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IMPACT OF TAXONOMIC STRUCTURE AND BENTHIC FAUNA BIOMASS ON THE BIOLOGICAL CLASSIFICATION OF RIVER WATERS

WPŁYW STRUKTURY TAKSONOMICZNEJ I BIOMASY FAUNY BENTOSOWEJ NA BIOLOGICZNĄ KLASYFIKACJĘ WÓD RZECZNYCH

Abstract: The study results presented include an analysis of the biological material and benthic sediments collected in 2007 from four streams located in the Oder River basin. These served as the basis for determining the taxonomic structure and biomass of macrobenthos at the sampling sites as well as of the water quality based on the Biological Monitoring Working Party index adapted for Poland (BMWP-PL). The streams studied varied with regard to the qualitative and quantitative structures of individual taxa, and the biodiversity in the streams was very high. Insecta was the dominant in terms of numbers in all of the streams studied, and among them Trichoptera was the most frequently occurring group of organisms. The macrozoobenthos biomass values from 66 to 252 g $\cdot$ m^{-2} might indicate that the biological capabilities of these streams are high. The BMWP-PL index evaluation system indicates that the studied streams can, in most instances, be classified as either marginally polluted or polluted (water quality classes III and IV).

Keywords: macrozoobenthos, domination structure, biomass, BMWP-PL index, lowland streams

Introduction

Many variables, including bottom type, water flow, temperature, and physico-chemical factors, can influence the richness of organisms in a given basin [1–2]. These factors and many others are largely responsible for the composition and density of

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benthic macrofauna in any body of water [2–4]. Evaluating biodiversity requires knowledge of the characteristics of three structural components of the aquatic biocenosis: species richness (which is the number of species that occur), domination structure, and density. As an example, the natural biocenosis of a stream that is not subjected to transformation is characterized by high species richness, evenly distributed individuals among species, and low to moderate abundance [5]. Pollution can lead to a decline in species richness, and in some cases this can be reduced to a single species that is capable of tolerating extreme environmental conditions. River biocenosis subjected to anthropogenic pressure exhibit continually diminishing biodiversity. It should also be borne in mind that all polluted environments are characterized by low biodiversity. Moderate pollution, on the other hand, can contribute to an initial increase in the number of taxons and a more even distribution among individuals, and consequently, in increased index values. Studies with the aim of reviewing all the groups occurring in a given stream as well as determining their biomass and density are conducted infrequently because of insufficient knowledge of the taxonomy of many groups and the intensive labor required of such undertakings. Detailed studies of single taxonomic groups are more common [5–6], and a range of indexes are used to calculate biodiversity [6]. These are used to determine the reaction of the structure of the entire assemblage of organisms, but without taking into consideration the reaction of indicator species. The use of biodiversity indexes is also burdened with other limitations. Their values fluctuate depending on when and how sampling is performed taking into consideration the different taxonomic and morphological-hydrological characteristics of the stream being studied [5, 7, 8].

The aim of the study presented in this article was to trace the quantitative and qualitative density and biomass of benthic fauna depending on the location of occurrence and their impact on the quality classification of stream waters through the use of biological indexes. The study was performed in four streams in the lowlands of the Oder River basin in northeastern Poland.

Materials and methods

The study was conducted on four streams (Wolczenica, Krapiel, Ina, Rurzyca) that are right-bank tributaries of the Oder River (Fig. 1). The samples were collected from May to June 2007 at sampling sites distributed from the stream sources to their mouths. The study was conducted as part of project entitled "Determining the biomass of benthic fauna in selected streams in Western Pomerania and determining the water quality of them based on the BMWP-PL (*Biological Monitoring Working Party* adapted for Poland) index in order to estimate the food base for fish". The project number is OR16-61535-OR1600014/07, and funding was obtained from the Sectoral Operational Programme "Fisheries and Fish Processing 2004–2006".

Benthic fauna samples were collected using a special bottom scraper with a square--shaped intake measuring 0.25 × 0.25 m along bottom segments 1 m in length. This permitted reporting results on both the quality and quantity of the samples. After the biological material was transported to the laboratory, it was sifted on sieves with a mesh

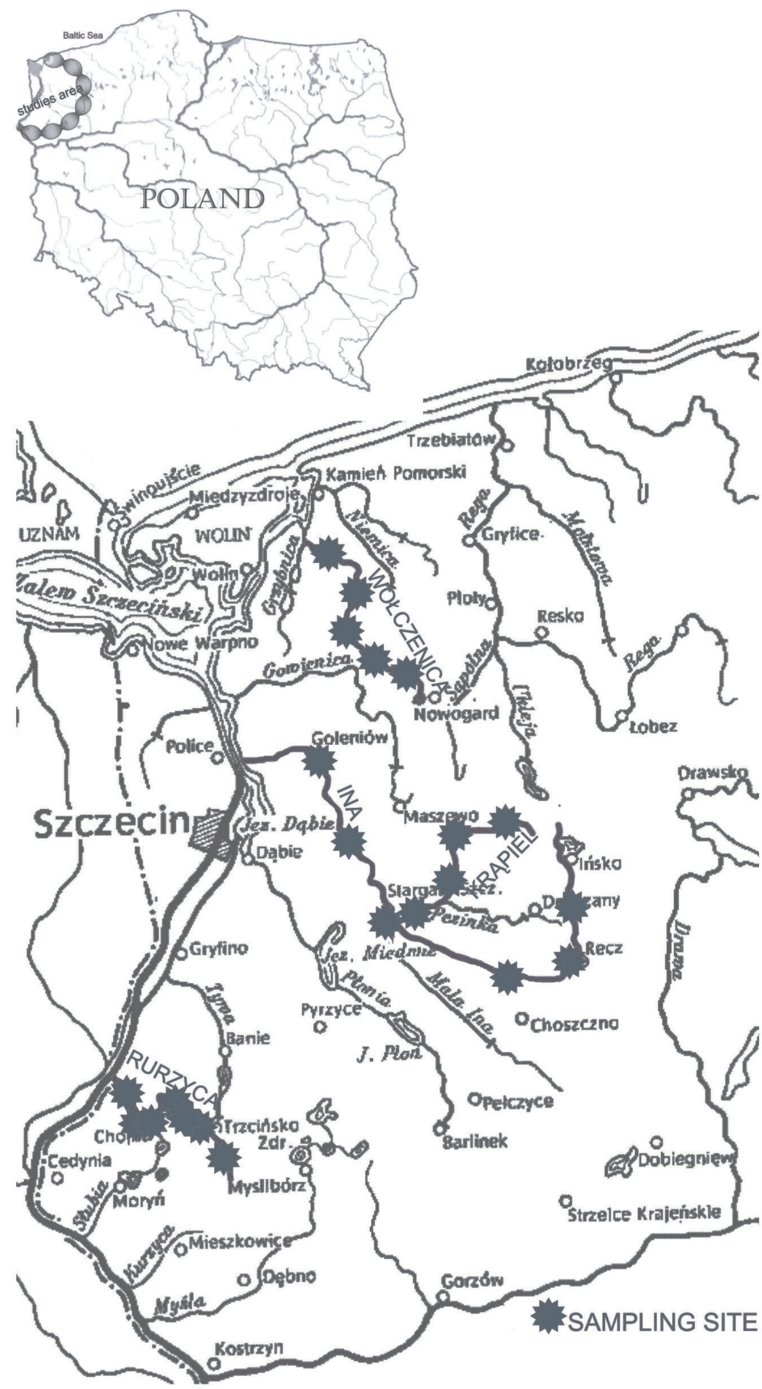

Fig. 1. Location of the surveyed streams drainages and location of sampling sites

bar length of 0.45 mm, placed in containers and preserved with 40 % alcohol. A Nikon stereo microscope was used to identify the material for quality analyses. Then the sorted material was weighed on a Radwag analytical scale to the nearest 0.01 mg.

The density of organisms per 1 m^2 of bottom area (N) was calculated with the following formula:

$$N = n / a \ [\text{indiv.} \cdot \text{m}^{-2}]$$

where : n – number of organisms in the sample,
a – surface area of collection site = length of scraper side × length of sampled segment = 0.25 × 1.00 m = 0.25 m^2.

Biomass (B) was also calculated per 1 m^2 according to the following formula:

$$B = b / a \ [\text{g} \cdot \text{m}^{-2}]$$

where: b – weight of individual in the sample [g],
a – sampling surface area = 0.25 × 1.00 = 0.25 m^2.

The results obtained were processed statistically and correlation coefficients were determined among sampling sites and the density and biomass of the organisms.

The results of the benthic fauna studies were also used to determine the water quality of the streams using two criteria: the value of the BMWP-PL index and the value of the biodiversity index [9, 10]. The values of the indexes were obtained by adding points for the families of the macrofauna (from 1 to 10 depending on their sensitivity to pollution) occurring at the various sampling stations, and then the results were verified with the biodiversity index. The final result was the basis for classifying the waters in one of the five water purity classes (I – very clean; II – clean; III – marginally polluted; IV – polluted; V – heavily polluted).

Results and discussion

The fauna density in all streams studied was 10132 individuals per 1 m^2, at a total biomass of 451.7 g · m^{-2}. The highest density of benthic organisms (4112 indiv. · m^{-2}) and the highest biomass (252.5 g · m^{-2}) was noted in the Rurzyca River. The values of these in the other streams were as follows: 2628 indiv. · m^{-2} and 45.4 g · m^{-2} in the Ina River; 1660 indiv. · m^{-2} and 66.4 g · m^{-2} in the Wolczenica River; 1732 indiv. · m^{-2} and 87.5 g · m^{-2} in the Krapiel River (Table 1). An interesting situation was noted in the Ina River, where a large number of organisms had the minimum biomass values. The reason for this is found in the quantitative structure of the organisms comprising the benthic fraction: of the 2628 indiv. · m^{-2} noted, 576 indiv. · m^{-2} were Oligochaeta with a biomass of just 0.6 g · m^{-2}; 652 indiv./m^2 were Diptera with a biomass of 0.1 g · m^{-2}; 588 indiv. · m^{-2} were Gammaridae with a biomass of 1.1 g · m^{-2}; 460 indiv. · m^{-2} were mussels from the family Sphaeridae with a biomass of 2.7 g · m^{-2}. However, Trichoptera, with only 76 indiv. · m^{-2} had a biomass of 35.5 g · m^{-2}, which represented nearly 80 % of the biomass of all organisms noted in this stream.

Table 1

Density, biomass and correlation coefficients of selected parameters studied streams

Factor	Wolczenica	Ina	Kapiel	Rurzyca
Density of macroinvertebrate [indiv. · m^{-2}]	1660	2628	1732	4112
Biomass of macroinvertebrate [g · m^{-2}]	66.4	45.4	87.5	252.5
Correlation coefficient between study sites and the density of macroinvertebrate	0.05	0.06	0.03	0.57
Correlation coefficient between study sites and the biomass of macroinvertebrate	0.26	0.08	0.01	0.59

The area studied was characterized by a high degree of taxonomic diversity among macroinvertebrates. The benthic organisms noted in the material analyzed were represented by 6 invertebrate classes (Fig. 2): Hirudinea, Crustacea (Amphipoda and Isopoda), Arachnida, Insecta (Ephemeroptera, Coleoptera, Odonata, Trichoptera, Heteroptera, Diptera, Megaloptera, Lepidoptera), Gastropoda and Bivalvia. Macroinvertebrate taxa found in the studied rivers are typical of many lowland rivers of Poland. A similar taxonomic composition was noted by Krolak and Korycinska [2] in the Liwiec River. The biomass dominants throughout all the streams were Insecta, while the co-dominants were Gastropoda and Bivalvia (Fig. 2). Among Insecta, the dominating group by weight was the caddisfly (Trichoptera) (Fig. 3). Krolak et al [11] and Zasepa et al [1] reported similar results. The distribution of benthic fauna biomass was slightly different in each of the streams. While the dominant was Insecta at most of the stations in three streams (Wolczenica, Krapiel, Ina), its domination was linked to the occurrence and dominating biomass of the caddisflies (Fig. 2–3). The exception was station 5 in the Wolczenica River, where the dominant was Diptera (Fig. 2–3), similarly to the studies by Bylak and Kukuly [12]. According to these authors, the rock fraction of the stream bottom played a decisive role in determining the domination structure. The bottom structure might also have played a role in determining the biomass of Diptera in the Wolczenica; the current author's own studies indicate that the dominant fraction here was fine-grained gravel of 4 mm. On the other hand, in the Rurzyca River, Trichoptera (and with this Insecta itself) dominated by weight only at site 6, while at sites 1 and 2 it was a subdominant. However, at the remaining sites it dominated by weight over either molluscs or crustaceans (Fig. 2–3). It is also of note that the highest Gastropoda biomass was recorded in the lower segments of the studied streams and in the source segment of the Rurzyca River. These situations could have been because of a lack of suitable environmental conditions at a given study station or because of periodic changes in conditions, which is noted distinctly in the study by Flecker and Feifarek [13] and Sawa and Popek [14]. The analysis of the degree of linear dependence between organism biomass and study station indicated there was a weak dependence between these variables in the Rurzyca River ($r = 0.59$), but no such dependence was noted in any of the other streams (Table 1).

The taxonomic structure and percentage share of the various benthic fauna classes was somewhat different in comparison with biomass (Fig. 2). Insecta dominated

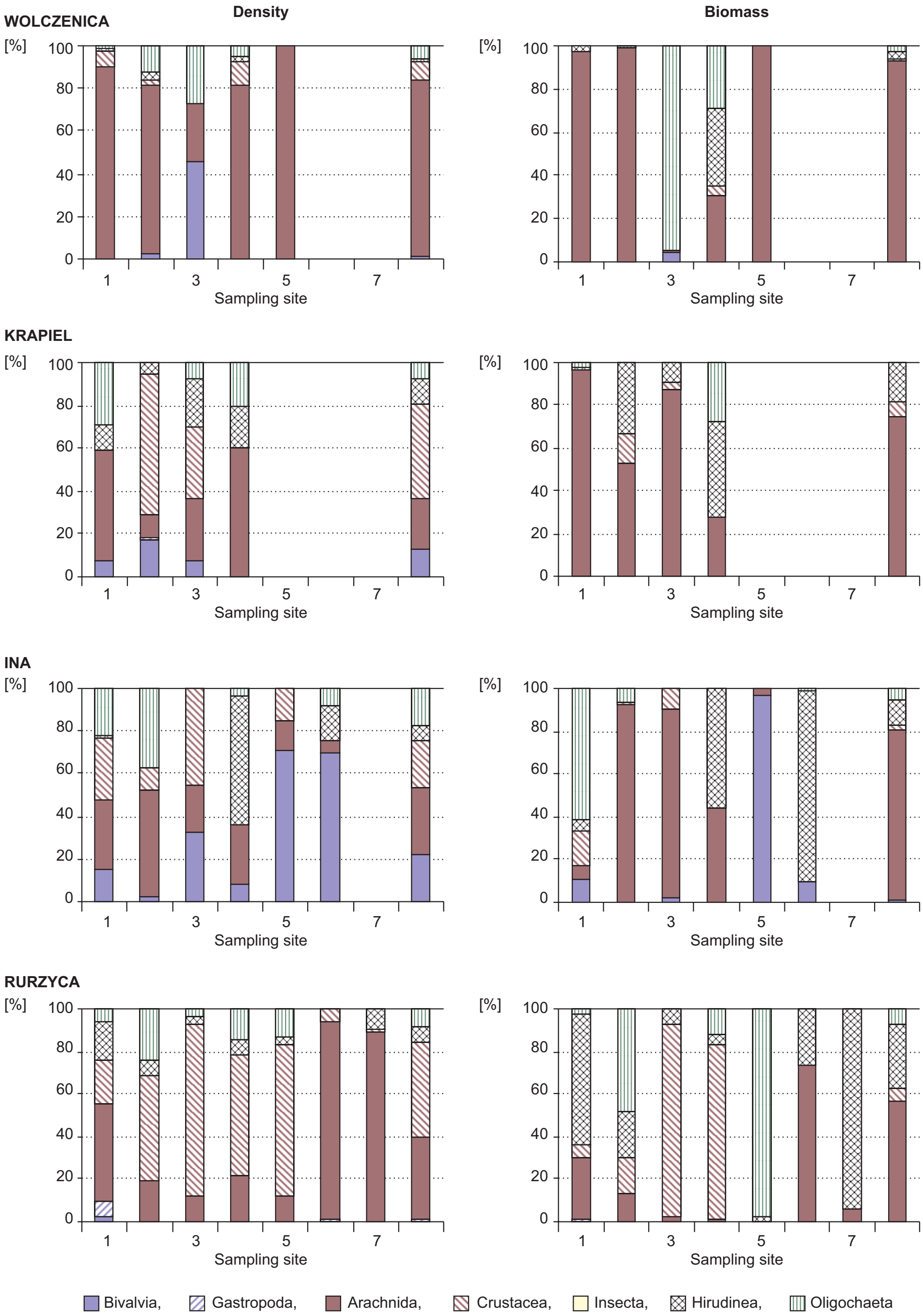

Fig. 2. Percentage of density and biomass invertebrate benthic fauna of selected streams (Wolczenica, Krapiel, Ina, Rurzyca)

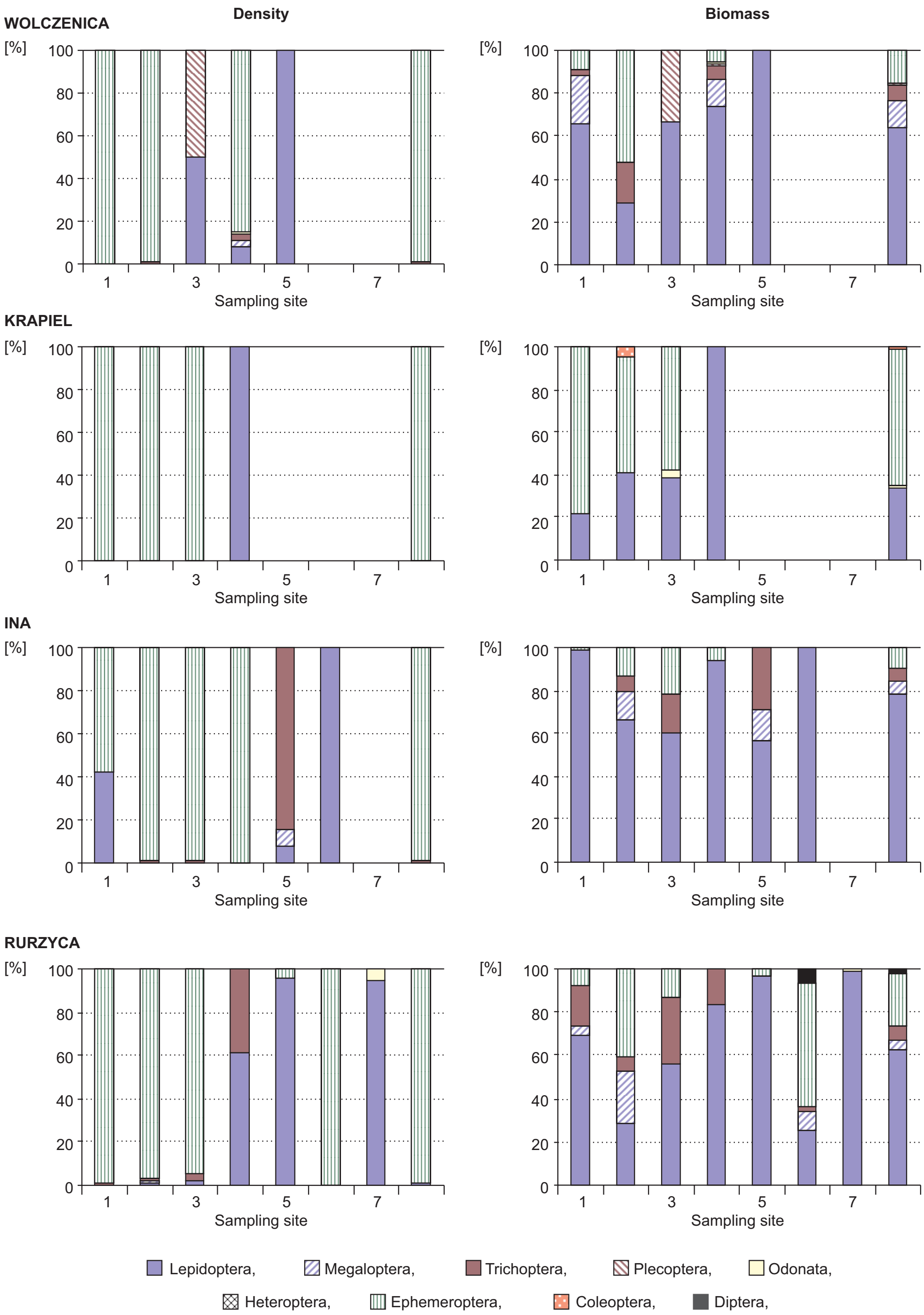

Fig. 3. Percentage of density and biomass among insects of selected streams (Wolczenica, Krapiel, Ina, Rurzyca)

quantitatively at most stations only in the Wolczenica River, while the highest density was noted for Diptera (Fig. 2–3). In the other streams, Insecta dominated quantitatively only at 2 or 3 sampling stations (which was also mainly due to the domination of Diptera, while there were greater numbers if specimens noted among Crustacea and Mollusca (Fig. 2–3). Only at two stations in the Rurzyca River was a dependence noted between the density and the biomass of the organisms; even so, the highest density and biomass were achieved by Crustacea at stations 3 and 4 (Fig. 2, Table 1). A weak degree of linear dependence between density and sampling station was also noted in the Rurzyca River (Table 1).

Benthic fauna is one of the most frequently used bioindicators applied during studies of the water quality of river environments [15], but the BMWP-PL index has been tried and tested under Polish conditions, and it is considered by many authors to be among the best [2, 11, 16–18]. This is because some of the species included in its list meet all the requirements above for being so-called “ideal indicator organisms”. The organisms among them that are not highly mobile are good indicators of local water states, while mobile species are good indicators of water quality over longer stretches of river. The domination structure in the studied streams should influence the evaluation of water quality assessed with biotic indexes since the assumption is that the occurrence or lack of certain organisms can reflect changes in the aquatic environment. The density of the benthic fauna and its biomass do not influence water classifications. In marginally polluted water, the numbers of Ephemeroptera, Trichoptera, and other species requiring clean water decline, while the numbers of Oligochaeta increase [9–11]. Since at most of the stations in the streams studied the dominant organisms were from the orders Trichoptera or Crustacea (Fig. 1–2) (of which 90 % were Gammaridae), which are characteristic of either clean or marginally polluted waters, then the water classification should be in either quality class II or III. The classification made using the criteria of the BMWP-PL index, however, was lower and water quality classes III and IV were generally more prevalent (Table 2).

The waters of the Rurzyca, Krapiel, and Ina rivers were classified in their various segments from clean water (class II) to marginally polluted (class IV) (Table 2). According to biological criteria, the quality of Wolczenica River waters at the sampling site near the mouth was site was heavily polluted (class V) (Table 2). Similar dependencies were reported by Krolak et al [11, 19]. Biodiversity and domination structure also have a significant impact on quality assessments. Several species, or groups of organisms, usually co-dominate in clean streams. As the aquatic environment changes in response to pollution, the number of dominant species, or groups, usually decreases [20]. This occurred in the streams studied when the domination of one or two groups lowered the biodiversity indicator, and, along with it, the water classification category. In places where there was no clear dominant in terms of density, for example in the Wolczenica (sampling site 4), Rurzyca (sampling sites 1, 2), Krapiel (sampling site 3), or Ina rivers (sampling site 4), the biodiversity coefficient increased, and, thus, the water quality classification was higher (class II quality) (Table 2). Since according to the BMWP-PL point scoring system Oligochaeta and the larvae of the family Chironomidae from Diptera are awarded only three points, the occurrence of these

Table 2

Water quality at particular stream study sites as assessed with biological methods

Sampling sites	1	2	3	4	5	6	7
Wolczenica							
Total points BMWP-PL	68	33	14	78	7		
Water quality class by BMWP-PL	III	IV	IV	II	V		
Biodiversity index – "d"	4.56	2.79	2.43	4.46	1.22		
Water quality class by biodiversity index "d"	II	III	IV	II	IV		
Water quality class by biological assessment (total "BMWP-PL" and "d"')	III	IV	IV	II	V		
Ina							
Total points BMWP-PL	35	70	43	46	24	25	
Water quality class by BMWP-PL	IV	II	III	III	IV	IV	
Biodiversity index – "d"	2.71	4.27	2.97	4.65	2.16	2.76	
Water quality class by biodiversity index "d"	III	II	III	II	IV	III	
Water quality class by biological assessment (total "BMWP-PL" and "d"')	IV	II	III	III	IV	IV	
Krapiel							
Total points BMWP-PL	31	54	76	11			
Water quality class by BMWP-PL	IV	III	II	IV			
Biodiversity index – "d"	2.80	4.06	5.56	2.31			
Water quality class by biodiversity index "d"	III	II	I	IV			
Water quality class by biological assessment (total "BMWP-PL" and "d"')	IV	III	II	IV			
Rurzyca							
Total points BMWP-PL	97	67	47	35	45	62	31
Water quality class by BMWP-PL	II	III	III	IV	III	III	IV
Biodiversity index – "d"	7.42	4.59	3.44	3.44	3.04	4.01	2.56
Water quality class by biodiversity index "d"	I	II	III	III	III	II	III
Water quality class by biological assessment (total "BMWP-PL" and "d"')	II	III	III	IV	III	III	IV

Legends: I – very clean; II – clean; III – marginally polluted; IV – polluted; V – heavily polluted.

organisms in streams led to a decreased classification category. The family Chironomidae is the worst indicator of pollution since the qualitative difference in their occurrence between clean and polluted streams is not pronounced [21, 22]. Similar dependencies were reported by Raczynska and Raczynski [23].

Conclusions

1. In all of the streams studied, Insecta and Mollusca dominated in terms of weight. Among the former, Trichoptera was dominant, and only in one instance (Wolczenica River) did Diptera dominate.

2. The analysis of the biomass distribution along the courses of the studied streams indicated that Insecta achieved the highest biomass values in the Wolczenica, Karpiel, and Ina rivers, while Crustacea and Mollusca did so in the Rurzyca River.

3. The domination structure of benthic fauna in terms of density did not correspond to that of biomass since Crustacea or Insecta dominated at most of the study sites.

4. According to biological criteria, at most of the sampling sites the waters of the streams surveyed were either marginally polluted (water quality class III) or polluted (water quality class IV), which was indicated by the low numbers of co-dominants.

5. Only on the Rurzyca River was a weak dependency between benthic macroinvertebrate density and study site confirmed.

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WPŁYW STRUKTURY TAKSONOMICZNEJ I BIOMASY FAUNY BENTOSOWEJ NA BIOLOGICZNĄ KLASYFIKACJĘ WÓD RZECZNYCH

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Abstrakt: Przedstawione wyniki badań obejmują analizę materiału biologicznego i osadów dennych uzyskanych z czterech cieków dorzecza Odry prowadzonych w 2007 r. Na tej podstawie określono strukturę taksonomiczną fauny makrobentosowej i jej biomasę w miejscu pobierania próbek, a także dokonano klasyfikacji wód na podstawie wskaźnika BMWP-PL. Badane rzeki charakteryzowała zróżnicowana struktura jakościowa i ilościowa poszczególnych taksonów, a bioróżnorodność w badanych rzekach była bardzo duża. Pod względem ilościowym we wszystkich badanych rzekach dominowały Insecta, a wśród nich – Trichoptera jako najczęściej występująca grupa organizmów. Wartości biomasy makrozoobentosu (od 66 do 252 $g \cdot m^{-2}$) świadczyć mogą o wysokiej zdolności biologicznej tych cieków. System oceny indeksu BMWP-PL wskazuje, że badane rzeki można zaliczyć w większości przypadków do wód słabo zanieczyszczonych i zanieczyszczonych (III i IV klasa).

Słowa kluczowe: makrobentos, struktura dominacji, biomasa, indeks BMWP-PL, cieki nizinne