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ZOOPLANKTON IN THE NIDA RIVER (THE UPPER WKRA RIVER) SUBJECTED TO REVITALIZATION TREATMENTS

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Key words: Wkra River, zooplankton, Rotatoria, Protozoa, revitalization.

Abstract

This paper focuses on the qualitative and quantitative characterization of zooplankton in a section of the Nida (the Upper Wkra) River subjected to revitalization treatments. At four established sites, biological samples were taken for analyses. In total, 44 taxa of zooplankton were determiend in the collected material. The upper section of the Wkra River, along which two sites were set up, was in general more varied in species composition, and the structure of biocenosis was shaped by rotifers and protozoa (mainly ameba species) in nearly equal halves. At the other two sampling sites, localized below, along a further section of the watercourse, the structure of zooplankton was poorer. It was colonized by larger numbers of individuals belonging to a few species of rotifers, among which *Keratella cochlearis* var. *tecta*, *Trichocerca similis* and *T. pusilla* are the species indicating a raised level of the trophy of the river water.

ZOOPLANKTON RZEKI NIDY (GÓRNA WKRA) PODDANEJ ZABIEGOM REWITALIZACJI

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Słowa kluczowe: Wkra, zooplankton, Rotatoria, Protozoa, rewitalizacja.

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Abstrakt

W pracy skupiono się na charakterystyce jakościowej i ilościowej zooplanktonu odcinka rzeki Nidy (górna Wkra) poddanego zabiegom rewitalizacji. Na wyznaczonych czterech stanowiskach pobrano próby biologiczne do analizy. W zebranym materiale oznaczono łącznie 44 taksony zooplanktonu. Górny odcinek rzeki Wkry, na którym zlokalizowano dwa stanowiska, charakteryzował się ogólnie większym zróżnicowaniem gatunkowym, a struktura biocenozy kształtowana była niemalże po połowie przez wrotki i pierwotniaki (przeważnie gatunki ameb). W kolejnych punktach, w dalszym odcinku cieku, struktura zooplanktonu uległa zubożeniu. Dominowało kilka gatunków wrotków, spośród których *Keratella cochlearis* var. *tecta*, *Trichocerca similis* i *T. pusilla* wskazywały na stan podwyższonej trofii wód.

Introduction

For decades, watercourses have been among the water bodies most radically reshaped by man. The intensive civilization growth in the 20th century, development of technologies and methods which interfer with the nature, including use of flowing waters, and man's activity in river valleys, have caused great changes in natural ecosystems, which often lead to irriversible degradation. Due to such transformations, the biological function of some rivers has become limited, the biological diversity of plants and animals inhabiting watercourses has declined and the aesthetic role of rivers in landscape has deteriorated.

The evaluation of threats and degradation of rivers is based on guidelines and forms of actions suggested by the Water Framework Directive (WFD) of 2000, which should improve the ecological quality of surface waters. The following biological components are recommended to be taken as a basis for such evaluation: phytoplankton, phytobenthos, macrophytes, benthos invertebrates and fish. The picture of degradation, obtained according to these bioindicators and additional hydromorphological parameters, enables us to design and implement suitable renaturation actions in river valleys, with an aim of approximating the once lost natural character of such habitats (ŻELAZO and POPEK 2002, LÜDERITZ et al. 2004).

Success in restoring the wholesome nature of a water system depends mosty on good recognition and understanding of biological, chemical and physical processes which occur within the system as well as their mutual dependences/interactions.

It is therefore crucial to analyse very carefully the structure and ecology of organisms which dwell in a given watercourse, including the link omitted in bioindication, i.e. zooplankton. The role of plankton animals in an ecosystem is to take part in transformation and circulation of organic matter (ALLAN 1998), to regulate the biomass of phytoplankton (GRIFFIN et al. 2001) and to serve as food for fish, especially for their earlier, larval stages and for fish fry (e.g. MILLS et al. 1986, MARMULLA and ROSCH 1990, SUTELA and HUUSKO 2000). Moreover, some specific zooplankton species help us to determine water purity of stagnant and flowing water bodies (PATUREJ and GOŹDZIEJEWSKA 2005), although they are not formally included in the control procedures established by the EU.

Zooplankton in flowing watercourses is much poorer than in stagnant waters, both in the variety of species and number of individuals. This is due to the the flow of water, which is a more demanding factor on many groups of organisms. The flow of water restricts the availability of food and makes it impossible for many groups of plankton to reproduce. The taxonomic structure and density of zooplankton in rivers are also shaped by the eutrophic effect of a river catchment basin (HILTON et al. 2006), presence of tributary rivers, river bends or old-river beds (RECKENDORFER et al. 1999), dam water reservoirs and lakes through which a watercourse flows (NIESLER and BIELAŃSKA-GRAJNER 2004), pressure produced by fish (JACK and THORP 2002) and some invertebrates, e.g. bivalves (LEVINTON and WALDMAN 2006).

This paper analyzes the qualitative and quantitative structure of zooplankton in the upper section of the Wkra River, locally named the Nida River (north-eastern Poland, Province of Warmia and Mazury, the administrative district of Nidzica). The section of the river is situated between the towns of Nidzica and Szymany. It has been subjected to revitalization treatments, including the planting of trees in the shore belt of the river bed, placing boulders and stones on the river bottom in order to diversity its structure and stocking with fish to rebuild the ichthyofauna of the river (SKRZYPCZAK et al. 2010).

The purpose of this revitalization effort was to restore the natural character of the ecosystem of the Wkra River, to rebuild and diversify plant and animal habitats and, consequently, to increase the biological diversity in the river channel. The underlying concept was that the river was a valuable natural component for the local forms of nature conservation and as an ecological channel in national and international nature networks. Additionally, the restoration of the natural values of the Wkra has a social and eco-sociological meaning. It should make the local community aware of the undeniable benefits of preserving clean nature, including the aspect of tourist assets of the whole region.

The aim of this paper has been to determine the qualitative and quantitative structure of the zooplaknton in the Nida River. The biocenosis of the Nida River was undergoing some changes stimulated by the restructuring of habitats and stocking with fish.

Materials and Methods

Zooplankton sampling and analysis methods

Samples of the zooplankton were taken on 2 and 15 of September 2009. Four sites were set up along the section of the Nida covered by the revitalization treatments (Figure 1). Stations varied in hydrology, habitat and due to the catchment impact (Table 1).

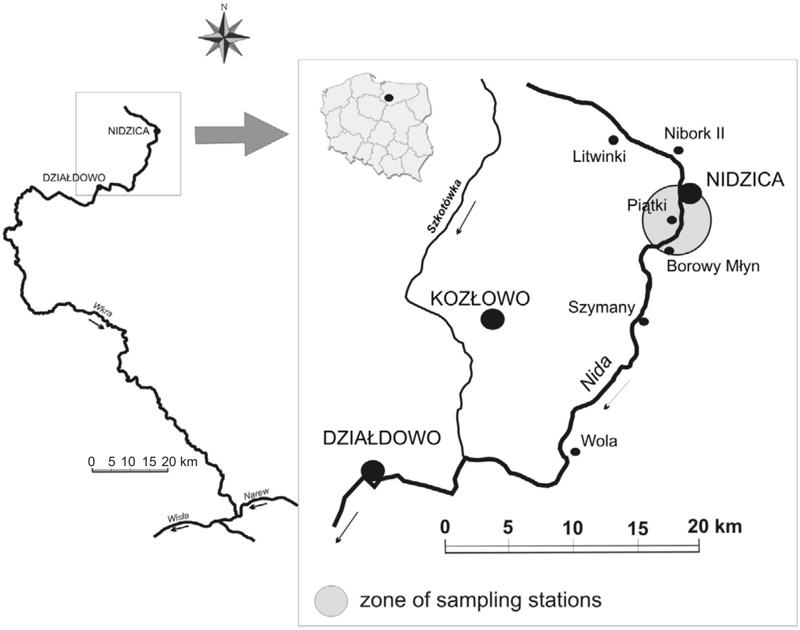

Fig. 1. Research area localization

Site 1 was situated in the southern outskirts of the town of Nidzica, in a developed area. Trees were planted in the shore belt between sites 1 and 2 (approximately 2 km) as part of the revitalization programme. Site 2 was set out near the location of sedimentation tanks of the wastewater treatment plant in Piątki. The surrounding area consists of fallow land and shrubs. Along two, 100-meter-long sections of the Nida River, between sites 3 and 4, the bottom of the river was made more diverse by placing boulders and pebbles. The immediate surroundings of the river, along these sections, comprise pastures, meadows and arable fields. No revitalization works were conducted at site 4, located the lowest along the river, in front of the weir in Borowy Młyn. The area on each side of the river channel comprises grasslands and arable fields.

Table 1

Characteristics of the zooplankton sampling sites. Modified from SKRZYPCZAK et al. (2010)

Sampling site Parameter	1	2	3	4
Geographical position	N 53°21.29' E 20°25.27'	N 53°20.59' E 20°24.93'	N 53°20.44' E 20°24.41'	N 53°20.21' E 20°23.62'
River-bed width [m]	3	3.5	4	4.5
Mean depth [m]	0.3	0.7	0.7	0.8
Water flow [m s^{-1}]	0.4	0.3	0.3	0.2
Bottom substrate	sand with gravel and stones	muddy sand	sand	muddy sand
Submerged plants	*Elodea canadensis* filamentous algae	*Sagittaria sagittifolia*	*Elodea canadensis* filamentous algae	*Elodea canadensis* filamentous algae
Features of river chanel	regulated	regulated with seminatural elements	regulated with seminatural elements	regulated
Trees along banks [% of bank]	10	50	50	50
Adjacent area	meadows and pastures	bushes and wasteland	pastures and cultivated area	pastures and cultivated area

At each site, 20 liters of water were sampled using a calibrated measuring vessel. The sampled biological material was made denser on a 30 μm mesh size plankton net and then fixed in 4% formalin.

The analysis of the zooplankton material involved determination of the qualitative and quantitative composition and assessment of the biomass, Identification of the zooplankton was carried out down to the lowest identifiable taxonomic unit and the growth stage (FLÖSSNER 1972, STERBLE and KRAUTER 1978, RADWAN et al. 2004, RYBAK and BŁĘDZKI 2005). The stages of nauplius and copepodid larvae of the copepods were not assigned to approprate taxa. The number of individuals among the zooplankton (indiv. dm^{-3}) was estimated according to the Hansen's rule (STARMACH 1955). In order to determine the individual biomass of particular zooplankton individuals, standard weights for rotifers were applied (RADWAN et al. 2004). Regarding crustaceans and protozoa, particular organisms were measured under a microscope with a measuring lens at the maximum precision to 0.01 mm, using transmitted light. For the purpose of estimating biomass, it was assumed that the density of a zooplankton organism = 1. i.e. 1 mm^3 = 1 mg (HERNROTH 1985). Based on the results of the measurements, cubic volume of individuals was calculated, by comparing their shape to the basic geometrical solids.

Methods for evaluating the qualitative structure of zooplankton

The diversity of the qualitative structure of the zooplankton was estimated in respect of the species richness – Margalef index (MARGALEF 1957), general species diversity – Shannon-Wiener index (SHANNON 1948), eveness value of species – Pielou index (1966) – Table 2, the similarity and diversity in species between communities – Jackard index (MARCZEWSKI and STEINHAUS 1959) and Bray-Curtis index (CLARKE 1993) – Table 3.

Statistical significance of differences in values of Shannon-Wiener index between particular sites was verified with t-test at $p < 0.05$.

Table 2

Measures of the diversity in the qualitative structure of the zooplankton at sampling sites

Station Biodiversity	1	2	3	4
Taxa Richness Index	4.98	5.82	3.42	5.44
Shannon's Index based on abundance	2.81	2.40	2.14	2.33
Pielou's Evenness	0.886	0.777	1.16	1.35

Table 3

Measures for evaluation of the similarity/difference in zooplankton communities between particular sites

Station Measure/indicator	1–2	1–3	1–4	2–3	2–4	3–4
Faunal similarity	0.353	0.333	0.237	0.36	0.285	0.296
Faunal dissimilarity	0.575	0.625	0.735	0.422	0.426	0.622

Results

Diversity of the qualitative structure of zooplankton

The zooplankton in the Nida River was determined to comprise 31 taxa of rotifers, 11 taxa of protozoa, 2 taxa of cladocerans and a growth stage of nauplius of the copepods (Table 4). The species diversity of the biocenosis at each site depended on the number of species and differences in the abundance of populations belonging to particular taxa. The smallest number of taxa appeared at site 3 (12), higher and comparable at sites 1, 2 and 4 (24, 22 and 23).

Table 4

Species composition and abundance (indiv. dm^{-3}) of zooplankton in particular sections of the Nida River

Taxon	Station			
	1	2	3	4
Brachionus angularis Gosse				<1
Brachionus diversicornis Daday	2			
Brachionus urceolaris O.F. Müller	2			
Cephalodella auriculata O.F. Müller				13**
Cephalodella psammophila Koch-Althaus	2			2
Cephalodella sp.	2	<1		
Colurella colurus Ehrenberg	5	11		
Colurella sulcata Stenroos		1		<1
Colurella uncinata bicuspidata Ehrenberg	3		2*	2
Euchlanis dilatata Ehrenberg				1
Filinia longiseta Ehrenberg	2	<1	1	
Keratella cochlearis Gosse	9*	5**	6**	15**
Keratella cochlearis var. *hispida* Gosse		<1		
Keratella cochlearis var. *tecta* Gosse		<1		5*
Lecane closterocerca Schmarda	2	1	1	
Lecane hamata Stokes		<1		
Lecane imbricata Carlin				1
Lecane lunaris Ehrenberg		1		
Lecane stenroosi Meissner		1		
Lepadella rhomboides Gosse				1
Mytilina mucronata O.F. Müller		<1		<1
Polyarthra longiremis Carlin	2	1		
Polyarthra major Burckhardt			1	<1
Polyarthra remata Skorikov	5	3*	4**	6**
Polyarthra vulgaris Carlin	5	1		
Pompholyx sulcata Hudson	2			
Synchaeta sp.			1	
Trichocerca cylindrica Imhof		<1		
Trichocerca pusilla Lauterborn	2	1	1	<1
Trichocerca similis Wierzejski	5	1	3**	<1
Trichotria pocillum O.F. Müller				1
Rotatoria – total	44	17	18	51
Actinosphaerium eichhorni Ehrenberg	2			<1
Arcella discoides Ehrenberg	12**	8**	3**	2
Arcella gibbosa Penard		5**		
Arcella megastoma Penard		1	1	2
Centropyxis aculeata Ehrenberg	3			
Codonella cratera Leidy	11**	8**	4**	
Difflugia acuminata Ehrenberg	2			
Difflugia lobostoma Leidy	18**			
Difflugia pyriformis Ehrenberg	6**			
Difflugia sp.				1
Trachelophyllum sigmoides Kahl	3			
Protozoa – total	56	20	7	5
Alona sp.				<1
Chydorus sphaericus O.F. Müller				<1
nauplius Copepoda	2			
Crustacea – total	2			1
Zooplankton – total	101	37	25	57

** – strong domination (> 10%)
* – domination (5–10%)

The closest similarity in the zooplankton fauna between sites was determined for sites 1 and 4 (Table 3, Figure 2). The zooplankton at sites 2 and 4 was characterized by a high diversity defined by comparable values determined by Shannon index (2.40 and 2.33 respectively) and species richness index (5.82 and 5.44) – Table 2. No statistically significant differences were found in values of the species diversity index by Shannon-Wiener between sites 2, 3 and 4 (t-test, $p > 0.05$). The species diversity of the zooplankton was the highest at site 1 (2.81), and the eveness index at 0.886 accompanied by the smallest general abundance of zooplankton (101 indiv. dm^{-3}) suggests dominance of a few taxa which achieve high density: *Difflugia lobostoma* (18%), *Arcella discoides* (12%) and *Codonella cartera* (10.5%). The species diversity at site 1, measured with Shannon-Wiener index, was significantly different from the other sites (t-test, $p < 0.05$, site 2 and $p < 0.001$ sites 3 and 4).

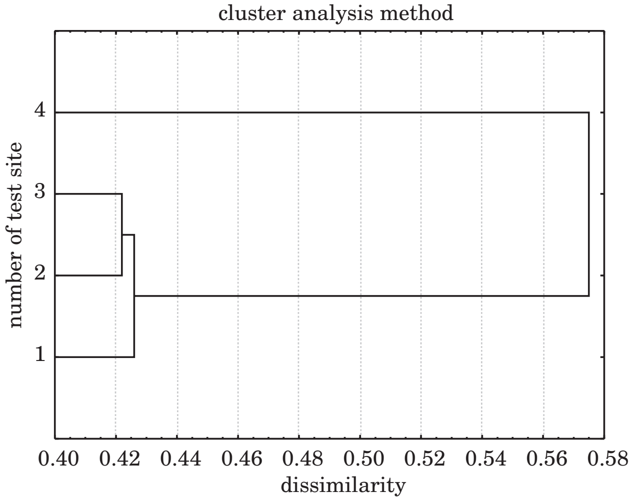

Fig. 2. A dendrogram of fauna dissimilarity between zooplankton communities in the analyzed sections of the Nida River

The most numerous and most diverse group of a higher order was Rotatoria (Table 4). Most of the taxa classified as rotifers were found at sites 2 and 4 (18 and 17, respectively), while the smallest number of such taxa was found at site 3 (9). Species which were present at all the analyzed sites along the river, being at the same time dominant ones in the structure of zooplankton, were *Keratella cochlearis* (max. 27.2% at site 4) and *Polyarthra remata* (max. 16% at site 3). Species of the genus *Trichocerca* were present constantly, although in smaller numbers.

T. similis appeared as a dominant (12%) at site 3. A large ecological group, especially at sites 2 and 4, consisted of small rotifers, usually dwelling amoung plants and/or characteristic for psammonic communities of the genera *Cephalodella*, *Colurella* and *Lecane* and *Lepadella*. *Cephalodella auriculata* reached up to 22.1% share in the total abundance of Rotatoria at site 4.

In general, the zooplankton at sites 3 and 4 was dominated in its abundance by rotifers, whose total share was 72 and 90.4%, respectively. At the other two sites, protozoa clearly dominated, constituting 55.2% (site 1) and 54.4% (site 4) of the total quantity of zooplankton.

The qualitative structure of the assemblage of protozoa consisted of ten identified species. Co-dominance of two species of amoeba was found, i.e. *Arcella* and *Difflugia*, as well as a typical plakton species of *Codonella cratera*.

Single specimens representing Crustacea were found only at site 4 (*Alona* sp. and *Chydorus sphaericus*) and at site 1 (growth stages nauplius of copepods)

Diversity of the quantitative structure of zooplankton

Values expressing the number of zooplakton at each analyzed site along the Nida River corresponded proportionally to the general volume of the biomass of plankton animals, which at all the sites was shaped by the weight of rotifers (Figure 3).

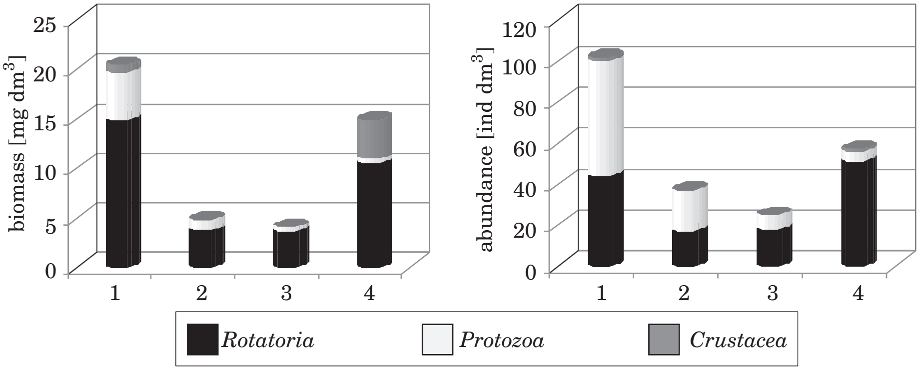

Fig. 3. Abundance and biomass of main groups of zooplankton at the analyzed sites along the Nida River

The highest zooplankton density and biomass were found at site 1 (101 indiv. dm^{-3} and 20.42 µg dm^{-3}) and the smallest ones – at site 3 (25 indiv. dm^{-3} and 4.09 µg dm^{-3}).

The prevailing number of Protozoa at the two sites located more upstream created just 32% (site 1) or 22.3% (site 2) of the total biomass, while the cladocerans present at the lowest sampling site along the river made up 37.4% of the value of this parameter (Figure 3).

Discussion

The general species diversity of the zooplankton along the analyzed section of the Nida River was not very high, which was due to the small number of identified taxa and their low density. This is, however, typical of lowland rivers similar in size to the Nida (second/third order rivers) in Poland. Plankton animals density fits in the range between dozen and maximum of two hundred in a litre. The highest values were recorded in spring and summer and along the sections where the water flow was slower, fed with tributaries from nearby lakes or dam reservoirs. It was confirmed by studies on the zooplankton of the Łyna River (BORKOWSKA 2001, DĄBROWSKA 2003) and its tributaries: the Symsarna (KUCHTA 2009, GOŹDZIEJEWSKA 2009) and Marózka Rivers, the Pasłęka River (GOŹDZIEJWSKA 2009) and the Wadąg River with its tributary, the Dymer (ENDLER et al. 2006). In general, the zooplankton in the Nida River was slightly less numerous than in the above watercourses, which could have been caused by a later date of water sampling (September), although the drastically decreasing tendency observed between sites 1 and 3 may have been due to the depressed quality of water caused by influx of pollutants from the river catchment basin and from the town of Nidzica. The diversity of the zooplankton biocensosis declines (10-fold less density and 30% fewer taxa) after the Dajna River passes through a catchment basin of agricultural and rural character (many villages), at a section 20 km in length, has been observed by GOŹDZIEJEWSKA (data not published).

The qualitative composition and proportions in the quantitative share of higher rank groups in the waters of the Nida River reveal an image typical of a river zooplankton biocenosis, associated with the dominance of Rotatoria, as observed in watercourses at different geographical latitudes and verified by researchers worldwide (SAUNDERS III and LEWIS Jr. 1988, ZARFDJIAN et al. 2000, MWEBAZA-NDAWULA et al. 2005, DJURKOVIC et al. 2008).

Adaptability of rotifers to flowing water and low concentration of foodstaff, such as phytoplankton, in water stems from a short time of generation in this group. At the same time, these two environmental factors limit the abundance of other assemblages, e.g. plankton crustaceans (cladocerans and copepods), which in stagnant water are a strong competition for shared food resources and often directly eliminate species of Rotatoria and Protozoa (LAMPERT and

SOMMER 2001). The qualitative and quantitative structure of the community of rotifers at all the sampling sites was mainly shaped by common eurytopic species: *Keratella cochelaris*, *Polyarthra remata*, *Trichocerca similis* and *T. pusilla.* While the two former species tolerate a very broad spectrum of environmental conditions, from lake ecosystems of different trophic relations, watercourses of variable flow (GOŹDZIEJEWSKA 2009), brackish water bodies (PATUREJ and GOŹDZIEJEWSKA 2005) to shallow ponds (GOŹDZIEJEWSKA and TUCHOLSKI, in press), the latter two species are quoted as indicators of high trophy RADWAN et al. (2004). The increasing role of these species in the structure of the zooplankton of the Wkra River occurred in its lower sections – sites 3 and 4. There, other indicators of eutrophication of river water appeared, i.e. *Brachionus angularis* and *K. cochlearis* var. *tecta.*

The upper section of the Wkra River was characterized by a generalny larger species diversity and the structure of biocenosis was shaped nearly equally by rotifers and protozoa. Noteworthy is the character of site 1, evidently different from the other sites. Higher species diversity determined at this site was attributable to a much faster regenerating population of protozoa, stimulated by a much more dynamic water flow in this part of the river, characterized by a narrower channel and shallower bottom. A similar growth in the number of Protozoa of the genus *Difflugia* sp. and *Arcella discoides* in water flowing into a river trough behind turbines of a power generating plant, coinciding with strong water turbulence, has been noticed by ENDLER et al. (2006). In turn, a biological factor which led to the dominance of plankton protozoa was most probably a very low (compared to the other sites) number of bivalves (SKRZYPCZAK et al. 2010), which while filtrating water eliminate both phytoplankton and small water animals (VAUGHN and HAKENKAMP 2001, LEVINTON and WALDMAN 2006). At the two following sites (downstream) on the Nida River, the genus *Difflugia* sp. was not noticed at all in the zooplankton, while the number of Bivalvia rose a hundred-fold (SKRZYPCZAK et al. 2010). Moreover, the poorest in taxa and the least numerous structure of rotifers and protozoa at site 3, versus all the other sites, could not have been caused, for example, by the pressure produced by fish because no presence of the analyzed Rotatoria species was determined in fish's digestive tracts (FURGAŁA-SELEZNIOW – oral report).

The single specimens representing cladocerans of the genera *Alona* sp. and *Chydorus sphaericus* captured at the site located most downstream (site 4) had most probably arrived from nearby fish culture ponds. The habitat conditions present in this section of the river favoured preservation of populations of small cladocerans and rotifers (e.g. *Cephalodella auriculata* was numerous), owing to an undisturbed, laminar flow of water and densly overgrown river bottom (mainly *Elodea canadensis*) (SKRZYPCZAK et al. 2010). Thus, the low number of species belonging to Cladocera, as noticed in this study, was not caused by the hydrological and habitat-related factor but by the pressure produced by plankton-grazing fish living in the river (the stickleback, the ninespine stickleback) (FURGAŁA-SELEZNIOW – oral report). Therefore, plankton crustacea did not have any considerable effect on the general biomass of zooplankton along this section of the river. Moreover, such a low number of Cladocera could not have had any greater role in shaping the structure and abundance of rotifers and protozoa.

Recapitulating the above, it can be concluded that the structure and dynamics of changes in the biocenosis of the Nida River was more strongly conditioned by the hydrological and habitat-related conditions as well as inter-species interactions. Biotic factors, including pressure exerted by fish and predators, produced multidirectional effects favoured greater diversity and more rapid regeneration of the structure of zooplankton in the lower sections of the river.

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