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BIOINDICATION OF ECOTOXICITY ACCORDING TO COMMUNITY STRUCTURE OF MACROZOOBENTHIC FAUNA

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Abstract. It has been established that macrozoobenthos communities in the Nemunas River are not harmed. In Kaunas water reservoir at Kapitoniškės and in the Nemunas at Liškiava and Rusnė, the pollution was low or average (in the backwaters). There have been established the disturbances in the functioning of macrozoobenthic communities and pollution-tolerant organisms dominated. This stretch was the most polluted.
Key words: benthos, biomass, species composition

INTRODUCTION

Zoobenthos is one of the most reliable indicators determining the ecotoxic effect on hydroecosystem. The community structure of macrozoobenthic organisms is closely related to physical-chemical factors as a whole, mechanical and chemical composition of bottom sediments, which are mostly influenced by regional impacts such as atmosphere pollution, waste materials from agriculture, enterprises and sewerage. Macrozoobenthic organisms with various aspects of diet serve as a filter for water quality improvement. However, they differ as bioconcentrators. Chironomidae and oligochaeta found on the ground accumulate Zn, V, Mn, and Ti more intensely, coleoptera larvae found on the ground surface as well as among macrophytes accumulate Cr, Co, whereas amphipods and molluscs – Pb, Cu, and Ni. The detoxication process (heavy metal reaction with amino acids SH-groups) contributes to the accumulation of large heavy metal concentrations, consequently, the pollution tolerance.

Due to high pollution, macrozoobenthic organisms through nutritious chains and body cover can accumulate great quantities of heavy metals, more than three times exceeding background values, established for separate organism groups. In case of such an intensive bioaccumulation, the quantitative amino acid changes in the organisms have been determined and the disturbances in the organism's functioning under the experimental conditions have been established, revealing an early ecotoxic effect before the extinction of species.

To establish the changes in zoobenthic fauna communities, the investigations have been performed in five stretches of the Nemunas River. The indices of indicator species distribution, the abundance of separate groups of species as well as biomass (productivity) provided for the evaluation criteria.

The aim of the present study was to evaluate the ecological state in the Nemunas River at Merkinė, Liškiava, in Kaunas water reservoir at Kapitoniškės, also in the Nemunas at Kulautuva and Rusnė by means of quantitative and qualitative indicating parameters of macrozoobenthic organisms, the community structure, and distribution of indicator species.

MATERIAL AND METHODS

During a complex expedition, the samples were collected from the most comparable biotopes in the riparian zone of the Nemunas River by means of Ekmann-Berdge dredge (the area of 225 cm^2), also for a more thorough qualitative composition, from macrophytes or their root turf, and pelophilous stones overgrown with algae theady. Twenty samples have been collected and examined under the laboratory conditions. Applying general widely used hydrobiological methods, there have been determined species diversity, qualitative and quantitative community structure, and indicator species.

RESULTS

As seen from the results of our analysis, certain macrozoobenthic fauna species inhabit specific ecological biotopes and their distribution in separate stretches of the Nemunas River is different (Table 1).

Biomass is effected by the predominance of smaller or larger forms in the samples. Separate species choose a biotope according to their environmental needs and the characteristic ecological conditions.

Psamorheophilic and pelopsamorheophilic fauna communities inhabiting sand and silt-sand bottom biotopes predominated in the Nemunas River at Merkinė and Liškiava. The species diversity of these communities significantly differed from similar communities in the Nemunas River at Kulautuva and less significantly from those at Rusnė and Kaunas water reservoir, depending on the environmental changes (Table 2).

Small oxiphilous chironomidae species *Stictochironomus psammophilus* Tschern and sensitive to pollution *Tanytarsus gr. mancus, Tanytarsus gr. exiguus, Glyptotendipes gripekoveni* Kieff., dominated in the Nemunas at Merkinė and Liškiava, and they made up 10.5% and 8.4%, respectively in the communities.

In psamorpheophilic communities of chironomidae, *Cryptochironomus* was predominant and *Limnochironomus gr. nervosus, Tendipes f. l. bathophilus* were subdominant species in Kaunas water reservoir at Kapitoniškės. These are bottom fauna species provided with much nutrition matter and oxygen. They made up 25.3% in the communities.

Chironomus f. l. plumosus, Chironomus f. l. thummi dominated whereas *Cryptochironomus defectus, Prodiamesa olivacea, Pelopia* subdominated in the Nemunas at Kulautuva. These are pollution-tolerant species, able to exist with little oxygen. They made up 9.7% in the communities.

Chironomidae *Cryptochironomus defectus* was dominant whereas *Limnochironomus gr. nervosus* and other chironomidae species were subdominant in the Nemunas at Rusnė, and made up 20.2%.

Due to the augmentation of saprophitic fauna in the bottom sediments, the abundance of oligochaeta has increased too in the Nemunas at Kulautuva, and they made up 55.8% in the communities and 25% in the Nemunas at Rusnė. The abundance increase was less noticeable in Kaunas water reservoir at Kapitoniškės, 19.6%, and in the Nemunas at Liškiava, 10%, and it was the lowest at Merkinė, 5.1%.

The greatest abundance of Ephemeroptera larvae (8-10 species) in the bottom and in the phytorheophilic communities has been established in the Nemunas up to Kaunas water reservoir. Ephemeroptera made up 11.1% of the bottom fauna communities at Merkinė and 10.6% at Liškiava, where *Ecdyonurus fluminum* dominated and *Oligoneurella rhenana, Ephemerella ignita* Poda were common. Ephemeroptera larvae made up 4.2% in the communities in Kaunas water reservoir at Kapitoniškės, 1.5% in the Nemunas at Rusnė, and the lowest number (0.15%) was established at Kulautuva, where genus *Baetis* dominated.

Stirunidae occupy a particular place among the bottom fauna. They are predatory parasites. Five stirunidae species have been established with three species in the Nemunas at Merkinė and Liškiava, which made up 2.4 and 3.4%, correspondingly. In each other stretch of the Nemunas, five stirunidae species have been identified, which in the bottom communities made up 6.8% at Kulautuva, 6.3% at Rusnė, and 3.4% in Kaunas water reservoir at Kapitoniškės. These are macrozoobenthic pollution-tolerant organisms inhabiting b- and a-mezosaprobial waters.

Molluscs comprised an important part in the bottom fauna communities where they made up 33.5% in the Nemunas River at Liškiava. Among gastropods, *Bithynia tentaculata* and *Theodoxus fluviatilis* were dominant. Bivalia pearl-oyster and anochonta were determined in pelopsamorheophilic community. Small gastropods *Ancylus* and *Theodoxus* as well as bivalia pearl-oyster and anochonta dominated in the Nemunas at Merkinė. Molluscs made up 21.1% in macrozoobenthic fauna communities, and 12.5% in Kaunas water

Table 1. Structure (%), abundance (ind./m^2) and biomass (g/m^2) of organisms of macrozoobenthic fauna communities in 1999

Sites of sample collection in the Nemunas River	Biomass, g/m^2	Abundance, ind./m^2	*Ephemeroptera*	*Plecoptera*	*Trichoptera*	*Hirudinea*	*Odonata*	*Mollusca*	*Crustacea*	*Coleoptera*	*Rhynchota*	*Chironomidae*	*Oligochaeta*
At Liškiava	149.0	4990	10.60	2.2	5.6	3.4	4.1	33.5	16.0	6.20	-	8.4	10.0
At Merkinė	85.0	3510	11.10	2.6	6.3	2.4	8.1	21.1	26.2	6.60	-	10.5	5.1
Kaunas water reservoir (at Kapitoniškės)	49.5	4740	4.20	0.8	2.8	4.8	4.2	12.5	16.9	5.90	3.0	25.3	19.6
At Kulautuva	9.0	2690	0.15	-	0.5	6.8	1.2	10.3	10.3	2.35	2.9	9.7	55.8
At Rusnė	60.0	3176	1.60	-	2.6	6.3	3.1	19.7	17.5	1.40	2.6	20.2	25.0

Table 2. Species composition of bottom fauna in the Nemunas River in 1999

Benthic fauna species	Sites of sample collection				
	At Liškiava	At Merkinė	Kaunas water reservoir at Kapitoniškės	At Kulau-tuva	At Rusnė
Hirudinea					
Glossiphonia complanata (Linné)	+	-	+	+	+
Glossiphonia heteroclita (Müller)	+	+	-	-	-
Helobdella stagnalis Bl.	-	-	+	+	+
Herpobdella octoculata (Linné)	-	+	+	+	+
Pisciola geometra (Linné)	+	+	+	+	+
Crustacea					
Asellus aquaticus Linné	+	+	+	+	+
Chaetogammarus tenellus Sars	-	-	-	-	+
Chaetogammarus warpachowskyi Sars	-	+	-	-	+
Pontogammarus robustoides Grimm.	-	+	+	-	+
Pontogammarus crossus Grimm.	+	+	+	-	+
Corophium curvispinum Sars	+	+	-	-	-
Paramysis lacustris Cz.	-	+	+	-	-
Gammarus sp.	+	+	-	-	+
Odonata					
Agrion splendens (Harris)	+	+	-	-	-
Gomphus flavipes Charp.	+	-	+	+	-
Gomphus vulgatissimus Linné	+	-	+	+	+
Libellula quadrimaculata Linné	+	+	-	-	-
Aeschna grandis Linné	-	+	+	-	-
Ephemeroptera					
Baetis bioculatus Linné	+	+	-	-	+
Baetis vernus Curtis	-	-	+	-	+
Baetis rhodani (Pictet)	-	-	+	+	+
Caenis horaria Linné	-	+	-	-	-
Caenis macrura Stephens	-	+	-	-	-
Caenis moesta BGtss	-	+	-	-	-
Centroptilum luteolum Müller	+	-	+	-	-
Cloeon dipterum Linné	-	+	-	-	-
Ecdyonurus fluminum (Pictet)	+	+	-	-	-
Ecdyonurus venosus Fab.	-	+	-	-	-
Ephemera vulgata Linné	+	-	+	-	-
Ephemerella ignita (Poda)	-	+	-	-	-
Heptagenia coerulans (Rostock)	+	-	-	-	-
Heptagenia fuscogrisea (Rostock)	-	+	-	-	-
Heptagenia sulphurea (Müller)	+	+	-	-	-
Oligoneuriella rhenana (Imhoff)	+	+	-	-	-
Potamanthus luteus Linné	+	-	-		
Polymitarcis virgo (Oliv.)	+	-	-	-	-
Plecoptera					
Nemurella picteti Klap.	-	+	-	-	-
Isogenia nubeculosa	+	-	-	-	-
Taeniopteryx nubeculosa Linné	-	+	+	-	-
Perlodes sp.	+	+	-	-	-

Coleoptera					
Nepa cinerea Linné	+	+	+	+	+
Ranatra linearis Linné	+	+	+	+	+
Notonecta glauca Linné	+	+	+	+	+
Aphelochirus aestivalis (Fabricius)	+	+	-	-	-
Trichoptera					
Hydropsyche angustipennis Curtis	-	+	-	-	-
Hydropsyche ornatula Mc Lach	+	+	+	-	-
Hydropsyche pellucidula Curtis	+	+	+	+	+
Cheumatopsyche lepida Pictet	+	-	+	-	-
Neuroclipsis bimaculata Linné	+	-	-	-	-
Polycentropus flavomaculatus (Pictet)	+	+	-	-	-
Agapetus comatus Pictet	-	+	-	-	-
Mollusca					
Ancylus lacustris Linné	+	+	-	-	-
Bithynia tentaculata (Linné)	-	+	+	+	+
Galba truncatula (Müller)	-	-	+	-	+
Dreissena polymorpha Pallas	-	-	+	-	+
Lithoglyphus naticoides Pfeiffer	+	+	-	-	-
Radix auricularia (Linné)	-	-	-	+	-
Radix ovata Draparnaud	-	-	+	+	+
Sphaerium rivicola (Lamarck)	-	+	-	+	+
Sphaerium corneum (Linné)	+	-	-	-	+
Theodoxus fluviatilis (Linné)	+	+	-	-	-
Valvata piscinalis (Müller)	-	-	+	-	+
Valvata naticina Menke	+	-	-	+	+
Viviparus viviparus (Linné)	+	-	+	-	+
Anodonta	+	+	+	-	+
Unio	+	+	-	-	+
Chironomidae					
Tanytarsus gr. exiguus Joh.	+	+	-	-	-
Tanytarsus gr. mancus v.d. Wulp	+	+	-	-	-
Tanytarsus gr. gregarius Kieffer	-	-	+	-	-
Cryptochironomus gr. defectus	-	-	+	+	+
Cryptochironomus rolli Kirpitsch	+	+	-	-	-
Cryptochironomus gr. vulneratus	+	+	+	-	-
Cryptochironomus gr. conjugens Kieffer	-	+	+	+	-
Chironomus f. l. plumosus Linné	-	-	+	+	+
Chironomus f. l. thummi Kieffer	-	-	+	+	+
Glyptotendipes gr. gripekoveni Kieffer	+	+	+	-	-
Limnochironomus gr. nervosus Staeger	+	+	+	-	+
Endochironomus gr. tendens F.	+	-	+	-	+
Polypedilum breviantennatum Tschern.	+	+	+	-	-
Tendipes f. l. bathophilus Kieffer	+	+	+	-	-
Stictochironomus psammophilus Tschern.	+	+	-	-	-
Prodiamesa olivacea Mg	-	-	-	-	+
Cricotopus gr. algarum Kieffer	+	+	+	-	+
Cricotopus latidentatus Tshern.	+	+	+	-	-
Pelopia punctipennis Mg.	-	-	-	+	+
Pelopia kraatzi Kieffer	-	-	-	+	+
Procladius Skuse	+	-	+	+	+

reservoir at Kapitoniškės. *Viviparus viviparus* and *Bithynia tentaculata* dominated among gastropods. Molluscs made up 10.3% in the Nemunas at Kulautuva and 19.7% at Rusnė in the bottom fauna communities. Pulmonata *Galba truncatula* and *Galba palustris* also, gastropods *Valvata piscinalis* were dominant in the communities. Bivalia *Sphaerium* and *Dreissena polymorpha* were subdominant.

According to the investigation results, plecoptera and trichoptera were the most sensitive to the environmental changes. The greatest number of plecoptera (three species) has been established in the Nemunas at Merkinė, where they made up 2.6% in the communities. Two species have been identified in the Nemunas at Liškiava, where they made up 2.2% in the communities. In addition, one species has been identified in Kaunas water reservoir at Kapitoniškės, which made up 0.84% in the bottom fauna communities. Plecoptera were absent in the Nemunas River at Kulautuva and at Rusnė.

Trichoptera *Hydropsyche ornatula, Hydropsyche angustipennis, Chematopsyche lepida,* and *Polycentropus flavomaculatus* have been identified on pelophilous stones overgrown with silt. The greatest number of trichoptera larvae (five species) has been established in the Nemunas at Merkinė, which made up 6.3%, four species at Liškiava, 5.6%, and three species in Kaunas water reservoir at Kapitoniškės, 3.8%. One species in each biotope has been identified in the Nemunas at Kulautuva and at Rusnė (0.5% and 2.6% respectively).

Odonata larvae are usually found on the bottom sediments and on the submerged vegetation. Hence, in the Nemunas at Kulautuva they made up 1.2%, at Rusnė, 3.1%, in Kaunas water reservoir at Kapitoniškės, 4.2%, in the Nemunas at Liškiava, 4.1%, and at Merkinė, 8.1%. The species composition of macrozoobenthic fauna and its distribution in the investigated stretches of the Nemunas reveal different impact of ecosystems on the communities (Table 2).

Very sensitive and sensitive to pollution organisms have been identified in the Nemunas at Merkinė in the macrozoobenthic fauna communities. Crustaceans and molluscs were dominant (26.2% and 21.1% respectively), ephemeroptera were subdominant (11.1%). Sensitive to pollution molluscs dominated (33.5%) in the Nemunas at Liškiava, while crustaceans were subdominant (16%). Chironomidae and oligochaeta dominated in the macrozoobenthic fauna communities in Kaunas water reservoir at Kapitoniškės (25.3% and 19.6% correspondingly), while crustaceans were subdominant (16.9%).

Oligochaeta and chironomidae dominated in the Nemunas at Rusnė (25% and 20.2% correspondingly), while molluscs and crustaceans were subdominant (19.7% and 17.5% correspondingly; Table 1). Oligochaeta dominated in the zoobenthic fauna communities in the Nemunas at Kulautuva (55.8%), with the most abundant *Tubifex tubifex*, while crustaceans (*Asellus aquaticus*) and pollution-tolerant chironomidae were subdominant (10.3% and 9.7% respectively).

Velocity of flow has a very important effect on the ecotoxic effect. In the backwaters, where the velocity slows down, a greater number of suspended matter of autochthonous and allochthonous nature also organic matter settles down. Various fungi and bacteria decompose this matter, which clarifies the abundance of oligochaeta. In addition, small silt fractions accumulate more intensely various pollutants. Consequently, species composition of macrozoobenthic organisms changes and pollution-tolerant specimens dominate.

Crustaceans, like amphipods, mysidae, corophins, and isopoda of the order Isopoda occupy an important part in the communities. The greatest number of them has been established in the rotting vegetation in the Nemunas at Kulautuva. Amphipods *Pontogammarus robustoides, Pontogammarus crassus, Chaetogammarus tenellus,* and *Chaetogammarus warpachowskyi* are the most common among macrophytes, whereas various species g. *Cricotopus, Glyptotendipes* and *Endochironomus* among chironomidae. Vegetation serves as a biotope for phytophylous fauna as well as their nutritive base. Chironomidae larvae *Tanytarsus gr. gregarius*, dwelling among macrophytes, gnaw out the soft vegetation tissues and thus, produce a net for food filtration. Other chironomidae species, dwelling on the bottom, feed on detritus, some of them are raptors (*Pelopia, Procladius*).

Coleoptera, heteroptera, and odonata are raptors feeding on various small bottom fauna, like worms or coleoptera larvae. Gastropods feed mostly on vegetation, bivalia on phyto- and zooplankton, and bacteria.

Macrozoobenthic organisms with their different diet character distinguish by high bioaccumulation intensity and are different as bioconcentrators. It has been established by the previous studies that oligochaeta accumulate intensely Zn, V, Mn, and Ti, coleoptera larvae Cr, Co, Pb, Cu, and amphipods and molluscs Ni. Heavy metals react with amino acids SH-groups during the bioaccumulation process. Thus, a new protein metalotyonyl is produced. The latter detoxification mechanism results in great heavy metal concentrations in the organisms as well as in pollution tolerance.

Very large bioaccumulated heavy metal concentrations more than three times exceeding background values established for the separate organisms of different groups induce biochemical changes revealing the early ecotoxical impact. In accumulating various pollutants, non-harmful to the existence concentrations, biota is improving water quality. The obtained results show that organisms of various trophic chains, like phytophagous, detritophagous, filtrators, raptor forms were found in the investigated stretches of the Nemunas among the bottom fauna communities, which ensure the intensive biological self-cleaning processes.

Discussion

87 macrozoobenthic organism species have been detected in the investigated stretches of the Nemunas River with 18 ephemeroptera species, 21 chironomidae, 15 molluscs, four plecoptera, seven trichoptera, four coleoptera, one heteroptera, five odonata, five stirudinae, seven higher crustaceans and oligochaeta.

The macrozoobenthic fauna species composition and distribution in the investigated stretches reveal different ecosystem impact on the communities. Slower velocity of flow in the backwaters has a considerable influence on the toxicity effect.

Basing on the investigation data as well as on the analogous investigations we have determined indicator mechanisms which according to their sensitivity could be enumerated in the following order:

Group 1: the most sensitive to pollution zoobenthic organisms, like plecoptera, trichoptera, and ephemeroptera – *Ecdyonurus fluminum, Ecdyonurus venosus*.

Group 2: sensitive to pollution zoobenthic organisms comprising the rest ephemeroptera species (except g. *Baetis*), odonata, bivalia (except g. *Sphaerium*), pulmonata *Ancylus, Theodoxus fluviatilis*, and crustaceans – amphipods, mysidae.

Group 3: less sensitive to pollution bottom fauna comprising the rest pulmonata species, bivalia g. *Sphaerium*, ephemeroptera g. *Baetis*, crustaceans *Asellus aquaticus*, stirudinae, most *Chironomidae* and *Oligochaeta* species.

Group 4: pollution-tolerant macrozoobenthic organisms comprising *Chironomus f. l. plumosus, Chironomus f. l. thummi*, *Cryptochironomus gr. defectus,* Oligochaeta *Tubifex tubifex.*

The distribution of indicator organisms allows us to evaluate ecological state, disturbances in the functioning of ecosystem that are the most noticeable in the Nemunas at Kulautuva.

Conclusions

The zoobenthic communities in the Nemunas at Merkinė function in natural ecological conditions. There have been identified very sensitive and sensitive to pollution macrozoobenthic species in the communities. No disturbances have been established in the communities.

Sensitive and less sensitive benthic fauna dominated in the bottom fauna communities in Kaunas water reservoir at Kapitoniškės and in the Nemunas at Liškiava and Rusnė. Apparently, it means a slight and in the backwaters, middle pollution.

Disturbances in the communities’ functioning have been established in the Nemunas at Kulautuva, particularly in the backwaters. Pollution-tolerant mezosaprobial organisms α dominated, and the stretch was the most polluted.

The qualitative and quantitative further investigations on macrozoobenthic organisms will permit us to analyse the dynamics of the ecological state, to evaluate the stability of ecosystem, also the disturbances of functioning in co-ordinating the excess of anthropogenic factors. Also, we need to make decisions on the problems of waste material treatment, such as the distribution of decomposed agricultural sewage.

References

Jagminienė I.B. 1988. Macrozoobenthic organisms as pollution bioindicators. *Nature ecology and protection* Riga, 220-222 (in Russian).

Jagminienė I.B., Antaninienė A.S. 1991. Heavy metal accumulation of amphipods and their biochemical variation under the different pollution levels. *II International Conference on the Fishing toxicology* 2: 287-288. Saint Petersburg (in Russian).

Makrushin A.V. 1974. *Biological water quality analysis*. *The USSR Ac. of Sc*., Leningrad, 1-60 (in Russian).

Methods of the freshwater biological analysis. (Collection of scientific works). 1976. *The USSR Ac. of Sc*., Leningrad, 1-163 (in Russian).

Standard methods on the water quality studies. 1976. Part III. Methods on biological water analysis. The head conference of the hydroeconomical institutions of the countries of the mutual aid.

Standard methods on the water quality studies. 1977. Part III. Atlas of saprophytic organisms. The head conference of the hydroeconomical institutions of the countries of the mutual aid.

Stroganov N.S. 1976. Comparative hydrobiont sensibility to toxicants. *General ecology*. *Biocenology. Hydrobiology* 3: 5-48, Moscow (in Russian).

Zenkevich L.A. 1979. Programme and methods on the water fauna community studies. (Collection of articles). Moscow, 213-227 (in Russian).

Ekotoksiškumo bioindikacija pagal zoobentosinių organizmų bendrijų struktūrą

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Santrauka

Nustatyta, kad Nemune prie Merkinės makrozoobentoso biocenozės nepažeistos. Kauno mariose prie Kapitoniškių, Nemune prie Liškiavos ir Rusnės konstatuotas silpnas ir vidutiniškas užteršimas (užutekiuose). Nemune prie Kulautuvos nustatyta makrozoobentoso biocenozių funkcionavimų pažeidimai, vyravo tolerantiški taršai organizmai. Ši atkarpa labiausiai užteršta.

Makrozoobentosinių organizmų kiekybiniai ir kokybiniai tyrimai ateityje leis analizuoti ekologinės būklės dinamiką, įvertinti ekosistemos stabilumą, funkcionavimo pažeidimus, normuojant antropogeninę apkrovą, išskaidytą taršą nuo dirbamų žemės ūkio teritorijų, sprendžiant kaimo nuotėkų valymo klausimus.

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