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Benthic macroinvertebrates and aquatic mosses in pristine streams of the Tolvajärvi region, Russian Karelia

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As a preliminary stage in characterizing the biodiversity patterns of pristine stream habitats in Russian Karelia, the macroinvertebrate fauna and bryophyte flora were studied in three river systems of the Tolvajärvi area. The pristine watercourses of this area are among the few representative watercourses to be used as reference sites for the studies dealing with the impact of forestry on lotic biodiversity. The benthic fauna and flora of the area were found to include many species considered as endangered, rare or with a northern distribution in Finland. In Canonical Correspondence Analysis, the most important environmental variables affecting the distribution and abundance of the benthic fauna were the abundance of aquatic mosses, the amount of organic matter and woody debris, the size of the drainage area and the concentrations of nutrients and iron in the water. Filter feeding trichopteran and algae feeding chironomid larvae dominated the stable lake outlet habitats with abundant moss vegetation, while small streams with higher nutrient and iron concentrations and large amount of organic matter were dominated by shredding stonefly species of the generas *Nemoura*, *Nemurella* and *Leuctra*.

Introduction

A central issue in the biodiversity management of boreal forest ecosystems is the maintenance and restoration of biodiversity hotspots in key biotopes. Among the most important key biotopes in boreal forest ecosystems are small brooks and streams, which form transition ecotones between forest and water, and exhibit great physical and biological heterogeneity (Naiman and Decamps 1990, Meffe and Carroll 1994). The increasing loss of indigenous habitat characteristics and biodiversity of the stream ecosystems may jeopardize not only the local biodiversity, but also the ecological integrity and landscape functioning of the forested watersheds (Naiman 1992, Maser and Sedell 1994). Both in Europe and North America, it is nowadays difficult to find a stream in its original natural state (Benke 1990, Zwick 1992, Vuori and Joensuu 1996).

The intensified forestry practices in the old growth forests in the Finnish-Russian border zone have raised major concern over the preservation of boreal forest biodiversity. As a part of the so-called Green Belt project (a network of conservation areas along the Finnish-Russian border from the Baltic Sea to the Arctic Ocean), plans have been made to establish a large landscape conservation area in the Tolvajärvi region (Kalamajev and Sazonov 1997). The catchments of this region are still in a fairly intact condition. However, there is growing pressure to harness the area for the needs of forest industry. Since the biodiversity of lotic ecosystems of the area is poorly known, we conducted preliminary studies on the macroinvertebrate fauna and bryophyte flora. Further, we studied the relations of benthic macroinvertebrates species with the predominant environmental factors. This information will be utilized in the future development of the monitoring and assessment of the impacts of forestry on lotic ecosystems in Russian and Finnish Karelia.

Study area

The study was conducted in three watersheds: the rivers Tolvajoki, Veljakkajoki and Uuksunjoki (Fig. 1). The Tolvajoki gathers water from the ponds and lakes of the Tolvajärvi region and drains into Lake Saimaa in Finland. The latter two rivers drain into Lake Ladoga, the Veljakkajoki from the north via Jänisjärvi, and the Uuksunjoki from the north-east. The land-use practices of the studied watersheds have been restricted and moderate over the last forty years. Cultivation, timber logging and modifications of river channels mainly took place in the beginning of the 19th century and the methods employed then were much less intense than are modern practices (Metsähallitus 1925).

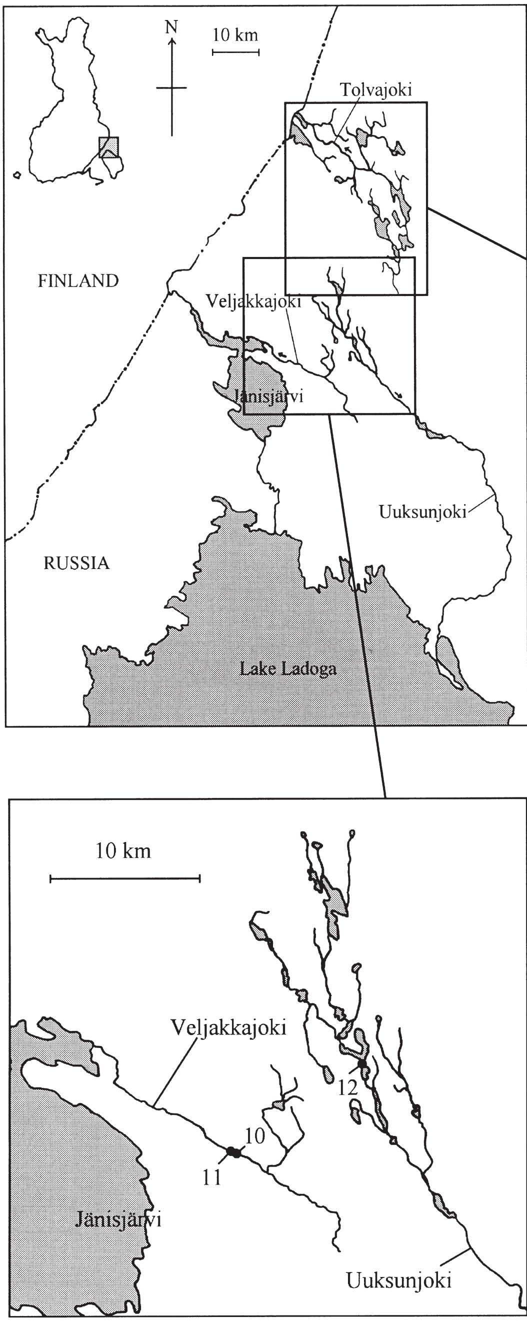
Benthic samples in the Tolvajoki were taken from two headwater streams (three sites: two in the Sauhopuro and one in the Nimetönpuro), and from the Juurikkajoki and Tolvajoki (six sites; Fig. 1). The headwater streams were in a fairly natural state and featured a large amount of woody debris and a rich mosaic of different kinds of bottom materials and microhabitats. The Juurikkajoki is a slowly flowing river floored with sand, gravel and rich vegetation cover. The river drains from the clearwater Juurikkajärvi to Saarijärvi. There were some indications of timber floating constuctions in the Juurikkajoki, such as remnants of woody deflectors and the removal of boulders to the bank. The main channel of the Tolvajoki had more marks of past clearings and restructuring, althought these activities have altered mainly the midchannel, leaving the river banks and shallow areas largely untouched.

The Veljakkajoki is a small river modified by beaver dams. The samples were taken from two sites: a slowly flowing, relatively deep outlet of an old beaver dam and a small cobble bottom riffle situated a few hundred meters downstream from the dam. The sampling site in the Uuksunjoki was a riffle approximately half a kilometer downstream from the outlet of Teronvaaranjärvi. There were slight marks of past clearings and restructuring of the river channel trough the removal of boulders to the stream banks.

Material and methods

Water samples were collected once at each site during the period from 17 to 21 September 1995. Samples were taken from swift currents from a depth of approximately 10 cm with polyethylene bottles. Water was analysed for chemical oxygen demand (COD_{Mn}), conductivity and pH. In addition, total nitrogen and phosphorous, manganese, iron, chloride, natrium, potassium, calcium, magnesium and aluminium concentrations were also measured. Analytical methods employed were those in standard use in the Finnish environmental administration. Analyses were conducted in the Environmental Laboratory of the North Karelia Regional Environment Centre.

Aquatic bryophytes were sampled along a 100-m stretch at each sampling station. The 100-m stretch was subdivided to upper-, middle- and downstream sites. At each site, mosses were collected from the stone and wood surfaces within two 5 × 5-m squares, one near the river bank and the second in the midchannel. Only those plants appearing to remain permanently under water were collected. The identification and nomencla-



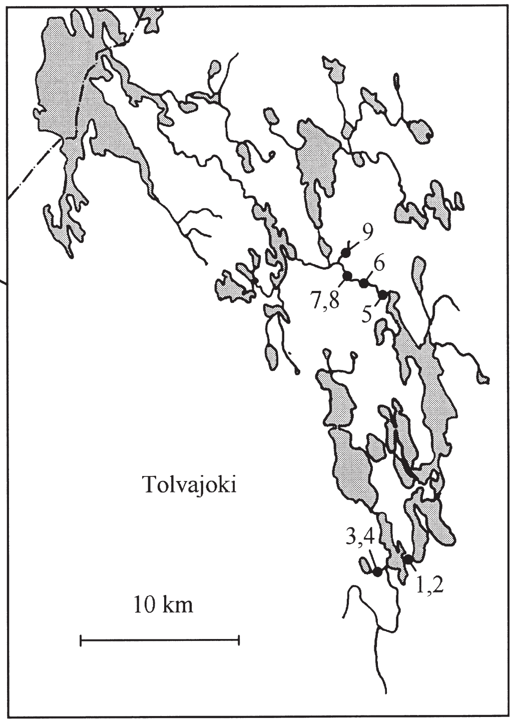


Fig. 1 (on the left and above). Location of the study sites. — 1 = Juurikkajoki, outlet; — 2 = Juurikkajoki, downstream; — 3 = Sauhopuro, upstream; — 4 = Sauhopuro, downstream; — 5 = Tolvajoki, outlet; — 6 = Tolvajoki, station 2; — 7 = Tolvajoki, station 3; — 8 = Tolvajoki, station 4; — 9 = Nimetönpuro, Tolvajoki; — 10 = Veljakkajoki, beaver dam outlet; — 11 = Veljakkajoki, downstream; — 12 = Uuksunjoki, outlet of Teronvaaranjärvi.

ture were based on Koponen *et al.* (1995).

Benthic macroinvertebrates were sampled in a standardised manner with a kick net (Suomen Standardisoimisliitto 1989, mesh size 0.5 mm). At each sampling station, five separate sites representing different habitat types of the riffle were sampled for one minute each. The samples were pooled as one five minute kick net sample. The samples were preserved in 70% ethanol on site. In the laboratory, the macroscopic invertebrates were picked and identified to the species level when possible. A number of environmental variables were measured or estimated for each sampling site, either via direct observations in the field or information collected from the maps (Finnish 1:100 000 maps from the 1930s). These environmental variables included classification of the bottom quality (Table 1), the proportional (%) coverage of aquatic mosses, the proportions (%) of forest, peatlands and lakes in the drainage area and the total area of the drainage basin. In addition, the amount of sand and detritus in the samples was estimated according to a nominal scale from 1 to 4 (scarce to abundant). A summary of the environmental variables is presented in Table 1.

The relationship between the abundance of benthic invertebrate species and environmental factors was analysed by canonical correspondence analysis with the computer program package CANOCO (ter Braak 1988, version 3.12). This weighted averaging method estimates the optimal unimodal responses of species to environmental variables with an iterative algorithm, integrating ordination and multiple regression.

Results

The sampling sites were distinguished by varying amounts of organic matter (reflected by the values of chemical oxygen demand), metals and nutrients in the water (Table 1). The lowest nutrient and metal concentrations were measured in the Juurikkajoki draining the oligotrophic Juurikkajärvi. The highest nutrient, iron, manganese, potassium, magnesium and calcium concentrations were measured in the Veljakkajoki impacted by the beaver dam.

The bryophyte flora differed among the sampling sites. Most of the sample sites were dominated by *Fontinalis*- and *Hygrohypnum*-species forming dense covers on stone surfaces (Table 2.). In the larger rivers, the Tolvajoki and Uuksunjoki, also *Dichelyma falcatum* and *Hygroamblystegium fluviatile* were common. Hepaticae, such as *Scapania* sp., *Marsupella* spp. and *Jungermannia* sp., were more typical to small stream sites than to larger streams. The species richness was highest in the Tolvajoki, where also a number of smaller species were found.These species included *Racomitrium aciculare*, *Schistidium* spp., *Brachythecium* spp., *Bryum* sp. and they occured predominantly on riffle stones in swift flowing water of the midchannel.

The highest numbers of invertebrate taxa were found in the Tolvajoki and Uuksunjoki (Appendix). While the taxonomic richness peaked at the

Table 1. Catchment and substrate characteristics and water quality of the sampling stations. — 1 = Juurikkajoki; — 2 = Sauhopuro; — 3 = Tolvajoki, outlet; — 4 = Tolvajoki, station 4; — 5 = Nimetönpuro, Tolvajoki; — 6 = Veljakkajoki; — 7 = Uuksunjoki. The amount of sand, gravel and detritus expressed according to a nominal scale from 1 to 4 (scarce to abundant). Stream order according to Horton (1945).

Variable	Sites						
	1	2	3	4	5	6	7
Catchment							
Area (km^2)	90	4.2	239	248	0.5	31	129
Lake (%)	19	7	19	18	20	1	6
Peatland (%)	40	40	50	50	60	50	60
Stream order	3	1	4	4	1	2	3
Substrate							
Moss cover (%)	80	60	90	70	20	10	80
Sand + gravel	1	2	2	2	1	1	2
Detritus	1	3	1	1	3	4	2
Water quality							
Conductivity mS m^{-1}	1.7	2.1	1.6	1.7	2.2	5.0	2.2
COD mg O_2 l^{-1}	7.2	12	8.1	8.7	18	12	12
Tot. N μg l^{-1}	260	340	240	300	250	530	360
Tot. P μg l^{-1}	14	25	9	10	12	42	22
Fe μg l^{-1}	110	230	220	230	350	920	560
Al μg l^{-1}	30	68	38	41	72	58	90
Mn μg l^{-1}	< 10	83	17	15	13	170	40
Na mg l^{-1}	1.1	1.5	1.0	1.1	2.1	1.8	1.4
K mg l^{-1}	0.4	0.5	0.4	0.4	0.7	1.1	0.5
Mg mg l^{-1}	0.4	0.4	0.4	0.4	0.5	1.9	0.6
Ca mg l^{-1}	1.4	1.8	1.4	1.4	1.8	5.2	2.0

downstream sites of the Tolvajoki (stations 6 and 8 in Fig. 1), the total zoobenthic abundance did so in the outlet habitats of the Juurikkajoki and Tolvajoki (Fig. 2). In general, the species composition of macroinvertebrates in the study streams represented typical lotic fauna of North Europe (Appendix). However, a number of species found are classified endangered or threatened in Finland (Rassi *et al.* 1992). These species included *Baetis liebenaue*, *Isoperla difformis*, *Aphelocheirus aestivalis* and *Stenelmis canaliculata*. Furthermore, although not found among our sample material, field observations were made on the trichopteran larvae of *Arctopsyche ladogensis* in the Tolvajoki (sites 6 and 7: Vuori, personal observations), which is threatened in southern Finland (Rassi *et al.* 1992).

Although all of the environmental variables were included in the first stage of the CCA-analysis, variables showing strong multicollinearity, as well as those with weak correlations with the ordination axes, were excluded from subsequent

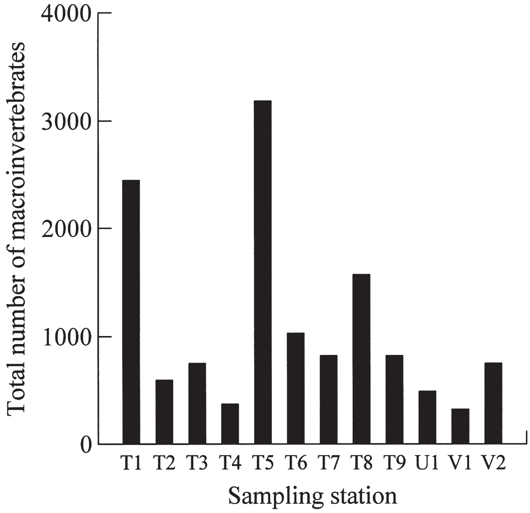


Fig. 2. Site-specific total abundances of macroinvertebrates in the kick net samples. Site numbers: — T1 & T2 = Juurikkajoki; — T3 & T4 = Sauhopuro; — T5, T6, T7 & T8 = Tolvajoki; — T9 = Nimetönpuro, Tolvajoki; — U1 = Uuksunjoki; — V1 & V2 = Veljakkajoki (*see* the study sites in Fig. 1).

Table 2. Occurrence (x) of bryophyta species at the sampling sites. — 1 = Juurikkajoki; — 2 = Sauhopuro; — 3 = Tolvajoki, outlet; — 4 = Tolvajoki, station 2; — 5 = Tolvajoki, station 3; — 6 = Tolvajoki, station 4; — 7 = Nimetönpuro, Tolvajoki; — 8 = Uuksunjoki.

Species	Sites							
	1	2	3	4	5	6	7	8
Musci								
Racomitrium aciculare (Hedw.)	–	–	x	–	–	–	–	–
Brachythecium rivulare B.S.G	–	–	–	x	–	x	–	–
Schistidium rivulare (Brid.) Podp.	–	–	–	x	x	–	–	–
S. apocarpum (Hedw.) Bruch & Schimp	–	–	–	x	–	–	–	–
Bryum spp.	–	–	x	–	–	x	–	x
Dichelyma falcatum (Hedw.) Myr.	–	–	x	x	x	x	–	x
Hygroamblystegium fluviatile (Hedw.) Loeske	–	–	x	x	–	x	–	x
Fontinalis antipyretica Hedw.	x	–	x	x	–	x	–	x
F. dalecarlica Bruch & Schimp	–	x	x	x	x	x	–	x
Hygrohypnum norvegicum (B.S.G.) Amann	–	–	–	–	–	–	x	–
H. ochraceum (Wils) Loeske	–	–	x	x	x	x	–	x
Calliergonella cuspidata (Hedw.) Loeske	–	–	x	–	–	–	–	–
Calliergon cordifolium (Hedw.) Kindb.	–	–	–	–	–	–	–	x
Warnstorfia trichophylla (Warnst.) Tuom. & T. Kop.	–	x	–	–	–	–	–	–
Warnstorfia sp. indet.	–	–	–	–	–	–	x	–
Oncophorus sp. indet.	–	–	x	–	–	–	–	–
Sphagnum riparium Ångst.	–	–	–	–	–	–	–	x
Mnium hornum (Hedw.)	–	–	–	–	–	–	–	x
Hepaticae	–	–	–	–	–	–	–	–
Scapania sp. indet.	–	–	x	–	x	–	x	x
Marsupella boeckii (Aust.) Lindb.	–	–	–	–	–	–	–	x
M. emarginata (Ehrh.) Dum.	–	–	–	x	–	–	–	–
Jungermannia sp. indet.	–	x	–	–	–	–	x	x
Ricciocarpos natans (L.) Corda	–	–	–	–	–	–	–	x

analysis.The eigenvalues were 0.84 and 0.61 for the canonical axis 1 and 2, respectively. The sum of all unconstrained eigenvalues was 3.79, hence 22.3 and 16.1% of species' distributions were related to the first and second canonical axis, respectively. The first canonical axis was strongly correlated with the environmental variables describing the amount of organic matter (COD: r = 0.86, DEBRIS, i.e. amount of detritus: $r = 0.52$). The second axes correlated most strongly with total phosphorus ($r = 0.78$), calcium ($r = 0.70$) and total iron ($r = 0.60$) concentrations. Together, these two axis explained 48% of the variation in the relation between the species and the environmental factors. However, only the second canonical axis contributed significantly to the species variation (Monte-Carlo permutation test, $F = 1.11$, $p = 0.05$).

In the CCA-biplot, the sampling stations were separated especially along the second canonical axis, excluding the Nimetönpuro, which was separated from the rest of the stations along the organic matter gradient represented by the first canonical axis (Fig. 3A). The nutrient- and metal-rich stream sites (Juurikkajoki, Sauhopuro) were located at the upper end of the second axis, whereas the larger, oligotrophic stations were located at the lower end. Similarly, macroinvertebrate species were distributed mainly along the second axis. The distribution of filter feeders, such as *Hydropsyche* spp., *Polycentropus flavomaculatus* and *Neureclipsis bimaculata,* and the algae- feeding chironomids of the genus *Cricotopus* followed the distribution of outlet stream sites with large drainage areas and abundant moss vegetation. The stoneflies *Leuctra digitata, Leuctra* sp., *Diura nanseni*, *Protonemura meyeri, Nemoura avicularis, Isoperla* spp., *Isoperla obscura* and *I. difformis* distributed along the phosphorus, calcium and iron gradient, whereas the species dominant in the Nimetönpuro brook (*Leuctra nigra*, *Nemurella pictetii*, *Nemoura* sp. and *Plectrocnemia conspersa*) distributed along the debris, aluminium and COD gradients (Fig. 3B).

Discussion

The water quality values measured in our study streams indicate oligotrophic, pristine conditions (Kristensen and Hansen 1994). Small headwater streams were characterized by somewhat higher nutrient and metal concentrations as compared to the larger rivers. The enhancing impact of beavers on the storage, processing and mobilisation of nutrients, organic matter and metals (Naiman *et al.* 1986) was indicated by the elevated nutrient, iron, manganese, potassium, magnesium and calcium concentrations in the Veljakkajoki.

The predominance of *Fontinalis* spp., and especially *Fontinalis antipyretica*, in the moss flora of the outlet habitats is a common feature of environmentally predictable lotic habitats. *Fontinalis* does not tolerate physical disturbances and fluctuating water levels very well (Englund 1991, Muotka and Virtanen 1995, Vuori and Joensuu 1996). The clearly higher diversity of the moss flora in the Tolvajoki and Uuksunjoki may be a consequence of a greater amount of suitable microhabitats available for bryophytes in large rivers as compared to small streams. In general, substrate heterogeneity increases and substrate mobility decreases the abundance and species diversity of mosses (McAuliffe 1983, Englund 1991, Steinman and Boston 1993, Muotka and Virtanen 1995). According to the Intermediate Disturbance Hypothesis (Connell 1978) both stable and harsh conditions are expected to lead to a low species diversity, while intermediate disturbance intensities maximize richness. The high species richness of mosses in the outlet habitats of our study sites may indicate such intermediate disturbance conditions.

The moss flora in the Tolvajärvi region also had northern characteristics. This is manifested by the occurrence of *Hygrohypnum norvegicum* in the Nimetönpuro and *Marsupella boeckii* in the Uuksunjoki. In Finland, these species mainly occur in Lapland (Koponen *et al.* 1995). These northern representatives of moss flora may indicate locally low summer temperatures prevailing in the natural headwater stream habitats. Temperature changes induced by forestry and other land-use practices may have restricted the distribution of these species in southern Finland.

The stonefly *Isoperla difformis*, which in Finland is considered threatened due to river reconstruction and deterioration of water quality (Rassi *et al.* 1992), was found at seven sites. The species is considered threatened in southern Finland in particular, and relatively few records have been

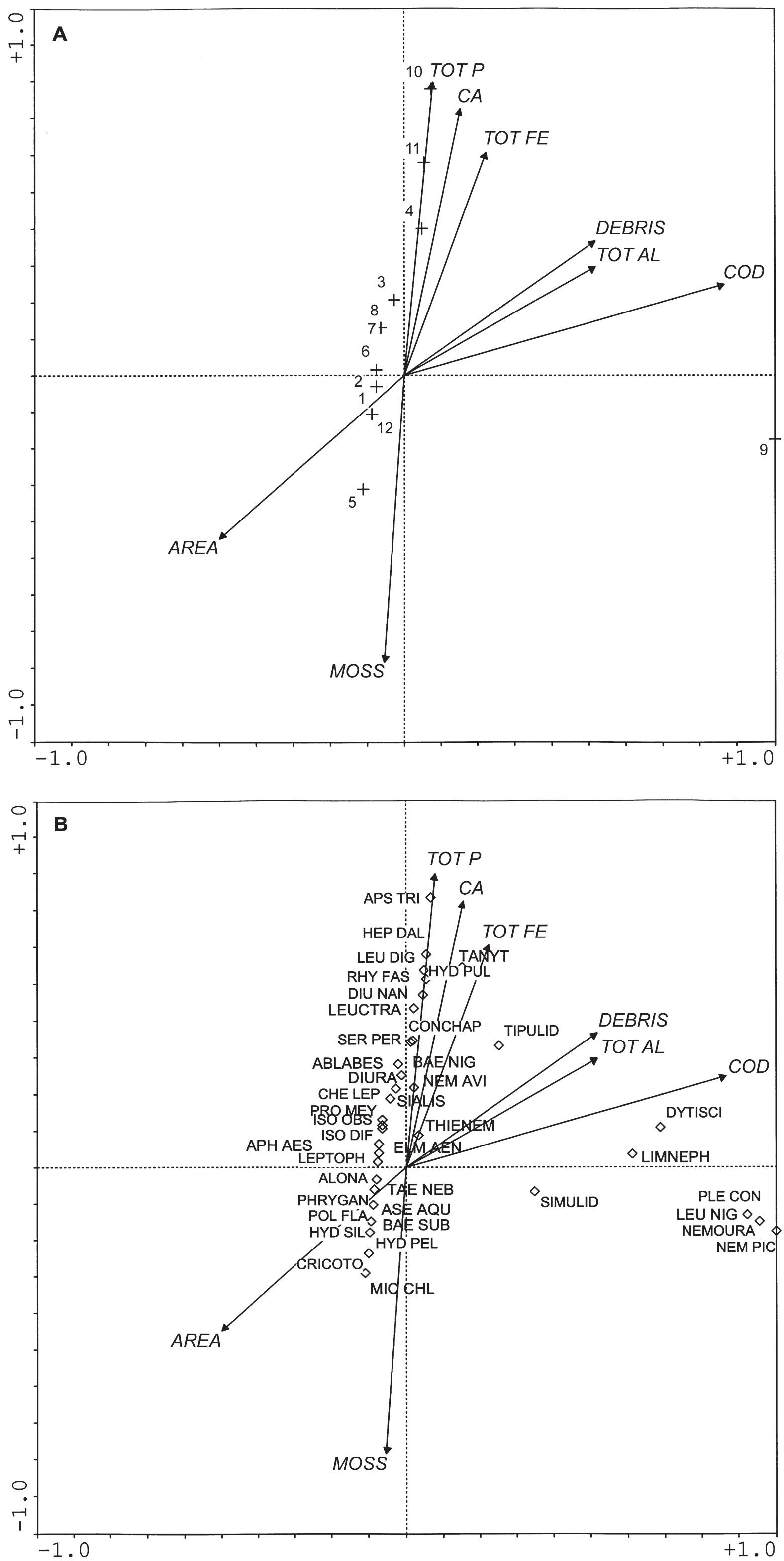


Fig. 3. The site-environment (A) and species-environment (B) biplots based on the CCA ordination. Site numbers (A) refer to those given in Fig. 1. The abbreviations refer the genera and species (the last three letters) of the macroinvertebrates listed in Appendix. TOT P = total phosphorus concentration in stream water, CA = total calcium concentration in stream water, DEBRIS = nominal amount of detrital material in the samples, TOT AL = total concentration of aluminium in the stream water, COD = chemical oxygen demand, MOSS = percent coverage of aquatic mosses on the stream bed, AREA = size of the drainage area (km^2).

made from the whole of eastern Fennoscandia (Meinander 1965, Muotka 1988, Hämäläinen 1992, Bagge and Hynynen 1995, Kuusela 1996, Kuusela and Huusko 1996). According to Malmqvist and Sjöström (1989), the distribution of the species appears to be more constrained by physico-chemical factors when compared to other *Isoperla* species. For instance, elevated summer temperatures may restrict the growth and survival of the species. Hence, such anthropogenic changes as afforestation of the riparian habitats and the consecutive rise in the water temperatures, as well as other changes in water quality, may have impaired the survival of *I. difformis* in many Finnish watercourses. It is also worth noting that the micropterous males of the species have a restricted dispersal ability (Malmqvist and Sjöström 1989, Bagge and Hynynen 1995). Kuusela and Huusko (1996) observed that *Isoperla difformis* tend to disperse only to the immediate vicinity of the river bank.

The water bug *Aphelocheirus aestivalis* was relatively abundant in the Tolvajoki. The species has been reported from many locations in the eastern Finland, North Karelia (Hämäläinen 1992), and it is abundant in the Kymijoki, southern Finland (K.-M. Vuori, unpublished material). In Finland as a whole, the bug is considered threatened (Rassi *et al.* 1992). Recently, the species was reported from northern Finland by Kuusela (1994). Beutler and Frutiger (1988) consider lake outlet habitats as the preferred habitats of the bug. In our study, the species was found both in the outlet and the downstream sites of the Tolvajoki.

Baetis liebenaue is a rare ephemeropteran species in Finland, which has been considered threatened due to river reconstructions and chemical pollution (Rassi *et al.* 1992). In the Tolvajoki, only two nymphs of this species were found. Another rarity, the coleopteran larva *Stenelmis canaliculata,* was also found from the Tolvajoki. This species was first recorded in Finland no earlier than the last decade (Hiilivirta *et al.* 1984). The species is more common than anticipated and is relatively widespread in eastern Finland (Hämäläinen 1992). According to Swedish investigations, *S. canaliculata* has very poor tolerance against acidification (Engblom *et al.* 1990).

In many stream habitats, aquatic mosses are the predominant producers and support a high zoobenthic diversity and abundance when compared to other lotic habitats (Glime and Clemons 1972, Friberg *et al*. 1977, Naiman 1983, Triska *et al*. 1982, Englund 1991, Suren 1991, Steinman and Boston 1993). Hence, it was not surprising that the total abundance of macroinvertebrates was highest in moss-rich outlet riffles (Fig. 2). The abundance of mosses contributed especially to the species richness and distribution of the filter feeders (Fig. 3). The dominant moss-dwelling species included the caddisflies *Hydropsyche pellucidula*, *H. siltalai, Polycentropus flavomaculatus* and *Neureclipsis bimaculata*, the chironomids *Cricotopus* sp. and *Thienemannimyia* sp., and the ephemeropteran species *Leptophlebia marginata*.

Plectrocnemia conspersa, Nemurella pictetii and *Leuctra nigra* have been considered as typical species of iron-rich, acid streams (Hildrew and Townsend 1980). However, in our data these species were dominant in the Nimetönpuro brook, which did not have a particularly high iron concentration. Presumably, the occurrence of these species is related to low temperature and to their ability to withstand not only iron, but also elevated concentrations of other metals, e.g. aluminium (*see* Fig. 3). The earlier observations on the distribution and physiology of these species support this conclusion (*Nemurella pictetii*: Brinck 1949, Thorup 1963, Townsend *et al*. 1983, Fialkowski 1986, Wolf and Zwick 1989, Gower *et al*. 1994, *Plectrocnemia conspersa*: Lepneva 1970, Edington and Hildrew 1981, Townsend *et al*. 1983, Darlington and Gower 1990, Gower *et al*. 1994, *Leuctra nigra*: Iversen 1978, Townsend *et al*. 1983, Elliott 1987).

In analogy to the moss flora, the benthic invertebrate fauna of the study sites also included many species with a northern distribution in Finland. The role of intensified forestry and other land-use practices in the prevailing northern distribution pattern and rarity of such species as *Diura nanseni*, *Isoperla obscura*, *I. difformis* and *Protonemura meyeri* in Finland (Kuusela 1996) should be clarified in future studies.

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Appendix. The frequency of macroinvertebrates in the kick-net samples collected from the Lake Tolvajärvi region, Russian Karelia. The site numbers reflect to the sites in the Fig. 1. — 1 = Juurikkajoki, outlet; — 2 = Juurikkajoki, downstream; — 3 = Sauhopuro, upstream; — 4 = Sauhopuro, downstream; — 5 = Tolvajoki, outlet; — 6 = Tolvajoki, station 2; — 7 = Tolvajoki, station 3; — 8 = Tolvajoki, station 4; — 9 = Nimetönpuro, Tolvajoki; — 10 = Veljakkajoki, outlet of a beaver dam; — 11 = Veljakkajoki, downstream; — 12 = Uuksunjoki, outlet of Teronvaaranjärvi.

Taxa	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Total number of taxons	32	22	32	35	43	61	42	57	19	36	36	49
Nematoda	–	–	–	–	1	–	–	–	–	–	–	1
Nematomorpha	–	–	–	–	–	–	–	–	–	–	–	1
Oligohaeta	2	–	3	–	8	10	1	–	1	1	1	–
Stylaria lacustris (L.)	10	–	–	–	–	–	–	–	–	–	–	–
Tubifex tubifex (Müll.)	–	–	–	–	–	–	–	1	–	–	–	1
Spirosperma ferox (Eisen)	–	5	–	–	–	–	–	14	–	–	–	24
Stylodrilus heringianus Clap.	–	7	–	–	–	–	–	10	–	–	–	–
Propappus spp.	–	5	–	–	–	–	–	4	–	–	–	–
Hirudinea												
Glossiphonia complanata (L.)	–	–	–	–	2	13	–	–	–	–	–	1
Helobdella stagnalis (L.)	–	–	–	–	–	9	2	–	–	–	–	2
Erpobdella octoculata (L.)	2	–	–	–	–	4	1	–	–	–	–	2
Crustacea												
Asellus aquaticus (L.)	6	12	3	9	57	29	13	6	2	10	1	31
Alona spp.	3	4	–	–	–	–	–	3	–	–	–	5

Continued

Appendix. Continued.

Taxa	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Total number of taxons	32	22	32	35	43	61	42	57	19	36	36	49
Insecta												
Ephemeroptera												
Baetis digitatus Bgtss.	–	–	–	–	–	–	–	1	–	–	–	–
B. niger L.	–	–	97	110	–	–	2	140	1	23	32	1
B. rhodani Pict.	–	–	–	1	10	47	126	8	–	22	302	1
B. subalpinus Bgtss.	–	–	–	–	–	2	–	1	–	–	–	9
B. liebenaue Kefferm.	–	–	–	–	–	–	–	2	–	–	–	–
Baetis spp. indet.	1	–	2	3	–	41	4	–	–	–	–	–
Heptagenia fuscogrisea Retz.	462	3	–	–	4	91	–	154	–	–	–	16
H. dalecarlica Bgtss.	–	–	–	–	–	–	–	–	–	–	9	–
H. sulphurea Müll.	–	–	–	–	1	12	41	6	–	–	–	15
Heptagenia spp. indet.	1	–	–	–	2	–	5	–	–	–	–	–
Leptophlebiidae indet.	–	–	–	–	–	26	1	–	–	–	–	–
Habrophlebia lauta Eaton	–	–	–	–	–	–	–	–	–	–	2	–
Leptophlebia marginata L.	1120	475	360	13	34	139	–	502	–	16	4	34
Paraleptophlebia cincta (Retz.)	3	–	–	–	–	4	–	–	–	–	–	–
Paraleptophlebia spp. indet.	2	–	–	–	–	15	–	–	–	–	–	9
Ephemerella mucronata Bgtss.	–	–	–	–	–	–	–	6	–	–	–	4
Caenis horaria L.	2	1	–	–	–	–	–	–	–	–	–	3
Plecoptera												
Diura bicaudata (L.)	–	–	–	–	–	–	–	–	–	1	–	–
D. nanseni (Kempny)	–	–	–	5	–	5	5	4	–	–	34	–
Diura spp. indet.	–	–	–	1	–	1	–	–	–	–	–	–
Isoperla difformis (Klap.)	–	–	3	–	3	2	6	28	–	–	2	3
I. grammatica (Poda)	–	–	–	–	–	–	–	–	–	–	3	–
I. obscura (Zett.)	–	–	–	–	2	–	2	35	–	–	1	1
Isoperla spp. indet.	–	–	–	3	1	3	16	67	–	–	5	11
Taeniopteryx nebulosa (L.)	–	–	–	–	13	4	3	15	–	2	2	22
Amphinemura borealis (Mort.)	–	–	–	–	–	–	–	3	–	–	–	7
Amphinemura spp. indet.	–	–	–	–	–	–	–	3	–	–	–	2
Nemoura avicularis Mort.	5	–	2	23	3	–	1	6	1	–	–	1
N. cinerea (Retz.)	–	–	–	–	–	–	–	–	1	–	–	–
Nemoura spp. indet.	–	–	3	12	–	2	–	–	548	6	3	1
Nemurella pictetii Klap.	–	–	–	–	–	–	–	–	84	–	–	–
Protonemura meyeri (Pict.)	–	–	–	–	–	–	2	3	–	–	–	–
Protonemura spp. indet.	–	–	–	–	–	–	–	–	–	–	–	–
Capnopsis schilleri (Rost.)	–	–	–	–	–	–	–	–	–	–	3	–
Leuctra digitata Kempny	–	–	18	29	–	–	–	–	–	3	224	–
L. hippopus Kempny	–	–	–	–	–	–	–	–	–	–	2	–
L. nigra (Oliv.)	–	–	–	–	–	–	–	–	31	–	2	–
Leuctra spp. indet.	–	–	22	31	–	–	–	2	–	6	–	–
Odonata												
Calopteryx virgo (L.)	–	–	–	–	–	–	–	2	–	–	–	–
Coenagrionidae indet.	1	–	–	–	–	–	–	–	–	–	–	–
Aeshna grandis (L.)	–	–	–	–	–	1	–	–	–	–	–	–
Gomphus forcipatus (L.)	–	–	–	–	–	1	–	–	–	–	–	–
G. cecilia (Fourcr.)	–	–	–	–	–	2	–	1	–	–	–	–
Cordulegaster boltoni Donovan	–	–	–	–	–	–	–	2	–	–	–	–
Corduliidae indet.	–	–	–	–	–	–	–	–	–	–	–	–
Somatochlora metallica (Lind.)	–	–	–	–	1	4	–	2	–	–	–	–
Leucorrhinia albifrons Burm.	–	–	–	–	–	1	–	–	–	–	–	–
Leucorrhinia sp. indet.	–	–	–	–	–	1	–	–	–	–	–	–

Continued

Appendix. Continued.

Taxa	1	2	3	4	5	6	7	8	9	10	11	12
Total number of taxons	32	22	32	35	43	61	42	57	19	36	36	49
Heteroptera												
Aphelocheirus aestivalis (Fabr.)	–	–	–	–	–	13	6	26	–	–	–	–
Sigara spp.	–	–	–	–	–	–	–	–	–	11	–	–
Notonecta lutea Müll.	–	–	–	–	–	–	–	–	–	9	–	–
Megaloptera												
Sialis lutaria (L.)	–	11	–	–	–	3	–	2	–	–	–	–
S. fuliginosa Pict.	–	1	2	1	–	–	–	–	–	–	–	–
Coleoptera												
Dytiscinae indet.	–	–	–	–	–	–	–	–	–	2	2	–
Agapus melanarius Aubé	–	–	–	–	–	–	–	–	5	–	–	–
Agapus spp. indet.	–	–	–	–	–	–	–	–	3	–	–	–
Hydraenidae indet.	–	–	–	1	–	–	–	–	–	–	–	–
Hydraena pulchella Germar	–	–	–	2	–	–	–	–	–	–	5	–
Stenelmis canaliculata (Gyll.)	–	–	–	–	–	–	1	–	–	–	–	–
Elmis aenea (Müll.)	–	–	–	2	–	28	39	3	–	–	–	–
Oulimnius tuberculatus (Müll.)	–	–	–	2	3	–	–	–	–	–	–	2
Limnius volckmari (Panzer)	–	–	–	–	–	1	–	–	–	–	–	–
Trichoptera												
Cheumatopsyche lepida (Pict.)	–	–	–	–	–	–	–	12	–	–	4	3
Hydropsyche angustipennis (Curt.)	–	–	–	–	–	1	5	–	–	–	3	–
H. contubernalis McLach.	–	–	–	–	–	1	1	2	–	–	–	–
H. pellucidula (Curt.)	–	–	–	–	315	53	79	–	–	–	–	114
H. siltalai Döhl.	–	–	–	–	235	21	124	–	–	–	–	9
Hydropsyche spp. indet.	–	–	–	4	–	2	14	4	–	–	–	6
Polycentropodidae indet.	–	–	–	–	–	–	–	–	–	–	1	–
Neureclipsis bimaculata (L.)	619	–	2	–	1763	12	–	–	–	–	2	8
Plectrocnemia conspersa (Curt.)	–	–	–	2	–	–	–	–	23	–	–	–
Polycentropus flavomaculatus (Pict.)	–	–	–	–	20	12	4	8	–	–	–	2
Lype reducta (Hagen)	3	–	–	–	–	–	–	–	–	–	–	–
Hydroptila spp.	–	–	–	–	–	–	–	5	–	–	–	–
Ithytrichia lamellaris Eaton	1	–	–	–	7	5	6	8	–	–	–	1
Oxyethira spp.	–	–	–	–	–	2	–	4	–	–	–	–
Rhyacophila fasciata Hagen	–	–	2	10	–	–	–	–	–	–	11	–
R. nubila (Zett.)	–	–	–	1	13	–	13	6	–	2	11	10
Rhyacophila spp. indet.	–	–	–	10	2	–	7	4	–	–	3	–
Limnephilidae indet.	–	–	1	1	1	–	2	2	16	2	1	–
Chaetopteryx villosa (Fabr.)	–	–	–	–	–	–	–	–	5	–	–	–
Limnephilus spp. indet.	–	–	–	–	–	–	–	–	–	1	–	–
Potamophylax cingulatus (Steph.)	–	–	–	–	–	–	–	–	–	1	–	–
Brachycentrus subnubilus (Fourcr.)	–	–	–	–	10	49	24	116	–	–	–	–
Micrasema setiferum (Pict.)	–	–	–	–	–	1	1	4	–	–	–	–
Lepidostoma hirtum (Fabr.)	2	–	–	–	6	7	30	107	–	–	–	11
Agrypnia obsoleta (Hagen)	–	–	–	–	–	–	–	7	–	–	–	–
Agrypnia spp. indet.	–	–	–	–	6	2	–	–	–	–	–	–
Phryganea bipunctata Retz.	1	–	–	–	–	–	–	–	–	–	–	–
Leptoceridae indet.	–	–	–	–	–	–	–	5	–	–	–	–
Athripsodes cinereus (Curt.)	2	8	–	–	1	1	–	–	–	–	–	2
Athripsodes spp. indet.	1	–	–	–	2	–	–	3	–	–	–	–
Ceraclea annulicornis (Steph.)	–	–	–	–	1	–	–	–	–	–	–	1
Mystacides spp. indet.	–	–	–	–	–	–	–	1	–	–	–	–
Ylodes spp. indet.	–	–	–	–	–	2	–	–	–	–	–	–

Continued

Appendix. Continued.

Taxa	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Total number of taxons	32	22	32	35	43	61	42	57	19	36	36	49
Molannidae indet.	–	1	–	–	–	–	–	–	—	–	–	–
Molanna spp. indet.	–	–	–	–	–	–	–	1	–	–	–	–
Molanna angustata Curt.	–	–	–	–	–	1	–	–	–	–	–	–
Molannodes tinctus (Zett.)	–	–	3	–	–	1	–	–	–	–	–	–
Sericostoma personatum (Spence)	–	–	5	4	–	–	–	–	–	1	–	–
Diptera												
Tipulidae	–	–	1	2	–	–	1	–	11	1	22	2
Tipula spp.	–	–	1	1	–	1	1	–	–	1	3	–
Pediciidae												
Dicranota spp.	–	–	–	–	–	–	–	–	–	–	1	–
Tabanidae	–	–	4	–	–	–	1	–	–	–	–	–
Tabanus spp.	–	4	1	–	–	–	–	–	–	–	–	–
Simuliidae	–	–	5	1	18	142	5	–	22	1	5	–
Chironomidae	1	–	–	3	–	2	–	1	–	1	–	–
Ablabesmyia longistyla Fitt.	–	–	–	–	–	–	1	–	–	–	–	–
A. phatta (Egger)	1	–	–	–	–	–	–	–	–	–	–	–
A. monilis (L.)	2	1	4	–	–	–	–	1	–	5	–	–
Apsectrotanypus trifascipennis (Zett.)	–	–	3	1	–	–	–	–	–	42	–	–
Conchapelopia spp.	–	4	1	16	–	4	–	–	–	2	5	–
Procladius spp.	–	30	4	–	–	6	–	9	–	15	–	–
Thienemannimyia spp.	157	8	88	43	31	4	3	67	53	53	5	12
Trissopelopia sp.	1	–	–	–	–	–	–	–	–	–	–	–
Potthastia longimana (Kieffer)	–	–	–	4	18	–	–	–	–	–	26	1
Brillia longifurca (Kieffer)	–	–	–	–	–	–	–	–	–	1	1	–
Corynoneura sp.	–	–	–	–	–	–	–	–	1	–	–	–
Cricotopus spp.	25	–	2	14	486	1	–	14	–	3	–	74
Eukiefferiella spp.	1	–	–	–	–	–	4	13	–	–	–	–
Heterotrissocladius marcidus (Walk.)	–	–	–	–	–	–	–	–	–	–	3	–
Nanocladius spp.	–	–	–	–	–	–	–	–	–	–	–	1
Orthocladius spp.	–	–	–	–	–	–	–	–	–	–	–	12
Psectrocladius limbatellus (Holm.)	–	–	–	–	–	–	–	–	–	–	–	1
Psectrocladius sordidellus gr.	6	1	–	–	–	1	–	–	–	–	–	–
Psectrocladius sp. gr. *calcaratus*	1	–	–	–	–	–	–	–	–	–	–	–
Symposiocladius lignicola (Kieff.)	–	–	–	–	–	–	–	–	–	2	–	–
Chironomus anthracinus (Zett.)	–	–	–	–	–	1	–	–	–	–	–	–
Demicryptochironomus vulneratus (Zett.)	–	–	–	–	–	–	3	–	–	–	–	–
Dicrotendipes modestus (Say)	–	–	–	–	6	4	–	–	–	–	–	–
Microtendipes gr. *chloris*	3	1	–	–	78	2	–	–	–	–	–	–
Parachironomus vitiosus (Goetg.)	–	–	–	–	5	–	–	–	–	–	–	–
Paratendipes albimanus (Meigen)	–	–	–	–	–	–	–	–	–	1	–	–
Polypedilum pullum (Zett.)	–	–	90	1	1	1	–	–	–	1	–	1
Polypedilum gr. *pedestre*	–	–	–	–	–	–	–	–	–	2	–	–
Pseudochironomus prasinatus (Staeg.)	–	2	–	–	–	–	–	–	–	–	–	–
Stenochironomus sp.	–	–	–	–	–	–	–	–	–	–	–	1
Stictochironomus sp.	–	–	–	–	–	–	–	–	–	–	–	12
Paratanytarsus spp.	–	–	1	–	1	–	–	77	1	6	–	–
Stempellinella brevis (Edw.)	–	–	2	–	–	–	–	–	–	–	–	–

Continued

Appendix. Continued.

Taxa	1	2	3	4	5	6	7	8	9	10	11	12
Total number of taxons	32	22	32	35	43	61	42	57	19	36	36	49
Tanytarsini indet.	–	2	4	7	3	–	–	4	11	71	–	1
Ceratopogonidae	–	–	–	–	–	–	–	–	–	–	–	–
Bezzia spp.	–	–	10	–	–	–	–	1	–	3	6	–
Acarina	1	–	–	–	–	–	–	–	1	–	–	1
Mollusca												
Planorbarius corneus (L.)	–	–	–	–	2	5	15	–	–	–	–	2
Lymnea peregra (Müller)	–	–	–	–	–	4	–	–	–	–	–	–
Sphaerium corneum L.	–	–	–	–	1	11	1	–	–	–	–	1
Pisidium spp.	–	9	–	–	4	152	205	16	–	–	–	5

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