4

Assessment of Quality of Various Water Types Based on Macrobenthic Bioindicators

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1. Introduction

The introduction of Water Framework Directive [5] imposed regular conduction of water quality assessment through biomonitoring on the institutions connected to aquatic environment. The Directive, at the same time has unified the system for all member states, and required that the research be executed through specific biotic components, such as assemblage of species, number, population pyramid for ichthyofauna, taxonomic classification, number and biomass of zoobenthos, phytoplankton or macrophytes. These are undoubtedly right and beneficial resolutions, hence they allow gathering information not only about the quality of water itself, but about the state of the entire environment [29]. This approach reveals the long-term impact of pollutants on bioindicators, especially harmful impact, and bioindicator reaction to the toxic substances [10]. Benthic organisms, occurring in the environment, are responsible for matter circulation. Making the effort of their observation, as well as gaining insight into their physiological processes and requirements with respect to various factors, enables determining the current state of the environment. It is also crucial to the attempt at understanding the processes taking place in ecosystems, and practical application of these processes in water treatment [8].

Freshwater macrozoobenthos, i.e. benthic bioindicators, are animal organisms adapted to lakebed and riverbed habitat [2]. They constitute a very important element of those ecosystems. The organisms consume both, the accumulated matter, made by producers and the one originating from human activity [13]. They often play the role of filter-feeders and constitute prey for fish and birds [3].

During recent years there were often cases of, both flowing and standing, water environment degradation. The outcome of the degradation was either partial or total elimination of macrozoobenthos. Beginning in mid 60's of the previous century, it was noticed that with the increase in pollution levels, Odonata, Ephemeroptera and eventually Trichoptera larvae successively disappear from the habitat [28]. Often the only remnants in the degraded habitat were Chironomus sp. larvae and Tubificidae, which are taxons resilient to periodic oxygen deficits. This fact was used to develop a research methodology of so called "Biotic Indices". Biotic Indices allowed the use of Macrozoobenthos for measuring ecological condition of waters. In Poland the so called biomonitoring is performed, using the mentioned organisms. The biomonitiring results are the main aim of this paper. The following which the following areas were analyzed with respect to the ecological condition of different types of water. The river Wogra, together with the Połczyn-Zdrój Dam Reservoir, the river Pysznica with its floodplains, and the river Dzierżęcinka.

2. Materials and methods

The samples were collected in 2006 and 2007 on sites at the Wogra River, the Połczyn Zdrój Dam Reservoir, the Pysznica River and the Dzierżęcinka River.

The river Wogra is a left-side tributary of the Dębnica River, which falls into the Parsęta River on the 5th kilometer of the latter. The Wogra flows out from Kłokowskie Lake. Its has 14.5 km in length, average fall is 6.7‰, and watershed area is 66 km^2.

In order to protect the city of Połczyn Zdrój as well as the Wogra River valley from flooding, and also to regulate the river's flow, a retention reservoir was built on the river. The area of the reservoir is 31 km^2, its volumetric capacity – 0.5 mln m^3, and mean depth 2.5 m. For the reservoir to serve recreational purposes, a dam was built on it (Fig. 1).

The Pysznica River supplises the river Parsęta on the 123rd kilometer. The river's springs are located near a village named Świemino. The river has 20 km in length, average fall of 1‰, and watershed area of 66 km^2. Its bed is regulated on the entire course of the river. The surrounding includes grazing fields, grasslands and arable fields. Due to riverbed elevation and in order to redirect its water back to its old valley, the "Pyszka Wetland" arose. The Wetland's area and the land within the reservoir's potential impact averages at 67 ha (Fig. 1).

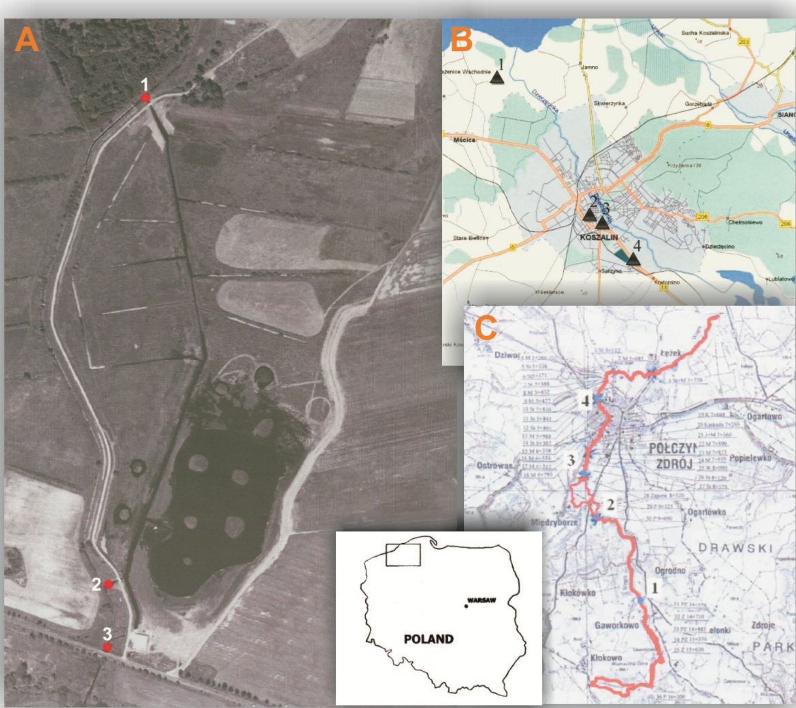

Fig 1. The comparison of research sites: A – the river Pysznica, B – the river Dzierżęcinka, C – the river Wogra and The Połczyn Zdrój Dam Reservoir.
Rys. 1. Zestawienie stanowisk badawczych: A – rzeka Pysznica, B – rzeka Dzierżęcinka, C – rzeka Wogra i Zbiornik zaporowy Połczyn Zdrój.

The Dzierżęcinka River located to the north-west of "Zacisze" forester's lodge has numerous seepage springs in the Manowo forest inspectorate. At the eighth kilometer from its spring the river flows into Lake Lubiatowskie. The Dzierżęcinka River meets its confluence with Lake Jamno, which, in turn is connected to the Baltic Sea by a channel. The river's length is 26 km, its drainage basin, 130 km^2. It is the only natural water stream passing through Koszalin. The Dzierżęcinka waters constitute 28% of Lake Jamno tributaries runoff. Mean flow volume is about 0.7 m^3/s, and the mean riverbed fall on the urban stretch is 0.5‰ (Fig. 1).

On each site, four quantity samples and one quality sample were taken. A hand net was used for (in compliance with [16]. The size of the openings in the net was 0.5 mm, while the intake surface was 400 cm^2. The samples obtained were preserved with 4% formaldehyde solution and transported to the laboratory. Before identification of the organisms, the samples were rinsed on a benthic screen with 0.5 mm mesh diameter, by pouring through it successive portions of the sediment diluted with water. The samples were placed under a Nikon Eclipse E 400 stereoscope microscope. For the assessment of taxonomic composition, appropriate keys and conductors were used. Straight majority of the collected material was identified to the species level. In cases where such precise identification was impossible, organisms were identified to the family level. For the purpose of assessment, density and number of identified taxa were used. Additionally, on the basis of the studies by [3, 11, 12, 15, 23] the following biotic indices were calculated: TBI (Trent Biotic Index), BMWPPL (the Biological Monitoring Working Party), adapted to the Polish conditions, S saprobe index, EPT index: ratio of the number of Ephemeroptera, Plecoptera and Trichoptera to the number of all taxa in a sample. In calculating the above indices, the methodically required level of taxonomic identification was used.

Trent Biotic Index (TBI) owes its name to the river Trent [23] and is based on analysis of zoobenthos. Presently it is commonly used for routine quality assessment of flowing waters. The index assumes values from 0 to 10.

The BMWP-PL index is based over a sum of points ascribed to individual taxa found in a sample. The method posits that certain taxa characterize biocenosis better than others. The evaluation consists in assignment of point values to 89 macrozoobenthic organism families according to their sensitivity to pollution.

The saprobe index, according to SEW list (Sladecka), was calculated with Pantle–Buck method [3] in accordance with the following formula:

$$S = \Sigma(h_i \cdot S_i) / \Sigma h_i$$

where:

S – saprobe index,
h_i – abundance of the species,
S_i – saprobe value of the species “i”.

The index used as an auxiliary water quality assessment measure was EPT, that is the ratio of Ephemeroptera, Plecoptera and Trichoptera taxa number to the total taxa number in the tested sample, to which no ecological indexation is assigned.

The index draws upon an assumption that the first to withdraw from the set of macrozoobenthic organisms due to the pressure of harmful conditions are these three insecta orders. Hence, their large presence (high EPT index) points to good water condition [3, 10].

Moreover, the measures used in order to better characterize separate sites were values of biological diversity, which display the number of taxa identified at a given site, and density value, which determines the number of specimen corresponding to 1 m^2 of the river bottom in the area under study.

3. Results

Taking into account the diversity index (Fig. 2) it can be seen that the most advantageous conditions for benthic fauna were presented in the Pysznica river, where as many as 43 macrozoobenthic taxa were identified. The least favorable conditions, on the other hand, were observed in the Połczyn Zdrój Dam reservoir, where only 6 taxa of the organisms in question were recorded.

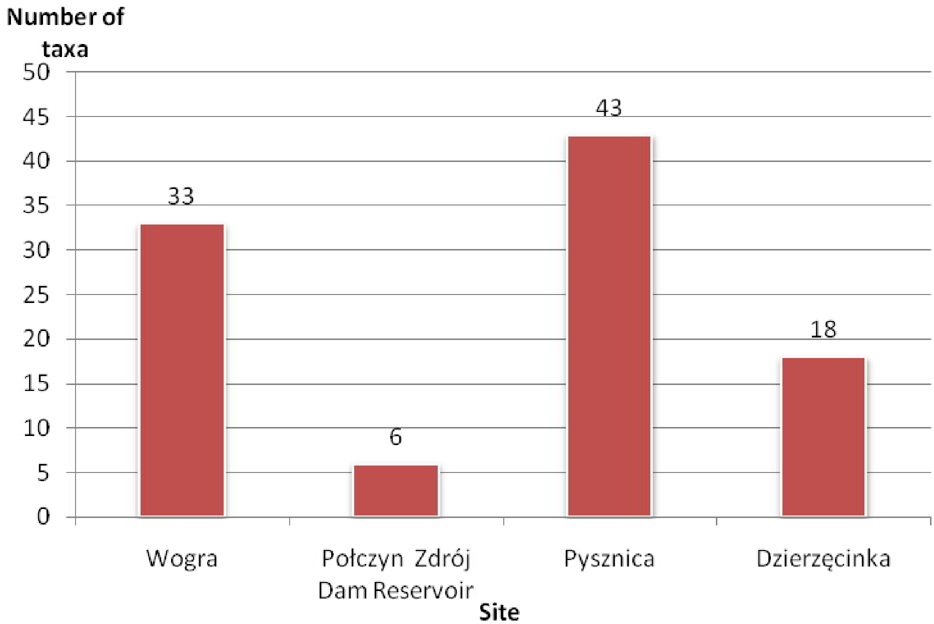

Fig. 2. The diversity in macrozoobenthos at research sites
Rys. 2. Zróżnicowanie makrozoobentosu na stanowiskach badawczych

The maximum density (Fig. 3) of benthic organisms In this paper was noted for the Pysznica river (1802 pcs per m^2), in contrast, the lowest numbers of macrozoobenthos per one square meter were detected in the Dzierżęcinka river.

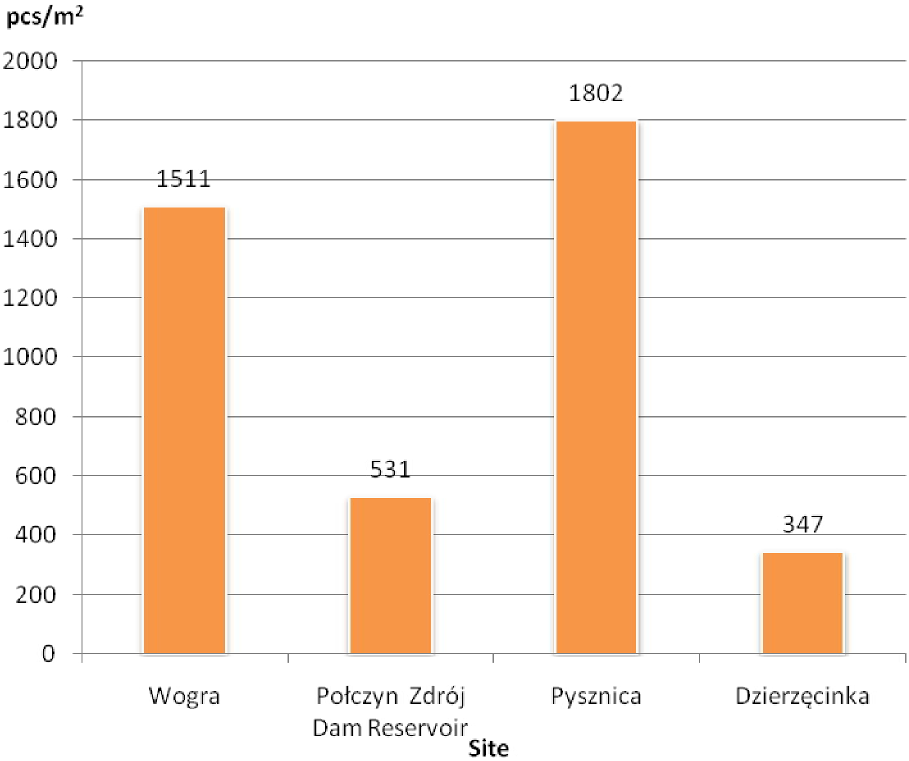

Fig. 3. Macrozoobenthos density at research sites
Rys. 3. Zagęszczenie makrozoobentosu na stanowiskach badawczych

Both, the Saprobe (Fig. 4) and BMWP-PL (Fig. 5) indices reached the optimal values, as did diversity (Fig. 1), for the Pysznica river (1.33 and 115 respectively). Less satisfying, however, were results recorded for the Połczyn Zdrój Dam reservoir (3.80 and 5).

According to the results gathered for TBI (Fig. 6) and EPT index (Fig. 7) the Wogra river possessed the most favorable conditions for the development of benthic fauna. The Dzierżęcinka river, in its turn, was characterized by the least favorable habitat conditions for benthic organisms. At the same time, zero EPT values were recorded twice in the case of the Połczyn Zdrój Dam Reservoir (Fig. 7).

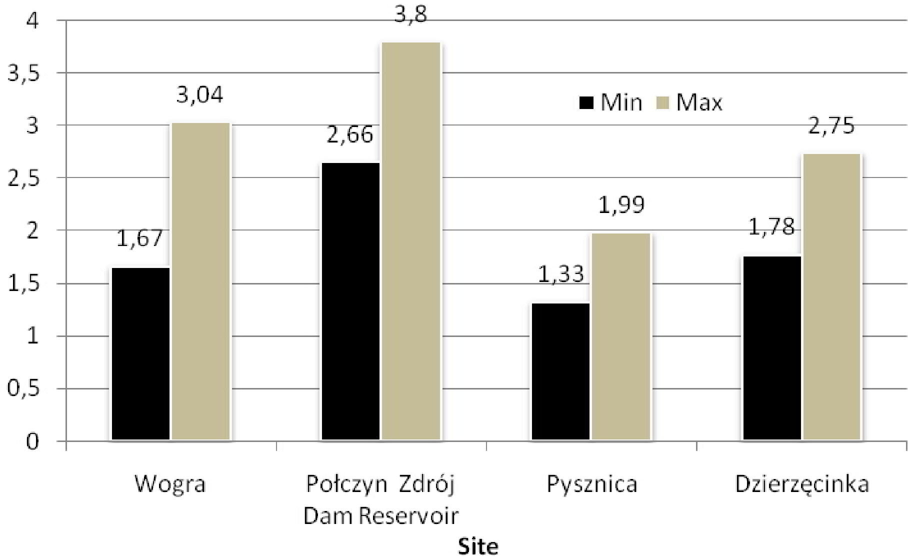

Fig. 4. Saprobe index comparison on research sites
Rys. 4. Zestawienie wskaźnika saprobowego na stanowiskach badawczych

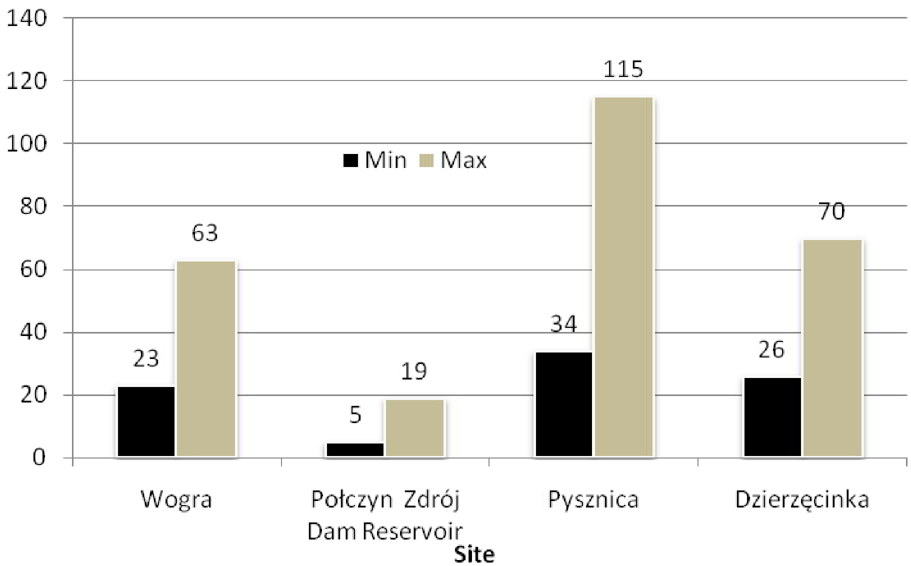

Fig. 5. BMWP-PL index comparison on research sites
Rys. 5. Zestawienie wskaźnika BMWP-PL na stanowiskach badawczych

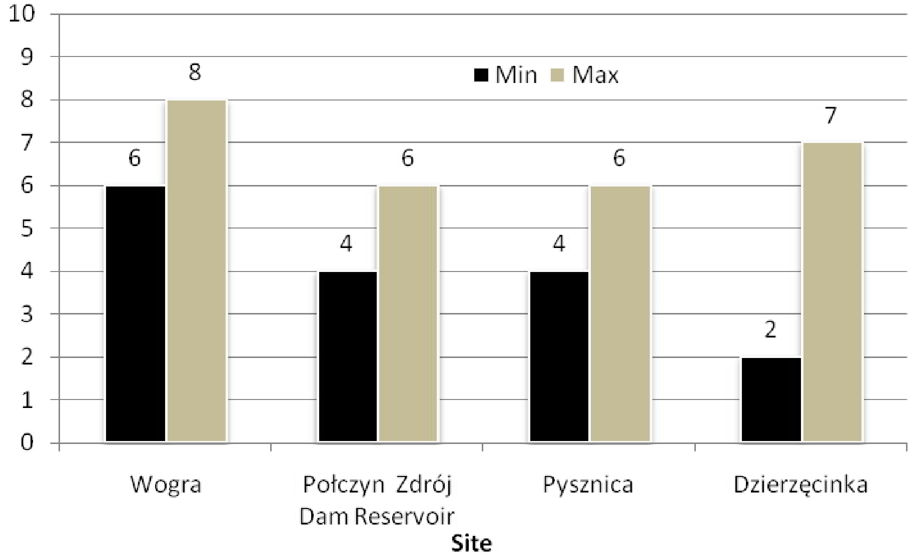

Fig. 6. TBI Index comparison on research sites
Rys. 6. Zestawienie wskaźnika TBI na stanowiskach badawczych

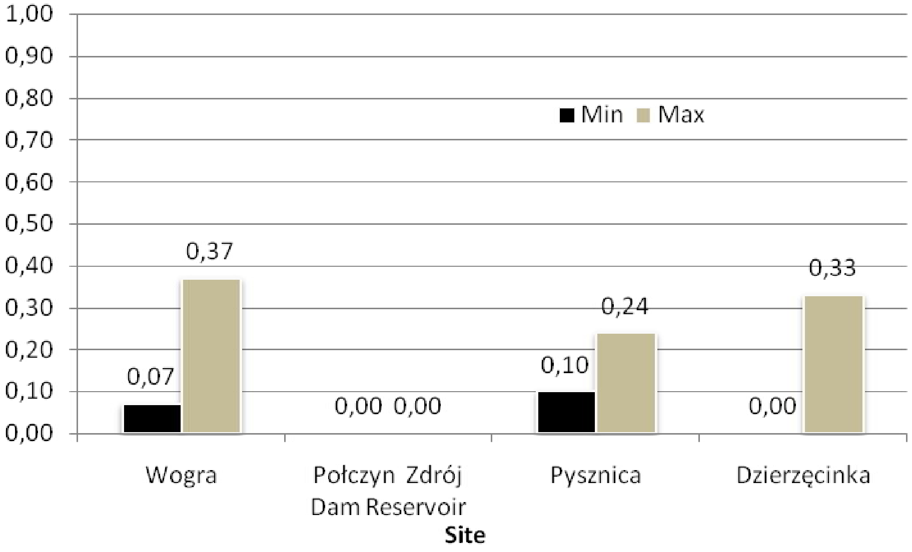

Fig. 7. EPT index comparison on research sites
Rys. 7. Zestawienie wskaźnika EPT na stanowiskach badawczych

4. Discussion

Biological methods record long-term changes in a given aquatic ecosystem, which is an undeniable advantage [6]. These changes are difficult to demonstrate while analysing physicochemical parameters as they characterize water quality only at the time of sample collection [28]. First biotic indices came into being already in the second half of the 19th century [9, 14, 25], the decline of many species of aquatic organisms as a result of adverse changes in water quality caused mainly by developing industry had its contribution to this process. Since the 60's of the 20th century, the indices became commonly used for water quality assessment. [1, 4, 14, 26].

Macroinvertebrates constitute a group of organisms most frequently used in biomonitoring studies of rivers [18]. One of the possible and most popular approaches is the use of taxonomic lists to calculate a "biotic index" which summarizes in a single number the information provided by the population structure [21]. Two types of such indices can be distinguished. Diversity indices are related to the population structure and are not specific to any type of contamination; in contrast biotic indices, are based on the tolerance of taxa to a particular pollutant [7].

Diversity (Fig. 2) and density (Fig. 3) indices proved that the highest water quality was found in the Pysznica river. This is a watercourse formerly put through the process of renaturalization, the aim of which was to recreate natural, existent before transformation, floodplains. River regulation and damming are considered to have the most important destructive impact on biota due to terrestrialisation and fragmentation of the river floodplain system [20]. The difference between natural and regulated river consists in the fact that the former is characterized by abundance of river structures, whereas the latter by their lack or poverty, which in turn has a vast impact on living and dwelling conditions of river organisms, including invertebrates [22]. The received diversity (Fig. 2) and density (Fig. 3) results confirmed that habitats formed in renaturalized watercourse were the most advantageous for benthos. Poor results for the Połczyn Zdrój Dam reservoir, created as a result of antropogenic regulations also indicate essential aspect of natural river continuum. Such situation may be as well explained by the young age of the reservoir which – as it results from the recent research conducted by the department of Environmental Biology at the Koszalin University of Technology – has not been inhabited yet by the typical hololimnic fauna. At the same time, scarce macrozoobenthos may be a result of adverse physiochemical conditions prevailing in these waters as for example lack of oxygen in the vicinity of the bottom, despite the very small depth of the reservoir. Such conditions cause the occurrence of specific group of organisms which can adapt themselves to those very hard conditions. Ephemeroptera, Plecoptera and Trichoptera families cannot be includes there, as they require more advantageous habitat conditions. It may be confirmed by the EPT index, which reached zero values for the reservoir (Fig. 7).

Also other biotic indices: S (Fig. 4), BMWP-PL (Fig. 5) support the above results concerning the dam reservoir. BMWP-PL index in literature is often judged to be the best for surface water assessment. According to [7, 27] only this index is seasonally independent and therefore it is adequate for water quality verification at different seasons of the year. The best value of this index occurred in the Pysznica river (Fig. 4) which may be confirmed by the positive aspects of conducted renaturalization process.

Comparing gathered results concerning the Dzierżęcinka river with results of [13] it can be observed that diversity and density reached lesser values than in 2006. Biotic indices did not reveal any significant differences. The drop in taxa quantity is significant (10 taxa), however an increase in EPT index took place. It may indicate decrease in the number of various habitats, as a type of substratum is the main factor influencing settlement of macroinvertebrates [17,19,24]. As a result of homogenization of the environment domination of conditions favored by organisms particularly vulnerable to pollutants (Ephemeroptera, Plecoptera and Trichoptera) took place.

The use of the biota in freshwater quality assessment is a requirement under the European Union's Water Framework Directive. The results gathered, show that biological indices, especially BMWP, adapted to Polish conditions, have sufficient sensitivity to assess the state of natural environment of various types of surface waters. However, methods based on these studies which are used in water quality assessment require further verification and testing on different river types [28].

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Ocena stanu jakości różnych typów wód na podstawie makrobentosowych wskaźników biotycznych

Streszczenie

Niniejsze badania prowadzono w 2006 i 2007 roku. Objęto nimi: rzeki: Pysznicę, Dzierżęcinkę oraz Wogrę, wraz ze zbiornikiem zaporowy w Połczynie Zdroju.

Każdorazowo pobrano cztery próby ilościowe i jedną próbę jakościową, za pomocą siatki ręcznej, co zgodne jest z normą PN-EN 27828:2001. Do oszacowania składu taksonomicznego wykorzystano stosowne klucze i przewodniki.

Na podstawie zaklasyfikowanych organizmów obliczono ich zróżnicowanie i zagęszczenie oraz indeksy biotyczne: TBI (ang. Trent Biotic Index), BMWP-PL (ang. Biological Monitoring Working Party), przystosowany do warunków polskich, wskaźnik saprobowy S, wskaźnik EPT – stosunek liczby taksonów jętek (*Ephemeroptera*), widelnic (*Plecoptera*) i chruścików (*Trichoptera*) do liczby wszystkich taksonów w próbie. Na tej podstawie wnioskowano o stanie ekologicznym badanych wód.

Najkorzystniejszy stan ekologiczny stwierdzono na rzece Pysznicy, która odprowadza wody ze zrenaturyzowanego terenu “Mokradło Pyszka”. Jest to obszar oddany do eksploatacji w 2004 roku. na którym m.in. usypano wyspy z gruntów organicznych. Spowodowało to zmianę morfologii koryta, co zaskutkowało wzrostem obfitości nowych mikrosiedlisk i pojawieniem się większej przestrzeni życiowej dla organizmów wodnych. Opisane zabiegi techniczne wpłynęły korzystnie na bioróżnorodność populacji, co spowodowało poprawę stanu ekologicznego wód.

W analizowanych badania najmniej korzystne wartości indeksów odnotowano w przypadku zbiornika zaporowego w Połczynie Zdroju. Fakt ten można tłumaczyć, młodym jego wiekiem, dlatego nie zdążyły się tutaj wytworzyć jeszcze typowe dla jezior, siedliska bytowania makrofauny, co niekorzystnie wpłynęło na stan wód.

Wyniki przeprowadzonych badań wykazały, że metody biologiczne oparte na makrobezkręgowcach (popularne i szeroko stosowane w wielu krajach Europy Zachodniej i nie tylko) charakteryzują się wystarczającą czułością i są wspólnie z badaniami fizyczno-chemicznymi oraz morfologicznymi, odpowiednie do oceny stanu ekologicznego wód.