with Outridge & Noller 1991, only two areas have recorded higher concentrations of nickel in aquatic plants. In the Pasvik River, the nickel-concentration in the plants are about the background-concentrations or possibly sligtly increased. In the outlet of Kuetsyarvi an average Ni-content at 907 ppm was found in 2 cm tip-samples of the aquatic moss *Fontinalis antipyretica* (Helleraker 1992, Langeland et al. 1993). This is nearly 10 times as high as the content found in *Sparganium angustifolium* and reflects the higher accumulation ability in aquatic mosses.

Table 9.2. *Concentrations of copper and nickel in* Sparganium angustifolium *in Lake Kuetsyarvi and the Pasvik River 1993. The numbers represent the value for a collection of plants.*

Locality	Copper µg Cu/g	Nickel µg Ni/g
loc. 9: Fuglebukta, outlet	10.5	1.58
loc. 12: Kuetsyarvi at Salmiyarvi	26.1	103
loc. 19: Skrukkebukta at Brattli	8.13	13.8

The concentrations of copper in plant materials from Kuetsyarvi are somewhat increased, as well (Tab. 9.2), but within the intervals from unpolluted areas (Outridge & Noller 1991). The level is the same as recorded e.g. in plant-materials from the polluted Kokemäenjoki River in western Finland (Aulio and Salin 1982). The concentrations in the Pasvik River are within the range of unpolluted areas, and ca. one-third of that in Kuetsyarvi. However, the concentrations of copper in plant-materials from Pasvik River are approximately two times as high as measured in the leaves of *Nuphar lutea* in Lakes Semsvann and Padderudvann (Akershus), which have both been polluted from road traffic (Bækken et al. 1994).

The variations in the concentrations of nickel in plant materials downstream in the watercourse agree with the concentrations in the water. The concentrations in water in the upper part of the Pasvik River, Kuetsyarvi and lower parts of the Pasvik River are <1, 80-90 and 5-10 µg Ni/l, respectively. Similarly, there is a slight increase in the concentration in plantmaterials in the Pasvik River after the inclusion of the water from lake Kuetsyarvi. The concentrations of copper in Pasvik River showed the same trend in plant materials as in water, indicating no increase downstream Kuetsyarvi.

Table 9.3. *Concentrations of copper and nickel in plant material from unpolluted and polluted areas (according to Outridge & Noller 1991). The data represent µg/g dry weight and represent unequal, unspecified plant pieces. Even though "Macrophytes" also includes the helophytes, the greater part consists of elodeids, nymphaeids and lemnids.*

		Copper unpolluted	polluted	Nickel unpolluted	polluted
Machrophytes	total variation	0.14-55	4-180	1.0-19	3.1-290
"	95% conf.interv.	9.7-16	-	4.9-7.6	-
"	median	7.9	42	4.2	6.1
Potamogeton-species	total variation	2.3-43	7-180	1.4-23	<6-290
Sparganium sp.	total variation	38	63	-	-

Concusively, both *Sparganium angustifolium* and *Potamogeton perfoliatus* seem to be tolerant species to heavy metal pollution. *Potamogeton perfoliatus* was the dominating species in Kuetsyarvi. However, the specimens in south-east seemed to have lower vitality, perhaps because of the direct pollution of heavy metal or sulphur from Nikel. As recorded for algae, the toxicity of heavy metals on macrophytes seems to be reduced in calcium-rich water (cf. Chapt. 8).

Figure 9.3. *Luxuriant stands of the eutrophic species* Polygonum amphibium *at Skrotnes reflects the high nutrient-content in Svanevatn.*

Figure 9.4. *Mass stands with the helophyte* Equisetum fluviatile *at Perslåtta is probably due to the HEP-regulations.*

10. INVERTEBRATES

Zooplankton

A total of 24 species (9 Rotatoria, 10 Cladocera, 3 Cyclopoida, 2 Calanoida) were recorded (Appendix 10.1). Dominant species at the two investigated localities were *Asplanchna priodonta* and *Bosmina* spp. The levels of zooplankton abundance in both Bjørnevatn and Skogfoss were almost similar (Appendix 10.2). However, average biomass in Skogfoss was about two times higher than in Bjørnevatn (406.06 mg w.w. $m^{-3}$and 232.23 mg w.w. m^{-3}, respectively). Mean relative abundance of rotifers in plankton abundance was the highest among taxa groups, and share of cladocerans was the highest in zooplankton biomass.

Zoobenthos

A total of 17 species of invertebrate were obtained Skogfoss. The chironomids *Chironomini* spp., *Orthocladiinae* spp., *Procladius spp.* as well as *Mollusca* spp., *Dytiscidae* spp., and *Oligochaeta* spp. dominated (Appendix 10.3). Skogfoss had the lowest zoobenthos abundance recorded among all areas studied within the Pasvik River System in 1991-1993 (Appendix 10.4).

The uppermost localities Ruskvatn and Lyngbukta showed considerably higher abundance and biomass than at Skogfoss and they were almost comparable with the Kuetsyarvi. In Bjørnevatn and Skrukkebukta the density of invertebrates, especially on the bottom without vegetation and on solid bottom substrate were considerably lower than in upper parts of the Pasvik River. The average abundance of zoobenthos in Bjørnevatn were higher than in Skrukkebukta (1991-1992). *Chironomidae, Trichoptera, Oligochaetae* and *Mollusca* were common groups in down parts of the river. Groups sensitive to pollution, *Ephemeroptera* and *Plecoptera*, showed very low relative abundance in all localities (Fig. 10.1).

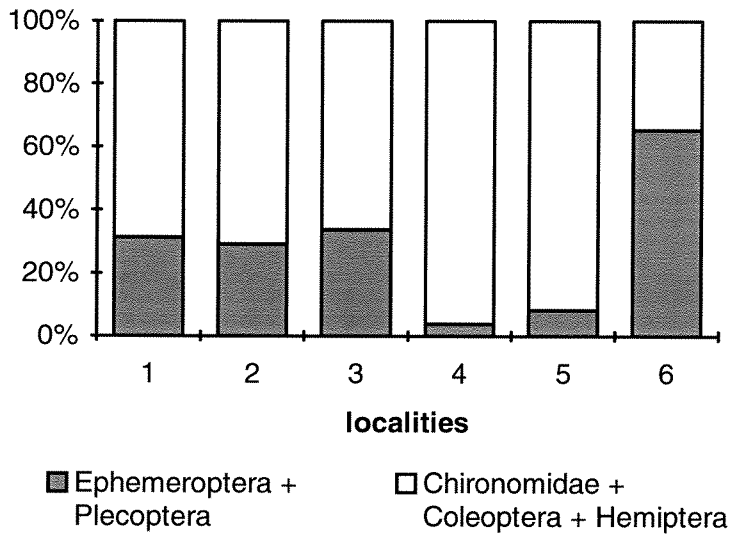

Figure 10.1. *Relative abundance of the pollution sensitive taxa (*Ephemeroptera *and* Plecoptera*) and tolerant taxa at the localities studied, 1991-1993. 1 - Lyngbukta, Ruskvatn and Skogfoss, 2 - Svanevatn and Salmiyarvi, 3 - Bjørnevatn and Skrukkebukta, 4 - lakes and streams in Nikel area, 5 - Kuetsyarvi, and 6 - Shuonijoki River*

At Salmiyarvi and Svanvik only *Chironomidae, Mollusca, Trichoptera* and *Oligochaeta* were common. Generally, in middle and down Pasvik River, composition and abundance of invertebrates showed very great variation. The highest abundance was found in shallow areas with submerged vegetation (cf chapter on macrophytes).

An extremly high abundance and biomass of invertebrates were recorded in the Kuetsyarvi. Groups tolerant to pollution, such as *Chironomidae, Oligochaeta* and *Mollusca* predominated. In the profundal zone, chironomids made up 60-80% of invertebrates number in 1991-1992. The lowest species richness and at the same time a considerable hight abundance of invertebrates were recorded in the lake area near to inlet of the Kolosyoki Stream. Here lake sediments dominated by black waste materials from the Nikel smelters. However, in localities of the Nikel area, pollution effect on the zoobenthos communities was observed in highly polluted streams, including the Kolosjoki Stream and small lakes near Nikel town. The low diversity recorded was mainly caused by the lack of several pollution sensitive taxa, such as *Ephemeroptera, Plecoptera, Hirundinea, Mollusca*. The most sensitive taxa, such as *Ephemeroptera* and *Plecoptera* were almost laking in the Kolosjoki Stream and at localities near Nikel town (Fig. 10.1). However, in east-southern direction from Nikel town (upper part Shuonijoki River drainage) where the pollution impact seemed to be week, the sensitive groups showed high diversity and density.

11. FISH

Altogether 15 species of fish from 11 families live in the Pasvik River System (Kristoffersen & Sterud 1985; Langeland et al., 1993; Amundsen et al., 1993). However, only 7 species were caught in our gillnet samples and 2 species (nine-spined sticklebacs - *Pungitius pungitius L.* and minnows - *Phoxinus phoxinus L.*) appeared to be in stomach of predatory fish and in hydrobiological kick samples:

Salmonidae
1. Brown trout - *Salmo trutta L.*

Coregonidae
2. Whitefish - *Coregonus lavaretus L.*
3. Vendace - *Coregonus albula L.*

Thymallidae
4. Grayling - *Thymallus thymallus*

Esoxidae
5. Pike - *Esox lucius*

Percidae
6. Perch - P*erca fluviatilis L.*

Gadidae
7. Burbot - *Lota lota L.*

Trout was caught practically in all localities of the Pasvik River system, but they are more numerous in tributaries of the river and its upper reaches. The trout was caught by size of 12.9 - 56.2 cm and weight 20.5 - 1947 g, age 2+ - 7+ years. Approximately 30 % of total numbers of trout had a fish farms label. Fruitfulness (number of eggs) was 800-8200 eggs depending on the sizes of fish.

Vendace is a new species for the Pasvik River System (Amundsen et al., 1993). This species was introduced in the lake Inari (Finland) and is, at present distributed in the Pasvik River System. In our catch vendace had a length of 8.2 - 16.9 cm and average weight of 14.2 g. In a middle part of the Pasvik River system fish at age of 2+ was dominated, however fish more older than 3+ were not found. Also in our samples fish at age of 0+ were away.

Whitefish is the most abundant species of fish in the Pasvik River System. Two forms can be distinguished, based on a number of morphological features. First of all these two forms of whitefish have various number and form of gill rakers: densely rakered whitefish (d.r whitefish) had 28 - 41 oblong gill rakers; sparsely rakered whitefish (s.r. whitefish) had 16 - 24 short thickening gill rakers (Amundsen et al., 1993). These forms differ by habitat and food habits: s.r. whitefish basically dwell on profundal habitats and feed benthic invertebrates. d.r whitefish - in pelagic and feed zooplankton. The last were the most numerous. The ratio of number in incorporated sample from one region fishing was 3 : 1 to d.r whitefish.

<u>D.r whitefish</u> have average body length of 15.4 - 19.7 cm, and a weight of 53.5 - 99.7 g. The sizes of these fish caught in various regions of Pasvik River system was reduced near to a source of pollution and had negative correlation with Ni concentration in sediments (r= -0.89) (Fig. 11.1).

In catch there d.r whitefish in age 1+ - 3+ prevailed. The fish older then 4+ were rare. The d.r whitefish have extremely early maturation. In Kuetsyarvi fish ready to spawn were found of body length 6 -9 cm in age 1 +. Their sizes were reduced near to Nikel (Fig. 11.2).

<u>S.r. whitefish</u> were of large size and submitted by greater number of age groups. In our catch these fish had maximum age 8+ -9+ (in the control lakes - 15+ - 18+). However, the basic population of s.r. whitefish were of the age 2+ - 4+. S.r. whitefish were of smaller sizes near to Nikel compared distant regions.

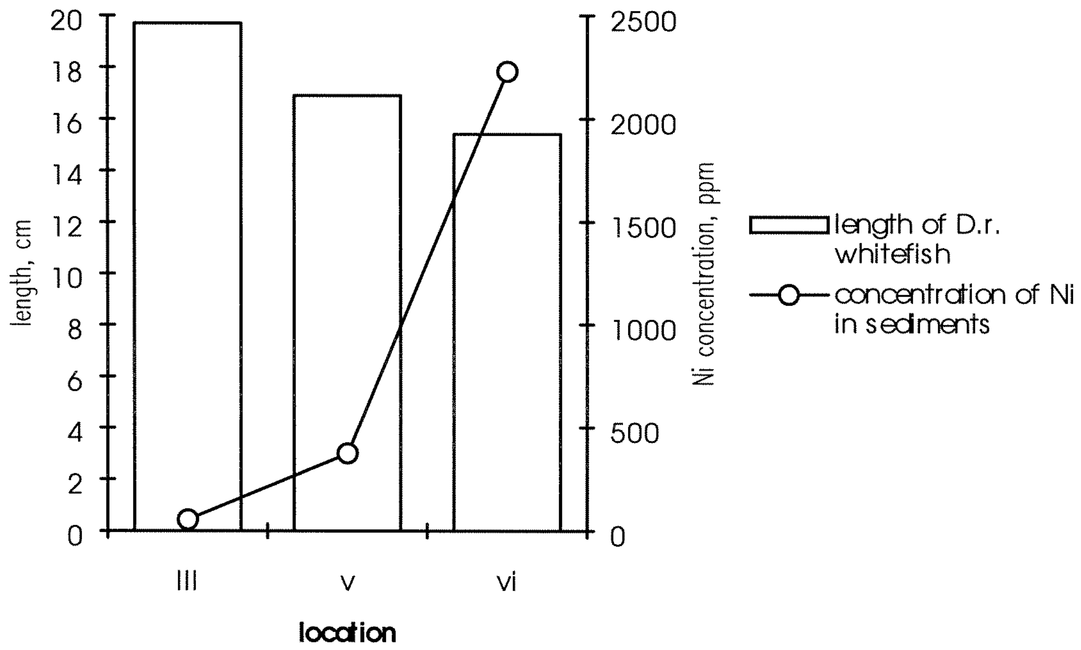

Figure 11.1. *Dependence of the sizes of d.r. whitefish from the concentration Ni in sediments (r= - 0.89)*

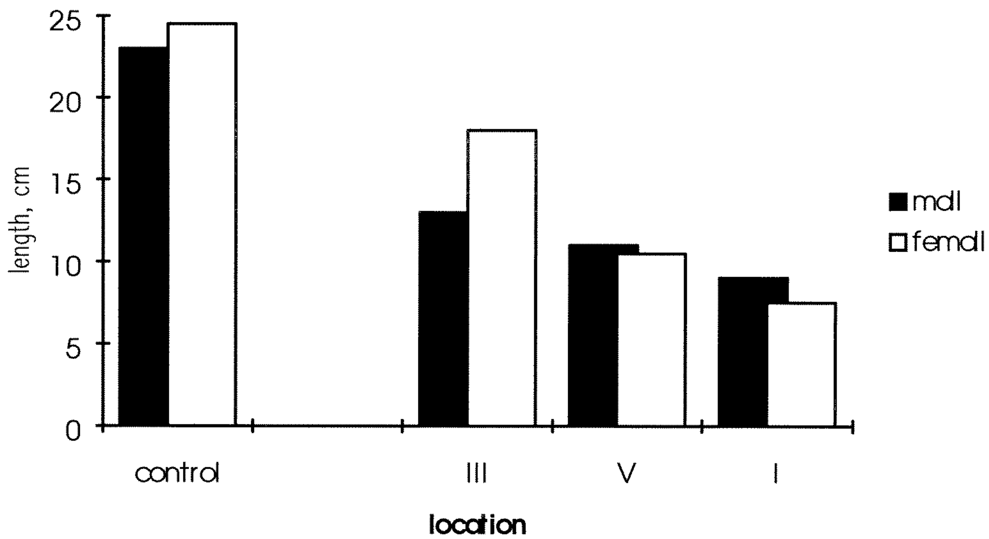

Figure 11.2. *The sizes of d.r. whitefish from Pasvik River system for the first time spawning (control - Chunozero Lake) (Reshetnikov, 1980).*

Pike was caught in all localities of the Pasvik River system. It prevailed on sites with macrophytes. The fish in our catch were 11.7 - 51.0 cm, with a weight of 18.5 - 1210.0 g. Individuals in age 3+ - 4+ dominanted.

Perch was found in all regions of the Pasvik River system with increacing numbers down in the system.

Stress and fish diseases in the Pasvik River

Contamination by heavy metals and river euthrophication create stress conditions for the fish vital functioning. Based on long-term investigations in clean rivers of the Kola North the average values and limits of the whitefish haematologic variations have been defined (Moiseenko & Yakovlev 1990). The control values are haemoglobin concentration in blood Hb - 11 g% (8 - 13), velocity of precipitation of erythrocytes (RDE) - 1.5 mm/hour (1 - 3).

In the regions Rajokoski and Skogfoss where heavy metal load is negligible, average haemoglobin in fish blood was lower then standard (9 g%) and a higher fish percent with anemia desease (Fig. 11.3).

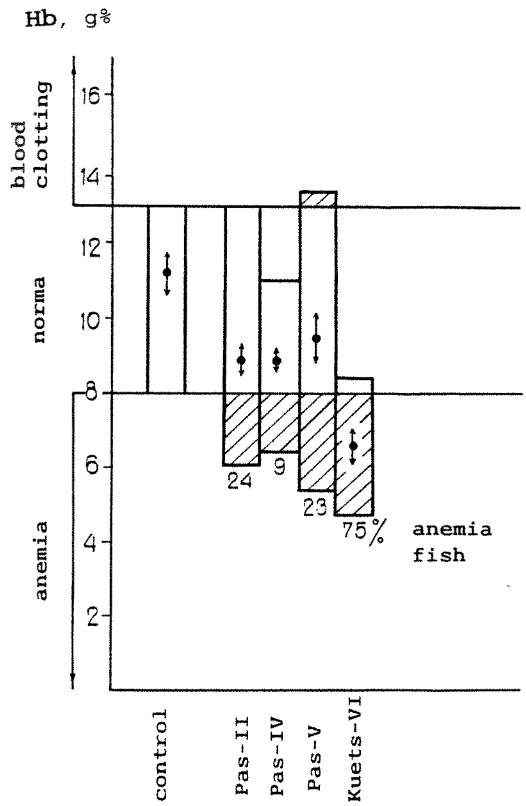

Figure 11.3. *Hemoglobin concentration heterogencity of s.r.whitefish population*

In blood smears there has been observed also a higher percentage of immature cells and leucocytes. In fish there was found out disorder in construction of gills and gonad asymmetry, but only negligible changes in liver and kidney. One should also notice high percentage of fish parasitic invasions in these regions. The given data indicate fish stress and less resistance to parasitic invasions.

The fish diseases increased in the lower part of the Pasvik River after sewage water input from the Kuetsyarvi. The haematologic value variations incresed. Alongside with anemia symptoms in blood smears there occurred pathologic forms of erythrocytes, irregular amitosis and others. The clinics of the illness was manifested in changes of colour and structure of liver, kidney, gills etc (Tab. 11.1 and Fig. 11.6 and 11.7).

Table 11.1. *Frequency of detection of fish pathology (in % from total numbers) and its seasonal variability in different regions of the Pasvik River System.*

Pathology		Kuetsyarvi		Pasvik V		Pasvik III		Pasvik II
		Sept	Jun	Sept	Jun	Sept	Jun	Sept
Change of colour		4.3	82.4	0.0	83.0	0.0	36.9	0.0
Transparence cranium		3.7	80.2	0.0	87.2	0.0	30.6	0.0
Change of gills		17.1	46.2	13.6	100	3.2	45.5	0.0
Change of liver		90.7	96.6	83.8	82.4	83.9	92.0	27.4
Change of kidney		32.1	64.7	62.2	84.4	19.4	50.0	9.6
Nephrocalcitosis		3.7	15.3	2.7	0.0	0.0	0.0	0.0
Change of gonads	male	67.4	8.7	57.2	6.3	32.0	26.1	6.8
	female	18.6	30.6	-	-	-	-	-

In the Kuetsyarvi practically all caught fish had disorders in vitally important organs, and low concentration of haemoglobin. In the flood mouth pathological and destroyed erythrocytes was revealed.

One should take into account that anthropogenic load on the Pasvik River is complex, related to airborne pollution, municipal sewage and wastes from smelters, and HEP regulation. Their simultaneous influence creates stress conditions for fish.

Heavy metal accumulation in fish

The levels of metal accumulation in the fish organism reflects a total load on water body for their life cycle strategy. Ni, as it was shown earlier, is a primary pollutant on the Pasvik River water catchment. An accumulation in whitefish kidney and gills is observed when approaching the source of pollution (Fig. 11.4).

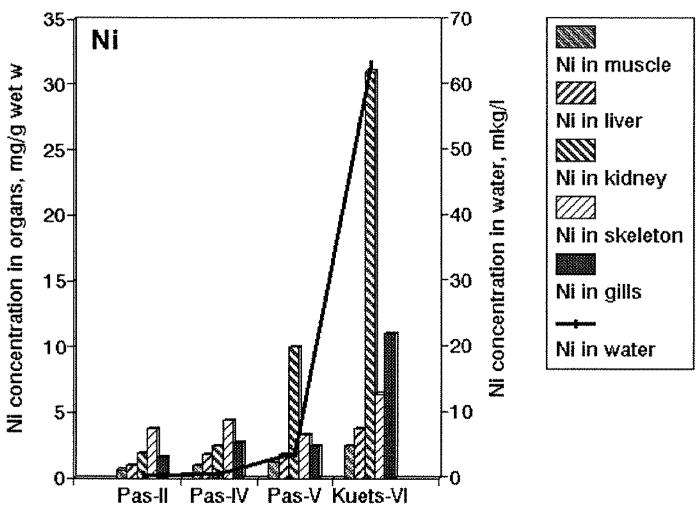

Figure 11.4. *Ni accumulation in fish organs*

Copper has the same tendency but its accumulation is less intensive (Fig. 11.5).

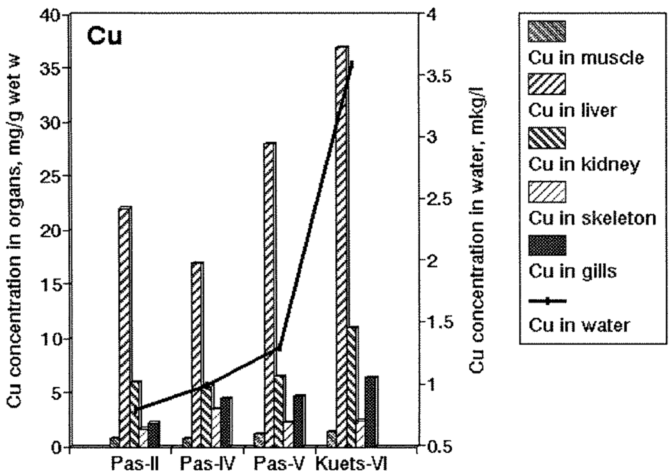

Figure 11.5. *Cu accumulation in fish organs*

The other trace elements, such as Mn, Co, Sr, Zn and Al was found in concentrations within natural variability of the species (Appendix 11.1). These elements are essential.

The Nickel and Copper accumulation apporently causes the change trace element composition functionally important organs, bringing about deceases above. By our investigations we have succeeded in defining that Ni accumulation leads to nephrocalcitosis, Cu - to anemia, Sr - pathology in bone tissue in fish (Moiseenko & Kudryavtseva 1990). In Russia the maximum allowable concentration of Ni in fish food for the human being is admitted as 0.5 mg/kg of wet weight. The Ni content in muscles tissue accounts for 0.49 mg/kg of muscles wet mass, i.e. approaches its critical value.

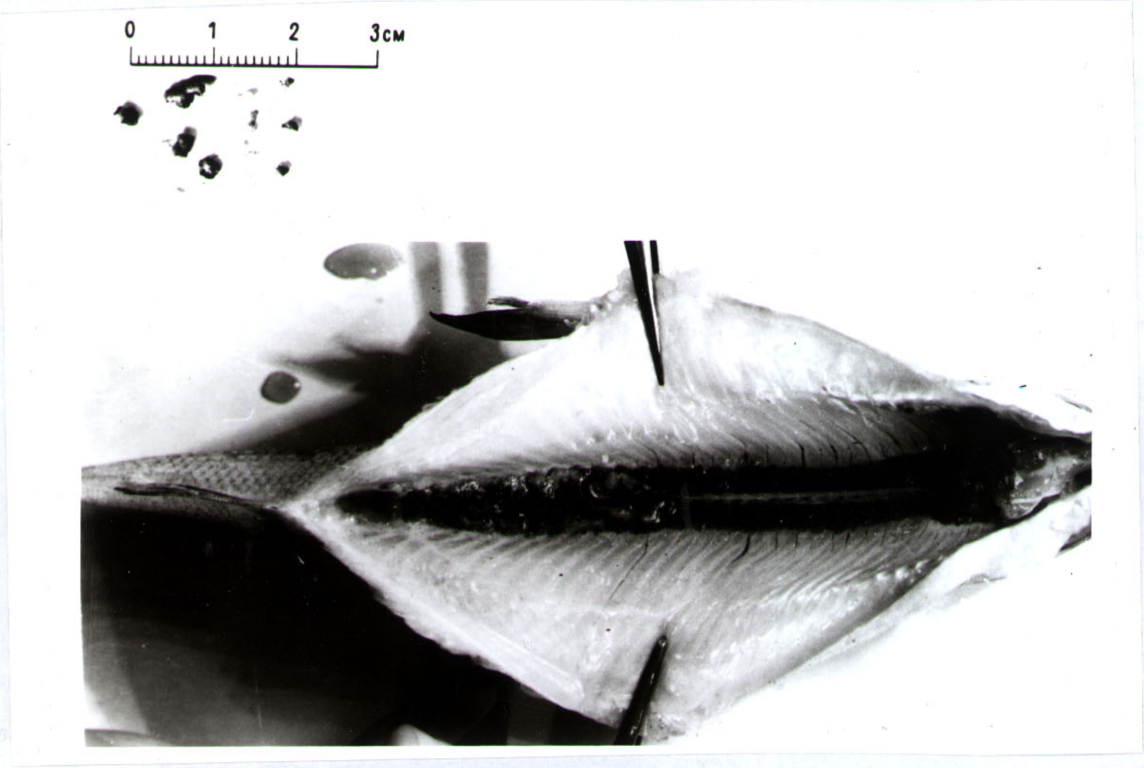

Figure 11.6 *Nephrocalcinosin in fish*

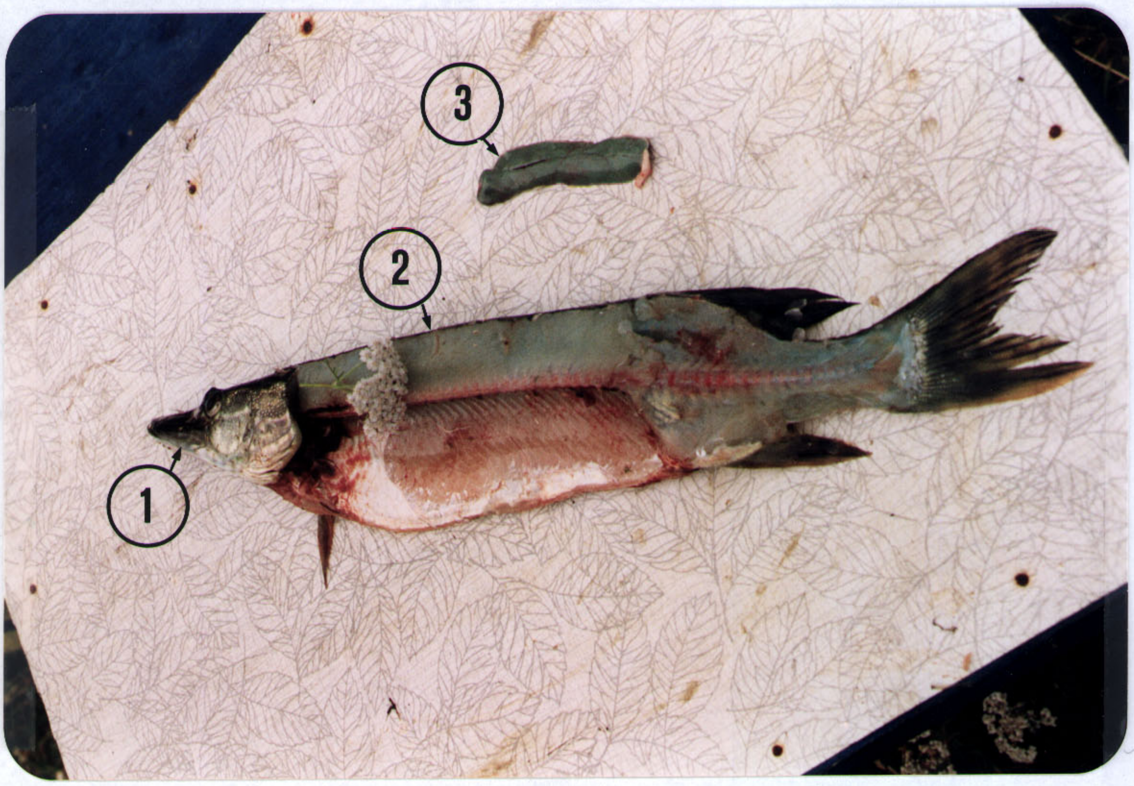

Figure 11.7. *Typical colour of skin (1), flesh (2) and liver (3) in pike from Kuetsyarvi. Foto: Leif Karlsen 1991.*

12. MAIN DISCUSSION

The Pasvik River is one of the largest river in the North Fennoscandia. Although its headwater is in Finland, the main river borders between Norway and Russia. Therefore, maintaining intact and balanced ecological conditions is important for both countries.

The river receives a complex anthropogenic load from: air pollution of the catchment by the "Pechenganikel" smelter emissions, runoff from smelter and mine wastes and domestic sewage from the settlements on the Russian and Norwegian sides. The Pasvik River is also strongly regulated for hydroelectric power production.

Assessment of waste matters from Russian side (25% of water catchment) shows that major amount of pollutants enters the Pasvik River from the Kuetsyarvi (Ni 36 tons/year, P 3.3. tons/year). Effluent waters from smelters and pits also are being dumped in the lake with the Kolosjoki Stream. The Ni and Cu input from the remaining part of the catchment is approximatly 10% and do not have any noticeable contribution to the total river pollution.

For the Pasvik River two major ecological problems are observed: 1) Effects of heavy metals. This process is observed especially in Kuetsyarvi and to a lesser extend in the lower part of the river. This is caused by the Ni and Cu input with waste waters from smelters and pits of the "Pechenganikel" company; 2) Eutrophication. This process is caused by domestic sewage from the settlements situated within the water catchment.

Water chemistry of the river is stable above the runoff from Kuetsyarvi. Ni and Cu concentrations correspond to the background values - less then 1 µg/l. However, in comparison with water chemistry of the Inari Lake, the P concentration is more than doubled. An increase in the content of nutrients was found in the lower parts of the river, indicating some euthrophication. According to the classification by Carlson (1991) the Pasvik river appears to be on the border between oligo- and mesotrophic state. In the lower part of the river a clear increase in Ni, Cu and also sulphates concentrations was seen. It results from water income from the heavily polluted Kuetsyarvi.

Analysis of heavy metal accumulation in the sediments did not show any distinct influence of smelter atmospheric emissions in the river above the inlet from Kuetsyarvi. Considerable accumulations of Ni and Cu were noticed below the Kuetsyarvi inlet, a contamination which obviously orginates from the "Pechenganikel" company effluent. Concentrations of other metals (Co, Zn, Cd, Pb) were also higher than background values. The Kuetsyarvi receiving the main part of "Pechenganikel" company effluent had maximum Ni, Cu, Hg, Co, Zn concentrations in the surface sediments. Hg did show a deviating pattern of accumulation, being present in the surface sediments of all investigated water localities. In our opinion, this may be caused by processes owing to the regulation of the river (for example, mercury methylation). According to the index of Håkanson (1980), the upper part of the river system had a moderate degree of contamination, mainly due to the Hg-content (C_d=10.9, C_fHg=5.0). The Pasvik River downstream Kuetsyarvi has considerable C_d values (C_d=22.1), and the Kuetsyarvi has a very high C_d value C_d=58.7, mainly due to the contribution from Ni and Cu.

According to sediment diatom analysis, the formerly oligotrophic water of the Pasvik River water-course has experienced some eutrophication during the last decades. The trophic status in the upper river part changed insignificantly according to the indexes used, but the species diversity increased in the surface sediments, and the abundance of alkaliphilous species increased. This may indicate a slight increase in trophic level. In the lower part of the Pasvik River (Bjørnevatn), the eutrophication is apparently more pronounced, according to the indexes. This is probably due to transport of nutrients from the eutrophic Kuetsyarvi. It should be noted, however, that the living planctonic and bentic communities recorded in 1993 did indicate an oligotrophic state also in the lower part of Pasvik River (see below). In Kuetsyarvi, the Stockner index increased 20-30 times during the last 50 years, species typical for eutrophic water became dominant, and the production increased 10-20 times. The Kuetsyarvi is a classical example of anthropogenic eutrophication of a water body, occurring together with an intensive heavy metal pollution.

The amounts of phytoplankton in the main course upstreams and downstreams Kuetsyarvi were almost the same throughout the growing season. In spite of some increase in the volume and some changes in the diversity at Bjørnevatn compared to Langvatn, both localities were still in the oligotrophic range. The dominant species in Kuetsyarvi were poorly represented at Bjørnevatn, and vice versa, dominating species of diatoms in Bjørnevatn were not at all found in Kuetsyarvi. In other words, based on the results of the phytoplankton analysis, the supply of water from Kuetsyarvi seems to have little influence on the water quality in the main course of the Pasvik River System. However, the species composition of sediment diatoms, indicate a somewhat more pronounced influence (see above).

Comparing the results of 1993 from Kuetsyarvi with similar results of phytoplankton analysis from 1991 and 1992 (Langeland et al. 1993), the volumes seem to be in good accordance, except for the extremely high value in July 1993. No samples were analysed from that time of the year in 1991-92. Both the present results and those of Langeland et al. (1993) indicate strongly eutrophic-hypertrophic conditions and this is also in accordance with the diatom analysis. The high phosporus concentrations measured seem to be the main reason for the great amounts of phytoplankton in Kuetsyarvi.

The phytoplankton productivity seems not to be negatively influenced by the high Ni concentrations in Kuetsyarvi. The Ni-tolerance was also demonstrated in laboratory experiments with Kuetsyarvi water (Traaen et al. 1993). Using water poor in ions, but with the same content of nickel as in Kuetsyarvi, the water inhibited the growth of the test algae *Selenastrum capricornutum*, reducing the growth rate with 90%. Doing the test on water from Kuetsyarvi gave an inhibition effect on the growth rate of only 10%. According to Traaen et al. (1993) the reason for this is the high concentration of calcium in the water from Kuetsyarvi. The calcium content of this water was 10.5 mg/l Ca, compared to 1 mg/l Ca in the test water. A more sensitive test algae, *Oscillatoria limosa*, was however almost completely inhibited in Kuetsyarvi water.

The macrophytic vegetation in the area was luxuriant with a high number of species, and Pasvik River is one of the most species-rich rivers in Norway. The aquatic vegetation of the Pasvik river is formerly poorly investigated, and includes a number of rare taxa for this region of Norway. Three of the species have a southern distribution (*Elatine hydropiper*, *Myriophyllum verticillatum* and *Lemna trisulca*) and 2 have north-eastern distribution (*Myriophyllum sibiricum* and *Sagittaria sagittifolia* x *natans*). New northern limits for *Elatine hydropiper* and *Sagittaria sagittifolia* x *natans* are hereby reported. The hybrid of *Sagittaria sagittifolia* x *natans* is new to Norway. A large and diviating variant of *Ranunculus peltatus* was also recorded.

The rich flora of the river is probably caused mainly by the stable water level throughout the year, the many shallow lakes and gently flowing parts combined with the continental climate. The luxuriant macrophytic vegetation at Svanvik and Skrotnes with massive stands of the eutrophic species *Lemna trisulca* and *Polygonum amphibium*, respectively, seem to reflect some eutrophication in Svanevatn due to the influence from Kuetsyarvi. The vegetation in Gjøkbukta and at Perslåtta seem to be due to some eutrophication from the great amounts of swans and from HEP-regulations, respectively. In Lake Kuetsyarvi, few species dominated and the large stands of *Potamogeton perfoliatus* and *Polygonum amphibium* seem to reflects the eutrophic conditions in the lake.

The concentrations of nickel and copper in plant-material reflected the concentrations in water. A Ni-content of 103 µg/g in plant material (Lake Kuetsyarvi, loc. 12) is very high also compared with other polluted areas. The content of nickel in plants in the Pasvik River is about the background level or some increased. The content of copper in plant-material from Lake Kuetsyarvi was somewhat increased, but within the intervals from unpolluted areas. We have not recorded any effects of heavy metals on the vitality of the aquatic vegetation, except for the stunted specimens of *Potamogeton perfoliatus* in the south-eastern part of Lake Kuetsyarvi. The few drifting specimens of the less tolerant species *Myriophyllum alterniflorum* and some reduced diversity can be due to some pollution of sulphate or heavy metals.

Our data show that in 1993 zooplankton species composition in both Bjørnevatn and Skogfoss areas was almost similar to that identified by T. Nøst in 1990-92 (Langeland et al. 1993). The differences in biomass between Bjørnevatn and Skogfoss areas are probably caused by higher relative abundance of large-sized cladocerans in latter locality. According to data reported by T. Nøst (Langeland et al., 1993), exceptionally high biomass was recorded in Kuetsyarvi in 1990. It was associated with a high water trophic level in the lake. However, in 1991 and 1992 the biomass was reduced to ca. 500 mg/m^3, similar to the general level recorded in most lakes within Jarfjord and Pechenga areas. This was due to much lower numbers of *Bosmina longirostris* and *Daphnia cristata* in the past years, a reduction which could be explained by changes in planktivorous fish predation pressure on the zooplankton. The zooplankton species composition and abundance in the Pasvik River system is apparently not influenced by toxic pollutants. Furthermore, the communities recorded (except at Kuetsyarvi) did not indicate any eutrophication effect, and this is in accordance with the phytoplankton study.

Negative pollution impact upon zoobenthos communities were recorded in all localities near Nikel town, especially in small lakes near smelters, in the Kolosyoki Stream, including its river outlet area in the Kuetsyarvi. Pollution-tolerant groups of *Chironomidae*, *Coleoptera* and *Hemiptera* predominated in these localities. However, high diversity and relative abundance of sensitive taxa to pollution was recorded in the Shuoniyoki River, south of Nikel.

The extreme high abundance of tolerant taxa belonging to chironomids and worms in Kutsyarvi clearly indicated anthropogenic eutrophication. The values of invertebrates biomass are almost comparable with those obtained in the Imandra Lake parts polluted by communal sewage waters (Moiseenko & Yakovlev 1990). The high abundance of the benthic invertebrates in the sites with high heavy metal concentrations is remarkable, but is probably due to the simultaneously high content of organic substances and calcium. It is documented that high levels of organic matter, nutrients or calcium decrease toxicity of heavy metals (Pierart 1986, Traaen et al. 1993).

Little negative changes in communities were observed in the Pasvik River. The high abundance of benthic invertebrates in the upper part of the river seems to be caused by natural eutrophication with organic matter and nutrients from surroundings and from luxuriant submerged vegetation.
Low abundance and biomass of zoobenthos obtained in downstream Kuetsyarvi are probably in accordance with natural characteristics of the substratum in Bjørnevatn and Skrukkebukta.

Negative impact upon the population structure of fish were recorded in the lower parts of the Pasvik River, especially in Lake Kuetsyarvi. Here we observed maximum pathology degeneration of tissues and organs of fish. Typical pathology for each species was diseases of kindney, liver and gills. A total of 82.4% fish from Kuetsyarvi had skin depigmentation, whereas in the upper part of the river this pathology was absent. Liver adipose depletion were observed in 96.6% of the fish from Kuetsyarvi. Kidney anomaly was frequently observed; 64.7% had expanded kidneys due to connective tissue and 15.3% fish had kidney disease (nephrocalcitosis). Firsh from the upper part of river had 50% (Pas3) and 9.6% (Pas2) connective tissue of kidneys and no nephrocalcitosis. Each species had specific pathology. Pike had blue and green colour of the muscles, whitefish had nephrocalcitosis and perch had specific twisted gonads. In the blood there have been revealed pathological and destroyed erytrocytes. The highest occurrance of diseases were observed in the spring. One should take into account antropogenic load on the Pasvik river is a result of airborne pollution, domestic sewage, wastes from smelters and river regulation. Their simultaneous influence creates stress conditions for fish. Using index of s.r.whitefish, three zones of pollution impact can be distinguished (Tab. 12.1).

Table 12.1. *Some index of s.r. whitefish from different zone pollution impact.*

Index	zone I Kuetsyarvi	zone II Svanvatn and below	zone III Skogfoss and above
Length of fist time spawning fish (cm)	< 11	11 - 19	16 - >20
Age of fist time spawning fish	1+	1+ - 3+	>3+
% fish with liver pathology	>90	80 -90	60 -80
% fish with kidney pathology	90 -100	50 -80	<10
% fish with nephrocalcitosis	>5	0 - 5	0

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APPENDIX

Appendix 3.1. Investigated localities in 1993

Loc.no	Locality	Location	
Water chemistry, sediments, phyto-and zoopl.		**North - East**	
I		68°57' - 28°45'	
II		69°02' - 29°00'	
III		69°03' - 29°08'	
IV	Skogfoss (Langvatn)	69°09' - 29°15'	
V	Bjørnevatn	69°30' - 30°07'	
VI	Kuetsyarvi	69°27' - 30°12'	
1		69°00' - 29°03'	
2		69°05' - 29°14'	
3		69°14' - 29°21'	
4		69°18' - 29°28'	
5		69°18' - 29°34'	
6		69°21' - 29°45'	
7		69°24' - 30°00'	
8		69°30' - 30°14'	
9		69°32' - 30°15'	
10		69°29' - 30°21'	
11		69°22' - 30°07'	
12		69°24' - 30°20'	
Fish and zoobenthos		**From**	**To**
	Kuetsyarvi	69°23' - 30°08'	69°27' - 30°12'
	Svanevatn - Bjørnevatn	69°25' - 30°00'	69°29' - 30°15'
	Upper reaches, Pasvik River	68°57' - 28°45'	69°09' - 29°15'
Macrophytes		**UTM-coord.**	
1	Gjøkbukta	35W NS 881 734	
2	Ruskebukta, Kilbukta near Nyheim	35W NS 895 796	
3	Tjærebukta, Kveldro	35W NS 853 782	
4	Lyngbukta	35W NS 867 832	
5	Vaggatem, Hauge	35W NS 892 898	
6	Nordvestbukta, Skogum	35W NS 922 925	
7	Langvatnet, Krokvika near Leite	35W PS 025 950	
8	Langvatnet upstream Skogfoss	35W PS 056 979	
9	Fuglebukta	35W PT 080 012	
10	Pasvik River, Perslåtta	35W PT 126 045	
11	Lake Kuetsyarvi, Akhmalakhti (N)	36W UC 896 110	
12	Lake Kuetsyarvi, Salmiyarvi	36W UC 878 057	
13	Lake Kuetsyarvi, south	36W UB 871 997	
14	Svanevatn, Svanvik	36W UC 831 079	
15	Svanevatn, Skrotnes	36W UC 826 054	
16	Svanevatn, Seljeli	36W UC 859 088	
17	Bjørnevatn, Sandneset	36W UC 873 151	
18	Skrukkebukta, Nordvik	36W UC 871 172	
19	Skrukkebukta, Brattli	36W UC 861 201	

Appendix 4.1 *Transport values for elements (ton/year) in the Pasvik River*

Tributary	Q, m^3/s	Ni	Cu	Zn	Al	SO_4	Ntot	Ptot	TOC
Runoff of the elements from catchment									
Kohisevanjoki	6.2	0.4	0.3	0.8	6.4	989	612	1.0	2.3
Cejdaijoki	2.3	0.1	0.1	0.4	3.6	444	636	1.2	2.1
Nalijoki	0.1	0.01	0.01	0.01	0.1	25	517	0.04	1.6
Kackamajoki	0.4	0.02	0.02	0.06	1.0	109	227	0.04	1.6
Laukkujoki	2.6	0.2	0.2	0.7	3.3	743	567	0.08	1.9
Menikkajoki	1.2	0.2	0.1	0.2	0.6	340	165	0.07	1.6
Pikkyjoki	0.2	0.1	0.05	0.03	1.1	147	24	0.02	1.6
Pienikujvajoki	0.06	0.05	0.01	0.01	0.1	50	9	0.02	1.6
Russianijoki	1.1	0.3	0.1	0.1	2.4	499	5	0.2	1.9
Runoff of the elements from Kuetsyarvi									
Kuetsyarvi	18.3	36.4	2.9	4.6	8.1	15061	3748	6.9	5.0

Appendix 4.2. *Transport values for elements in the Kuetsyarvi. Unit: tons/year*

	Q, m^3/s	Ni	Cu	Zn	Al	SO_4	Ntot	Ptot	TOC
Shuonijoki	5.8	3.6	0.9	2.9	4.1	2158	695	1.1	2.4
Kuvernerinjoki	1.6	0.7	0.2	0.3	1.0	481	146	0.02	4.5
Kolosojki	3.2	50.8	3.0	1.3	13.2	21415	1624	3.0	2.6

Appendix. 5.1. *Seasonal variations of the Pasvik River water chemistry*

Points	PAS-IV				PAS-V				Kuets-VI			
Data	june	july	aug.	sept.	june	july	aug.	sept.	june	july	aug.	sept.
pH	6.96	7.05	6.96	7.0	7.0	7.1	6.93	7.0	7.2	7.65	6.9	7.49
TOC, mg/l	3.98	4.5	3.9	4.4	4.1	5.1	4.05	3.4	4.76	3.74	3.5	3.5
Cond (20), µS/cm	27	27	28	26	29	34	29	29	104	106	113	119
Alk, µeq/l	160	160	163	166	154	172	172	170	270	239	275	302
Ca, mg/l	2	2.2	1.8	2.3	2.5	2.8	1.96	2.6	8.97	9.7	8.4	11
Mg, mg/l	0.74	0.8	0.8	0.8	0.8	0.9	0.83	0.8	3.5	3.4	3.4	4
Na, mg/l	1.81	1.7	1.1	1.1	1.4	1.7	1.18	1.4	5.82	3.7	6.2	7.1
K, mg/l	0.2	0.4	0.3	0.3	0.3	0.3	0.24	0.3	0.86	0.7	0.8	0.82
SO_4, mg/l	2.8	3.0	2.7	2.8	3.6	4.8	3.4	3.5	28.2	30.6	35.7	36.3
Cl, mg/l	1.3	2.2	1.4	1.2	1.4	1.6	1.54	1.4	4.7	4.3	5.1	5.2
Ptot, µg/l	3	8	14	5	3	8	20	6	3	9	22	14
Ntot, µg/l	303	255	164	188	275	217	148	164	292	353	179	182
NO_3/N, mg/l	37	15	4.5	19	33	6	2.3	10	90	2	29.7	3
NH_4/N, mg/l	0	10	22	12	104	20	26.3	2	65	26	57.7	4
Si, mg/l	1.9	2.2	2.0	2.1	1.5	1.3	1.84	1.9	1.4	0.95	1.4	0.7
Fe, µg/l	173	40	31	29	136	37	26.3	30	2.1	33	24.2	128
Ni, µg/l	3.0	2.9	0.7	1	3.9	6.9	3.9	3.5	68	57	63.3	64
Cu, µg/l	1.5	0.8	1.0	0.7	0.8	1.3	1.3	1.2	5.1	4.5	3.7	4
Zn, µg/l	4.6	4.2	4.8	2.8	4.6	6.1	5.5	1.7	9.9	10.1	11.9	2.2
Mn, µg/l	2.6	2.0	2	0.5	22	1.6	2.7	0.6	2.1	33	18.9	3.6
Al, µg/l	20	13.2	7.1	14	15	18	6.97	10	19	19.7	4.4	3
Sr, µg/l	8	8	10	14	9	9	11	18	32	33	45	53

Appendix 5.2. *Water chemistry of the Pasvik river system, August, 1993*

	PAS-I	PAS-II	PAS-III	PAS-IV	PAS-V	Kuets-VI
pH	6.89	6.83	6.86	6.96	6.93	6.94
TOC, mg/l	4.45	4.39	4.33	4.5	4.64	4.22
Cond (20), µS/cm	26	27	26	27	30	110
Alk, µeq/l	160.0	162.2	158.0	162.4	172.1	273.7
Ca, mg/l	1.62	1.76	1.62	1.78	1.96	8.37
Mg, mg/l	0.83	0.86	0.85	0.77	0.83	3.37
Na, mg/l	1.02	1.10	1.02	1.08	1.18	6.18
K, mg/l	0.27	0.27	0.19	0.25	0.24	0.84
SO_4, mg/l	2.52	2.52	2.67	2.7	3.4	35.7
Cl, mg/l	1.06	1.2	1.08	1.42	1.54	5.09
Ptot, µg/l	11	12	14	14	20	22
Ntot, µg/l	110	160	--	164	170	179
NO_3/N, mg/l	23	26	25	5	3	7
NH_4/N, mg/l	21	5	4	8	15	25
Si, mg/l	2.51	2.37	2.32	2.02	1.84	1.4
Fe, µg/l	30	32	38	31	26	24
Ni, µg/l	0.4	0.4	0.9	0.7	3.9	63
Cu, µg/l	0.8	0.8	--	1.0	1.3	3.6
Zn, µg/l	9.1	8.5	8.0	4.8	5.4	12.1
Mn, µg/l	2.3	2.6	4.3	2.0	2.6	7.6
Al, µg/l	7.5	6.4	6.6	7.1	6.9	4.4
Sr, µg/l	10	10	10	11	12	45

Appendix 6.1. *Water content (W, %) and loss on ignition (LOI, %) values and metals concentrations (µg/g dry substance) in the sediments of the Skogfoss Lake.*

Sediment depth,cm	W	LOI	Ni	Cu	Co	Zn	Cd	Pb	Mn	Fe	Ca	Mg	Na	K	Al
0-1	87.05	46.47	47	51	12	78	1.03	11	162	15761	133	5077	320	1420	11193
1-2	86.48	48.36	46	50	13	80	1.01	12	178	14943	157	4773	339	1380	12443
2-3	85.46	52.62	44	50	13	81	1.07	12	183	15864	198	4757	358	1444	13791
3-4	85.83	56.27	43	48	15	87	1.10	11	194	12273	164	4494	357	1552	13428
4-5	83.26	57.94	42	49	14	95	1.00	11	175	11779	167	3442	331	1687	13496
5-6	84.91	63.36	42	48	15	97	1.00	10	164	12071	176	4706	356	1193	13328

Appendix 6.2. *Water content (W, %) and loss on ignition (LOI, %) values and metals' concentrations (µg/g dry substance) in the sediments of the Bjørnevatn Lake.*

Sediment depth,cm	W	LOI	Ni	Cu	Co	Zn	Cd	Pb	Mn	Fe	Ca	Mg	Na	K	Al
0-1	90.40	13.42	368	163	35	120	1.92	17	3506	46561	303	9113	687	4521	20899
1-2	88.91	12.44	287	148	33	120	1.94	18	3021	46071	364	10047	719	5059	21890
2-3	84.57	9.20	172	108	32	123	2.02	14	1995	48567	509	10612	814	6356	25048
3-4	79.59	7.18	97	40	26	118	1.72	14	955	43712	645	11225	829	6265	25605
4-5	75.43	7.12	62	43	21	109	1.37	9	581	41580	575	10477	743	6734	25622
5-6	77.71	6.98	56	43	26	108	1.72	9	1163	60842	375	10020	847	6628	24057
6-7	75.61	6.92	48	38	30	101	1.72	9	1232	60610	295	9890	738	6167	23270
7-8	74.66	7.20	50	39	30	99	2.06	14	1024	84977	173	8700	752	4090	22400
8-9	75.66	7.81	46	38	26	94	2.73	9	881	72091	176	8643	734	4219	21458
9-10	71.42	6.16	45	38	21	99	1.39	9	294	33827	582	9384	768	4294	24269
10-11	70.00	6.00	47	39	21	108	1.39	9	235	33337	603	9694	748	4358	24310

Appendix 6.3. *Water content (W, %) and loss on ignition (LOI, %) values and metals' concentrations (μg/g dry substance) in the sediments of the Kuetsyarvi Lake.*

Date of sampling	NN Station	Depth of sampling	Sediment depth,cm	W	LOI	Ni	Cu	Co	Zn	Cd	Pb	Mn	Fe	Sr	Ca	Mg	Na	K	Al
22.04.91	Ku-5	10.5	0-2	90.15	10.57	2254	1210	165	274	-	-	1371	62700	151	13100	46400	-	-	49500
			2-4	82.40	10.26	2681	1337	149	310	-	-	1258	59900	144	13300	43600	-	-	50500
			4-6	86.48	10.20	2848	1219	242	277	-	-	1155	65100	145	12800	50700	-	-	45600
			6-8	66.03	4.43	1433	653	64	210	-	-	1073	66000	137	11500	85100	-	-	55500
			8-10	80.36	9.09	1388	647	74	278	-	-	1831	73100	146	13200	53200	-	-	49200
03.09.91	Ku-1	32.0	0-1	95.75	19.94	3073	859	139	270	2.40	13	15343	35672	52	637	7381	646	2805	13770
			24-25	81.73	12.93	57	67	20	126	2.61	14	563	34232	28	1254	11199	1546	4248	26818
02.09.91	Ku-2	20.0	0-1	89.00	13.51	2206	700	97	269	0.72	22	1384	46819	3	529	17590	835	2197	23352
			24-25	80.77	10.83	132	82	34	145	0.74	11	981	55823	3	919	13507	1020	2972	28089
03.09.91	Ku-3	14.0	0-1	90.39	13.31	1556	765	97	245	2.17	22	1820	62510	3	581	18436	798	2128	22106
			24-25	81.55	10.39	173	96	31	152	0.75	11	806	48477	14	784	12171	859	2560	25539
03.09.91	Ku-4	7.2	0-1	88.75	12.12	3051	1269	153	300	2.72	11	10625	65387	21	264	17324	761	3054	18832
			24-25	66.72	7.84	70	58	26	132	0.72	10	3420	44160	14	663	10770	1068	3625	21394
03.09.91	Ku-5	14.5	0-1	82.71	10.02	2206	1499	145	309	2.12	11	21294	59430	7	284	21294	894	2955	19450
			24-25	74.47	8.43	83	68	29	130	0.71	11	11148	56142	14	555	11148	1026	3395	19623
07.09.91	Ku-3	15.6	0-1	-	1.22	1686	874	117	235	0.66	11	2675	74643	3	294	29868	743	3320	24817
			24-25	-	10.26	109	71	5	171	0.67	11	1473	57614	3	459	14642	1124	3928	28418
07.09.91	Ku-3	11.0	0-1	-	14.00	2304	951	122	310	0.67	11	3359	65999	3	352	17624	708	3245	21500
			24-25	76.38	8.15	131	88	32	154	2.42	11	2720	68212	2	820	12938	1181	3807	28703
07.09.91	Ku-3	5.0	0-1	90.01	12.89	2354	855	128	269	1.63	22	3287	63314	11	464	16333	712	3126	21778
			24-25	76.43	8.37	76	47	16	118	3.44	23	2504	70460	6	441	10603	870	3498	24990
07.09.91	Ku-3	2.7	0-1	86.77	10.37	1663	465	81	162	1.12	11	3981	32729	6	324	10789	643	2694	16297
			24-25	63.27	5.52	62	59	17	111	0.94	9	438	28344	8	1701	11338	934	7811	25360

Appendix 6.4. *Heavy metals' concentrations (µg/g d.w.) in the surface (surf.) and background (back.) layers and contamination factor (**C_f**) and contamination degree (**C_d**) values in the Kuetsyarvi, Bjørnevatn and Skogfoss localities*

Lake	Layer	Ni	Cu	Co	Zn	Cd	Pb	Hg	(C_d)
Kuetsyarvi	Surf.	2233	915	120	263	1.58	15	0.410	
	Backg.	99	71	23	137	1.44	12	0.030	
	C_f	**22.6**	**12.9**	**5.2**	**1.9**	**1.1**	**1.3**	**13.7**	**58.7**
Bjørnevatn	Surf.	368	163	35	120	1.92	17	0.120*	
	Backg.	47	39	21	108	1.39	9	0.030*	
	C_f	**7.8**	**4.2**	**1.7**	**1.1**	**1.4**	**1.9**	**4.0**	**22.1**
Skogfoss	Surf.	47	51	12	78	1.03	11	0.100*	
	Backg.	42	48	15	97	1.00	10	0.020*	
	C_f	**1.1**	**1.1**	**0.8**	**0.8**	**1.0**	**1.1**	**5.0**	**10.9**

*- data from Rognerud, 1990.

Appendix 7.1. *Ecological characteristics of diatoms from sediments of the Bjørnevatn and Skogfoss localities*

Layer cm	Dominant taxa	A/C	S	pl	b	ecological group: al	ac	ciz	in.s	n.s.	con.	Trophic type and saprobity
0-1	Aulacoseira italica+var subarctica Aulacoseira ambigua	Skogfoss, depth 5 m										
		0.2	1.48	62 15	38 43	50 31	25 12	24 14	1 2	58	0.5	Oligotrophic Oligo-ß-mesosaprobic
1-2	Cyclotella kutzingiana Aulacosera italica+var tenuissima	0.3	1.47	54 15	46 64	37 36	27 18	21 19	15 6	79	1	
2-3	Subd. Cyclotella kutzingiana ,Tabellaria flocculosa Eunotia pectinalis	0.5		45 14	55 54	15 17	40 16	40 30	5 5	68	0.62	
3-4	Pinnularia viridis var. sudetica Pinnularia subcapitata	0.2	0.75	11 9	89 34	10 6	56 11	32 22	2 4	43	0.12	Oligotrophic
4-5	et var. hilseana, et f. undulata	0.5		2 6	98 31	10 7	41 9	47 6	2 5	37	0.08	Xenosaprobic
		Bjørnevatn, depth 4 m										
0-1	Fragilaria construens et var. Tabellaria fenestrata Tabellaria flocculosa	2.8	1.63	18 18	83 67	42 54	35 12	17 13	6 7	85	3	Mesotrophic Oligo-ß-mesosaprobic
1-2	Subd. Aulacoseira valida, A. subarctica Aulacoseira alpigena	0.2	1.24	31 10	59 34	47 36	19 7	22 6	10 10*	54	0.12	Oligotrophic Oligosaprobi c
3-8	Melosira nummuloides Paralia sulcata Isthmia nervosa	Marine species										

Table explanation: 1) dominant taxa > 10% valves, subd.-subdominants - 5-10%; 2) A/C - Index Stockners; 3) S - saprobity, Pantle Buck; 4) pl - plankton, b - benthos and periphyton, al - alkalipilous and alkalibiontic, ac - acidophilous and acidobiontic, cir - circumneutral; in.s. - indefinite ecology species, above line- % concentration; below line number specils; 5) n.s. - _ number species; 6) con. - concentration - mln valves per 1 gram dry sediment

Appendix 7.2. *Ecological characteristics of diatoms from sediments of the Kuetsyarvi Lake*

Layer cm	Dominant taxa	A/C	S	pl	b	al	ac	ciz	in.s	n.s.	con.	Trophic type and saprobity
						ecological group						
0-2	Diatoma tenuis Stephanodiscus astraea var. minutula Aulacoseira islandica	Kuetsyarvi, depth 14 m										
		2.8	1.67	72 18	28 42	58 39	18 8	12 7	12 6	60	90	
2-4		2.7		81 15	19 43	84 35	1 4	3 15	12 4	58	120	Eutrophic
4-6	Subd. Asterionella gracilluma+ Asterionella formosa	3.6	1.63	90 15	10 47	70 40	1 7	1 17	28 4	67	170	ß-mesosaprobic
6-8	Stephanodiscus hantzschii	2.0		83 15	14 53	84 43	2 7	2 11	12 7	68	40	
8-10	Aulacoseira islandica Aulacoseira ambigua Aulacoseira alpigena	0.1	1.37	88 12	12 41	82 32	3 3	14 12	1 5	53	16	Oligotrophic Oligo-saprobic
10-20	Aulacoseira alpigena Tabellaria flocculosa	0.1		65 9	34 54	78 31	18 5	13 18	1 10	64	16	
20-30	Tabellaria flocculosa Aulacoseira alpigena	0.03	0.8	44 9	56 21	45 16	53 3	1 11	1 1	30	20	xenosaprobic
30-40	Aulacoseira alpigena Aulacoseira islandica Tabellaria flocculosa	0.01		70 9	30 41	76 21	22 18	1 11	1 1	50	12	
40-50		0.01		74 9	26 37	75 26	20 14	4 5	1 1	46	12	
50-60		0.1	1.21	67 12	33 63	73 35	18 10	7 28	2 2	75	24	Oligotrophic oligosaprobic

Appendix 8.1. Analysis of quantitative phytoplankton samples (mm³/m³), Langevatn (Skogfoss)

	Langvatn (Skogfoss)			
	22/06/93	15/07/93	09/08/93	21/09/93
Cyanophyceae (bluegreen algae)				
Snowella lacustris			1.99	
Woronichinia naegeliana				1.60
Sum			**1.99**	**1.60**
Chlorophyceae (green algae)				
Botryococcus braunii		0.70		
Carteria sp. (l=6-7)	0.53			
Chlamydomonas sp. (l=10)	0.93			
Chlamydomonas sp. (l=8)		0.27		0.27
Elakatothrix gelatinosa (genevensis)	0.56	0.37		0.24
Gloeotila pulchra			2.65	0.53
Gyromitus cordiformis			1.39	
Monoraphidium dybowskii	0.45	0.68	0.23	0.40
Paulschulzia pseudovolvox				0.32
Tetraedron minimum v.tetralobulatum	0.87	1.11	0.29	0.44
Sum	**3.34**	**3.12**	**4.56**	**2.19**
Chrysophyceae (golden algae)				
Aulomonas purdyi	0.13			
Chromulina sp.		1.06		
Chrysochromulina parva	1.21	3.22	0.95	
Chrysococcus sp.		0.37		
Chrysolykos planctonicus	0.15	0.15		
Chrysolykos skujai	1.91	0.15	0.29	0.15
Craspedomonads	0.16		0.32	0.86
Cysts of Chrysolykos skujai	0.48			
Desmarella moniliformis	1.06			
Dinobryon bavaricum	1.59	0.18	1.60	
Dinobryon borgei	3.43	1.67	0.11	0.09
Dinobryon crenulatum	0.74	0.40	0.40	
Dinobryon cylindricum	1.40			
Dinobryon divergens	0.24	0.09	7.63	0.20
Dinobryon sociale			0.87	0.06
Dinobryon sociale v.americanum	0.79			
Dinobryon suecicum	0.64		0.48	
Epipyxis polymorpha			0.27	
Kephyrion litorale		0.40	0.16	
Large chrysomonads (>7)	38.76	46.51	30.14	18.09
Mallomonas caudata				0.70
Mallomonas spp.	2.92			
Ochromonas sp. (d=3.5-4)	9.80	9.73	8.16	7.15
Pseudokephyrion entzii	0.53	0.27	0.13	
Single cells of Dinobryon spp.	0.36	0.40	2.78	0.44
Small chrysomonads (<7)	37.97	34.19	13.67	9.54
Spiniferomonas sp.			0.30	
Uroglena americana		0.91		0.72
Sum	**104.25**	**99.67**	**68.27**	**37.99**
Bacillariophyceae (diatoms)				
Asterionella formosa	2.97	0.11	4.37	11.66
Aulacoseira alpigena			0.26	1.87
Aulacoseira italica v.tenuissima		0.16	1.20	1.28
Aulacoseira subarctica		0.71		
Cyclotella comta	0.48		3.36	1.44

Appendix 8.1. cont.

	Langvatn (Skogfoss)			
	22/06/93	**15/07/93**	**09/08/93**	**21/09/93**
Cyclotella glomerata		2.07		0.16
Cyclotella kutzingiana				0.96
Cyclotella sp. (d=8-12 h=5-7)	0.93	3.18		0.93
Diatoma tenuis	1.33			
Rhizosolenia longiseta			3.18	0.33
Synedra acus v.angustissima			0.54	0.48
Synedra acus v.radians			0.90	
Synedra sp. (l=30-40)	1.67			
Synedra sp. (l=40-70)		0.80	0.16	0.08
Tabellaria fenestrata	0.60	1.20		3.96
Tabellaria flocculosa	3.52		0.60	0.60
Tabellaria flocculosa v.geniculata			4.50	1.20
Sum	**11.49**	**8.23**	**19.07**	**24.95**
Cryptophyceae				
Cryptomonas cf.parapyrenoidifera			1.40	
Cryptomonas erosa			5.04	
Cryptomonas erosa v.reflexa (Cr.refl.?)		0.96	12.24	
Cryptomonas marssonii		1.54	6.89	
Cryptomonas sp. (l=15-18)	1.06			
Cryptomonas sp. (l=20-22)	1.92	15.90	28.62	6.36
Cryptomonas spp. (l=24-28)	0.80	2.40	17.50	4.00
Indet.cryptomonade (Chroomonas sp.?)		6.89	13.78	3.45
Indet.cryptomonade (l=6-8) Chro.acuta ?			0.48	
Katablepharis ovalis	4.05	5.25	2.15	1.19
Rhodomonas lacustris (+v.nannoplanctica)	53.42	9.94	8.90	0.66
Sum	**61.26**	**42.87**	**96.99**	**15.66**
Dinophyceae (dinoflagellats)				
Ceratium hirundinella		6.00		
Gymnodinium cf.lacustre	15.77	9.94	4.24	3.18
Gymnodinium cf.uberrimum		8.00		
Gymnodinium helveticum			4.80	2.00
Gymnodinium sp. (l=14-16)	0.21	0.96		
Indet. dinoflagellat (l=9-10)	1.86	1.86		1.19
Peridinium goslaviense			0.76	
Peridinium inconspicuum	3.22	9.00	5.78	
Peridinium sp. (l=15-17)		0.99		
Peridinium willei		32.00		
Sum	**21.05**	**68.74**	**15.58**	**6.37**
Euglenophyceae				
Euglena sp. (l=40)		0.48		
Sum		**0.48**		
My-algae				
My-algae	12.61	12.93	12.51	8.80
Sum	**12.61**	**12.93**	**12.51**	**8.80**
Total volume :	**214.01**	**236.05**	**218.96**	**97.56**

Appendix 8.2. Analysis of quantitative phytoplankton samples (mm³/m³), Kuetsyarvi

	Kuetsyarv			
	20/06/93	**14/07/93**	**07/08/93**	**21/09/93**
Cyanophyceae (bluegreen algae)				
Achroonema sp.		29.15	34.98	59.76
Anabaena flos-aquae	2.70			
Sum	**2.70**	**29.15**	**34.98**	**59.76**
Chlorophyceae (green algae)				
Carteria sp. (l=6-7)				0.79
Chlamydomonas sp. (l=10)	1.86	5.57		
Closterium sp.				1.40
Cysts of Chlorogonium maximum		19.08		
Dictyosphaerium pulchellum				2.12
Elakatothrix gelatinosa (genevensis)	0.37			
Gyromitus cordiformis	1.19			5.57
Koliella longiseta	1.66	1.06	0.66	
Lagerheimia genevensis	0.16			
Micractinium pusillum				1.38
Monoraphidium contortum	3.34	71.13	18.44	24.49
Monoraphidium minutum	0.85	4.45	0.48	0.37
Mougeotia sp. (b=10-12)				130.22
Pandorina morum			6.16	18.24
Paulschulzia pseudovolvox	2.88		0.80	10.56
Pediastrum boryanum			3.20	
Scenedesmus armatus		2.65	7.95	
Scenedesmus dimorphus	1.33			
Scenedesmus quadricauda			2.16	
Tetraedron minimum v.tetralobulatum	1.91	4.45		
Sum	**15.53**	**108.39**	**39.85**	**195.14**
Chrysophyceae (golden algae)				
Bitrichia chodatii	0.33			
Chromulina sp.	1.99			
Chrysochromulina parva	1.51		1.70	
Chrysococcus cordiformis	0.27			
Chrysolykos planctonicus	0.27			
Craspedomonads	0.32		5.09	
Desmarella moniliformis			1.27	
Dinobryon bavaricum	1.44	52.87		19.48
Dinobryon borgei	6.15			
Dinobryon crenulatum	0.99			
Dinobryon korsikovii	0.40			
Large chrysomonads (>7)	44.79	170.53	5.17	22.39
Mallomonas spp.		5.04	0.93	
Ochromonas sp. (d=3.5-4)	10.30	26.33	4.72	10.02
Pseudokephyrion alaskanum	0.16			
Pseudokephyrion entzii	0.53			
Pseudokephyrion sp.	0.13			
Single cells of Dinobryon spp.	1.43			7.42
Small chrysomonads (<7)	33.42	183.96	14.12	30.32
Synura sp. (l=9-11 b=8-9)	1.06			
Uroglena americana	1.52		0.99	0.79
Sum	**107.00**	**438.72**	**33.99**	**90.42**

Appendix 8.2. cont.

	Kuetsyarv			
	20/06/93	**14/07/93**	**07/08/93**	**21/09/93**
Bacillariophyceae (diatoms)				
Achnanthes sp. (l=15-25)		367.29		
Asterionella formosa	491.18	4057.68	1229.60	162.31
Cyclotella catenata	19.01	649.25	1.40	1961.66
Cyclotella sp. (d=8-12 h=5-7)	5.57			
Cymbella spp.		255.99		
Diatoma tenuis	99.11	1923.90	159.00	276.93
Fragilaria capucina		6232.80		2.40
Melosira varians		333.90		
Nitzschia sp. (l=40-50)		170.66	3.71	
Rhizosolenia eriensis	0.40		5.96	22.26
Rhizosolenia longiseta	0.40		0.79	
Stephanodiscus hantzschii	0.86	16.96		5.76
Synedra sp. (l=30-40)	3.90	257.10		
Synedra sp. (l=40-70)	54.06	1309.63	25.97	5.57
Synedra ulna		424.00	1.40	1.40
Tabellaria fenestrata		28.62		
Tabellaria flocculosa	7.00	185.50		
Sum	**681.48**	**16213.28**	**1427.84**	**2438.29**
Cryptophyceae				
Cryptomonas cf.parapyrenoidifera		21.47		
Cryptomonas erosa			8.64	
Cryptomonas erosa v.reflexa (Cr.refl.?)				19.08
Cryptomonas sp. (l=15-18)		278.25		
Cryptomonas sp. (l=20-22)	9.54			38.16
Cryptomonas spp. (l=24-28)				42.40
Katablepharis ovalis	6.31	6.20		6.20
Rhodomonas lacustris (+v.nannoplanctica)	19.88	181.02	41.74	47.22
Sum	**35.72**	**486.94**	**50.38**	**153.06**
Dinophyceae (dinoflagellats)				
Gymnodinium cf.lacustre	2.98			
Gymnodinium helveticum				38.00
Gymnodinium sp. (l=14-16)			0.24	
Peridinium inconspicuum			0.80	
Peridinium sp. (l=15-17)	0.66			
Sum	**3.64**		**1.04**	**38.00**
Euglenophyceae				
Trachelomonas furcata			1.46	
Sum			**1.46**	
My-algae				
My-algae	15.90	59.47	11.98	18.66
Sum	**15.90**	**59.47**	**11.98**	**18.66**
Total volume :	**861.97**	**17335.94**	**1601.52**	**2993.32**

Appendix 8.3. Analysis of quantitative phytoplankton samples (mm³/m³), Bjørnevatn

	Bjørnevatn			
	22/06/93	15/07/93	09/08/93	21/09/93
Cyanophyceae (bluegreen algae)				
Achroonema sp.			1.46	0.83
Sum			**1.46**	**0.83**
Chlorophyceae (green algae)				
Carteria sp. (l=6-7)		0.79		0.99
Chlamydomonas sp. (l=12)	1.59	1.59		
Chlamydomonas sp. (l=8)	0.27	0.27		
Chlorogonium maximum		2.40		
Closterium sp.				0.70
Crucigenia tetrapedia				0.40
Cysts of Chlorogonium maximum	0.40	74.20		
Elakatothrix gelatinosa (genevensis)			0.21	
Gloeotila pulchra			0.53	
Gonium sociale	0.12			
Gyromitus cordiformis		1.59		
Koliella longiseta	0.30	0.33		0.27
Monoraphidium contortum		0.93	0.32	0.16
Monoraphidium dybowskii				0.68
Monoraphidium griffithii			0.53	0.53
Mougeotia sp. (b=10-12)				12.42
Pandorina morum		7.42		
Paramastix conifera		2.58		1.33
Tetraedron minimum v.tetralobulatum	0.40		0.27	0.27
Sum	**3.08**	**92.10**	**1.86**	**17.73**
Chrysophyceae (golden algae)				
Aulomonas purdyi		0.13		
Bicosoeca sp.				0.13
Chromulina sp.				0.40
Chrysidiastrum catenatum			5.57	
Chrysochromulina parva	0.42		0.69	1.58
Chrysolykos planctonicus			0.15	0.13
Chrysolykos skujai	0.44			
Craspedomonads	0.95	4.82	0.16	1.02
Cysts of Chrysolykos skujai	0.16			
Desmarella moniliformis				0.64
Dinobryon bavaricum	1.19	3.71	1.37	0.35
Dinobryon bavaricum v.vanhoeffenii			0.33	
Dinobryon borgei	2.33		0.09	1.27
Dinobryon cylindricum	2.64			
Dinobryon divergens			4.56	1.37
Dinobryon suecicum	0.15			0.32
Large chrysomonads (>7)	39.62	26.70	14.64	11.20
Mallomonas akrokomos (v.parvula)	0.53			
Mallomonas caudata			0.80	
Ochromonas sp. (d=3.5-4)	12.95	6.44	7.44	9.23
Pseudokephyrion sp.			0.13	
Single cells of Dinobryon spp.	3.71	1.39	3.25	
Small chrysomonads (<7)	31.26	17.23	15.27	13.75
Spiniferomonas sp.	0.27			
Synura sp. (l=9-11 b=8-9)	0.79			0.79
Uroglena americana			10.60	0.36
Sum	**97.41**	**60.42**	**65.03**	**42.53**

Appendix 8.3. cont.

	Bjørnevatn			
	22/06/93	15/07/93	09/08/93	21/09/93
Bacillariophyceae (diatoms)				
Achnanthes sp. (l=15-25)	1.19	1.19		
Asterionella formosa	4.18	7.29	65.59	20.36
Aulacoseira alpigena				0.43
Aulacoseira italica v.tenuissima				1.12
Aulacoseira valida			5.44	
Cyclotella catenata	6.03	67.71		5.22
Cyclotella comta				1.32
Cyclotella glomerata	0.44		0.48	0.37
Cyclotella sp. (d=8-12 h=5-7)				0.93
Diatoma tenuis	5.30	1.19	1.33	5.40
Nitzschia sp. (l=40-50)		5.57		
Rhizosolenia eriensis			0.33	
Rhizosolenia longiseta			1.99	3.58
Stephanodiscus hantzschii	4.24	6.36	2.12	3.24
Synedra sp. (l=30-40)	5.57	0.56		
Synedra sp. (l=40-70)	15.90	7.42		1.44
Synedra ulna	6.00		1.40	
Tabellaria fenestrata	2.70		0.72	2.88
Tabellaria flocculosa	10.40	0.40		
Tabellaria flocculosa v.geniculata				1.20
Sum	**61.94**	**97.68**	**79.39**	**47.47**
Cryptophyceae				
Cryptomonas cf.parapyrenoidifera	0.48	3.18		
Cryptomonas erosa		2.52	25.44	6.89
Cryptomonas erosa v.reflexa (Cr.refl.?)	0.80		9.86	3.96
Cryptomonas marssonii	0.26		2.92	
Cryptomonas sp. (l=15-18)		1.06		
Cryptomonas sp. (l=20-22)			6.36	
Cryptomonas spp. (l=24-28)	0.40		12.50	5.20
Katablepharis ovalis	2.15	1.91	0.24	2.19
Rhodomonas lacustris (+v.nannoplanctica)	20.39	14.38	12.59	19.94
Ubest.cryptomonade (Chroomonas sp.?)	1.99		17.23	0.13
Ubest.cryptomonade (l=6-8) Chro.acuta ?			0.21	
Sum	**26.47**	**23.04**	**87.34**	**38.31**
Dinophyceae (dinoflagellats)				
Ceratium hirundinella	6.00		6.00	
Gymnodinium cf.lacustre	5.30		1.86	0.93
Gymnodinium cf.uberrimum	8.00			
Gymnodinium helveticum		1.60	3.60	4.00
Indet. dinoflagellate (l=9-10)	2.39			
Indet.dinoflagellate	0.40			0.46
Peridinium goslaviense			1.12	
Peridinium inconspicuum			31.50	
Peridinium sp. (l=15-17)	4.37			0.33
Sum	**26.46**	**1.60**	**44.08**	**5.72**
Euglenophyceae				
Trachelomonas furcata				0.06
Sum				**0.06**
My-algae				
My-algae	13.25	20.56	14.10	12.61

Appendix 8.3. cont.

	Bjørnevatn			
	22/06/93	15/07/93	09/08/93	21/09/93
Sum	13.25	20.56	14.10	12.61
Total volume :	228.60	295.41	293.24	165.26

Appendix 9.1. *General description of macrophyte communities*

Helophytes

The investigation was concentrated on the aquatic vegetation, but the dominant helophytes were recorded. These were *Phragmites australis*, *Equisetum fluviatile*, *Carex rostrata* and *C. aquatilis*.

Stands of *Phragmites australis* were only observed in the upper part of the Pasvik river (Gjøkbukta and Ruskebukta) and in the northern part of Lake Kuetsyarv. According to Edvardsen (unpubl.) the species is common in coves in the Pasvik river. "Overgrowing bogs" had also scattered occurrences of the species. The species is dispersed vegetativly and seeds are seldom found in Finnmark (Gjærevoll 1985, ref. in Edvardsen (unpubl.)). The *Equisetum fluviatile* communities were common throughout the river with optimum conditions in Gjøkbukta and Svanevatnet at Svanvik. Huge quantities were also seen in streaming parts of the river, at Perslåtta. About the distribution of the other helophytes we refer to Edvardsen (unpubl.).

Aquatic vegetation

Tab. 1 shows the aquatic plants found in the Pasvik river and Lake Kuetsyarv. A total of 29 species were recorded (7 isoetids, 16 elodeids, 4 nymphaeids, 1 lemnide and 1 charophyte). Generally, the aquatic vegetation was luxuriant with a high number of species. Gjøkbukta, Fuglebukta and Svanevatn at Svanvik had the highest number of species.

The isoetids were present at most of the localities, but large and continuous stands were rare, except for *Isoetes lacustris*, which in Svanevatn built continuous stands in water deeper than 1.5-2 meters. The species is probably more widespread than observed, especially in deeper water. Otherwise, *Isoetes setacea* and *Subularia aquatica* were the most common isoetids, whereas the rare *Elatine hydropiper* was found at four localities in Pasvik river. This species belongs to the small, annual isoetids that commonly appears on clayey bottoms in shallow water. In the Pasvik river, however, the species stayed at depths between 0.5 and 1 meter. In shallow water at Skrukkebukta, another small annual isoetide, *Limosella aquatica,* was recorded. Dahl (1934) found this species in Svanevatn.

The elodeids played the most prominent role in the river, concerning number of species and abundance. The most common species were *Myriophyllum alterniflorum* and *Potamogeton perfoliatus.* In some localities these species built large stands in water deeper than 0.5 - 1 meter. *Potamogeton perfoliatus* was the only elodeide found rooted at all localities in Lake Kuetsyarv. *Callitriche palustre* was common in shallow water together with the isoetids, whilst small specimens of the more rare *Callitriche hermaphroditica* occurred scattered, with the largest occurrence in Fuglebukta. *Ranunculus peltatus* was fairly abundant, with a large population in the outlet of Fuglebukta and at Perslåtta. At the latter locality the species built large flowering stands, covering an area of ca. 100 - 200 meters. The stands, being influenced by the streaming water, were built up by large and extended specimens without any epiphytic growth. In between the ordinary plants of *Ranunculus peltatus* some divergent specimens of *Ranunculus* were found, with larger and more extended submerged leaves. Such divergent specimens were also observed in Svanevatn at Seljeli. *Potamogeton berchtoldii* had its largest occurrence in the upper part of the river, and produced mass-stands in Gjøkbukta together with *Myriophyllum sibiricum.* Gjøkbukta was also the only locality where *Ranunculus confervoides* were recorded. *Potamogeton gramineus* occurred both in shallow and deeper water. In shallow water the species were stocky and shrubby, whilst in deeper, especially streaming, water the species became larger and slender.

A total of 4 nymphaeids were recorded. *Sparganium angustifolium* was the most common one in the river and occurred both as rosette and with floating leaves, but in small stands. *Polygonum amphibium* was not as common as *Sparganium angustifolium,* but at certain places this species developed extensive stands. In Svanevatn at Skrotnes *Polygonum amphibium* made a fantastic flowering stand extending at least 100 x 40 meters.

The lemnid *Lemna trisulca* occurred in Lake Kuetsyarv (middle and southern part), and in Svanevatn at Svanvik and Skrotnes. This plant had its largest occurrence at Svanvik, and in early summer covered probably most of the surface in the bay. This may also have been the case in the south-western bay of Lake Kuetsyarv. In the late summer during our registrations, however, these plants were lying on the bottom. At other places the species had scattered occurrence.

Table 1. *Aquatic vegetation in Pasvik river and Lake Kuetsyarv 24-27. august 1993. Occurrence: 1=rare, 2=scattered, 3=common,4=local dominant and 5=dominant. +:drifting specimens.*

	localities																			
Latin names	1A	1B	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
ISOETIDS																				
Elatine hydropiper			**2**												**3-4**	**2**			**3**	
Eleocharis acicularis	**1**	**2-3**		**4**	**3**	**3**				**2-3**			**2**	**4**		**3**			**5**	**5**
Isoetes lacustris			**+**		**4**	**1**				**2**	**3**			**+**	**5**		**5**	**2**		**x**
Isoetes setacea		**2**	**3**	**x**	**4**					**3**	**2**	**2**	**3**	**4**	**2**	**2**	**4**	**2**		
Limosella aquatica																				**1**
Ranunculus reptans		**2**				**2**			**2**	**2**	**2**				**2**			**2-3**	**2**	
Subularia aquatica	**2**	**3**	**3**	**x**	**3**	**4**			**4**	**3**	**3**	**2**		**2**		**2**	**2**			**5**
ELODEIDS																				
Callitriche hamulata	**3**		**2**	**x**	**2**				**4**	**3**	**2**				**2**	**2**				
Callitriche hermaphroditica	**2**		**2**						**2**	**3**					**1**				**3**	**2**
Callitriche cf. palustris						**2**								**1**	**2**				**2**	**3**
Hippuris vulgaris	**4**				**1**		**3**	**4**	**3-4**	**2**					**2-3**					
Myriophyllum alterniflorum		**4**	**3**		**2**	**3-4**	**3**	**2**	**4**	**2-3**	**2**	**+**			**2**		**3**	**4**	**3**	**3**
Myriophyllum sibiricum	**5**	**2**			**x**		**3**		**4**						**2**					
Potamogeton alpinus			**1**						**2**				**2**	**3**						
Potamogeton berchtoldi	**5**	**1**	**2**	**x**						**1**										**2**
Potamogeton filiformis														**3**						
Potamogeton gramineus	**2**	**3**				**4**				**3**	**5**			**2**		**4-5**	**3**	**3**		
Potamogeton perfoliatus	**2**	**3**	**3-4**	**x**	**3-4**		**4-5**			**5**	**4**	**4**	**5**	**5**	**3**	**3**	**2**		**3-4**	**3**
Potamogeton praelongus													**?**		**2**					
Potamogeton sparganifolius							**2-3**													
Ranunculus confervoides	**2-3**																			
Ranunculus peltatus	**1**		**3-4**		**3**	**3**	**3**	**4**		**5**	**5**	**+**					**3**	**2**	**2-3**	**2**
Utricularia vulgaris	**2**			**x**	**3**		**3-4**	**2**	**3**						**4**					
NYMPHAEIDS																				
Nuphar pumila	**4**														**2**					
Polygonum amphibium			**4**	**x**	**3**	**3**	**3**					**4**	**3**	**3**	**3**	**5**	**3**			
Sagittaria sagittifolia x natans	**3**				**2**															
Sparganium angustifolium	**3**	**3**	**4**	**4-5**	**4**	**4**	**4**	**1**	**4**	**5**	**5**	**3**	**3**	**4-5**	**3**	**4-5**	**3**	**2**		**4**
LEMNIDS																				
Lemna trisulca													**2**	**3**	**5**	**2**				
CHAROPHYTES																				
Nitella opaca/flexilis	**2**	**3-4**				**4**	**1**		**3**	**4**	**4**	**3**		**2**				**2**	**2-3**	**4**
AQUATIC MOSSES																				
Fontinalis antipyretica											**2**									
moss (indet.)	**4**	**3**					**5**		**3**	**4**				**3**	**5**					
Number of isoetids	2	4	4	3	4	4	0	0	2	5	4	2	2	4	4	4	3	3	3	4
Number of elodeids	10	5	7	4	7	4	7	4	7	8	6	3	2	5	9	3	5	3	5	6
Number of nymphaeids	3	1	2	2	3	2	2	1	1	1	1	2	2	2	3	2	2	1	0	1
Number of lemnids	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0
Number of charophytes	1	1	0	0	0	1	1	0	1	1	1	1	0	1	0	0	0	1	1	1
Aquatic plants and charoph.	**16**	**11**	**13**	**9**	**14**	**11**	**10**	**5**	**11**	**15**	**12**	**8**	**7**	**13**	**17**	**10**	**10**	**8**	**9**	**12**
Aquatic mosses	**1**	**1**	**0**	**0**	**0**	**0**	**1**	**0**	**1**	**1**	**1**	**0**	**1**	**1**	**1**	**0**	**0**	**0**	**0**	**0**

Rare and interesting species

Most of the species recorded in the Pasvik river are common in this part of the country and in Norway as a hole, and few of the plants have special nutrient requirments. In the following we will describe the more rare and interesting plants.

Callitriche hermaphroditica

This species occurred scattered at 7 localities in the Pasvik river (Fig. 1). The plants were found at depths of 0.5-1 meter. They were small, solitary and probably annual in the river (Martinsson 1988). Edvardsen (unpubl) has reported the species from Svanevatn at Svanvik, whilst Dahl (1936) reported from the lower part of the Pasvik river (Klistervatnet, Elvenes). It seems to be no essential changes in the occurrence since the registrations of Dahl.

The species is classified as semi-eutrophic (Nordiska Ministerrådet 1984), but according to Martinsson (1988) increasing eutrophication has negative influences on the species. The species seems to require some more calcareous localities and not necessarily localities rich in phosphorus and nitrogen. A regional compilation of macrophytic data concerning acidification, showed *Callitriche hermaphroditica* mainly at localities with high conductivity and pH > 7, and were counted as a no acid-tolerating species (Brandrud and Mjelde 1993). This is in agreement with Samuelsson (1934) who mentioned *Callitriche hermaphroditica,* together with *Potamogeton filiformis, Ranunculus confervoides and Myriophyllum spicatum,* as alkalifile, and not typical eutrophic, species.

Elatine hydropiper

This species was recorded at 4 localities in the Pasvik river; Ruskebukta at Nyheim, Svanevatn at Svanvik and Skrotnes and Skrukkebukta at Nordvik (Fig. 2). The finds in Pasvik represent a new northern limit for this species.

Elatine hydropiper belongs to the small and annual isoetids. According to Brandrud (1994) the species is found in shallow water in slow-streaming rivers, backwaters and lakes, usually at clayey and silt substrate in meso-eutrophic water and especially at open shores and banks without dense helophytic vegetation. According to Uotila (1974) the species of *Elatine* in northern Europe avoid calcareous areas. This is, however, not the case in Norway, where the species is for instance found in Lake Steinsfjord (Buskerud), a typical cambrosiluric limestone area. The species also avoid acid oligotrophic water (Brandrud 1994).

The former northern limit of *Elatine hydropiper* was Senja in Troms (Spjelkavik 1979). In Finland the species is recorded in the southern part of Lake Inare, which belongs to the upper part of the Pasvik watercourse. The specimens in the Pasvik river are probably water spread from the Inare area.

Lemna trisulca

Lemna trisulca was recorded at 2 localities in Lake Kuetsyarv, and in Svanevatn at Svanvik and Skrotnes (Fig. 3). At Svanvik the species occurred in large quantities, partly also at the southern locality in Lake Kuetsyarv. The species is classified as eutrophic (Nordiska Ministerrådet 1984).

The species was recorded in Pasvik river already in 1984 (Edvardsen unpubl.), and those finds represented new northern limit for the species. In the north of Norway the species is otherwise known only from the Kautokeino river at Kautokeino (Sivertsen 1978, Elven and Johansen 1981). In Finland the species is found as far north as Suompi Lappmark, whilst in Sweden it is spread north to Torne Lappmark. The occurrence in Pasvik river is perhaps spread with water from the Russian localities (figure 5). It is also possible that the species have been spread with birds from the localities in Sweden or Finland.

Myriophyllum sibiricum

Myriophyllum sibiricum was recorded at 5 localities in the Pasvik river; from Gjøkbukta in south to Svanevatn at Svanvik in the north (Fig. 4). At two of these localities the species built quite large stands. Edvardsen (unpubl.) recorded large quantities of the species in the same area in 1984, and the occurrence of the species seems to be unchanged since 1984. *Myriophyllum sibiricum* was formerly treated as part of *Myriophyllum spicatum*. According to Dahl (1934) *M. spicatum* was found in Svanevatn at Svanvik and in Goalsjavrre in the Pasvik river. The occurrence in Svanevatn is probably the same as the one mentioned by Økland (1970). After the revision of the material of *M. spicatum* in Norway, both the records of Dahl and of Økland was renamed *M. sibiricum* (conf. Fægri 1982). *M. sibiricum* has a north-eastern occurrence in Norway, and is concentrated to N Norway and the central mountain areas in S Norway. The southernmost certain find is Selsmyrene in the valley of Gudbrandsdalen, and the species has been named *Myriophyllum spicatum* ssp. *squamosum* (Fægri 1982, Lid 1985). According to Fægri (1982) the species is eutrophic and restricted to calcareous areas.

Myriophyllum verticillatum

Myriophyllum verticillatum was not found during our fieldwork, but was included in Økland (1970) and Edvardsen (unpubl). In 1970 the species was found in Svanevatn at Svanvik, which was described as a nearly closed cove of the water. This locality is probably Lonken, in the inner part of the cove at Svanvik. The registration of Edvardsen in 1984 is probably identical with this locality. Økland (1970) was afraid that *Myriophyllum verticillatum* would not stand the regulations of the river. *Myriophyllum verticillatum* is regarded as an eutrophic species (Lohammer 1965).

Polygonum amphibium

Polygonum amphibium was one of the most common species in the area, recorded at 11 localities in the Pasvik river and Lake Kuetsyarv (Fig. 5). At some localities the species produces large stands, for instance in Svanevatn at Skrotnes where the species built an impressive flowering stand extending at least 100x40 meters. Dahl (1934) mentioned the species from Valjavrre at Brennhaug and Salmijavrre (Svanevatn) at Svanvik, and the species has apparently increased since the thirties.

Even though *Polygonum amphibium* has its main occurrence in the southern part of Fennoscandia, Samuelsson (1934) counted the species as widely spread. In Norway it is common in the south-east, and has scattered occurrence along the coast north to Finnmark (Hultèn 1971, Lid 1985). According to Hultèn (1971) *Polygonum amphibium* has two localities in Finnmark apart from Pasvik, the watercourse Anarjohka (probably in a small lake at Vassuovde (Basevuovdi), mentioned by Dahl (1934)) and the Kautokeino river upstream Kautokeino. The species was recollected in Anarjohka in 1984 (Elven, pers. comm.). *Polygonum amphibium* is rare in northern Finland (Inari Lapland) where the largest stands are found in coves in shallow water (Mäkinen et al. 1982). According to Nordiska Ministerrådet (1984) the species is counted as semi-eutrophic.

Potamogeton filiformis

A small population of *Potamogeton filiformis* was found at the southern locality in lake Kutesyarv. The calcium-content in the water of lake Kutesyarv is approximately 10 mg Ca/l (Traaen et al. 1993). The species was recorded in Langvatn in 1958 (leg. & det. J. Kaasa, herb. O), and at Elvenes (brackish water) by Dahl (1934). According to Samuelsson (1934) high calcium-content is a key factor for the occurrence of *Potamogeton filiformis* in fresh water, whilst the requirement concerning other nutrients is low. Generally, this is in agreement with our observations in Norway (pers.obs.). The calcium-content in the water of Pasvik river is 3-5 mg Ca/l (Traaen et al. 1993), which is less than normal for the species. However, some parts of the Pasvik watercourse has calcium-rich bedrock and the sediments in the river are probably partly calcium-rich. Some uptake of calcium through the roots can be the reason why some specimens of *Potamogeton filiformis* have been found in the Pasvik river.

Ranunculus peltatus

Ranunculus peltatus is widespread in Scandinavia and is a common species in Pasvik river as well, where it could build large stands. At two localities (loc. 10 and 16) we found some large specimens with very long submerged leaves. The leaves, which could be up to 24 cm long, were longer than the internodes and somewhere they seemed to be branched 6 times. The specimens were sterile and had only submerged leaves. These characters can fit with the description of *Ranunculus penicillatus* ssp. *pseudofluitans* (conf. Dahlgren 1993). However, *Ranunculus penicillatus* ssp. *pseudofluitans* is known only from the south of Sweden and Denmark. Moreover, in the north of Sweden and especially in riverlocalities, unusually large specimens of *Ranunculus peltatus* with elongated leaves are recorded (Kari Martinsson pers. inf.). According to this, we choose to treate these diverging specimens as a especially large growing variant of *Ranunculus peltatus.*

Sagittaria sagittifolia x natans

The hybrid between *Sagittaria sagittifolia* and *S. natans* was recorded at two localities, Gjøkbukta and Lyngbukta, at water depth approximately 0.5 meter (Fig. 6). The specimens were sterile and had both submerged leaves (rosette) and small elongated floating leaves, the latter reminding of *Sagittaria natans.* The hybrid is new to Norway and the one parent, *S. natans*, has never been recorded, but the find by Økland (1960) in lake Vaggatem, published as *Sagittaria sagittifolia* (Økland 1962), has been renamed *Sagittaria sagittifolia x natans* (det. Stefan Ericsson). Juha Suominen (1986) supposed that the find of *Sagittaria sagittifolia* in the Pasvik river in 1960 could be the hybrid. In addition, we suppose that the find in Gjøkbukta in 1984 (Edvardsen, unpubl.), named as *Sagittaria sagittifolia*, is identical with the hybrid.

In 1960 the plant was recorded in a little stand, with some flowering specimens (Økland 1962) and these plants diverge from ours by the occurrence of typical emerged leaves. The hybrid looks very different in different areas, and thereby difficult to determine (Suominen 1986). In Finland, however, specimens within the same watercourse seem to be very alike. The large differences between the specimens found in the Pasvik River are probably due to the fact that the former specimens have grown in more terrestrial areas than the latter.

The hybrid between *Sagittaria sagittifolia* and *S. natans* is common in the north of Finland and is known from the north of Sweden and north-west Russia (Suominen 1986), whilst *Sagittaria sagittifolia* is not recorded in the north of Sweden (Stefan Ericsson, pers. inf.). In Norway, *Sagittaria sagittifolia* is only recorded in the south-eastern part, whilst *S. natans* is not known in the country (Hultèn 1971).

Sagittaria natans is regarded as a north-eastern species in Fennoscandia (Hultèn 1971, Suominen 1986). *Sagittaria sagittifolia* has a more southern and western occurrence, and according to Samuelsson (1934) it can be counted as a southern species. The latter species seems to be a more eutrophic species than *S. natans* and the hybrid (Suominen 1986).

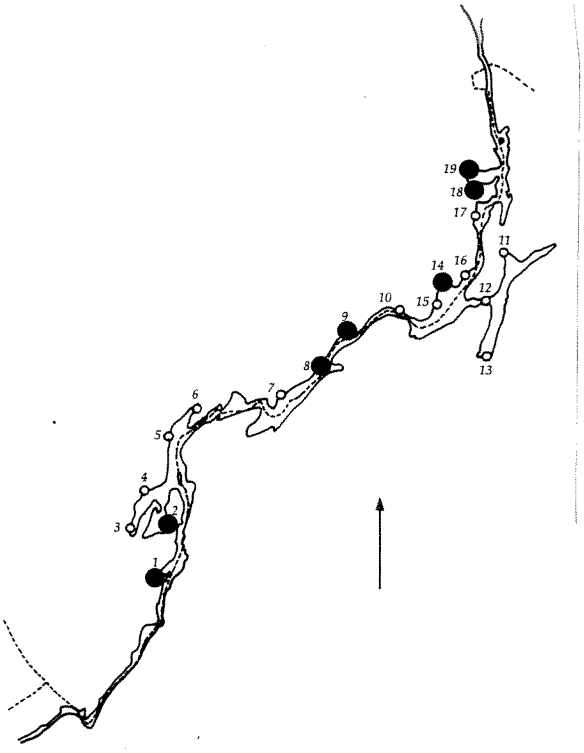

***Figure 1**. The finds of* Callitriche hermaphroditica *in the Pasvik River 1993.*

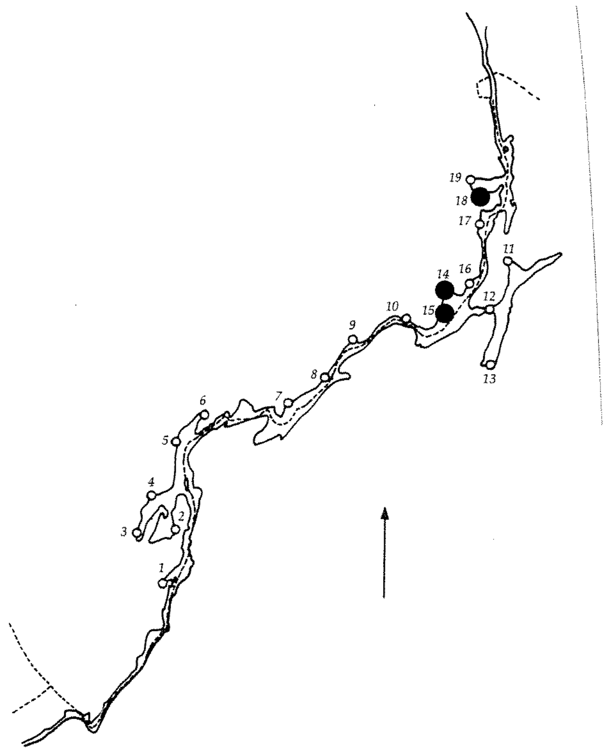

***Figure 2**. The finds of* Elatine hydropiper *in the Pasvik River 1993.*

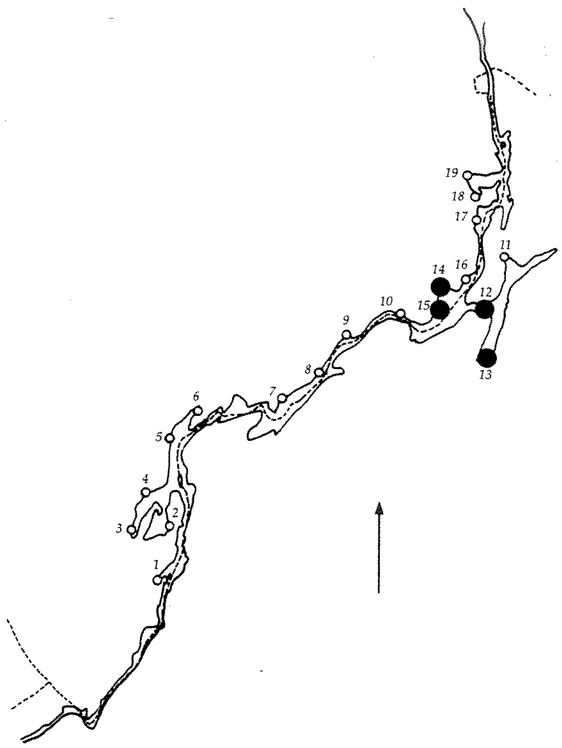

***Figure 3**. The finds of* Lemna trisulca *in the Pasvik River 1993.*

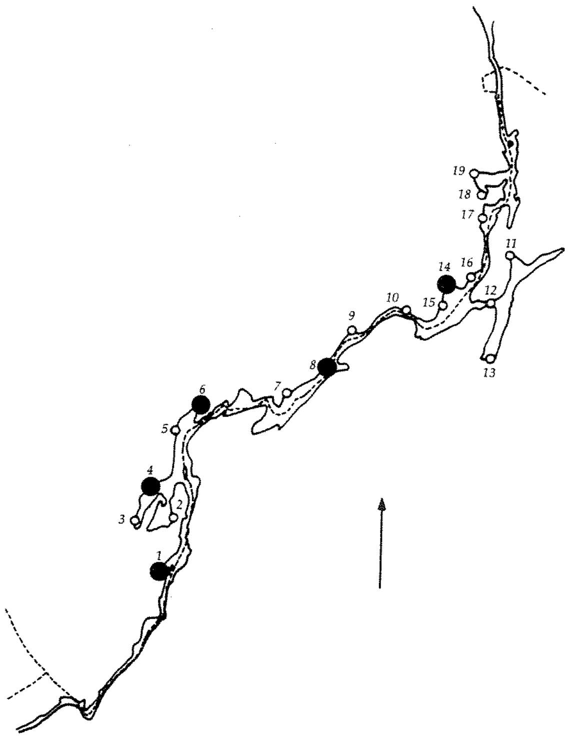

***Figure 4**. The finds of* Myriophyllum sibiricum *in the Pasvik River 1993.*

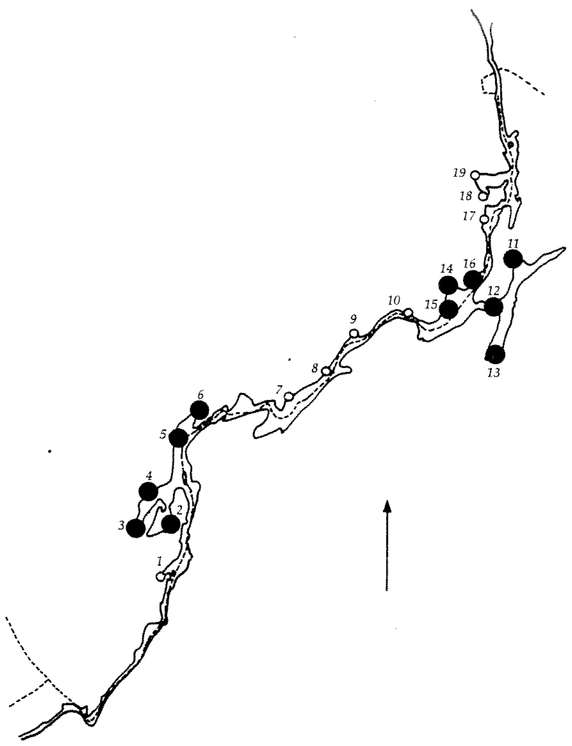

Figure 5. The finds of Polygonum amphibium *in the Pasvik River 1993.*

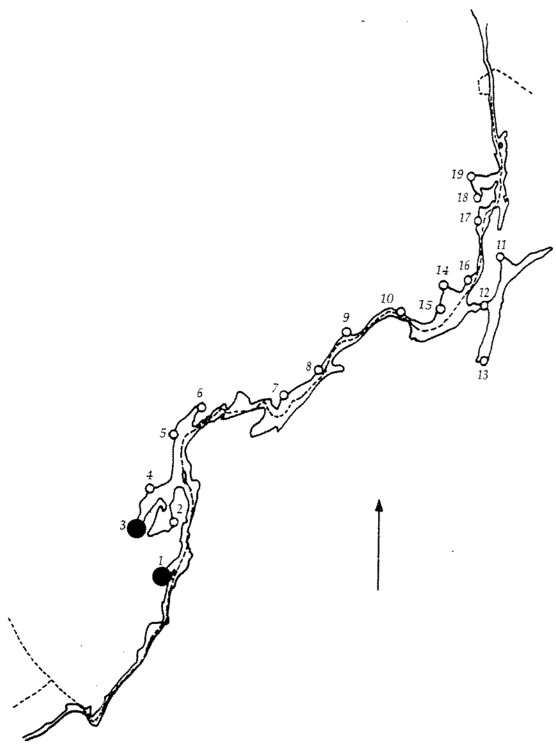

***Figure 6.** The finds of* Sagittaria sagittifolia x natans *in the Pasvik River 1993.*

***Appendix 9.2.** Detailed description of the localities*

Loc. 1: Gjøkbukta

Gjøkbukta is a north-east faced cove in Lake Fjørvatnet and has restricted connection with the Pasvik River. The altitude is 52 m.a.s. The brooks Gjøkbekken and Kjeldebekken, which have their inlet in the inner part of the cove, drain large bog-areas south-west of the locality. The outlet of Gjøkbukta is situated approximately 5km downstream the power station Hestfossen.

The cove is shallow, with maximum depth approximately 1.5m. The sediments in the inner parts are very porous and organic. In the middle parts, the area is more exposed and the sediment is more solid and dominated by silt. The aquatic vegetation is overgrown with epiphytes, especially in the inner parts.

The helophytes built luxuriant stands and the dominating species were *Carex aquatilis, Phragmites australis* and *Equisetum fluviatile. Carex aquatilis* had the largest occurrence in the inner parts, by the inlet of the creek. The other species, however, made some large stands in the outer parts of the cove and the outlet of Gjøkbukta into Fjørvatnet was nearly filled with these helophytes. For more information about the helophytes, we refer to Edvardsen (unpubl.).

In the inner parts of the cove, the isoetids were rare and only a few specimens of *Eleocharis acicularis* and *Subularia aquatica* were observed. These species were common at more solid substrates in the outer parts, where we also recorded some specimens of *Isoetes setacea* and *Ranunculus reptans.*

However, the elodeids dominated the aquatic vegetation and 10 species were represented. *Myriophyllum sibiricum* made large stands in the inner parts of the cove together with some small specimens of *Potamogeton berchtoldii* and *Hippuris vulgaris*. The latter species made a large stand outside the inlet of the creek. These specimens were well developed and had both emerged and submerged leaves. Some small specimens of *Ranunculus confervoides* were also recorded in this part of the locality. The nymphaeids counted 3 species. Some specimens of the nymphaeide *Sagittaria sagittifolia* x *natans* occurred at the north-western side in the inner part of the cove. The small specimens were found in shallow water, where they made rosettes with slandered floating-leaves. *Nuphar pumila* made some small stands by the south-eastern side replaced by large occurrence of aquatic mosses at the outside. The latter species dominated the middle part of Gjøkbukta together with the charophyte *Nitella opaca/flexilis* and *Sparganium angustifolium*. *Myriophyllum alterniflorum* made large stands by the north-western side, partly together with *Potamogeton perfoliatus* and *P. gramineus*.

Loc. 2: Ruskebukta, Kilbukta at Nyheim

The cove Ruskebukta is a part of Lake Vaggatem and the altitude is 52 m.a.s. The registration was concentrated to Kilebukta, a south-west faced cove in the eastern part of Ruskebukta. By the northern side *Phragmites australis* made a 5-6m wide, but sparse, stand replaced by large stands of *Carex aquatilis* at the inside. Sand, partly covered with twigs and detritus, dominated the sediment.

Sparganium angustifolium and *Polygonum amphibium* dominated the aquatic vegetation and made large stands in the eastern and northern parts. The former species made both rosettes at the bottom in shallow water and plants with floating leaves. It seems as the stands of *Polygonum amphibium* do not exceed water depth 1.5m.

The number of species was high both concerning isoetids and elodeids, but none of them built large stands. The most important elodeids were *Potamogeton perfoliatus* and *Ranunculus peltatus*.

Some specimens of the isoetide *Elatine hydropiper* were found at water depth 0.5-1 meter, mainly in the northern part of the locality. Other isoetids that can be mentioned are *Isoetes setacea* and *Subularia aquatica*. The large amounts of *Isoetes lacustris* found drifting at the shore by Nyheim likely indicates larger occurrence of the species in deeper water.

Loc. 3: Tjærebukta

Tjærebukta is situated in the south westernmost part of the Lake Vaggatem. We did some sparse registrations at Kveldsro, without the boat. *Carex aquatilis* and a sparse stand of *Equisetum fluviatile* dominated the helophytes. The latter specimens seemed to be in bad conditions.

Sparganium angustifolium dominated the nymphaeids whilst *Potamogeton perfoliatus* seemed to be the most common elodeide. In shallow water *Eleocharis acicularis* had large occurrence.

Loc. 4: Lyngbukta

Lyngbukta is a large and open cove in the western part of Lake Vaggatem. The cove is north-west faced and the registration was concentrated around the outlet of a river. The river drains the area west and south-west of the hill Lyngklumpen. The studied area had gradually bottom slopes and sand dominated the substrate.

Isoetes setacea and *I. lacustris* dominated the isoetide-vegetation. The former species had large occurrence in shallow water whilst the latter formed scattered stands in deeper water than 1.5m. The largest stands of *Potamogeton perfoliatus* and *Ranunculus peltatus* were found in the same area, and especially in water depth 1.5-2m. *Sparganium angustifolium* dominated the nymphaeids and made both small rosette-plants and plants with floating leaves.

The lower part of the small river is wide and comparatively slow floating. In this part *Potamogeton alpinus*, *Myriophyllum sibiricum*, *Sparganium angustifolium* and *Callitriche hamulata* had large occurrence.

Loc. 5: Vaggatem at Hauge

The registrations include an open, east faced cove in the northern part of Lake Vaggatem. The creek Spurvebekken, which originate from the two Spurvevatn lakes, join the cove in the southern part. Together with the creek Emanuelbekken, it drains most of the area between the northern part of Lake Vaggatem and the Finnish border.

The cove had gradually bottom slopes and sand dominated the substrate. *Potamogeton gramineus* had large occurrence in water depth 0.5 - 1.5m. In shallow water the specimens were small and tight. Outside the vegetation of *Potamogeton gramineus*, the charophyte *Nitella opaca/flexilis* had scattered occurrence. *Myriophyllum alterniflorum* was a common species throughout the cove, and south in the locality it was growing at sandy substrate with ripples. *Sparganium angustifolium* dominated the nymphaeide-vegetation.

Loc. 6: Nordvestbukta at Skogum

The locality is situated in the innermost of the bay Nordvestbukta and is not exposed to the wind. The locality is fed from some bog-areas north of the bay. The helophytes were dominated by *Carex aquatilis*, on both sides of the locality, and sparse stands of *Equisetum fluviatile* on the outside. Some specimens of *Menyanthes trifoliata* and *Potentilla palustre* were recorded in the innermost parts of the locality partly outside the *Carex*-vegetation.

In addition, mass stands with aquatic mosses (*Drepanocladus* sp.) and *Utricularia vulgaris* were recorded in the innermost part of the locality. Other common species were *Hippuris vulgaris* and *Myriophyllum sibiricum*, which both made stands in the inner parts. A few specimens of *Potamogeton sparganifolius* (a hybrid between *P. gramineus* and *P. natans*) were also recorded in this area. Elongated specimens of *Potamogeton perfoliatus* made large stands in the outer part of the locality, in water depth 1.5-2m. *Ranunculus peltatus* and *Myriophyllum alterniflorum* had largest occurrence in the outer part, whilst the specimens of the nymphaeide *Sparganium angustifolium* were found throughout the area.

Loc. 7: Langvatnet, Krokvika at Leite

The registration was concentrated to the cove north of Leite, which is south west faced. The influence of the dam at Skogfoss can easily be seen; stumps and twigs in water depth 1-1.5m. The locality was influenced by the bogs and had a porous and organic substrate. Epiphytic growth of bacteria and fungi in a little creek in the western part of the cove indicated some pollution. *Carex aquatilis* and some sparse stands with *Equisetum fluviatile* dominated the helophytes.

The aquatic vegetation was sparse and most of the area did not contain any vegetation. A small stand of *Hippuris vulgaris*, however, was found in the inner, north-eastern part of the locality. The most common species, *Ranunculus peltatus*, had its largest occurrence in water depth 0.8-1m.

Loc. 8: Langvatnet, upstream Skogfoss

The locality was influenced by the surrounding bog-areas and the substrate was dominated by peat. The bottom contained several hollows, probably caused by the regulation at Skogfoss (dam). *Carex aquatilis* and *C. rostrata* dominated the helophytes.

The most common species were *Sparganium angustifolium*, *Hippuris vulgaris* and *Myriophyllum sibiricum* and they all made stands in both shallow and some deeper water. *Callitriche hamulata* and *Subularia aquatica* were often found growing together in shallow water. *Utricularia vulgaris* was found throughout the cove, whilst *Myriophyllum alterniflorum* had the largest occurrence in the outer part of the cove.

Loc. 9: Fuglebukta

Fuglebukta is a shallow and circled cove with restricted connection to the river, situated approximately 3km downstream Skogfoss and 2km upstream the dam at Melkefoss. Maximum depth is estimated to 1-1.5m, and sand and silts are the dominating substrates. The helophytes had sparse occurrence and *Carex aquatilis* was the dominating species.

The locality is one of the most species-rich localities in the Pasvik River, but none of the species made large stands inside the cove. In a part with a little deeper water at the outlet of the cove, however, the elodeids built massive stands. These were dominated by flowering specimens of *Ranunculus peltatus* and *Potamogeton perfoliatus*. *Potamogeton perfoliatus* and *Sparganium angustifolium* dominated the vegetation inside the cove. The latter species occurred both with rosettes in shallow water and some elder plants with floating leaves. The isoetids *Subularia aquatica* and *Eleocharis acicularis* occurred in shallow water together with *Callitriche hamulata*, whilst the charophyte *Nitella opaca/flexilis* dominated the middle part of the cove. Several species had scattered distribution in the cove, for instance the comparatively rare species *Callitriche hermaphroditica*.

Loc. 10: The Pasvik River at Perslåtta

Compared with the upper parts of the river, which can be counted as a row of lakes, the section between Melkefoss and Svanevatn evidently is a steaming part of the river. The river is wide and slow streaming with luxuriant stands of *Equisetum fluviatile* on both sides. The registration was concentrated to the area by the farm Perslåtta. Possibly because of some pollution from the farm, the epiphytic growth at the inner part of the stands of *Equisetum fluviatile* was considerably.

Elodeids and nymphaeids made massive stands and dominated the aquatic vegetation. The most common species, *Ranunculus peltatus*, built large flowering stands with an extent of 100 - 200 meters and to water depth 1.5-2m. The stands were influenced by the streaming water, built up by large and extended specimens without any epiphytic growth. In between the ordinary plants of *Ranunculus peltatus* some divergent specimens were found, with larger and more extended submerged leaves. *Potamogeton gramineus* occurred both in shallow and deeper water. In shallow water the species were stocky and shrubby, whilst in deeper and more streaming water the species became larger with a more extended form. *Sparganium angustifolium* occurred both with rosettes and with floating leaves.

Loc. 11-13: Kuetsyarvi

Lake Kuetsyarvi is situated west of Nikel and is approximately 12 km long. The outlet of the lake joins the Pasvik River at Svanevatn. The maximum depth (36 meters) is found in the north-east part of the lake and the rest of the northern part is not deeper than 25 meters. Comparatively, the southern part is shallow; not deeper than approximately 10 meters, and with large areas not deeper than 1.5-2m.

These areas have large occurrences with aquatic vegetation, dominated by *Potamogeton perfoliatus* and *Polygonum amphibium*.

The river Shuoni Yoki joins Lake Kuetsyarvi in the southernmost part of the lake and means 1/3 of all the water-supply. The areas south of the lake contain large depositions of sand and the trees seemed to be in comparatively good health (?). The main part of the areas north of Nikel (the eastern side of the lake) contains mountain areas and the air-pollution from Nikel could be seen in the terrestrial vegetation.

The registrations in Kuetsyarvi are concentrated to 3 localities: loc. 11 (Akhmalakhti - the cove in north-west), loc.12 (Salmijarvi, the area around the outlet) and loc. 13 (the southern part of the lake).

Loc. 11: Kuetsyarvi at Akhmalakhti

The registration was concentrated to the cove in the north-west, by a Marina area. The substrate in the cove was dominated by sand added with some stones and peat especially in north-west. *Equisetum fluviatile* and *Phragmites australis* dominated the helophytes. The former species made a stand by the northern side whilst some smaller stand of the latter stood by the southern side. *Carex aquatilis* and *C. rostrata* had scattered occurrence.

The nymphaeids contained two species, *Sparganium angustifolium* and *Polygonum amphibium*, and both had their largest occurrence in north-west. *Potamogeton perfoliatus* dominated the submerged vegetation and occurred with sparse stands in water depth 0.5-1.5m throughout the cove. In the east part of the locality (by the harbour) the charophyte *Nitella opaca/flexilis* was found inside the stands of *Potamogeton perfoliatus. Isoetes setacea* had scattered occurrence in water depth 0.2-0.3m. *Subularia aquatica* was found only in the south-eastern part. *Myriophyllum alterniflorum* was found drifting at the eastern shore, and this was the only observation of the species in the lake.

Loc. 12: Kuetsyarvi at Salmijarvi

The registration contained both sides of the outlet. Sand dominated the substrate, somewhere together with stones or a looser more organic substrate in between the helophytes. *Equisetum fluviatile* made large stands on both sides with smaller stands of *Carex*-vegetation, firstly *C. aquatilis*, at the inside.

Potamogeton perfoliatus dominated the aquatic vegetation and made sparse stands throughout the area at water depth approximately 1.5m. The south-eastern shore was apparently exposed by the wind and had very little vegetation outside the *Equisetum*-stands. A higher amount of species appeared in north-west in the inner part of the locality. The most common species were *Potamogeton alpinus*, *Eleocharis acicularis*, *Isoetes setacea* and *Lemna trisulca*. The latter species is normally floating at the surface in summer, but in august the plants were lying at the bottom.

Sparganium angustifolium was found throughout the area, whilst *Polygonum amphibium* made one little stand in the southern part of the locality.

Loc. 13: Kuetsyarvi at Nikel

The registration contained the whole southern shore including the south-western cove and the south-east area up to Kolosioki. The area around the inlet of the Shuoni Yoki River is flat and the river is slow streaming with sparse aquatic vegetation. The substrate was dominated by sand containing ripples. The helophyte-vegetation was sparse, except from the south-western cove where *Equisetum fluviatile* made large stands partly together with *Carex*-species.

The isoetids *Isoetes setacea* and *Eleocharis acicularis* made continuous stands (more or less) deeper than 0.5-0.6 meters. The most common species in the area, *Potamogeton perfoliatus*, occurred together with the isoetids and outside the stands of *Equisetum fluviatile. Sparganium angustifolium* and *Lemna trisulca* made large stands in the south-western cove. *Polygonum amphibium*, however, made large stands by the south-eastern side and, together with *Potamogeton perfoliatus,* in the middle of the southern part of the lake.

Small specimens of *Potamogeton filiformis* and the charophyte *Nitella opaca/flexilis* occurred in shallow water at the western shore. In addition, the former species was found together with *Potamogeton gramineus*, *P. perfoliatus* and *Subularia aquatica* at the exposed southern shore. Only drifting specimens of *Isoetes lacustris* were recorded.

The recorded areas (loc.11-13) seemed to be the owners of the most luxuriant aquatic vegetation in Lake Kuetsyarvi. The substrate at the eastern and western shores was often dominated by stone and without much helophytes except for small stands with *Carex*-vegetation. We suppose that scattered occurrence of *Potamogeton perfoliatus* can be found throughout the lake.

Loc. 14: Svanevatn at Svanvik

The registration was concentrated to the large cove in the western part of Svanevatn. The innermost part of the cove, called Lonken, is restricted from the rest of the locality and was not included in our registration. The cove is south-eastern faced and protected from the wind and wave-erosion by tongues and small islets. The maximum depth in the middle and inner parts of the cove seemed to be 1.2-1.5m and clay and stone dominated the substrate. The helophyte *Equisetum fluviatile* built luxuriant stands in most of the cove.

In the outer part of the locality *Isoetes lacustris* made continuous stands deeper than 1.2m, and probably in most areas with water depth between approximately 1.5 and 4-5 meters (assumed depth limit) in Svanevatn. In water depth less than 1 meter in the middle part of the cove the small isoetide *Elatine hydropiper* was common and made some small stands.

In the innermost part, outside Lonken, the aquatic moss *Drepanocladus* sp. built large stands together with *Hippuris vulgaris*, *Utricularia vulgaris* and *Myriophyllum sibiricum. Potamogeton perfoliatus*, which was a common species especially in the outer part of the locality, made no continuous stands. Some specimens of *Potamogeton praelongus* were recorded together with *P. perfoliatus.*

The floating plant *Lemna trisulca* made mass stands in the middle and inner parts of the cove and, similar to Lake Kuetsyarvi, the species were lying on the bottom. The occurrence of the nymphaeids was comparatively rare. *Sparganium angustifolium* made some small stands throughout the cove whilst only one small stand with *Nuphar pumila* was recorded.

Loc. 15: Svanevatn at Skrotnes

The locality is situated at the south-western side of Svanevatn and is exposed to the wind. The bottom slopes gradually and clay seemed to dominate the substrate. The helophyte-vegetation contained a large stand of *Equisetum fluviatile* with *Carex aquatilis* and *Eleocharis palustris* at the inside.

In the northern (downstream) parts of the locality *Polygonum amphibium* built a fantastic flowering stand extending at least 100x40 meters and with the largest extension in the east-west direction.

The rest of the aquatic vegetation contained fairly large stands with *Potamogeton gramineus* and *Sparganium angustifolium.* In addition, 4 isoetids were recorded and *Eleocharis acicularis* was the most common of these.

Loc. 16: Svanevatn at Seljeli

The locality is situated at the north-western side of Svanevatn out from the farm Seljeli. The substrate contained stones, blocks and clay. The stand of *Equisetum fluviatile* had a width extending 30-40 meters and some sparse stands of *Carex aquatilis* at the inside.

Isoetes lacustris and *I. setacea* dominated the aquatic vegetation. The former species made continuous stands deeper than 1-1.5m whilst the latter was found in shallow water.

The elodeids had less abundance in the area and were dominated by *Potamogeton gramineus*, *Myriophyllum alterniflorum* and *Ranunculus peltatus*. Like locality 10, some divergent specimens of *Ranunculus*, with larger and more extended submerged leaves, were found in between the ordinary plants.

Loc. 17: Bjørnevatn at Sandneset

The registration contained an area south of the boundary marker number 167. Small stones dominated the substrate in shallow water whilst clay dominated in water deeper than 0.5m. The area is obviously exposed to the wind with a number of ripples in the clay-substrate. The steep bottom slope started 20-30 meters out of the shore and the area possible for vegetation-growth is narrow. The helophyte had little abundance and only a small stand of *Carex aquatilis* was recorded. *Myriophyllum alterniflorum* dominated the aquatic vegetation and grew deeper than 0.5m approximately.

Loc. 18: Skrukkebukta at Norvik

Like the former locality, this area was exposed by the wind and had ripples in the clay-substrate. A sparse stand of *Equisetum fluviatile* in the inner part of the cove made the helophytic vegetation.

The isoetids, firstly *Eleocharis acicularis* and *Elatine hydropiper*, dominated the aquatic vegetation and occurred in water depth between 0.5-2m.

The most common elodeide, *Potamogeton perfoliatus*, made a small, but vigorous, stand in water depth 0.5-0.8m. Otherwise, the rare and alkalifile species *Callitriche hermaphroditica* was common at the locality.

Loc. 19: Skrukkebukta at Brattli

The registration was concentrated to a cove at Brattli. The cove is south-east faced, is not exposed by the wind and has gradually bottom slope. The locality has clayey substrate with some stone at the shoreline. A sparse stand of *Equisetum fluviatile* in the inner part of the cove made most of the helophytic vegetation.

The small and annual isoetids dominated the aquatic vegetation, especially in the inner part in water depth less than 1.5m. The most common species were *Subularia aquatica* and *Eleocharis acicularis*, added with small specimens of the elodeids *Callitriche palustre*, *Potamogeton berchtoldii*, *Callitriche hermaphroditica* and the charophyte *Nitella opaca/flexilis*. Some places, small stands with *Sparganium angustifolium*, *Myriophyllum alterniflorum* and *Ranunculus peltatus* could be found. Outside this vegetation the charophyte, together with the perennial isoetide *Isoetes lacustris*, were the dominating species.

***Appendix 10.1**. Zooplankton species present in the Bjørnevatn and Skogfoss studied areas*

Taxon	Bjørnevatn	Skogfoss
Rotatoria		
Asplanhna priodonta	+	+
Bipalpus hudsoni	+	+
Conochilus unicornis	+	
Kellicottia longispina	+	+
Keratella cochlearis	+	+
Keratella hiemalis	+	
Notholca caudata	+	
Poluarthra sp.	+	+
Synhaeta sp.	+	+
Cladocera		
Alonopsis elongata	+	+
Bosmina sp.	+	+
Ceriodaphnia quadrangula	+	
Chydorus sp.	+	
Daphnia cristata	+	+
Daphnia longiremis	+	
Holopedium gibberum	+	+
Leptodora kindti	+	+
Polyphemus pediculus	+	+
Sida crystallina		+
Cyclopoida		
Acanthocyclops sp.	+	+
Cyclops scutifer	+	+
Mezocyclops leuckarti	+	+
Copepodits	+	+
Nauplii	+	+
Calanoida		
Eudiaptomus graciloides	+	+
Heterocope appendiculata	+	
Nauplii	+	+

***Appendix 10.2**. Abundance (ind. m^{-3}) and biomass (mg wet weight m^{-3}) of zooplankton in the studied areas in July 1993. Biomass values are in parenthesis*

Taxa	Bjørnevatn	Skogfoss
Rotatoria	9248 (51.0)	5299 (72.3)
Cladocera	2234 (106.6)	4693 (13.4)
Cyclopoida	810 (28.2)	497 (18.6)
Calanoida	968 (46.4)	294 (1.8)
Total	13260 (232.2)	10783 (406.1)

***Appendix. 10.3**. List of the six most common taxa in the three parts of Pasvik River System. Species are listed in decreasing order of average frequency of occurence and relative abundance.*

Upper part	Kuetsyarvi	Down part
	Shallow zones	
Orthocladiinae spp.	*Cricotopus* spp.	*Lumbriculidae* spp.
Procladius spp.	*Stictochironomus* spp.	*Tanypodinae* spp.
Lymnaea spp.	*Pisidium* spp.	*Gyraulus albus*
Dytiscidae spp.	*Lumbriculus variegatus*	*Heterotrissocladius* spp.
Pisidium spp.	*Procladius* spp.	*Spirosperma ferox*
Lumbriculidae spp.	*Polycentropidae* spp.	*Molanna angustata*
	Deep zones	
Chironomini spp.	*Chironomus* spp.	*Procladius* spp.
Procladius spp.	*Procladius* spp.	*Spirosperma ferox*
Lymnaea peregra	*Stictochironomus* spp.	*Polypedilum* spp.
Pisidium spp.	*Ablabesmyia* spp.	*Pisidium* spp.
Hydracarina spp.	*Pisidium* spp.	*Heterotrissocladius* spp.
Spirosperma ferox	*Tubificidae* spp.	*Zalutschia* spp.

***Appendix. 10.4.** Mean values of abundance (ind m^{-2}) of zoobenthos in different localities of Pasvik River in 1991-1993, using Ekman grab.*

	Total	*Chironomidae*	*Oligochaeta*	*Mollusca*	*Trichoptera*	Others
Lyngbukta and Ruskebukta	1980.0	1250.9	199.0	431.5	15.4	83.2
Langvatn	150.9	97.8	42.3	3.4	0	7.4
Kuetsyarvi	2211.7	1306.1	802.0	56.4	16.4	30.8
Salmiyarvi and Svanevatn	1487.5	896.1	397.1	69.3	20.6	104.4
Bjørnevatn	608.4	374.4	210.6	0	0	23.4
Skrukkebukta	290.7	190.1	40.6	13.1	3.1	43.8

Appendix 11.1. *The metals µg/g dr.w. accumulation in organism systems of fishes*

Element	Organs:	PAS-**II**	PAS-**IV**	PAS-**V**	Kuets- **VI**
Ni	kidneys	1.9	2.4	10.0	31
	liver	0.9	1.8	1.8	3.7
	gills	1.6	2.7	2.4	11
	skeleton	3.7	4.4	3.3	6.4
	muscle	0.6	1.0	1.3	2.5
Cu	kidneys	7	5.6	6.5	11
	liver	22	17	28	37
	gills	2.2	4.5	4.7	6.4
	skeleton	1.7	3.6	2.3	2.4
	muscle	0.8	0.8	1.2	1.4
Zn	kidneys	145	382	294	205
	liver	151	109	129	108
	gills	215	547	708	256
	skeleton	118	188	132	121
	muscle	15	15	14	14
Al	kidneys	31	22	33	33
	liver	3.3	8.7	8.1	10
	gills	32	9.1	23	17
	skeleton	28	6.7	22	11
	muscle	4.5	3.7	3.0	3.8
Sr	kidneys	13	1.3	3.0	8.1
	liver	4.1	1.0	3.7	3.2
	gills	51	42	59	27
	skeleton	200	107	146	42
	muscle	4	1.8	1.5	1.2
Mn	kidneys	2.1	4.1	2.6	20
	liver	6.9	9.5	6.3	8.6
	gills	103	24	20	83
	skeleton	28	33	37	114
	muscle	0.7	1.3	1.1	3.5
Co	kidneys	1.3	2.0	3.2	2.8
	liver	0.2	1.0	0.8	1.0
	gills	1.6	2.6	1.6	1.2
	skeleton	2.7	4.1	2.5	2.2
	muscle	0.4	0.8	0.9	0.5