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Research Article

# EXPERIENCE OF USING PHYTOPERIPHYTON MONITORING IN URBAN WATERCOURSES*

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**Key words**: rivers, phytoperiphyton, monitoring, north-western Russia

## Abstract

The purpose of this paper is to assess how informative phytoperiphyton structural parameters are, and to assess the feasibility of using them for biological monitoring of river quality. The spatial distribution of the attached algae community was studied in some of rivers in Republic of Karelia (NW Russia). The influence of anthropogenic impacts on periphyton communities was analysed in terms of species richness, species diversity, species ecology values, biomass and chlorophyll concentration. All rivers are subjected to different kind of anthropogenic impacts in addition to natural disturbance. With regards to the species composition the differences between the urban and natural stretches of rivers are obvious. The data obtained demonstrate that the phytoperiphyton communities in urban streams are dominated by broadvalent, pollution-tolerant and even saprophilic taxa. Substantial changes in periphyton structure were often caused by an enhanced mechanical impact by storm run-off, which retarded colonisation, rather than any chemical influence. The burial of algae by sand and silt resulted in the loss of species or entire algal assemblages were observed. As result the communities are dominated by a few species with high recolonization potential.

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## INTRODUCTION

The Republic of Karelia (NW Russia) does not have a high population density. The total territory is 172 000 km$^2$ with a population about 700 000 people, giving an average density of only 4 person per square km. There are more than 60 thousand lakes and 27 thousand rivers in the Republic of Karelia, and most rivers are rather small in catchment area and length. A dense river network, which combines various landscapes, supports their ecological stability. Small rivers draining large catchment areas influence the water quality of larger bodies of water and thus play an important environmental role. However, the closed character of the catchments of these small rivers coupled with direct contact with the results of human activities lead to rapid response of ecosystems to human impacts.

The algal flora is the most sensitive constituent of aquatic ecosystems, and is responsible for the structure and functioning of its components. The advantage of using algae to monitor aquatic ecosystems is due to their short life cycle, enabling both assessment of the present state of a water body during short-term observations, but also prediction of possible changes. Phytoperiphyton can be helpful for assessing long-term changes in small rivers, such as those associated with eutrophication, river management, changes in land use at the scale of the watershed and in last years for monitoring in NW Russian rivers (Komulaynen 2002a).

The main objectives of this study were to describe the spatial distributions of phytoperiphyton in small rivers, which were affected by human activity. The periphyton communities were analysed in terms of species richness, species diversity, species ecology values, biomass and chlorophyll concentration. In addition, I try to assess how informative phytoperiphyton structural parameters are, and to assess the feasibility of using these for biological monitoring of the river status.

## MATERIAL AND METHODS

Phytoperiphyton samples and environmental measurement were made in riffle zones on the Tohma, Neglinka, Lososinka, Lizma, Kumsa, Letnja'a and Kenty rivers located in the different parts of Republic of Karelia (Fig. 1). The main characteristics of these rivers are given in Table 1. The rivers channels are poorly incised, their valleys are poorly developed, and the longitudinal profile shows a stepwise pattern formed by alternating rapids and pools, which often expand into lake-like water bodies and lakes. In total about 60 riffle zones, scattered through the rivers, were examined under base-flow conditions. Here

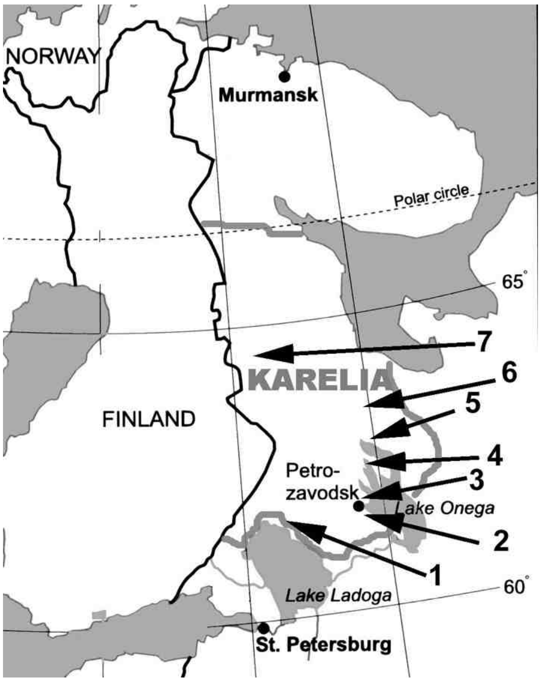


**Fig. 1** The study area, with arrows indicating the investigated rivers: 1- Tohma, 2-Neglinka, Lososinka, 3-Lizma, 4- Kumsa, 5-Letnja'a, 6-Kenty, and 7-Kumsa.

the streambed is stony and deposition of silt and sand is at a minimum. The rivers were approximately 10-25 m wide with maximum depths ranging from 1 to 2 m. In all rivers the highest level was observed during the spring flood, caused by snow melt, the minimum during August. The basins studied generally lie far from urban and industrial areas, therefore as a rule most of river reaches are relatively undisturbed for most of their length and are altered by human activities only at their mouths.

Qualitative periphyton samples were collected during August on all rivers except the Lososinka and Neglinka where samples were collected in all seasons. About 10 samples were collected at each site from e 3-5 randomly chosen stones removed carefully from a depth of 30-50 cm. The periphyton removed from a defined area by scraping the surface of rocks, stones and pebbles.

**Table 1**

River's length (L), catchment area (S), area covered by lakes (lS), bogs (Wl) and water discharge (WD)

| RIVERS | | L km | Catchment | | | WD $m^3/c$ |
|---|---|---|---|---|---|---|
| | | | S $km^2$ | lS % | wlS % | |
| Tohma | 1 | 99 | 1618 | 5.5 | 5.0 | 14.7 |
| Neglinka | 2 | 15 | 43 | <1.0 | 10.0 | 0.5 |
| Lososinka | 3 | 25 | 302 | 7.0 | 9.0 | 4.0 |
| Lizma | 4 | 68 | 717 | 19.4 | 11.0 | 7.6 |
| Kumsa | 5 | 60 | 753 | 9.0 | 7.0 | 7.5 |
| Letnja'a | 6 | 61 | 590 | 6.9 | 13.0 | 5.3 |
| Kenty | 7 | 75 | 930 | 11.9 | 18.1 | 14.8 |

Cell counts were used to calculate Shannon-Weaver diversity index (Shannon, Weaver 1963). Periphyton biomass was estimated on each rock from chlorophyll *a* standing stock and ash-free dry mass (AFDM) ($g/m^2$). Chlorophyll *a* was determined spectrophotometrically (Strickland & Parsons, 1972).

The diatom database software "Omnidia" (Lecointe *et al*. 1993) was used to calculate several indices: trophic diatom index –TDI (Kelly, Whitton 1995) and IDAP –Prigiel *et al*. 1996). These indices reflect better the water quality differences in humic waters (Eloranta 1999).

Water chemistry data were obtained from the Northern Water Problems Institute Karelian Research Center RAS, who measured nutrient concentration at sites corresponding with our periphyton sampling.

## RESULTS AND DISCUSSION

### *General habitat condition*

All rivers studied have exceptionally soft water with low conductivity (Table. 2) and often deep-brown water colour due to humic materials (50-240 mg Pt $l^{-1}$). Based on pH value, the rivers waters are classified as transition from neutral to slightly acid (pH 6.5-7.5). Phosphorus and nitrogen concentrations are low in most location in all rivers, indicating oligotrophic conditions. High concentration of nutrients were observed in a limited zone in Lososinka and Neglinka rivers and reached 32.0-49.0 $\mu g\ l^{-1}$ of total phosphorus and 0.54-1.73 mg $l^{-1}$ of nitrate-N. Iron concentration in surface waters varies from < 0.01 to 3.1 mg $l^{-1}$ with an average value of 0.59 mg $l^{-1}$.

Longitudinal changes in water quality were detected along the stretch of the rivers studied. Differences in nutrient content in the rivers can be attributed to anthropogenic activities in urban areas whilst the increase in nitrate-nitrogen concentrations may be related to agricultural practices in the surrounding area. Elevated levels of phosphate may be result from domestic sewage waters input.

The changes observed in chemical composition are not generally disastrous, in contrast to those reported from many industrial areas in Russia. In many cases considering a small increase in biogenic substances versus a rise in electrical conductivity and a decline in pH, it is possible that the quality of the water supplied to the end user in the watercourses studied has even slightly improved.

In addition to chemical pollution, river valleys and river channels are affected by mechanical pollution. Human activities cause the disappearance of tributaries or a reduction in their length, silting of river channels, decreasing of water turbidity, overgrowing and paludification. The urbanization of a territory is accompanied by changes in water balance. For small rivers within a city, a longitudinal rise in water discharge does not correspond with a natural increase in basin area. Runoff increases by 160-450% during summer floods and by 200-360% during low water level periods compared to unimpacted streams.

**Table 2**

Water chemical composition of studies rivers

| RIVERS | | Cond. mg S/m | mg Pt $l^{-1}$ | $P_{tot}$ | $P_{min}$ | $NH_4$ | $NO_2$ | $NO_3$ |
|---|---|---|---|---|---|---|---|---|
| | | | | μg P $l^{-1}$ | | mg N $l^{-1}$ | | |
| Tohma | 1 | 61.0 | 115.0 | 43.0 | 12.0 | 0.47 | 0.004 | 0.85 |
| Neglinka | 2 | 143.6 | 240.0 | 49.4 | 10.5 | 0.63 | 0.012 | 1.73 |
| Lososinka | 3 | 43.5 | 95.0 | 32.0 | 18.8 | 0.88 | 0.020 | 0.36 |
| Lizma | 4 | 53.1 | 65.0 | 28.0 | 7.2 | 0.11 | 0.003 | 0.45 |
| Kumsa | 5 | 45.2 | 43.0 | 32.0 | 8.0 | 0.08 | 0.004 | 0.67 |
| Letnja'a | 6 | 44.7 | 45.0 | 42.3 | 9.5 | 0.15 | 0.004 | 0.54 |
| Kenty | 7 | 217.3 | 35.0 | 22.0 | 7.0 | 0.01 | 0.013 | 0.80 |

### *Composition of algaeflora*

Seven of the rivers contained diverse algal floras with indifferent, stenotopic, euperiphytic species adapted to high flow. In all rivers studied the most common and frequent species were diatoms *Achnanthes minutissima, Cocconeis placentula, Cymbella affinis, C. ventricosa, Didymosphenia geminata, Eunotia pectinalis, Frustulia rhomboides, Gomphonema angustatum, G. constrictum, Hannaea arcus, Melosira varians, Tabellaria flocculosa*. These species contributed the majority of diatoms counted for every sampling period. Green algae were occasionally abundant in upstream location. The most frequent of these was *Zygnema*. In locations with well development riparian vegetation, attached algal communities consisted predominately of diatom films. It should be noted that such a periphyton structure is characteristic of most of rivers of North-western Russia (Komulaynen 1990, 2002b).

The same taxa were also abundant in urban locations, but in downstream stretches the periphyton was composed mainly of macroscopic green mats of *Spirogyra, Oedogonium* and *Cladophora*. Dominant rheophilous χ-saprobic diatoms of the genera *Achnanthes, Eunotia, Cymbella* were observed to drop out, and *Tabellaria* became less important. Diatoms belonging to the genera *Diatoma, Gomphonema, Nitzschia, Pinnularia* and *Navicula* were more abundant in these locations.

The distribution of phytoperiphyton communities in rivers agrees, in general, with the main proposition of the River Continuum Concept. River channels contain a mosaic of habitats. The differences in composition and biomass between individual sites depend primarily on interactions between flow and substrate. Unlike the gradual changes in species composition observed in rivers that are in natural condition, those in urbanised areas are chaotic, so that communities differing markedly in composition can be found side by side. The structure of phytoperiphyton in separate reaches in urbanised areas is also less stable, which is due to storm runoff and the mosaic distribution of drifting material and deposits.

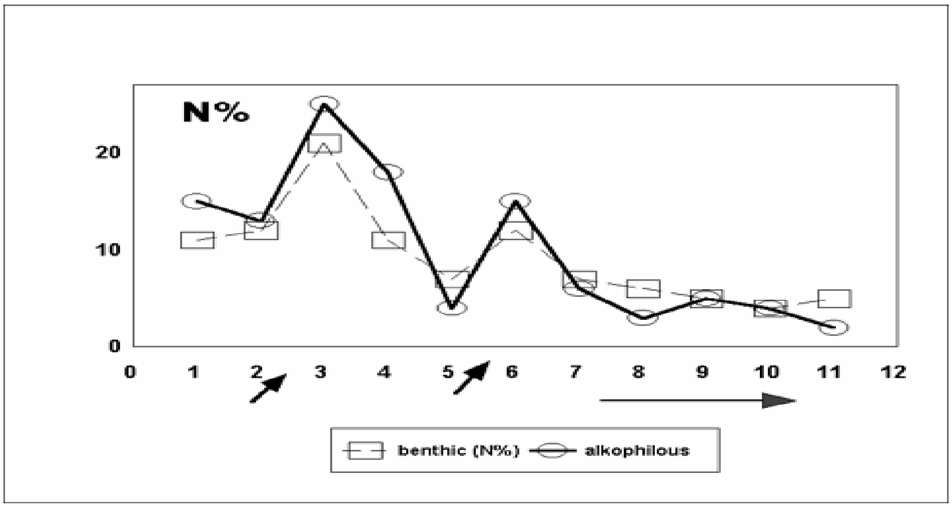


**Fig. 2.** Relative abundance of some ecological forms (b-benthic, al- alkaliphilic) in periphyton communities for different sites on the River Kenty with vertical arrows indicating sites of sludge introduction.

In the zone affected by domestic sewage the number of species typical of the natural environment had greatly decreased. Diatoms most closely associated with urban locations were *Achnanthes minutissima, Cymbella minuta, Navicula menisculus, Navicula cryptocephala, N. lanceolata, Gomphonema parvulum, Nitzchia palea, Fragilaria vaucheriae* and *Fragilaria virescens*. These are species with broad ecological spectra, known from various eutrophic environments.

The most common and abundant blue-green algae in upstream location were species of the genus *Calothrix* and *Tolypothrix.* A number of species of the genus *Oscillatoria* were found to increase in downstream retches.

Substantial changes in periphyton structure were often caused by an enhanced mechanical impact due to storm runoff retarding colonisation, rather than by any chemical influence. This impact became particularly noticeable when river channels were restructured, the riverbeds levelled and the amount of unconsolidated materials increased and the effect was exacerbated by destruction of the riverbank vegetation. Drainage of mires, leading to pieces of timber entering and floating in the river caused the most significant changes in the periphyton composition in some rivers. Changes in flow and water level led to bark being deposited on the periphyton and the subsequent destruction of algal communities.

The burial of algae by sand and silt resulted in decreases in the number of species recorded and their abundance. Turbulence decreases rapidly in locations with sewage waters input and the presence of even loosely aggregated organic and inorganic sediment increased the sedimentation of algae. In addition to variations in species composition, there were changes in the ecological spectra of algal flora. The data obtained demonstrate that the flora here is enriched by eubenthic (unattached, motile) forms (Fig. 2) such as Navicula and Pinnularia.

These forms do not reach high numbers but are quite diverse and common in urban sites where patches combining organic and inorganic substances are formed (Komulaynen 1990, 1999). The presence of debris in these underwater islands form the base for filamentous algae. The filamentous alga (*Spirogyra, Mougeotia, Cladophora, and Batrachospermum*) exist in large number on this debris and formed a secondary base supporting the development of a secondary epiphytic algal flora and accumulate plankton algae. This increases habitat heterogeneity and explains higher specific richness of attached communities in the most of urban sites of studied rivers.

Changes in periphyton structure result in altered values for the Shannon-Weiner diversity index as increased anthropogenic impacts mean that the communities become less diverse and structurally simpler. The average specific abundance of families and genera commonly declines. However, such changes were observed in a limited zone directly adjoining the site where sewage effluent entered the river. Figure 3 illustrates the changes in diversity index for the periphyton communities in River Lososinka. At the initial stages of contamination the presence of different species and the marked increase of some species that were previously scarce influenced the structure of the community.

According to diatom indices all studied rivers are of a good quality (Fig. 4). This may be because the diatom taxa which dominate in the polyhumic brown waters with low pH and conductivity common in north-western Russia are, in general, classified as xeno- to oligosaprobic. As result diatom indices did not reflect the differences in nutrient content in unpolluted rivers in all cases.

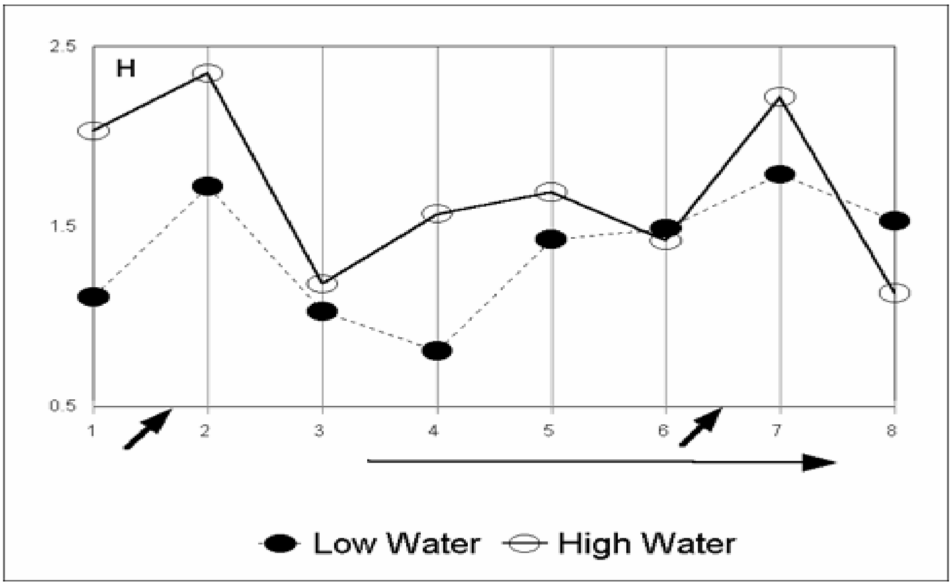


**Fig. 3.** Changes of mean value of Shannon-Weaver index at different sites on River Lososinka with vertical arrow at location of domestic waters input.

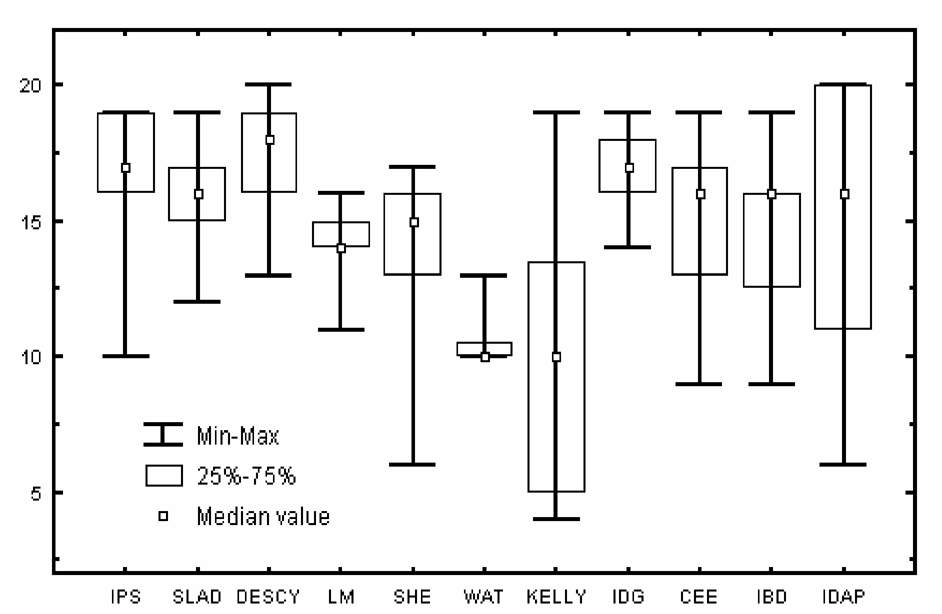


**Fig. 4.** Box plot of different diatom indices value for studied rivers.

**Table 3**

Means (min-max) periphyton characteristics for rivers studied

| RIVERS | | Number of cells | Biomass | Chlorophyll a |
|---|---|---|---|---|
| | | $10^4$ cell $cm^{-2}$ | mg $cm^{-2}$ | mg $m^{-2}$ |
| Tohma | 1 | 62.2 (2.0 –116.0) | 4.81 (0.40-24.13) | 148.8 (8.0-1084.5) |
| Lososinka | 2 | 40.5 (0.2 –823.0) | 1.89 (0.05-31.00) | 80.7 (4.0-759.5) |
| Neglinka | 3 | 18.6 (0.1 –181.6) | 2.20 (0.05-23.43) | 115.5 (2.5-807.3) |
| Lizma | 4 | 23.6 (0.7 –90.8) | 4.56 (0.10-28.04) | 142.6 (3.0-1260.0) |
| Kumsa | 5 | 41.8 (0.8 –620.0) | 4.10 (0.10-12.03) | 102.5 (7.0-510.0) |
| Letnja'a | 6 | 43.6 (7.1 –472.6) | 1.81 (0.20-22.31) | 82.5 (5.0-482.6) |
| Kenty | 7 | 42.4 (2.9 –2120. 0) | 4.33 (0.30-29.56) | 139.7 (3.0-1258.0) |

The percent organic matter of the periphyton was low in all studied rivers. On average, from 10 to 30% of periphyton dry mass was organic matter, indicating that greater than 50% of the periphyton matrix was inorganic matter. The periphyton biomass in river studied ranging from 0.1 to 31.0 mg $cm^{-2}$ and Chl *a* from 2.5 to 1260.0 mg $m^{-2}$. Chl *a* generally constitutes approximately 1-2% of the dry mass of algae (Table.3). This suggests that much of organic material covered substrates in rivers studied consisted of detritus and heterotrophic organisms. Periphyton biomass and Chl *a* concentration varied significantly among sites and was highest in downstream sites where attached algal communities were composed of macroscopic green filamentous mats of *Zygnema, Mougeotia, Ulothrix,* and *Oedogonium,* whereas in upstream sites the periphyton consisted predominately of thin diatom films. Simultaneously, Chl *a* concentration in the total organic material attached to the substratum showed a general tendency to decrease in urban areas (Fig 5). All these changes were more distinct in years when the flow, and hence water level, was lower.

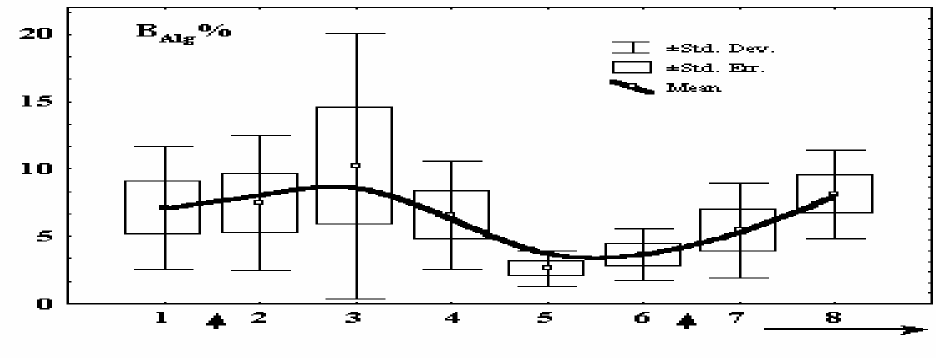


**Fig. 5.** Relative abundance of algal biomass (B%) in total attached organic material at different sites on River Lososinka with vertical arrow at location of domestic waters input

## CONCLUSION

Agriculture, fish farming and domestic sewage waters only weakly loaded the studied rivers. A general feature of the periphyton of the studied rivers was oligotrophy with various taxa dominating. A study on dynamics of phytoperiphyton show that biomass changes of attached algal communities, composed mostly of diatoms and green algae, was for most of the year dependent on flow, light and substratum (Komulaynen 1999). In river reaches unaffected by human activities, especially their upper reaches, periphyton typically exhibits a strikingly stable species composition (Komulaynen 2002a). But physical factors and variation in the growth of this community in different seasons of the year alone cannot explain all variations in phytoperiphyton community density.

It can be concluded that increasing human impact on rivers affects the species composition of periphyton communities. Eutrophication causes structural changes, but the differences in nutrient concentration were not large enough to be seen in all index values, because xenosaprobic species remain fairly abundant. In small streams it is extremely difficult to interpret changes in the periphyton communities in terms of water quality changes at a given site. The community sampled at one site is the result of physical, chemical and biological determinants, which interact in separate stretches. In fact, changes in the assemblage, although seemingly related to water quality changes, may not reflect water quality at all. But it was found that the TDI and IDAP diatom indices can also be applied to rivers even with weak loads

The impacts of urban areas lead to the formation of riverine patches by increasing the downstream transport of organic and inorganic material. Increases in the size of these patches leads to an increase in the number of species and diversity of attached algal communities (Komulaynen, 2002b). The human impact increases mosaicity in biomass, which is chiefly due to a stronger purely mechanical effect that slows down colonization.

Based on the observations of the present study, some methodologically important conclusions were drawn.

- Any attempt to apply one method of sampling or data analyses, one concept, theory, or one cause-effect relationship to explain the river space dynamics leads to errors.
- Inclusion of the «patch and disturbance» concept to the river continuum concept more accurately reflects the pattern of spatial variations in algal flora (from outlet to mouth) in lake-river systems.
- During the spring and winter seasons, the species composition of periphyton in habitats influenced by human activities does not differ

markedly from the periphyton formed under natural conditions. In July-September, taxonomic heterogeneity becomes obvious, as shown by the decreased species similarity index.

- Floristic diversity of algal communities is also maintained by the asynchronism of succession in various types of lakes in lake-river systems, and algal drift can explain the simultaneous presence of spring, summer, and autumn species in algal cenosis in rivers.

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