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Biodiversity, distribution and ecology of macrozoobenthos in small Lithuanian rivers

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The aim of this work was to estimate the distribution, abundance, ecology, and biodiversity of macrozoobenthos in small rivers of Lithuania. The studies were performed in four rivers (the Rieðë, Elmë, Susiena, Varius) located in Vilnius and Anykðèiai Districts during May–November in 2003. The habitat of each study site was determined with respect to some environmental factors: bottom structure (stones, pebble, and sand), water temperature (warm or cold-water river), depth, flow velocity, and river position (river in the woodland or in open space). The samples of zoobenthos were collected by the kick-sampling method in three 0.1 m^2 areas at each study site. All samples were analyzed according to the generally accepted hydrobiological methods. The composition of benthic species, biomass (g/m^2) and abundance ($ind./m^2$) were determined for each sample. The species composition, biodiversity, and ecological state of river fauna were analyzed and discussed. The diversity, number of species, abundance, and biomass of benthic organisms have been found to depend upon different environmental factors of their habitats and seasonal changes of zoobenthos.

Key words: macrozoobenthos, caddisflies, biodiversity, abundance, biomass

INTRODUCTION

The physical (bottom structure, temperature, light, current, depth) and chemical factors (hardness, dissolved oxygen, pH) of a water body provide a habitat for the animal group called the benthos. Macrozoobenthos in various hydrocenoses consists of such groups of animals as Insecta, Oligochaeta, Hydrachnidia, Turbelliaria, Crustacea, Mollusca and some others. The greatest diversity and abundance are shown by larvae, pupae and adult insects. Some of them pass all their life in water and others only part of their development period. Invertebrates are distributed in various calm and running water bodies with different thermal conditions, pollution level, current speed, and bottom structure. Some organisms serve as indicators of water pollution (organically or nutrient enriched waters) such as Oligochaeta, some Syrphidae (Diptera). Often, the greater the density of these organisms, the greater the degree of organic pollution. The lower species diversity index in general shows a more polluted water body. Tolerance to pollution is important for understanding the distribution of species. Benthic organisms take a great part in trophic relations, fluctuations and abundance of biomass, and water quality evaluation.

Caddisfly larvae comprise one of the main parts among aquatic insects. Caddisflies are freshwater species, and the diversity of species is greatest in small rivers and streams. According to the number of species and diversity of ecological adaptations they take the dominant place (next to Diptera larvae) in running water bodies. In a number of cases caddisfly larvae compose the main part of abundance and biomass in small rivers, so they are an important component of food for fishes and other animals and could be used as water bioindicators (most of their species require clean water). Some of caddis larvae can live in diverse hydrocenoses. Most of them choose specific living conditions (a particular temperature, current speed or bottom structure). Seasonal changes of caddisfly development rotate biomass in water and terrestrial communities.

The aim of this work was to estimate the distribution, abundance, ecology, and biodiversity of macrozoobenthos with a focus on caddisflies in some small rivers of Lithuania.

MATERIALS AND METHODS

The studies were performed in four small rivers located in the eastern part of Lithuania. We investigated the Elmë, Susiena, Varius (Anykðèiai District), and Rieðë (Vilnius District) rivers during May–November 2003. The attention was focused on caddisfly larvae as one of the greatest parts of zoobenthos. Other benthic organisms were investigated in May

Table 1. **Characteristics of the rivers studied**

River	Bottom structure	Temperature (°C, average per year)	Depth (cm, average per year)	Flow velocity (m/s, average per year)
Elmë	stones	11.4	11	0.8
Susiena	stones	12.2	12	0.4
Varius	sand	10.4	16	0.2
Rieðë (wooded landscape)	pebble	14.9	25	0.7
Rieðë (open landscape)	pebble	14.8	39	0.5

because of their greatest diversity in spring. The habitat of each study site was characterized with respect to several environmental factors: bottom structure (stones, pebble, and sand), water temperature (warm (the annual average was up to 12 °C) or cold-water river), depth, flow velocity, and river position (woodland or open landscape) (Table 1).

The samples of zoobenthos were collected by the kick-sampling method in three 0.1 m^2 areas at each study site (Manual…, 1993). About 100 samples were collected and analyzed according to the routine hydrobiological methods. The individuals were defined according to the species or genera by using special literature (Edington, Hildrew, 1995; Nilsson, 1996, 1997; Wallace et all., 2003; Кутикова, Старобогатов, 1977; Лепнева, 1964; Цалолихин (ред.), 1997, 1999, 2001). The composition, biomass (g/m^2) and abundance ($ind./m^2$) of benthic species were determined for each sample. The species composition, biodiversity, and ecological state of river fauna were analyzed and discussed. Statistical analyses were used. The sørensen coefficient of similarity of the species content in the rivers was calculated (Brower, Zar, 1984). The diversity of species in different hydrocenoses was calculated according to the index of Shannon (Brower, Zar, 1984). The dominant species are the most influential in the habitat. They show the structure and species composition of the community by affecting its physical and chemical factors. The frequency in general indicates the number of samples in which a species occurs. To estimate the impact of environmental factors on caddisfly diversity and abundance, the main effects ANOVA and correlations were applied.

RESULTS AND DISCUSSION

The results show that the diversity, abundance, and biomass of benthic organisms depend upon environmental factors of their habitats and seasonal changes of species. In all the rivers the following groups of animals were found: Oligochaeta, Turbellaria, Nematomorpha, Crustacea, Hydracarina (each 1 species), Hirudinea (2), Mollusca (5), Heteroptera (1), Plecoptera (3), Odonata (3), Ephemeroptera (6), Coleoptera (10), Diptera (27), and Trichoptera (39 species). The number of species varied from 27 (the Elmë River) to 47 (the Rieðë River in open landscape). Some species were common to all rivers; the dominants were Oligochaeta, Hydracarina, *Baethis rhodani* (Ephemeroptera), *Dicranota bimaculata* (Diptera), *Elmis* sp. larvae, *Oulimnius tuberculatus* imago (Coleoptera), *Glyphotaelius pellucidus*, *Silo pallipes*, *Rhyacophila fasciata* (Trichoptera). The species *Amphinemoura* (Plecoptera), *Heptagenia sulphurea* (Ephemeroptera), *Scleroprocta sororcula* (Diptera), *Agapetus ochripes*, *Polycentropus irroratus*, *Baraeodes minutus* (Trichoptera) were rare and found in one locality.

According to caddisfly fauna, the eudominant species in all the rivers were *Hydropsyche pellucidula* and *Hydropsyche siltalai* (18% each) (Table 2). They prefer fast-flow waters, stony bottom, and good water quality. Often these species occur together. The dominant species were *Potamophylax nigricornis*, *Brachycentrus subnubilus* (each 8%), *Silo pallipes*, *Micrasema setiferum* (7%). Nine species were subdominant (dominance index was 2% to 5%). All the dominant species are ecologically adaptated to running water and hard substrata.

In separate rivers the index of dominance for caddisfly species was different. In the Elmë River the eudominant species were *Potamophylax nigricornis* (32%), *Potamophylax latipennis* (18%), and *Hydropsyche pellucidula* (15%), the dominant species being *Silo pallipes* (10%), *Hydropsyche siltalai* (9%), *Halesus radiatus* (8%), and *Rhyacophila fasciata* (6%). Most of the species prefer clean, cold, fast-running stream with a sufficient content of oxygen. In the Varius River the eudominant species were *Potamophylax nigricornis* (38%) and *Halesus radiatus* (29%). These two species occur only in cold streams or small rivers with a pretty different bottom structure and current. One dominant species was *Potamophylax latipennis* (9%). The other ten species were subdominant (the dominance index was from 1.8 to 4.3). The eudominant species in the Susiena River were *Hydropsyche pellucidula* (20%) and *Polycentropus flavomaculatus* (17%), the dominant being *Hydropsyche siltalai* (13%), *Rhyacophila fasciata* (10%), *Halesus digitatus* (8%), *Athripsodes albifrons* (6%), *Potamophylax nigricornis* (5.1%). Most of these species occur in streams and rivers with a high current speed and stony bottom, but some of them are capable of adapting to the changing environmental

Table 2. **Statistical data on the collected caddisfly larvae. N – number of individuals, D – dominance (%), F – frequency (%)**

	Rivers					Indices		
Species	Elmë	Susiena	Varius	Rieðë (o.l.)	Rieðë (w.l.)	N	D	F
Rhyacophilidae								
Rhyacophila fasciata H.	17	42				59	2.58	40
Rhyacophila nubila Zett.					6	6	0.25	20
Glossosomatidae								
Agapetus ochripes Curt.	5					5	0.20	20
Glossosoma boltoni Curt.		3				3	0.15	20
Hydroptilidae								
Hydroptila sp.				52		52	2.26	20
Ithytrichia lamellaris Eaton		7		20	89	116	5.05	60
Psychomyidae								
Psychomyia pusilla Fabr.				3	3	6	0.26	40
Lype phaeopa Steph.		3	3			6	0.26	40
Polycentropodidae								
Neureclipsis bimaculata L.				12		12	0.51	20
Plectronemia conspersa Curt.		3				3	0.15	20
Polycentropus flavomaculatus Pict.		69				69	3.02	20
Polycentropus irroratus Curt		3	3			6	0.26	40
Hydropsychidae								
Hydropsyche pellucidula Curt.	41	83		171	117	412	18.00	80
Hydropsyche siltalai Döhler	25	53		22	309	409	17.87	80
Phryganeidae								
Oligostomis reticulata L.			3			3	0.15	20
Odontoceridae								
Odontocerum albicorne Scop.			3			3	0.15	20
Molanidae								
Molana angustata Curt.				3		3	0.15	20
Baraeidae								
Baraeodes minutus L.			3			3	0.15	20
Sericostomatidae								
Notidobia ciliaris L.		8				8	0.33	20
Sericostoma personatum K. & Sp.	4	3	8			15	0.66	60
Leptoceridae								
Athripsodes cinereus Curt.				56	10	66	2.88	40
Athripsodes albifrons L.		23				23	1.02	20
Mystacides azurea L.				3		3	0.15	20
Oecetis furva Ramb.				3		3	0.15	20
Brachycentridae								
Brachycentrus subnubilus Curt.				3	169	172	7.51	40
Micrasema setiferum Pict.		3		81	80	164	7.16	60
Lepidostomatidae								
Lasiocephala basalis Kol.					3	3	0.15	20
Lepidostoma hirtum Fabr.				14	37	51	2.23	40
Goeridae								
Silo pallipes F.	27	18		3	122	170	7.43	80
Limnephilidae								
Glyphotaelius pellucidus Retz.			3			3	0.15	20
Limnephilidae sp.		7				7	0.29	20
Limnephilus flavicornis Fabr.			3			3	0.15	20
Limnephilus lunatus Curt.			7			7	0.29	20
Anabolia soror McL.				7		7	0.29	20
Potamophylax latipennis Curt.	51	21	17			89	3.89	60
Potamophylax nigricornis Pictet	90	21	68			179	7.82	60
Halesus digitatus Schr.		33	7	3		43	1.88	60
Halesus radiatus Curt.	22	3	52	3	3	83	3.63	100
Chaetopteryx villosa Fabr.		7				7	0.31	20
Total number of individuals	282	415	181	462	949	2289		
Number of species	9	20	13	17	12			
Shannon H'	0.82	1.07	0.80	0.87	0.82			

factors. The Rieðë River in a wooded landscape (w.l.) had two eudominant species, *Hydropsyche siltalai* (33%) and *Brachycentrus subnubilus* (18%); the dominant species were *Silo pallipes*, *Hydropsyche pellucidula*, *Ithytrichia lamellaris*, and *Micrasema setiferum* (13%, 12%, 9%, and 8% respectively), the eudominant species in the Rieðë River in open landscape (o.l.) were *Hydropsyche pellucidula* (37%) and *Micrasema setiferum* (18%), the dominant species being *Athripsodes cinereus* (12%) and *Hydroptila* (11%). According to the caddisfly species ecology the Rieðë River has a sufficient rate of oxygen as a result of current and a stony bottom for larvae inhabitation.

The Shannon biodiversity index was calculated for the rivers studied. According to the Trichoptera fauna composition, the highest biodiversity index was established for the Susiena River (1.07), a warm-water river with a stony bottom and middle flow velocity (Table 2). The lowest diversity index was found in the Varius River (0.80) with a poor of sandy species community.

The Sørensen index of similarity was calculated for caddisflies and other benthic invertebrate species separately in all hydrobiocenoses (Table 3). The coefficient of similarity among caddisfly larvae species composition in different rivers varied from 0.08 to 0.57. The highest similarity was determined between the Elmë and the Susiena rivers (0.57, or 57%). The rivers belong to the same Ðventoji river basin; they have similar thermal conditions and bottom structure. The lowest index of similarity was calculated for the Varius and the Rieðë (w.l.) rivers (it was 0.08, or 8%). The main reason for the differences was belonging to the different river basins (Ðventoji and Neris), different thermal conditions and the structure of river bottom. The low value of this index was also determined between the Varius and the Rieðë (o.l.) rivers (0.13, or 13%).

The values of the Sørensen similarity index for the composition of benthic organisms, except caddisflies, in different rivers varied from 0.29 to 0.55 (Table 3). The highest similarity (the same as in the Trichoptera example) was determined between

Table 3. **S¸rensen coefficient of similarity in the rivers studied on the examples of caddisfly species (left side) and other invertebrates (right side)**

	Elmë	Susiena	Varius	Rieðë (w.l.)	Rieðë (o.l.)
Elmë		**0.55**	0.32	0.51	0.33
Susiena	**0.57**		0.35	0.43	0.30
Varius	0.36	0.44		0.30	**0.24**
Rieðë (w.l.)	0.38	0.39	**0.08**		0.46
Rieðë (o.l.)	0.31	0.39	0.13		

Other invertebrates

Caddisflies

the Elmë and the Susiena rivers (it was 0.55, or 55%), implying very similar conditions of their hydrocenoses. The lowest index of species similarity was calculated for the Varius and the Rieðë (o.l) rivers (0.29, or 29%). The low value of this index was also determined between the Varius and the Rieðë (w.l.) rivers. It means that the rivers from different basins differ in many aspects such as bottom structure, water temperature, flow velocity and others.

The results of the study show that the diversity and abundance of separate caddisfly species depend upon different environmental factors of their habitats.

For example, for the species *Silo pallipes* the most important abiotic factors were the bottom characteristic ($p = 0.0001$) and water depth ($p = 0.0004$). For the distribution of *Ithytrichia lamellaris*, the main factor was bottom ($p = 0.0006$), the depth being a weaker factor ($p = 0.014$). For *Hydropsyche pellucidula* there were three important factors: water depth, bottom structure and flow velocity ($p = 0.0001$, $p = 0.001$, and $p = 0.15$ respectively). The main importance of flow velocity ($p = 0.0003$) was estimated for the genus *Athripsodes*. For the genera *Rhyacophila* spp. bottom is the only factor for larvae distribution ($p = 0.4$). For the genera *Potamophylax* and *Halesus* no important environmental factors were discovered. It was interesting to find out whether the factor of river position (open or woodland landscape) was important for caddisfly larvae. Statistical calculations on the Rieðë River example showed that this factor influenced the composition ($p = 0.001$) and abundance of species ($p = 0.03$).

Different environmental factors showed a different significance for the abundance and distribution of caddisfly species. A negative correlation was found between bottom structure and biomass abundance of some caddisfly species (*Ithytrichia lamellaris*, *Rhyacophila*), implying that on a large-scale bottom these species would live more abundantly; the biomass would concentrate on stones, but not on gravel. The influence of flow velocity and water depth was the same: larvaes were more abundant in a stronger current and at a greater depth.

The seasonal changes are explained by the imago turning of larvae and their flying out of a water body. The species composition and biomass of caddisflies depend on seasonal development. Most of the species have a particular time of development of different duration. In the study of caddisfly phenology, some different periods of water stage development (or adult flying periods) were determined. There were species whose larvae and pupae on different development levels could be founded in the water all year round (species from the genera *Hydropsyche*, *Rhyacophila*, *Polycentropus*) (Fig. 1a). Other species were found in different shorter or longer periods. Spring activity for caddisfly adults was

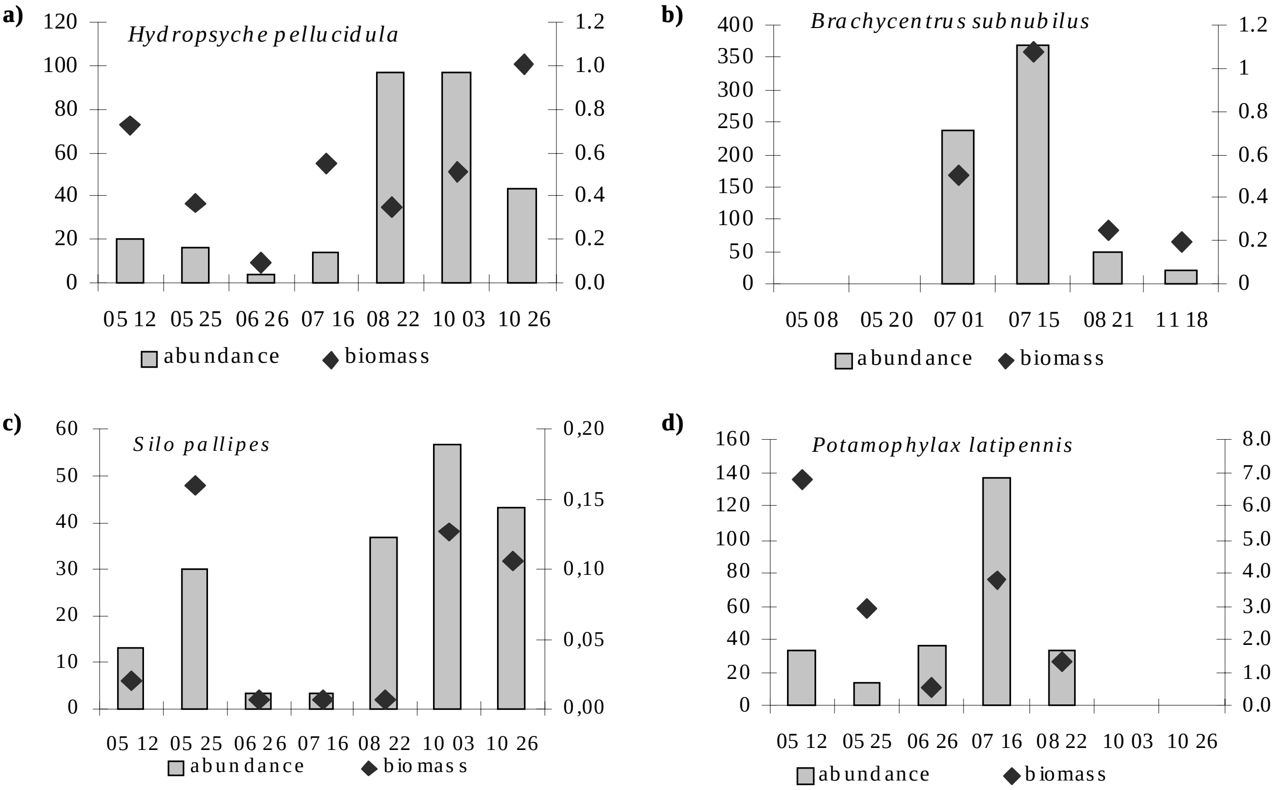

Fig. 1. Seasonal changes of species abundance (ind./m^2) and biomass (g/m^2): a) *Hydropsyche pellucidula,* b) *Brachycentrus subnubilus*, c) *Silo pallipes* d) *Potamophylax latipennis*

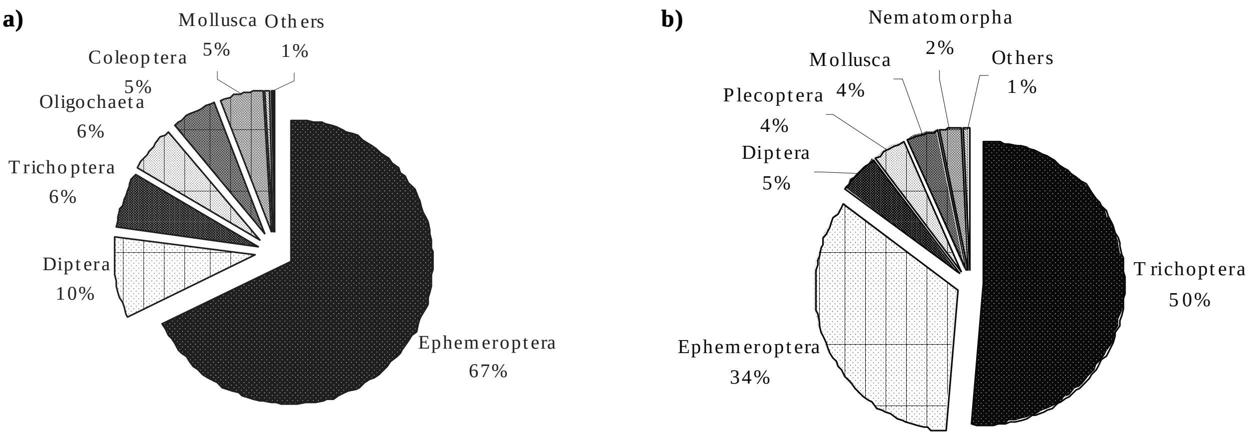

Fig. 2. Abundance (*a*) and biomass (*b*) of benthic invertebrates in the Elmë River in May 2003

determined for the species of the family Brachycentridae, whose pupae were found in May and larvae from July till the end of the year (Fig. 1b). Grown larvae of these species spend the winter in the river, while adults fly and reproduce in the spring. Summer flying activity was determined for the species *Silo pallipes* (Fig. 1c). Its larvae and pupae were found till the end of July, and small larvae came again in August. Similar periods were stated for some Leptoceridae, *Lepidostoma hirtum*, *Ithytrichia lamellaris* species. The autumn flying period showed the greatest diversity of species, *i.e.* larvae of these species were found till July or August. Most of Limnephilidae appeared in the autumn period (the genera *Anabolia*, *Halesus*, *Limnephilus*, *Potamophylax latipennis*) (Fig. 1d).

In ecological population studies, the number of individuals and biomass comprise the basic information. It is useful in visualizing the trophic structure of a community. The species diversity in various water bodies is greatest in spring and autumn, but the abundance and biomass often show no positive correlations. Some groups of animals are abundant, but have a low biomass; others can be not abundant, but make the main part of biomass. The relations between abundance and biomass were different in the rivers studied. In the Elmë River msot of individuals in May belong to Ephemeroptera (67% of

Table 4. **Number of species (s), abundance (ind./m^2) and biomass (g/m^2) of benthic invertebrates in the rivers studied in May 2003**

Taxon	Rivers									
	Elmë		Susiena		Varius		Rieðë (o.l.)		Rieðë (w.l.)	
	s	ind./m^2 g/m^2	s	ind./m^2 g/m^2	s	ind./m^2 g/m^2	s	ind./m^2 g/m^2	s	ind./m^2 g/m^2
Nematomorpha	1	3 0.39								
Turbellaria									1	3 0.04
Oligochaeta	1	110 0.11	1	37 0.03	1	13 0.04	1	83 0.22	1	83 0.21
Hirudinea							2	17 0.14		
Mollusca	1	100 0.59	3	27 0.53			3	820 35.9	3	307 1.9
Crustacea	1	3 0.001					1	20 0.35		
Hydracarina	1	3 0.002			1	7 0,01	1	7 0.002	1	157 0.007
Ephemeroptera	2	1350 5.57	1	840 3.3	3	60 1.17	3	107 2.92	3	797 4.12
Plecoptera	1	10 0.6	1	3 0.01	1	7 0.01	1	13 0.1	1	127 1.7
Trichoptera	8	120 8.48	7	157 9.7	2	23 0.7	8	137 1.6	6	287 2.2
Odonata							2	10 1.31	2	27 0.63
Coleoptera	5	103 0.03	5	183 0.27	3	10 0.04	4	67 0.09	8	653 1.06
Diptera	5	193 0.75	4	33 0.06	10	100 0.22	11	613 2.22	6	273 3.03
Heteroptera							1	293 5.99	1	180 2.41

all animals), but its biomass was 34%. Meanwhile the main biomass was determined for Trichoptera (50% all invertebrates), although their abundance was very low – only 6% (Fig. 2). The situation was similar in the Susiena River (Table 4). In the Varius River, the biggest part of individuals belonged to Diptera species (about 46% of all invertebrates), but Ephemeroptera prevailed by biomass (54%). This situation reflects good conditions of habitat for small Diptera species and confirms spring development of Ephemeroptera larvae.

The number of species and individuals changes depending on the ecological factors, such as the substratum, the depth of water, water current speed, and food availability (Kiss, 2002). In our studies, according to the Shannon diversity index calculated for caddisfly species, the main factor for species diversity was the habitat of a river. The highest diversity of caddisfly species was found in rivers with a stony bottom and high current speed, and a sandy bottom was always low in species diversity, because running water on the stones provides for good oxygen and food conditions. The Sørensen index of similarity for benthic invertebrates showed differences among species in different hydrocenoses. A great similarity was determined among rivers with similar conditions (bottom structure, temperature or flow velocity). The differences in habitats result in different species composition in rivers.

In conclusion, it could be stated that a complex of factors determines the distribution of species in aquatic ecosystems. The different proportions among these conditions are important for the dominance and frequency of species. Some statistical calculations showed that every caddisfly species has one or another main factor important for its survival. In many cases the bottom structure was the only or one of the main environmental factors for Trichoptera larvae. It means that changes in the factors that are important for species living can lead to species extinction. Anthropogenic impact is one of the factors that change river conditions and lead to changes or extinction of species of benthic organisms living in aquatic ecosystems. For some species there no key factor was determined; these species are eurybiotic and can live in greatly different aquatic communities. To know more reasons for the ecological distribution of macrozoobenthic species, more data on species from different rivers must be collected, and some chemical factors should be analyzed in future.

The seasonal development of aquatic invertebrates influences their species composition, biomass, and abundance in rivers. The diversity of macrozoobenthos is greatest in spring and autumn because of their development periods. Most of the benthic insects spend winter in water and their adults begin to fly from the water body in spring. By the ecological adaptation of different species we know how seasonal development influences the fluctuations of biomass and abundance of species in aquatic and terrestrial communities, as it is an important fact for trophic relations.

CONCLUSIONS

1. The highest similarity was determined among rivers belonging to the same river basin, with similar thermal conditions and bottom structure.

2. According to caddisfly fauna, the eudominant species in all the rivers studied were *Hydropsyche pellucidula* and *Hydropsyche siltalai*, which represent fast-flow rivers and streams with a stony bottom and good water quality.

3. According to Trichoptera fauna composition the highest biodiversity index was established for a warm-water river with a stony bottom and middle flow velocity. The diversity index was lowest in sandy communities.

4. The diversity and abundance of separate caddisfly species depend on different environmental factors of their habitats, such as bottom characteristic, water depth, flow velocity, and river position (in an open or woodland landscape).

5. The different seasonal development levels of species influence biomass and abundance fluctuations in aquatic and terrestrial communities. Development periods for caddisfly species (activity throughout the year, in spring, summer and autumn) were determined.

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Giedrë Višinskienë

MAKROZOOBENTOSO BIOÁVAIROVË, PASISKIRSTYMAS IR EKOLOGIJA MAÞOSE LIETUVOS UPËSE

Santrauka

Šio darbo tikslas buvo iðtirti makrozoobentoso gausumà, pasiskirstymà, ekologijà ir bioávairovæ maþose Lietuvos upëse. Tyrimai atlikti keturiose upëse (Rieðëje, Elmëje, Susienoje, Variuje) Vilniaus bei Anykðèiø rajonuose 2003 m. geguþës–lapkrièio mënesiais. Kiekviena upës tyrimo vietovë apibrëþiama keliais aplinkos faktoriais: upës grunto struktûra (akmenys, gargþdas, smëlis), vandens temperatûra (ðiltavandenë ar ðaltavandenë upë), gyliu, srovës greièiu, upës padëtimi (upë miðkingoje ar atviroje vietovëje). Zoobentoso mëginiai kiekvienoje vietovëje rinkti „spyrio“ metodu trijuose 0,1 m^2 dugno ploteliuose. Surinkti mëginiai iðanalizuoti pagal galiojanèias hidrobiologines metodikas. Kiekvienam mëginiui nustatyta gyvûnø rûðinë sudëtis, biomasë (g/m^2) ir gausumas ($ind./m^2$). Straipsnyje analizuojama upiø gyvûnø rûðinë sudëtis, bioávairovë, ekologinë bûklë. Nustatyta, kad bentosiniø organizmø rûðiø skaièius, ávairovë, gausumas ir biomasë priklauso nuo ávairiø aplinkos sàlygø bei sezoninio rûðiø aktyvumo ir kaitos.

Raktaþodþiai: makrozoobentosas, apsiuvos, bioávairovë, gausumas, biomasë