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Sari Sivonen (ed.)

Ecological State of the River Tenojoki –

Periphyton, Macrozoobenthos and Fish Communities

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ROVANIEMI 2006

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Preface

The transboundary River Tenojoki running between Finland and Norway is a subarctic, oligotrophic river. The river is 382 km long and the total catchment area of the Tenojoki River Basin is 16 386 km^2, of which approximately 70 % lies in Norway. The River Tenojoki is one of the biggest and the most productive Atlantic salmon rivers in the world that is still in its natural state. The brooks, tributaries and main channel of the River Tenojoki form a river reach in excess of 1 000 km long that is a suitable habitat for salmon and has potential areas for spawning.

During years 2002–2006, the Lapland Regional Environment Centre, Norwegian Water Resources and Energy Directorate and County Governor in Finnmark carried out a project named *Preservation of the River Tenojoki as a salmon river in its natural state – environmental work, ecological condition and monitoring*. The aim of the project was to conserve the river as a salmon river in its natural condition and to develop recreational use of the river according to the principles of sustainable development. The project was financed by the EU / Interreg III A North, Finnish Ministry of Labour / Employment and Economic Development Centre, Ministry of the Environment / Lapland Regional Environment Centre, and the Municipalities of Utsjoki, Inari, Tana and Karasjok, and the State of Norway.

The project consisted of six different sub-projects:

1. Completing the survey of obstacles to fish migration in tributaries
2. Restoring areas downstream from culverts to allow fish migration
3. Landscaping of erosion constructions along the river
4. Environmental work; development of recreational use and tourism
5. Mapping the ecological and hydrological state of the River Tenojoki
6. Developing a watershed model and data exchange

This publication includes four articles that were drawn up to describe the ecological state of the River Tenojoki. The article on the periphyton survey was written by Juha Miettinen (University of Joensuu) and the articles concerning macrozoobenthos, fish communities and effects of culvert restorations on juvenile Atlantic salmon were written by Heikki Erkinaro and Jaakko Erkinaro (Finnish Game and Fisheries Research Institute).

Part I

Juha Miettinen

River Tenojoki: Periphyton Survey 2003

Table

Objectives

Phytobenthos was studied in the River Tenojoki (Tana) and its tributaries to assess the ecological status of the waters in 2003. Phytobenthos assemblages are mainly defined by water quality, whereas benthic fauna and fish reflect more also the bottom quality of the rivers.

In rivers water quality varies greatly. Chemical measurements give only momentary values for the water quality. Low discharge causes increases in the concentrations of nutrients, and high discharge dilution, making interpretations of nutrient or other loading difficult in rivers. Biological assemblages reflect the conditions in rivers over their life cycle periods. Development of a diatom film on a hard surface takes some weeks (Eloranta & Soininen 2002). The growing rate of different species varies greatly, and so diatom analysis gives indications of water quality for longer periods during the growing season (Jarlman et al. 1996).

The use of diatoms instead of the whole phytobenthos have become general practise in the last years, for a number of reasons. Diatoms form a very diverse group, by morphology and ecology, and feature all kinds of natural waters. They comprise a large proportion of algal species in many rivers, including River Tana (Traaen et al. 1990, Lindström & Johansson 1996). They have been studied extensively, and methods for interpreting results have been developed further than for the other algae.

This study was carried out as a part of an Interreg project ”Preservation of the River Tenojoki as a salmon river in its natural state – environmental work, ecological condition and monitoring” financed by EU/Interreg IIIA. According to the project proposal, one of the objects in the project is that the collected data will satisfy the needs of the EU Water Framework Directive (WFD; European Parliament 2000). Earlier phytobenthos studies from the River Tana (Traaen et al. 1990, Lindström & Johansson 1996) have used the whole phytobenthic community in the river, including mosses by Traaen et al. (1990), but the ecological status of the river has been interpreted only qualitatively. Quantitative analysis on the diatom community results into more spesific and detailed estimates on the state of the rivers.

2 Material and methods

2.1 Sites

Phytobenthos was sampled mainly in the same sites as in 1989 (Traaen et al. 1990) and 1994 (Lindström & Johansson 1996). Also five sites in benthic fauna survey by Hämäläinen et al. (1996) were sampled to include smaller rivers and brooks in the data. The site codes used in the earlier surveys were also used here, in cases where the sites are the same. Total number of 33 sites were sampled in the River Tenojoki and its tributaries (Fig. 1, Table 1).

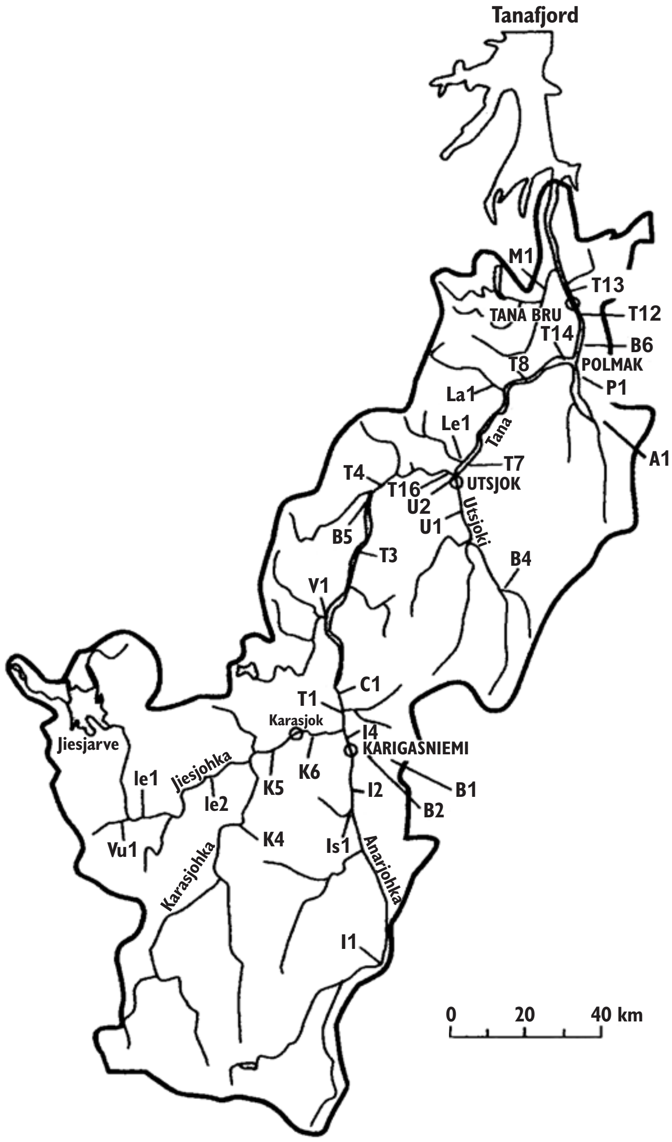

Figure 1. Phytobenthos sampling sites in the Tenojoki catchment area, sampled 3.–13.9.2003.

Table 1. Sites sampled for phytobenthos in the River Tenojoki and other rivers (all tributaries of Tenojoki) in 3.–13.9.2003.

CODE	SITE	KKJ-north	KKJ-east	SITE DESCRIPTION
B1	"poroerotus", 8 km east Karigasniemi	7702693	3463670	deep, narrow, shading
B2	Ailigas, right upstream from culvert	7702715	3460474	deep, narrow, shading
B4	Kenespuro	7733704	3503516	deep, narrow, shading
B5	Leavvajohka, Saraskaidi	7756790	3477278	rapid
B6	Jouvvajohka	7786964	3546055	mountain brook
A1	Arola, brook running to Polmakelva	7762129	3540066	rapid, deep
C1	Culloveijohka, near Outakoski	7726119	3460641	rapid
I1	Inarijoki, Angeli village	7646823	3445103	rapid, shallow
I2	Inarijoki, 1 km upstream Cappesjohka	7697755	3452509	shallow
I4	Inarijoki, Karigasniemi	7705478	3453177	slow, wide, sand
Ie1	Iesjoki, 2 km from Suossajavre	7701369	3397424	rapid
Ie2	Iesjoki, upstream Sadejohka	7706224	3415203	shallow, wide
Is1	Iskurasjohka	7685565	3448512	rapid, shallow
K4	Karasjohka, end of the road	7696477	3426057	rapid
K5	Karasjohka, upstream Karasjok	7707611	3435016	slow
K6	Karasjohka, downstream Karasjok	7708807	3444502	slow
La1	Laksjohka	7776464	3521111	rapid
Le1	Levssejohka	7760397	3503254	shallow rapid
M1	Masjohka, river mouth	7800915	3543460	sand, constructed bank
P1	Polmakelva, 1–2 km from river mouth	7775359	3540332	sand
T1	Tenojoki, Rovisuvanto	7709234	3454439	slow
T3	Tenojoki, Nuvvos	7748333	3471023	slow
T4	Tenojoki, Yläköngäs	7763589	3483076	rapid
T7	Tenojoki, Kostejärvi	7759750	3503830	shallow, moderate
T8	Tenojoki, Alaköngäs	7777134	3527424	rapid
T12	Tenojoki, Tana Bru, upstream bridge	7791344	3545414	rapid
T13	Tenojoki, Seida	7795204	3544422	wide, moderate
T14	Tenojoki, Nuorgam	7779760	3536707	rapid
T16	Tenojoki, 2 km upstream Utsjoki	7761383	3499901	moderate flow
U1	Utsjoki, Patoniva	7745020	3500143	shallow rapid
U2	Utsjoki, river mouth	7759067	3502038	shallow rapid
V1	Valljohka	7734500	3454590	shallow, moderate
Vu1	Vuottasjohka, Suossjavri	7702384	3391170	clear water

2.2 Sampling and laboratory treatments

Sampling, preservation and laboratory treatment for the samples was done according to the European standard (CEN 2002). Type of river bottom and abundance of macro-vegetation were evaluated, and water temperature measured at every site. Water depth was measured for every cobble sampled.

From every sampling site, three parallel samples comprising five cobbles (stones with diameter 6–26 cm) each were collected. The diatom film was rubbed from the stones using toothbrush. Macroalgae and mosses were brushed also into the samples, but long filaments of macroalgae were cut off, and cobbles most covered with macrovegetation were avoided. Each sample (five cobbles) was brushed in water, the water was mixed, and 100 ml was poured in a plastic bottle.

At the sampling sites, 0.5 ml of Lugol's solution was added to the samples. In laboratory, 1–2 weeks later, 1% of formalin was added to the samples for long-term storage (temperature 4–8 °C). Part of the samples was used for diatom slides. For diatom identifications, mixture of nitric and sulphuric acids (9:1) was used to remove all organic material from the samples. Permanent slides were prepared by drying about 0.2 ml of diluted sample on a cover glass, and glueing it to a heated slide with Naphrax®.

2.3 Identifications

Diatoms were identified according to Krammer & Lange-Bertalot (1986–1991). A minimum of 400 diatom frustules was counted from each of the 99 samples, and identified to the species level, when possible. One diatom cell forms two frustules, that are counted separate units. Magnification 1000× and phase contrast optics were used for the counting. The abundance of each of the taxa was divided by the sample size, and the relative abundances are used for all quantitative analyses.

2.4 Similarity of parallel samples

Multi-response permutation procedure (MRPP) and Bray-Curtis dissimilary were used to assess dissimilaries between parallel samples (A, B, C) in the 33 studied sites. MRPP tests the hypothesis that parallel samples are more similar compared to each other than samples from other sites (Huttunen 2000). Program PC-ORD v. 4.25 (McCune & Mefford 1999) was used for the calculation of MRPP.

Bray-Curtis index (Kelly 2001) was used to measure similarity between the parallel samples in each site:

$$D_{1,2}=\Sigma q_I,$$

where $D_{1,2}$ is the similarity between samples 1 and 2, and q_I is the smaller relative proportion (%) of the taxon I in the two samples. $D_{1,2}$ varies between 0–100 %, and values > 60 % are considered as indicating replicate samples (Kelly 2001). In this case the parallel samples (A, B, C) are not sub-samples divided from one sample, but they test the representativeness of the sampling effort, in addition to the laboratory treatments and identifications.

2.5 Multivariate methods: ordinations

In undirect ordinations, samples are placed in a space defined by so-called ordination axis, according to their similarities in species compositions. Correlations are used in the placing of the samples, so the closer two samples are, the more similar they are according to species compositions (ter Braak 1987).

Sites were ordinated with Detrended canonical methods correspondence analysis (DCA; Hill & Gauch 1980), which assumes that the species respond unimodally to the environmental gradients they confront in their growing sites. Usually this is true when different enough sites are sampled for the data. In theory, when two sites ordinate at least four variation units apart, they don't have any species common. When the length of the first ordination axis exceeds two of these variation units, most of the species are considered to respond unimodally to the differences in the samples (ter Braak & Prentice 1988). If the first ordinations axis is shorter than this, linearly based methods are more appropriate. Program CANOCO 4 (ter Braak & Šmilauer 1998) was used for the ordinations.

2.6 Inferences of trophy level, saprobity and pH

The ecological classifications of Van Dam et al. (1994) were used to calculate proportion of diatom frustules indicating different trophy levels and saprobity classes at the sampled sites. In addition, Biological Diatom Index (IBD; Prygiel and Coste 2000) was used to infer general ecological status, and especially organic loading into the waters. IBD was chosen from the large set of different diatom indices, because it is standardized (AFNOR 2000) and is accessible as an open calculation table with data on the species' indicator values. In IBD, 14 chemical parameters of water quality (water temperature, pH, conductivity, suspended matters, BOD, COD, dissolved oxygen, NTK, NH_4, NO_2, NO_3, PO_4 and chloride) have been associated to the 209 apparent taxa included in the index. Also pH was inferred using the index of Renberg and Hellberg (1982). pH is a very important factor for diatom compositions, and so can aid in the interpretations of the ecological status.

3 Results

Data collected at the sampling sites is presented in Table 2. Sandy sites differ greatly from the other sites, with seemingly lower water velocities (not measured) and, in some cases, difficulties to find cobbles to sample.

Table 2. Observed dominating type of substrate and abundance of mosses and macroalgae at the sampled sites, mean of the measured water depths for the sampled cobbles (N=15), and water temperature (°C) at the sampling sites.

CODE	SITE	DOMINANT SUBSTRATE	MOSSES	MACRO-ALGAE	WATER DEPTH cm	WATER TEMP.
B1	”poroerotus”	sand	some	-	23	7
B2	Ailigas	mud	abundant	-	13	9
B4	Kenespuro	boulders	abundant	-	20	8
B5	Leavvajohka	boulders	rare	rare	20	?
B6	Jouvvajohka	cobbles	rare	rare	19	6
A1	Arola	boulders	rare	rare	19	6
C1	Culloveijohka	cobbles	-	-	21	10
I1	Inarijoki	cobbles	some	-	11	9
I2	Inarijoki	cobbles	-	-	15	12
I4	Inarijoki	sand	-	-	15	10
Ie1	Iesjoki	boulders	some	some	13	10
Ie2	Iesjoki	cobbles	some	some	23	10
Is1	Iskurasjohka	pebbles	some	some	13	11
K4	Karasjohka	boulders	some	some	27	6
K5	Karasjohka	sand	-	-	15	10
K6	Karasjohka	sand	-	-	18	9
La1	Laksjohka	cobbles	rare	rare	23	?
Le1	Levssejohka	cobbles	-	-	24	7
M1	Masjohka	sand	rare	rare	23	8
P1	Polmakelva	sand	abundant	abundant	24	?
T1	Rovisuvanto	sand	abundant	-	22	10
T3	Nuvvos	sand	-	-	16	10
T4	Yläköngäs	sand	-	-	25	9
T7	Kostejärvi	boulders	some	some	17	10
T8	Alaköngäs	sand	?	?	14	8
T12	Tana Bru	boulders	some	abundant	19	8
T13	Seida	sand, pebbles	abundant	-	28	8
T14	Nuorgam	boulders	abundant	-	18	8
T16	Aittisuvanto	boulders	some	-	34	8
U1	Utsjoki Patoniva	pebbles	abundant	abundant	22	10
U2	Utsjoki	cobbles	abundant	abundant	29	10
V1	Vallijoki	pebbles	rare	rare	25	10
Vu1	Vuottasjoki	boulders	some	some	33	9

Total of 109 diatom taxa were identified. Mean number of taxa in one site was 38.5, minimum 20 (A1, Arola), and maximum 57 (M1, Masjohka). The most abundant species in the data is *Tabellaria flocculosa*, a very common diatom in oligotrophic northern rivers (e.g. Lindström & Johansson 1996, Niemelä et al. 2002). Also very abundant is *Achnanthes minutissima*, cosmopolite diatom, common in e.g. Central Europe (Kelly & Whitton 1995) and in Finland (Soininen 2002). Other abundant taxa in the data include *Fragilaria capucina* var. *gracilis* and *F. ulna*.

3.1 Similarity of parallel samples

MRPP resulted in value A = 0.562, meaning that parallel samples are much more similar than samples from other sites (p-value is 0.000). If the value of A was 1, samples would be identical within groups (at the same site), and if it was 0, the variance within sites would be equal to among sites.

Bray-Curtis similarity was over 60 % for all the other parallel samples, except B4 (similarity A-B 54.6 %, A-C 54.5 %), B5 (similarity A-B 58.5 %), K6 (similarity A-B 56.4 %) and M1 (similarity A-C 49.6 %). Generally the sampling effort seems to have been large enough, but some extra caution is needed when interpreting the results especially for the sites B4 and M1. The counts for the parallel samples were combined as one sample per site for all the other analyses.

3.2 Ordinations

DCA resulted in gradient length of 2.78 for the first ordination axis, suggesting that the unimodally based DCA is an appropriate method ordinating the sites. Rare taxa with maximum abundance in the dataset less than 1% were excluded from ordinations. The final DCA ordination (Fig. 2) was run with default settings (no transformation of data, no downweighting of rare species).

The most dissimilar site compared to other sites is B6, Jauvvajohka, which contains e.g. *Diatoma moniliformis, Fragilaria rumpens* and large amount of alkalibiontic *Epithemia adnata* (species are plotted in Fig. 3). Small brooks B2 (abundant *Aulacoseira alpigena*) and B1 (abundant *Achnanthes pusilla* and *Fragilaria pinnata*) deviate also from other sites, but into different direction. To the opposite direction of B1 and B2, from other sites deviate A1, M1, T12, P1, T14, T3 and T13. The rest of the sites, including the sites of Karasjohka, Inarijoki, Utsjoki and most of the sites in Tenojoki, are grouped relatively close to each other, reflecting similar diatom assemblages in these sites.

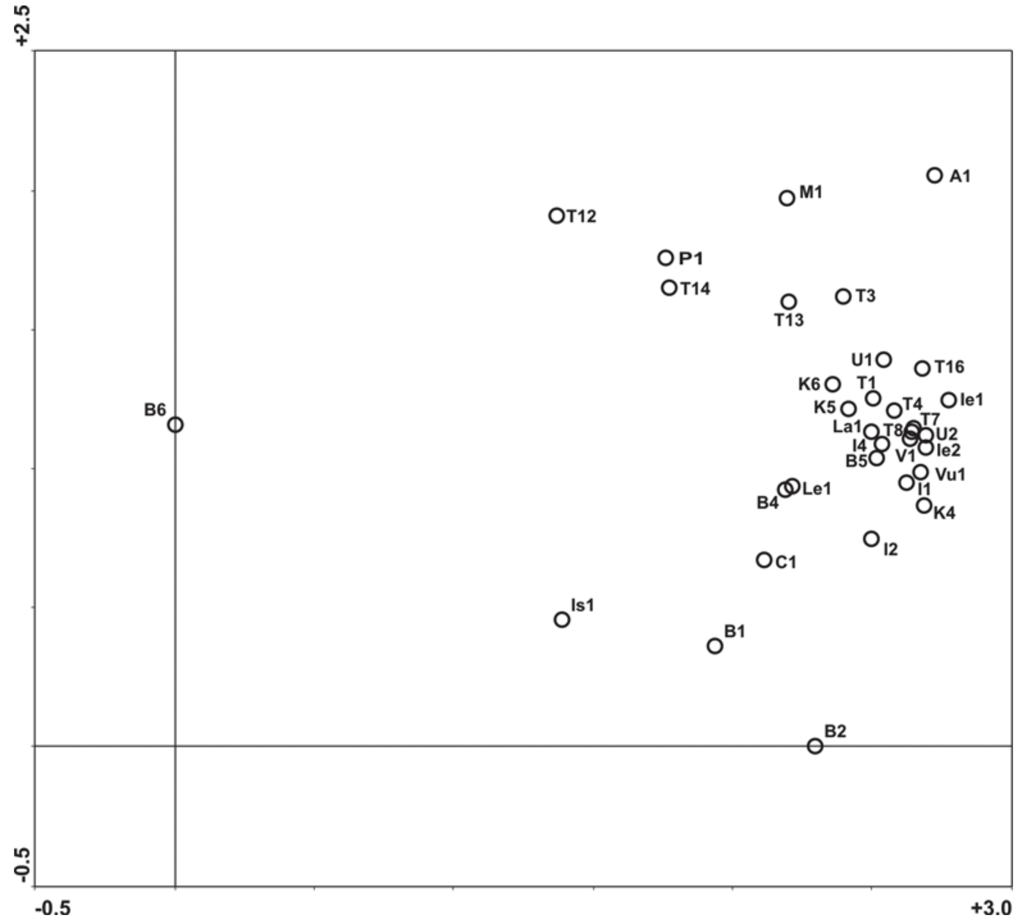

Figure 2. Placing of the sites in the DCA ordination axes 1 (horizontal) and 2 (vertical).

The ordination of the alkalibiontic species *Epithemia adnata* and *Rhopalodia gibba* at the low end (left), and acidophilic *Eunotia* species to the high end of the first ordination axis, leads to an interpretation that the first, horizontal ordination axis represents water pH values in the sites. In site B6 alkaline conditions prevail, whereas most of the sites, situated right on the ordination plot, have neutral or slightly acidic conditions.

On the second, vertical ordination axis, at the high end is situated *Achnanthes minutissima* var. *saprophila*, a form found mostly in polluted sites (e.g. Prygiel & Coste 2000). Also *Diatoma tenuis* and *Achanthes lanceolata* near the high end of the axis 2 indicate meso- to eutrophic conditions (Van Dam et al. 1994). At the low end of the axis 2 (down in the figure 3), of the species situate *Aulacoseira alpigena* and *Frustulia rhomboides*, indicators of oligotrophic conditions. Generally the the placing of the different taxa would suggest that the axis 2 represents the trophy level, but caution must be taken, when trying to interpret the second axis in DCA (ter Braak 1987).

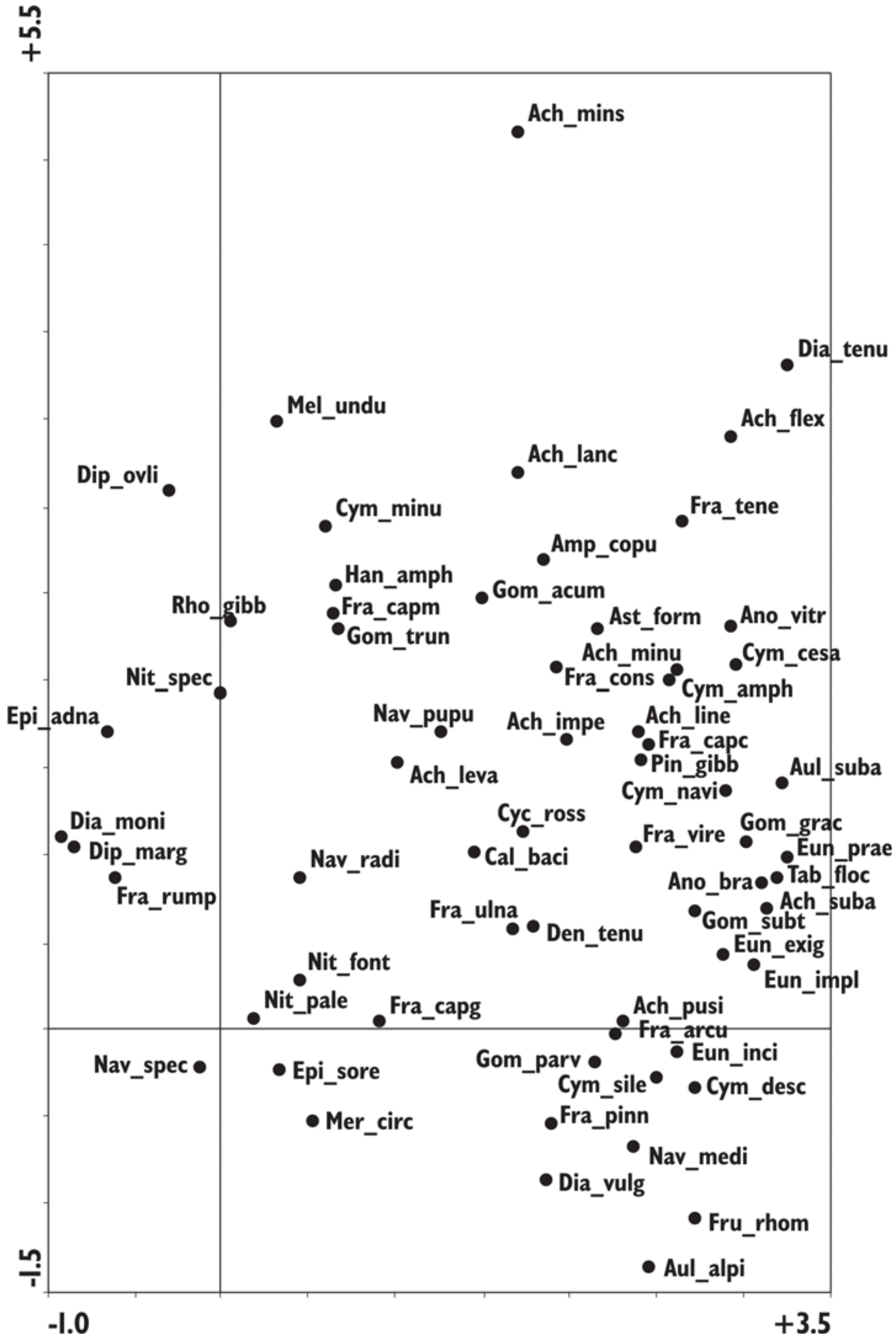

Figure 3. Placing of the species in the DCA ordination axes 1 and 2. The first three letters from the genus name and four letters of the species name (three in some cases, where an intraspecific taxon is indicated by the last letter) are used for the taxa codes.

3.3 Species composition in the River Tenojoki

In Fig. 4. abundant taxa found in the main River Tenojoki are presented. In the upstream parts of the river (from Rovisuvanto to Alaköngäs) diatom assemblages are different than in the downstream parts of the river (from Nuorgam to Seida). *Tabellaria flocculosa* is very abundant in the upper parts of the river, but is mostly replaced by *Fragilaria capucina* var. *mesolepta, Epithemia adnata* and *Cymbella minuta* below Nuorgam.

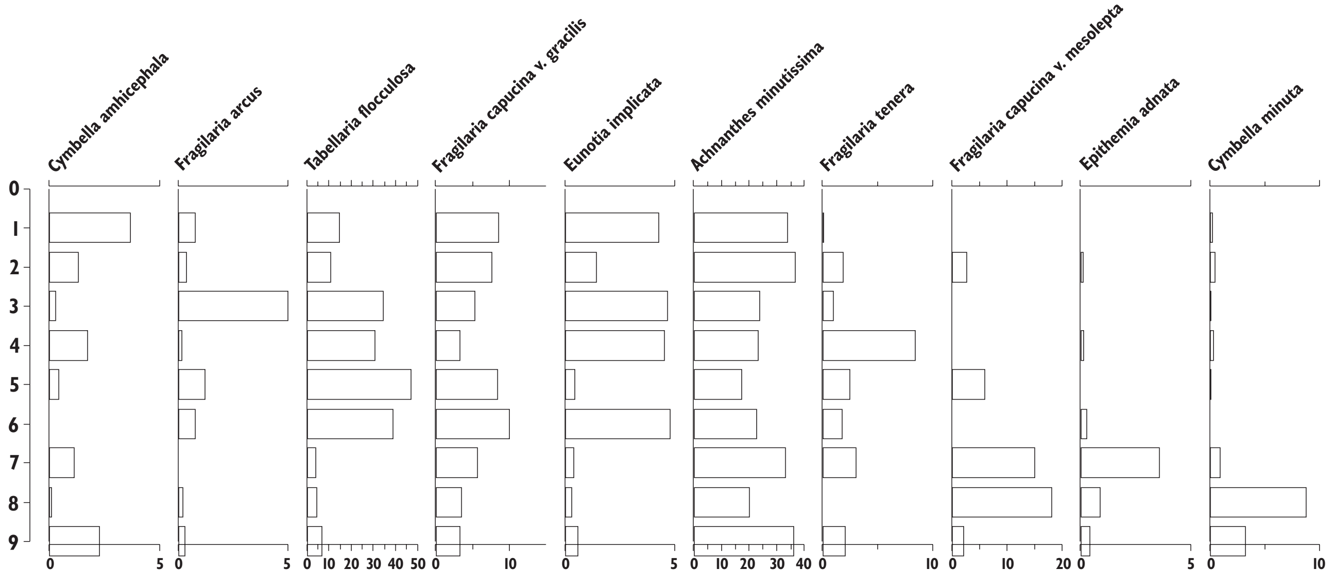

Figure 4. Common taxa in the nine sites sampled in the River Tenojoki. The sites are ordered from upstream to downstream, so that number 1 is T1 (Rovisuvanto) and number 9 is T13 (Seida).

Fragilaria capucina var. *gracilis* is a oligo-mesotrophic form (Van Dam et al. 1994), whereas *F. capucina* var. *mesolepta,* thriving in sites T14 and T12, indicates a little higher, mesotrophic, conditions (Hall & Smol 1992). *Epithemia adnata*, abundant in T14, and *Cymbella minuta*, abundant in T12, tolerate some pollution (Van Dam et al. 1994, Cholnoky 1968).

3.4 Inferred pH

In Fig. 5 the inferred pH values for the sites, based on the pH index of Renberg & Hellberg (1982) are presented. The only site with inferred pH just below 6 is B2 (Ailigas). B6 (Jouvvajohka) has very high inferred pH, 8.81, as would be expected from the abundance of the alkalibiontic species *Epithemia adnata*. Values over 7 have also sites C1, Is1, P1, T12, and T14, which can indicate either high primary production or alkaline bedrock and soils.

3.5 Indicators of eutrophy in the samples

The taxa in the samples were classified according to the trophy levels assigned for diatoms in Van Dam et al. (1994). Many species are classified as indifferent of trophic level or unknown, as can be seen in the Fig. 6. The most abundant species, *Tabellaria flocculosa*, is classified as mesotrophic by Van Dam et al., although in nordic rivers it thrives in oligotrophic conditions. Because of this, only the fourth and fifth classes (meso-eutrophic and eutrophic), should be taken as indications of elevated nutrient levels from oligotrophy.

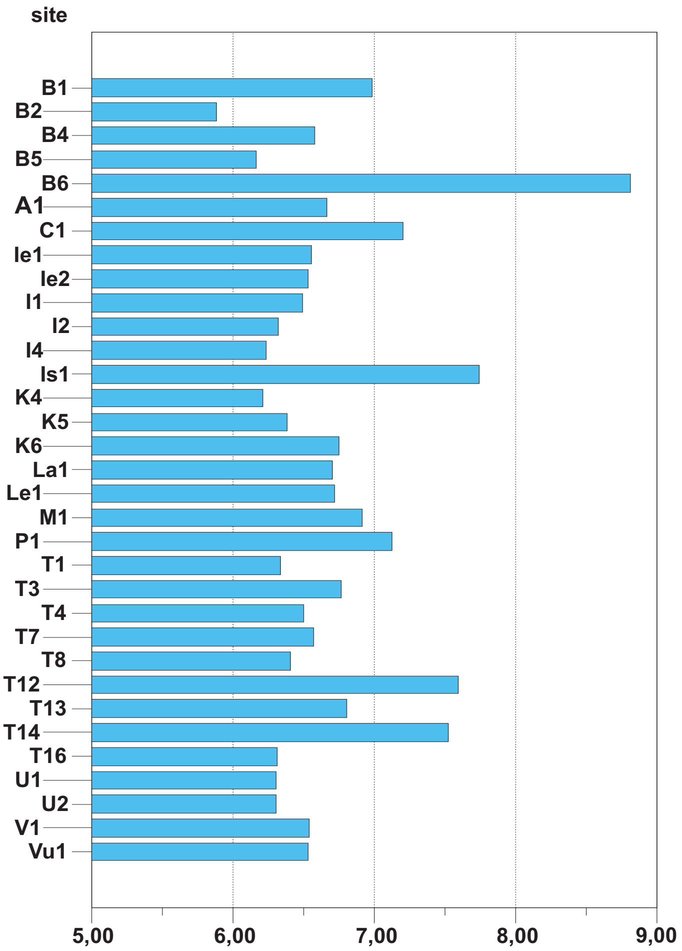

Fig. 5. Inferred pH for the sites.

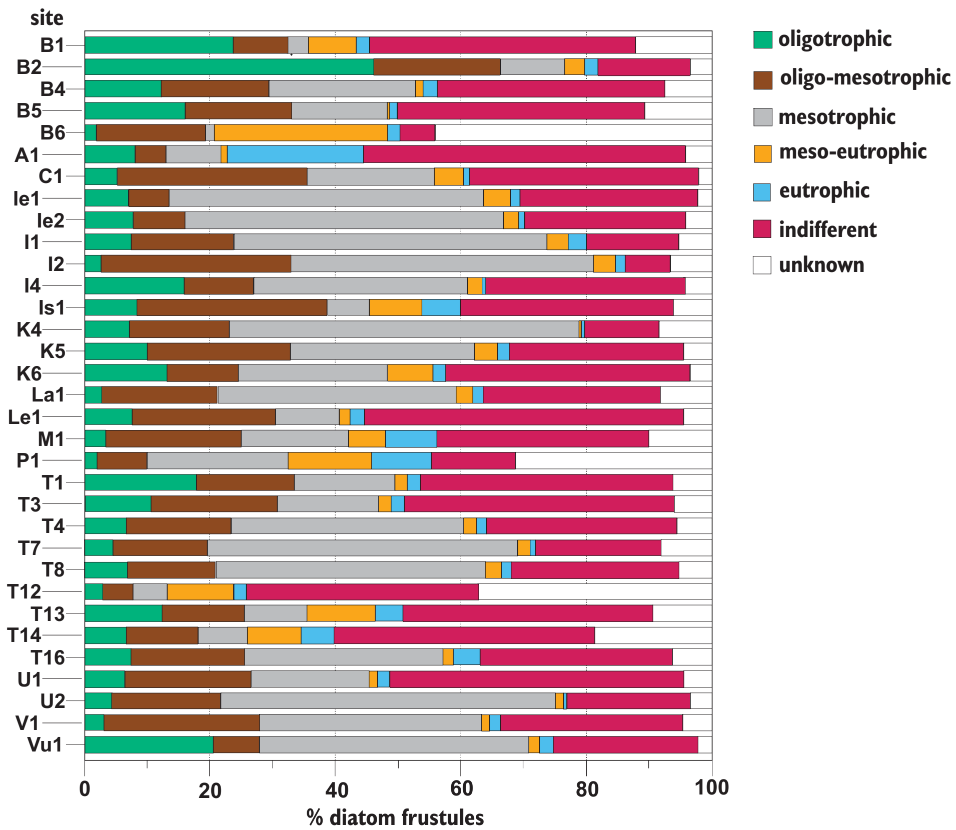

Figure 6. Percentage of the taxa assigned to the different classes of trophy.

A1 (Arola) has the largest amount (22 %) of diatoms indicating eutrophy, which can be assigned to slight to moderate eutrophication. M1 and P1 eutraphentic species over 10%, which may indicate slight eutrophication.

3.6 The saprobic system

The saprobity classes for the taxa were also taken from Van Dam et al. (1994). All species have been assigned to some saprobity class, or classified as unknown (Fig. 7). The saprobity classification for *Tabellaria flocculosa* is problematic or misleading, as in the trophy classification. It is classified as beta-mesosaprobic, making beta-mesosaprobic the largest class in almost all samples. Alfa-mesosaprobic taxa form 22% of the sample A1, 11% of the sample P1, and less than 10% for the other sites. Polysaprobic taxa seem to be rare in the Tenojoki catchment area.

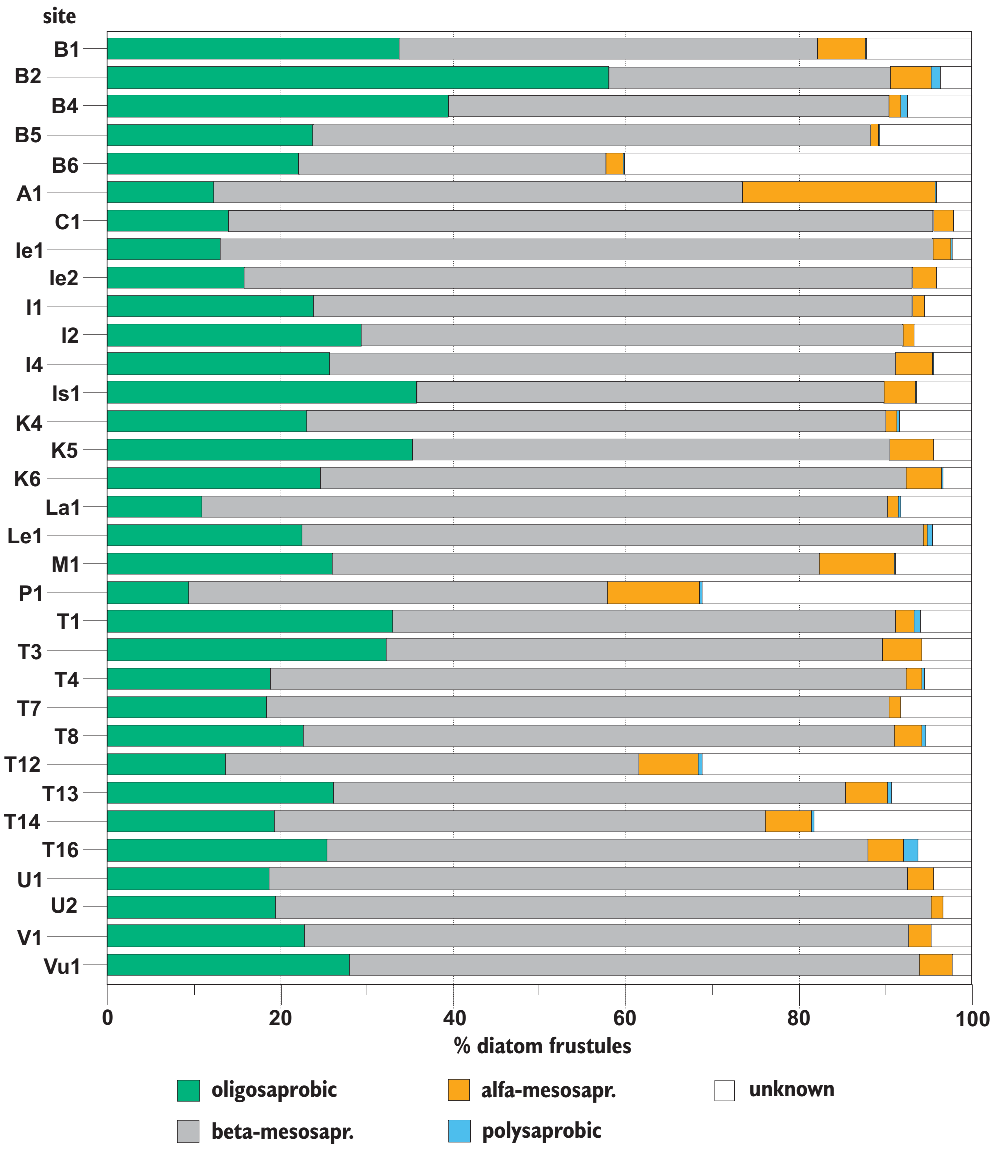

Figure 7. Diatom counts classified as percentages of frustules in the different saprobity levels (Van Dam et al. 1994).

3.7 Results of the Biological Diatom Index (IBD)

IBD results for the sites B1, B2, B6, and Is1 were not used, because less than 50% of the diatom counts from these sites belong to the taxa included in the IBD. Niemelä (2002) used the following interpretation for IPS- and GDI-indices: values 18.1–20 excellent; 16.1–18 good; 14.1–16 moderate; etc. Most of the sites receive classification as excellent, including all the sites in Inarijoki, Karasjohka and Utsjoki (Fig. 8).

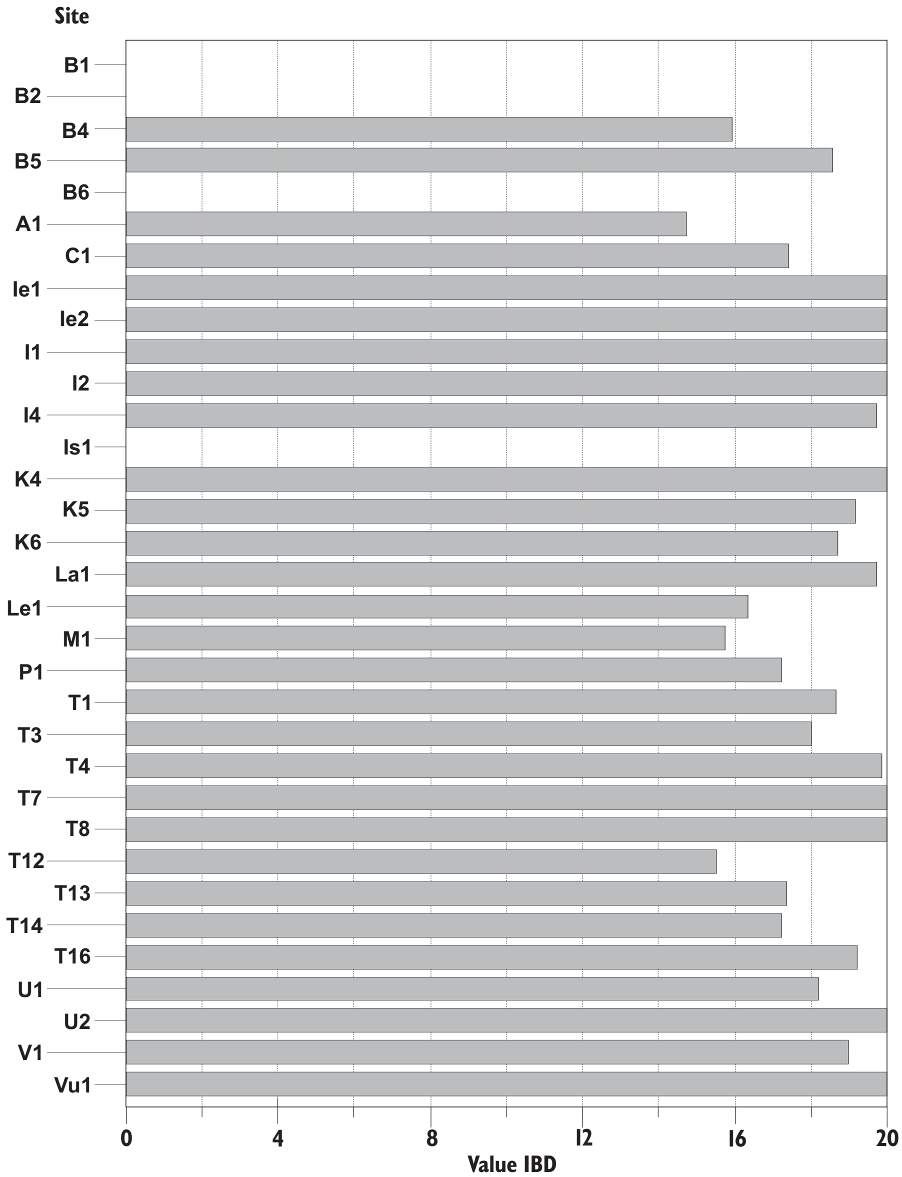

Figure 8. Values of the Biological Diatom Index (Prygiel & Coste 2000), assessing water quality in the studied sites.

Culloveijohka, Levssejohka, Polmakelva, and Tenojoki sites Nuvvos, Seida and Nuorgam would be classified as good according to this system. B4 (Kenesjoki), Arola, Masjohka and Tana Bru would be classified as moderate. Abundance of the species *Diatoma tenuis* causes the lowest inference for water quality in Arola. This species indicates eutrophy also according to Van Dam et al. (1994). In the sample B4, no actual indicators of eutrophication are found. The IBD value for B4 is 15.94, and Prygiel and Coste have estimated the possible errors in the calculation be about 1 unit large.

4 Discussion

Soininen (2002) has presented a coarse classification system of Finnish river, based on the dominating species in the samples. According to this system, the small brooks ('B-samples') are classified as clear ultraoligotrophic, and the other samples as clear oligotrophic. The species indicating eutrophy according to Soininen (2002) are not so dominating in any of the samples, that they would be classified as eutrophic or polluted. However, some samples could not be classified according to the list of the species by Soininen; unclassified are A1, B6, Ie2, and T13.

4.1 Tenojoki

The River Tenojoki has typical diatom assemblages for an oligotrophic northern river, but phosphorus concentrations rise in Pulmanki-Teno area. During the years 1988–1994, observed total phosphorus concentration (median) was about 4 $\mu g\ l^{-1}$ in sites from T1 to T7, but 7 $\mu g\ l^{-1}$ in T13 (Traaen 1996). This same rise of phosphorus concentrations is reflected also in the diatom assemblages in 2003. For example, diatom *Cymbella minuta* (synonym *C. ventricosa* var. *minuta*) indicates more eutrophic conditions, and was counted in the sampling sites T12 and T13, and also earlier by Traaen et al. (1990).

Along the River Tenojoki, the bedrocks are mainly granulites and granitoids, but in the area around Pulmankijärvi and Tana Bru there are Svecokarelian mafic and ultramafic intrusive rocks (Koljonen 1992). Elevated levels of phosphorus and calcium in these intrusive rocks may cause slightly higher levels of these nutrients in Tenojoki downstream from Nuorgam (sampling sites T14, T12 and T13).

Also agriculture probably has some effect to the inferred increase in the nutrient levels in the samples T12-T14. According to Huru et al. (1996) agriculture accounts for most of the phosphorus loading in Tenojoki, concentrating along Karasjohka, downstream part of Tenojoki and Utsjoki commune on Finnish side of Tenojoki.

4.2 Tributaries

Based on phytobenthos and microbiological quality, waste waters degraded the water quality in Karasjohka downstream the Karasjok commune in late 1980's (Traaen et al. 1990). According to Traaen (1996) and Lindström & Johansson (1996), after 1992 waste waters have not had any significant loading to the river. According to the one sample upstream Karasjok commune, and two samples downstream from Karasjok, sampled in this study, the water quality in Karasjohka was excellent in 2003.

Arola (A1) and Kenesjoki (B4) would appear to be eutrophicated according to the results. However, in Arola and Kenesjoki no factors that would deteriorate the water quality are known. In B4, no large amounts of actual indicators of eutrophication were found, but still the IBD value is just below good.

In the sites A1 and B4 the river bottom is mainly formed by large boulders, and cobbles are difficult to find in places, where there is good water current. This favors the build-up of debris on the cobbles, and so probably also the growth of meso-to polysaprobic algae. Also shading of the trees is a problem, especially in the site B4. The results are questionable for these sites, especially for B4. The cause for possible eutrophication in the site A1 remains to be studied.

B6 (Jauvvajohka) between Polmak and Tana Bru deviates from other samples. The same site was the most deviant of the ”B-sites” also by its bottom fauna, containing eight taxa missing in other brooks (Hämäläinen et al. 1996). The rich flora and fauna seems to be thriven by high alkalinity and electrolyte content of the water.

For Levssejohka, inaccuracy in the IBD system probably lowers the IBD value. Different variations of species *Fragilaria capucina* are lumped into one taxa in IBD. *F. capucina* var. *gracilis* is abundant in Levssejohka, whereas *F. capucina* var. *mesolepta* is very abundant in Polmakelva and Tenojoki 12 and 14.

According to Traaen et al. (1990), *Didymosphenia geminata* is a common species in Tenojoki, forming thick mats in fast-flowing sites. In this study it was found only in small amounts (< 1 %), so the species may have declined. Sampling strategies may have also an effect to the presence of this species in the samples, since the species has very distinct microhabitat it can occupy.

5 Conclusions

Water quality appears excellent in the River Tenojoki and its tributaries, with an exception of some slight increase in trophy levels in the area of Polmakelva, Masjohka and downstream parts of Tenojoki. Exceptional geology may explain partly the elevated trophy level in Tenojoki downstream of Nuorgam. High ecological status can be assigned to the upstream parts of the River Tenojoki, and good ecological status for the downstream parts below Nuorgam. Karasjohka downstream of the Karasjok commune seems to be mostly recovered from the eutrophication indicated in the late 1980's.

Using expert judgement, the river mouth of Masjohka seems to be the only site where definitely diatom assemblages indicating eutrophication were sampled. Masjohka would be the only site with diatom compositions deviating enough from the natural conditions to be classified as having only moderate ecological status based on phytobenthos. However, one must consider also, that the sampling at the site M1 was only possible from the artificial river bank, constructed of large boulders. It is not known if this type of sampling site could have an effect on the results.

The classification of the sites according to the WFD will be based on the typology of the rivers. The geologically exceptional area along Polmakelva and north of it seems to produce phytobenthos communities deviating to some extent from the other areas. The geology factor would be necessary to take into the typology, to avoid classifications of the rivers to worse status than the true conditions.

Extra caution is necessary with the interpretation, when using most of the trophy indices, developed in central Europe (see e.g. Eloranta 1999). Models and indices designed for the northern boreal and subarctic rivers are needed for phytobenthos surveys. Generally, diatom methods have shown their sensitivity to detect even small changes in the water quality, also in the waters of the Tenojoki catchment area.

6 Yhteenveto

Osana Interreg-projektia ”Tenojoen säilyttäminen luonnontilaisena lohijokena – ympäristötyöt, ekologinen tila ja seuranta” tehtiin perifytonin eli pohjalevien kartoitus, jota varten näytteet kerättiin syyskuussa 2003. Piileviä käytettiin perifytonia kuvaavana indikaattoriryhmänä niiden hyvien indikaattoriominaisuuksien ja standardoitujen menetelmien vuoksi. Piilevien koostumus kivien pinnalla kuvaa veden laatua näytepaikalla noin 1–2 kuukauden aikana ennen näytteenottoa. Määritysaineisto on suunniteltu täyttämään EU:n vesipolitiikan puitedirektiivin vaatimukset perifytonin osalta.

Tenojoesta, Inarijoesta, Kaarasjoesta, Utsjoesta ja 15 pienemmästä joesta Tenojoen valuma-alueella otettiin piilevänäytteet kivien pinnalta. Yhteensä näytepaikkoja on 33, joista Tenojoen pääuomassa yhdeksän. Jokaiselta tutkimuspaikalta kerättiin kolme rinnakkaista näytettä, kukin sisältäen viisi läpimitaltaan 6–26 cm suuruista kiveä, joiden pinnalta harjattiin levämateriaali irti hammasharjalla. Laboratoriossa näytteistä tuhottiin hapoilla orgaaninen aines, niin että jäljelle jäi mikroskopoitavaksi vain piilevien silikaattiset kuoret. Jokaisesta näytteestä määritettiin vähintään 400 piileväkuorta, käyttäen mikroskoopissa 1 000-kertaista suurennosta ja vastavaiheoptiikkaa.

Näytteenoton riittävyyttä kullakin paikalla testattiin vertailemalla rinnakkaisten näytteiden samanlaisuutta MRPP-testillä ja Bray-Curtis samanlaisuusindeksillä. Ordinaatiomenetelmistä käytettiin oikaistua korrespondenssianalyysiä (DCA) näytepaikkojen vertailuun ja tärkeimpien ympäristötekijöiden arvioimiseen aineistossa. Lopuksi veden laatua näytepaikoilla määritettiin veden ravinnetasoa ja pH:ta sekä leväyhteisön saprobisuutta kuvaavilla indekseillä ja luokituksilla.

Rinnakkaisten näytteiden vertailutulosten mukaan kerätty kivien määrä on pääsääntöisesti riittävä, ja rinnakkaisten näytteiden piileväkoostumus on yleensä lähellä toisiaan. Yhdistettyjen rinnakkaisnäytteiden DCA ordinaatiossa tulee esille Jauvvajohkan (lähellä Tana Bruta) erottuminen kaikista muista näytepaikoista veden korkeaa pH:ta vaativalla lajistollaan. Myös Ailigastunturin eteläpuolisten purojen näytteet erottuivat muista, mutta luultavasti alhaisten ravinnepitoisuuksiensa ja puiden varjostuksen ansiosta. Korkeampaa ravinnepitoisuutta suosivat lajit taas erottavat Tenojoen alajuoksun, Arolan (Pulmankijärven eteläpuolella), Pulmankijoen ja Masjohkan muista näytteistä. Näitä korkeampaa ravinnepitoisuutta osoittavia lajeja tai muotoja ovat mm. *Achanthes lanceolata, A. minutissima* var. *saprophila*, *Diatoma tenuis, Cymbella minuta* ja *Fragilaria capucina* var. *mesolepta*. Koko aineistossa runsaimpia lajeja ovat *Tabellaria flocculosa*, *Achnanthes minutissima*, *Fragilaria capucina* var. *gracilis* ja *F. ulna*.

Tulosten mukaan veden laatu on yleensä erinomainen ja ravinnetasot alhaisia Tenojoessa ja sen sivuvesistöissä, poikkeuksena alue Nuorgamista ja Pulmankijoesta alavirtaan päin, missä veden ravinteisuustaso hieman nousee. Pohjalevätulosten perusteella Tenojoen yläosan voidaan sanoa olevan erinomaisessa ekologisessa tilassa, ja Nuorgamin alapuolisen osan hyvässä ekologisessa tilassa. Samanlainen lievä veden ravinteisuustason nousu samoissa paikoissa on havaittu myös aikaisemmissa perifytonin kartoituksissa 1989 ja 1994. Kohonnut veden ravinteisuus alueella voi johtua osittain alueen muusta alueesta poikkeavasta geologiasta.

7 Sammendrag

Som en del av Interreg-prosjektet ”Bevaring av Tanaelv som en lakseelv i naturtilstand – miljøtiltak, økologisk status og overvåking” ble det gjennomført en kartlegging av perifyton eller bunnalger. Prøvene ble samlet inn i september 2003. Som en indikatorgruppe ble det brukt kiselalger, som karakteriserer perifyton på grunn av sine gode indikatoregenskaper og standardiserte metoder. Sammensetning av kiselalgene på steiner gir en beskrivelse av vannkvaliteten på prøvetakingsstedet i en periode på 1–2 måneder før prøvetakingen. Man har planlagt artsbestemmelsesmaterialet slik at det oppfyller kravene i EUs vanndirektiv angående perifyton.

Det ble samlet inn kiselalgeprøver fra steiner i Tanaelva, Anarjohka, Karasjohka, Utsjoki og 15 mindre elver i Tanavassdraget. Til sammen var det 33 prøvetakingssteder, og ni av dem var i hovedløpet Tanaelva. På hver av prøvetakingsstedene ble det hentet tre parallelle prøver som hver besto av fem steiner med en diameter på 6–26 cm. Man børstet algematerialet av steinene med en tannbørst. På laboratoriet ble det organiske materialet i prøvene brutt ned med syrer, slik at bare kiselalgenes silikatskall var igjen til mikroskopering. I hver av prøvene ble minst 400 kiselalgeskall artsbestemt ved å bruke 1 000 gangers forstørrelse og push-pull-optikk.

Hvorvidt man hadde tatt tilstrekkelig mange prøver i hver lokalitet, ble testet ved å sammenligne likheter i parallelle prøver ved hjelp av en MRPP-test og Bray-Curtis-likhetsindeks. Av ordineringsmetoder ble det brukt detrending korrespondanseanalyse (DCA) til sammenligning av prøvetakingssteder og for å vurdere hvilke miljøfaktorer som er de viktigste i materialet. Til slutt ble vannkvaliteten på prøvetakingssteder definert ved hjelp av indekser og klassifiseringer som beskriver vannets nivå av næringssalter og pH samt algesamfunnets saprobieringsgrad.

Ut fra resultatene av sammenligning av parallelle prøver er antall innsamlede steiner i hovedsaken tilstrekkelig, og kiselalgesammensetningen i parallelle prøver ligner som regel på hverandre. DCA-ordineringen av kombinerte parallellprøver viser at Jauvvajohka (nær Tana bru) skiller seg fra alle andre prøvetakingssteder med sin artssammensetning som forutsetter høye pH-verdier. Også prøvene fra bekker sør for Ailigas-fjellet skilte seg fra de andre, men det var trolig på grunn av et lavt innhold av næringssalter og skyggende trær. Arter som krever høye konsentrasjoner av næringssalter er på sin side det som skiller det nedre løpet av Tanaelva, Arola (nedenfor Polmak-vannet), Polmakelva og Masjohka fra de andre prøvene. Slike arter eller former som er tegn på et høyere innhold av næringssalter, er bl.a. *Achanthes lanceolata, A. minutissima* var. *saprophila*, *Diatoma tenuis, Cymbella minuta* ja *Fragilaria capucina* var. *mesolepta*. Artene som er mest tallrike i hele materialet er *Tabellaria flocculosa*, *Achnanthes minutissima*, *Fragilaria capucina* var. *gracilis* og *F. ulna*.

Resultatene tilsier at vannkvaliteten generelt er utmerket og næringssaltnivåene lave i Tanaelva med sidevassdrag, unntatt strekningen fra Nuorgam og Polmakelva nedstrøms, hvor vannets innhold av næringssalter stiger litt. Ut fra bunnalgeresultatene kan man si at det øvre løpet av Tanaelva har en høy økologisk tilstand, og strekningen nedenfor Nuorgam en god økologisk tilstand. En lignende, svak stigning i nivået av næringssalter i de samme lokalitetene har man observert også ved de tidligere kartleggingene av perifyton i 1989 og 1994. Det at innholdet av næringssalter på strekningen er høyere, kan delvis skyldes områdets geologiske forhold som skiller seg fra resten av området.

8 Čoahkkáigeassu

Oassin Interreg-prošeavtta "Deanu seailluheapmi luondduviđá luossajohkan – birasbarggut, ekologalaš dilli ja čuovvun" dahkkui perifyton, nuppiid sániiguin bodnedebbuid kárten, man várás čájánasat čoggojedje čakčamánus 2003. Didnodebbot geavahuvvojedje perifyton govvideaddji indikáhtorjoavkun daid buriid indikáhtoriešvuođaid ja standardavugiid dihte. Didnodebbuid čohkiidus geđggiid alde govvida čázi kvalitehta čájánasbáikkis sullii 1–2 mánotbaji áigge ovdal čájánasváldima. Dutkanmateriálat leat plánejuvvon deavdit EU:a čáhcepolitihka rámadirektiivva gáibádusaid perifyton oasil.

Deanus, Anárjogas, Kárášjogas, Ohcejogas ja 15 smávit jogas Deanu golganguovllus váldojedje didnodeappočájánasat geđggiid alde. Oktiibuot čájánasbáikkit leat 33, main Deanu váldooalis ovcci. Juohke dutkanbáikkis váldojedje golbma bálddalas čájánasa, iešguđet sisttisdoalai vihtta čađamihtu dáfus 6–26 cm sturrosaš geađggi, maid alde gustejuvvui deappomateriála luovus bátnegusttain. Laboratorios čájánasain duššaduvvui sivrrain orgánalaš ávnnas, nu ahte báhce dušše mikroskohpa dutkama várás dušše didnodebbuid silikáhtagarat. Juohke čájánasas meroštallojedje uhcimustá 400 didnodeappogara nu, ahte geavahuvvui mikroskohpas 1 000-geardásaš stuorideapmi ja vuostemuddooptihka.

Čájánasváldima doarváivuohta iešguđet báikkis testejuvvui nu, ahte veardádallui bálddalas čájánasaid seammaláganvuohta MRPP-teasttain ja Bray-Curtis seammaláganvuođaindeavssain. Ordinaatiovugiin geavahuvvui njulgejuvvon korrespondensaanaliisa (DCA) čájánasbáikkiid veardádallamii ja dehaleamos birasdahkkiid árvvoštallamii materiálas. Loahpas čázi kvalitehta čájánasbáikkiin meroštallui čázi biebmodási ja PH sihke deapposervoša saprobivuođa govvideaddji indeavssain ja luohkáin.

Bálddalas čájánasaid veardádallanbohtosiid mielde čoggojuvvon geđggiid mearri lea eanaš doarvái, ja bálddalas čájánasaid didnodeappočohkiidus lea dábálaččat seammasullasaš. Ovttastahtton bálddalasčájánasaid DCA ordinaatios boahtá ovdan Jauvvajohka (lahka Tana Bru) earráneapmi buot eará čájánasbáikkiin čázi alla PH gáibideaddji šlájain. Maiddái Áilegasa máttabeale ádjagiid čájánasat earránedje earáin, muhto kánske vuollegis biebmomeriid ja muoraid suoivaniid dihte. Allagut biebmomeari dárbbašeaddji šlájat fas earuhit Vuolle-Deanu, Arola (Buolbmatjávrri máttabealde), Buolbmatjoga ja Masjohka eará čájánasain. Dát allagut biebmomeari šlájat dahje hámit leat ee. *Achanthes lanceolata, A. minutissima var. saprophila, Diatoma tenuis, Cymbella minuta* ja *Fragilaria capucina var. mesolepta.* Olles materiálas valjimus šlájat leat *Tabellaria flocculosa, Achnanthes minutissima, Fragilaria capucina var. gracilis ja F. ulna.*

Bohtosiid mielde čázi kvalitehta lea dábálaččat erenomáš ja biebmomearit vuollin Deanus ja dan oalgečáziin, spiehkastahkan guovlu Njuorggámis ja Buolbmatjogas vulos, gos čázi biebmodássi vehá loktana. Didnodeappobohtosiid vuođul Badje-Deanu sáhttá dadjat leat erenomáš ekologalaš dilis, ja Njuorggáma vulobealde guovllu buorre ekologalaš dilis. Seamma uhcánaš čázi biebmodási badjáneapmi seammá báikkiin lea fuopmášuvvon maiddái ovddit perifyton kártemiin 1989 ja 1994. Badjánan čázi biebmomearri guovllus sáhttá boahtit muhtin muddui geologiijas, mii spiehkkasa eará guovlluid ektui.

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The diatom counts for all the taxa observed in the 99 samples.

Diatom counts in Tenojoki catchment area. Sampling 3.–13.9.2003.

TAXON	B1A	B2A	B4A	B5A	B6A	A1A	C1A	Ie1A	Ie2A	I1A	I2A	I4A	Is1A	K4A	K5A	K6A	La1A	Le1A
Achnanthes flexella	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Achnanthes impexa	3	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	2	0
Achnanthes lanceolata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
Achnanthes levanderi	10	0	6	2	4	0	0	0	2	1	0	0	0	2	8	16	3	3
Achnanthes linearis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0
Achnanthes minutissima	26	21	215	230	10	224	31	95	86	48	6	92	16	50	130	81	95	89
A. minutissima v. saprophila	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Achnanthes pusilla	39	20	0	31	2	21	2	14	8	5	0	12	22	2	19	23	0	8
Achnanthes subatomoides	2	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0
Amphora copulata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Anomoeoneis brachysira	0	12	0	2	0	14	0	0	12	18	6	56	0	41	2	20	0	0
Anomoeoneis vitrea	4	0	0	0	0	18	0	7	4	4	0	28	0	16	14	18	6	2
Asterionella formosa	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
Aulacoseira alpigena	9	174	12	0	0	0	18	0	0	0	0	0	0	0	0	0	0	19
Aulacoseira ambigua	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8
Aulacoseira distans	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aulacoseira subarctica	0	0	0	0	0	0	0	0	0	0	0	0	0	2	12	0	0	0
Caloneis bacillum	2	2	2	0	0	0	0	0	0	0	0	0	22	0	0	0	0	5
Cocconeis pediculus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cocconeis placentula	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	2	2	0
Cyclotella comensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyclotella radiosa	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyclotella rossii	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0
Cyclotella stelligera	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cymbella amphicephala	0	0	0	0	0	0	0	0	0	2	0	0	0	0	4	2	4	0
Cymbella cesatii	0	2	0	0	0	0	0	0	2	0	2	2	0	0	10	5	0	0
Cymbella descripta	0	23	0	0	0	0	0	6	9	0	0	14	18	2	6	2	8	0
Cymbella minuta	4	2	2	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cymbella naviculiformis	0	0	0	0	0	0	0	4	0	18	0	2	0	0	0	0	0	8
Cymbella silesiaca	0	14	2	0	0	0	5	0	11	3	0	2	2	8	2	2	0	0
Denticula tenuis	0	2	46	0	6	0	2	0	0	0	0	0	0	0	0	2	0	0
Diatoma moniliformis	0	0	0	0	70	0	0	0	0	0	0	0	0	0	0	0	0	0
Diatoma tenuis	0	0	0	0	0	67	3	0	0	0	0	2	0	2	2	6	4	0
Diatoma vulgaris	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

...TAXON	B1A	B2A	B4A	B5A	B6A	A1A	C1A	Ie1A	Ie2A	I1A	I2A	I4A	Is1A	K4A	K5A	K6A	La1A	Le1A
Didymosphenia geminata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Diploneis ovalis v. lineata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Epithemia adnata	0	0	0	0	60	0	13	0	2	0	0	0	0	0	0	0	0	0
Epithemia sorex	0	0	0	0	0	0	0	0	0	0	0	0	18	0	0	0	0	0
Eunotia bilunaris	0	0	0	0	0	0	0	2	2	0	2	0	0	2	4	0	0	4
Eunotia exigua	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
Eunotia faba	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eunotia implicata	20	8	10	34	0	22	2	0	7	8	41	15	4	19	12	10	6	10
Eunotia incisa	6	10	4	8	0	2	2	0	6	2	4	0	0	4	2	0	0	2
Eunotia meisteri	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0
Eunotia praerupta	0	0	2	0	0	0	0	0	0	2	0	0	0	6	12	0	0	4
Eunotia serra	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
Eunotia trioides	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fragilaria arcus	4	27	32	42	8	2	80	2	0	0	42	6	19	4	0	0	40	50
Fragilaria brevistriata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
F. capucina v. capucina	0	6	14	10	0	4	5	16	6	10	10	5	0	28	26	4	4	10
F. capucina v. gracilis	40	39	38	12	82	0	26	0	15	31	100	20	152	40	51	42	16	40
F. capucina v. mesolepta	0	0	0	0	28	0	4	0	2	0	0	0	0	0	18	14	2	0
F. capucina v. vaucheriae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fragilaria construens	0	4	0	0	0	0	2	22	0	30	0	0	0	2	2	0	2	2
Fragilaria crotonensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fragilaria pinnata	96	0	6	0	0	0	0	0	0	0	0	0	2	0	0	0	0	4
Fragilaria rumpens	0	0	0	0	74	0	0	0	0	0	6	0	25	0	0	2	0	0
Fragilaria tenera	0	0	0	0	0	8	4	2	2	13	20	0	0	4	0	7	10	2
Fragilaria ulna	64	5	18	0	0	32	120	4	14	43	12	11	84	11	10	35	33	96
Fragilaria virescens	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Frustulia rhomboides	0	22	0	2	0	0	0	0	0	0	0	4	0	0	4	0	0	2
Gomphonema acuminatum	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
Gomphonema gracile	4	0	6	4	0	0	0	0	0	2	0	2	0	2	20	0	4	0
Gomphonema parvulum	2	8	0	0	0	2	0	0	0	0	0	0	2	4	0	2	2	8
Gomphonema truncatum	0	0	0	0	0	0	12	0	2	0	0	0	0	0	0	0	2	4
Gomphonema subtile	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hantzschia amphioxys	2	0	0	0	2	0	0	0	0	0	0	2	2	2	2	0	0	0
Melosira undulata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Melosira circulare	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2

...TAXON	B1A	B2A	B4A	B5A	B6A	A1A	C1A	Ie1A	Ie2A	I1A	I2A	I4A	Is1A	K4A	K5A	K6A	La1A	Le1A
Navicula costulata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Navicula cryptocephala	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Navicula indifferens	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Navicula jaernefeltii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Navicula mediocris	0	7	0	2	0	0	0	0	0	0	0	0	2	0	0	0	0	0
Navicula menisculus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Navicula pseudoscutiformis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Navicula pupula	4	5	0	2	2	0	0	0	0	0	0	2	0	2	12	3	0	4
Navicula radiosa	6	4	0	0	6	0	0	4	6	0	0	4	0	0	4	4	0	0
Navicula seminulum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Navicula spp.	7	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0
Neidium ampliatum	0	2	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0
Nitzschia fonticola	10	9	2	0	8	0	0	0	0	0	0	4	7	0	2	4	0	0
Nitzschia palea	2	0	2	0	6	0	0	0	1	0	0	0	14	0	0	0	0	0
Nitzschia spp.	5	2	0	0	16	0	2	2	1	2	0	0	0	0	2	0	0	0
Peronia fibula	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
Pinnularia borealis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pinnularia gibba	0	0	0	0	0	0	4	8	0	2	0	6	0	0	0	0	0	0
Pinnularia maior	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pinnularia nodosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pinnularia spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rhoicosphenia abbreviata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rhopalodia gibba	0	0	0	0	4	0	2	0	0	0	0	0	0	0	0	0	0	0
Stauroneis phoenicenteron	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Stauroneis angustata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Stauroneis ovalis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tabellaria fenestrata	0	0	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0
Tabellaria flocculosa	10	34	2	24	4	24	76	270	207	176	168	128	4	187	93	122	159	28
DIATOM SUM	403	472	421	414	410	442	417	477	407	426	421	421	417	442	489	430	416	414

TAXON	M1A	P1A	T1A	T3A	T4A	T7A	T8A	T12A	T13A	T14A	T16A	U1A	U2A	V1A	Vu1A	B1B	B2B	B4B
Achnanthes flexella	0	0	1	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
Achnanthes impexa	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0
Achnanthes lanceolata	30	10	0	0	0	0	0	0	0	0	0	0	0	0	0	9	0	0
Achnanthes levanderi	0	7	7	2	0	0	2	20	3	8	1	0	0	0	0	16	0	2
Achnanthes linearis	9	0	2	0	0	4	0	4	0	5	6	2	2	2	0	0	9	8
Achnanthes minutissima	156	49	149	198	90	88	65	86	131	214	128	161	73	56	60	34	41	82
A. minutissima v. saprophila	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Achnanthes pusilla	8	0	5	16	14	4	4	0	11	10	0	0	2	2	31	83	0	30
Achnanthes subatomoides	2	0	2	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0
Amphora copulata	4	6	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	10
Anomoeoneis brachysira	0	0	60	0	22	12	17	2	26	4	32	16	8	13	16	0	3	8
Anomoeoneis vitrea	3	4	9	37	4	7	0	2	2	2	8	8	4	4	12	3	2	0
Asterionella formosa	2	8	0	0	0	0	0	0	0	0	0	1	2	0	2	0	0	0
Aulacoseira alpigena	2	0	14	0	0	0	0	0	0	0	0	0	0	0	0	13	101	24
Aulacoseira ambigua	0	0	0	2	0	0	0	0	0	0	0	0	0	0	4	0	0	0
Aulacoseira distans	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aulacoseira subarctica	0	2	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0
Caloneis bacillum	0	0	6	0	0	0	0	0	8	0	2	0	0	2	0	3	0	0
Cocconeis pediculus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cocconeis placentula	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyclotella comensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyclotella radiosa	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
Cyclotella rossii	0	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyclotella stelligera	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cymbella amphicephala	0	0	12	2	4	0	0	2	10	4	8	0	0	20	4	0	0	2
Cymbella cesatii	0	0	22	18	2	0	2	0	8	0	0	3	0	0	0	2	4	0
Cymbella descripta	3	0	22	6	4	2	4	2	8	2	8	6	2	4	20	6	33	0
Cymbella minuta	10	20	4	4	0	0	0	26	19	2	2	0	0	0	0	2	1	6
Cymbella naviculiformis	2	0	0	0	0	0	0	0	7	0	6	2	0	0	2	0	2	0
Cymbella silesiaca	2	0	2	8	0	4	4	6	0	4	6	2	0	0	6	2	18	2
Denticula tenuis	0	9	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	98
Diatoma moniliformis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Diatoma tenuis	8	14	2	2	6	4	8	0	8	0	6	12	2	4	0	0	2	0
Diatoma vulgaris	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	0	0

...TAXON	M1A	P1A	T1A	T3A	T4A	T7A	T8A	T12A	T13A	T14A	T16A	U1A	U2A	V1A	Vu1A	B1B	B2B	B4B
Didymosphenia geminata	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
Diploneis ovalis v. lineata	9	0	4	0	0	0	0	28	0	2	0	0	0	0	0	0	0	0
Epithemia adnata	6	0	0	0	0	0	0	4	0	6	0	0	0	0	0	0	0	0
Epithemia sorex	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0
Eunotia bilunaris	0	0	0	0	0	0	0	0	4	2	0	0	0	0	0	2	2	0
Eunotia exigua	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Eunotia faba	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	2	0	0
Eunotia implicata	0	0	12	6	19	0	16	0	2	2	18	0	10	18	0	40	2	12
Eunotia incisa	10	0	2	0	2	4	0	10	0	0	4	12	2	0	14	22	12	10
Eunotia meisteri	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eunotia praerupta	0	0	0	0	6	2	2	0	0	0	0	6	0	8	0	0	0	0
Eunotia serra	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
Eunotia trioides	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0
Fragilaria arcus	2	4	4	2	18	2	8	0	4	0	2	18	14	81	0	0	28	46
Fragilaria brevistriata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
F. capucina v. capucina	48	21	0	6	2	8	6	4	8	6	4	24	11	0	10	0	20	6
F. capucina v. gracilis	0	8	34	39	27	29	50	16	15	30	4	18	52	24	15	32	67	4
F. capucina v. mesolepta	0	114	0	0	0	10	0	54	13	49	0	2	0	0	12	0	0	0
F. capucina v. vaucheriae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fragilaria construens	7	15	6	0	0	2	2	0	8	4	4	4	0	0	0	4	0	8
Fragilaria crotonensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fragilaria pinnata	0	5	8	0	0	0	2	0	2	0	0	0	2	0	0	75	0	4
Fragilaria rumpens	0	0	0	0	2	0	0	0	4	2	0	0	4	4	0	0	0	0
Fragilaria tenera	36	0	0	12	6	0	0	0	8	4	22	16	30	10	0	0	0	2
Fragilaria ulna	9	15	8	18	22	9	12	64	7	12	16	22	2	40	7	88	8	29
Fragilaria virescens	0	0	0	0	0	0	0	2	1	0	0	0	6	0	0	0	0	0
Frustulia rhomboides	0	0	0	0	2	0	0	0	4	0	0	2	0	0	4	2	11	0
Gomphonema acuminatum	2	0	2	0	0	0	0	8	0	0	0	0	0	0	4	0	0	0
Gomphonema gracile	0	0	0	0	0	2	9	0	2	0	0	0	0	22	0	10	0	4
Gomphonema parvulum	0	4	2	0	2	0	0	0	4	0	2	0	0	0	0	0	2	6
Gomphonema truncatum	0	4	0	0	0	4	0	34	0	0	0	0	0	0	0	0	0	0
Gomphonema subtile	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hantzschia amphioxys	10	12	2	4	0	0	0	12	0	10	0	0	0	0	0	4	0	0
Melosira undulata	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0
Melosira circulare	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0

...TAXON	M1A	P1A	T1A	T3A	T4A	T7A	T8A	T12A	T13A	T14A	T16A	U1A	U2A	V1A	Vu1A	B1B	B2B	B4B
Navicula costulata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Navicula cryptocephala	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Navicula indifferens	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Navicula jaernefeltii	0	2	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
Navicula mediocris	2	0	2	0	0	0	0	0	0	2	0	2	0	0	0	0	4	0
Navicula menisculus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Navicula pseudoscutiformis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Navicula pupula	2	9	4	0	0	0	2	1	8	2	2	0	0	1	0	9	0	0
Navicula radiosa	10	5	1	0	0	2	2	3	11	5	2	0	2	0	2	2	9	0
Navicula seminulum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Navicula spp.	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	4
Neidium ampliatum	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nitzschia fonticola	2	0	0	0	0	2	2	0	10	2	2	0	0	0	2	6	0	0
Nitzschia palea	5	3	0	0	0	0	0	0	0	5	0	0	0	0	2	0	0	0
Nitzschia spp.	12	0	4	0	0	0	2	2	12	6	0	0	0	0	0	2	1	0
Peronia fibula	0	0	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0
Pinnularia borealis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pinnularia gibba	0	0	2	0	0	0	2	8	2	0	12	0	0	0	10	2	0	0
Pinnularia maior	0	0	0	0	0	0	0	0	0	0	0	2	0	0	2	0	0	0
Pinnularia nodosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pinnularia spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rhoicosphenia abbreviata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rhopalodia gibba	2	0	4	0	0	2	0	0	0	4	0	0	0	0	0	0	0	0
Stauroneis phoenicenteron	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Stauroneis angustata	2	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	2
Stauroneis ovalis	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tabellaria fenestrata	0	0	0	6	0	0	0	0	0	0	0	4	2	0	0	0	0	0
Tabellaria flocculosa	25	75	36	45	166	233	200	23	38	11	98	84	208	116	182	7	36	9
DIATOM SUM	464	444	455	438	424	438	423	427	418	433	413	433	440	431	423	529	420	421

TAXON	B5B	B6B	A1B	C1B	Ie1B	Ie2B	I1B	I2B	I4B	Is1B	K4B	K5B	K6B	La1B	Le1B	M1B	P1B	T1B
Achnanthes flexella	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Achnanthes impexa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	0	0
Achnanthes lanceolata	0	0	0	0	2	0	0	0	0	0	0	0	1	0	0	15	9	0
Achnanthes levanderi	0	6	4	0	0	0	4	0	2	0	0	8	4	0	0	8	0	0
Achnanthes linearis	0	0	0	0	0	10	0	3	0	0	0	0	0	0	0	25	2	3
Achnanthes minutissima	80	12	208	72	121	110	21	28	106	16	29	80	196	95	116	129	30	163
A. minutissima v. saprophila	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	5	0	0
Achnanthes pusilla	28	2	27	4	4	0	7	0	9	15	2	11	19	4	2	0	0	0
Achnanthes subatomoides	0	0	0	0	6	0	0	0	0	0	0	5	0	0	0	0	0	0
Amphora copulata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	10	0
Anomoeoneis brachysira	14	3	0	0	8	10	12	6	39	0	12	4	17	4	16	0	0	32
Anomoeoneis vitrea	0	0	0	0	10	6	2	0	4	0	0	36	4	0	0	8	0	6
Asterionella formosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	8	0
Aulacoseira alpigena	2	0	0	8	0	0	0	0	0	4	0	2	0	0	16	0	0	2
Aulacoseira ambigua	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
Aulacoseira distans	0	0	0	0	2	0	0	0	0	0	0	0	0	2	0	0	0	0
Aulacoseira subarctica	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Caloneis bacillum	0	0	0	0	0	0	2	0	0	2	0	0	0	0	0	0	2	0
Cocconeis pediculus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cocconeis placentula	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Cyclotella comensis	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
Cyclotella radiosa	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0
Cyclotella rossii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0
Cyclotella stelligera	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cymbella amphicephala	0	0	0	0	0	0	4	0	2	0	0	2	0	8	2	3	0	18
Cymbella cesatii	0	0	0	0	0	6	2	0	2	0	0	8	2	0	0	0	0	0
Cymbella descripta	4	0	2	2	6	16	0	13	2	10	3	10	20	0	0	2	0	3
Cymbella minuta	0	2	0	0	0	0	6	0	0	2	0	0	2	0	0	11	16	0
Cymbella naviculiformis	0	0	0	0	0	0	10	0	0	0	0	0	2	0	0	0	0	0
Cymbella silesiaca	4	0	0	6	2	4	2	2	4	0	0	2	4	0	0	2	0	0
Denticula tenuis	0	0	0	2	0	0	0	0	0	2	0	2	2	0	0	4	0	0
Diatoma moniliformis	0	72	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Diatoma tenuis	2	0	75	0	3	0	2	6	2	0	2	2	0	4	0	2	16	4
Diatoma vulgaris	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

...TAXON	B5B	B6B	A1B	C1B	Ie1B	Ie2B	I1B	I2B	I4B	Is1B	K4B	K5B	K6B	La1B	Le1B	M1B	P1B	T1B
Didymosphenia geminata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Diploneis ovalis v. lineata	0	15	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0
Epithemia adnata	0	122	0	2	0	4	2	0	0	0	0	2	0	0	0	12	0	0
Epithemia sorex	0	0	0	0	2	0	0	0	0	19	0	0	0	0	2	4	0	0
Eunotia bilunaris	2	0	0	0	0	0	6	0	4	2	2	0	0	0	0	0	2	1
Eunotia exigua	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0
Eunotia faba	0	0	1	0	0	0	2	0	0	0	0	0	0	0	0	2	0	0
Eunotia implicata	54	0	16	14	0	6	27	31	24	2	30	10	0	8	10	0	0	24
Eunotia incisa	22	0	4	4	0	0	6	0	0	0	0	2	0	0	6	0	2	2
Eunotia meisteri	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
Eunotia praerupta	0	0	0	0	4	0	4	2	0	0	0	2	0	2	0	0	2	0
Eunotia serra	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eunotia trioides	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Fragilaria arcus	66	2	4	68	0	1	4	4	8	13	0	6	0	31	18	5	5	4
Fragilaria brevistriata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
F. capucina v. capucina	14	0	2	24	4	5	0	6	0	6	14	32	6	4	16	27	57	11
F. capucina v. gracilis	36	80	0	55	5	29	41	75	41	93	48	50	17	24	34	0	25	35
F. capucina v. mesolepta	0	8	0	0	0	0	0	0	0	0	4	4	6	10	12	0	104	2
F. capucina v. vaucheriae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fragilaria construens	0	4	0	0	11	0	0	0	0	0	0	0	10	7	4	0	14	0
Fragilaria crotonensis	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
Fragilaria pinnata	0	0	0	0	2	0	2	0	0	0	0	2	0	0	0	2	4	7
Fragilaria rumpens	0	93	0	0	0	0	0	0	0	25	0	0	0	0	0	0	0	0
Fragilaria tenera	2	0	16	0	6	4	12	20	0	2	2	0	0	6	6	61	0	0
Fragilaria ulna	15	6	28	83	13	13	28	20	30	156	12	26	10	48	85	12	5	20
Fragilaria virescens	0	0	0	2	2	2	4	0	2	0	0	2	0	2	0	0	2	0
Frustulia rhomboides	8	0	0	2	0	0	0	0	0	4	0	2	0	0	0	0	2	0
Gomphonema acuminatum	2	2	0	0	0	0	2	0	0	0	0	0	0	6	4	2	0	2
Gomphonema gracile	6	0	0	0	0	0	4	0	0	0	2	4	0	2	0	6	0	0
Gomphonema parvulum	2	0	0	0	2	0	0	0	2	0	0	0	0	2	0	0	0	6
Gomphonema truncatum	0	0	0	4	0	2	0	0	0	8	0	0	4	0	0	2	10	0
Gomphonema subtile	0	0	0	0	0	0	0	0	0	0	0	0	0	0	36	0	0	0
Hantzschia amphioxys	0	6	0	2	4	0	0	0	2	8	0	2	8	0	0	16	14	2
Melosira undulata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Melosira circulare	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0

...TAXON	B5B	B6B	A1B	C1B	Ie1B	Ie2B	I1B	I2B	I4B	Is1B	K4B	K5B	K6B	La1B	Le1B	M1B	P1B	T1B
Navicula costulata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Navicula cryptocephala	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
Navicula indifferens	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Navicula jaernefeltii	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0
Navicula mediocris	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
Navicula menisculus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
Navicula pseudoscutiformis	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Navicula pupula	0	0	12	0	0	0	2	0	2	0	0	4	6	2	0	2	11	0
Navicula radiosa	0	6	0	2	0	6	4	0	4	16	0	2	6	2	0	8	7	0
Navicula seminulum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
Navicula spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Neidium ampliatum	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0
Nitzschia fonticola	0	2	0	0	2	0	0	0	2	8	0	0	14	0	0	2	0	0
Nitzschia palea	0	0	0	0	2	8	0	0	0	8	0	0	0	0	0	1	5	0
Nitzschia spp.	0	2	0	2	0	1	0	0	0	0	0	5	2	0	0	5	0	0
Peronia fibula	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pinnularia borealis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pinnularia gibba	0	0	0	2	4	0	2	0	0	0	0	2	0	0	0	2	0	0
Pinnularia maior	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
Pinnularia nodosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pinnularia spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rhoicosphenia abbreviata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rhopalodia gibba	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Stauroneis phoenicenteron	0	0	0	0	2	0	0	0	0	0	0	0	0	2	0	0	0	0
Stauroneis angustata	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	4	0
Stauroneis ovalis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tabellaria fenestrata	0	0	0	0	0	0	0	0	0	0	2	2	3	0	0	2	0	2
Tabellaria flocculosa	60	2	39	44	174	187	188	218	142	26	274	94	63	154	28	43	62	75
DIATOM SUM	429	451	438	408	415	430	419	441	435	448	438	435	439	429	413	458	452	426

TAXON	T3B	T4B	Tj7B	T8B	T12B	T13B	T14B	T16B	U1B	U2B	V1B	Vu1B	B1C	B2C	B4C	B5C	B6C	A1C
Achnanthes flexella	15	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
Achnanthes impexa	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0	2	0	0
Achnanthes lanceolata	4	0	0	0	2	1	0	0	0	0	0	0	13	0	2	0	0	0
Achnanthes levanderi	6	0	2	0	0	0	6	0	0	2	0	4	15	2	6	1	2	2
Achnanthes linearis	0	0	2	0	2	0	2	0	0	0	4	0	0	4	10	0	0	0
Achnanthes minutissima	152	152	55	127	100	182	102	72	192	64	72	113	29	58	59	161	17	186
A. minutissima v. saprophila	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Achnanthes pusilla	0	6	0	4	0	17	15	4	0	0	0	43	52	13	14	30	1	16
Achnanthes subatomoides	0	1	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0
Amphora copulata	0	0	0	2	0	2	0	0	0	2	0	0	0	0	0	0	0	0
Anomoeoneis brachysira	2	0	7	18	0	14	2	4	6	8	0	17	6	14	16	8	2	14
Anomoeoneis vitrea	32	40	10	6	2	29	0	18	0	0	16	12	4	0	0	0	0	0
Asterionella formosa	0	0	4	0	0	0	0	0	0	5	0	0	0	0	0	0	0	1
Aulacoseira alpigena	2	0	0	0	0	10	14	0	11	0	0	0	26	85	15	0	0	0
Aulacoseira ambigua	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0
Aulacoseira distans	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
Aulacoseira subarctica	0	4	1	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
Caloneis bacillum	6	0	0	2	0	2	0	0	0	2	0	0	2	0	0	2	0	0
Cocconeis pediculus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cocconeis placentula	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyclotella comensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyclotella radiosa	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0
Cyclotella rossii	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0
Cyclotella stelligera	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cymbella amphicephala	8	0	2	0	0	8	4	14	8	2	0	2	0	4	4	0	0	0
Cymbella cesatii	18	8	0	8	0	2	2	0	0	0	0	0	0	0	0	0	0	0
Cymbella descripta	14	4	4	0	2	8	2	8	0	2	0	27	0	32	0	0	0	2
Cymbella minuta	2	0	0	0	64	10	10	2	2	0	0	0	0	0	10	2	8	0
Cymbella naviculiformis	0	0	0	0	0	2	0	19	0	0	0	0	0	0	2	0	0	0
Cymbella silesiaca	0	4	2	0	0	0	2	0	8	0	6	6	9	12	2	4	0	0
Denticula tenuis	0	2	0	0	0	7	4	0	0	0	0	0	8	0	90	2	0	0
Diatoma moniliformis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	34	0
Diatoma tenuis	6	2	0	8	6	7	0	0	4	4	5	0	0	0	0	0	0	151
Diatoma vulgaris	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0

...TAXON	T3B	T4B	Tj7B	T8B	T12B	T13B	T14B	T16B	U1B	U2B	V1B	Vu1B	B1C	B2C	B4C	B5C	B6C	A1C
Didymosphenia geminata	0	2	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
Diploneis ovalis v. lineata	0	0	0	0	22	0	3	0	0	0	0	0	0	0	0	0	24	0
Epithemia adnata	0	0	0	2	0	2	16	2	0	0	0	0	0	0	0	0	133	0
Epithemia sorex	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
Eunotia bilunaris	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0
Eunotia exigua	0	0	0	0	0	0	0	0	0	0	0	0	0	2	4	0	0	0
Eunotia faba	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	2	0	0
Eunotia implicata	4	14	4	18	2	0	4	25	19	6	10	0	49	8	29	38	2	18
Eunotia incisa	0	2	0	4	2	2	2	0	14	2	0	6	9	6	7	26	2	0
Eunotia meisteri	0	0	0	0	0	0	0	0	0	0	2	0	2	2	0	4	0	0
Eunotia praerupta	2	2	0	0	0	2	0	0	0	0	8	0	0	2	0	0	0	0
Eunotia serra	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
Eunotia trioides	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fragilaria arcus	2	13	10	2	2	0	0	0	33	10	16	0	4	55	53	24	8	4
Fragilaria brevistriata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
F. capucina v. capucina	22	14	11	6	8	14	8	0	24	18	4	10	0	18	2	38	4	16
F. capucina v. gracilis	30	24	42	30	17	21	24	36	34	25	32	14	17	38	26	24	48	0
F. capucina v. mesolepta	2	0	36	0	56	4	95	0	0	8	6	10	0	0	2	0	8	0
F. capucina v. vaucheriae	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
Fragilaria construens	10	0	0	0	0	0	14	0	4	0	0	0	4	4	4	0	0	0
Fragilaria crotonensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fragilaria pinnata	4	4	0	0	0	4	0	0	2	0	4	0	58	2	0	0	2	0
Fragilaria rumpens	0	0	0	0	0	24	0	0	0	2	0	0	0	0	0	0	97	0
Fragilaria tenera	14	2	22	18	0	10	4	36	22	20	18	0	0	4	6	0	0	15
Fragilaria ulna	18	15	10	8	36	0	22	26	8	8	58	3	37	6	31	6	12	23
Fragilaria virescens	2	0	4	3	0	0	2	0	0	0	0	0	2	2	2	2	0	0
Frustulia rhomboides	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	4	0	0
Gomphonema acuminatum	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	2
Gomphonema gracile	0	0	2	0	0	2	0	0	0	0	6	0	2	0	12	2	0	0
Gomphonema parvulum	0	0	2	2	0	0	0	16	0	0	0	0	0	6	4	0	2	0
Gomphonema truncatum	0	0	0	2	32	2	2	0	0	0	0	0	0	0	0	0	2	0
Gomphonema subtile	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hantzschia amphioxys	0	0	0	2	12	6	14	0	0	0	0	0	4	0	0	0	2	0
Melosira undulata	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0
Melosira circulare	0	0	0	0	0	2	0	0	0	0	0	0	12	0	0	0	4	0

...TAXON	T3B	T4B	Tj7B	T8B	T12B	T13B	T14B	T16B	U1B	U2B	V1B	Vu1B	B1C	B2C	B4C	B5C	B6C	A1C
Navicula costulata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Navicula cryptocephala	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Navicula indifferens	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
Navicula jaernefeltii	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
Navicula mediocris	0	2	0	0	0	0	0	0	0	0	2	0	0	0	0	2	0	0
Navicula menisculus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Navicula pseudoscutiformis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Navicula pupula	0	4	2	6	4	4	3	0	0	0	0	0	6	0	0	0	6	0
Navicula radiosa	0	8	0	0	2	8	18	0	2	0	0	6	4	5	0	0	11	0
Navicula seminulum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Navicula spp.	0	0	0	0	2	0	0	0	0	0	0	0	2	0	0	0	0	0
Neidium ampliatum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nitzschia fonticola	2	2	0	2	12	6	2	0	0	0	2	0	7	0	0	2	2	0
Nitzschia palea	0	0	0	0	0	0	6	0	0	0	0	2	0	4	2	0	2	0
Nitzschia spp.	2	0	0	0	12	1	1	2	0	2	0	2	2	5	0	2	6	0
Peronia fibula	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	2	0	0
Pinnularia borealis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pinnularia gibba	8	0	2	4	0	2	16	2	0	6	2	4	2	5	0	0	0	0
Pinnularia maior	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
Pinnularia nodosa	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
Pinnularia spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rhoicosphenia abbreviata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rhopalodia gibba	0	2	2	0	2	2	16	0	0	0	0	0	0	0	0	0	4	0
Stauroneis phoenicenteron	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
Stauroneis angustata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Stauroneis ovalis	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
Tabellaria fenestrata	2	0	0	2	0	0	0	0	2	2	0	0	0	0	0	0	0	0
Tabellaria flocculosa	60	103	190	126	22	36	14	120	42	230	142	137	2	21	4	34	2	34
DIATOM SUM	453	440	428	416	433	457	463	408	439	434	417	424	411	445	418	432	447	484

TAXON	C1C	Ie1C	Ie2C	I1C	I2C	I4C	Is1C	K4C	K5C	K6C	La1C	Le1C	M1C	P1C	T1C	T3C	T4C	Tj7C
Achnanthes flexella	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	19	0	0
Achnanthes impexa	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Achnanthes lanceolata	0	0	0	0	0	0	0	2	0	2	0	0	2	2	0	6	0	0
Achnanthes levanderi	0	0	1	0	0	4	0	0	5	7	0	0	5	0	0	8	0	0
Achnanthes linearis	0	0	4	0	0	0	0	0	0	0	8	0	3	0	2	0	0	12
Achnanthes minutissima	28	109	76	16	24	100	7	20	77	130	55	124	78	24	132	206	70	82
A. minutissima v. saprophila	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
Achnanthes pusilla	4	16	0	10	4	6	15	0	6	8	0	3	0	2	0	14	2	0
Achnanthes subatomoides	0	4	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0
Amphora copulata	0	0	0	0	0	0	0	0	0	2	0	0	0	4	4	0	0	0
Anomoeoneis brachysira	4	14	13	13	2	47	4	20	0	11	4	4	0	0	46	2	14	16
Anomoeoneis vitrea	0	7	0	0	0	0	0	0	26	12	0	0	8	7	8	46	8	4
Asterionella formosa	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	8
Aulacoseira alpigena	12	0	8	0	0	2	6	0	0	0	0	8	0	12	0	8	0	0
Aulacoseira ambigua	0	0	0	0	0	0	0	0	4	0	0	0	8	0	0	0	0	0
Aulacoseira distans	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aulacoseira subarctica	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Caloneis bacillum	0	0	6	0	0	0	0	0	0	0	0	0	5	4	0	2	0	0
Cocconeis pediculus	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0
Cocconeis placentula	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyclotella comensis	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
Cyclotella radiosa	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyclotella rossii	0	1	0	2	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Cyclotella stelligera	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cymbella amphicephala	0	0	2	2	2	2	6	4	0	4	2	0	4	6	18	10	0	4
Cymbella cesatii	0	0	0	2	0	0	0	0	10	0	4	0	0	0	4	30	0	0
Cymbella descripta	2	10	6	12	0	4	8	6	8	14	4	0	0	0	9	14	0	6
Cymbella minuta	0	2	2	0	0	0	0	0	0	0	0	0	0	8	0	2	2	2
Cymbella naviculiformis	0	2	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
Cymbella silesiaca	2	2	4	2	0	4	4	0	2	2	2	0	3	0	0	0	2	2
Denticula tenuis	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	2	0	0
Diatoma moniliformis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Diatoma tenuis	2	0	4	0	2	2	0	0	14	1	2	0	2	14	2	10	2	0
Diatoma vulgaris	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

...TAXON	C1C	Ie1C	Ie2C	I1C	I2C	I4C	Is1C	K4C	K5C	K6C	La1C	Le1C	M1C	P1C	T1C	T3C	T4C	Tj7C
Didymosphenia geminata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
Diploneis ovalis v. lineata	0	2	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0
Epithemia adnata	0	2	0	0	0	0	12	0	0	6	0	0	10	0	0	2	0	0
Epithemia sorex	0	0	0	0	0	0	16	0	2	0	0	0	0	0	0	0	0	0
Eunotia bilunaris	0	0	0	2	0	0	0	2	4	0	0	0	2	0	0	0	0	0
Eunotia exigua	0	0	0	0	0	0	0	0	9	0	0	0	0	0	0	0	0	0
Eunotia faba	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eunotia implicata	2	0	12	18	14	16	4	48	4	2	4	20	2	0	20	12	28	2
Eunotia incisa	0	0	0	6	0	2	0	2	8	2	0	3	4	0	0	0	0	0
Eunotia meisteri	0	2	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0
Eunotia praerupta	0	0	2	10	0	0	0	2	4	2	0	0	0	0	6	0	0	2
Eunotia serra	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eunotia trioides	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
Fragilaria arcus	122	0	0	0	8	10	11	0	0	0	66	38	5	5	2	2	34	4
Fragilaria brevistriata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
F. capucina v. capucina	16	16	22	8	2	8	2	6	4	32	16	9	16	18	2	12	12	8
F. capucina v. gracilis	16	16	29	60	148	16	91	86	59	30	6	22	10	16	43	48	19	38
F. capucina v. mesolepta	0	0	2	5	0	4	0	12	4	2	32	4	0	110	0	40	0	32
F. capucina v. vaucheriae	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0
Fragilaria construens	0	12	0	0	0	8	0	0	18	17	14	0	0	58	0	8	4	0
Fragilaria crotonensis	0	0	0	0	0	2	0	0	0	0	0	0	2	0	0	0	0	0
Fragilaria pinnata	0	4	0	0	0	0	0	0	0	14	0	2	2	2	0	0	0	0
Fragilaria rumpens	0	0	4	0	0	0	19	0	0	0	16	0	0	0	0	6	0	0
Fragilaria tenera	0	2	2	18	16	8	0	0	8	2	8	12	140	4	2	3	6	11
Fragilaria ulna	83	4	6	20	6	26	123	20	14	12	21	111	17	8	22	10	34	2
Fragilaria virescens	0	2	6	0	0	0	2	0	4	0	0	0	2	8	0	2	0	0
Frustulia rhomboides	0	2	0	0	0	2	0	0	2	0	0	2	0	2	0	0	0	0
Gomphonema acuminatum	0	2	0	0	0	0	0	0	0	2	0	0	6	0	0	2	2	2
Gomphonema gracile	0	0	0	4	0	4	0	2	16	0	2	6	2	0	0	0	4	0
Gomphonema parvulum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	2	0
Gomphonema truncatum	14	0	0	0	0	0	12	0	0	2	0	0	0	0	0	0	8	0
Gomphonema subtile	0	0	0	0	0	0	0	0	0	0	0	20	0	0	0	0	0	0
Hantzschia amphioxys	0	0	0	0	0	26	4	0	0	2	0	0	10	0	0	8	0	0
Melosira undulata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Melosira circulare	2	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0

...TAXON	C1C	Ie1C	Ie2C	I1C	I2C	I4C	Is1C	K4C	K5C	K6C	La1C	Le1C	M1C	P1C	T1C	T3C	T4C	Tj7C
Navicula costulata	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
Navicula cryptocephala	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
Navicula indifferens	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Navicula jaernefeltii	0	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0	0
Navicula mediocris	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Navicula menisculus	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
Navicula pseudoscutiformis	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Navicula pupula	0	0	3	0	0	0	0	0	6	5	1	0	2	1	2	0	0	0
Navicula radiosa	6	0	0	2	0	0	5	0	0	4	0	2	5	8	5	0	0	0
Navicula seminulum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Navicula spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
Neidium ampliatum	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
Nitzschia fonticola	2	2	0	1	0	0	16	0	2	2	0	0	2	0	0	2	0	0
Nitzschia palea	0	0	0	0	0	0	5	0	0	0	0	0	0	8	1	0	0	1
Nitzschia spp.	0	0	0	0	0	0	0	0	1	0	2	0	2	0	0	4	0	1
Peronia fibula	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
Pinnularia borealis	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
Pinnularia gibba	2	2	0	2	0	0	0	0	2	4	0	2	2	4	4	10	2	0
Pinnularia maior	0	0	0	0	0	6	0	0	0	0	0	0	0	0	2	0	0	0
Pinnularia nodosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pinnularia spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rhoicosphenia abbreviata	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0
Rhopalodia gibba	6	0	0	4	0	0	0	0	0	0	0	0	12	0	0	0	0	0
Stauroneis phoenicenteron	0	0	0	0	0	0	0	0	0	4	0	0	0	2	0	0	0	0
Stauroneis angustata	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0
Stauroneis ovalis	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0
Tabellaria fenestrata	0	4	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	2
Tabellaria flocculosa	79	186	219	280	332	161	42	235	108	75	130	29	59	56	82	62	179	187
DIATOM SUM	404	441	434	503	570	470	416	467	442	417	405	421	446	426	422	616	436	428

TAXON	T8C	T12C	T13C	T14C	T16C	U1C	U2C	V1C	Vu1C
Achnanthes flexella	0	0	0	0	0	0	0	0	0
Achnanthes impexa	0	0	0	0	0	0	0	0	0
Achnanthes lanceolata	0	0	2	0	0	0	0	0	0
Achnanthes levanderi	0	0	4	3	5	0	0	2	0
Achnanthes linearis	0	0	0	0	2	0	0	0	0
Achnanthes minutissima	94	81	164	138	94	206	62	74	64
A. minutissima v. saprophila	0	0	0	2	0	0	0	0	0
Achnanthes pusilla	0	0	19	5	0	0	2	0	11
Achnanthes subatomoides	0	0	0	0	0	0	0	0	0
Amphora copulata	2	2	0	0	0	0	0	0	0
Anomoeoneis brachysira	12	0	14	4	23	6	13	8	32
Anomoeoneis vitrea	6	6	26	5	18	0	2	15	0
Asterionella formosa	0	0	0	0	0	0	0	0	0
Aulacoseira alpigena	0	0	6	6	0	0	8	0	0
Aulacoseira ambigua	0	0	0	0	0	0	0	0	0
Aulacoseira distans	0	0	0	0	0	0	0	0	0
Aulacoseira subarctica	0	0	0	0	0	0	6	0	0
Caloneis bacillum	2	2	6	2	0	0	2	2	0
Cocconeis pediculus	0	0	0	0	0	0	0	0	0
Cocconeis placentula	0	0	0	0	0	0	0	2	0
Cyclotella comensis	0	0	0	0	0	0	0	0	0
Cyclotella radiosa	0	0	0	0	0	0	0	0	0
Cyclotella rossii	0	0	0	0	0	0	0	0	0
Cyclotella stelligera	0	0	0	0	0	0	0	0	0
Cymbella amphicephala	0	0	12	8	0	6	0	2	0
Cymbella cesatii	0	0	2	0	0	2	2	2	0
Cymbella descripta	2	0	4	4	2	0	0	0	28
Cymbella minuta	0	26	14	2	0	0	0	0	0
Cymbella naviculiformis	0	0	0	9	0	0	0	0	0
Cymbella silesiaca	2	15	8	6	10	2	0	2	16
Denticula tenuis	0	0	0	0	0	0	0	0	0
Diatoma moniliformis	0	0	0	0	0	0	0	0	0
Diatoma tenuis	0	2	8	3	4	8	2	11	4
Diatoma vulgaris	0	0	0	0	0	0	0	0	0

...TAXON	T8C	T12C	T13C	T14C	T16C	U1C	U2C	V1C	Vu1C
Didymosphenia geminata	0	0	0	0	0	2	0	0	0
Diploneis ovalis v. lineata	0	30	2	2	0	0	2	0	0
Epithemia adnata	2	8	4	27	0	0	0	0	0
Epithemia sorex	0	0	0	2	0	0	0	0	0
Eunotia bilunaris	0	0	0	0	2	0	4	0	0
Eunotia exigua	0	0	0	0	0	0	0	0	0
Eunotia faba	0	0	0	0	0	0	0	0	0
Eunotia implicata	26	2	6	0	14	23	6	8	0
Eunotia incisa	8	0	0	0	2	4	2	0	2
Eunotia meisteri	0	0	0	0	0	0	0	0	0
Eunotia praerupta	0	0	0	0	0	0	4	2	0
Eunotia serra	0	0	0	0	0	0	0	0	0
Eunotia trioides	0	0	0	0	0	2	0	0	0
Fragilaria arcus	0	1	0	0	0	45	10	0	0
Fragilaria brevistriata	0	0	0	0	0	0	0	2	0
F. capucina v. capucina	6	0	6	25	4	8	20	4	0
F. capucina v. gracilis	46	15	9	24	3	28	20	36	26
F. capucina v. mesolepta	0	130	12	62	0	0	0	6	4
F. capucina v. vaucheriae	0	0	0	0	0	0	0	0	0
Fragilaria construens	2	10	50	0	0	0	0	4	0
Fragilaria crotonensis	0	0	0	0	0	0	0	0	0
Fragilaria pinnata	0	0	0	0	0	0	0	0	0
Fragilaria rumpens	0	0	0	0	0	4	2	0	0
Fragilaria tenera	5	0	10	34	48	12	10	20	4
Fragilaria ulna	9	44	5	22	10	5	28	43	6
Fragilaria virescens	1	0	0	4	0	0	2	0	2
Frustulia rhomboides	0	0	2	0	0	0	0	0	6
Gomphonema acuminatum	0	0	2	0	0	0	0	0	4
Gomphonema gracile	23	0	0	0	0	0	2	4	0
Gomphonema parvulum	4	4	0	4	2	0	0	0	0
Gomphonema truncatum	0	25	2	0	0	0	0	0	0
Gomphonema subtile	0	0	0	0	0	0	0	0	0
Hantzschia amphioxys	0	16	0	0	0	0	0	2	0
Melosira undulata	0	13	0	0	0	0	0	0	0
Melosira circulare	0	0	0	0	0	0	0	0	0

...TAXON	T8C	T12C	T13C	T14C	T16C	U1C	U2C	V1C	Vu1C
Navicula costulata	0	0	0	0	0	0	0	0	0
Navicula cryptocephala	0	0	0	0	0	0	0	0	0
Navicula indifferens	0	0	0	0	0	0	0	0	0
Navicula jaernefeltii	0	0	2	0	0	0	0	0	0
Navicula mediocris	0	0	0	0	0	0	0	1	0
Navicula menisculus	0	0	0	0	0	0	0	0	0
Navicula pseudoscutiformis	0	0	0	0	0	0	0	0	0
Navicula pupula	2	0	3	0	6	0	0	1	0
Navicula radiosa	0	0	7	12	0	2	2	3	4
Navicula seminulum	0	2	0	2	0	0	0	0	0
Navicula spp.	0	0	0	2	0	0	0	0	0
Neidium ampliatum	0	0	0	0	0	0	0	0	0
Nitzschia fonticola	0	4	4	0	0	0	0	0	0
Nitzschia palea	0	0	0	0	0	0	0	0	0
Nitzschia spp.	0	4	2	0	8	0	0	0	0
Peronia fibula	0	0	0	4	0	0	0	0	0
Pinnularia borealis	0	0	0	0	0	0	0	0	0
Pinnularia gibba	0	6	2	0	4	0	4	0	0
Pinnularia maior	0	0	0	0	0	0	0	0	0
Pinnularia nodosa	0	0	0	0	0	0	2	0	0
Pinnularia spp.	0	0	0	2	0	0	0	0	0
Rhoicosphenia abbreviata	0	0	0	2	0	0	0	0	0
Rhopalodia gibba	0	0	2	8	2	0	0	0	6
Stauroneis phoenicenteron	0	0	0	0	0	0	0	0	0
Stauroneis angustata	0	0	0	0	0	0	0	0	0
Stauroneis ovalis	0	0	2	0	0	0	0	0	0
Tabellaria fenestrata	0	0	0	0	0	0	2	0	0
Tabellaria flocculosa	164	14	18	33	169	62	192	146	208
DIATOM SUM	418	462	441	468	432	427	413	402	427

Part II

Heikki Erkinaro and Jaakko Erkinaro

Ecological status of the River Tenojoki system: macrozoobenthos in rivers

Table

Introduction

Benthos integrates some central components and processes in a river ecosystem. While controlling the primary producers, benthic animals are at the same time the main food source for many invertebrates as well as for fish. Accordingly, benthic animals have been widely used as ecological quality indicators in the river assessments. There are many advantages in using them in ecological status assessments. They are quite ubiquitous, sedentary organisms with a relatively long lifespan, which also have the stressor-specificity needed: perturbations such as organic pollution, acidification and habitat degradation all affect macroinvertebrate communities in a different way. With this well-proven assessment tradition macroinvertebrates were also included in the ecological assessment scheme of the EU Water Framework Directive (WFD). Life-history characteristics make benthic animals a biological group with a typically intermediate response time compared with other biological quality elements used in the WFD, e.g. fish and benthic algae. One of the aims in the project ”The preservation of the River Tenojoki as a salmon river in its natural state – environmental work, ecological condition and monitoring” was to make an ecological status assessment in the water system. Benthic animals were part of this assessment. In this connection, special attention was also paid to the assessment criteria required in the WFD.

2 Material and methods

General ecological status assessment, including also benthos surveys, has been undertaken twice, in 1989 and 1994, in the River Tenojoki watercourse (Lax et al. 1993, Hämäläinen et al. 1996). For the present study, benthic animals were collected mainly in the years 1990 and 1991. The studies are, however, not directly comparable in some aspects. Firstly, sampling stations were not the same – in the present study sampling was done at the permanent electrofishing stations belonging to the Atlantic salmon monitoring program of Finnish Game and Fisheries Research Institute (FGFRI). Secondly, the sampling methods used did also differ – Surber sampler was used in this study while kick-net was the method used in the surveys of 1989 and 1994 (Lax et al. 1993, Hämäläinen et al. 1996).

In the present study, benthic animals were sampled in the River Tenojoki and its main tributaries in August–September in 1990 and 1991 (Fig. 1). In addition, benthos samples collected at two brooks (Padda, Vidgaveädji) and two main stem stations in the rivers Tenojoki and Utsjoki in August–September 1993 were also included to the present study. All samples were taken with a Surber sampler (frame size 0.30 m x 0.30 m, mesh size 500 μm), three replicates at each sampling station covering a total bottom-area of 0.27 m^2. Sampling areas were situated at riffle habitats in the very proximity of the electrofishing stations. Sampling procedure was conducted following the guidelines of CEN-standard (SFS-EN-28265). Samples were preserved with 70–80 % ethanol in the field and later picked and sorted on a white plate in the laboratory before identification. Animals were identified to the lowest feasible level, mainly to the species level.

Fig. 1. The River Tenojoki watercourse in northernmost Finland and Norway. Zoobenthos sampling sites are indicated with open circles.

2.1 Biotic indices

General ecological status was studied with biotic indices. Biological Monitoring Working Party (BMWP) is an index depicting organic pollution and general ecological water quality (Armitage et al. 1983). The index is based on family-specific sensitivities towards organic pollution. Family scores range from 1 (pollution-tolerant) to 10 (sensitive) and the final score is given by adding up the scores of the families present. Accordingly, high scores indicate high ecological status. ASPT-index (Average Score Per Taxon) is derived from BMWP by dividing the total BMWP-index score by the actual number of scoring taxa. This is done to diminish the effect of overall faunal richness on the index value. Comparisons among different sampling stations should be done with these indices only intra-seasonally (Clarke et al. 2002).

EPT-index summarizes the total number of species belonging to the orders Ephemeroptera, Plecoptera and Trichoptera – all insect orders known for their pollution-sensitivity. The index was originally used to indicate polluted water bodies, but it has been used also more generally as an index for water quality (Lenat 1988).

2.2 A multimetric approach

AQEM (The Development and Testing of an Integrated Assessment System for the Ecological Quality of Streams and Rivers throughout Europe using Benthic Macro-invertebrates) assessment system includes a multimetric tool, which classifies sampling stations into ecological quality classes from 5 (high) to 1 (bad) based on benthos composition. The method has a stressor-specific approach specifying the main stressor currently affecting the stream. Three perturbation types are recognized in the assessment: acidification, organic pollution and morphological degradation of the stream (AQEM CONSORTIUM 2002). Many of the metrics used in this multimetric assessment procedure are common, widely used biotic indices (e.g. ASPT, EPT-index, Saprobic-index and Shannon-Wiener diversity-index). AQEM method is also stream type-specific and, being based on the tested assessment criteria of the AQEM project, it can be applied for altogether 28 different stream types occurring in the 8 member countries of AQEM CONSORTIUM (2002). Finland was not participating in the development of the AQEM method. Therefore, boreal highland streams in Sweden (type S03 in the AQEM scheme) were the reference stream type used in this study. The multimetric AQEM system for the given stream type (S03) uses only two metrics: the Acid Index by Henrikson & Medin (1986) and the number of EPT taxa.

2.3 Multivariate analysis

Non-metric Multidimensional Scaling (NMS) was used to study similarities in the species composition and abundance among the sampling stations. NMS is an indirect ordination method, which diminishes multidimensionality in a community data to fewer dimensions. The process is aimed at ordering samples to emphasize underlying trends or patterns. Proximity of two samples in the ordination space reflects their ecological similarity. All three replicates from each sample station were pooled before the analysis and the species abundances used were (log n+1)- transformed. The data of Hämäläinen et al. (1996) was also included in the analysis for comparison. Each kick-net sample replicate was estimated to account for a sampled area of one square meter. This subjective data modification had to be done because kick-netting is not a truly quantitative sampling method.

Results

3

In total, 78 benthic macroinvertebrate taxa were encountered in the present study. Taxa numbers per sampling site varied remarkably between the rivers. The highest numbers were attained in the samples of the upper Inarijoki area (43) whereas samples from the brooks and the River Kevojoki were poorest in taxa numbers (Fig. 2). The median number of taxa present per sampling site was 22 in the whole study material. For comparison, survey material of Hämäläinen et al. (1996) is also included in the result pictures. Comprehensive taxa list is presented in the Appendix 1.

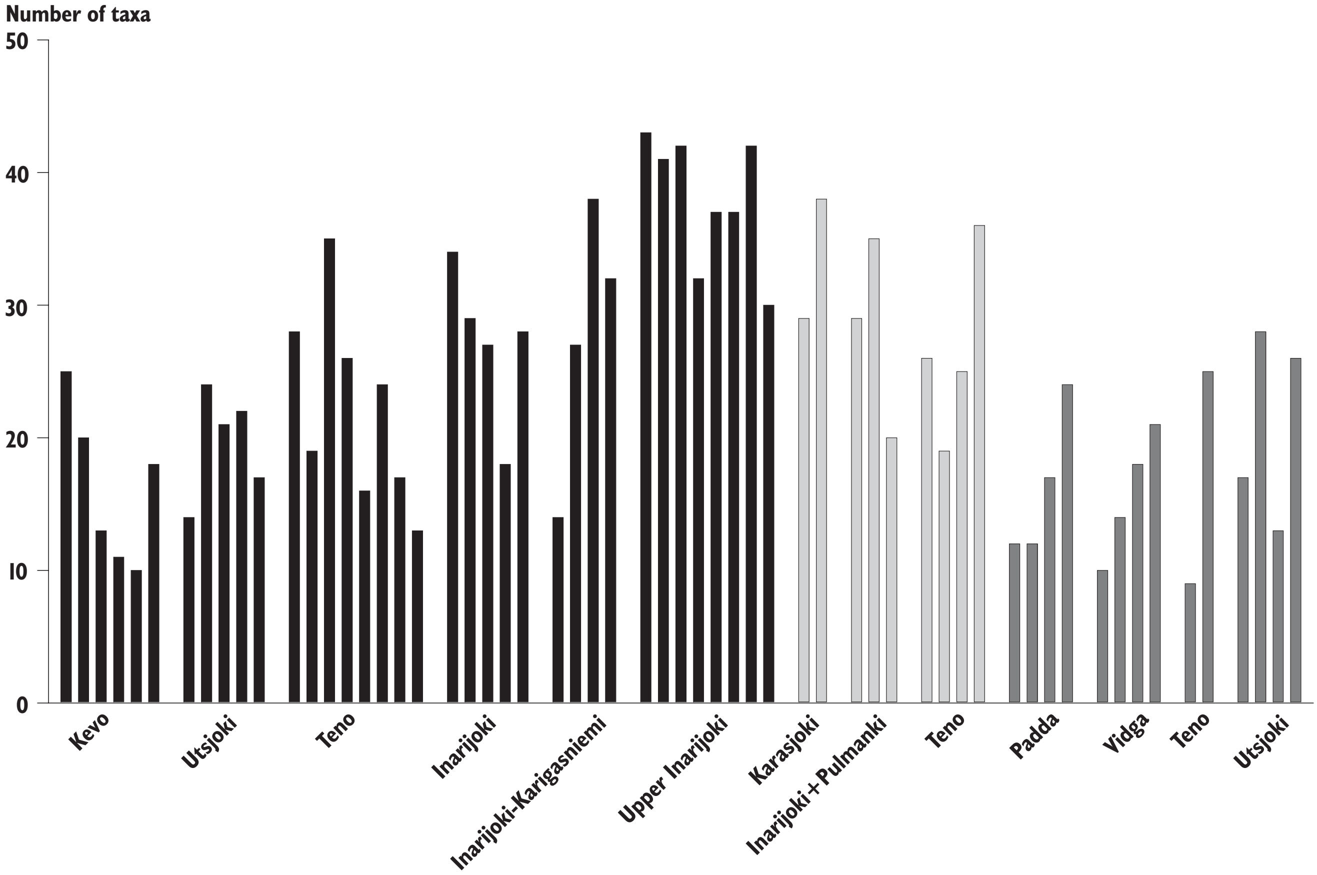


Fig. 2. Number of taxa in different sampling sites in the River Tenojoki system. Survey 1990–1991 in black, data of Hämäläinen et al. (1996) in light gray, survey 1993 material in dark gray.

The most abundant taxa in the River Tenojoki system were chironomid larvae (Diptera) and mayfly nymphs (Ephemeroptera), especially *Baetis rhodani*. Other abundant taxa included e.g. mayflies *Ephemerella aurivillii*, *Heptagenia dalecarlica* and *Ameletus inopinatus*. Upper parts of the River Inarijoki were richest in abundance (*c.* 5 000–13 000 ind./m^2; Fig. 3). Lowest densities (*c.* 100–300 ind./m^2) were met in the River Kevojoki and the two brooks.

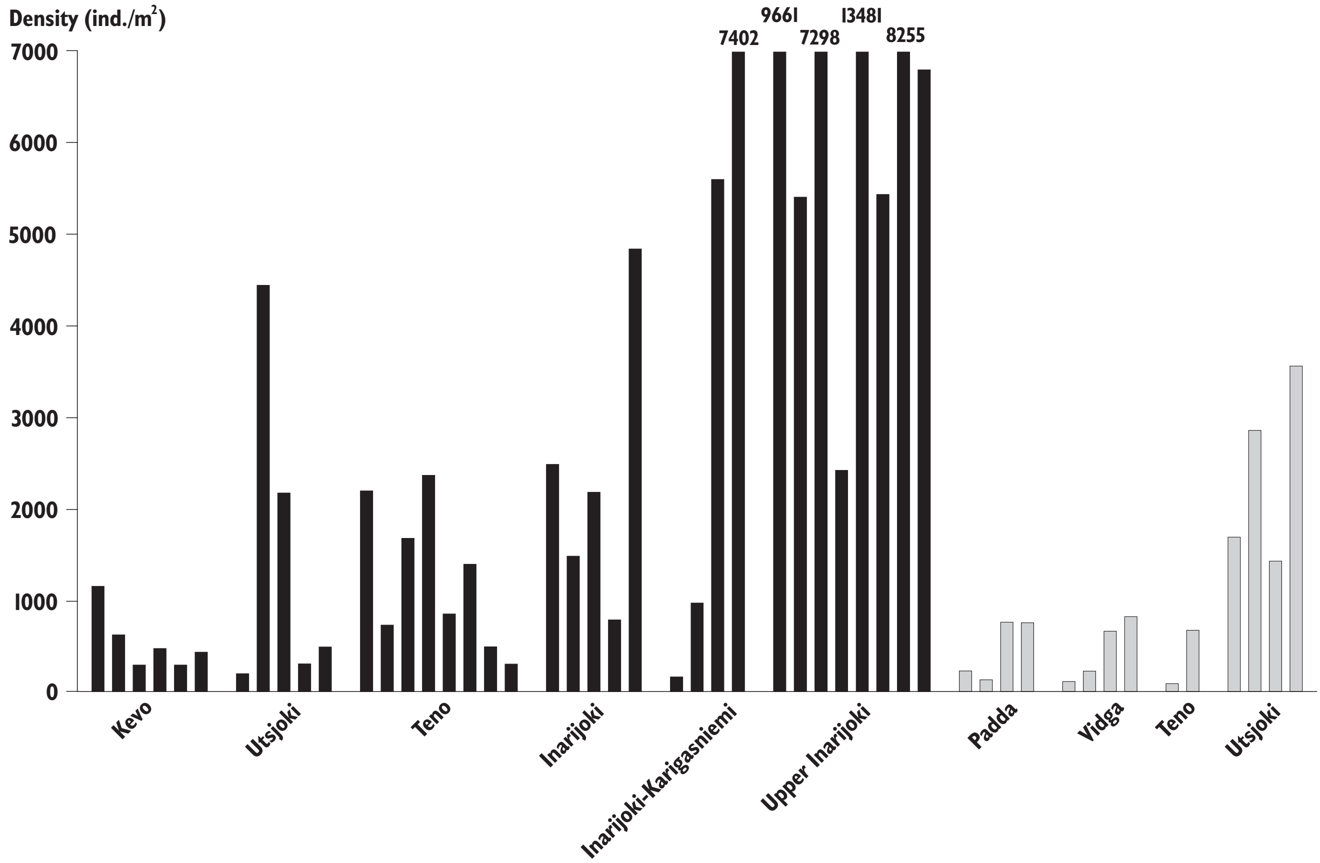
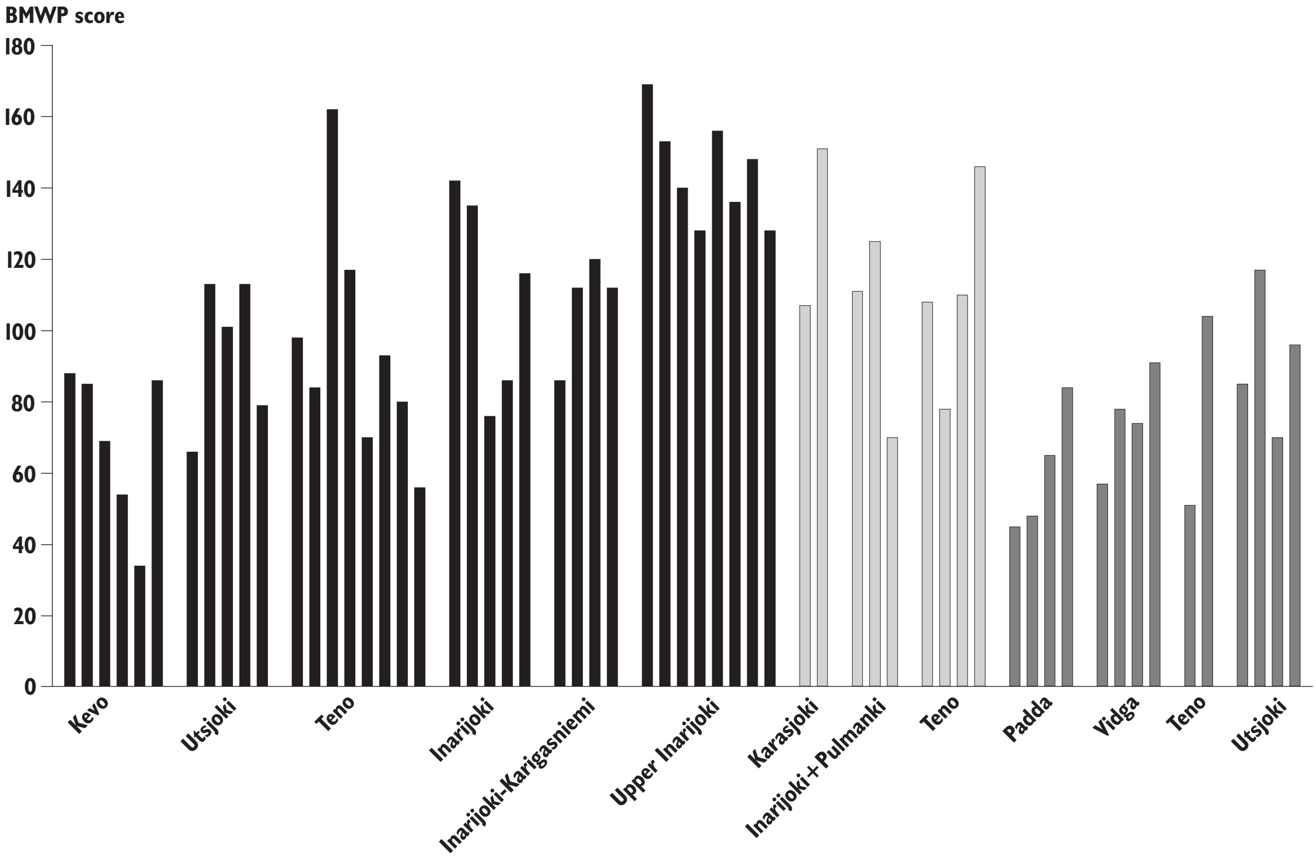
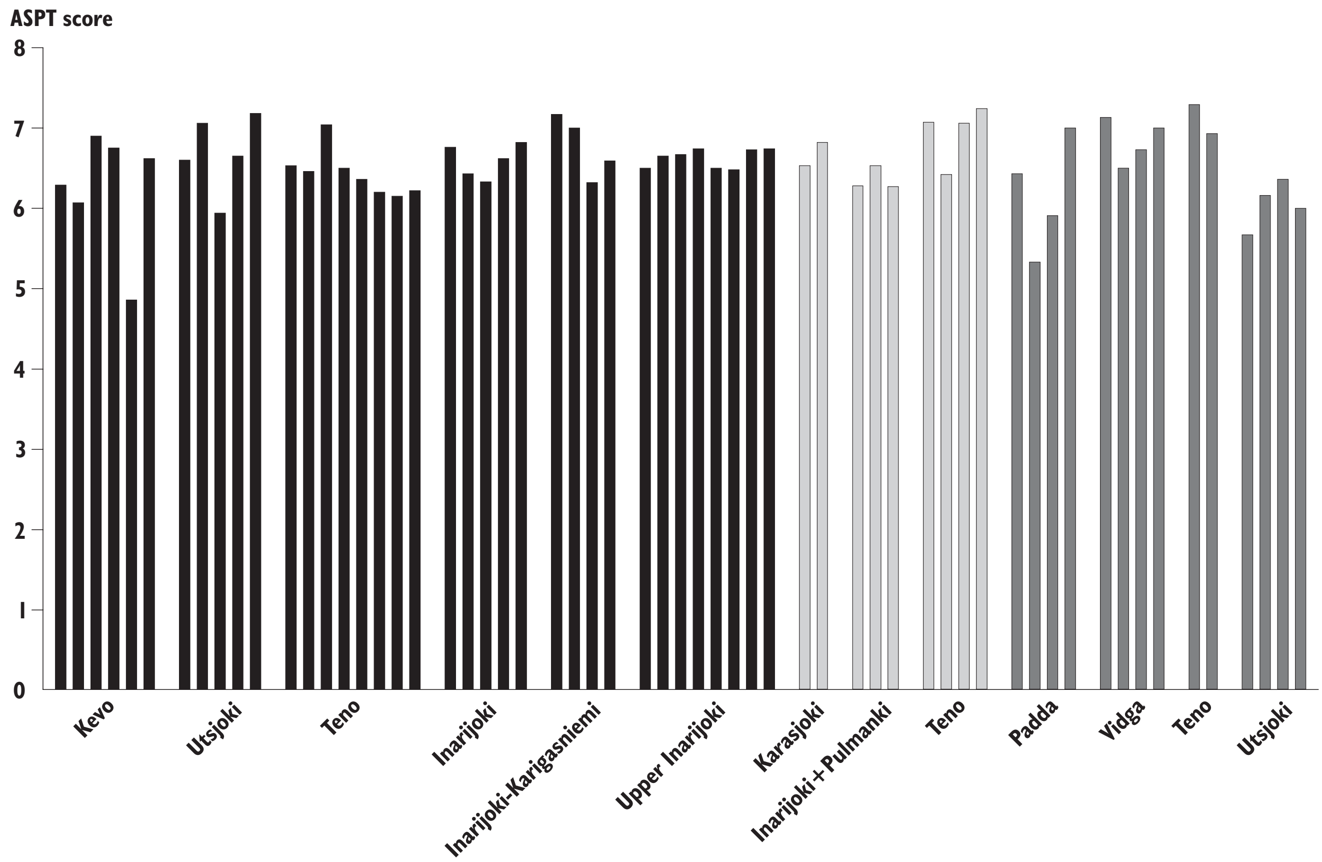


Fig. 3. Density of benthic animals. Survey 1990–1991 in black, survey 1993 material in dark grey. Data of Hämäläinen et al. (1996) are not included, because the sampling method (kick-net) was not quantitative.

Ecological status in different parts of the River Tenojoki system varied depending on the biotic indices (ASPT, BMWP) used. Overall, ASPT-index attained fairly even results (scores between 6 and 7) with only few exceptions (Fig. 4). On the contrary, BMWP scores varied a lot among the sampling stations. The highest BMWP scores were reached in the upper River Inarijoki area, while the lowest values were found again in the River Kevojoki and the two brooks (Fig. 4). The number of EPT- taxa per sampling site ranged between 5 and 29 (median 16) showing quite a similar pattern with the BMWP scores (Fig. 5).





Figs. 4. BMWP (upper panel) and ASPT (lower panel) scores in different sampling sites in the River Tenojoki system. Survey 1990–1991 in black, data of Hämäläinen et al. (1996) in light gray, survey 1993 material in dark gray.

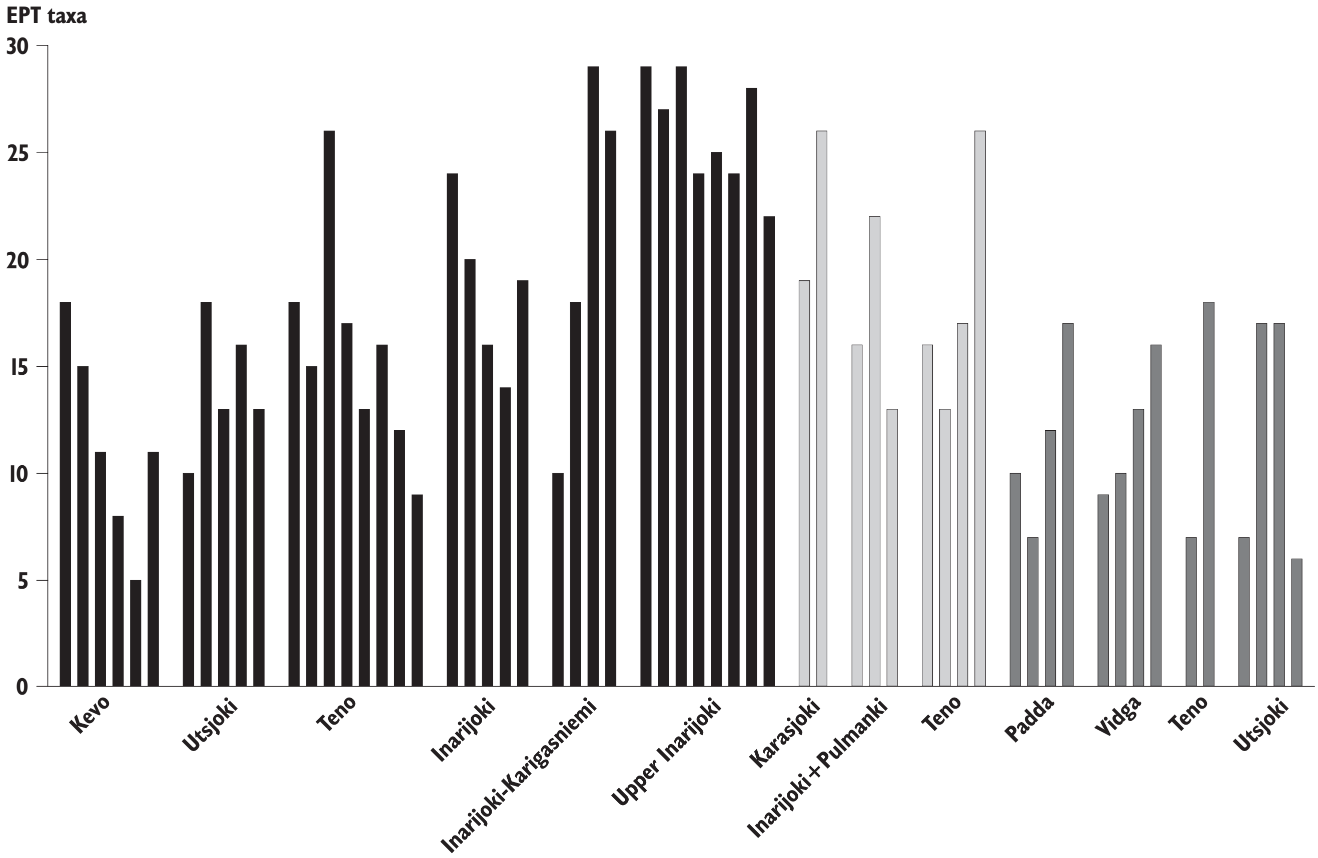


Fig. 5. Number of EPT taxa in different sampling sites in the River Tenojoki system. Survey 1990–1991 in black, data of Hämäläinen et al. (1996) in light gray, survey 1993 material in dark gray.

The multimetric AQEM-index placed sampling areas mainly to the highest class (class 5) indicating high ecological status. The most remarkable exceptions were many sampling stations in the River Kevojoki and in the brooks Vidgaveädji and Padda (Table 1). When considering the components of the AQEM-index separately, the Acid Index reached more often lower class scores.

Table 1. AQEM-index values for all sample sites. All samples have been collected in 1991 if not indicated otherwise. Survey data by Hämäläinen et al. (1996) also included.

Site	Acid Index	EPT-index	AQEM-class	Site	Acid Index	EPT-index	AQEM-class
River Kevojoki				**Upper Inarijoki**			
Ke 1	4	5	**5**	In-Su-1990	5	5	**5**
Ke 8	5	5	**5**	In 1-1990	5	5	**5**
Ke 13	2	5	**3**	In 2-1990	5	5	**5**
Ke 18	2	4	**2**	In 4-1990	5	5	**5**
Ke 22	3	2	**2**	In-Su-1991	5	5	**5**
Ke 25	5	5	**5**	In 1-1991	5	5	**5**
River Tenojoki				In 2-1991	5	5	**5**
Te 1	5	5	**5**	In 4-1991	5	5	**5**
Te 4	5	5	**5**	**Hämäläinen et al. (1996)**			
Te 10	5	5	**5**	K 1	3	5	**4**
Te 18	5	5	**5**	K 2	5	5	**5**
Te 22	2	5	**3**	I 2	4	5	**5**
Te 25	4	5	**5**	P1	5	5	**5**
Te 29	5	5	**5**	PY 1	3	5	**4**
Te 32	3	4	**3**	T 1	3	5	**4**
River Utsjoki				T 7	2	5	**3**
Uts 2	2	4	**2**	T 12	4	5	**5**
Uts 5	5	5	**5**	T 13	5	5	**5**
Uts 8	5	5	**5**	**Brooks (1993)**			
Uts 10	5	5	**5**	Pad up Aug	4	4	**4**
Uts 12	2	5	**3**	Pad low Aug	2	3	**2**
River Inarijoki				Pad up Sep	5	5	**5**
In 1	5	5	5	Pad low Sep	5	5	**5**
In 3	5	5	**5**	Vid up Aug	2	4	**2**
In 6	5	5	**5**	Vid low Aug	5	4	**5**
In 9	3	5	**4**	Vid up Sep	3	5	**4**
In 10	5	5	**5**	Vid low Sep	3	5	**4**
River Inarijoki at Karigasniemi				**River Tenojoki (1993)**			
Kar-Norway	3	4	**3**	Te Aug 93	1	3	**2**
Kar 1	5	5	**5**	Te Sep 93	5	5	**5**
Kar 2	5	5	**5**	**River Utsjoki lake outlet, Mantokoski (1993)**			
Kar 3	5	5	**5**				
				Man up Aug	5	3	**4**
				Man low Sep	5	3	**4**
				Man up Sep	5	5	**5**
				Man low Sep	5	5	**5**

In the NMS ordinations, three-dimensional solutions were selected. Three first axes accounted for 87.1 % of the variance in the data. Only two most important axes are shown in Figures 6 and 7 because two major gradients captured 67.6 % of the variance (first and second axes 36.2 and 31.4 %, respectively) in the benthos communities. Different rivers were separated quite well in the first ordination (Fig. 6). In general, sample stations of each river were located also close to each other indicating faunal resemblance. Most main stem stations were placed in the middle of the sample space, but the lake outlet sites from the uppermost areas of the River Inarijoki were located high along the second axis. The two lake outlet sites in the River Utsjoki (Man low and Man up) were situated close to each other in the upper ordination space. All lake outlet sites showed hence a diverged location in the ordination. Species-poor samples from the River Kevojoki and the two brooks were located at the lower left corner, especially the August-samples of the brooks were clearly distinguished. In addition, sampling areas from the study of Hämäläinen et al. (1996) stood apart from other areas showing different faunal composition.

Second ordination was performed without the 1993 material and that of Hämäläinen et al. (1996). This was because samples from these datasets deviated quite clearly from other samples. Three first axes accounted for 93.5 % of the variance in the data set (two first axes 43.2 and 26.8 %, respectively). Sites from the upper Inarijoki were again clearly separated, as were also samples from the River Kevojoki (Fig. 7). A couple of species- and individual-poor sampling stations were at the left corner of the ordination.

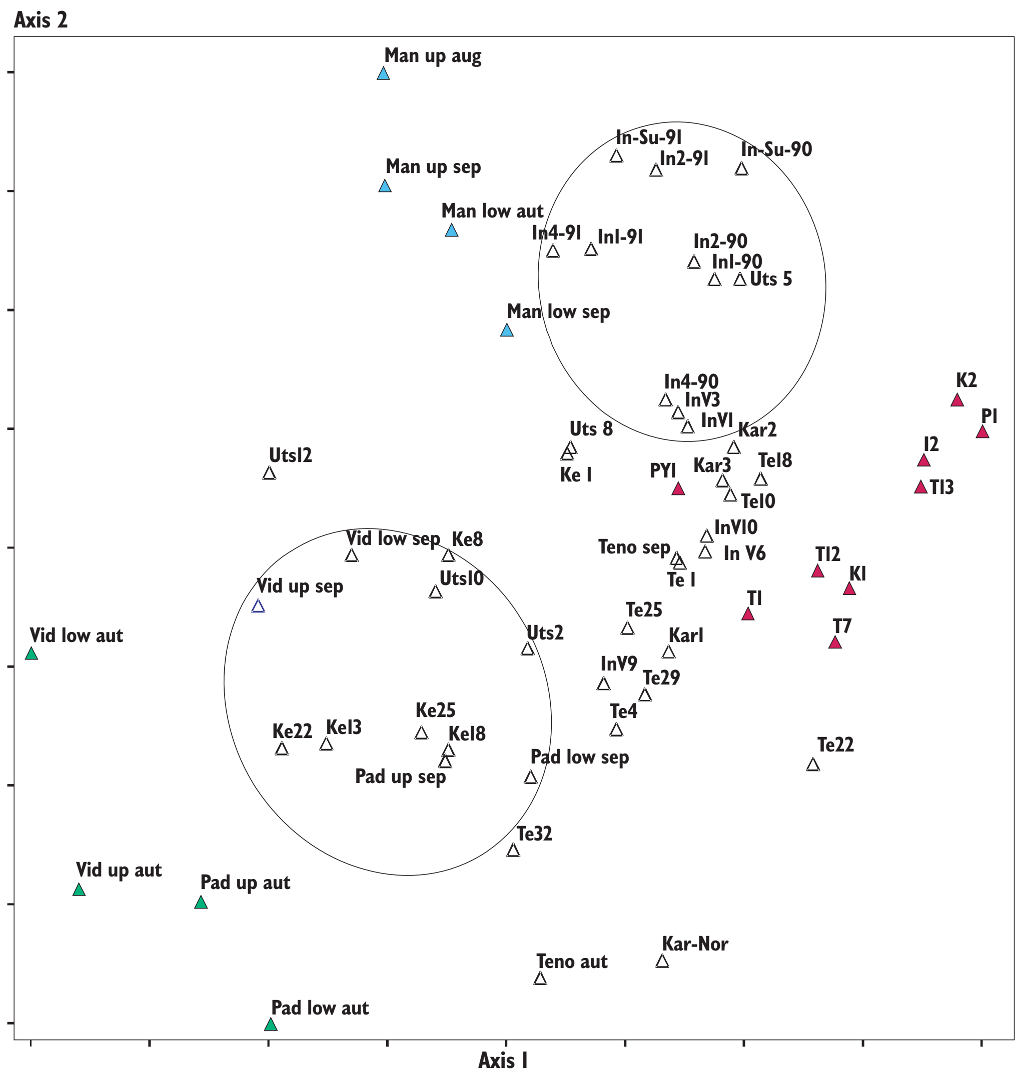


Fig 6. NMS ordination of the zoobenthos sampling sites. Red triangles: data of Hämäläinen et al. (1996); green triangles: August samples from the brooks; blue triangles: lake outlet sites of the River Utsjoki (Mantokoski up and low). For site description, see Table 1.

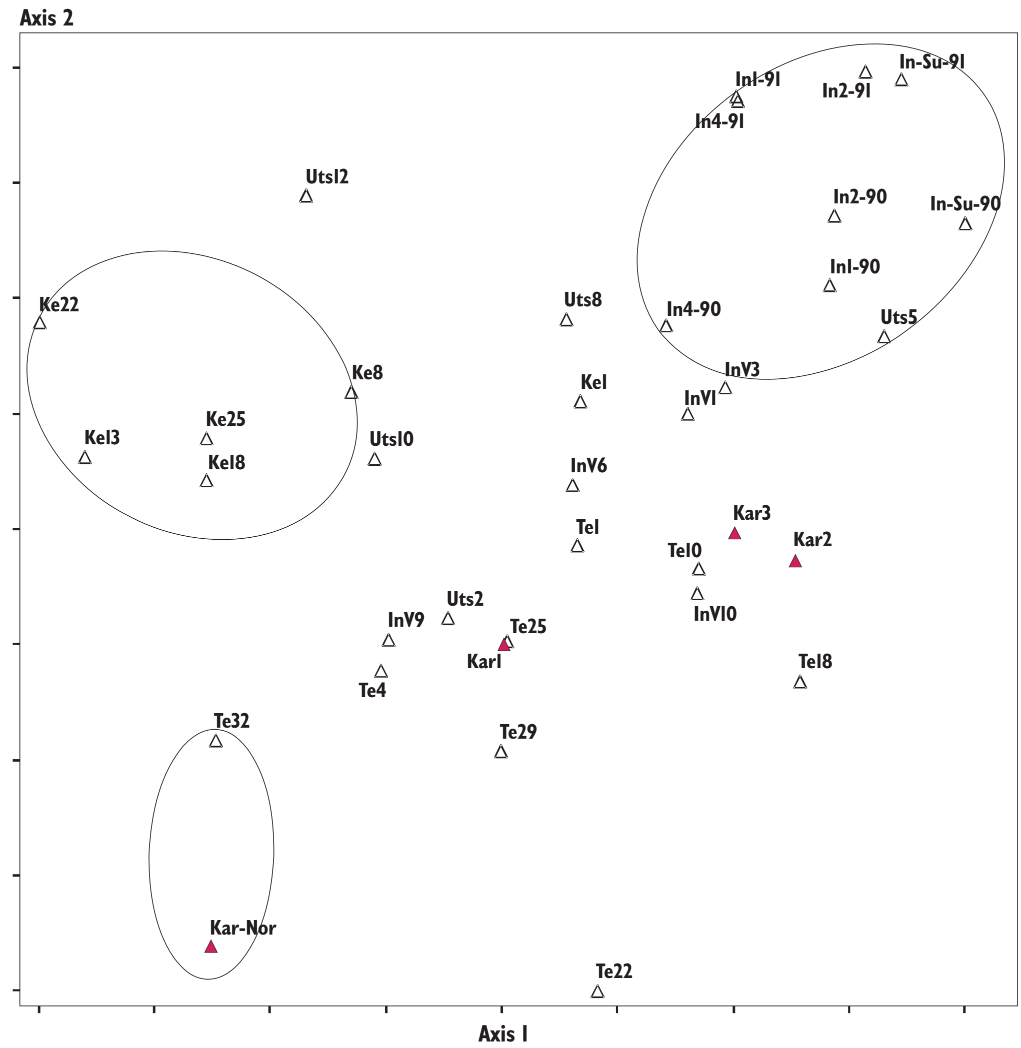


Fig 7. NMS ordination based on the 1990–1991 zoobenthos survey. Inarijoki samples nearby Karigasniemi marked with red. Sites Kar-Nor and Kar1 are situated upstream from the wastewater treatment plant, Kar2 and Kar3 downstream on the Finnish side.

4 Discussion

The total number of taxa (78) represented in the present study corresponds well to the levels discovered in the earlier surveys. Hämäläinen et al. (1996) identified 62 taxa from the main stems of the River Tenojoki and its major tributaries. Brooks included, the taxa number in the Hämäläinen et al. (1996) totalled 74. The median taxa number per sampling area (29) was a bit higher in Hämäläinen et al. (1996) compared with our results (22). Sampling methods and areas were not, however, identical in these studies.

BMWP scores varied a lot among the sampling areas. Half of the sampling areas reached 100 points, a level used as a lower limit for unpolluted or lightly polluted waters (e.g. Zamora-Munoz & Alba-Tercedor 1996). The number of taxa correlated strongly with BMWP scores, as was already shown in Hämäläinen et al. (1996). In the present study, also EPT-taxa numbers showed a similar relationship. Paradoxically, the highest as well as the lowest BMWP scores were attained in the most pristine river stretches – areas supposed to be least affected by human impacts: upper reaches of the River Inarijoki and the River Kevojoki. Upper parts of the River Inarijoki are lake-fed areas differing also geologically from the middle and lower parts of the River Tenojoki system (Koljonen 1992). Both factors – the lake outlet effect and the calcium-rich mafic-ultramafic bedrock are likely to elevate local nutritional conditions. The River Kevojoki, in turn, is a nutrient-poor river system harbouring low taxa numbers with low individual densities (Figs. 2 and 3).

Most parameters depicting the benthos status have obviously a unimodal response to eutrophication. This is at the prevailing low nutrient levels reflected e.g. in higher BMWP scores and a consequent status improvement along the nutrient gradient. Nevertheless, BMWP scores seemed to reflect also human-induced changes in nutrient levels. This was shown already in the elevated species numbers and BMWP scores downstream the Karasjok village by Lax et al. (1993) and Hämäläinen et al. (1996). In the present study, four closely spaced areas were sampled near to the Karigasniemi village. Two of the stations lay just above the outlet of a wastewater plant on both sides of the River Inarijoki (stations Kar-Nor and Kar1). Two other stations (Kar2 and Kar3) were situated at 200-meter intervals downstream from the wastewater treatment plant on the Finnish side. A probable enriching effect of the plant was reflected in many compositional and abundance aspects (see Figs. 2–5). Abundance, species richness and two of the biotic indices (BMWP scores and the number of EPT-taxa) all scored higher in the two impacted sites. The NMS ordinations did also point to a diverged faunal composition. ASPT was, however, the only metric to separate the sites ″correctly″ – two upper stations without the wastewater impact gained higher scores despite of the faunal poorness especially at the Norwegian sampling site.

In general, assessment results with ASPT scores seemed more plausible and showed overall very stable level among the study areas. While no defined criteria exist for status categories based on ASPT scores, values > 6.0 have generally been used to indicate high ecological status (e.g. Swedish EPA 2000). In the present study, ASPT scores varied mostly between 6 and 7. Similar score levels were observed also in two other northern benthos studies covering the Rivers Kola (NW Russia), Näätämöjoki (Meissner 2003) and Simojoki (Liljaniemi 2003). Benthos surveys in more southern rivers have generally shown somewhat lower ASPT scores (e.g. Nyman et al. 1986).

The AQEM method classified most sampling areas to the highest class indicating high ecological status. However, some reservations concerning the method must be noted. Firstly, there are some faunistic drawbacks in the assessment criteria of the Acid Index, at least when used in the north. For example, the occurrence of specimens belonging to the order Crustacea (e.g. Asellus spp., Gammarus spp.) plays too big a role in the calculation procedure. While occurrence of even a single specimen is worth 3/14 of all points available in the scheme, species of this order do not even normally occur in the northern riffle habitats. Anyway, Sandin et al. (2004) found this index quite applicable also in the northern Swedish conditions. They persuaded use of this method first of all due to its seasonal consistency; acidity levels prevailing during the springtime could be reliable determined also based on sole autumn samples. Secondly, the use of EPT-taxa as an assessment metric gives somewhat erratic response in these species-poor conditions, as already noted above in the case of BMWP. Nevertheless, AQEM method gained mainly reasonable classification results and the impact-specific approach of the method is highly agreeable.

Multivariate NMS ordinations showed that sample areas of the main stems (Tenojoki, Utsjoki, Inarijoki) were quite similar in benthos composition. However, smaller water bodies as well as lake outlet areas were clearly separated from each other and from the rest of the sampling sites lying in the opposite ends of the productivity-linked gradient. This observation clearly calls for the need of stratification in the future monitoring practices. The dataset of Hämäläinen et al. (1996) was also placed separately in the ordination picture showing hence a different benthos composition. This deviation can be partly explained by different sampling areas. For instance, the species-rich areas in the River Karasjoki and at the lower parts of the River Tenojoki system (main stem and tributaries) were not covered by the present study. Both these areas differ also with geological properties from the rest of the watershed. Calcium-rich mafic and ultramafic rocks may thus partly stand for the observed high values along the first axis (Fig. 6). In addition, the sampling methods used were not the same. Interannual variability contributed also most probably to the difference. Many environmental factors such as annual variations in climate, unstable bottom conditions and large variability in spring flood all influence the local invertebrate life cycles and cause inevitably interannual variability to some degree. This variability was shown to play a big role already in Hämäläinen et al. (1996): seasonally identical surveys conducted at the same sampling sites with same methods (in 1989 and 1994) differed distinctively in benthos composition. In addition, even intra-annual variability is always large at any single sampling station, yet alone due to the species naturally variable life cycles. In the River Tenojoki watershed, this was clearly brought out in the seasonal community comparisons by Lax et al. (1993).

In general, water quality has been shown to be good in the whole River Tenojoki water system. Nutrient contents have been typically low and no evident signs of eutrophication have been detected since the renewal of the wastewater purification system of the Karasjok village in the beginning of 1990s (Hämäläinen et al. 1996, Traaen 2003, Miettinen 2006). Finnish Environmental Institute has also classified the whole water system to the class ”excellent” in its general water quality classification system for surface waters. In the present study, no signs of human-induced eutrophication could be detected either. The only exception was the local effect of a wastewater treatment plant downstream from the Karigasniemi village. Nevertheless, possible eutrophicative effects of larger communities should be regularly monitored also in the future. With regard to other human impacts, current land-use practices do not pose any acute threat for the local stream biota. Flood protection measures – the only notable water constructions in the watershed – have seemingly been moderate enough. Agricultural activities occur in the watershed only patchily and are concentrated on the narrow shoreline strip in the river valleys. Diffuse load from agriculture may be difficult to monitor also in the future.

Acidification has been considered an acute threat during the last decades also in the River Tenojoki system. This holds for the local river ecosystem as well. Lowered pH of stream water is one of the most important factors associated with changes in benthic macroinvertebrate communities of running waters (e.g. Townsend et al. 1983, Larsen et al. 1996). In the River Tenojoki catchment area, acid deposition reached its peak in the late1980s but has since declined considerably because of the reduction in sulphur emissions in the main source areas of the Kola Peninsula (e.g. AMAP 1998). In the present study, no compositional aspects in the benthos communities pointed to acid-induced disturbances, as many acid-sensitive animal groups occurred abundantly. For example, the median number of acid-sensitive EPT-taxa per sampling site was 16 in the present material. However, the most impact-prone areas such as headwaters and brooks were not largely covered in this study. Hämäläinen et al. (1996) found some possibly acidity-related changes in the benthos communities of two brooks based on a weighted average method (Hämäläinen 2000). Thus they recommended that a large invertebrate dataset from the brooks of the River Tenojoki watershed should be collected that would serve as a reference in future assessments. However, it is not clear to what extent changes, even if caused by acidity, can be attributed to human influence. Laudon et al. (2000) estimated recently that only 1/10 of the yearly drop in the acidity values of some northern Swedish streams would be due to human impacts. In other words, the magnitude of the anthropogenic component to the pH decline of 1–3 units in spring hardly ever exceeded the range of 0.1–0.3 pH units. Same phenomenon might apply also for the brooks of the River Tenojoki system where human influence is likely to be even smaller. In their study, Laudon et al. (2000) reported sulphate deposits of 2–4 kg/ha/a (given in sulphur) as prevailing background values. Measurements in the Kevo meteorological station have shown yet much lower deposit levels (approx. 1 kg/ha/a in 1990–2000; Leppänen et al. 2000). Anyway, all future efforts in acidification monitoring should be targeted to the most probable impact areas, i.e. headwaters and brooks.

In the WFD, high status-criteria for the biological element ”benthos” require that taxonomic composition, abundance, occurrence of disturbance sensitive taxa and the level of diversity all correspond totally or nearly totally to undisturbed conditions. Based on expert judgement, these status criteria would be fulfilled in all studied river areas despite the big compositional variability of the communities. Nevertheless, diversity of benthos communities was not measured in the present study. Diversity indices relate taxon richness to abundance. However, the relevance of diversity measures in oligotrophic, species-poor conditions could be questionable. As with other unimodally responding metrics, diversity indices score often higher in human-impacted, semipolluted conditions (Magurran 1988). Accordingly, e.g. Liljaniemi (2003) found diversity indices less useful in the status assessment of the River Simojoki and recommended the use of taxa numbers instead.

Classification of the ecological status should be based on functionally reliable typologies so that monitoring systems used could be able to detect anthropogenic impacts from variability caused by natural pressures. In the preliminary Finnish typology scheme, rivers of this study would belong to the river classes 2a, 5a and 8a (Pilke et al. 2002). The main stem of the River Tenojoki would be categorized as a very large river with low humic content (type 11) in the scheme. Additional stratification in the upcoming monitoring practices is, however, needed, as clearly shown by Miettinen (2006) and also in the present study. In both studies, geological factors were shown to be regionally important in shaping the community structures.

Based on benthos communities, at least catchment size and bedrock geology would be appropriate stratification criteria to be used. Other possible criteria for delineating workable typologies are to be considered. For instance, Sandin (2003) found tree limit to be a strong delimiter both for assemblage structure and the number of benthic invertebrate taxa. In the present study, no sampling sites were situated above the tree limit. Based on comparisons of many scale-related benthos studies, Hawkins et al. (2000) concluded that a typology including both large-scale (e.g. catchment area, ecoregions) and local-scale (e.g. substratum composition and stream velocity) features is evidently needed to detect anthropogenic stress in running water ecosystems.

The biotic indices used in this study showed generally good ecological status. However, applicability of the assessment tools, which have been developed elsewhere, is not a straightforward question. All assessment methods used here should probably be locally adapted for oligotrophic, species-poor conditions (cf. Hämäläinen et al. 1996). The WFD created a strong need for the development of assessment tools that would meet the requirements of the WFD assessment scheme. A multimetric AQEM method was tested in the present study and it showed fairly plausible results. Nevertheless, the special characteristics in the composition and abundance patterns of northern communities were not fully accounted for in the method. This perception seems to apply more generally to the tools, which are based on cross-European development, as shown e.g. in the case of the ECOFRAME classification scheme for shallow lakes (Nykänen et al. 2005).

Monitoring of benthic invertebrates is included in the upcoming ecological assessment practices of the WFD. Nevertheless, benthos surveys should also more generally be included as an essential part in any ecological status assessment. This is because different biological elements have been shown to lack concordance in relation to ecological conditions, and accordingly towards various human impacts (Paavola 2003); in spite of its conceptual appeal, sensitive surrogate measures have been shown to be hard to find for reliable assessment. This means that differing pressures should be analysed based on the best responsive, relevant study object. Both the pressures and the groups used to indicate the effects operate in various scales, in space as well as in time.

5 Summary

A large benthic invertebrate survey, conducted in the River Tenojoki water system mainly in 1990–1991, showed congruent results with two earlier surveys. Abundance and species composition of the benthos communities pointed to no deviation from the natural ecological state. General biotic indices and a multimetric assessment tool classified sampling areas mainly to high ecological status class. Spatial differences in the status assessment results are best explained by naturally differing environmental conditions, especially in relation to local nutrient levels.

Based on expert judgement, all study areas fulfil the criteria for high ecological status defined in the Water Framework Directive. Likewise, they can be judged as being possible reference sites in the forthcoming monitoring practices. In future, attention should however be paid to adequate regional stratification in the monitoring schemes. At least geological as well as catchment size-related factors are to be carefully considered.

In general, monitoring practices should be targeted for detecting most likely human impacts, that is, changes in eutrophication and acidification status. Possible effects of eutrophication should be monitored nearby the largest potential sources of human impact, the largest communities. Monitoring of acidification development would in turn be based on a representative set of comparable headwater and brook areas.

6 Yhteenveto

Tenojoen vesistön ekologista tilaa arvioitiin vuosina 1990–1991 ja 1993 kerättyjen pohjaeläinnäytteiden perusteella. Pohjaeläinyhteisöjen koostumuksessa ei havaittu ihmisperäisiä muutoksia luonnontilaisiin olosuhteisiin verrattuna. Tulokset olivat näin ollen yhteneväisiä vuosina 1989 ja 1994 tehtyjen kartoitusten kanssa. Ekologisessa tila-arvioinnissa käytetyt biologiset indeksit osoittivat pääsääntöisesti hyvää tai erinomaista tilaa. Pohjaeläinyhteisöissä havaitut alueelliset erot heijastavat lähinnä paikallisia ympäristöolosuhteita, näin etenkin suhteessa ravinteisuuteen.

Vesipuitedirektiivin edellyttämien arviointiperusteiden mukaan kaikki tutkitut Tenon vesistönosat täyttävät pohjaeläimistön osalta erinomaisen ekologisen tilan tunnusmerkit. Näin ollen vesistöalueen pohjaeläinyhteisöjen voidaan katsoa edustavan kokonaisuudessaan myös tyyppikohtaisia vertailuolosuhteita tulevia seurantatarpeitakin silmälläpitäen. Tulokset osoittivat kuitenkin, että sekä vesistöalueen koko että sen geomorfologiset ominaisuudet ovat keskeisiä tekijöitä tulevien seurantojen tyypittelyssä.

Tenon vesistössä ei ole havaittavissa tällä hetkellä ilmeisiä ihmistoiminnasta aiheutuvia uhkia. Tulevissa ympäristöseurannoissa tulisi huomio kuitenkin kohdentaa mahdollisten uhkatekijöiden alueelliseen seurantaan. Tenojoen vesistön ekologisen tilan seurannassa tulisi keskittyä mahdolliseen rehevöitymiskehitykseen suurimpien asutuskeskusten läheisyydessä sekä muutoksiin happamoitumistilanteessa alueen pienvesistöissä.

7 Sammendrag

Den økologiske tilstanden i Tanavassdraget ble vurdert på grunnlag av bunnfaunaprøver som ble samlet inn i årene 1990–1991 og 1993. Det ble ikke konstatert menneskeskapte endringer i sammensetningen av bunnfaunasamfunn sammenlignet med forhold under naturtilstand. Resultatene var dermed sammenfallende med kartlegginger som ble gjort i 1989 og 1994. De biologiske indeksene som ble brukt i den økologiske tilstandsvurderingen viste hovedsakelig god eller høy tilstand. De geografiske forskjellene som ble observert i bunnfaunasamfunnene gjenspeiler først og fremst lokale miljøforhold, og da spesielt næringsforholdene.

Ifølge de vurderingene som kreves i vanndirektivet, oppfyller alle undersøkte deler av Tanavassdraget kriteriene for en høy økologisk tilstand når det gjelder bunnfaunasamfunnene i vassdraget. Dermed kan bunnfaunasamfunnene i sin helhet anses for å representere referanseforhold for ulike typer vannforekomst, også med tanke på fremtidige behov for overvåking. Resultatene viser likevel at både vassdragets størrelse og områdets geomorfologiske egenskaper er sentrale typifiseringsfaktorer ved fremtidig overvåking.

I Tanavassdraget kan det ikke for øyeblikket observeres åpenbare trusler forårsaket av menneskelig virksomhet. I fremtidige miljøovervåkingsprogrammer bør det likevel fokuseres på overvåking av eventuelle trusselfaktorer i enkelte områder. I økologisk overvåking av Tanavassdraget bør man konsentrere seg om en eventuell eutrofieringsutvikling i nærheten av de største befolkningssentra samt om endringer i forsuringssituasjonen i områder med kilder og bekker.

Čoahkkáigeassu

8

Deanu čázádaga ekologalaš dilli čielggaduvvui jagiin 1990–1991 ja 1993 čohkkejuvvon bodneealličájánasaid vuođul. Bodneeallenáliid čoakkádusas eai gávdnon olbmo dagahan nuppástusat veardidettiin luondduviđá diliide. Dáná bohtosat ledje seammaláganat go jagis 1989 ja 1994 dahkkon gártemat. Ekologalaš dilleárvvoštallamis geavahuvvon biologalaš indeavssat čujuhedje eanaš buori dahjege earenoamáš buori dili. Guovlluguovdasaš bodneeallenális gávdnon erohusat speadjalastet lagamustá báikkálaš birasdiliid, dáná eandalitge biebmodili ektui.

Čáhcerápmadirektiivva eaktuda árvvoštallanprinsihpaid, maid vuođul buot dutkojuvvon Deanu čázádaga oasit devdet bodneealliid oasil earenoamáš buorre ekologalaš dili dovdomearkkaid. Nuba čázádaga bodneeallináliin sáhttá dadjat, ahte dat ovddastit obban maiddái tiipaguovdasaš buohttastahttindiliid geahčadettiin boahttevuođa vákšundárbbuid. Bohtosat čujuhedje goittotge, ahte sihke čázádagaid viidodat ja dan geomorfologalaš iešvuođat leat váldooasis boahttevaš vákšumiid luohkkájuogus.

Deanu čázádagas eai leat oidnosis dál čielga olbmo doaimmaid dagahan áitagat. Boahttevaš birasvákšumiin galggašiige giddet fuopmášumi goittotge vejolaš áitagiid guovloguovdasaš vákšumii. Deanu čázádaga ekologalaš dili vákšumis galggašii váldit váldočuovvumii vejolaš mohtiluvvama leavvama stuorámus čoahkkebáikkiid lagašvuođas ja maiddái guovllu smávvačázádagaid suvrundili nuppástusaid.

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Zoobenthos taxa list with abundances in Individual Surber samples (three per site, 0.09 m^2 each) in 1990–1991 and 1993 surveys in the River Teno system.

	Inari Suukoski Aug 1990			Upper Inari Aug 1990 I			Upper Inari Aug 1990 II			Upper Inari Aug 1990 IV			Inari V1			Inari V3			Inari V6			Inari V9			Inari V10			Inari Karigasn Nor			Inari Karigas I			Inari Karigas II			Inari Karigas III		
MOLLUSCA																																							
Lymnaea spp.	52	150	9	33	20	6	14	92	3	1		1		6	1	4	32	7							1	12	19			1	10	6	7	3	14	5	1	3	7
Pisidium spp.	16	16	29	46	37	41	117	133	10	1	5	2	1			3	4	27																					
Planorbidae		4	2		1												1																	3	3	1			
OLIGOCHAETA	31	132	106	5	60	88	222	51	40	30	40	54	1	1	1	2	15	2		2	14			3	3	3	3				2			11				1	
HIRUDINEA																																							
Glossiphonia complanata		1	1																																				
HYDRACHNELLAE	1	2	1		1	1		4												2							2									1			
CRUSTACEA																																							
Gammarus lacustris																																							
EPHEMEROPTERA																																							
Ameletus inopinatus	1	1	3											3		3	16				1		1		4	3	1							6	2	3	2		
Siphlonurus alternatus													1																										
Baetis spp.																																							
Baetis digitatus	1	32		6	11	7	15	24	3	1	1	4	6	77	13	2	24	2																2	2	3	3		
Baetis fuscatus	2																								3	2													
Baetis lapponicus																																						1	
Baetis muticus	66	81	112	4	5	23	18	9	16	6	5	6	1	1	2			8	3	4	7				4	2	27						1	35	4	3	2		5
Baetis niger										1				2																									
Baetis rhodani	60	90	38	14	10	27	34	35	55	35	44	39	22	13	5	17	4	12	31	49	43	25	36	45	405	335	145	1		1	15	22	21	417	190	193	236	279	582
Baetis subalpinus								1																															
Heptagenia spp.																										3								1			3		
Heptagenia dalecarlica	3	8		2			1	5		10	4	4	7		13	6	2	8	4			5	7	4	2	6	5	3	3	2	6	6	8	16	3	2	11	1	5
Heptagenia joernensis																																							
Heptagenia sulphurea		6						1																															
Paraleptophlebia spp.		9		1													2																						
Caenis rivulorum							1				2			1			3	1																					
Ephemerella aurivillii	28	20	50		2	7	7	3	6	4	9	5	19	52	22	6	29	7	10	21	11	3	6	8	3	17	55	3	4	4	3	6	5	8	1	2	3	9	17
Ephemerella ignita																																							
Ephemerella mucronata	3	1		1	1	4		5		2	6	3		1	1	1			10	12	7	1	1	1	1	3	4				1	4	2	2	1			2	1
PLECOPTERA																																							
Taeniopteryx nebulosa	5	31	1			1	6	20	7	10	5	6	4	11	5	4	11	1						2		1	3					2		1					1
Amphinemura borealis	3	3		1		2		1											1															3			1		2
Protonemura spp.																				1																			
Protonemura meyeri																																							
Nemoura spp.	3	11	2			1	1													1					1		1							2					2
Nemoura avicularis														1			6																						
Leuctra spp.						2																							2		1					1			
Leuctra digitata	11	2	3	10		18	7	3	12	9		2	2	8	3		1		16	68	22				1	3	1					2	1	9	3		2	4	6
Leuctra fusca	1	7	2		1	1	3	1	1			1																						2					
Leuctra hippopus																																							
Leuctra nigra																																		1					
Capnia spp.		1												1		1	1	1																					
Capnia atra																																		6					
Capnia pygmaea																						2			10	16	4		1	2	1			35	3	2	2	6	1
Capnopsis schilleri										1																								2		1			1
Dinocras cephalotes	10		9				5	1	6	1																													
Arcynopteryx compacta														1																				2			1		
Diura nanseni						3	4		2	4	1	1	5	5	4		1	2		2	1	2	1			3		1			1	1				1	1		2
Isoperla spp.	15	2	21			12	13	7	6	2	1	2	1	2			1	1	2	2	4	2		2		6	37					4	2						
Isoperla difformis	4	1	1																															2	1		3	1	4
Siphonoperla burmeisteri																										1													
Xanthoperla apicalis																																							

	Inari Suukoski Aug 1990			Upper Inari Aug 1990 I			Upper Inari Aug 1990 II			Upper Inari Aug 1990 IV			Inari V1			Inari V3			Inari V6			Inari V9			Inari V10			Inari Karigasn Nor			Inari Karigas I			Inari Karigas II			Inari Karigas III		
MEGALOPTERA																																							
Sialis spp.																																							
TRICHOPTERA																																							
Rhyacophila nubila	9	7	6	4	1	5	3	1	6	2		3	2	5		2	2	3	1	1	2			5		3	10			2	1	3			9	4	6	8	16
Philopotamus montanus	6	2	2						4																														
Polycentropus flavomaculatus	2	4	1	3	6	1		1					1	8	5		13					1				1	1								19	16	6	4	8
Plectrocnemia conspersa																																							
Psychomyia pusilla																																							
Hydropsyche spp.		2																																					
Hydropsyche nevae						1	2					1	10	3	1	1		1		6	3	6	5	2				3		6	6	19	12		1		1		1
Hydropsyche pellucidula	5	11	4			7	1	1	7																														
Arctopsyche ladogensis				2		4				1		1	2	2	2				2	1		2	2	2							2	8	7						1
Hydroptila spp.	78	100	49	12	15	29	13	12	3	4	2		3	8	4			1																	3	8		5	143
Oxyethira spp.	13	27		11	8	4	3	11	5	5	2	5		8																					1				1
Apatania spp.						1				1																	3					1			1		5		1
Apatania stigmatella																																							
Apatania wallengreni																	1		1			1	1	1		2	2		1		5			6		2	10	2	12
Potamophylax spp.																																							
Ceraclea spp.						1	1			1																													
Ceraclea annulicornis																															1								
Ceraclea dissimilis	7	2					7	1																															
Ceraclea nigronervosa		2							1			1																											
Athripsodes spp.				2		1	6	4																															
Lepidostoma hirtum		2			1	2		1	1	1	2	1																											
Brachycentrus subnubilus																														1									
Glossosoma intermedium																																	1						
Sericostoma personatum				1										2																									
Micrasema gelidum																																							
DIPTERA																																							
Chironomidae	287	347	211	129	140	494	303	265	131	88	73	43	57	84	124	13	37	31	34	96	39	7	9	11	30	21	55		2	1	7	19	14	168	115	131	101	110	321
Simulidae		1			1	2	1	4	10	1	1	2	1					1	2	4	1	1				1	9			1		4	1	3		2	1	4	
Ceratopogonidae	1	1	2				1						1							4	2										1								
Empididae	27	26	16	8	12	24	18	9	13	7	3	11		3	2			5	4	5	4						1									1	4	2	12
Limonidae																																							
Dicranota spp.														1					4	4	7									1									
Pedicia spp.				1	3		2	2	4		2	1	2	2	1	2	3	3	1												1	2	1						
Eloeophila spp.																			1																				
Tipulidae		1																						1															
Psychodidae						1		1																	3	1	1												
Atherix ibis		1	2		1		1																										1						
COLEOPTERA																																							
Hydraena spp.			1	2		1																												1					
Oreodytes spp.																											1												
Dytiscidae																																							
Elmis aenea	12	14	6	10	24	52	19	61	2	5	9			2						1	8						2					2		1	1		1		3
Limnius volckmari												6																			3	2	1						
Oulimnius tuberculatus				2				1								1	1			1																			

	Kevojoki 25			Kevojoki 22			Kevojoki 18			Kevojoki 13			Kevojoki 8			Kevojoki 1			Teno 1			Teno 4			Teno 10			Teno 18			Teno 22			Teno 25			Teno 29		
MOLLUSCA																																							
Lymnaea spp.													1		2	53	62	44	4	2	1	1	1		20	13	7	16	9	18	1			1	2	1	2	2	
Pisidium spp.														3			1	3									1												
Planorbidae															1													6	4	8									
OLIGOCHAETA		1	2	1	1					1						9		2	2	1		3		1	4	3	1		2	2					2		1	1	1
HIRUDINEA																																							
Glossiphonia complanata																																							
HYDRACHNELLAE	1																1	1	2	1								1		1					1	1			
CRUSTACEA																																							
Gammarus lacustris																																							
EPHEMEROPTERA																																							
Ameletus inopinatus		1					1							2	1			6		1					4	5	3	41	12	29	38	15	12	4		2	18	6	6
Siphlonurus alternatus																																							
Baetis spp.																																							
Baetis digitatus																									3	3		1		1	1								
Baetis fuscatus																																							
Baetis lapponicus																																							
Baetis muticus	3	3	3		2								1		2	1	1	2		1	1			2	3														
Baetis niger													4		1																								
Baetis rhodani	37	17	11	6	30	6	14	24	24	9	16	10	33	9	32	1	3	6	86	51	71	16	7	10	3	14	5	9	10	2	1	1		7	13	8	1	3	5
Baetis subalpinus					1																																		
Heptagenia spp.											2																												
Heptagenia dalecarlica		1					1	1	7	1		1			1			3	9	16	6	7	5	4	16	17	16	24	10	14	22	20	7	8	3	3	11	8	
Heptagenia joernensis																																							
Heptagenia sulphurea																																							
Paraleptophlebia spp.																										1		1											
Caenis rivulorum																																							
Ephemerella aurivillii			2				1	6		5	7	3	4		2	5		2	8	6	18	2	1	3	16	14	8	11	6	10	1		4	8	19	17	6	3	1
Ephemerella ignita																																							
Ephemerella mucronata																			3	3	19			2	4	2	1	6	2	5	5				2	1			1
PLECOPTERA																																							
Taeniopteryx nebulosa											1		2		2	4	2				1					1													
Amphinemura borealis																									1														
Protonemura spp.																																							
Protonemura meyeri	1																																						
Nemoura spp.																																							
Nemoura avicularis																																							
Leuctra spp.												1				2		2																					
Leuctra digitata																			2	2	12	2		1	1				1										
Leuctra fusca										1																													
Leuctra hippopus																																							
Leuctra nigra																																							
Capnia spp.																																							
Capnia atra																																							
Capnia pygmaea																						4	1	2	7	2	13	6	7	3	8	9	2	1	1			3	
Capnopsis schilleri																																							
Dinocras cephalotes																																							
Arcynopteryx compacta											2			1	1			1							1									2					
Diura nanseni			1				1		2	1			2			3			2	5	3	4	1	3	3	1	1	1							2	1		2	
Isoperla spp.					2		1	2	1	4	2	1	4	1	5	4		4	2	3	13	1				1	1												
Isoperla difformis																																							
Siphonoperla burmeisteri																																							
Xanthoperla apicalis																			1		1																		

	Kevojoki 25			Kevojoki 22			Kevojoki 18			Kevojoki 13			Kevojoki 8			Kevojoki 1			Teno 1			Teno 4			Teno 10			Teno 18			Teno 22			Teno 25			Teno 29		
MEGALOPTERA																																							
Sialis spp.																												1											
TRICHOPTERA																																							
Rhyacophila nubila	1		3		1	1	3	7	5	1			2		2	1	2	3	4	1	4	3	1	1	2	1	1	1	1				1	2	2	2		1	
Philopotamus montanus	1		2																																				
Polycentropus flavomaculatus														2	1		1	2								11	11	6	5	3	5		1				1		1
Plectrocnemia conspersa		1																																					
Psychomyia pusilla																																							
Hydropsyche spp.																		1																					
Hydropsyche nevae															11	1		1	3	2	2	5	3		1	1	1				3			1	3	1			
Hydropsyche pellucidula																																							
Arctopsyche ladogensis										1	5			1	1			1			2		1			2		1	1					2	1	4			1
Hydroptila spp.																	3	1	1						5			1		7								1	1
Oxyethira spp.									2				1	2		1		3							3	6													
Apatania spp.																			2	3	1			1															
Apatania stigmatella																			2	1	2										10	2	2						
Apatania wallengreni																1	2		1		1				1		2	1		3		1				1	1	2	1
Potamophylax spp.																											1												
Ceraclea spp.																									1														
Ceraclea annulicornis																												1											
Ceraclea dissimilis																																							
Ceraclea nigronervosa																													1	1									
Athripsodes spp.																																							
Lepidostoma hirtum																									1														
Brachycentrus subnubilus	1																										1												
Glossosoma intermedium																								1									1	1					
Sericostoma personatum																																							
Micrasema gelidum																																							
DIPTERA																																							
Chironomidae	4	5	4	6	4	4	6	10	5	1	1	5	7	12	9	29	7	18	87	41	51	16	1	3	73	52	35	99	122	101	49	4	9	12	113	77	20	17	6
Simulidae	3		2		4	10			1				1		1				2	2	8	51	6	22	1	1									30	6			
Ceratopogonidae			1																		3								1	1									
Empididae	1		2	2	1	1	1	3	1							2	1	2	2						2										2				
Limonidae																																							
Dicranota spp.																2									2										2			1	
Pedicia spp.																			1																				
Eloeophila spp.																																							
Tipulidae																																							
Psychodidae																																							
Atherix ibis																																							
COLEOPTERA																																							
Hydraena spp.						1																																	
Oreodytes spp.																																							
Dytiscidae																																							
Elmis aenea	1		3																1	1	3				4	5			2	1		1			3	1	1		
Limnius volckmari																																							
Oulimnius tuberculatus																			1						1			1											

	Teno 32			Utsjoki 2			Utsjoki 5			Utsjoki 8			Utsjoki 10			Utsjoki 12		
MOLLUSCA																		
Lymnaea spp.		2		3	1		9	44	22	1	9	4	1	1	1			2
Pisidium spp.							161	225	146		1		3		6			
Planorbidae					2		34	38	41		5	1				4	1	6
OLIGOCHAETA										6	3	20		1				
HIRUDINEA																		
Glossiphonia complanata																		
HYDRACHNELLAE																		
CRUSTACEA																		
Gammarus lacustris																		
EPHEMEROPTERA																		
Ameletus inopinatus				1	3	1	20	5	12							1		
Siphlonurus alternatus																		
Baetis spp.																		1
Baetis digitatus																		
Baetis fuscatus																		
Baetis lapponicus																		
Baetis muticus							1	1	5	1	2	6		2				
Baetis niger																		
Baetis rhodani	3		2				7	12	5	16	46	60	2	7	5		4	2
Baetis subalpinus																		
Heptagenia spp.							1											
Heptagenia dalecarlica	6	13	6		2	8	3			9	4	3	5	8	2	1		
Heptagenia joernensis					1											1		
Heptagenia sulphurea							3		11		1	1		1		1		2
Paraleptophlebia spp.																		
Caenis rivulorum																		
Ephemerella aurivillii	1	1	3	1	1	2	5	16	8	5	11	8	2	1	2		1	
Ephemerella ignita																		
Ephemerella mucronata									2									
PLECOPTERA																		
Taeniopteryx nebulosa						5	9	36	37	10	31	58	1	1			2	3
Amphinemura borealis									1									
Protonemura spp.																		
Protonemura meyeri																		
Nemoura spp.																		
Nemoura avicularis																		
Leuctra spp.							8	9	4									
Leuctra digitata															1			
Leuctra fusca																	1	
Leuctra hippopus																		
Leuctra nigra																		
Capnia spp.							7	4	8		1							
Capnia atra																		
Capnia pygmaea																		
Capnopsis schilleri																		
Dinocras cephalotes																		
Arcynopteryx compacta	1			1	2	2								2		7	1	1
Diura nanseni	1	1		3	1	1		2		3	3		1					
Isoperla spp.																		
Isoperla difformis							6	7	17	7	18	31	1				1	2
Siphonoperla burmeisteri																		
Xanthoperla apicalis																		

	Inari Suukoski Aug 1991			Upper Inari Aug 1991 I			Upper Inari Aug 1991 II			Upper Inari Aug 1991 IV			Vidgaveädji low Aug 1993			Vidgaveädji low Sep 1993			Vidgaveädji up Aug 1993		
MOLLUSCA																					
Lymnaea spp.	1	82	160	2	3	2	49	12	33	4	10	1		1							
Pisidium spp.	11	28	140	26	57	29	516	86	124	7	95	10	1								
Planorbidae	1	3	38	1		1	1														
OLIGOCHAETA	27	10	17	23	71	28	17	64	11	83	27	549		1	1	4		1			
HIRUDINEA																					
Glossiphonia complanata		2	1																		
HYDRACHNELLAE		2	1	1				1	1							4		1			
CRUSTACEA																					
Gammarus lacustris																					
EPHEMEROPTERA																					
Ameletus inopinatus																					
Siphlonurus alternatus																					
Baetis spp.																4	4				
Baetis digitatus		1	1																		
Baetis fuscatus	6	3	16				5	2		6	3	4	5								
Baetis lapponicus																			3	1	
Baetis muticus	3	9	4	2	10	4	8	4	2	2	1	2									
Baetis niger			1																		
Baetis rhodani	34	27	19		2	1			3			3	4	2	8	19	9	7	4	2	1
Baetis subalpinus	11	32	15	18	17	6	6	6	7	8	4	15	2	3	4			1			
Heptagenia spp.																					
Heptagenia dalecarlica	6	2	4	1	1	1	1	4	2	3	1	4									
Heptagenia joernensis					1					1	1										
Heptagenia sulphurea	5	3	4		1		1	1	2		1										
Paraleptophlebia spp.		1	1					1	1	1											
Caenis rivulorum			2				1														
Ephemerella aurivillii	101	50	51	20	84	10	12	13	17	108	21	180	1			3	5	4		1	
Ephemerella ignita																					
Ephemerella mucronata																1					
PLECOPTERA																					
Taeniopteryx nebulosa	76	36	23		3		7	8	8	22	3	20	1			1	1	9			
Amphinemura borealis																					
Protonemura spp.																		1			
Protonemura meyeri					1								3	2		10	9	30	2		
Nemoura spp.		1	6															1			
Nemoura avicularis																					
Leuctra spp.					1																
Leuctra digitata												2									
Leuctra fusca	11	27	37	3	24	5	133	53	19	15	31	36									
Leuctra hippopus																1					
Leuctra nigra							1														
Capnia spp.																	1				
Capnia atra																					
Capnia pygmaea																					
Capnopsis schilleri													1								
Dinocras cephalotes	21	20	7		1		13	2	1												
Arcynopteryx compacta													1	1						2	
Diura nanseni				2	2	1	7	5		3	2	7					2			1	
Isoperla spp.	6	4	2		1		3		3	1		1						1			
Isoperla difformis																					
Siphonoperla burmeisteri																					
Xanthoperla apicalis																					

	Teno 32			Utsjoki 2			Utsjoki 5			Utsjoki 8			Utsjoki 10			Utsjoki 12			Inari Suukoski Aug 1991			Upper Inari Aug 1991 I			Upper Inari Aug 1991 II			Upper Inari Aug 1991 IV			Vidgaveädji low Aug 1993			Vidgaveädji low Sep 1993			Vidgaveädji up Aug 1993		
MEGALOPTERA																																							
Sialis spp.																																							
TRICHOPTERA																																							
Rhyacophila nubila			1							3	6	14	1		1		1		19	10	4	10	21	9	4	6	4	8	4	8				7	12	10	2		1
Philopotamus montanus																			1		1		1									1				1			
Polycentropus flavomaculatus						1						3	1	1							4	7	1	2	2	5	1	1		1									
Plectrocnemia conspersa																																							1
Psychomyia pusilla																																							
Hydropsyche spp.																										1													
Hydropsyche nevae			1							1					1							1	1																
Hydropsyche pellucidula																			7	9	1	1		1	4		1												
Arctopsyche ladogensis	7	3	4																				2	2			1	1		1									
Hydroptila spp.					1		1	1	1				1		2				97	26	19	12	13	16	9	4	5			1									
Oxyethira spp.											1									1																			
Apatania spp.																																							
Apatania stigmatella																																							
Apatania wallengreni		1			1	4	3	2	2																														
Potamophylax spp.																																		2					
Ceraclea spp.															1										1		1												
Ceraclea annulicornis																											1			1									
Ceraclea dissimilis																			2	3	2				1	1	2	1		3									
Ceraclea nigronervosa							1		2									1	1	5	7		1		3	4	4		2	1									
Athripsodes spp.																						1			5		2												
Lepidostoma hirtum							4		3						1										3		1		1	2									
Brachycentrus subnubilus																																							
Glossosoma intermedium																																							
Sericostoma personatum																					1		1	1	2														
Micrasema gelidum																																1					1		
DIPTERA																																							
Chironomidae	2	1	11	2	1	5	56	27	97	23	51	88	12	1	3	30	30	26	775	634	461	192	280	134	293	225	151	180	44	248	17	1	1	20	8	27	4	5	2
Simuliidae		5	6			1				2	1	2	1						159	51	15	20	53	2	1	6		1	1	3				1					
Ceratopogonidae																							1		9		1												
Empididae												6				1			31	3	3	7	27	8	30	2	4	3	3	7									
Limonidae																																			1	1			
Dicranota spp.	1		1				1		1						1											2	1												
Pedicia spp.																			3			1	4	4	11		1												
Eloeophila spp.																								1															
Tipulidae																																							
Psychodidae																																							
Atherix ibis																					1				2														
COLEOPTERA																																							
Hydraena spp.																																							
Oreodytes spp.																																							
Dytiscidae																																							
Elmis aenea												1							10	36	25	67	57	44	59	3	78	1	6	6									
Limnius volckmari																																							
Oulimnius tuberculatus							3	3	1															1			1	1											

	Vidgaveädji up Sep 1993			Padda low Aug 1993			Padda low Sep 1993			Padda up Aug 1993			Padda up Sep 1993			Utsjoki Manto low Aug 1993			Utsjoki Manto low Sep 1993			Utsjoki Manto up Aug 1993			Utsjoki Manto up Sep 1993			Teno Aug 1993			Teno Sep 1993		
MOLLUSCA																																	
Lymnaea spp.																	1	1	2	10	9	1	3	4	2	15	21				1		
Pisidium spp.																9	8	41	1	44	7	4	17	7	8	16						1	1
Planorbidae																1		1			1	16	23	24	24	20	22						
OLIGOCHAETA	2	1	1		1									1		11	32	1		2	5	7	1								2	1	5
HIRUDINEA																																	
Glossiphonia complanata																								1									
HYDRACHNELLAE	1	2	1			1	3	2							2	5		2	1	2			2				2						
CRUSTACEA																																	
Gammarus lacustris																1							2		4	1							
EPHEMEROPTERA																																	
Ameletus inopinatus																					2										1	1	7
Siphlonurus alternatus																																	
Baetis spp.	1	3					34	14	4		1	2	14	26	9			2															
Baetis digitatus																																	
Baetis fuscatus					1	2	1			2	4	2	1	1																			
Baetis lapponicus	1																					1											
Baetis muticus							3	1	4		1	2	7	6	2					1													
Baetis niger																																	
Baetis rhodani	5	3			1	1	35	9	5	2	4	4	25	24	21				59	12													
Baetis subalpinus					4	1	1					2	1	2	2		1	4	2														
Heptagenia spp.									1										1														1
Heptagenia dalecarlica				2	1	2		5		4	2	2	6		2										1	1		2	1			6	
Heptagenia joernensis		1														1						1											
Heptagenia sulphurea																1										1	1						
Paraleptophlebia spp.																																	
Caenis rivulorum																																	
Ephemerella aurivillii	2	1	1				1	1	1				3	2				1							1		1	1			1	8	5
Ephemerella ignita																	1					4	3										
Ephemerella mucronata								1							1					1													
PLECOPTERA																																	
Taeniopteryx nebulosa																	1	2	3			1	12	11	2							4	5
Amphinemura borealis																																	
Protonemura spp.			1																														
Protonemura meyeri		12	6				2		1		10	1			1																		
Nemoura spp.																																	
Nemoura avicularis																																	
Leuctra spp.																																	
Leuctra digitata																																	
Leuctra fusca																3	5	4				3	3	2					1				1
Leuctra hippopus	1	1					2																										
Leuctra nigra																																	
Capnia spp.							2																										1
Capnia atra																																	
Capnia pygmaea																																	
Capnopsis schilleri									1																								
Dinocras cephalotes																																	
Arcynopteryx compacta	1									1	1	1												1									
Diura nanseni	1	2	1			1					1	1				2		1	3	1	1												2
Isoperla spp.			1																3			1		4	1							1	
Isoperla difformis																																	
Siphonoperla burmeisteri																																	
Xanthoperla apicalis																																	

	Vidgaveädji up Sep 1993			Padda low Aug 1993			Padda low Sep 1993			Padda up Aug 1993			Padda up Sep 1993			Utsjoki Manto low Aug 1993			Utsjoki Manto low Sep 1993			Utsjoki Manto up Aug 1993			Utsjoki Manto up Sep 1993			Teno Aug 1993			Teno Sep 1993		
MEGALOPTERA																																	
Sialis spp.						1																											
TRICHOPTERA																																	
Rhyacophila nubila	4	6	3				3	2	3		1		3	1	1		2	4	5	1									2		2	2	1
Philopotamus montanus		1																															
Polycentropus flavomaculatus																													1	1			
Plectrocnemia conspersa						1								1	1																		
Psychomyia pusilla																																	1
Hydropsyche spp.					1																												
Hydropsyche nevae																																2	
Hydropsyche pellucidula																																	
Arctopsyche ladogensis																	1	2	2												1	3	
Hydroptila spp.																1	1	2	6	4	2												
Oxyethira spp.																																	
Apatania spp.								2									1		1		1							1			1	2	1
Apatania stigmatella																																	
Apatania wallengreni																2			1									3	1	6	2	6	2
Potamophylax spp.									1						1																		
Ceraclea spp.																1																	1
Ceraclea annulicornis																																	1
Ceraclea dissimilis																			2						1								
Ceraclea nigronervosa																		1															
Athripsodes spp.																																	
Lepidostoma hirtum																																	
Brachycentrus subnubilus																																	
Glossosoma intermedium								2																									
Sericostoma personatum																																	
Micrasema gelidum																																	
DIPTERA																																	
Chironomidae	12	28	60	1	8	3	19	2	19		4	3	9	6	16	68	270	263	178	189	382	70	58	168	53	109	79		3	2	7	53	24
Simulidae	1	9	2	5			9	3	2				1	4	2			1															
Ceratopogonidae																																	
Empididae									1								2		1	3													
Limonidae							1										1			2												1	
Dicranota spp.																																	
Pedicia spp.																																	
Eloeophila spp.																																	
Tipulidae																						2											
Psychodidae			1				1																										
Atherix ibis																																	
COLEOPTERA																																	
Hydraena spp.																																	
Oreodytes spp.																																	
Dytiscidae																				2	3			1									
Elmis aenea								1			5	1			3		1													2	1	5	9
Limnius volckmari																																	
Oulimnius tuberculatus																																	

Part III

Heikki Erkinaro and Jaakko Erkinaro

Ecological status of the River Tenojoki system: fish communities in rivers and lakes

Table

Introduction

Monitoring of the status of fish populations has typically focused on economically important fish species. More recently, use of fish communities as indicators of ecological water quality has grown as well (e.g. Malmquist et al. 2001). Fish pose many advantageous features for environmental assessment purposes. They are long-lived organisms with different ontogenetic stages integrating ecosystem functions over long time span (Malmquist et al. 2001). Fish are also easy to identify and their biology and responses to anthropogenic perturbations are quite well understood. Last but not least, as being socio-economically important resources they are well known and attract attention both among politicians and the general public.

Single metrics have been the most typically used tools in fish-based assessments. These include measures such like abundance, composition and diversity of fish communities as well as occurrence of stress-specific indicator species. However, the trend in the development of assessment methods has recently been towards combined or multimetric indices, which are mostly derived from the idea and approach of Index of Biotic Integrity (IBI; Karr 1981). The original IBI consisted of 12 metrics representing various aspects in species richness and composition, trophic relations and habitat condition of the given fish community (Karr 1981).

The EU Water Framework Directive (WFD) included fish as one of the quality elements to be used in the status assessment of surface waters. The WFD requires use of species composition, abundance, sensitive species, age structure and reproduction within assessment criteria. Inclusion of fish in the WFD has created the current need to develop new ecological assessment tools. For example, a Swedish multimetric Fish Index (FIX) was developed for fish-based assessment both in lakes and rivers (Appelberg et al. 2000). A similar tool for lake fish assessments is under development also in Finland (Tammi et al. 2005a). With regard to rivers, a new fish-based multimetric assessment method was created among 12 European countries in a joint project called FAME (Development, Evaluation, and Implementation of a standardised Fish-based Assessment Method for the Ecological Status of European Rivers; FAME CONSORTIUM 2004). Finland was not participating in this cross-European project, but also here a national assessment method based on IBI approach is under preparation (Vehanen & Sutela 2005).

One of the general objectives in the EC- funded project ”The preservation of the River Tenojoki as a salmon river in its natural state – environmental work, ecological condition and monitoring” was to make an ecological status assessment of the River Tenojoki water system. It was first time when fish communities were part of the assessment in this river system. In addition to general status assessment, compatibility of the results with the assessment criteria used in the WFD was discussed.

2 Study area

Rivers

The River Tenojoki is a subarctic, oligotrophic, more than 300 km long river running in a large, sparsely populated river valley to the Barents Sea. In total, 14 common fish species are reported to occur in the river system (Niemelä et al. 1999), but riffle areas are typically characterized by only 1–4 species with Atlantic salmon (*Salmo salar*) being the most abundant species. All fish releases and transfer of fish or eggs from other watersheds have been prohibited since 1986. The only non-native fish species nowadays occurring in the river system is bullhead (*Cottus gobio*), which was met in the River Utsjoki first time in 1979 (Pihlaja et al. 1998). This most probably unintentionally released immigrant has extended its range since that to the main stem of the River Tenojoki, but it still occupies mainly the middle and lower reaches of the River Utsjoki.

The River Tenojoki is one of the biggest and most productive Atlantic salmon rivers in the world with an annual salmon catch between 100 and 200 tons (Niemelä 2004). Finnish Game and Fisheries Research Institute (FGFRI) has monitored these economically important Atlantic salmon stocks since 1979 regularly by electrofishing. Juvenile monitoring is carried out annually at permanent sampling stations in the three main stems of the River Tenojoki system (Rivers Tenojoki, Utsjoki and Inarijoki). The long-term monitoring programme also includes collection of catch statistics and catch samples (Niemelä 2004).

Lakes

There are over 600 lakes (> 5 ha) on the Finnish side of the River Tenojoki system and the number of bigger lakes (> 50 ha) is almost 50. Lakes are oligotrophic and the water quality is generally high. Conductivity values are normally low (2–5 mS/m) and the lakes are also quite poor in nutrients (tot P 4–8 μg/l). In the summer, oxygen concentration is good throughout the water column, but during winter, natural oxygen depletion can occur in some shallow lakes. Lakes are quite well buffered against acidification, alkalinity values vary normally between 0,10 and 0,40 mmol/l. The open-water season is short – lakes normally freeze in the mid-October and ice-breakup takes place in the beginning of June.

The most common fish species in the lake catches are brown trout (*Salmo trutta*), whitefish (*Coregonus lavaretus* s.lat.), burbot (*Lota lota*), pike (*Esox lucius*), Arctic charr (*Salvelinus alpinus*) and grayling (*Thymallus thymallus*) – in that order of occurrence frequencies (Niemelä & Vilhunen 1987). Cyprinid species, which are widely and abundantly inhabiting the lakes of southern and central Finland, are here represented by only one species, European minnow (*Phoxinus phoxinus*). Fish fauna of the lakes differs most distinctively from the local river fauna by the common occurrence of whitefish, pike and perch (*Perca fluviatilis*) and the general absence of Atlantic salmon.

Unlike in rivers, fish releases have been intensive in the lakes until 1986, when fish stocking was forbidden in the River Tenojoki system. Stocking activities have altered the species composition radically in many lakes and the local fish communities are no more intact in that sense. The most popular target species have been whitefish (stockings to 135 lakes), followed by Arctic charr (61) and brown trout (7) (Niemelä & Vilhunen 1987).

Lakes of the Tenojoki river system have not been studied very intensively in comparison to the rivers. This is largely due to the minor economical importance of the lake fisheries. However, based on catch inquires, the total lake fish catch yielded 11 tonnes in 1980 and yet 7 tonnes in 1986 in the Finnish part of the catchment area alone (Niemelä & Vilhunen 1987). On the other hand, the trend in the lake fisheries had been decreasing already since the 1970s (Niemelä & Hynninen 1983) and the recent development points to the same direction (Seppänen 2002). Anyway, the lakes still have importance for local recreational and household fisheries.

3 Material and methods

Rivers

Fish material used in this study comprised juvenile Atlantic salmon monitoring data gathered annually at permanent electrofishing stations. Three years were chosen to represent temporal variability in the fish communities (1983, 1993, 2003). Number of the sampling stations in the three main stems (Rivers Tenojoki, Utsjoki and Inarijoki) totalled 167 (56, 57 and 54 in each year, respectively). The year 1993 was chosen also for spatial comparisons, because regional coverage of electrofishing surveys carried out by FGFRI was as largest in that year. In total, 240 sampling sites from 12 tributaries, electrofished in 1993, were included in this study. The location of the rivers is shown in the figure 1.

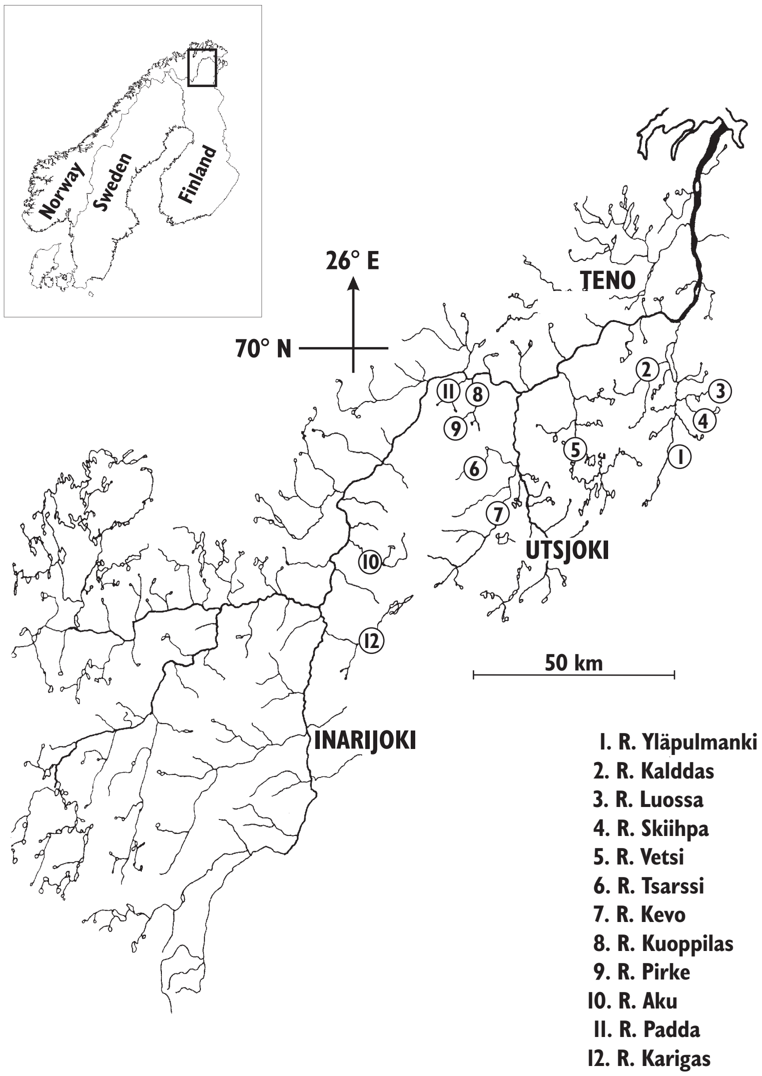

Figure 1. The River Tenojoki system and the location of the river stretches and tributaries where the electrofishing surveys have been conducted.

Electrofishing is a standardised, widely used method for the assessment of species composition and abundance especially in fluvial habitats (Bohlin et al. 1989). Electrofishing was performed in accordance with the CEN standard ”Water Analysis – Fishing with Electricity EN 14011”. Surveys were done between mid-July and early September in strict rotation during the same time each year (Niemelä et al. 1999; Niemelä 2004). Sampling stations represented typical riffle areas with substratum varying from pebbles/cobbles to boulders (Erkinaro 1995). The mean size of the electrofishing stations was 115 m^2 in the three main stems (range 59–196 m^2) and 125 m^2 (42–300 m^2) in the tributaries.

Species composition and population densities are the basic parameters attained by electrofishing. Scale samples can also be taken for age and growth analyses. In this study, species composition and population densities were the main interests. Special attention was paid to the occurrence of young-of-the-year salmon (0+, fry), whereas juvenile salmon density estimates presented here include all age groups (mainly 0+ – 3+). Other growth parameters were not considered in this study.

Ecological status of the fluvial stretches was assessed with a multimetric European Fish Index (EFI). Its idea is to measure the deviation of observed metric values from theoretically predicted values, which represent the reference conditions (FAME CONSORTIUM 2004). The reference values are calculated as a function of 13 abiotic variables (e.g. altitude, geology, catchment size). The calculation is based on data in a large, cross-European database (FIDES), which was compiled during the FAME project. Next, ten metrics are used to describe the community in functionally various aspects. These metrics cover trophic structure of the fish assemblage (density of insectivorous and omnivorous species), reproduction guilds (density of phytophilic species and relative abundance of lithophilic species), physical habitat (number of benthic and rheophilic species), tolerance (relative number of intolerant and tolerant species) and, in the case of migratory fish, migration type/behaviour (long-distance migrants, potamodromous species). Finally, based on the deviation between observed and reference values the probability that a site is a reference site is calculated. After this, the mean of the probability metrics gives the final index score ranging from 0 (bad status) to 1 (high status).

Lakes

Lakes of this study cover only the Finnish part of the river system. The data originates from test-fishing carried out for management plans of mountain lake fisheries in the municipality of Utsjoki (Niemelä & Hynninen 1983, Niemelä & Vilhunen 1987). Almost 100 lakes were sampled with gillnets in 1980, but due to the somewhat deficient data, only 36 large lakes (> 50 ha) are considered here in more detail. Furthermore, additional data from two lakes (Vetsijärvi and Vuogojärvi) was available also from the years 1992 and 1993.

Fish were caught by a traditional test-fishing method with gillnets. The method includes a series of ten gillnets, 30 m each. Mesh sizes range from 15 mm to 60 mm at 5 mm intervals (knot to knot). Nets were normally fishing overnight. More than one set was used in some important lakes.

Species composition and abundance were the main interests in this study. Special attention was put to the occurrence of species used as indicators for anthropogenic impacts, such as brown trout, charr, burbot and European minnow. In addition, a multimetric FIX index was tested with the data.

The FIX index estimates human-induced deviation of a given fish community from the pristine status. Nine different community metrics in three functional categories relating to various aspects of the fish community are calculated and compared with the reference values (Table 1). The distribution of reference values is based on a large Swedish database containing fish community data from almost 10 000 lakes (Appelberg et al. 2000). The mean of all metrics is finally fitted to the reference value distribution and the measured deviation indicates the status of the community. Lakes are classified to five status categories varying from the class ″no or minor deviation from the reference conditions″ (class 1) to ″very large deviation from the reference conditions″ (class 5). Some single metrics may be omitted from the calculation if they are irrelevant in the particular situation (e.g. due to geographical range of species).

Table 1. FIX metrics used in describing lake fish communities. Biomass and abundance are calculated as weight and number per unit effort (one gillnet, one night).

Metric number	Category	Metric description
1.	Structure	Number of fish species native to the habitat
2.	Structure	Species evenness (Shannon-Wieners H´)
3.	Structure	Catch per unit effort in weight of fish species native to the habitat
4.	Structure	Catch per unit effort in numbers of fish species native to the habitat
5.	Guild	Proportion biomass of cyprinid species in relation to total biomass
6.	Guild	Proportion biomass of piscivorous percid species in relation to total biomass
7.	Env. disturb.	Occurrence of acid sensitive fish species and stages
8.	Env. disturb.	Proportion biomass of fish species tolerant to oxygen deficit in relation to total biomass
9.	Env. disturb.	Proportion biomass of non-native fish species in relation to total biomass

Results

4

Rivers

In total, 10 fish species were present in the electrofishing data. However, the average number of fish species caught per sampling area was generally low – 1.82 species in the whole data set (range 0–5 in single areas). The average number of species present varied quite markedly between different parts of the water system being 2.23 in the three main stems and only 1.54 in the tributaries (Table 2). There was also some temporal variation in the species numbers among the three main rivers (see Table 2).

Atlantic salmon, followed by brown trout, was by far the most frequently met species (Table 2). In the three main stems salmon was present at 98 % and brown trout at 7 % of all electrofishing occasions. The corresponding frequencies were 89 % and 44 % in the tributaries, respectively. European minnow, burbot and grayling occurred also in many parts of the river system. Occurrence of other fish species was negligible (Table 2).

Table 2. Average number of species per sample site and occurrence frequencies (%) of each species in the study rivers. Abbreviations 3-sp. and 9-sp. stand for three-spined stickleback and nine-spined stickleback, respectively. Summary statistics for the main stems in bold.

	Number of sp.	Atlantic salmon	Brown trout	Minnow	Burbot	Grayling	Bullhead	Whitefish	3-sp.	9-sp.	Arctic charr	Number of areas
Tenojoki	**2.26**	**98**	**4**	**39**	**29**	**33**	**1**	**9**	**10**	**3**		**102**
1983	3.17	100	11	57	46	54		26		9		35
1993	1.74	94		20	26	31				3		35
2003	1.84	100		22	19	13	3		28			32
Utsjoki	**2.26**	**94**	**17**	**37**	**6**	**9**	**46**		**9**	**6**	**3**	**35**
1983	2.36	91	27	45	18	9	18			18	9	11
1993	2.17	92	17	33		17	42		17			12
2003	2.25	100	8	33			75		8			12
Inarijoki	**2.07**	**100**	**3**	**47**	**27**	**30**						**30**
1983	2.40	100		50	30	60						10
1993	1.70	100		20	40	10						10
2003	2.10	100	10	60	20	20						10
Yläpulmanki	1.25	100	17									12
Kalddas	1.81	90	90									21
Luossa	1.69	92	77									13
Skiihpa	1.45	73	73									11
Vetsi	1.47	72	5	49	21							43
Tsars	1.46	100	36	2			8					50
Kevojoki	1.45	91	18	12	6	3	6		3		3	33
Kuoppilas	1.56	94	61									18
Pirke	2.09	100	100									11
Aku	1.56	100	56									9
Padda	1.20	40	80									5
Karigas	1.69	88	63									16

Juvenile salmon densities varied a lot among the rivers studied, the mean density being 73.4 ind./100 m² in the main stems and 36.1 ind./100 m² in the tributaries (Table 3). Salmon densities varied quite markedly also between the years in the three main stems (Table 3). The occurrence frequency of young-of-the-year Atlantic salmon (fry) was 80 % in the three main stems. In the tributaries, the average occurrence frequency of fry was remarkably lower (36 %).

Table 3. Density estimates of juvenile Atlantic salmon (all age groups) and occurrence (%) of Atlantic salmon fry (0+) in the River Tenojoki water system. Summary statistics for the main rivers in bold.

	Salmon density (ind./100 m²)	Occurrence freq. of salmon fry (%)	Number of areas
Tenojoki	**67**	**83**	**102**
1983	61	77	35
1993	38	77	35
2003	103	97	32
Utsjoki	**86**	**60**	**35**
1983	89	45	11
1993	61	58	12
2003	108	75	12
Inarijoki	**82**	**93**	**30**
1983	57	100	10
1993	50	80	10
2003	139	100	10
Yläpulmanki	69	83	12
Kalddas	22	33	21
Luossa	32	31	13
Skiihpa	24	27	11
Vetsi	17	30	43
Tsars	51	24	50
Kevojoki	58	30	33
Kuoppilas	40	61	18
Pirke	18	36	11
Aku	6	22	9
Padda	15	0	5
Karigas	33	63	16

The EFI index classified the vast majority of the sampling stations to the class ″good status″, the most notable exceptions were quite many stations in the Rivers Tenojoki, Utsjoki and Vetsijoki classified as ″moderate″ (Table 4). Besides good and moderate, only five sites in the whole data set (n = 409) attained other grades. No obvious trend was shown in the status classes between 1983 and 2003, except for the clear drop in the River Tenojoki status in 2003 (Table 4).

Table 4. Ecological status classes in the River Tenojoki system based on the EFI index. Numbers of areas differ to some extent from Tables 2 and 3 because index values for empty sample areas could not be evaluated with EFI. Range of index values in every status class is given in parentheses. Summary statistics for the main rivers in bold.

	Bad (0.00–0.19)	Poor (0.19–0.28)	Moderate (0.28–0.45)	Good (0.45–0.67)	High (0.67–1.00)	Number of areas
Tenojoki		**4**	**24**	**72**		**100**
1983			5	30		35
1993			6	27		33
2003		4	13	15		32
Utsjoki			**4**	**29**		**33**
1983			2	8		10
1993			1	10		11
2003			1	11		12
Inarijoki				**29**	**1**	**30**
1983				9	1	10
1993				10		10
2003				10		10
Yläpulmanki				12		12
Kalddas				21		21
Luossa				13		13
Skiihpa				10		10
Vetsi			12	30		42
Tsars				50		50
Kevojoki				32	1	33
Kuoppilas				18		18
Pirke				11		11
Aku				9		9
Padda				5		5
Karigas				16		16

Lakes

Altogether, eight fish species occurred in the 36 lakes studied (Table 5). The average number of species present per lake was 2.7 (range 1–5). Catch per unit effort (CPUE; one 30-meter net, one night) averaged 974 g (range 113 g–4 303 g) in weight or 4 fish individuals (range 0.4–11.8). The most abundant species in weight were whitefish, grayling and pike (mean CPUEs 374 g, 221 g and 210 g, respectively). Whitefish and grayling were also the most numerous species in the catches (mean CPUEs 1.8 and 0.7 individuals, respectively).

Table 5. Catch statistics of 36 large (> 50 ha) mountain lakes in the River Tenojoki system. Catch per unit effort (CPUE) denotes catch per one 30-meter net and one fishing night.

Lake	Area (ha)	No. of species	CPUE (g)	Grayling	Whitefish	Pike	Burbot	Brown trout	Arctic charr	Perch	Flounder
Vuognoljavrrik 1	91	3	676		268		44	363			
Vuognoljavririk 2	58	3	373		89	210	74				
Vetsijärvi summer	819	5	670	422	120	3	27			99	
Vetsijärvi autumn	819	5	1 940	952	331	209	404			485	
Vetsijärvi 1992	819	5	1 786	265	274	1 151	100				
Vetysijärvi 1993	819	4	2 002	1 256	360	159	227				
Stuorrajavri summer	253	3	323		60		3		261		
Stuorrajavri autumn	253	3	448		187		120		134		
Nuorttahjavri	194	3	942		487		24		431		
Stuorra Paldokjavri	150	3	1 604		696			225		711	
Vuogojavri	401	2	339	254					85		
Vuogojavri 1992	401	4	1 210	645			535	10	21		
Vuogojavri 1993	401	4	751	675			13	6	57		
Vuolimus Skaidejavri	57	2	1 198		1 189			9			
Keävomus Paldokjavri	55	2	971					761		210	
Ravdojavrrik 1	53	1	608						608		
Ravdojavrrik 2	56	1	309						309		
Puolbmakkeäsjavri	69	2	2 836	1 857		978					
Tuoddar Kalddojavri	58	3	322	43	177	102					
Vuobme Kalddojavri	78	4	1 304	223		410	134	536			
Tuolbajavrrik	63	2	739	301	438						
Kaskamus Rievssakjavri	68	3	1 093		396	35				661	
Keädgejavri	65	1	670		670						
Stuorra Tsahppesjavri	93	3	661		579			34	48		
Farppaljavri	71	3	640		388			40	212		
Savdsajavri	129	1	558		558						
Tsuomasjavrrik 1	96	3	168		50		92			26	
Tsuomasjavrrik 2	75	2	1 240		925	315					
Nanapeäljajavri	69	2	717	552		165					
Vudnejavri	74	4	918		445	176				29	
Stuorra Tuolbajavri	288	3	2 167	170	1 727	270					
Fallejavri	113	3	4 303		1 419	2 611				273	
Puksajavri	55	1	1 276	1 276							
Pajib Puolddsakjavri summer	216	4	1 275	89	536	421				230	
Pajib Puolddsakjavri autumn	216	5	1 797	115	108	1 080	270			220	
Njuohkarjavri	106	2	305			193	112				
Kaskamus Kuktsejavri	93	2	1 519		1 389	130					
Vuolimus Kuktsejavri	81	3	843	50	380	413					
Keävojavri	116	4	539		422		106	9	3		
Puolbmagjavri	1 214	5	945	18	874		16		19		19
Maddajavri	197	3	390	16	366			8			
Kanesjavri	71	4	256	58	67	12	119				
Mierasjavri	218	2	113		88		25				

Whitefish (75.0 %), pike (44.4 %), burbot and grayling (both 38.9 %) were the most frequently met species in the material (Fig. 2). Occurrence frequencies of the indicator species – brown trout, Arctic charr and burbot – were 27.8 %, 25.0 % and 38.9 %, respectively. European minnow, also widely used as indicator species, did not occur at all in this study. Occurrence frequencies of fish species from a larger data set (n = 277 lakes; Niemelä & Vilhunen 1987) comprising both test-fishing results and fisheries inquires from the River Tenojoki catchment area, are also included for comparison.

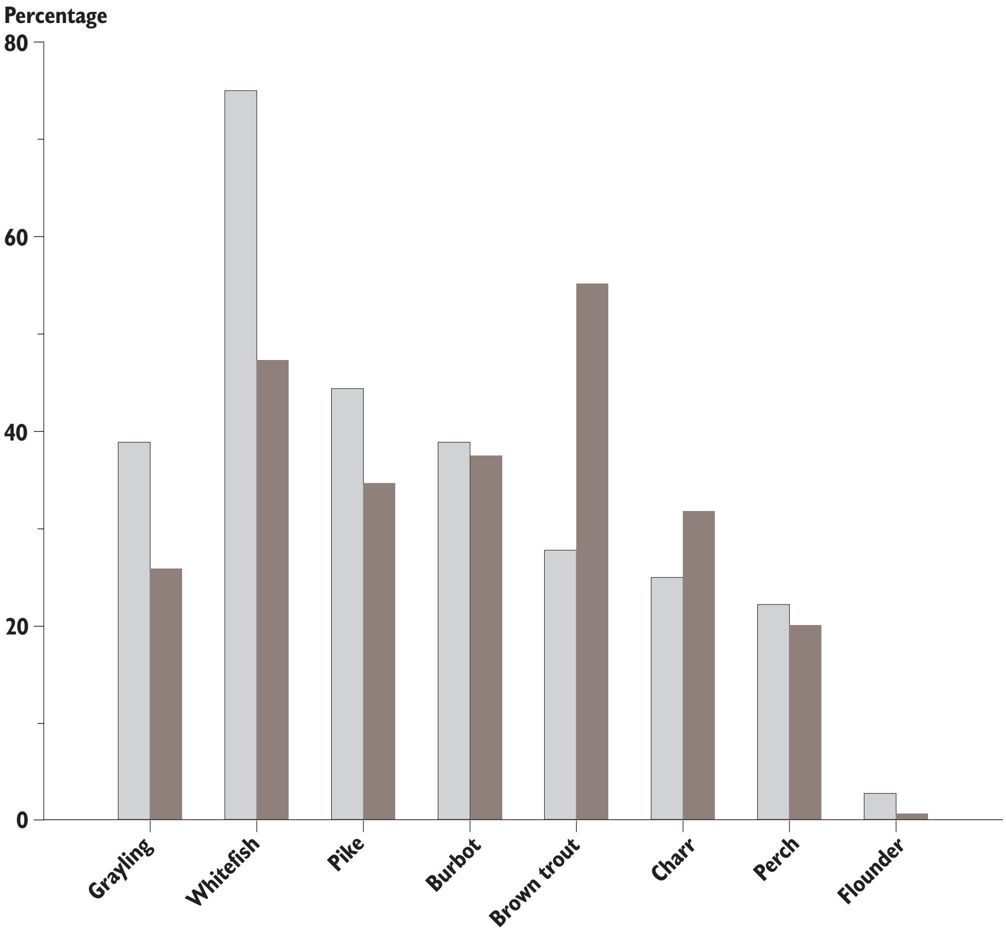

Fig. 2. Occurrence of fish species in the test-fishing catches of 36 study lakes (light grey). Occurrence frequencies in a larger dataset (n = 277; dark grey) are based on both test-fishing and fisheries inquiries (Niemelä & Vilhunen 1987).

The multimetric FIX-index placed most (35/43) fishing occasions to the classes 3 and 4 indicating ”evident deviation” and ”large deviation” from the reference (Table 6). Only one lake, Nuorttahjavri, attained the highest grade (index value 1) indicating ”none, or minor deviation from the reference”. Considering single metrics, metric no. 1 (number of native species) and no. 4 (CPUE in numbers) showed the largest deviation from the reference (Table 6).

Table 6. FIX-index values for different metrics. The final score is given by adjusting the mean of the indices to the distribution of index values in two Swedish lake fish databases (Swedish EPA 2000).

Lake	Metric(1)	Metric(2)	Metric(3)	Metric(4)	Metric(6)	Metric(7)	Metric(9)	Mean	Final score
Vuognoljavrrik 1	3	1	2	5	-	3	1	2.50	**3**
Vuognoljavririk 2	3	1	3	5	-	3	1	2.67	**4**
Vetsijärvi summer	3	2	2	4	4	3	1	2.71	**4**
Vetsijärvi autumn	3	1	2	3	5	3	1	2.57	**3**
Vetsijärvi 1992	3	2	2	4	-	3	1	2.50	**3**
Vetsijärvi 1993	3	1	2	4	-	3	1	2.33	**3**
Stuorrajavri summer	2	3	3	3	-	3	1	2.50	**3**
Stuorrajavri autumn	2	1	2	4	-	3	1	2.17	**3**
Nuorttahjavri	2	1	1	2	-	3	1	1.67	**1**
Storra Paldokjavri	3	1	1	2	1	3	1	1.71	**2**
Vuogojavri	5	1	4	5	-	3	1	3.17	**5**
Vuogojavri 1992	3	2	1	3	-	3	1	2.17	**3**
Vuogojavri 1993	3	4	2	4	-	3	1	2.83	**4**
Vuolimus Skaidejavri	4	5	1	5	-	3	1	3.17	**5**
Keävomus Paldokjavri	4	1	1	4	3	3	1	2.43	**3**
Ravdojavrrik 1	5	-	1	3	-	3	1	2.60	**3**
Ravdojavrrik 2	5	-	3	5	-	3	1	3.40	**5**
Puolbmakkeäsjavri	4	1	1	4	-	3	1	2.33	**3**
Tuoddar Kalddojavri	1	1	3	5	-	3	1	2.33	**3**
Vuobme Kalddojavri	2	1	1	5	-	3	1	2.17	**3**
Tuolbajavrrik	4	1	2	4	-	3	1	2.50	**3**
Kaskamus Rievssakjavri	3	1	1	3	1	3	1	1.86	**2**
Keädgejavri	5	-	2	4	-	3	1	3.00	**4**
Stuorra Tsahppesjavri	3	3	2	4	-	3	1	2.67	**4**
Farppaljavri	3	1	2	5	-	3	1	2.50	**3**
Savdsajavri	5	-	2	5	-	3	1	3.20	**5**
Tsuomasjavrrik 1	3	1	4	5	4	3	1	3.00	**4**
Tsuomasjavrrik 2	4	1	1	4	-	3	1	2.33	**3**
Nanapeäljajavri	4	1	3	5	-	3	1	2.83	**4**
Vudnejavri	2	1	1	4	5	3	1	2.43	**3**
Stuorra Tuolbajavri	3	2	1	3	-	3	1	2.17	**3**
Fallejavri	3	1	2	4	4	3	1	2.57	**3**
Puksajavri	5	-	1	4	-	3	1	2.80	**4**
Pajib Puolddsakjavri summer	3	1	1	4	3	3	1	2.29	**3**
Pajib Puolddsakjavri autumn	2	1	1	5	4	3	1	2.43	**3**
Njuohkarjavri	4	1	4	5	-	3	1	3.00	**4**
Kaskamus Kuktsejavri	4	3	1	4	-	3	1	2.67	**4**
Vuolimus Kuktsejavri	3	1	2	5	-	3	1	2.50	**3**
Keävojavri	3	3	2	3	-	3	1	2.50	**3**
Puolbmagjavri	4	5	1	1	-	3	1	2.50	**3**
Maddajavri	4	5	2	2	-	3	1	2.83	**4**
Kanesjavri	3	1	4	5	-	3	1	2.83	**4**
Mierasjavri	5	1	4	5	-	3	1	3.17	**5**

Discussion

5

Rivers

The diversity of fish communities is generally very low in the rivers of Nordic countries with usually no more than 2–8 species co-existing in a single water body (Ridderborg & Appelberg 1997). Species-poorness is largely due to the last ice age, after which the recolonisation is still under way (Ahlén & Tjernberg 1992). In the present study, 409 electrofishing sites harboured only an average of 1.82 species per site. Nevertheless, the total number of species met (10) was quite at the level reported from electrofishing surveys in other northern, oligotrophic rivers (cf. Bergersen 1989, Niemelä et al. 2001). However, sampling with electricity is a size- and species-selective method (Bohlin et al. 1989). The method has been used mainly for sampling of salmonids and results concerning other species should be considered with caution. This holds especially for the reliability of density estimations.

Atlantic salmon, followed by brown trout and European minnow, was by far the most frequently met species in the study material. Overall, species composition patterns in different parts of the watercourse were best explained by local habitat characteristics, not by any human-induced pressure. As an example, a number of studies have demonstrated that brown trout prefer smaller water bodies and lower water velocities than Atlantic salmon and, under higher velocities, will seek shelter (e.g. Armstrong et al. 2003). In essence, habitat preferences and competitive interactions are both liable to affect to the segregated distribution of these two species. In the present study, this pattern was best manifested in the different occurrence frequencies of brown trout between main stems and tributaries. The scarcity of Atlantic salmon fry (young-of-the-year) in the headwaters and some minor tributaries is in turn explained by physically unsuitable conditions for spawning in those reaches. Habitat characteristics linked to flow velocity are largely responsible for the occurrence patterns of some other species. European minnow, for instance, is a species typically preferring milder currents or still water, which are not fully represented in the present data set. Altogether, specific habitat preferences of each fish species seem to adequately account for the observed distribution patterns.

Abundance of juvenile Atlantic salmon is a complex result of factors both in the river and at sea. In general, adult Atlantic salmon stocks have been detected to fluctuate quite identically over large geographical areas, e.g. depending on fishing and environmental conditions (Niemelä et al. 2004 and references therein). Stock alterations should also be reflected in the juvenile abundances of the rivers (Niemelä et al. 2005). In this study, abundance of juvenile salmon showed a spatially typical pattern: best production areas in the main stems were most densely populated and abundances were thinning towards the marginal areas of the water system. Some areas with low salmon densities lay outside the regular spawning range. Such was the case e.g. for most of the areas in the River Vetsijoki and for the whole river stretch in Padda. However, no evidence of human-induced density differences between different rivers could be detected.

Atlantic salmon, brown trout, burbot and European minnow are all used as indicator species for their sensitivity to many forms of human-induced degradation, e.g. acidification, habitat alteration, eutrophication and oxygen deficit (Malmqvist et al. 2001). In the River Tenojoki watercourse, all these indicator species occurred evenly across most of the study area thus giving no indications of possible anthropogenic effects.

Age-class composition can be used to examine possible recruitment failures in fish populations. In addition, different ontogenetic stages have also different responses to human-induced pressures, e.g. organic pollution or acidification. Occurrence of Atlantic salmon fry has been widely used as an indicator of the acidification status (e.g. Norrgren & Degerman 1993). In the present study, Atlantic salmon fry were frequently met in suitable spawning areas over the whole watercourse. This result is also consistent with the observed alkalinity levels in the River Tenojoki watercourse – there seems to be no current threat of acidification under prevailing conditions (Traaen 2003). Widespread distribution of salmon fry reflects also a good availability of suitable physical spawning habitat.

The European Fish Index (EFI) classified most of the study sites to the class ″good″. Nevertheless, some reservations should be kept in mind, when considering the results gained by the EFI. Firstly, the method has been developed for sites only located in the ecoregions of the participating FAME countries, and it should not be applied as such in areas with a fish fauna deviating from those of the tested ecoregions, as pointed by FAME CONSORTIUM (2004). In our case, the nearest comparable areas included in the project FAME were situated in northern Sweden. Secondly, some prerequisites in using the EFI were not met in every instance of our study. For example, minimum sample size requirements for appropriate statistical confidence (30 fish specimens per catch and 100 m^2 in area) were not always met. Finally, two special cases were noticed to be problematic already in FAME CONSORTIUM (2004), and the EFI should hence be used with care: undisturbed rivers with naturally low fish density and heavily disturbed sites where fish are nearly extinct. In these cases ″fish might not be good indicators for human impacts and even expert judgement is sufficient to assess the ecological status of the river″ (FAME CONSORTIUM 2004).

The EFI method proved to be somewhat conservative or insensitive in class resolution – the vast majority (89 %) of the study sites were monotonously classified as good. The risk of misclassification was already mentioned in the manual of the EFI: ″some of the status classes should be considered with caution, because due to low number of minimally disturbed sites (class 1) and heavily disturbed sites (class 5) in FIDES database, the limits between class 1 and 2 and class 4 and 5 have been set arbitrarily. Therefore, the probability to misclassify sites of high (class 1) and bad (class 5) status is higher than for sites of good, moderate and poor status″ (FAME CONSORTIUM 2004). Based on our experiences, it was also obvious that classification criteria were too stringent or inappropriate in some cases. For example, all four sites classified as poor in the present study contained only two species: in addition to abundant Atlantic salmon, one specimen of three-spined stickleback occurred in each occasion. Three-spined stickleback is an original and widespread species in the River Tenojoki catchment area, but while being categorized as omnivorous and stress-tolerant species in the EFI scheme, it was affecting too strongly the assessment result.

Lakes

Test-fishing results from the lakes showed quite low overall species richness. On average, there were only 2,7 species present per lake. Nevertheless, the mean CPUE in the whole data set (974 g) was not that low, at the same level recently reported from the oligotrophic lake Pyhäjärvi in south-eastern Finland (Rask et al. 2005). Interestingly, the CPUEs in individual numbers did however differ quite distinctly between these two studies (4 vs. 43 individuals per net night). This difference is at least partly caused by the absence of cyprinid species (first of all roach) in the north. In another large data set comprising 36 meso- and eutrophic lakes from southern Finland, Olin et al. (2002) reported average CPUEs of 1870 g in weight and 89 in individuals. Nutrient concentration and lake area were attributed to be the two main factors determining species richness, and the increase of CPUE along a nutrient gradient was caused mainly by increased numbers of cyprinids (Olin et al. 2002). The low individual numbers per catch in the present study might also partially be explained by the use of different sampling methods: the minimum mesh size used in this study (15 mm, knot-to-knot) does not catch smaller individuals efficiently.

The high variability both in species composition and abundance among the lakes studied was not surprising, taken into account the variable physical characteristics of the lakes and the locally strong human impact through fish stockings and fisheries. In addition, stochastic factors may easily have contributed to the test-fishing results – most of the study lakes were sampled only once overnight with a single set of nets. The indicator species for human-induced impacts occurred frequently in the lakes studied and showed no geographical pattern. Nevertheless, the widely used indicator species for acidification, European minnow, did not occur at all in the catches. Supposedly, also this result was solely due to the sampling methods used: even the biggest individuals ever met in the study area (8–9 cm total length) are too small to be caught with mesh sizes used in this study.

Difficulties in catching smaller individuals would partly be overcome by using electrofishing as an additive sampling method in the littoral areas. In addition, the use of the so-called Nordic multi-mesh net series would improve capture efficiency of smaller individuals. The Nordic net series includes in each single 30-meter net 12 different panels with a range of 5–55 mm in mesh sizes. Tammi et al. (2005b) judged that individuals more than 5 cm in length would be efficiently captured by the Nordic method. This approximation is in line with the experiences of the present study. The youngest individuals found were two-year old grayling and whitefish juveniles, some single one-year old individuals did also occur occasionally (Niemelä & Hynninen 1983). The Nordic net series will most probably be the standardized fishing method in the EU lake monitoring practices. In addition, catch statistics and fishing inquires are usually still highly needed to get as unbiased a picture as possible of the whole fish community.

Fish community classifications based on the multimetric FIX method indicated mostly ”evident” or even ”large deviation” from the reference conditions. Technically, these somewhat surprising results were mostly caused by high index values (i.e. low ecological status) in two metrics accounting for the number of species present and CPUE in individual numbers. Biogeographical factors related to the distribution of different fish species largely account for the lower than predicted values in these metrics. For instance, the typically large variety of cyprinid species in more southern regions was represented by European minnow solely in the present study. Nevertheless, Tammi et al. (2002) found the FIX method capable of separating lakes which were differently exposed to human disturbance in southern Finland. Eutrophication was the main stress factor in that study material. In contrast, lakes in the present study were oligotrophic throughout and hence did not provide opportunity for nutrient-based comparisons. In addition, the test-fishing method used here was not based on the standardised Nordic multi-mesh net series, which is demanded in the FIX approach. Accordingly, smaller fish individuals were in general underrepresented in the catches, as already discussed above. The metric describing the proportion of piscivore percids seems to be inappropriate in the northern areas because of the limited occurrence of percids; while perch is rare in most lakes, pikeperch is totally absent from the northernmost parts of Finland.

Tammi et al. (2002) concluded that the method needs regional adaptation, yet alone for the prevailing extensive fishing activity, which has a central role in shaping most fish communities.

More generally, fisheries and fish stocking have a controversial role in ecological assessments. Both impacts are outside the scope of the WFD. However, as an example, Hesthagen & Sandlund (2004) estimated that more than 95 % of the fish populations in the lakes of a mountain area in southern Norway existed as a result of human introductions. Similar impacts are clearly illustrated in the lakes of the present study, where fishing and fish releases have evidently been the most important anthropogenic impacts on the fish communities. Whitefish has displaced Arctic charr in many lakes after extensive whitefish stocking (Niemelä & Vilhunen 1987). In general, presence of introduced species is clearly a man-made alteration in a fish community with possibly serious biological consequences such as competitive exclusion or spreading of diseases. On the other hand, some non-native species have such a long history of presence in the community that pristine status would be hard to restore or even determine anymore. Strictly speaking, fish stocking in the present study comprised only different genetic strains of the original species, not real fish introductions in the sense of non-native species.

6 Ecological status of the River Tenojoki fish communities

The results of this study did not indicate any deterioration in the ecological status of the rivers and lakes of the River Tenojoki water system based on fish communities. This conclusion is also in accordance with the requirements of the WFD. High ecological status of the quality element ″fish″ is defined in the WFD as following:

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

The status assessment in the present study is, however, partly based on expert judgement. For instance, criteria concerning the age structure and reproduction failures in the lakes could be assessed only indirectly due to the deficiencies in the sampling methods used. Any anthropogenic impacts on the life-history features are especially hard to detect in the lakes. In the rivers, the ten metrics used in the EFI cover only aspects belonging to first two of the WFD criteria above. This is because the FAME project did not have enough age-related data for the method development (FAME CONSORTIUM 2004).

Fish are, despite of their central role in the River Tenojoki water system, perhaps not the best assessment tools for detecting subtle impacts in some ecological aspect. Human-induced degradation, such as slight eutrophication, would be most likely manifested through enhanced growth due to higher primary production, but likely not in any parameters accounting for species composition or abundance. In this respect, periphyton or benthos would offer more refined tools. On the other hand, physical perturbations such as habitat structure alterations or connectivity changes do normally have a direct traceable effect on fish communities. Fish communities normally harbour only 1–3 species per site in the Tenojoki system. Accordingly, community-based approaches may not be very efficient in status assessments. Instead, occurrence of impact-specific indicator species seems to be a simple and reliable way to assess fish community responses to various human-induced pressures (e.g. Lappalainen et al. 1995). Fish are useful indicators in biological status assessment, however, in that they combine spatial and temporal elements of their physico-chemical environment in a more covering manner than many other groups, e.g. zoobenthos and periphyton. Accordingly, in an aquatic ecosystem, both degradation and recovery processes are often manifested on different spatial and temporal scales, depending on the impact and the biological response. This was clearly demonstrated by Hesthagen et al. (in press) who showed that recovery from acid-induced effects was much slower in fish than in macrozoobethos.

Some of the possible anthropogenic threats to fish populations in the River Tenojoki system are acidification, global climate change, habitat deterioration and spreading of diseases and parasites (see also Erkinaro et al. 2001, Erkinaro 2003, Niemelä 2004). Acidification has been considered a serious threat in the northeastern Fennoscandia until the end of the late 1980s, but the changes in the main emission sources of the Kola Peninsula have lowered the actuality of the risk. The results of the present study reflect the situation prevailing in 1980–2003 (year 1980 in lakes, 1983–2003 in rivers), and the threat from acid emission has declined during this period of time (e.g. Traaen 2003, Tammi et al. 2003).

In an earlier cooperative project between Finnish and Norwegian environment authorities an inventory of erosion banks detected more than 80 unstable river banks in the River Tenojoki valley (Fergus & Rönkä 2001). In most of the cases (63%), the reason for erosion was natural, mainly due to steep banks with fine post-glacial, stratified soils. In certain areas, however, removal of bank vegetation in connection with agriculture activities and road construction has caused erosion. Norwegian and Finnish authorities have introduced river bank protection plans and carried out bank lining projects. The levels of suspended particles in the River Tenojoki have been rather low, however, and no obvious indications of negative changes caused by erosion, i.e. sedimentation, in the substratum of the rivers have been detected (Fergus & Rönkä 2001).

In future, the already ongoing global atmospheric change will inevitably pose big challenge for maintaining local fish community integrity as well. Species such like Arctic charr, having only narrow, typically low temperature optima for growth, may not easily adapt to a warming climate (ACIA 2004). Spreading of the devastating fish parasite *Gyrodactylus salaris* is a permanent risk for the River Tenojoki salmon. This parasite has already destroyed salmon stocks in 41 Norwegian salmon rivers (Anon. 2003). Infection would most probably happen through unintentional transportation of living fish material or contaminated fishing gear. In addition, genetic mixing and spreading of diseases by farmed salmon escapees from the nearby sea areas are threats to the wild salmon stocks of the Tenojoki system. Hence, strong precautionary measures to safeguard the fish communities are needed in the future management of the River Tenojoki. This is not only for the sake of the community integrity, but also because of the great socio-economic importance of the fish resources, especially that of the wild Atlantic salmon stock complex of the Tenojoki system.

7 Summary

Ecological fish community status was assessed first time in the River Tenojoki system. It was shown that, based on the fish communities, ecological status in the area corresponded to high ecological status. All impact-sensitive fish species occurred regularly over the whole watershed and no signs of recruitment failures or lowered reproduction success were detected. Intensive fish stocking has affected the fish community structure in many lakes of the Tenojoki system. However, the role of fish releases and introductions in the status assessment practices remains to be unclear so far. In the rivers, a human-induced immigrant species, bullhead, has established its presence in the fish communities over most parts of the River Utsjoki.

Fish community richness is generally low in the study area with normally only 2–3 species present at a given study site. Thus, community-based assessment methods may not provide the best approaches for ecological status monitoring. Instead, the use of indicator species is recommended. In future, lake fish monitoring should be carried out with a standardised Nordic multi-mesh gillnet method, whereas in rivers electrofishing is an appropriate method also for community assessment purposes. These methods will also satisfy the needs of the WFD monitoring practices.

No acute threats to the fish communities are foreseeable with regard to physico-chemical or physical habitat characteristics. Nevertheless, issues such as acidification and global climate change both call for consideration in the future monitoring. Possible spreading of the fish parasite *Gyrodactylus salaris* and possible impacts of escaped farmed salmon pose imminent threat to the existence of wild salmon stocks. Management of the River Tenojoki environment and fish stocks should safeguard the fish communities both for the community integrity and because of the great socio-economic importance of the fish resources.

8 Yhteenveto

Tenojoen vesistön ekologista tilaa tarkasteltiin tässä työssä ensimmäistä kertaa kalayhteisöjen perusteella. Jokien osalta aineistona käytettiin Riista- ja kalatalouden tutkimuslaitoksen Tenojoen lohikantojen pitkäaikaisseurannan sähkökoekalastustuloksia vuosilta 1983–2003. Järvien tilaa arvioitiin pääasiassa 1980-luvulla tehtyihin koeverkkokalastuksiin nojautuen. Kalayhteisöjen perusteella vesistön ekologinen tila on erinomainen. Ihmistoimintaan herkästi reagoivia, alueelle tyypillisiä kalalajeja esiintyi kauttaaltaan alueen vesissä. Merkkejä lisääntymishäiriöistä tai kalayhteisöjen vinoutuneesta ikäjakaumasta ei myöskään löytynyt. Kalaistutukset ovat kuitenkin muuttaneet voimakkaasti useiden Tenojoen vesistön järvien kalalajikoostumusta. Merkittävä tulokaslaji vesistössä on kivisimppu, joka on vuoden 1979 ensihavainnon jälkeen vakiintunut pysyväksi osaksi Tenojoen suurimman Suomen puolen sivujoen, Utsjoen kalayhteisöä. Lajin levinneisyys ulottuu nykyisellään Tenojoelle saakka. Kaikenlainen istutustoiminta sekä kalojen ja mädin siirtäminen muista vesistöistä ovat olleet kiellettyjä Tenojoen vesistössä vuodesta 1986 lähtien.

Kalayhteisöt ovat Tenojoen vesistössä tyypillisesti lajiköyhiä. Tässä työssä esiintyi tutkittua aluetta kohti keskimäärin ainoastaan 2–3 lajia. Niinpä kalayhteisöihin perustuvien ekologista tilaa arvioivien menetelmien sijaan suositellaankin seurannoissa käytettävän ihmistoiminnan aiheuttamiin ympäristövaikutuksiin herkästi reagoivia indikaattorilajeja. Tulevat kalastoseurannat tulisi tehdä järvien osalta ns. Nordic-yleiskatsausverkoilla; jokien osalta sähkökoekalastus sopii myös ekologisessa tila-arvioinnissa käytettäväksi. Molemmat menetelmät täyttävät myös vesipolitiikan puitedirektiivin mukaiset seurantavaatimukset.

Tenojoen valuma-alueella ei nykyisellään ole nähtävissä paikallisia ja välittömiä joen veden laatua tai kalojen elinympäristöä vakavasti heikentäviä uhkatekijöitä. Kalakantojen seurannassa tulee kuitenkin yhä kiinnittää huomiota yleisempiin uhkakuviin, kuten happamoitumisen sekä ilmastomuutoksen mahdolliseen kehittymiseen. Lohiloisen (*Gyrodactylus salaris*) mahdollinen leviäminen ja merikasvatuksesta karanneet lohet muodostavat sen sijaan välittömän ja jatkuvan uhan Tenojoen vesistön alkuperäisen lohikannan monimuotoisuudelle ja olemassaololle. Alueen ympäristöä koskevan päätöksenteon keskeisenä tavoitteena tulee olla kalayhteisön alkuperäisyyden säilyttäminen, ei vähiten Tenojoen lohen suuren sosio-ekonomisen merkityksen vuoksi.

9 Sammendrag

Tanavassdragets økologiske tilstand ble i dette arbeidet for første gang studert på grunnlag av fiskesamfunnene. Når det gjelder elvene, ble det anvendt resultater av elfiske fra årene 1983–2003 i forbindelse med langtidsovervåking av laksebestandene i Tanavassdraget. Tilstanden i innsjøene ble hovedsakelig vurdert på basis av prøvegarnfiske på 1980-tallet. Bedømt ut fra fiskesamfunnene har vassdraget en høy økologisk tilstand. Overalt i vassdraget forekom det fiskearter som raskt reagerer på menneskelig virksomhet og som er typiske for regionen. Man fant heller ikke tegn på forstyrrelser i reproduksjon eller skjev aldersfordeling i fiskesamfunn. Utsetting av fisk har likevel påført flere av Tanavassdragets innsjøer store endringer i fiskeartsammensetningen. En viktig fremmed art i vassdraget er hvitfinnet steinulke, som etter den første observasjonen i 1979 har befestet seg som en permanent del av fiskesamfunnet i den største sideelva på finsk side, Ohcejohka. Utbredelsen av arten strekker seg i dag frem til Tanaelva. All utsettingsvirksomhet og overføring av fisk og rogn fra andre vassdrag har vært forbudt i Tanavassdraget siden 1986.

Artsfattigdom er typisk for fiskesamfunnene i Tanavassdraget. I dette arbeidet forekom det bare 2–3 arter per undersøkt område. Derfor anbefales det at det i stedet for metoder som vurderer økologisk tilstand på basis av fiskesamfunn, brukes indikatorarter som reagerer raskt på miljøpåvirkninger forårsaket av menneskelig virksomhet. Fremtidig overvåking av fiskebestandene bør i innsjøer gjøres ved hjelp av et så kalt Nordic-oversiktsnett, i elver er elektrofiske velegnet også i vurdering av økologisk tilstand. Begge metoder oppfyller også vanndirektivets krav til overvåking.

I Tanavassdragets nedbørsfelt kan man i dag ikke se lokale og umiddelbare trusselfaktorer som i en alvorlig grad svekker vannkvaliteten eller fiskens levemiljø. I overvåking av fiskebestander bør man likevel fremdeles være oppmerksom på mer generelle trusselbilder, slike som en eventuell utvikling av forsuring og klimaendringer. Derimot er eventuell spredning av lakseparasitten (*Gyrodactylus salaris*) og rømt oppdrettslaks en umiddelbar og konstant fare for mangfoldet i og eksistensen av den opprinnelige laksebestanden i Tanavassdraget. Et sentralt mål for beslutningstaking i miljøsaker bør være bevaring av det opprinnelige fiskesamfunnet, ikke minst på grunn av den store sosiologisk-økonomiske betydningen av Tanalaksen.

10 Čoahkkáigeassu

Deanu čázádaga ekologalaš dilli čielggaduvvui dán barggus vuosttas háve guollenáliid vuođul. Jogaid dutkkadettiin materiálan geavahuvvojedje Fuođđo- ja guolledoalu dutkanlágádusa guhkes áigge vákšojuvvon šleađgaiskkusbivddu bohtosat jagiin 1983–2003. Jávrriid dilit čielggaduvvojedje eanaš 1980-logus dahkkon iskkosfierbmebivdobohtosiid vuođul. Guollenáliid vuođul čázádagaid ekologalaš dilli lea earenoamáš buorre. Dakkár guollenálit, mat leat guvlui mihtilmasat ja reagerejit álkit olbmo doaimmaide gávdnojit miehtá čázádaga. Maiddái mearkkat gođđanhehttehusain dahjege guollenáliid bonju ahkejuohkašumis eai gávdnon. Veajetgilvimat ja guollesirdimat leat sakka nuppástuhttán máŋggaid Deanu čázádaga jávrriid guollenállečoakkádusa. Mearkkašahtti ođđa nálli lea áhkaraš (kivisimppu), mii áicui vuosttas háve jagis 1979 Deanu stuorámus oalgejogas, Ohcejogas ja dan maŋŋá dat lea stáđásmuvvan bissovaš guollenállin. Dál nálli lea leavvan gitta Detnui. Buotlágan veajetgilvin sihke guliid ja meađđemiid sirdin eará čázádagain leat leamaš gildon Deanu čázádagas gitta jagis 1986.

Mihtilmas Deanu čázádahkii lea, ahte doppe gávdnojit vánet sierralágan guollenálit. Dán barggus gávdnojedje ain ovtta dutkon guovllus gaskamearálaččat dušše 2–3 guollenáli. Nuba metodaid sadjái, mat árvvoštallet guollenáliid ekologalaš dili, ávžžuhuvvojitge indikáhtoršlájat, mat reagerejit álkit olbmo doaimmaid dagahan birasváikkuhusaide. Boahttevaš guollevákšumiid galggašiige dahkat jávrriin ng. Nordic-oppalašgeahčastatfirpmiin; jogain šleađgaiskkusbivdu heive maiddái ekologalaš dillerárvvoštallamis geavahanláhkai. Goabbáge metoda deavdá maiddái čáhcepolitihkalaš rápmadirektiivva vákšungáibádusaid.

Deanu golganguovllus dál eai leat oidnosis báikkálaš ja njulges áitagat, mat duođalaččat heajudit Deanu čázi dahjege guliid eallinbirrasa. Guollenáliid vákšumis galgá goittotge ain giddet fuopmášumi dábálut áittavejolašvuođaide, nugo suvrumii ja dálkkádatnuppástusa vejolaš vearráneapmái. Luossaparasihta (*Gyrodactylus salaris*) vejolaš leavvan ja guollešaddadanrusttegiin mearas gárgidan luosat leat njuolggo ja bissovaš áitagat Deanu čázádaga álgoálgosaš luossanáli máŋggabealatvuhtii ja leahkimii. Guovllu birrasa guoski mearrádusaid dahkamis galgá leat váldoulbmilin guovllu guollenáliid álgosašvuođa seailluheapmi, iige uhcimustá Deanu luosa stuorra sosioekonomalaš mearkkašumi geažil.

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Part IV

Heikki Erkinaro and Jaakko Erkinaro

Effects of culvert restoration in distribution and abundance of juvenile Atlantic salmon in small tributaries of the River Tenojoki

Table

Introduction

Small streams and brooks are important habitats for many fish species in a river system. In the River Tenojoki system, e.g. brown trout (*Salmo trutta*) and Arctic charr (*Salvelinus alpinus*) typically occupy these habitats. Brooks have been shown to be important rearing areas also for juvenile Atlantic salmon (*Salmo salar*), although salmon do not reproduce in the brooks (Erkinaro 1997). Juvenile salmon enter the brooks from the spawning habitats in the main stems and stay in the brooks for one or more years before the next phase in the life-cycle, smolt migration to the sea. In some cases, residence in these small tributaries is mostly seasonal as a majority of the fishes descend to the main stems during the autumn (Erkinaro 1995). Brook-dwelling salmon juveniles are larger compared to their counterparts of the same age living in the main rivers (Erkinaro & Niemelä 1995). The enhanced growth of juveniles has been attributed at least partly to more abundant food resources available in the brooks (Erkinaro & Niemelä 1995, Erkinaro & Erkinaro 1998).

Road constructions, first of all culverts, pose obstacles for free fish movements in the brooks. Especially for Atlantic salmon, brook stretches that are no more reachable for the juveniles have also consequences in salmon stock status and abundance and thus a negative effect on the valuable resource. Occurrence and distribution of juvenile salmon in the brooks of the River Tenojoki system is fairly well documented (Erkinaro 1988, 1997), and physical migration barriers and potential restoration targets have been listed as well (Lundvall et al. 2001, Jørgensen 2004). Based on this information, brook habitat restorations have been conducted in the River Tenojoki system since 2000 by diminishing or eliminating the threshold between the culvert and the water surface level below. The aim of this study was to evaluate the effects of the brook restorations on fish distribution and threshold heights of the culverts.

2 Material and methods

The brooks selected for restoration (Fig. 1) have been chosen based on the recommendations by Erkinaro (1988) and Lundvall et al. (2001). First restorations took place in 2000–2003. On the Finnish side, three of the brooks (Beasnjeara, Juntejohka and Sieiddejohka) were restored in 2000 during the first phase of the project ”The preservation of the River Tenojoki as a salmon river in its natural state – environmental work, ecological condition and monitoring”. Upper branch of Vuolit Boratbokca was restored in 2001 by the Road District of Lapland (National Road Office) and the lower branch in 2003. In Norway, Bajit Hoassirjohka and Jovnnitjohka were restored in 2000 and 2002, respectively. Five brooks on the Finnish side were included in the present project as restoration targets: Bajit Boratbokca, Garnjarjohka, Koappeloaivinjohka, Mohkkarasaja and Beahkaguraja, which were restored in autumn 2004. In each brook, one or two sampling areas were electrofished at both sides of the culvert. A single-pass electrofishing method was used, as quantitative information on fish densities was not a major issue in this study. The threshold height of the culvert was measured in each brook. Fish densities were calculated and ages determined from the scale samples. The main interest was to evaluate the functioning of the culverts for free fish migration in the brooks. This was done by a) documenting the presence / absence of fish, and b) estimating the abundance of juvenile salmon above the culvert before and after the culvert restoration. While brown trout and Arctic charr are resident species occurring permanently in the brooks, presence of Atlantic salmon was used as an indicator of a passable culvert. Salmon do not reproduce in the brooks – hence all specimens above the culverts have definitely migrated from the downstream areas of the tributary and the main stem. Sampling was done in August each year to minimize seasonal variation in water level and temperature conditions.

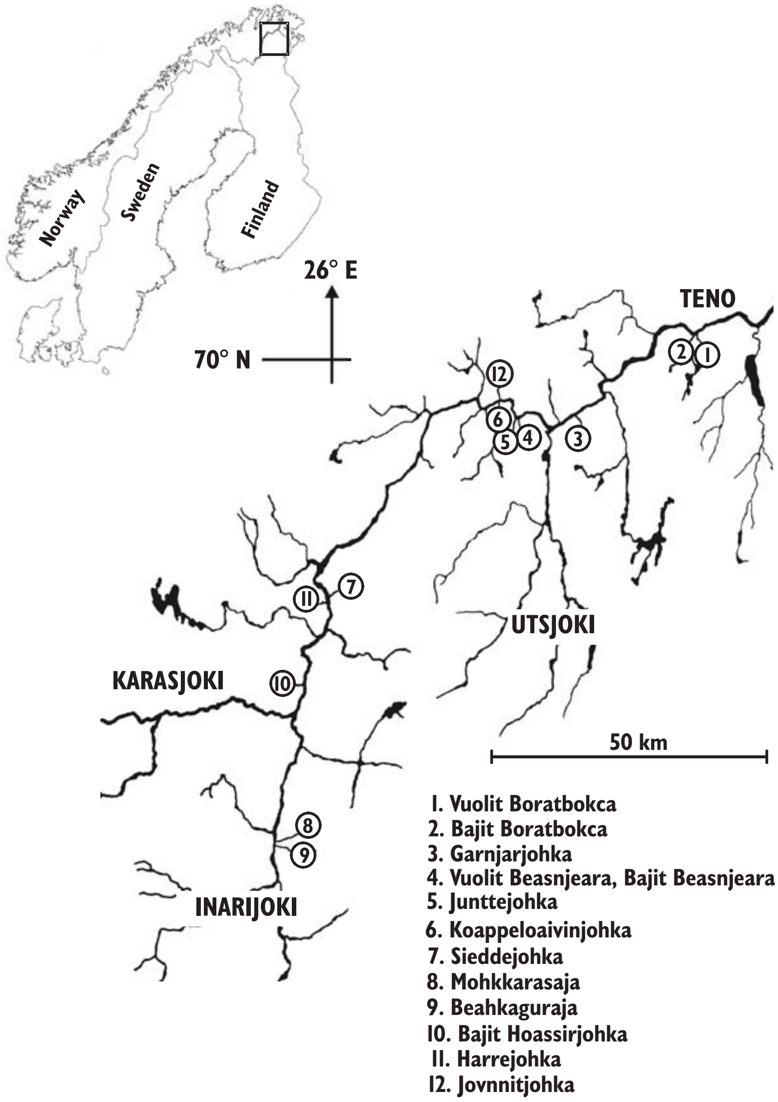

Fig. 1. Location of the restoration brooks in the River Tenojoki system.

3 Results

In four brooks out of the eight restored in 2000–2003, culvert restoration has increased the distribution area for juvenile salmon (Table 1). In addition, permanent distribution of juvenile salmon in Juntejohka has been established through culvert restoration in 2000, although a single specimen was encountered already in 1988 (Table 1). In six brooks, restoration has totally eliminated the threshold below the culvert (Table 1). Based on a single-year ”after”-monitoring period, culvert restorations in 2004 did not result in expansion in juvenile salmon distribution (Table 1).

Densities (single-pass electrofishing catches) of juvenile salmon in the lower parts of the small tributaries ranged mostly between 40 and 100 individuals per 100 m^2. Abundances of salmon typically decreased towards sampling sites further upstream. In addition to salmon, brown trout were frequently captured in most of the upstream sites, whereas trout was absent or scarce in most sites close to the main stem. Few individuals of Arctic charr were captured in uppermost sites of the brooks.

The youngest year class, underyearling (0+) salmon were generally the most abundant age group in the lower parts of the brooks, followed by relatively high proportions of 1+ and 2+ parr (Fig. 2). In sites above the culverts, 1+ and 2+ parr dominated the age distribution of juvenile salmon, whereas single individuals of 0+ group were detected in only three brooks (Fig. 2).

Table 1. Occurrence of juvenile Atlantic salmon in small tributaries of the River Tenojoki in different sampling years (1987–2005). Shaded columns indicate years after culvert restoration. Vertical line between sampling sites denote the location of the road crossing and the culvert. Threshold heights (cm) have been shown for each sampling year. o = no sampling; – = no salmon; + = 1–2 salmon specimens per site; ++ = > 2 salmon specimens per site; **?** = no height measurements.

Vuolit Boratbokca lower branch

cm	?	?	?	105	30	45
Site	**1988**	**1991**	**1995**	**2003**	**2004**	**2005**
3	–	o	o	–	–	+
2	o	o	++	++	o	o
1	++	o	o	++	++	++

Bajit Boratbokca

cm	90	?	?	80	80	20
Site	**1988**	**1991**	**1995**	**2003**	**2004**	**2005**
4	o	–	–	–	–	–
3	–	–	–	+	–	–
2	o	o	o	++	++	++
1	++	++	++	++	++	++

Vuolit Beasnjeara

cm	?	0	0	0
Site	**1987**	**2003**	**2004**	**2005**
4	o	–	–	–
3	–	++	++	++
2	++	++	o	o
1	++	++	++	++

Garnjarjohka

cm	?	115	130	8
Site	**1988**	**2003**	**2004**	**2005**
2	–	–	–	–
1	+	–	–	–

Mohkkarasaja

cm	?	25	25	16
Site	**1988**	**2003**	**2004**	**2005**
3	o	–	–	–
2	o	–	–	–
1	–	o	++	++

Sieiddejohka

cm	?	?	0	0	0
Site	**1988**	**1995**	**2003**	**2004**	**2005**
3	++	–	++	++	++
2	o	o	++	++	++
1	++	++	++	++	++

Harrejohka

cm	30 30	36 20	(two roads)
Site	**2004**	**2005**	
2	–	–	
1	++	++	

Vuolit Boratbokca upper branch

cm	30	?	?	0	0	0
Site	**1988**	**1991**	**1995**	**2003**	**2004**	**2005**
3	o	o	o	–	–	–
2	++	++	++	++	++	++
1	++	++	++	++	++	++

Junttejohka

cm	40	?	0	0	0
Site	**1988**	**1991**	**2003**	**2004**	**2005**
4	o	–	–	–	–
3	+	–	++	++	++
2	o	o	++	o	o
1	++	++	++	++	++

Bajit Beasnjeara

cm	20	0	0	0
Site	**1988**	**2003**	**2004**	**2005**
4	o	–	–	–
3	–	++	++	++
2	o	++	++	++
1	++	++	++	++

Koappeloaivinjohka

cm	?	33	32	0
Site	**1988**	**2003**	**2004**	**2005**
3	o	–	–	–
2	o	–	+	–
1	–	–	–	–

Beahkaguraja

cm	?	22	24	20
Site	**1988**	**2003**	**2004**	**2005**
2	o	++	–	++
1	+	++	++	++

Bajit Hoassirjohka

cm	0	0	10
Site	**2003**	**2004**	**2005**
4	–	–	–
3	++	++	++
2	++	++	++
1	++	o	o

Jovnnitjohka

cm	?	20	22
Site	**1991**	**2004**	**2005**
2	–	–	+
1	+	++	++

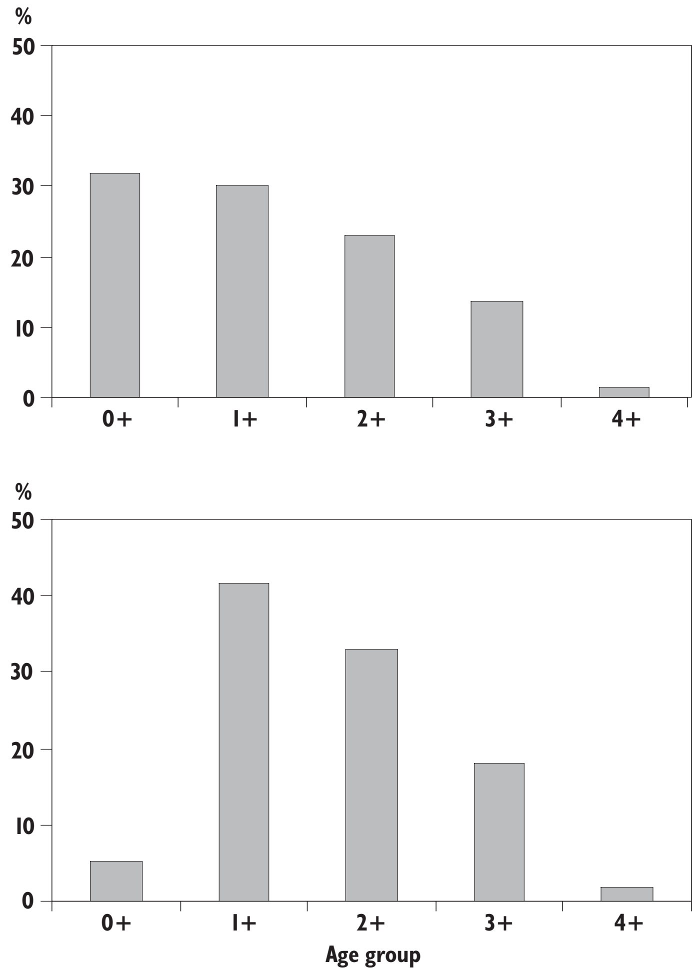

Fig. 2. Age distribution of juvenile Atlantic salmon in 12 small tributaries of the River Tenojoki. Upper panel: below the road culvert, lower panel: above the culvert.

Discussion

4

The results of the present study showed that the brook restorations carried out in the River Tenojoki system, aiming at expanding the distribution area of juvenile salmon in small tributaries, have been successful to certain extent. This holds true especially for the restorations in years 2000–2003: permanent distribution range of juvenile salmon had enlarged in four brooks and salmon juveniles were found upstream from the culverts in every study year (2003–2005). However, the brooks restored in the autumn 2004 did not show similar responses. There are many possible reasons for these observations. Firstly, compared with the brook set of 2000–2003, the brooks restored in 2004 were not as widely and densely populated by salmon juveniles before the treatment either. In addition, in the post-treatment sampling in 2005, three study areas out of five below the culverts were empty of fish; hence, these areas did not seem to be optimal habitats for salmon juveniles. For instance, Garnjarjohka and Koappeloaivinjohka have both shallow and narrow channels with a monotonous bottom structure devoid of any coarser substrate, which would provide resting or hiding places for juvenile fish (cf. Erkinaro 1995). In Garnjarjohka, the channel has been strongly eroded during spring flood in most years and all coarser bottom material has been washed out each year resulting in a monotonous pebble bottom. Consequently, this process has packed all cobbles and boulders to the mouth of the brook forming a great threshold totally preventing fish migration from the main stem. The problem has been ameliorated by the restoration of 2004, but the threshold for fish migration still exists under normal water level conditions. In Mohkkarasaja, the lowermost stretch of the brook was densely populated by salmon juveniles. However, a large marshy area with a pond between the lower brook stretch and the upper areas near the road may not attract and guide fish to ascend the brook further. In the course of this study, no fish were met in the two upper areas, either below or above the culvert.

One potential reason for little success with the 2004 restoration could be the fact that monitoring period after the activities has been only one year. Nevertheless, the distribution area of juvenile salmon can be expected to increase in some cases, especially in the Bajit Boratbokca where abundances of salmon below the culvert have been constantly high and the vertical drop caused by the culvert has been decreased from 80 cm to 20 cm through restoration.

Year to year variation in water level, e.g. in the magnitude of the spring flood, cause yearly differences in the ability of juvenile salmon to enter many brooks. This was shown e.g. in the cases where salmon had passed the culvert even if the prevailing conditions, i.e. high threshold, would have predicted the opposite. Similarly, natural obstacles up to 1 m height seem to be passable for salmon parr under certain conditions (Erkinaro 1988).

Young-of-the-year salmon juveniles were also met in the lower parts of the brooks to a larger extent than in earlier investigations (Erkinaro 1988; 1995; Johansson 2004). This may partly reflect the high levels of juvenile salmon densities in the main stem during the study years (Erkinaro et al. 2005). In addition, the present set of brooks included more small streams with a low-gradient outlets than the earlier studies did. These outlet areas provide suitable and easily reachable habitat for underyearlings that have recently emerged in nearby spawning sites in the main stem.

The restoration experiences gained in the present project could be used as guidelines also in future road management practices, both in the River Tenojoki system and elsewhere. Planning of culvert restoration should include sufficient evaluation of the potential rearing habitat that can be gained by the operation, and the present levels of fish abundance below the culvert possibly aiming at migrating upstream. Culvert restoration has been shown to increase juvenile salmon habitat, and particularly in safeguarding valuable species like the Atlantic salmon, all available habitat should be protected and enhanced.

5 Summary

Effect of culvert restorations on the distribution of Atlantic salmon juveniles was evaluated by electrofishing in 12 brooks in the River Tenojoki system. Restoration has increased the distribution area of juvenile salmon in four brooks. In addition, restoration has totally eliminated the threshold below the culvert in six occasions. Nevertheless, no change could be detected in the salmon distribution of the five brooks restored during the present project. This finding was largely attributed to the short monitoring period after the restoration and the suboptimal juvenile habitats in the given brooks. In all, restoration experiences in the River Tenojoki watercourse have showed that reasonable culvert restorations should also in future be part of the road management practices in safeguarding the prosperity of Atlantic salmon stocks.

6 Yhteenveto

Kalojen vaellusesteiden poistamisen vaikutuksia selvitettiin Tenojoen vesistöalueen puroissa. Lohenpoikasten levinneisyysalue oli laajentunut neljässä kunnostetuista 12 purosta. Kunnostuksen ansiosta 6 purossa ei esiintynyt enää lainkaan tierummun aiheuttamaa nousukynnystä. Lohenpoikasten esiintymisalueen ei kuitenkaan voitu osoittaa laajentuneen tämän hankkeen aikana syksyllä 2004 kunnostetuissa 5 purossa. Lyhyt kunnostuksen jälkeinen seuranta-aika sekä aiempia kunnostusalueita heikompi poikasten elinympäristön laatu selittänevät osaltaan tulosta. Tenojoen vesistöalueella tehdyt purokunnostukset osoittavat kuitenkin nousuesteiden huomioonottamisen olevan tärkeää myös tulevissa teiden rakennus- ja hoitokäytännöissä.

7 Sammendrag

Påvirkninger av fjerning av fiskens vandringshindre i Tanavassdragets bekker ble utredet. Utbredelsesområdet for lakseunger var blitt utvidet i fire av de utbedrete 12 bekkene. Takket være utbedringen var det 6 bekker som ikke hadde noen oppvandringsbarrierer på grunn av en kulvert/stikkrenne. Man kunne likevel ikke påvise at utbredelsesområdet for lakseunger hadde blitt utvidet i 5 bekker som ble utbedret i dette prosjektet høsten 2004. Den korte overvåkingstiden etter utbedringen samt dårligere kvalitet i leveområdet for lakseungene enn i tidlige utbedringsområder, er antakelig en delforklaring på dette. De utbedringer av bekker som er gjennomført i Tanavassdraget, viser likevel at det er viktig å ta hensyn til oppvandringshindre også ved fremtidig vegbyggings- og vedlikeholdspraksis.

8 Čoahkkáigeassu

Guliid goargŋun- ja vulosmannaneastagiid váikkuhusat čilgejuvvojedje Deanu čázádaga ádjagiin. Luossaveajehiid leavvanviidodat lei laskan njealjis divoduvvon 12 ádjagis. Divvuma geažil guđa ádjagis ii šat gávdnon olláge geaidnorumbbu dagahan goargŋunšielbmá. Dán fidnu áigge, čakčat 2004 divvojuvvon 5 ádjagis ii sáhttán čájehit, ahte luossaveajehiid leavvanviidodat livččii laskan. Divodeami maŋŋá oanehis čuovvunáigi ja ovddit divodanguovlluid veajehiid eallinbirrasa heajut šládja čilgejit muhtumassii bohtosiid. Deanu čázádagas dahkkon ájadivvumat čujuhit goittotge, ahte goargŋun- ja vulosmannaneastagiid vuhtiiváldin lea dehálaš maiddái boahtteáiggi geainnuid huksen- ja dikšungeavadagain.

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Title of publication	Ecological State of the River Tenojoki – Periphyton, Macrozoobenthos and Fish Communities	
Parts of publication/ other project publications	The publication is also available in the Internet http://www.environment.fi/publications	
Abstract	The transboundary River Tenojoki running between Finland and Norway is a sub-arctic, oligotrophic river. The river is 382 km long and the total catchment area of the Tenojoki River Basin is 16 386 km^2, of which approximately 70 % lies in Norway. The River Tenojoki is one of the biggest and the most productive Atlantic salmon rivers in the world that is still in its natural state. The brooks, tributaries and main channel of the River Tenojoki form a river reach in excess of 1 000 km long that is a suitable habitat for salmon and has potential areas for spawning. This publication includes four articles, which describe and assess the ecological state of the River Tenojoki. The article on periphyton survey was written by Juha Miettinen (University of Joensuu) and the articles concerning macrozoobenthos, fish communities and effects of culvert restorations on juvenile Atlantic salmon were written by Heikki Erkinaro and Jaakko Erkinaro (Finnish Game and Fisheries Research Institute). On grounds of the periphyton survey high ecological status can be assigned to the upstream parts of the River Tenojoki, and good ecological status for the downstream parts below Nuorgam. Based on the macrozoobenthos and fish community surveys all the studied areas fulfil the criteria for high ecological status defined in the Water Framework Directive (2000/60/EU). Monitoring practices of the ecological state of the River Tenojoki water system should be targeted for possible eutrophication nearby the largest potential sources of human impact. Monitoring of acidification development would in turn be based on a representative set of comparable headwater and brook areas.	
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Julkaisun osat/ muut saman projektin tuottamat julkaisut	Julkaisu on saatavana myös Internetistä: http://www.environment.fi/publications	
Tiivistelmä	Suomen ja Norjan välillä virtaava Tenojoki on subarktinen, oligotrofinen joki. Tenojoen vesistön valuma-alueen pinta-ala on 16 386 km², josta noin 70 % on Norjan puolella. Tenojoki on yksi maailman suurimmista ja tuottavimmista luonnontilaisista lohijoista. Tenojoen pääuoman pituus on 382 km, mutta purot, sivujoet ja pääväylä yhteensä muodostavat yli 1 000 km pituisen jokijakson, joka mahdollistaa Pohjois-Atlantin lohen nousun ja soveltuu lohen elinalueeksi. Julkaisu sisältää neljä artikkelia, jotka on laadittu Tenojoen ekologisen tilan kuvailemiseksi. Perifyton-selvityksen on kirjoittanut Juha Miettinen (Joensuun yliopisto). Pohjaeläin- ja kalastoselvitykset samoin kuin artikkelin purokunnostusten vaikutuksista lohen nousumahdollisuuksiin ovat kirjoittaneet Heikki Erkinaro ja Jaakko Erkinaro (Riista- ja kalatalouden tutkimuskeskus). Pohjalevätulosten perusteella Tenojoen yläosa on erinomaisessa ekologisessa tilassa ja Nuorgamin alapuolinen osa hyvässä ekologisessa tilassa. Euroopan unionin vesipolitiikan puitedirektiivin (2000/60/EY) edellyttämien arviointiperusteiden mukaan kaikki tutkitut Tenojoen vesistönosat täyttävät myös pohjaeläimistön ja kalaston osalta erinomaisen ekologisen tilan tunnusmerkit. Tenojoen vesistön ekologisen tilan seurannassa tulisi keskittyä mahdolliseen rehevöitymiskehitykseen suurimpien asutuskeskusten läheisyydessä sekä muutoksiin happamoitumistilanteessa alueen pienvesistöissä.	
Asiasanat	hydrobiology, salmonids, periphyton, zoobenthos, water quality, restorations of river system, the River Tenojoki (hydrobiologia, lohikalat, perifyton, pohjaeläimistö, vedenlaatu, vesistöjen kunnostus, Tenojoki)	
Julkaisusarjan nimi ja numero	Regional Environmental Publications 417	
Julkaisun teema		
Projektihankkeen nimi ja projektinumero	Tenojoen säilyttäminen luonnontilaisena lohijokena – ympäristötyöt, ekologinen tila ja seuranta (Interreg)	
Rahoittaja/ toimeksiantaja	EU / Interreg III A Pohjoinen, työministeriö, ympäristöministeriö / Lapin ympäristökeskus, Norjan vesistö- ja energiahallinto ja Finnmark'in lääninhallitus	
Projektiryhmään kuuluvat organisaatiot	Lapin ympäristökeskus, Norjan vesistö- ja energiahallinto, Finnmark'in lääninhallitus, Utsjoen, Inarin, Tanan ja Karasjoen kunnat	
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Julkaisun myynti/ jakaja	Lapin ympäristökeskus PL 8060, 96101 Rovaniemi puh. (016) 329 4760, faksi (016) 310 340	
Julkaisun kustantaja	EU / Interreg III A Pohjoinen, työministeriö, ympäristöministeriö / Lapin ympäristökeskus, Norjan vesistö- ja energiahallinto, Finnmark'in lääninhallitus	
Painopaikka ja -aika	Lapin yliopistopaino Rovaniemi, 2006	

Kolofonside

Utgiver	Lappland miljøsenter Dato: Februar 2006
Forfatter(e)	Sari Sivonen (red.)
Utgivelsens tittel	Ecological State of the River Tenojoki – Periphyton, Macrozoobenthos and Fish Communities
Utgivelsens deler/ andre utgivelser fra samme prosjekt	Rapporten er i Internett: http://www.environment.fi/publications
Sammendrag	Tanaelva mellom Finland og Norge er en subarktisk, oligotrofisk elv. Arealet på Tanavassdragets nedbørsfelt er 16 386 km^2, hvorav ca. 70 % ligger på norsk side. Tanavassdraget er en av verdens største og mest produktive lakseelver i naturtilstand. Hovedløpet av Tanavassdraget er 382 km langt, men bekker, sideelver og hovedløpet danner til sammen en over 1 000 km lang elvestrekning som hvor det er mulig for den nordatlantiske laksen å gå opp, og som egner seg til laksens leveområde. Utgivelsen består av fire artikler som er utarbeidet for å beskrive den økologiske tilstanden i Tanavassdraget. Perifytonutredningen er skrevet av Juha Miettinen (Universitetet i Joensuu). Utredningene om bunnfauna og fiskesamfunn samt hvilke virkninger utbedring av oppvandringsbekker har på laksens oppgangsmuligheter, er skrevet av Heikki Erkinaro og Jaakko Erkinaro (Institutt for vilt- og fiskeriforskning RKTL). Ut fra resultatene av bunnalgeundersøkelsene har den øvre delen av Tanavassdraget en høy økologisk tilstand og strekningen nedenfor Nuorgam god økologisk tilstand. Vurdert etter kriteriene i EUs rammedirektiv for vannpolitikk (2000/60/EF) oppfyller alle undersøkte deler av Tanavassdraget kriteriene for en høy økologisk tilstand også når det gjelder bunnfauna og fiskesamfunn. I økologisk overvåking av Tanavassdraget bør man fokusere på en eventuell eutrofieringsutvikling i nærheten av de største befolkningssentra samt på endringer i forsuringsstatus i områder med kilder og bekker.
Emneord	hydrobiology, salmonids, periphyton, zoobenthos, water quality, restorations of river system, the River Tenojoki (hydrobiologi, laksefisk, perifyton, bunnfauna, vannkvalitet, utbedring av oppvandringsbekker, Tanavassdraget)
Utgivelsesseriens navn og nummer	Regional Environmental Publications 417
Emnet i rapporten	
Prosjektnavn og prosjektnummer	The preservation of the River Tenojoki as a salmon river in its natural state – environmental work, ecological condition and monitoring (Interreg)
Finansier av/ oppdragsgiver	EU / Interreg III A North, Finlands Arbeidsdepartement, Miljøministeriet / Lapplands miljøcentral, Norges vassdrags- og energidirektorat og Fylkesmannen i Finnmark
Organisasjonene i prosjektgruppen	Lapplands miljøcentral, Norges vassdrags- och energidirektorat og Fylkesmannen i Finnmark, Utsjoki, Inari, Tana og Karasjok
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Salg/distributør av utgivelsen	Lapin ympäristökeskus PL 8060, 96101 Rovaniemi, Finland tel. +358 16 329 4760, fax +358 16 310 340
Forlegger	EU / Interreg III A North, Finlands Arbeidsdepartement, Miljøministeriet / Lapplands miljøcentral, Norges vassdrags- och energidirektorat og Fylkesmannen i Finnmark
Trykkersted og -år	Lapin yliopistopaino, Rovaniemi 2006

Sisdoallosiidu

Almmustahtti	Lappi birasguovddáš	Almmustahttináigi Guovvamánnu 2006
Dahkki(t)	Sari Sivonen (doaimm.)	
Prentosa namma	Ecological state of the River Tenojoki – Periphyton, macrozoobenthos and fish communities	
Prentosa oasit / eará seammá prošeavtta prentosat	Preanttus lea oažžumis maiddái Interneahtas http://www.environment.fi/publications	
Čoahkkáigeassu	Suoma ja Norgga rádjajohka Deatnu lea subárktalaš, oligotrofálalaš johka. Deanu čázádaga golganguovllu viidodat lea 16 386 km^2, mas sullii 70 % lea Norgga bealde. Deatnu lea okta máilmmi stuorámus ja guollásamos luondduviđá luossajogain. Deanu váldooali guhkkodat lea 382 km, muhto ádjagat, oalgejogat ja váldooalli ráhkadit oktiibuot badjel 1 000 km guhkkosaš johkaleagi, mii dahká vejolažžan Davvi-Atlántta luosa goargŋuma ja heive luosa eallinbirrasin. Preanttus sisttisdoallá njeallje artihkkala, mat leat ráhkaduvvon Deanu ekologalaš dili govvideami várás. Perifyton-čielggadusa lea čállán Juha Miettinen (Joensuu universiteahta). Bodneealle- ja guollenálleččielggadusaid seammago artihkkala ádjagiid ordnemiid váikkuhusain luosa goargŋunvejolašvuođaide leat čállán Heikki Erkinaro ja Jaakko Erkinaro (Meahcivalji- ja guolledoalu dutkanguovddáš). Bodnedeappobohtosiid vuođul Deanu giera lea erenomáš ekologalaš dilis ja Njuorggáma vuolábeali oassi buorre ekologalaš dilis. Eurohpa uniovnna čáhcepolitihka rápmadirektiivva (2000/60/EY) gáibidan árvvoštallanvuođustusaid mielde buot dutkojuvvon Deanu čázádatoasit devdet maiddái bodneealliid ja guollenáliid oasil erenomáš ekologalaš dili dovdomearkkaid. Deanu čázádaga ekologalaš dili dutkamis galggašii bidjat deattu vejolaš liiggášsaddama dutkamii stuorát ássanguovddážiid lahkosis ja maiddái suvrunnuppástusaid čuovvumii guovllu smávvačázádagain.	
Guovddášsáššit	hydrobiology, salmonids, periphyton, zoobenthos, water quality, restorations of river system, the River Tenojoki (hydrobiologia, luossaguolit, perifyton, bodneeallit, èázi kvalitehta, èázádagaid ordnen, Deatnu)	
Prentosa namma ja nummir	Regional Environmental Publications 417	
Prentosa temá		
Prošeaktabarggu namma ja nummir	The preservation of the River Tenojoki as a salmon river in its natural state – environmental work, ecological condition and monitoring (Interreg)	
Ruhtadeaddji/ doaibmaaddi	EU / Interreg III A North, Suoma bargoministeriija, Birasministeriija / Lappi birasguovddáš, Norgga čázádat- ja energiijadirektoráhta, Finnmarkku leanaráđđehus	
Prošeaktajovkui gullevaš organisašuvnnat	Lappi birasguovddáš, Norgga čázádat- ja energiijadirektoráhta, Finnmarkku leanaráđđehus, Ohcejohka, Anár, Táná (Deatnu), Kárášjohka	
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Prentosa goasttedeaddji	EU / Interreg III A North, Suoma Bargoministeriija, Birasministeriija / Lappi birasguovddáš, Norgga čázádat- ja energiijadirektoráhta, Finnmarkku leanaráđđehus	
Prentenbáiki ja áigi	Lapin yliopistopaino, Rovaniemi 2006	

Ecological State of the River Tenojoki –
Periphyton, Macrozoobenthos and Fish Communities

The transboundary River Tenojoki running between Finland and Norway is a sub-arctic, oligotrophic river. The river is one of the biggest and the most productive Atlantic salmon rivers in the world that is still in its natural state. The brooks, tributaries and main channel of the River Tenojoki form a river reach in excess of 1 000 km long that is a suitable habitat for salmon and has potential areas for spawning.

This publication includes four articles, which describe and assess the ecological state of the River Tenojoki. The article on periphyton survey was written by Juha Miettinen (University of Joensuu) and the articles concerning macro-zoobenthos, fish communities and effects of culvert restorations on juvenile Atlantic salmon were written by Heikki Erkinaro and Jaakko Erkinaro (Finnish Game and Fisheries Research Institute).

These articles were drawn up as a part of an Interreg III A North project named ”Preservation of the River Tenojoki as a salmon river in its natural state – environmental work, ecological condition and monitoring”. The project was carried out during years 2002–2006 by the Lapland Regional Environment Centre and Norwegian Water Resources and Energy Directorate.

The publication is also available in the Internet:
http://www.environment.fi/publications

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