

## STRUCTURE AND DYNAMICS OF ALGAL COMMUNITIES IN SMALL RIVER OF THE REPUBLIC OF KARELIA (RUSSIA)

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### Abstract

Komulaynen S., 2018: Structure and dynamics of algal communities in small river of the Republic of Karelia (Russia). – *Botanica*, 24(1): 59–68.

Distribution of phytoplankton, phytoperiphyton and microphytobenthos communities was simultaneously studied in the River Lihzma (Republic of Karelia, Russia). Comparison includes both taxonomic and quantitative parameters along river continuum. Special attention was given to the analysis of causes of spatial inhomogeneity of algal communities. In the studied river, the pattern and trends of dynamics in the community were dependent on high current velocities and the alternation of lake, pool, and riffle zones. Algae are constantly removed from bottom biotopes, attached forms are detached from their substrate and are transported by the stream, and planktonic forms settle down, disturbing the distinctive characteristics of communities and resulting in the formation of “mixed” communities.

**Keywords:** lake-river systems, microphytobenthos, phytoperiphyton, phytoplankton.

### INTRODUCTION

Republic of Karelia is remarkable for its high hydrological differentiation and abundance of water. There are more than 60 thousand lakes and 27 thousand rivers in the Republic of Karelia, and 90% of rivers are rather small in catchment area (< 100 km<sup>2</sup>) and length (< 10 km) (VODOGRETSKIY, 1972). Small rivers have an important role in controlling the water balance, and are widely used for fish farming, water supply and recreational activities. They have lately been subjected to anthropogenic impacts that have led to perceptible changes in their hydrobiological regime. However, the study of small rivers for a long time tended to be neglected in the Republic of Karelia, with phycological studies concentrated on the phytoplankton of large rivers and lakes (KOMULAYNEN, 2007).

Lotic systems are characterized by longitudinal profile and fluvial processes driven by permanent unidirectional flow (ALLAN & CASTILLO, 2007). The morphological and biological changes along a river have been introduced by VANNOTE et al. (1980) as «a river continuum». This concept, which is widely used to describe the function of lotic ecosystems, assumes that the geo-physical variables within a river system present a continuous gradient from source to mouth. Of course, rivers are not homogeneous. The hydrological regime and river channel vary, while the pool portions of a river and rapids alternate. The influence of spring floods, ice drift and other disasters that vary in intensity not only from one river to another, but also from section to section may disturb “a classical continuum” on rivers and should also be taken into consideration (GRIMM, 1994; HOLMES et al., 1998; ROBSON & MATTHEWS, 2004). Furthermore, a «classical continuum» in most of the rivers is disturbed by fluvial (riverine) lakes (MOSLEY, 2004). Practically

each lake-bounded stream is an independent river, which has its own source and mouth.

There are three types of algal communities in aquatic ecosystems: phytoplankton, phytoplankton and microphytobenthos (WETZEL, 1979). The term periphyton adopted here follows the definition of ODUM (1971): "Assemblages that include both plant and animal organisms growing attached to submerged objects". The prefix phyto- is added to indicate that of the whole biocoenoses only phototrophs are considered in this study. This term microphytobenthos refers to the microscopic, unicellular eukaryotic algae and the prokaryotic Cyanobacteria that live on sediment surfaces (KROMKAMP et al., 2006). All communities are used in monitoring of river systems (Li et al., 2010; ECTOR et al., 2012). Therefore, it is essential to reveal their characteristics and the reasons for their natural heterogeneity, otherwise, during monitoring the natural dynamics of species composition and quantitative characteristics could be taken for the result of an increased anthropogenic load.

Algae are constantly removed from bottom biotopes, attached forms are detached from their substrate and are transported by the stream, and planktonic forms settle down, disturbing the distinctive characteristics of algal communities and resulting in

the formation of "mixed" communities. The biomass is also regulated by algal emigration (STEVENSON, 1983, 1991).

Our study focused on the influence of fluvial lakes on the algal community formation in rivers. The main goal of the present study was to find out how phytoplankton, phytoplankton and microphytobenthos structure in a river varies with a distance from fluvial lakes.

## STUDY AREA

Our studies were conducted at two sections selected in the lower reaches of the River Lihzma. The River Lihzma (Fig. 1) rises from a small forest lake (62°45' N, 34°48' E) and discharges into Lake Onega (62°22' N, 34°30' E). It is 68.3 km long with a catchment area of 974 km<sup>2</sup>. Section 1: station (St.) 1–8 between Lake Tarasmozero and Lake Onega is 1.9 km long (gradient 11 m/km) and consists of two rapids divided by a pool, 200 m long portion of the river between stations 4 and 5. Section 2 (St. 9–12) is a 800 m long rock bar (gradient 18 m/km) between lakes Kedrozero and Tarasmozero, with very short pool (20 m long) between stations 10 and 11.

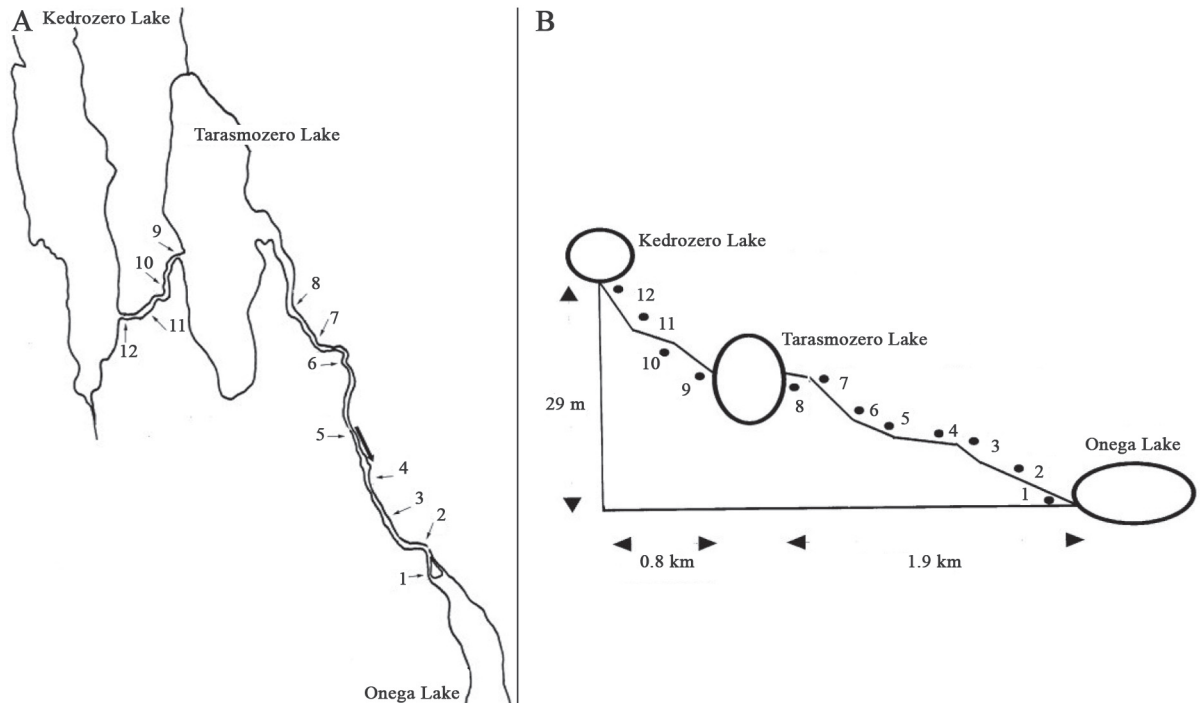


Fig. 1. Location of the study stations on the River Lihzma (A) and the scheme of the river slope (B)

The River Lihzma was selected because of its hydrographic network typical of Karelia and has been the subject of many hydrobiological and algological studies (GENKAL & KOMULAYNEN, 2000; KOMULAYNEN et al., 2006; GENKAL et al., 2015).

## MATERIALS AND METHODS

All 176 samples were collected during the hours of daylight on 27 July 2013 in the low water discharge period from 12 separate sites in open, unshaded areas with sections of rocky riffles and soft, muddy substrates. To assess the lake effect and exclude the influence of variations in hydrological regime, samples were collected in location with similar depth of 30–40 cm, where current velocity was in the range of 20–30 cm/s, and stones and rocks covered about 80–90% of river bottom.

The methods used are generally comparable to the CEN standard (CEN, 2005). Water velocity was measured using flow meter (Valeport-Model-001). Water samples for water chemistry (two replications from sites 1, 8, 12) and phytoplankton analyses (four replications from all 12 sites) were taken from the surface by plastic bottles. Water chemistry data were obtained from the Northern Water Problems Institute Karelian Research Centre RAS, who measured nutrient concentration at the sites corresponding to our sampling by standard methods (BOEVA, 2009). The characteristics determined in the analyses of water chemistry included water colour index (CI), nutrient concentrations, i.e. total N (N<sub>tot</sub>) and total P (P<sub>tot</sub>); the concentrations of dissolved gases (O<sub>2</sub>%), mineralization ( $\Sigma$ ) and water pH.

At least four samples of microphytobenthos and phytoperiphyton were collected at each location. The microphytobenthos was sampled by siphoning the surface of soft, muddy sediments using a large pipette. Periphyton was sampled by brushing with a scalpel blade, knife or a toothbrush from three to five (~30 cm sized) stones without a visible coating of silt from a defined area (5–20 cm<sup>2</sup>) depended on the density of attached filamentous algae.

Two samples of phytoplankton, microphytobenthos and phytoperiphyton were conserved by adding Lugol's and were used for enumeration and identification of algae. A minimum of 400 natural

unit counts (cells, colonies or filaments) were identified. Unit counts were used to calculate the Shannon-Weaver diversity index (SHANNON & WEAVER, 1963). Species showing an average relative abundance in the algal flora of a separate river  $\geq 10\%$  are considered as «dominant». The rest of the samples were used to determine the chlorophyll *a* spectrophotometrically (STRICKLAND & PARSONS, 1972). Statistical and ecological analyses were conducted using the STATISTICA 7 software package.

Taxonomic classifications and identifications were primarily made according to KOMÁREK & FOTT (1983), STARMACH (1985), KRAMMER & LANGE-BERTALOT (1986, 1988, 1991a, b), KOMÁREK & ANAGNOTIDIS (1999, 2005), ELORANTA & KWANDRANS (2007), KOMÁREK (2013).

## RESULTS AND DISCUSSION

### Chemical characteristics of water

The water of the River Lihzma system belongs to the hydrocarbonate class, it is clear and oligotrophic. During sampling in the River Lihzma, algal communities functioned practically at constant temperature (19–20°C), mineralization, pH and nutrient concentration values (Table 1).

Table 1. Water chemical composition in the River Lihzma (July 2013)

Parameters	Stations		
	12	8	1
Cl, grad.	20.0	28.0	22.0
P <sub>tot</sub> , mg/L	0.005	0.007	0.007
N <sub>tot</sub> mg/L	0.45	0.43	0.40
$\Sigma$ , mg/L	37	37	38
O <sub>2</sub> , %	86	93	97
pH	6.8	7.1	7.0

### The algal communities

The list of algae found in all three communities comprised 143 taxa (Table 2), which is about 30% of taxa known for the River Lihzma (KOMULAYNEN et al., 2006). Bacillariophyta made up the greatest number (74–94%) of taxa in all three communities in the most samples and stations (70%).

Forty taxa of algae were recorded as dominants ( $\geq 10\%$  of total community cell counts), 27.9% of

the total number of recorded taxa (Table 3). Of these, 25 taxa were dominant in only one community and of little consequence in the others. Only two taxa, *Tabellaria flocculosa* and *Fragilaria capucina*, were recorded as dominant in phytoplankton, phytoperiphyton and microphytobenthos.

### Phytoplankton

Phytoplankton or rather algal drift or pseudoplankton in the River Lihzma is formed from lake (limno) plankton and algae removed from benthic and attached communities. The number of algal taxa in plankton on separate samples ranged from 5 to 29. The poorest plankton community was observed in

Table 2. Number of taxa and percentage composition of algal repartition/distribution in communities (combined results of 12 stations): pl – phytoplankton, per – phytoperiphyton, mpb – microphytobenthos

Taxa	pl	per	mpb	For all communities
Cyanobacteria	7 (11.3)	1 (1.4)	–	7 (4.9)
Chrysophyta	2 (3.2)	1 (1.4)	1 (1.0)	2 (1.4)
Dinophyta	–	–	1 (1.0)	1 (0.7)
Bacillariophyta	46 (74.2)	59 (79.7)	93 (94.0)	114 (79.7)
Chlorophyta	6 (9.7)	9 (12.2)	4 (4.0)	15 (10.5)
Rhodophyta	1 (1.6)	4 (5.4)	–	4 (2.8)
Total	62	74	99	143 (100.0)

Table 3. A list of dominant algae from the phytoplankton (pl), phytoperiphyton (per) and microphytobenthos (mpb). Dominant (D)  $\geq 10\%$ , (C) common and (P) present species

Taxa	pl	per	mpb
Cyanobacteria			
<i>Hapalosiphon pumilus</i> Kützing ex Bornet et Flahault	D	P	–
<i>Aphanizomenon flos-aquae</i> Ralfs ex Bornet et Flahault	D	C	–
Chrysophyta			
<i>Dinobryon divergens</i> Imhof	D	C	C
Bacillariophyta			
<i>Aulacoseira ambigua</i> (Grunow) Simonsen	D	P	P
<i>A. islandica</i> (O. Müller) Simonsen	D	D	C
<i>A. italica</i> (Ehrenberg) Simonsen	D	D	C
<i>Cyclotella bodanica</i> Eulenstein ex Grunow	D	P	P
<i>C. radiosa</i> (Grunow) Lemmermann	D	C	C
<i>C. meneghiniana</i> Kützing	D	C	P
<i>Tabellaria fenestrata</i> (Lyngbye) Kützing	D	D	C
<i>T. flocculosa</i> (Roth) Kützing	D	D	D
<i>Fragilaria capucina</i> Desmazieres	D	D	D
<i>F. construens</i> (Ehrenberg) Grunow	D	D	C
<i>F. virescens</i> Ralfs	P	C	D
<i>Asterionella formosa</i> Hassall	D	P	P
<i>Cocconeis placentula</i> Ehrenberg	C	D	D
<i>Achnanthes exigua</i> Grunow	–	P	D
<i>A. linearis</i> (W. Smith) Grunow	C	D	C
<i>A. lanceolata</i> (Brébisson) Grunow	P	C	D
<i>A. minutissima</i> Kützing	D	D	C

Taxa	pl	per	mpb
<i>Frustulia rhomboides</i> (Ehrenberg) De Toni	–	D	D
<i>Cymbella affinis</i> Kützing	P	D	D
<i>C. helvetica</i> Kützing	–	D	–
<i>Cymbella silesiaca</i> Bleisch in Rabenhorst	P	D	–
<i>Didymosphenia geminata</i> (Lyngbye) M. Schmidt.	P	D	P
<i>Gomphonema angustatum</i> (Kütz.) Rabenhorst	–	D	P
<i>G. clavatum</i> Ehrenberg	P	D	P
<i>G. parvulum</i> (Kützing) Kützing	–	D	P
<i>Epithemia turgida</i> (Ehrenberg) Kützing	–	D	D
Chlorophyta			
<i>Sphaerocystis Schroeteri</i> Chodat	D	P	–
<i>Scenedesmus obliquus</i> (Turpin) Kützing	D	P	–
<i>Microspora amoena</i> (Kützing) Rabenhorst	D	D	–
<i>Bulbochaete</i> sp.	P	D	–
<i>Spirogyra</i> sp.	P	D	–
<i>Zygnema</i> sp.	D	D	–
<i>Mougeotia</i> sp.	D	D	–
Rhodophyta			
<i>Batrachospermum gelatinosum</i> (Linnaeus) De Candolle	D	D	–
<i>Audouinella chalybea</i> (A. Roth) Bory	P	D	–
<i>A. hermannii</i> (A. Roth) Duby	–	D	–
<i>Lemanea fluviatilis</i> (L.) Agardh	–	D	–

the outlet from Kedrozero Lake. The highest number of species in plankton was found at the stations 4 (25 species) and 10 (29 species), where typical riverine attached forms dominated: *Tabellaria flocculosa*, *Achnanthes minutissima*, *Cymbella silesiaca*, *Batrachospermum gelatinosum* (Table 4).

Table 4. The dominant algae from the phytoplankton, phytoperiphyton and microphytobenthos of 12 stations (St.)

St. No.	Phytoplankton	Phytoperiphyton	Microphytobenthos
1	<i>Aulacoseira islandica</i> <i>A. italica</i> <i>Tabellaria fenestrata</i> <i>Achnanthes minutissima</i>	<i>Aulacoseira islandica</i> <i>Tabellaria fenestrata</i> <i>Fragilaria virescens</i> <i>Zygnema</i> sp.	<i>Tabellaria flocculosa</i> <i>Cocconeis placentula</i>
2	<i>Tabellaria fenestrata</i> <i>Achnanthes minutissima</i> <i>Zygnema</i> sp.	<i>Tabellaria flocculosa</i> <i>Spirogyra</i> sp.	<i>Tabellaria flocculosa</i> <i>Cymbella affinis</i> <i>Cocconeis placentula</i>
3	<i>Tabellaria fenestrata</i> <i>Achnanthes minutissima</i> <i>Zygnema</i> sp.	<i>Tabellaria flocculosa</i> <i>Zygnema</i> sp.	<i>Tabellaria flocculosa</i> <i>Achnanthes lanceolata</i>
4	<i>Tabellaria fenestrata</i> <i>Asterionella formosa</i> <i>Achnanthes minutissima</i>	<i>Tabellaria flocculosa</i> <i>Bulbochaete</i> sp. <i>Scenedesmus obliquus</i>	<i>Tabellaria flocculosa</i>
5	<i>Aulacoseira ambigua</i> <i>Tabellaria fenestrata</i> <i>Cyclotella meneghiniana</i>	<i>Tabellaria flocculosa</i> <i>T. fenestrata</i> <i>Cymbella affinis</i> <i>Gomphonema parvulum</i>	<i>Tabellaria flocculosa</i> <i>T. fenestrata</i> <i>Achnanthes lanceolata</i> <i>Cocconeis placentula</i>
6	<i>Tabellaria fenestrata</i> <i>T. flocculosa</i> <i>Achnanthes minutissima</i> <i>Batrachospermum gelatinosum</i>	<i>Tabellaria flocculosa</i> <i>Gomphonema angustatum</i> <i>Didymosphenia geminata</i> <i>Zygnema</i> sp.	<i>Tabellaria flocculosa</i> <i>Achnanthes lanceolata</i> <i>Cocconeis placentula</i>
7	<i>Cyclotella radiosa</i> <i>Tabellaria fenestrata</i> <i>Microspora amoena</i> <i>Fragilaria construens</i>	<i>Tabellaria fenestrata</i> <i>T. flocculosa</i> <i>Cocconeis placentula</i> <i>Batrachospermum gelatinosum</i>	<i>Tabellaria flocculosa</i> <i>Fragilaria construens</i> <i>Cocconeis placentula</i>
8	<i>Dinobryon divergens</i> <i>Aulacoseira islandica</i> , <i>Cyclotella bodanica</i> <i>Tabellaria fenestrata</i> <i>Sphaerocystis Schroeteri</i> <i>Mougeotia</i> sp.	<i>Tabellaria fenestrata</i> <i>Cocconeis placentula</i> <i>Gomphonema parvulum</i> <i>Microspora amoena</i> <i>Zygnema</i> sp. <i>Lemanea fluviatilis</i>	<i>Tabellaria flocculosa</i> <i>Fragilaria virescens</i>
9	<i>Tabellaria fenestrata</i> <i>T. flocculosa</i> <i>Frustulia rhomboides</i>	<i>Tabellaria flocculosa</i> <i>Frustulia rhomboides</i> <i>Cymbella helvetica</i> <i>Zygnema</i> sp. <i>Mougeotia</i> sp. <i>Lemanea fluviatilis</i>	<i>Tabellaria flocculosa</i> <i>Epithemia turgida</i> <i>Cocconeis placentula</i>
10	<i>Tabellaria fenestrata</i> <i>T. flocculosa</i> <i>Fragilaria capucina</i> <i>Achnanthes minutissima</i> <i>Cymbella silesiaca</i>	<i>Tabellaria fenestrata</i> <i>Cymbella helvetica</i> <i>Epithemia turgida</i> <i>Zygnema</i> sp. <i>Lemanea fluviatilis</i>	<i>Achnanthes linearis</i> <i>Epithemia turgida</i> <i>Cocconeis placentula</i>
11	<i>Aulacoseira islandica</i> <i>Cyclotella radiosa</i> <i>Tabellaria fenestrata</i> <i>Microspora amoena</i>	<i>Tabellaria fenestrata</i> <i>Fragilaria capucina</i> <i>Gomphonema clavatum</i> <i>Microspora amoena</i> <i>Audouinella chalybea</i>	<i>Tabellaria flocculosa</i> <i>Achnanthes linearis</i> <i>Microspora amoena</i> <i>Fragilaria capucina</i>
12	<i>Aulacoseira islandica</i> <i>Tabellaria fenestrata</i> <i>Fragilaria capucina</i> <i>Microspora amoena</i>	<i>Tabellaria fenestrata</i> <i>Fragilaria capucina</i> <i>Cocconeis placentula</i> <i>Zygnema</i> sp.	<i>Tabellaria flocculosa</i> <i>Fragilaria capucina</i> <i>Cocconeis placentula</i>

The highest index values of similarity for phytoplankton were calculated in samples collected at the mouth of both river sections (St. 1 and 9;  $K_s = 68, 8$  and  $62.4\%$ ), and the lowest – in samples from stations 7 and 12 ( $K_s = 24.4$  and  $28.3\%$ ) located at the outlet of the fluvial lakes. At the outlet of Kedrozero Lake (St. 12), the euplanktonic forms of plankton dominated. At the outlet of shallow Tarasmozero Lake (St. 8), diverse plankton communities together with attached and benthic algae forms are constantly present (STERLIGOVA et al., 2001).

Phytoplankton in the river stations distant from the lakes was sparse and generally represented by the same species as found in attached and benthic habitats. Periphytic forms such as *Achnanthes minutissima* and *Tabellaria flocculosa* were the most abundant there (Table 3). The mean biomass values for separate station ranged from  $0.02$  to  $1.34 \text{ g/m}^3$  (Fig. 2), and concentration of chlorophyll *a* from  $0.01$  to  $2.45 \text{ mg/m}^3$ .

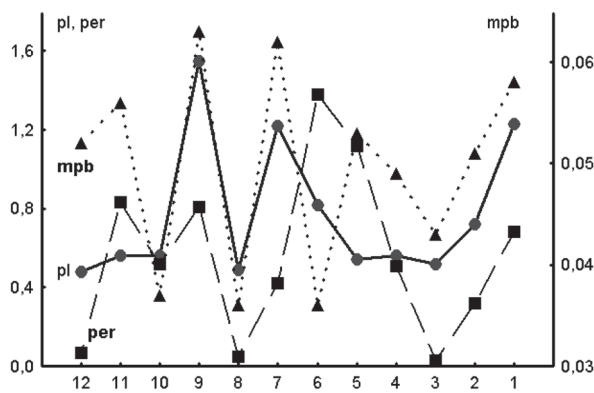


Fig. 2. Spatial fluctuation of phytoplankton (pl-mg/m<sup>3</sup>), phyto-periphyton (per-mg/dm<sup>2</sup>) and microphytobenthos (mpb-mg/dm<sup>2</sup>) mean biomass at different sites (X axis) along the studied river stations

The occurrence of large filamentous green algae such as *Ulothrix* sp., *Mougeotia* sp., *Zygnema* sp., *Oedogonium* sp. and diatoms *Didymosphenia geminata*, *Surirella* spp., *Cymatopleura* spp., *Campylodiscus* spp. in the plankton was noteworthy. These taxa could not be omitted in the estimation of the total biomass of plankton communities. In the upper zone of pools after riffles (St. 5 and 10), *Zygnema* constituted 90% of total biomass in plankton samples. The presence of filamentous algae increased the biomass in separate samples up to  $3.5 \text{ mg/dm}^3$  and the mean biomass in separate stations (St. 9) up to  $1.34 \text{ mg/dm}^3$ .

### Phytoperiphyton

As many as 74 taxa were found in periphyton. The most numerous group was diatoms (84.8%), then green (12.9%) and red algae (5.4%). Despite their large quotas in taxa, diatoms were less significant in total biomass of community. Relatively high biomass of diatoms (15–23%) was noted only in attached communities dominated by *Didymosphenia geminata* (St. 4, 10). Percentage of green algae in total biomass in periphyton was larger than in other communities (St. 6, 9). Because of its flora and species dominance, the community can be referred to as «chlorophytic» with large percentage in biomass (up to 50%) of *Mougeotia* sp. and *Oedogonium* sp.

Compositions of attached algal communities particularly on stone were more complex than benthic and plankton ones. Species diversity (H) of periphyton ranged from 2.1 to 3.8 (Table 5) and was higher as compared to plankton and benthic communities. Values were greater in the middle sections (St. 5, 6, 10, 11), decreased towards upstream and the mouth of each separate river sections.

Table 5. The number of algal taxa (Spp), values of the Shannon (H) and Sørensen ( $K_s$ ) indexes for phytoplankton (pl), phyto-periphyton (per) and microphytobenthos (mpb) communities

		Stations											
		1	2	3	4	5	6	7	8	9	10	11	12
Spp	pl	7	12	15	21	12	29	18	15	11	29	22	5
	per	21	28	21	15	18	20	24	13	21	23	28	14
	mpb	22	30	32	17	15	14	28	17	28	34	31	27
H	pl	1.8	2.1	2.4	2.0	2.7	2.1	2.0	2.4	2.5	2.7	2.4	2.0
	per	1.2	2.2	3.0	2.1	3.8	2.5	2.1	2.6	2.8	3.3	3.2	2.2
	mpb	1.4	2.2	2.1	2.4	2.5	3.1	2.0	1.2	2.1	2.8	2.9	1.3
$K_s$	pl	68.8	40.2	42.4	50.2	38.8	46.7	24.4	50.1	62.4	50.2	49.7	28.3
	per	35.4	33.2	40.4	58.1	54.4	37.3	38.7	61.0	62.3	42.3	41.1	67.0
	mpb	39.6	40.2	33.0	40.8	59.3	37.0	38.1	35.1	38.7	42.0	54.1	60.2

The periphyton has been most frequently cited as the greatest contributor of total biomass and productivity in rivers (ROSEMARIN, 1975; WETZEL, 1979; BIGGS & CLOSE, 1989; BIGGS, 2000). In the River Lihzma, the density of attached algal cells on stones was several times higher than the density of microphytobentos. The biomass of epilithon in samples varied from 0.5 to 230.0 g/m<sup>2</sup>, and for epiphyton from 0.2 to 28.7 g/m<sup>2</sup>. The lowest biomass of epilithon was noted in the samples collected at the sites with high (> 0.5 m/s) current velocity.

### Microphytobenthos

The microphytobenthos communities had the richest algae flora. Ninety-nine taxa were collected from sand and mud. Totally diatoms contributed 99%, and *Tabellaria flocculosa* was the most abundant species that comprised more than 80% of total biomass in most stations. The average biomass of algae on sand and mud, expressed as chlorophyll *a*, ranged from 0.01 to 0.12 mg/dm<sup>2</sup>. The biomass of microphytobenthic communities was heterogeneously disturbed over the each station and sample. No longitudinal trend was observed for microphytobenthos communities (Fig. 2).

The lowest index values of similarity for microphytobenthos were calculated for samples collected in the mouth of both river sections (St. 1, 2, 9 and 10;  $K_s$  24, 3–32.4%) and the highest for samples from stations 5 and 4 ( $K_s$  = 46.4 and 58.2%) situated at middle locations of the river sections.

The biomass of each separate sample was higher (1.94–3.01 mg/dm<sup>2</sup>) close to the bank than in the mid-stream (0.90–2.01 mg/dm<sup>2</sup>), and it was higher (2.56–3.01 mg/dm<sup>2</sup>) on mud than on sand (0.90–1.86 mg/dm<sup>2</sup>). The samples with relatively high density on mud were observed in all stations. The potential for larger microphytobenthos biomass seems limited only by available habitat in river dominated by stone substrates.

From Kedrozero Lake to mouth, distribution for biomass based on chlorophyll *a* analysis among all three communities showed the profile for microphytobenthos to be even to irregular, while that of planktonic and attached algal communities was closely related to allochthonic species migrations from the lakes. Therefore, the effect of fluvial lake on the attached and benthic communities was high. In gen-

eral, the phytoplankton, phytoperiphyton and microphytobenthos showed great changes in the diversity indices.

The highest value of the Sørensen index was observed for down section of the river, where the lake influence was minimal. Diversity indices of phytoplankton correlated with those of periphyton ( $r = 0.74$ ;  $p \geq 0.025$ ). Thus, the results generally supported the hypothesis that river phytoplankton (patamplankton) communities arose from microphytobenthic and phytoperiphytic ones.

On the basis of the presented table (Table 5), it may be said that the number of species occurring permanently and simultaneously in all habitats examined was small (5–10 species). But these species formed more than 60% of the total biomass in most sections. Other of the differentiating «characteristics» emphasising floristic individual features of the three communities was the number of species found in only one given community. In periphyton, there were as many as 28 taxa, i.e. 37.8%, in phytoplankton – 16 (25.8%) and in microphytobenthos – 44 (44.4%).

The spatial dynamics of algal communities in the River Lihzma mainly did not agree with the river continuum concept. Succession was rather autonomous at every site. The diversity in general seemed more closely related to alternation of riffles and pools, and the presence of fluvial lakes was responsible for the pulse-like pattern of the changes observed in the taxonomic composition, ecological structure and abundance of algal communities. The structure of allochthonous flora varies with the trophic status of lakes and their catchment area morphometry (FILATOV & KUKHAREV, 2013).

### CONCLUSIONS

Our previous studies in the River Lihzma have shown that nutrients, light, current and predation can regulate the rate of algal community development in streams (KOMULAYNEN, 2004).

The effect of fluvial lakes on the rivers that flow from them is similar to the impact of reservoirs upon regulation of rivers. In this case, a hydrological regime, river channel morphometry and the structure of communities of aquatic organisms are changed (COLLIER et al., 1996; HAN et al., 2010; LIN, 2010).

Fluvial lakes may affect water discharge, temperature, nutrients direct and indirect effects on algal communities (KOMULAYNEN, 2004). In the first case – due to some changes in the hydrological regime in stream sections, in the second case – by enriching algal communities in rivers with the allochthonic species from lake.

Previously, it has been reported (REYNOLDS, 1986) that species composition of phytoplankton in streams and small rivers is similar to the composition of benthic algal assemblages. Emigration and immigration of some species constitute substantial proportions of algae abundance (KOMULAYNEN, 2004).

Due to increased turbidity and removal of attached algae forms from periphyton, changes of species composition and reduction of their diversity occur in the riffle zones of the river. Therefore, simultaneous examination of various ecological groups of algae is important for better understanding of interrelations in such type of ecosystems. Mixing of large number of algae between communities and from lakes to rivers leads to significant changes in the diversity of indices, which constant fluctuations indicate the low organization and stability of algal communities, particularly in plankton ones. Because of such “mutual enrichment”, 90% of predominant species are common for the three communities and the specificity of algal coenoses declines. Each of communities simultaneously may be an incubator of allochthonous algal flora for other ones and a collector for senescent algal populations. This role varied depending on the hydrology of stream, fluvial lakes presence, and channel and bed morphometry. Diversity of algal communities is also maintained due to asynchronism of succession in various types of lakes (FILATOV & KUKHAREV, 2013), and algal drift can explain the simultaneous presence of spring, summer and autumn species in algal cenoses in rivers (KOMULAYNEN, 2004).

## ACKNOWLEDGEMENTS

The author is indebted to colleagues from the Institute of Biology for their excellent field cooperation and assistance. The work was financially supported by the Federal budget of Russia (contract no. 0221-2014-0005, no. 0221-2014-0038 and no. 0221-2017-0045).

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## DUMBLIŲ BENDRIJOS STRUKTŪROS KAITA MAŽAME UPELYJE (KARELIJOS RESPUBLIKA, RUSIJA)

Sergey KOMULAYNEN

### Santrauka

Fitoplanktono, fitoperifitono ir mikrofitobentos bendrijos buvo tirtos tuo pačiu laiku nedidelėje Ližma upėje (Karelijos Respublika, Rusija). Lyginant dumblių taksonominius ir kiekybinius skirtumus, atsirandančius einant link upės žiočių, buvo siekiama nustatyti priežastis, lemiančias dumblių bendrijų erdvinius skirtumus. Dumblių bendrijos sudėtis ir jos pokyčiai Ližma upėje priklauso nuo

upės tėkmės greičio bei ežerų, duburių ir akmeningų ruožų išsidėstymo. Bentosiniai ir kiti prisitvirtinę dumbliai yra nuolat nuplaunami nuo dugno, kitų pasinėrusių biotopų ir nunešami pasroviui. Tuo tarpu tose upės dalyse, kur srovės greitis mažesnis, planktoninės formos nusėda ant skirtingų paviršių ir suformuoja nebūdingas bentosui ir perifitonui dumblių bendrijas.