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Water Chemistry and Bacterioplankton in Two Subalpine Rivers in Finnish Lapland

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Water chemistry and bacterioplankton were analysed for two subalpine rivers, River Kidisjoki and River Utsjoki, in northernmost Finland. The data set is based on continuous runoff measurements and weekly chemical and biological samples. The data were collected during the open water period, from May to October, in year 2000. The runoff patterns during the summer were similar in the two rivers at though the size of the catchments is very different (the catchment of River Utsjoki 1,520 km^2 and of River Kidisjoki 22 km^2). For both rivers, variations in runoff were followed by variations in the water quality and bacterial densities. The measured chemical concentrations were usually the highest in the headwaters of river Kidisjoki, while in the lower Kidisjoki they were clearly lower than in Utsjoki. Bacterial densities were on average highest in Utsjoki and the strongest relationships between water chemistry and bacteria were found in Kidisjoki. Both the chemical concentrations and bacterial densities were low in the two rivers when compared to other studied rivers in northern Finland.

Introduction

Due to the cold climate, the open water period is only about half the year in Finnish Lapland. Even in summer, the water temperatures of northern rivers are usually low. Oligotrophic conditions and rapid flushing of water out from the catchment also characterize the northernmost rivers. The organic soil layer is thin and concentrations of TOC (Total organic carbon) in the runoff are therefore low compared to river water in temperate and boreal landscapes (Kortelainen 1999).

In lakes, the potential carrying capacity of bacteria has been shown to depend on the amount of DOM (dissolved organic matter) (Tranvik 1988) and also on its quality (Tulonen *et al.* 1992), but there have not been large differences in bacterial densities in lakes having different humus concentrations (Münster *et al.* 1999).

In this paper chemical and bacterial conditions in two northern rivers are related to the seasonal weather of year 2000 and the site-specific conditions.

Study Area

River Utsjoki, catchment area 1,520 km^2, is located in Finnish Lapland, in the northernmost part of the country where sub-alpine landscape dominates. A major part of the catchment is situated on altitudes between 200 and 300 m a.s.l. River Utsjoki is a tributary of River Teno that drains into the Arctic Ocean. The main rock types in the catchment are granulite and gneisses. Forests are characterized by birch (*Betula pubescens,* subsp. *Tortuosa*), with some isolated pine groves occurring in the river valleys (Seppälä and Rastas 1980), but most of the forests are very sparse, and a major proportion of the upland birch forests were damaged by the geometric moth *Epirrita autumnata* in 1960's (Kallio and Lehtonen 1973).

Water sampling is done at the River Utsjoki catchment outlet at Patoniva, on a tributary River Kidisjoki just before the confluence with the main river, and very upstream in River Kidisjoki. The catchment of River Kidisjoki is 22 km^2. The drainage area at the upstream, Skallovara, see Fig. 1, is about 1 km^2. Most of the river water at Skallovaara is from the Skallovaara palsa mire.

Material and Methods

Hourly data on temperature and precipitation were collected on Skallovaara palsa mire from 12th of May to 8th of October by the University of Kuopio. Weather data were also collected by the the Finnish Meteorological Institute at Kevo Subarctic Research Station, situated some 12 km from the palsa mire but 200 m lower than the mire and close to the sampling point Patoniva in River Utsjoki (*cf.* Fig.1).

For River Utsjoki, the continuous discharge is measured by the Finnish Environment Institute. For River Kidisjoki, a limnigraph was set up in June 2000 to measure the water level close to the Skallovaara palsa mire. The above information was combined to get estimations of runoff in lower River Kidisjoki.

Water quality monitoring in River Utsjoki and in River Kidisjoki was initiated by the "Arctic Feedbacks to Global Warming: a Circumpolar Assessment" project in spring 2000, and it was continued through the open water period. The samples for total and inorganic nitrogen and phosphorus and bacteria were collected weekly. The samples for inorganic nutrients were filtered through Millipore Millex-GS filter

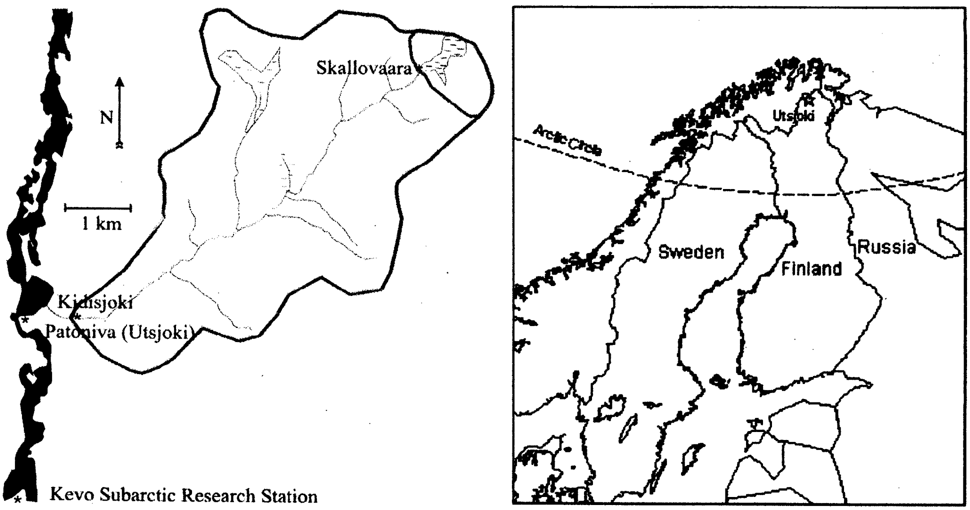

Fig. 1. The location of the study area and a map of the study area including the catchment of River Kidisjoki (mires on the catchment are marked with short lines).

(approximate pore size 0.2 µm); all nutrient samples were stored frozen in dark till the analyses. The samples were analysed at the laboratory of the Lammi Biological Station, University of Helsinki. The chemical analyses were carried out using standard methods (cf Arvola *et al.* 1996). Samples for bacteria were preserved with Lugol's solution. Before staining with acriflavine (Bergström *et al.* 1986), samples were clarified with thiosulphate crystals. Samples were filtered through black Poretics polycarbonate filters (pore size 0.22 µm) and counted with an inverted microscope (Olympus IX 50), using the analySIS 3.0 image analysing program to determine bacterial densities and volumes. The conversion factor from bacterial cell volumes to carbon was 0.36 pg C μm^{-3} (Tulonen 1993).

Results and Discussion

Even though the Skallovaara palsa mire is situated only some 12 km from the Kevo Subarctic Research Station, the daily mean temperatures and monthly precipitation values of the two measuring points somewhat differed from each other: the temperatures were always higher at the lower situated research station and the precipitation more than 30% higher in Skallovaara during August and September. Monthly mean values are shown in Fig. 2. During the winter, the temperatures at the Kevo Subarctic Research Station are often much lower than on the Skallovaara palsa mire, due to the cold air flowing down the slopes to the Kevo valley, where the station is situated (Seppälä 1983).

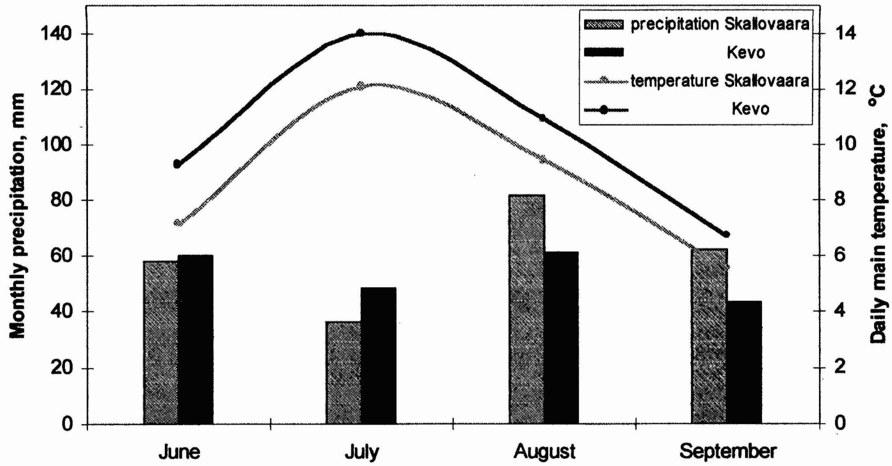

Fig. 2. Weather in Skallovaara and Kevo during the open water period.

The runoff patterns during the summer is similar in the big river Utsjoki and the small upstream brook at Skallovaara, when the weekly averages are considered (Fig. 3) with high flows during snowmelt in late May and low flow during summer. The small peak in the Skallovaara runoff on week 32 is due to a heavy rain of one day (the 9th August: 39 mm, which was clearly the highest daily precipitation measured during the study period). The precipitation recorded at Kevo that day was less than half of the value in Skallovaara.

The average values of the measured chemical concentrations were the highest in the very upstream Skallovaara sampling point, except for the concentration of $NO_{2\text{-}3}$, which was slightly higher in River Utsjoki (Table 1). The concentrations of

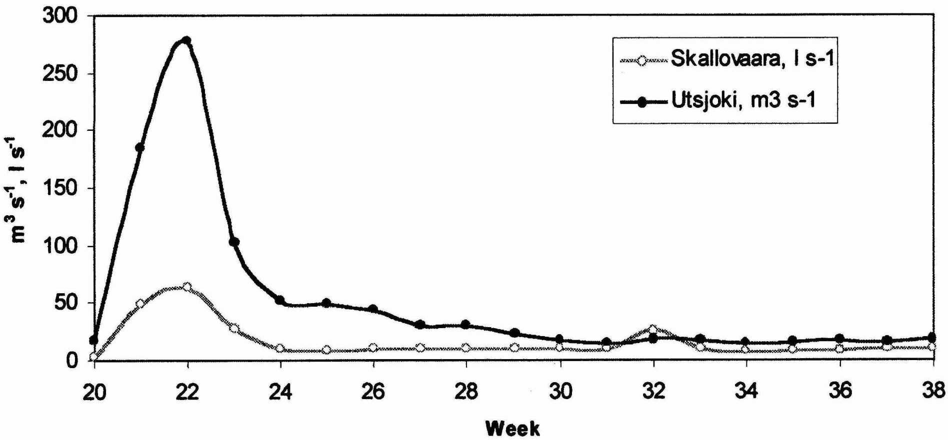

Fig. 3. Runoff in sampling points Skallovaara and Patoniva: weékly average during weeks 20 to 38.

Table 1 – Chemical properties of the studied rivers during open water period 2000.

	Utsjoki			Kidisjoki			Skallovaara		
	average	median	range	average	median	range	average	median	range
tot N (mg m^{-3})	154.4	166	72-244	141.9	122	70-268	193.3	177	103-346
tot P (mg m^{-3})	5.7	5	3-12	5.9	4	4-16	7.5	6	4-18
NO_2+NO_3 (mg m^{-3})	14.8	11	5-72	7.5	6	5-15	11.5	10	6-23
NH_4 (mg m^{-3})	7.1	5	3-20	6.6	5	2-25	9.5	7	4-38
PO_4 (mg m^{-3})	1.5	1	1-2	2.0	2	1-9	2.3	2	1-6
TOC (g m^{-3})	3.6	3.5	2.4-5.5	3.4	3.3	2.1-7.5	5.2	4.6	3.3-9.7

n = 19, except for TOC n = 14

Table 2 – Bacterial densities, volumes and biomasses in the studied rivers.

	Utsjoki			Kidisjoki			Skallovaara		
	average	median	range	average	median	range	average	median	range
Density (10^6 cells ml^{-1})	0.892	0.852	0.342-1.814	0.497	0.390	0.228-1.465	0.875	0.750	0.395-1.819
Cell volume (mm^3)	0.031	0.022	0.010-0.084	0.029	0.028	0.010-0.055	0.029	0.025	0.013-0.069
Biomass (mg C l^{-1})	11.0	7.8	3.0-44.7	6.3	3.9	1.6-25.4	10.2	6.9	2.3-39.5

n = 19

nutrients, especially nitrogen, were lower at the outlet of River Kidisjoki than upstream. This dilution effect is explained by the thin organic soil layer of the slopes along the river. The low nutrient concentrations at the lower part of River Kidisjoki seem to result in low biomass. As seen in Table 2, the medium biomass here is only half of that of the main river and that of the biomass downstream the Skallovaara mire.

Bacterial densities were on average highest in the main River Utsjoki (Table 2). Almost the same densities were observed at Skallovaara sampling point while at the lower Kidisjoki sampling point the average densities were lower. Average cell volumes were almost similar at all sampling points, so the bacterial biomasses were determined by the densities.

When considering the influence of runoff on water quality and bacteria, the runoff seemed to have a profound effect on almost all the studied variables (Table 3). The highest correlations, about 0.8, were found between runoff and total phosphorus concentrations, and also between runoff and bacterial biomass, 0.73-0.90. For Kidisjoki and Utsjoki, there was also a clear relationship between runoff and TOC, 0.6-0.7, but not at the very upstream Skallovaara. Since the phosphate concentrations are low and rather poorly correlated to the runoff, it is clear that the total phosphorous relation to runoff is mainly an organic phosphorous relation.

Table 3 – Correlations between runoff and water chemistry and bacteria (n = 19 except for TOC n = 14).

	Skallovaara	Kidisjoki	Utsjoki
runoff vs tot N	0.37**	0.61***	0.45**
runoff vs tot P	0.76***	0.77***	0.84***
runoff vs TOC	0.18	0.67***	0.62***
runoff vs NH4	0.53***	0.65***	0.57***
runoff vs PO4	0.33*	0.00	0.25*
runoff vs NO2 + NO3	0.21*	0.59***	0.08
runoff vs cell volume	0.52***	0.33*	0.42**
runoff vs biomass	0.90***	0.75***	0.73***
runoff vs density	0.65***	0.65***	0.55***

*** = significant at 0.1% risk level
** = significant at 1% risk level
* = significant at 5% risk level

Table 4 – Correlations between water chemistry and bacteria (n=19 except for TOC n=14).

	Skallovaara		Kidisjoki		Utsjoki	
	Biomass	Density	Biomass	Density	Biomass	Density
tot N	0.44**	0.81***	0.55***	0.60***	0.36**	0.18
tot P	0.77***	0.74***	0.87***	0.92***	0.75***	0.48**
TOC	0.21	0.55**	0.84***	0.83***	0.62***	0.44*
NH4	0.50**	0.41**	0.77***	0.77***	0.18	0.12
PO4	0.25*	0.27*	0.00	0.01	0.26*	0.22*
NO2 + NO3	0.37**	0.33**	0.63***	0.60***	0.01	0.02

Also the relationship between water chemistry and bacteria was studied. In general there is a relation between total N as well as total P with biomass and cell density as is seen in Table 4, although it is weak for the main river. For the lower Kidisjoki all correlation coefficients, except between bacteria and PO_4-P, were significant. The bacterial densities and biomasses followed the changes in total phosphorus concentrations in all the study points. The relationships between TOC concentrations and bacteria were clear in Utsjoki and Kidisjoki, while at Skallovaara only the bacterial density was correlated with TOC concentrations.

Arvola and Nurmesniemi (2001) found bacterial densities close to $2x10^6$ cells ml^{-1} in the oligotrophic Kitka River, which is double to these observed at Patoniva and at Skallovaara in this study. In the humic River Kiiminkijoki the densities are on the average $2.9x10^6$ cells ml^{-1} (Heikkinen and Visuri 1990), about three times higher than those found in the present study. However, the bacterial densities of the present study are still in the density range (10^5 to 10^7 cells ml^{-1}) reported for Canadian

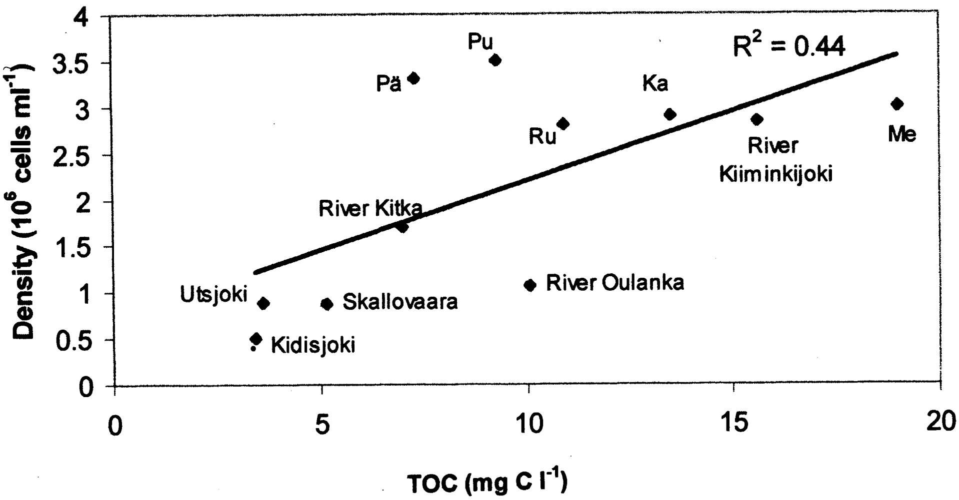

Fig. 4. The relationship between TOC and bacterial densities in the studied rivers and River Kiiminkijoki (Heikkinen and Visuri 1990), Rivers Oulanka and Kitka (Arvola and Nurmesniemi 2001) and five lakes in Lammi, southern Finland: Pä = Pääjärvi (Tulonen 1993), Me = Mekkojärvi (Munster *et al.* 1992), Pu = Pussijärvi, Ru = Ruuttanajärvi and Ka = Karhujärvi (Salonen *et al.* 1994). The TOC values for rivers Kitka and Oulanka were calculated on grounds of the water colour values (see Arvola 1999).

rivers in "natural state" (Albricht *et al.* 1980).

The relationship between average TOC concentrations and bacterial densities is clear in the present study. When results of some lakes situated in southern Finland are included in the analyses, the correlation coefficient is lower but still indicative (Fig.4). In the present study the most upstream sampling site (Skallovaara) was situated just below the mire, so it is reasonable to assume that the bacteria in this habitat are from the mire ecosystem. In the sampling site close to the mouth of the River Kiddisjoki the diluting effect is evident both in the nutrient concentrations as in the bacterial number and the biomass. The higher bacterial densities in River Utsjoki may be a result of the upstream lakes in the river system (*cf.* Arvola and Nurmesniemi (2001).

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