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BIOMONITORING IN THE REVITALIZATION OF THE UPPER WKRA RIVER (NIDZICA COUNTY) ON THE BASIS OF BENTHIC MACROINVERTEBRATES

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Key words: Wkra River, bioindication, BMWP-PL index, benthic invertebrates, revitalization.

Abstract

Water quality of the Nida River (NE Poland) was evaluated using the BMWP-PL biotic and diversity indices. Revitalization works were undertaken in the river during the study. Benthic macroinvertebrate samples were collected from seven different sites. Twenty-four taxa in total were recorded. Most of the studied sites (59%) were ranked into water quality class III, while 35% of sites were of poor water quality (class IV). Good water quality (class II) was found at only one site (the upper Nida section). The revitalization works did not significantly change values of the BMWP-PL index at the studied sites.

BIOMONITORING REWITALIZOWANEGO ODCINKA GÓRNEJ WKRY W GMINIE NIDZICA NA PODSTAWIE MAKROBEZKRĘGOWCÓW BENTOSOWYCH

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Słowa kluczowe: Wkra, bioindykacja, indeks BMWP-PL, bezkręgowce bentosowe, rewitalizacja.

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A b s t r a k t

Używając indeksu biotycznego BMWP-PL oraz indeksu różnorodności, oceniono jakość wód rzeki Nidy (północno-wschodnia Polska). W czasie trwania badań rzekę rewitalizowano. Na siedmiu stanowiskach pobierano próby makrobezkręgowców bentosowych. Zanotowano obecność 24 taksonów. Większość badanych stanowisk (59%) zakwalifikowano do III klasy czystości wód, natomiast 35% stanowisk miało złą ich jakość (IV klasa). Tylko na jednym stanowisku stwierdzono dobrą jakość wód (II klasa). Wartości indeksu BMWP-PL otrzymane dla prób przed urozmaicaniem dna i po tym zabiegu rewitalizacyjnym nie wykazały statystycznie istotnych różnic.

Introduction

In the 20th century, due to the industrial development, rivers and streams were altered by sewage pollution, regulation and straightening for land reclamation, and agricultural use or channelization for flood protection. Similar modifications have been performed on the Nida River. Its straightening caused reduction of invertebrate diversity in lotic habitats. Such modifications are sometimes considered more destructive for stream biodiversity than chemical pollution (ROGERS et al. 2002). Moreover, the industrial development and antiquated water treatment systems degraded water quality of the Wkra River in the 1960–90s. These processes reduced taxonomic diversity of the fish fauna to only 1–3 species in the upper part of the Wkra River in the 1960s (PENCZAK et al. 2001).

The Nida River and its banks underwent revitalization, which included planting trees and bushes, improving the riverbed heterogeneity and fish stockings aimed at raising the riverine ichthyofauna diversity. The main goal of the study is to present the recovery of the ecological function of the Wkra River by the reconstruction of its ecological corridors in the valley and to investigate potential effects of the diversity of fauna and flora (SKRZYPCZAK et al. 2009). The revitalization of a river can be achieved through various measures, which are carried out on large rivers (DAVIS 1997), small rivers and streams (WOOLSEY et al. 2006, KLIVAR 2000).

The European Water Framework Directive recognises the need to combine physicochemical, biological and geomorphological parameters for routine monitoring in freshwaters. Macroinvertebrates are the most frequently used group of organisms for assessment of the water quality in lotic habitats worldwide (ROSENBERG and RESH 1993, HERING et al. 2004). The use of these organisms as bioindicators has more advantages than those based on diatoms, fish or aquatic vegetation (METCALFE 1989). Biotic indices are the combined results of quantitative measurements of species diversity and qualitative information on the ecological sensitivity of individual taxa (CZERNIAWSKA-KUSZA 2005).

The monitoring of the Nida River was conducted by the Voivodship Inspectorate for Environmental Protection in Olsztyn, and was based on physicochemical and biological features, chlorophyll *a* (*Raport...* 1999, *Raport...* 2009, 2010) and colonies of diatoms (*Raport...* 2011). The ecomorphological evaluation of river sections different in the degree of anthropogenic modification covered approximately the mid-course of the Wkra River (WASILEWICZ and OGLĘDZKI 2006). Benthic invertebrates had not been previously examined.

The impact of the revitalization efforts on the diversity and density of the bottom fauna, and thus on the indices used to assess the water quality classes, may be either positive or negative. An example of a positive effect is the increased heterogeneity of the river bottom owing to the introduction of piles of stones, providing the bottom fauna with shelters and modifying the physical habitats (BECHARA et al. 1993, DOUGLAS and LAKE 1994). The planting of deciduous trees along the river banks results in the periodical enrichment of water with coarse particulate organic matter (CPOM), constituting shelters and valuable food sources for many species of macrozoobenthos (GRAÇA 2001, HIEBER and GESSNER 2002). On the other hand, fish stocking increases the predator pressure on the benthic invertebrates (FLECKER 1984, ARNEKLEIV and RADDUM 2001) and seems to be a negative effect of the revitalization on macroinvertebrates.

The main purpose of this study was to assess water quality in the upper catchment of the Nida River using the biotic and diversity indices. In addition, the potential impact of the revitalization efforts on the water quality indices was observed. We hypothesise that revitalisation works carried out in selected river sites will result in increased values of the water quality indices.

Study Area, Material and Methods

The Wkra River (total length 249 km) is a right-side tributary of the Narew River (the Vistula catchment). The section of the Wkra within the Nidzica County borders, called the Nida, was selected for the study.

The samples were collected in 2008 (sites nos 1–5), 2009 (2, 3, 6, 7), and 2010 (1, 2, 3, 6). The areas directly adjacent to the studied river sites belonged to agricultural lands cultivated mainly as meadows and pastures (Table 1). The bed of the upper section (sites 1–4) of the river was regulated. The lower river course (sites 5–7) has the most unaltered bed. The shores are overgrown by trees (*Salix sp.*, *Alnus sp.*) and the bed is shaded at stations 1 (before the town) and in the lower course (6–7).

Table 1

Characteristics of study sites in the Nida River in 2008–2010

Parameter	Site						
	1	2	3	4	5	6	7
Geographical position	N 53° 21.92’ E 20° 25.38’	N 53° 21.29’ E 20° 25.27’	N 53° 20.59’ E 20° 24.93’	N 53° 20.56’ E 20° 24.78’	N 53° 20.48’ E 20° 24.48’	N 53° 20.44’ E 20° 24.41’	N 53° 20.21’ E 20° 23.62’
River bed width: mean [m]	3.5	3.0	3.5	3.5	4.0	4.0	4.5
Depth: mean [m]	0.3	0.4	0.6	0.6	0.8	0.7	0.8
Velocity [m s^{-1}]	0.3	0.4	0.2	0.2	0.3	0.3	0.2
Substrate type:							
stones	–	+	–	–	–	–	–
gravel	+	+	+	–	–	+	+
sand	+	+	+	+	+	+	+
clay	–	+	+	+	+	+	+
Character of anthropogenic changes:							
strengthening of the banks – inert fascine	+	+	+	+	+	+	+
piles of stones	–	–	+	+	–	+	–
anthropogenic debris	–	+	–	–	–	–	–
Riparian vegetation:							
trees	+	–	+	–	–	+	+
bushes	+	–	+	+	–	–	–
herbaceous plants	+	+	+	+	+	+	+
Land use category:							
suburban	+	+	–	–	–	–	–
meadow	–	–	+	+	+	+	+
pasture	–	+	–	+	+	+	+
agriculture	–	–	–	–	–	+	+
Others:							
submersed macrophytes	–	+	+	+	+	+	–
woody debris	–	–	–	+	–	–	–
muddy patches	–	+	–	+	–	–	–

The sampling was started before the onset of the renaturalization works in April 2008.

In May 2008, 15 tonnes of rocks and boulders with the maximal diameter of 256 mm and pebbles 64–256 mm in diameter were put into the river. The mineral material was distributed on the sandy bottom of the Wkra, along a 200 – meter-long section, both near the bank under the fascine embankment as heaps of several pebbles and in mid-stream as clusters of several rocks (SKRZYPCZAK et al. 2009). Another 15 tonnes of rocks and boulders were put into the river, approx. 200 m downstream of site 4, where the bottom had been revitalised a year before (SKRZYPCZAK et al. 2010).

Sites 1–5 were selected in the first study year (Figure 1). Site 1 was set up on the river just before it entered the built-up area and site 2 was located at a short distance (30 m) downstream of the town. Sites 3 and 4 were located within the river section where the bottom heterogeneity was increased by the addition of stones between two sampling dates, while site 5 was located downstream of that section. In the second sampling year, two additional sites were established: site 6, located in another river section with the bottom enriched with stones, and site 7, placed downstream of site 6. In 2008, material was collected at four sites (numbers from 2 to 5) in April and at five sites (1–5) in September. In September 2009 and 2010, material was collected at four sites (2, 3, 6, 7 and 1, 2, 3, 6, respectively). New sites had to be set up as the length of the river sections with the revitalized riverbed gradually increased.

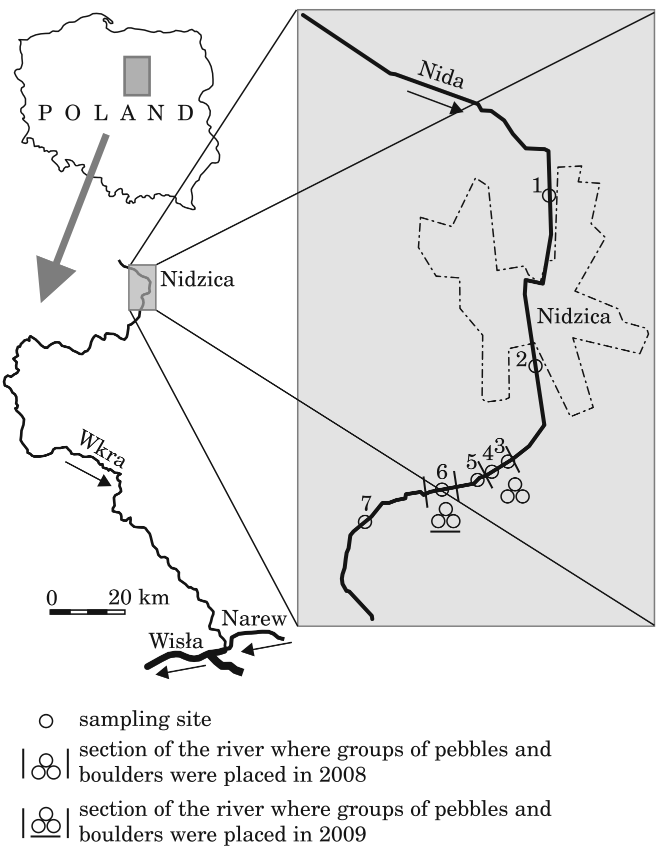

Fig. 1. Location of the sampling sites along the Nida River

A core sampler (steel tube of 29.2 cm^2 area) was used for collecting bed sediments and invertebrates. Twelve sediment cores were taken across the stream from each station on each sampling occasion, taking into account all kinds of bottom habitats. Samples were washed through a 0.25 mm mesh-size sieve. The material was sorted under a stereoscopic microscope, fixed and preserved in 70% ethanol. Macroinvertebrates were counted and identified to the family level (except the class Oligochaeta).

A Surber net (frame size of 25x25 cm) was used to collect the material during the first year of study (April, September). However, the qualitative samples did not provide any new taxa (families) which should be used in water quality evaluation; they were only helpful for identification of organisms in quantitative determinations.

The BMWP-PL method modified by KOWNACKI et al. (2002) was used for biological evaluation of Nida River water quality. The class of the river water was determined from two calculations. The value of the BMWP-PL index is the sum of scores of individual families present in a sample. Scores of 10–1 were allocated according to their tolerance to pollution. Also, Margalef's diversity index, proposed for biological evaluation of Polish freshwaters, was calculated.

The relationships between the values of biotic indices and environmental variables were tested using Spearman's non-parametric rank coefficient of correlation. Analyses were performed using the results for all the years and sampling sites (BMWP-PL- Margalef's diversity index, $n=17$) or, if a correlation existed between the indices (BMWP-PL, Margalef's diversity index) and environmental variables (dissolved oxygen, pH, total phosphorus, total nitrogen, COD), the data from the research carried out in September in 2008–2010 at site 2 and at the site situated most downstream with respect to the position of the water physicochemical sampling sites in a given year were used (SKRZYPCZAK et al. 2009, 2010, 2011).

The Wilcoxon non-parametric rank sum test was used to compare two groups of samples to determine if changes in the environmental conditions caused by revitalization works affected the BMWP-PL index scores. The groups were created by dividing the samples into the ones taken before and after the addition of stones and fish stocking treatments.

The non-parametric Friedman ANOVA test was applied to test time effects on the values of both of the indices. Kendall's coefficient of concordance was used to measure the degree of association among the three groups of distinguished sites (upstream, modified, downstream) with respect to time.

All statistical analyses were performed using the STATISTICA package, version 9.1 (StatSoft 2010).

Results

From the benthic indicators used for determination of water quality, 24 taxa were found in the studied Nida River. Four families, including Gammaridae, Sphaeridae, Glossiphonidae, Chironomidae and a class of Oligochaeta, were recorded at all of the sampling stations (Table 2).

The highest biological diversity was observed at sites 2 and 3, where as many as 17 taxonomic groups used as water quality indicators were found.

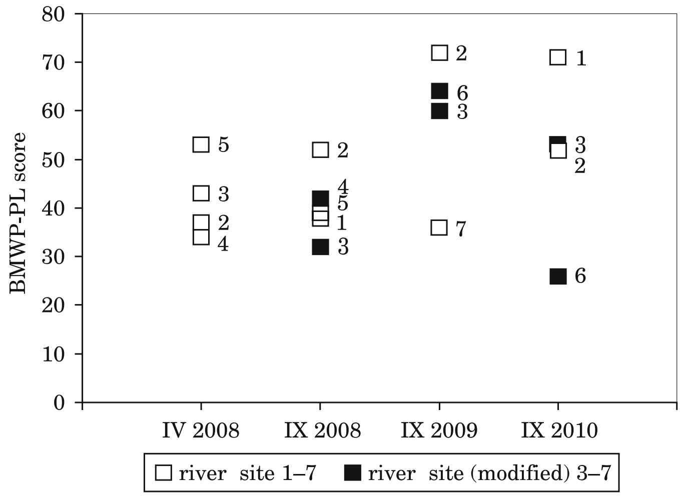

Fig. 2. Changes of the BMWP-PL score at seven sites along the River Nida in 2008–2010

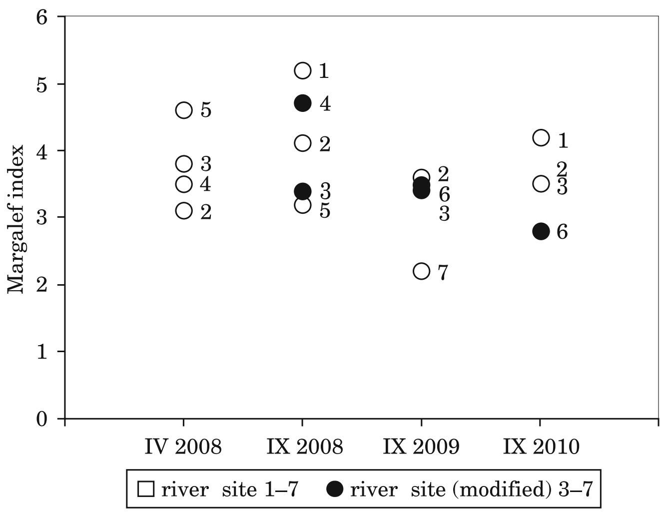

Fig. 3. Changes of the Margalef's score at seven sites along the River Nida in 2008–2010

Table 2

Taxonomic list of benthic macroinvertebrates found at the seven sites in the Nida River during present investigation

Taxa	Sites	1		2				3				4		5		6		7
	score \ date	09. 2008	09. 2010	04. 2008	09. 2008	09. 2009	09. 2010	04. 2008	09. 2008	09. 2009	09. 2010	04. 2008	09. 2008	04. 2008	09. 2008	09. 2009	09. 2010	09. 2009
Goeridae	9	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Ephemeridae	7	–	–	–	–	+	–	–	–	–	–	+	–	–	–	–	–	–
Calopterygidae	7	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Limnephilidae	7	–	–	–	–	–	+	+	–	–	+	+	–	+	–	+	–	+
Elmidae	7	–	+	–	–	+	+	–	–	–	–	–	–	–	–	–	–	–
Gammaridae	6	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	–	+
Baetidae	6	+	+	+	+	+	–	+	–	+	+	–	–	–	+	+	+	–
Limoniidae	6	+	+	+	+	+	–	+	+	–	–	–	+	+	+	+	+	–
Simuliidae	6	–	+	–	+	–	–	+	–	+	+	–	–	–	+	+	–	–
Neritidae	6	–	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–
Hydropsychidae	5	–	+	–	+	–	–	+	–	–	+	–	–	–	–	+	+	–
Dytiscidae	5	+	+	–	+	–	+	–	–	–	+	–	–	–	–	–	–	–
Haliplidae	5	+	+	–	–	–	+	–	+	+	–	–	+	–	–	+	+	+
Corixidae	5	–	–	–	–	–	–	–	–	+	–	–	–	–	–	+	–	–
Tipulidae	5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+
Ceratopogonidae	4	–	+	+	–	–	+	–	–	+	–	–	+	–	–	–	–	–
Planorbidae	4	+	–	–	–	+	–	–	–	+	–	–	–	–	–	–	–	–
Sphaeriidae	4	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Erpobdellidae	3	–	–	+	+	–	+	+	+	+	+	+	+	+	+	+	+	–
Glossiphonidae	3	–	+	–	+	–	+	+	–	+	+	+	+	+	–	+	+	+
Asellidae	3	–	–	–	+	+	+	–	–	+	+	+	+	+	–	+	+	+
Sialidae	3	–	–	–	–	–	–	+	+	+	–	+	+	+	–	–	–	+
Chironomidae	3	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Oligochaeta	2	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+

Table 3

Values of indices – biotic BMWP-PL and Margalef's diversity and classification of water quality in studied sites sampled along the Nida River

Index	Sites																
	1		2				3				4		5		6		7
	09. 2008	09. 2010	04. 2008	09. 2008	09. 2009	09. 2010	04. 2008	**09. 2008**	**09. 2009**	**09. 2010**	04. 2008	**09. 2008**	04. 2008	09. 2008	**09. 2009**	**09. 2010**	09. 2009
BMWP-PL	38	71	37	52	72	52	43	**32**	**60**	**53**	34	**42**	53	39	**64**	**26**	36
	IV	II	IV	III	II	III	III	**IV**	**III**	**III**	IV	**III**	III	IV	**III**	**IV**	IV
Margalef's	5.2	4.2	3.1	4.1	3.6	3.5	3.8	**3.4**	**3.4**	**3.5**	3.5	**4.7**	4.6	3.2	**3.5**	**2.8**	2.2
	II	II	III	II	III	III	III	**III**	**III**	**III**	III	**II**	II	III	**III**	**III**	IV
General classification of water quality	III	II	IV	III	III	III	III	**IV**	**III**	**III**	IV	**III**	III	IV	**III**	**IV**	IV

According to the BMWP-Pl scoring system (KOWNACKI et al. 2002), a result indicating 'good water quality' was obtained once – at one site and for one sampling date (Table 3), but in most cases (10) the values of the water quality indices classified the Nida River as water quality class III, corresponding to moderate quality. In the remaining cases (6), the water quality was poor – class IV.

The observed variation in the BMWP-PL index score against sampling dates, illustrated in Figure 2, assumes a sinusoid-like shape. The values of modified Margalef's biodiversity index demonstrated a relatively small range of variation (Figure 3).

Changes in the values of both indices for all sampling sites demonstrated moderate relationships (R=0.45), which were not significant.

The values of the BMWP-PL index calculated before and after the riverbed improvement did not show any statistically significant differences. Values of the index changed differently during the experiment and exhibited contradictory trends depending on which river sections were compared.

The values of both indices at the sites where water was sampled for physicochemical analyses showed negative correlation with the environmental variables (pH, total phosphorus, total nitrogen, COD) and positive correlation with the oxygen concentration in water, but the correlations were not statistically significant.

The Friedman Repeated Measures ANOVA test applied in the analysis, based on four data sets (four dates of studies), showed no differences among the three parts of the Nida River (p = 0.717), and there were strong differences among the sampling dates (Kendall's Coefficient of Concordance W=0.11).

Discussion

The results for water purity obtained using macrozooinvertebrates showed that the river water belonged to the same quality class, a finding confirmed by CZERNIAWSKA-KUSZA (2005), who observed good correlation of the BMWP-PL index with results based on chemical properties.

The results of monitoring observations presented in environmental reports (*Raport*... 2009, *Raport*... 2010) concern the fragment of the Nida River downstream of the sites used in this study. They show the ecological condition in 2008 as moderate and in 2009 as good. The water quality in the Wkra has been gradually improving since the 1990s (PENCZAK et al. 2001); however, considering the requirements set out in the *Water Framework Directive* (2002), the goal of achieving good water quality, determined based on the aquatic organisms living in it, has not been achieved in the river section where the study was conducted.

The study sites were colonised mainly by taxa representing groups highly tolerant to environmental pollution, such as oligochaetes (VERDONSCHOT 1989), chironomid larvae (WATERHOUSE and FARREL 1985) and members of family Sphaeriidae (small freshwater bivalves) (LOCH et al. 1996), as well as relatively sensitive organisms like gammarids (BLOOR and BANKS 2006). The presence of individuals representing the highest ranked family Goeridae (Trichoptera), as well as the only water quality general classification result indicating good water quality, occurred in the river section situated upstream from the town. However, the results obtained during the investigations indicated the highest values of the BMWP index for the river section most severely exposed to anthropopression – at the site near the outflow from the urban areas. The most probable cause may be the high diversity of the riverbed. Despite locally abundant muddy deposits originating from organic matter transported from the catchment, the bottom was inhabited by the most diverse macroinvertebrate fauna. At this site, 17 taxonomic groups were recorded out of the total of 24 groups found in the river during the investigations. The site was also inhabited by the most taxonomically diversified zooplankton (GOŹDZIEJEWSKA et al. 2010). The direct impact of humans was manifested by the presence of various items found on the riverbed surface, which acted as artificial substrates for algae, macrophytes and macrobenthic fauna. An increase in the taxonomical diversity of benthic fauna after the introduction of artificial substrates was demonstrated by MEIER et al. (1979), and the exposure of artificial substrates was applied in water quality assessment (CZERNIAWSKA-KUSZA 2004). In the future, a similar effect may also be observed in sections of the Nida River where the bottom was enriched with items of natural origin such as pebbles and boulders. So far, the results have not indicated a significant increase in the numbers of indicatory taxa of benthic fauna, in contrast to the observations of many authors reporting a rise in taxonomic diversity after a very short time as an effect of enriching habitats with additional natural elements such as cobbles (HOSE et al. 2007) or large-woody debris (HRODEY et al. 2008). However, diversifying the bottom as an element of restoration does not always give the expected results when the quality of the water in the river is poor (SUNDERMANN et al. 2011). Moreover, MARCHANT et al. (1991) claim that the number of taxa and the rate of their colonization are proportional to the locally-occurring number of taxa and their density. PURCELL et al. (2002) observed recolonization of fauna on restored sites from the upstream sites in the third season of their study. WENN (2008) demonstrated higher BMWP and ASPT scores no sooner than three to four years post-remediation. Having cut off a point source of pollution improved the chemical water quality, but the macroinvertebrates in the stream called the Spen Beck failed to correspond to the good water quality conditions until the sixth year post-remediation.

One reasons for the worse quality of water in river sections downstream from the town, especially the most distant ones, could be agricultural treatments. The large amount of bivalve shells (mostly of Sphaeriidae) found at site 7 indicates deceleration of the current but could also suggest infiltration of pesticides or fertilizers to the river with the surface runoff from surrounding fields. According to HECKMAN (1981), the feeding behaviour of bivalves makes them particularly sensitive to chemical compounds dissolved in water or deposited in river bed sediments.

Conclusions

The Nida River waters in the investigated section were most often classified as class III and IV(moderate and poor quality status). Based on our analysis of the benthic fauna associations, the introduction of additional mineral substrate on the riverbed surface did not affect the water quality.

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