ZOOPLANKTON, ZOOBENTHOS AND ZOOPERIPHYTON

SEASONAL DYNAMICS OF BENTHOS AND INVERTEBRATE DRIFT IN SOME TRIBUTARIES OF ONEGA LAKE

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Seasonal changes in taxonomical composition, abundance and biomass of benthos and invertebrate drift in a small (Lososinka river) and large (Shuya river) tributaries of Onega lake have been investigated. It has been shown that annual changes in hydrology of river systems and seasonal changes of temperature greatly influenced quantitative characteristics of invertebrates. Insect's larva (Chironomidae, Trichoptera and Ephemeroptera) dominated in bottom communities. Their abundance was substantially affected by spring flood when the abundance of drift increased and the density of benthos decreased manifold. Biomass of benthos increased from the beginning of June in Shuya river and from the middle of August in Lososinka river till the middle of October in both rivers. In winter invertebrate drift was an order less abundant than in summer.

INTRODUCTION

The fauna of invertebrates, abundance of benthos [6, 11] and drift [14, 15] in the rivers of Onega lake, and also seasonal dynamics of benthos [12] and drift [8, 14] are studied sufficiently enough. Abundance, biomass of benthos and density of invertebrate drift in rivers vary annually. No studies covering seasonal dynamics of both drift and benthos in the rivers of Onega lake were performed. Species composition and density of benthos and drift in winter is poorly studied; it is not known, how catastrophic flood drift influences structure, abundance and biomass of bottom invertebrates. Relationship between hydrological conditions in various river types and seasonal dynamics of structure and abundance of benthos and drift is not studied.

The purpose of the work is to study taxonomic structure of invertebrates, seasonal dynamics of benthos and drift abundance in two Onega tributaries differing in river length and relative lake surface area in their catchments (lake area ratio).

MATERIALS AND METHODS

Research was performed at rapid sections of Lososinka (61°47'1" N., 34°23'5" E.) and Shuya (61°52'5" N., 34°16'3" E.) rivers during daytime from September, 1999 till August, 2000. The rivers' hydrological parameters differ as follows: Lososinka river is 23 km long with average annual discharge of 3.7 m^3/s and lake area ratio of 5.7%; Shuya river is 272 km long with average annual discharge of 96.3 m^3/s and lake area ratio of 10.3% [1]. Lososinka river accumulates runoff ot two lakes with total surface area of 18 km^2; Shuya river is a complicated system of lakes and rivers with a cascade of lakes. Distance from the sampling station to the nearest upstream Lososinka river lakes was 18 km; in Shuya river the distance was 20 km up to the group of small lakes with the total area of 11 km^2.

Benthos was sampled (with 3 replications) by a 0.04 m^2 quantitative Surber frame once a month. Drift particles were sampled using a drifter-trap with 0.2 x 0.5 m input aperture and a cone of filtering fabric (23 meshes per 1 cm) once a month in winter and biweekly in summer. The top edge of the trap was positioned 1 cm above water level that allowed us to sample both water column and surface organisms-[5]. Cameral treatment was performed according to standard methods [4]. Obtained abundance and biomass values for benthos were recalculated as per 1 m^2 of bottom surface [5]. Quantitative estimates of drift included numbers and biomass of organisms caught by the trap within 15 minutes [2, 16, 17]. Benthos and drift samples totaled 76 and 109 samples accordingly. Taxonomic composition analysis included categorization of insects to different orders (ephemerans, plecopterans and trichopterans-to species, and dipterans-to families). Migrants from air environment were united into a single "terrestrial and emerging" group.

RESULTS

Bottom river communities included representatives of the following groups: Nemaioda, Oligochaeta, Hirudinea, Gastropoda, Bivalvia, Ostracoda, Collembola, Acari (Hydrachnellae), Ephemeroptera (*Centroptilum luteolum* Müller, *Nigrobaetis muticus* L., *N. niger* L., *N.* sp., *Baetis*

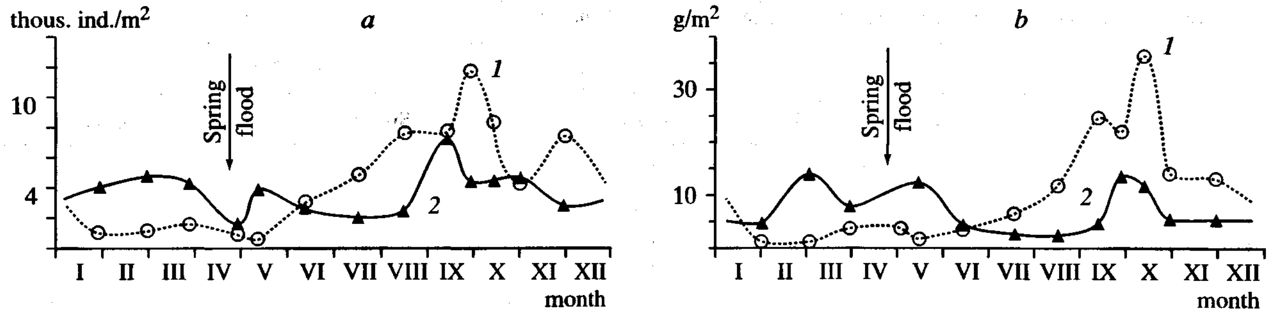

Fig. 1. Abundance *(a)* and biomass *(b)* of bottom invertebrates in Shuya (7) and Lososinka (2) rivers.

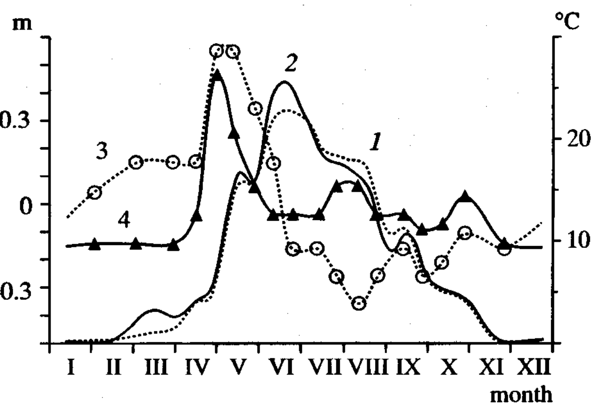

Fig. 2. Temperature (*1, 2*) and water level (*3, 4*) in Shuya (*7, 3*) and Lososinka (*2, 4*) rivers at the sampling stations.

fuscatus L., *B. rhodani* Pictet, *Heptagenia sulphurea* Müller, *H. coerulans* Rostock, *Habrophlebia fusca* Curtis, *Paraleptophlebia submarginata* Stephens, *Ephemerella ignita* Poda, *E mucronata* Bengtsson, *Ephemera vulgata* L., *E. danica* Müller, *Caenis macrura* Stephens), Plecoptera (*Isogenus nubecula* Newman, *Perlodes dispar* Rambur, *Isoperla difformis* Klapalek, *I. grammatica* Poda, *I. obscura* Zetterstedt, *Siphonoperla burmeisteri* Pictet, *Xanthoperla apicalis* Newman, *Taeniopteryx nebulosa* L., *Amphinemura borealis* Morton, *Nemoura avicularis* Morton, *N. cinerea* Retzius, *N. flexuosa* Aubert, *Protonemoura intricata* Ris, *Capnia afra* Morton, *Leuctra digitata* Kempny, *L. fusca* L., *L. hippopus* Kempny), Trichoptera *(Rhyacophila nubila* Zetterstedt, *Agapetus ochripes* Curtis, *Agraulea multipunctata* Curtis, *Hydroptila tineoides* Dalman, *Ithytrichia lamellaris* Eaton, *Oxyethira flavicornis* Pictet, *Wormaldia subnigra* MacLachlan, *Psychomia pusilla* Fabricius, *Neureclipsis bimaculata* L., *Polycentropus flavomaculatus* Pictet, *Arctopsyche ladogensis* Kolenati, *Cheumatopsyche lepida* Pictet, *Hydropsyche angustipennis* Curtis, *H. contubernalis* MacLachlan, *H. guttata* Pictet, *H. nevae* Kolenati, *H. ornatula* MacLachlan, H. pellucidula Curtis, *H. silfvenii* Ulmer, *Sericostoma personatum* Kirby et Spence, *Athripsodes commutatus* Rostock, Triaenodes sp., *Brachycentrus subnubilus* Curtis, *Lepidostoma hirtum* Fabricius, *Silo pallipes* Fabricius, *Anabolia furcata* Brauer, *Halesus* sp., *Limnephilus sericeus* Say), Megaloptera, Simuliidae, Coleoptera, Chironomidae and Limoniidae. Annually, abundance and biomass of benthos in Lososinka river varied from 1.4 thousand ind./m^2 and 2.4 g/m^2 up to 7.4 thousand ind./m^2 and 13.6 g/m^2 accordingly; and in Shuya river benthos varied from 0.5 thousand ind./m^2 and 1.0 g/m^2 up to 11.7 thousand ind./m^2 and 36.3 g/m^2 (Fig. 1).

Temperature and water level in both rivers varied considerably (Fig. 2). In winter, from early December till the middle of February, the temperature was close to zero, and then it started to rise (in Lososinka river it raised faster than in Shuya river). In that period, amphibiotic insects' larva (Chironomidae, Trichoptera and Ephemeroptera) were numerically dominant in bottom communities. By biomass, larvae of trichopterans and gastropods prevailed (Table 1). In Lososinka river, abundance and biomass of benthos in December and January did not change, in February there was noted an increase in biomass. In Shuya river, on the contrary, abundance and biomass of benthos decreased to minimum values from early December until early February.

In spring, from early March until late May water temperature increased from 1-2 to 15-16°C. During this period, in addition to chironomids' larvae and oligochaetes dominating in both rivers, trichopterans' larvae were numerous in Shuya river, and larvae of ephemerans were abundant in Lososinka. Major contribution to biomass was due to oligochaetes, larvae of trichopterans and ephemerans. Along with these invertebrates, in Lososinka river a significant portion of biomass was formed by larvae of plecopterans. In the middle of April when temperature of water reached ~4°C, the spring flood led to a sharp decrease in benthos density, which was quickly restored after the end of flood.

Table 1. Seasonal changes of average abundance and biomass of benthos in Lososinka and Shuya rivers

Group	1999				2000			
	Autumn		Winter		Spring		Summer	
	L	Sh	L	Sh	L	Sh	L	Sh
Oligochaeta	0.26	0.12	0.36	0.11	0.44	0.31	0.06	0.36
	0.53	0.12	0.48	0.13	1.26	1.34	0.03	0.50
Bivalvia	0.03	0.22	0.00	0.13	0.00	0.04	0.00	0.26
	0.03	0.42	0.01	0.09	1.01	0.01	0.01	0.33
Gastropoda	0.84	0.01	0.24	0.07	0.18	0.07	0.11	0.04
	3.61	0.05	2.54	0.27	1.90	0.17	0.92	0.05
Ephemeroptera	1.92	0.93	0.64	0.55	0.77	0.06	0.76	0.55
	1.24	2.58	0.40	1.28	1.21	0.28	0.85	1.19
Plecoptera	0.19	0.08	0.08	0.04	0.20	0.01	0.09	0.22
	0.17	0.30	0.16	0.02	1.23	0.05	0.03	0.24
Trichoptera	1.05	3.71	0.75	0.81	0.49	0.05	0.38	1.25
	0.89	19.27	0.70	4.07	2.89	0.21	0.88	3.10
Chironomidae	0.65	2.40	0.99	2.08	1.22	0.43	0.63	2.26
	0.12	0.25	0.09	0.51	0.43	0.43	0.16	0.37
Others	0.40	0.43	0.33	0.36	0.32	0.08	0.31	0.52
	2.38	1.20	0.75	0.56	0.81	0.14	0.22	1.71
Total	5.34	7.91	3.40	4.14	3.61	1.07	2.35	5.45
	8.96	24.19	5.13	6.94	9.74	2.63	3.11	7.49

Note. L — Lososinka river, Sh - Shuya river; above the line - abundance, ind./m^2, below the line-biomass, mg/m^2.

In summer, the water temperature reached its peak by the second half of June (26°C in Lososinka and 24°C in Shuya), and benthos featured a lot of amphibiotic insects' larvae: chironomids, trichopterans and ephemerans. In Shuya river, the share of ephemerans' larvae was significantly less than in Lososinka river. In both rivers, the basis of biomass was formed by larvae of ephemerans and trichopterans. Besides, in Lososinka river, the share of gastropods (28%) was great in the benthos biomass. Post-flood decrease of water level in Lososinka river ended by the mid-June, and in Shuya river was over by early July. Then the water level in Lososinka was temporarily raising from the middle of July until mid-August; and in Shuya it was decreasing until the middle of August. During this period, abundance and biomass of benthos in Shuya were much greater (5,000 ind./m^2 and 7.5 g/m^2 accordingly) than in Lososinka (900 ind./m^2 and 1.8 g/m^2 accordingly). By the end of August, the water temperature in the rivers had sunk to 14-15°C.

In autumn, the temperature of water was still decreasing, and it had almost reached zero by the end of November. Benthos of the both rivers was numerically dominated by chironomids' larvae; in Shuya abundant were also larvae of trichopterans, and in Lososinka-larvae of ephemerans. Biomass was mainly constituted by trichopterans and ephemerans, and in Lososinka it was also formed by gastropods. By late September-early October the rivers featured the maximum abundance and biomass of benthos.

During a year, quantitative characteristics of drift varied substantially (Fig. 3, Tables 2 and 3). Thus, in early and mid-March, despite the initial increase in water temperature, density of drift in the rivers was insignificant-as in wintertime. However, during the second half of March (when the ice broke up on the rives and the water got warm up to 2-3°C) it was observed a sharp increase in abundance and biomass of invertebrate drift (up to 305 ind. and 471 mg in Shuya and up to 174 ind. and 266 mg in Lososinka).

During this period, the share of drifting larvae of ephemerans and trichopterans in Lososinka river was greater than in Shuya river. At spring flood (early May to mid-May; temperature >=4°C), the abundance of drifting organisms in both rivers decreased down to its winter values. Aerial insects started to get into the stream and essentially contributed to drift until November. By early June, the water level dropped down, the temperature of water reached its summer values (17-18°C), and the abundance and biomass of organisms in drift surpassed their winter and autumn values manifold. During this period, ephemerans and chironomids (both at larval and flying-out stages) prevailed in Lososinka

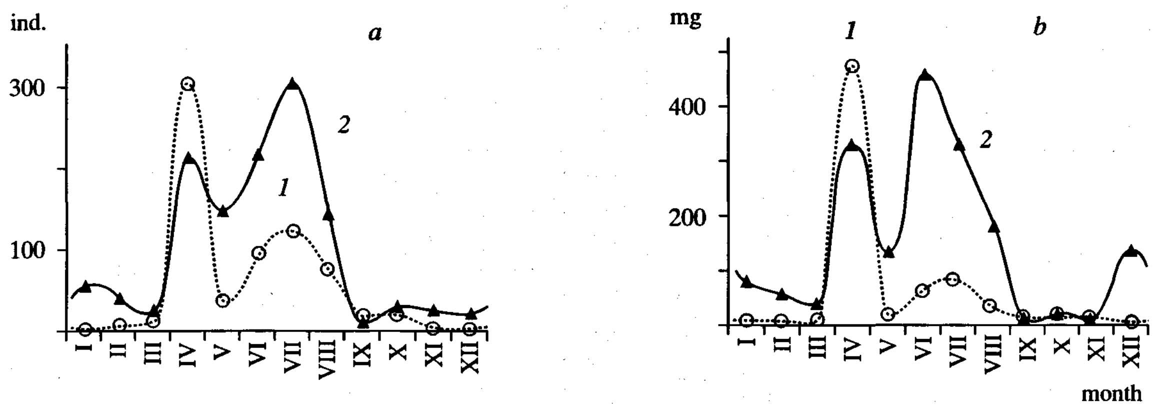

Fig. 3. Average abundance *(a)* and biomass *(b)* of drift in Shuya (7) and Lososinka (2) rivers.

and Shuya rivers. By the middle of July (temperature 19-20°C), during the period of intensive adult emergence of amphibiotic insects (chironomids, ephemerans, trichopterans and simuliides), their share in the drift amounted to 86%. In late August, the overall pattern was practically the same. From early September (temperature 13-14°C) till February-March, abundance and biomass of drift have decreased and remained low (from 2 ind. and 0.63 mg in Shuya and 10 ind. and 10.1 mg in Lososinka). In winter, larvae of ephemerans, chironomids and trichopterans prevailed in the invertebrate drift.

DISCUSSION

Larvae of amphibiotic insects (specifically, chironomids, ephemerans and trichopterans) dominated in benthos and drift of the investigated rivers year-round. Such a structure of bottom communities is usual for rivers of Karelia [11, 15]. Similar taxonomic composition of benthos has been revealed in the rivers of Northern Urals [13]. The author's studies have shown that during a year, in rivers with different hydrological regimes, minimum abundance and biomass of benthos deviated from their maximum values by an order of magnitude, and density of drift varied within two orders. Such significant changes are associated with hydrobionts' living conditions, which are affected by temperature and water level.

Especially intensive or catastrophic drift occurs at the beginning of spring flood when the water level has not reached its maximum yet. In Shuya river having a greater length and higher lake area ratio than Lososinka river, the water level changed smoothly, therefore the spring flood began later and stayed longer (Fig. 2). The water temperature began to rise as

Table 2. Seasonal changes of drift composition in Lososinka river

Group	1999				2000							
	IX	X	XI	XII	I	II	III	IV	V	VI	VII	VIII
Oligochaeta	0.0	0.2	0.3	0.0	0.0	0.0	0.0	4.5	3.6	1.1	1.1	1.0
	0.0	0.1	0.3	0.0	0.0	0.0	0.0	2.1	0.8	1.4	0.2	0.2
Ephemeroptera	3.0	13.1	14.4	10.8	42.4	26.9	11.4	83.6	17.3	58.4	132.8	30.2
	2.6	7.9	5.5	8.5	30.7	18.3	5.9	84.1	26.8	116.2	43.8	12.2
Plecoptera	0.0	1.1	0.3	0.7	0.5	0.3	0.2	4.2	1.1	0.0	0.0	1.0
	0.0	1.5	0.2	9.6	0.3	0.2	1.0	19.5	6.2	0.0	0.0	0.2
Trichoptera	2.3	4.8	1.6	6.6	5.3	4.9	4.5	10.9	6.5	9.6	47.9	8.8
	2.0	5.0	3.9	119.9	33.3	25.8	18.2	383	6.2	10.7	97.7	43.2
Chironomidae	1.9	5.9	3.6	3.4	3.8	4.7	5.5	72.4	90.4	86.7	52.6	39.6
	0.3	0.8	0.5	1.9	1.8	1.3	0.9	70.8	72.6	293	10.4	7.5
"Terrestrial and emerging"	0.3	1.0	3.2	0.0	0.0	0.0	0.0	1.1	10.5	34.6	37.3	16.1
	0.5	3.2	5.7	0.0	0.0	0.0	0.0	11.7	2.7	65.1	112.1	42.6
Others	2.8	3.1	2.0	0.6	3.3	3.6	3.9	38.4	19.2	29.3	34.4	49.1
	4.8	3.1	1.3	2.1	14.2	15.6	15.6	108.5	20.9	239.5	719	81.2

Note. Here and in Table 3: above the line — abundance, ind.; below the line — biomass, mg.

Table 3. Seasonal changes of drift composition in Shuya river

Group	1999				2000							
	IX	X	XI	XII	I	II	III	IV	V	VI	VII	VIII
Oligochaeta	2.0	0.5	0.7	0.0	0.0	0.0	0.0	1.7	1.8	0.2	1.6	0.4
	0.1	0.0	0.1	0.0	0.0	0.1	0.2	0.4	0.4	0.0	1.4	0.0
Ephemeroptera	1.1	2.0	0.2	0.5	0.5	1.1	1.8	255.7	0.9	9.1	9.4	11.2
	1.1	0.8	0.6	0.1	0.1	0.5	0.9	355.1	1.1	2.2	7.3	6.7
Plecoptera	0.4	0.2	0.2	0.0	0.2	0.2	0.2	6.6	0.3	0.0	0.4	0.4
	0.0	0.5	3.4	0.0	0.4	0.2	0.1	59.3	1.5	0.0	0.0	0.0
Trichoptera	3.6	1.2	0.5	0.3	0.2	1.1	2.1	1.0	1.8	3.1	11.3	6.9
	5.4	0.7	0.4	0.1	0.5	2.0	3.5	0.7	2.7	8.3	34.5	12.0
Chironomidae	10.4	11.3	0.2	1.0	2.0	3.3	4.5	8.6	23.1	52.8	64.4	48.6
	4.0	3.4	0.0	0.3	0.5	0.5	0.6	5.6	9.2	10.8	16.9	8.5
"Terrestrial and emerging"	0.2	2.6	2.7	0.0	0.0	0.0	0.0	0.6	0.6	18.8	4.5	2.5
	0.0	4.7	9.0	0.0	0.0	0.0	0.0	1.1	0.2	44.3	9.0	3.1
Others	3.5	1.7	0.2	0.2	0.0	1.2	2.4	30.9	6.5	11.1	30.7	7.3
	5.1	3.7	0.4	0.2	0.0	0.2	0.4	49.5	4.3	4.0	16.8	1.8

early as in March prior to ice break when the water level did not change yet. At a further increase in water temperature, the ice broke up on the rivers. The growing current velocity caused ground displacement and drift of large amounts of plant remains which affected the attached organisms. Apparently, this was the major cause of catastrophic invertebrate drift [2, 3]. After the end of the flood, the quantity of benthos and downwashed animal organisms sharply decreased; however, recovery of benthos density was fast (Fig. 1). It is explained by the fact that during the flood, organisms are concentrated behind river bends [19], in holes or behind large boulders [2], and after the flood they leave their refugia and quickly spread in usual habitats. Hatching of larvae of many amphibiotic insects increases this effect further, as it was shown for rivers of the Far East [21.

In summer months, the water temperature reached the maximal values (Fig. 2). Decrease in water level was not as catastrophic as it was in some other rivers [2] due to the presence of lakes in the catchment area. High water temperature promoted growth and active migrations of hydrobionts that explains increase in drift density, abundance and biomass of benthos. However, in Lososinka river abundance and biomass of benthos in summer months were rather low (Figs. 1 and 2). Apparently, it is associated with different amplitude of water level fluctuations in the studied rivers during the second half of summer.

In autumn, the temperature of water decreased from 10-12°C in early September to near zero values in late November. The water level came close to minimum and slightly changed due to rain floods. It is obvious, that low drift density during this period was caused by reduced mobility of hydrobionts due to decrease in water temperature [2]. Nevertheless, abundance and biomass of benthos in September-October reached their maximum annual values (Fig. 1). Similar results were obtained in other rivers of Onega lake: Lizhma, Pyalma, and Tuba [11]. The increase in benthos abundance is, possibly, connected with hatching of larvae and termination of adult emergence of amphibiotic insects, and with reduction of fish feeding rate in autumn period [10].

The rivers of Karelia, even as small as Lososinka river, do not get completely frozen unlike many watercourses in the areas with sharply continental climate [2, 7, 9]; therefore, despite decreasing benthos abundance in winter period, bottom communities continue their cyclic development during the freezing-over period. The decrease in density and biomass of benthos may be explained by the fact that many of hydrobionts are able to bed into a bottom substratum as deep as 30 cm, where the temperature is higher and wintering conditions are much safer [9, 18]. Density of drift in both rivers during winter months is insignificant. Only in December, a temporary increase in quantity of migrating benthic organisms was observed in Lososinka river, which may be accounted for specific freezing-over conditions.

Results of performed research prove that seasonal changes of temperature and water level, and catastrophic (spring and rain) floods in rivers with various hydrological conditions occur in a different way, thus forming various living conditions for hydrobionts. The water stream in the small river Lososinka more quickly gets warm in spring, and faster gets cold in autumn, and its temperature extensively varies during a day, unlike Shuya river. The water level in the river is also rather stable, except for spring and rain floods. In Shuya, the dynamics of water level is more complicated. The hydrographic network with plenty of lakes provides water supply during winter period, and the summer level depends on seasonal rainfall as a whole, instead of short-time rains. In Shuya, floods, including spring ones, are smoothed as compared with Lososinka river.

Differences in seasonal changes of hydrobionts' habitat conditions in the studied rivers can explain the difference in structure, abundance and biomass of bottom invertebrates during a year. Thus, a sharp spring flood in Lososinka determined intensive changes in the abundance of benthos. During summer, the abundance and biomass of benthos in the river remained at the same level, and in Shuya, they gradually increased. Apparently, it can be explained by the fact that water level in Lososinka hardly changed, while in Shuya it was gradually decreasing and hydrobionts concentrated on the remained riverbed area. The assumption is proved by the fact that autumn increase of water level in Shuya was accompanied by a short-term reduction of abundance and biomass of benthos as a result of hydrobionts' spread in the re-flooded areas. An additional distinction between the rivers is connected with the terrestrial and emerging components of the drift. Insects permanently get into Lososinka which runs through the forest, while into the wide Shuya river, they mainly get during the blasts of wind.

Thus, abundance and biomass of benthos, as well as the density of drift in Onega lake rivers differing in their hydrological regimes are noticeably changing during a year due to seasonal fluctuations of temperature and water level. An important factor of forming dynamics of bottom communities is a spring flood when a great number of hydrobionts is washed out of a substratum and is driven downstream. Right after the flood, abundance and biomass of bottom communities are quickly restored, which, apparently, is connected with hydrobionts' spreading from temporal refugia into their usual habitats and with hatching of larvae of many amphibiotic insects.

Conclusions. Representatives of five classes of invertebrates were registered in Lososinka and Shuya rivers. Larvae of amphibiotic insects (chironomids, ephemerans and trichopterans) prevailed in both rivers. Fifty nine species of Ephemeroptera, Plecoptera and Trichoptera were found. Quantitative characteristics of benthos and invertebrate drift in the rivers were changing significantly during a year. In both rivers, the maximum density and biomass of benthos were registered in late September-early October. The minimal abundance of bottom communities was observed in May, and their minimum biomass was registered in August in Lososinka river and in February in Shuya river. The maximal density of drift was noted during spring flood when the water level was increasing. Distinctions in river length and lake area ratio in hydrographic networks of Lososinka and Shuya rivers caused a pronounced difference in seasonal changes of hydrological parameters and dynamics of water temperature, thus creating specific living conditions for hydrobionts in each river.

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