Annales Universitatis Paedagogicae Cracoviensis
Studia Naturae, 9: 139–164, 2024, ISSN 2543-8832
DOI: 10.24917/25438832.9.8

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Macroinvertebrates as bioindicators of water quality in the Skawa River and Mucharskie Lake (Southern Poland)

Abstract

Aquatic macroinvertebrates are organisms sensitive to changes in the environment in which they function and are therefore used to assess the quality of surface waters. This study aimed to assess the water quality of the Skawa River and Mucharskie Lake based on benthic macroinvertebrates, using the BMWP-PL index. Water samples from six research sites were used for the study – three from the Skawa River and three from Mucharskie Lake. Various macroinvertebrates were identified in water samples from the study sites, such as mayflies, caddisflies, stoneflies, beetles, crustaceans, snails, and leeches. The assessment of the water quality of the Skawa River and Mucharskie Lake, taking into account the BMWP-PL index, indicates a generally poor condition of the studied waters. The BMWP-PL indices obtained at the studied sites ranged from 3 to 93 points. Such a score corresponds to four water quality classes – II, III, IV, and V. Sites S1, S2 and S6 on the Skawa River were characterised by good and moderate water quality (II and III class). However, the sites S3 (Dąbrówka) and S4 (Mucharz) on Mucharskie Lake were distinguished by poor water quality.

Keywords: environmental monitoring, invertebrates, water quality indicators

Received: [2024.11.26]

Accepted: [2024.12.22]

Introduction

Currently, freshwater accounts for about 2.5% of resources, of which 0.6% is drinking water (Musie, Gonfa, 2023). As the Earth's population grows, humans generate enormous amounts of waste and pollution which directly affect the drinking water resources and biodiversity of the different habitats (Jania, 2008; Grizzetti et al., 2019). These pollutions include untreated municipal and industrial wastewater, residues of fertilisers used for fields and agricultural land, and runoff from landfill sites for various types of waste (Salachna et al., 2022). The appearance of these substances in water alters its properties and affects its odour, colour, clarity, and the occurrence of living organisms (Wiech et al., 2018). One of the effects of water pollution is eutrophication, caused by increased biogenic compounds, nitrogen, and phosphorus in water contributing to a rapid rise in water fertility. This process disturbs the homeostasis of the reservoir, changes its biodiversity, and disrupts the habitat structures of aquatic organisms (Górniak, Kajak, 2020).

Due to the unsatisfactory quality of surface waters, both in Poland and other European countries, water reservoirs and watercourses are subject to regular monitoring studies. The Water Framework Directive – WFD – imposes an obligation on EU Member States to achieve good (ecological and chemical) status of waters and the ecosystems that depend on them. Under the WFD, European countries are obliged to take measures to halt the deterioration of water status and to maintain or improve the good quality of waters, to increase environmental awareness in society, to take measures for the validity of the research carried out and to assess the status of water quality (*Good Water Quality in Europe*… https://eur-lex.europa.eu).

The provisions of the WFD were implemented in the "*Water Law Act of 2017; Dz.U. 2024 poz. 1087*". According to this legislation, biological indicators and, as a complement, hydromorphological and physicochemical indicators should be taken into account in monitoring studies to assess the ecological status of waters. Biological indicators include phytoplankton, macrophytes, phytobenthic, benthic macroinvertebrates, and ichthyofauna.

Macroinvertebrates are found in the shoreline areas of water bodies, attached to stones, moving in the water depths, and also at the bottom of the water bodies. They are one of the indicators considered in the biological assessment of water bodies (Lewin et al., 2013; Schneid et al., 2017; Silva et al., 2018; Slimani et al., 2019). Aquatic invertebrates are widely recognised as the most recommended indicator organisms in the biological assessment of the quality of running waters (e.g. Rosenberg, Resh, 1993; Verdonschot, 2000; Statzner et al., 2001). The use of macroinvertebrates to assess water quality is conditioned by their wide availability, easy sampling, and relatively simple identification to the rank of family (Salachna et al., 2022). Their life cycle is long enough to record the state of the aquatic environment and changes occurring in it, and their relatively sedentary lifestyle reflects the local conditions of the environment. These organisms are sensitive to changing conditions in water caused by various pollutants and can be treated as bioindicators of water status (Czerniawska-Kusza, 2005; Kiesel et al., 2009; Pan et al., 2012; Bis, Mikulec, 2013; Lewin et al., 2015; Calapez et al., 2017; Su et al., 2019; Kownacki, Szarek-Gwiazda, 2022). Based on their presence, the ecological status of a reservoir can be assessed quickly and easily (Kerans, Karr, 1994; Meng et al., 2010; Sumudumali, Jayawardana, 2021; Orozco-González, Ocasio-Torres, 2023). The advantages of macroinvertebrates have been used to develop biotic indices, which are based on quantitative changes in taxa with increasing water pollution (Rybak, Umińska-Wasiluk, 2007; Obolewski, 2010; Spyra et al., 2017; Salachna et al., 2022).

According to Kownacki and Soszka (2004), the indicators best suited for assessing the quality of rivers in Polish conditions are the Biological Monitoring Working Party (BMWP) and the modified Margalef biodiversity index (Death, 2008). The Polish Biotic Index (BMWP-PL) was created based on the BMWP and adapted to Polish biomonitoring methods and the unified system used in the European Union (Kownacki, Soszka, 2004). The BMWP Index, used e.g. in Great Britain, is based on the analysis of the occurrence of 80 taxa of macroinvertebrates, which are assigned points from 0 to 10 depending on their sensitivity to pollution. The BMWP index value is the sum of individual points assigned to taxa found in the standard sample. It depends on the number of taxa found, the size of the sample, and the method and accuracy of sampling. The list of BMWP indicator families was modified as BMWP-PL and 5 quality classes were designated for this indicator (Bis, Mikulec, 2013).

The study aimed to assess the water quality of the Skawa River and Mucharskie Lake (Southern Poland) in spring and autumn based on benthic macroinvertebrates. The BMWP-PL index was used to determine the quality class of the studied waters.

Study area

The study sites are located in the western part of the Małopolskie Voivodeship near Sucha Beskidzka, Mucharz, and Wadowice (Southern Poland). The Skawa River is a right-bank tributary of the Vistula River, the entire course of which lies within the territory of the Małopolskie Voivodeship. It flows from its source in the vicinity of the Spytkowicka Pass and passes through the area of the Western Beskids, Beskid Żywiecki, Beskid Makowski and Beskid Mały (Kondracki, 1998). It flows into the Vistula River in the municipality of Zator, in the village of Smolice. Before flowing into Mucharskie Lake, the waters of the Skawa River flow near the Municipal Facilities in Sucha Beskidzka and the Regional Waste Processing Plant in Sucha Beskidzka, which may affect water quality.

The Mucharskie Lake (The Świnna Poręba Dam Reservoir – this name was in force until 2018; 49°49'57"N 19°31'44"E) reservoir is located in the Carpathian Mountains, in the western part of the Małopolskie Voivodeship, in the Wadowice district.

This dam reservoir with an area of 10.4 km^2 is located about 12 km south of Wadowice, about 13 km north of Sucha Beskidzka, and about 50 km south-west of Kraków (Fig. 1). The lake occurs on the Skawa River, which flows into the reservoir in the village of Zembrzyce and flows out at the dam in the village of Świnna Poręba.

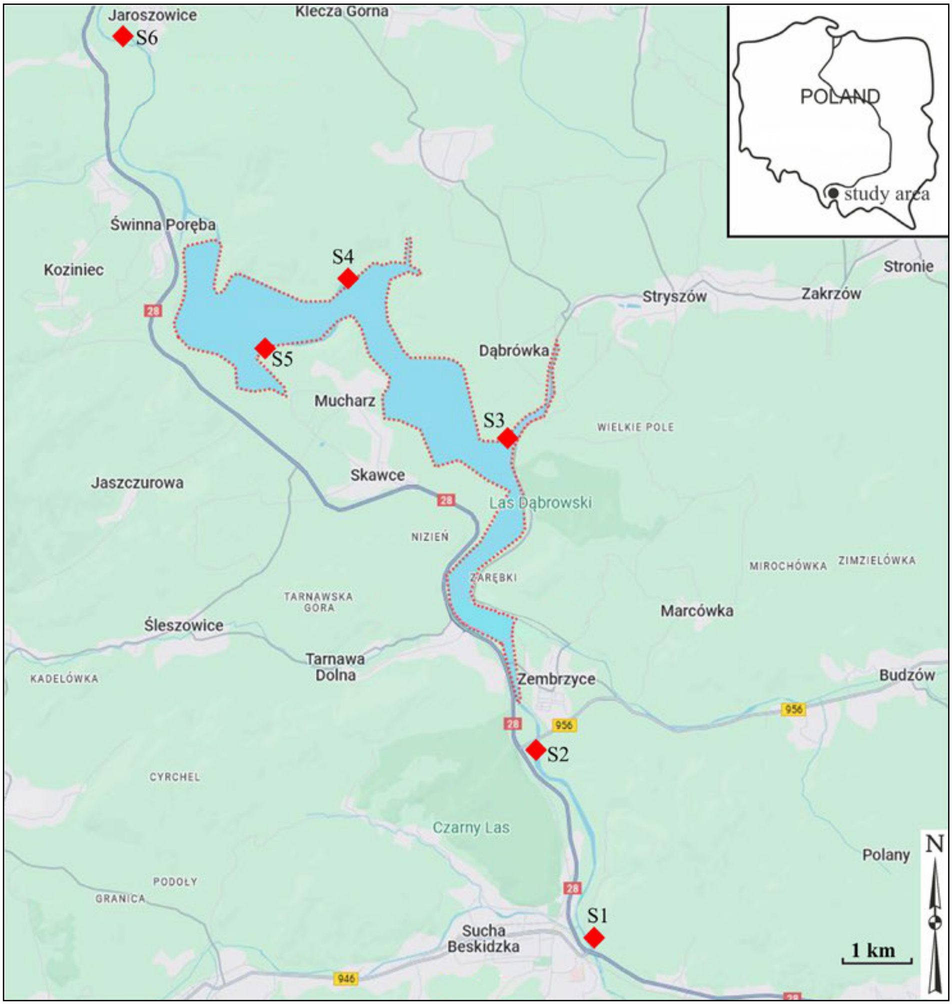

Fig. 1. Location of water sampling: sites S1–S6

Materials and methods

Water samples for biological testing were taken from six sites (S1–S6). The S1, S2, and S6 sites were located on the Skawa River: S1 – upstream of the sewage treatment plant, S2 – downstream of the sewage treatment plant, and S6 – downstream of the dam. The S3 (on the Skawa inflow to the reservoir), S4, and S5 (middle part of the lake) sites were located on Mucharskie Lake (Fig. 1; Fig. 2 – Appendix 1).

To obtain reliable results for assessing the ecological status and water quality of the Skawa River and Mucharskie Lake, water samples were taken in two periods – in spring and autumn 2023 according to GIOŚ (*Chief Inspectorate for Environmental Protection*) guidelines (https://www.gios.gov.pl). Ten water samples were taken from each location over a distance of approximately 100 meters. To obtain aquatic invertebrates, sieves, a scoop, and containers were used into which live forms were transferred to label them using aquatic organism identification keys (Stańczykowska, 1986; Kołodziejczyk, Koperski, 2000; Rybak, 2000; Bis, Mikulec, 2013).

In this study, BMWP-PL (Biological Monitoring Working Party-Poland) was used to determine the water quality of the Skawa River and Mucharskie Lake. By classifying aquatic invertebrates into a family, they were assigned scores ranging from 0 to 10 according to the organisms' sensitivity table (Tab. 1 – Appendix 2). When the scores are added up, the assessed river and water body can be classified into one of the five quality classes according to BMWP-PL (Tab. 2 – Appendix 2) (Traczewska, 2011).

Results

Diversity of fauna at the Sucha Beskidzka site (S1)

In water samples taken at the S1 site, 174 invertebrate specimens were identified, including larval, pupal, and adult forms (Fig. 3–4, 5A – Appendix 1), belonging to 15 families from such systematic units as: Branchiopoda, Diptera, Coleoptera, Ephemeroptera, Plecoptera, Odonata and Trichoptera.

Diptera were the dominant group (46.6%), including as many as 56 larvae and 4 pupae of Chironomidae (Tab. 3 – Appendix 2). In addition to these, larval and adult forms of Culicidae and larvae of Thaumaleidae were identified in the samples. Branchiopoda was abundant (29%), including adult forms of Cladocera, Copepoda and Ostrocoda. Ephemeroptera accounted for more than 11% of all aquatic invertebrates and were represented, among others, by the larvae of the Baetidae (*Baetis* sp.), *Rhithrogena semicolorata* Curtis, 1834 and *Cloen dipterum* Linnaeus, 1761 (Fig. 3B–D – Appendix 1). Among the Coleoptera, adult forms *Hydrous piceus* Linnaeus, 1758 from the Hydrophilidae family (Fig. 3A – Appendix 1) and from the Gyrinidae family were identified. The larvae of the Plecoptera from the family Perlidae and of the Capniidae orders were also identified in the spring samples. The group of Trichoptera was represented by the larvae of the Limnephilidae family (Fig. 3E–F – Appendix 1).

In the autumn of 2023, 114 forms were identified at this site including larvae, pupae, and adult forms (Tab. 3 – Appendix 2). The most numerous group was the larvae of the Ephemeroptera order – over 33%, including 38 larvae of Ephemeridae, *Heptagenia* larvae (Fig. 4D – Appendix 1), and *Cloeon dipterum* Linnaeus, 1761 larvae. The order Trichoptera constituted almost 23%, with most of them being larvae from the Hydropsychidae family. A larva *Polycentropus flavomaculatus* Pictet, 1834 of the Polycentropodidae family was also identified (Fig. 4E–F – Appendix 1). Branchiopoda were also abundant – almost 29%, including adult forms of *Daphnia* sp. and Cyclopoida. From the Diptera order, there were recognised larvae of the Chironomidae family, larvae of the Rhagionidae family, and also a pupa of *Chaoborus* sp. At this site, adult forms of *Elmis maugei* Bedel, 1878 beetles (Hydrophilidae), *Dytiscus marginalis* Linnaeus, 1758 from Dytiscidae, and a larva of *Agabus* sp. were collected from water samples (Fig. 4A–C – Appendix 1). Mites (Acari, Hydrachnellae) and a snail *Theodoxus fluviatilis* Linnaeus, 1758 as well as leeches *Haementeria* sp. (Glossiphoniidae) were also identified (Fig. 4G–H, Fig. 5A – Appendix 1).

Diversity of fauna at the Zembrzyce site (S2)

At the S2 site, 109 invertebrate forms were caught, belonging to Branchiopoda, Diptera, Ephemeroptera, Plecoptera, Trichoptera, and snails (Tab. 4 – Appendix 2; Fig. 5B–J, Fig. 6A–C – Appendix 1). Among them, nine families of invertebrates were identified and considered when classifying water quality according to BMWP-PL: Branchiopoda (Copepoda: Cyclopoida, Ostracoda, and Cladocera: Bosmina) – just under 40%, Diptera 34%, and Ephemeroptera – almost 23%, predominated in the spring water samples (Tab. 4 – Appendix 2). Among the Diptera, 29 larvae of the Chironomidae family and single larvae from the Thaumaleidae, Limoniidae, and Athericidae families were observed. The order Ephemeroptera included 23 larvae and an adult of the genus *Ephemera* sp., as well as a larva of the Baetidae family (*Baetis* sp.). At this site there were also identified a Plecoptera larva from the Perlidae family, Trichoptera larvae from the Limnephilidae family, and an adult form of the *Lymnaea stagnalis* Linnaeus, 1758 (Gastropoda) (Tab. 4 – Appendix 2; Fig. 5B–E – Appendix 1).

Fewer invertebrates were identified in the autumn water samples than in the spring samples. Of the 71 individual organisms noticed, the Diptera and Ephemeroptera orders accounted for 24% of the total forms. Diptera included 13 of the Chironomidae family larvae, a larva of the Thaumaleidae family, larvae from the Athericidae family, and a pupa of *Chaoborus* sp. (Fig. 5H–I – Appendix 1). Of the Ephemeroptera order, there were 10 larvae and one pupa *Polycentophlebia submarginata* from the Leptophlebiidae family (Fig. 6A–B – Appendix 1). Of the Coleoptera, 12 individual organisms of the great diving beetle *Dytiscus marginalis* and *Elmis maugei* (Fig. 5J – Appendix 1) were found. As at the S1 site, Trichoptera larvae of the Polycentropodidae and Hydropsychidae families were identified. In the water sample from site 2, also *Cyclops* sp. and Cladocera belonging to Branchiopoda (Fig. 5F–G – Appendix 1), and a leech (Hirudinea: Glossiphoniidae, Haementeria) and pond slaters belonging to Crustacea were found.

Diversity of fauna at the Dąbrówka site (S3)

At site S3, 78 invertebrate specimens were identified, of which only two families were considered for water quality assessment using BMWP-PL. These are Diptera of the Chironomidae family represented by 10 larvae and 13 pupae, and two specimens of the Culicidae family. In spring, as in previous sites, the dominant group was Branchiopoda accounting for almost 67% of all forms. Diptera were half as numerous – 32,1%. The least represented group was Gryllidae (Tab. 5 – Appendix 2, Fig. 6D – Appendix 1).

In autumn, only 11 benthic organisms at the S3 site were recorded, including 5 Chironomidae family larvae, one larva from the Culicidae family, and pupa of the *Chaoborus* genus, *Cyclops* (Branchiopoda) and adult forms of Dytiscidae (Tab. 5 – Appendix 2).

Diversity of fauna at the Mucharz site (S4)

In the water samples taken from the S4 site, only four systematic groups were identified: Branchiopoda, Diptera, Entognatha, and Heteroptera. The dominant group was Diptera (almost 53%) of the Chironomidae family: larvae, pupae, and an adult from the Tipulidae family. Among the Branchiopoda (41%), the Copepoda, the Cladocera (Bosmina sp.), and the Ostracoda were identified. Other forms of Collembola were also present in the samples, and Hemiptera from the Anthocoridae family were also observed (*Orius insidiosus* Say, 1832).

Chironomidae (Diptera) larvae and imagines accounted for 100% of the autumn sample (Tab. 6 – Appendix 2). Two families (Tipulidae and Chironomidae) of invertebrates were included in the water quality assessment.

Diversity of fauna at the Zagórze site (S5)

In the S5 site few invertebrates were identified in water samples from this site: 51 individual organisms in the spring and 17 in the autumn samples. These included representatives of Branchiopoda, Diptera, and Trichoptera. Diptera predominated in the spring samples, including Chironomidae larvae, but also adults: Tipulidae, Simuliidae, and Culicidae were present. The order of Trichoptera was represented by adults of the Sericostomatidae family (Tab. 7 – Appendix 2).

In autumn, the most numerous were Branchiopoda and Diptera, represented by the larvae of the Chironomidae, a larva of the Athericidae, larvae of the Thaumaleidae, and adult forms of Culicidae. Coleoptera was represented by the larvae of the great diving beetle *Dytiscus marginalis* (Tab. 7 – Appendix 2).

Diversity of fauna at the site at the village of Jaroszowice (S6)

At this site, only 16 specimens belonging to the dominant Branchiopoda, Diptera, and Trichoptera were identified in the spring sample (Tab. 8 – Appendix 2; Fig. 6E – Appendix 1).

In the autumn sample, 61 specimens were found (Fig. 6F–H – Appendix 1), of which *Asellus aquaticus* Linnaeus, 1758 were the most numerous. The Diptera order was represented by larvae from two families Thaumaleidae and Psychodidae, and a pupa from the Tipulidae family (Fig. 6G – Appendix 1). Of the Trichoptera, larvae from the Leptoceridae family and 10 *Polycentropus flavomaculatus* Pictet, 1834 larvae from the Polycentropodidae family were identified. The Ephemeroptera included the larvae from the Leptophlebiidae family. Coleoptera was also present at the site – larvae of *Hydropsyche* sp. and *Dytiscus marginalis*, Amphipoda (Ostracoda) (Fig. 6F – Appendix 1), and also leeches *Glossiphonia* sp. and alpine flatworms *Crenobia alpina* Dana, 1766 (Tab. 8 – Appendix 2; Fig. 6H – Appendix 1).

Water Quality Assessment

BMWP-PL values ranged from 3 to 93 points (Tab. 1, 9 – Appendix 2). The assessed sites were assigned to the II, III, IV and V quality classes (Tab. 10).

Tab. 10. Comparison of scores and water quality classes according to BMWP-PL at the S1–S6 sites in spring 2023 and autumn 2023

Season/Characteristics		BMWP-PL Values					
		S1 Sucha Beskidzka	S2 Zambrzyce	S3 Dąbrówka	S4 Mucharz	S5 Zagórze	S6 Jaroszowice
Spring 2023	Total scores	93	58	5	8	23	15
	Class according to BMWP-PL	II	III	V	V	IV	IV
Autumn 2023	Total scores	56	62	10	3	28	55
	Class according to BMWP-PL	III	III	IV	V	IV	III

Good water quality (Class II) in spring was observed at the S1 site in Sucha Beskidzka, where BMWP-PL was the highest and amounted to 93 (Tab. 9 – Appendix 2). This site showed the highest number (174 individual organisms) and diversity of aquatic invertebrates. Twenty-one families were identified and the highest-ranked families, according to BMWP-PL, were the family Thaumaleidae – 10 points, the families Heptageniidae, Capniidae, Perlidae – 8 points, the families Ephemeridae, Limnephilidae – 7 points, and the families Baetidae, Coenagrionidae, Limoniidae, Simuliidae – 5 points. At the S2 site in Zembrzyce, water quality corresponded to Class III – moderate status (58 points). The S3 and S4 sites had Class IV water quality. The bad water status resulted from low scores of families tolerating water pollution Chironomidae – 3 points and Culicidae – 2 points. In contrast, poor water quality was found at the S5 and S6 sites, where diversity was the lowest (Tab. 9 – Appendix 2; Tab. 10).

Water quality at the assessed sites during autumn was similar, ranging from moderate to bad. According to BMWP-PL, the assessed sites were classified into quality classes III, IV, and V. The S1 site in Sucha Beskidzka, S2 in Zembrzyce, and S6 in Jaroszowice were charcterised by moderate water quality (Class III). These sites had the highest biodiversity (13–14 families). The highest-ranked families were: Thaumaleidae, Leptoceridae, Athericidae, Ephemeridae, Leptophlebiidae, Polycentropodidae, Tipulidae, Gyrinidae, Dystiscidae, and Hydropsychidae (Tab. 9 – Appendix 2; Tab. 10).

Poor status – water quality Class IV – was recorded at the S3 site in Dąbrówka and the S5 site in Zagórze Bad water status was identified at Mucharz. At this site only the Chironomidae family was identified and had the lowest score (Tab. 9 – Appendix 2; Tab. 10). Water quality at the sites in Zembrzyce, Mucharz, and Zagórze in both study periods was the same (Class III, V and IV, respectively). An improvement in water quality was recorded at the S3 site on the Skawa River inflow to the reservoir (Class IV) and at the S6 site downstream of the dam (Class III).

Discussion

The diversity of benthic macroinvertebrates can be a good indicator for assessing ecological status in many different water types (Orozco-González, Ocasio-Torres, 2023). Water quality degradation is shown by the presence or absence of sensitive and tolerant organisms, as different taxa have different habitat preferences and broad tolerances to pollution (López- López, Sedeño-Díaz, 2015). Among the benthic fauna, there are taxa that are sensitive to water pollution, e.g. Ephemeroptera, Trichoptera, and Odonata larvae, and those that show some tolerance to bad environmental conditions, e.g. Oligochaeta, or larvae of the Chironomidae family – Fig. 3–6 – Appendix 1 (Lampart-Kałużniacka et al., 2012; Lewin et al., 2017).

As a relatively new reservoir, Mucharskie Lake has been filled since 2016 using the waters of the Skawa River. Ultimately, it is intended to be a drinking water reservoir for nearby municipalities and cities such as Sucha Beskidzka and Wadowice. It also collects excess runoff mountain water and protects riverside villages and towns from flooding (Górska et al., 2018). A mountain river feeds the reservoir, so the pollution in its waters is negligible. This is confirmed by the value of BMWP-PL, which in spring 2023 at the site in Sucha Beskidzka indicated the good quality of the Skawa River water at the site in Sucha Beskidzka in spring 2023. (Tab. 3, 9 – Appendix 2; Tab. 10). Also, WIOŚ (Voivedeship Inspectorate for Environmental Protection) reports from earlier years indicated that the ecological status of the Skawa River in the section to the Świnna Poręba reservoir in 2016 was good, and in 2017 it was moderate, while from the Świnna Poręba dam to Klęczanka, it was moderate.

However, surveys show that quality water of Mucharskie Lake is poor or even bad – class IV and V at sites in Dąbrówka, Mucharz and Zagórze (Tab. 5–7 – Appendix 2, Tab. 10). The low biodiversity of macroinvertebrates indicates an impoverished ecosystem (Lampart-Kałużniacka et al., 2012) that is adapting to the changes that have been ongoing since 2016. Balcerzak and Rybicki (2011) studied the Skawa River in the final phase of the reservoir's construction for eutrophication. Also, in the Dobczycki Dam

Reservoir, Szczepańska et al. (2017) and Pawełek, Spytek (2008) indicated a threat of eutrophication. Both of the above-mentioned reservoirs are exposed to significant anthropogenic impacts, the consequence of which is, among others eutrophication. Similar impacts are also observed in the case of Mucharskie Lake. Anthropogenic pollution of the Skawa River water, the post-agricultural landscape where Mucharskie Lake is currently located, and the presence of a sewage treatment plant cause the gradual release of biogenic compounds such as nitrogen or phosphorus into the lake and river. This may contribute to the eutrophication of this reservoir and, consequently, a reduction in its biodiversity, including macroinvertebrates.

Lampart-Kałużniacka et al. (2012), in their study of the Rega River, found varying BMWP-PL scores, ranging from sufficient to good. They recorded the least favorable ecological status at sites covering the waters of the "Gryfice A" Canal, which acts as a receiver of water from drainage facilities. On the other hand, Wiatkowski et al. (2013) assessed the water quality of the Włodzienin reservoir on the Troja River in the first period of its operation. They classified the water of this reservoir into quality Class II due to excessive nitrates and total suspended solids. Thus, the BMWP-PL indicator also used in the Mucharski reservoir water purity study yields comparable and satisfactory scores (Tab. 3–9 – Appendix 1; Tab. 10). The BMWP index has also been used in other regions of the world to determine water quality, including Iran (Varnosfaderany et al., 2010), rivers in China (Pan et al., 2012) and Africa (Meng et al., 2010; Slimani et al., 2019), in Brazil (Uherek, Pinto Gouveia, 2014), Colombia (Romero et al., 2017), or rice fields in Costa Rica (Kumar et al., 2013).

Conclusions

The water quality assessment of the Skawa River and Mucharskie Lake is based on benthic macroinvertebrates, and taking into account the BMWP-PL biotic index, indicates different water quality classes. The sites on the Skawa River differed in the studied periods. The spring samples showed water quality classes II (S1), III (S2), and IV (S6), i.e. from good to unsatisfactory. In the autumn samples, all sites on the Skawa River showed moderate water quality, i.e. quality class III. The sites on Mucharskie Lake were characterised by poor and unsatisfactory water quality in both periods. In these locations, the diversity of macroinvertebrates was the lowest. The overall poor and unsatisfactory condition of water in the reservoir may be influenced by anthropogenic pollution of the Skawa River.

Conflict of interest

The authors declare no conflict of interest related to this article.

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Appendix 1

Fig. 2. Study sites: S1 – Sucha Beskidzka, left riverbank, eastern side; S2 – Zembrzyce, left riverbank, western side; S3 – Dąbrówka, southwest view, right side of site; S4 – Mucharz, west view, right side of site; S5 – Zagórze, south view, left side of site; S6 – Jaroszowice, left riverbank, western side (Photo. A. Sadlak, 2023)

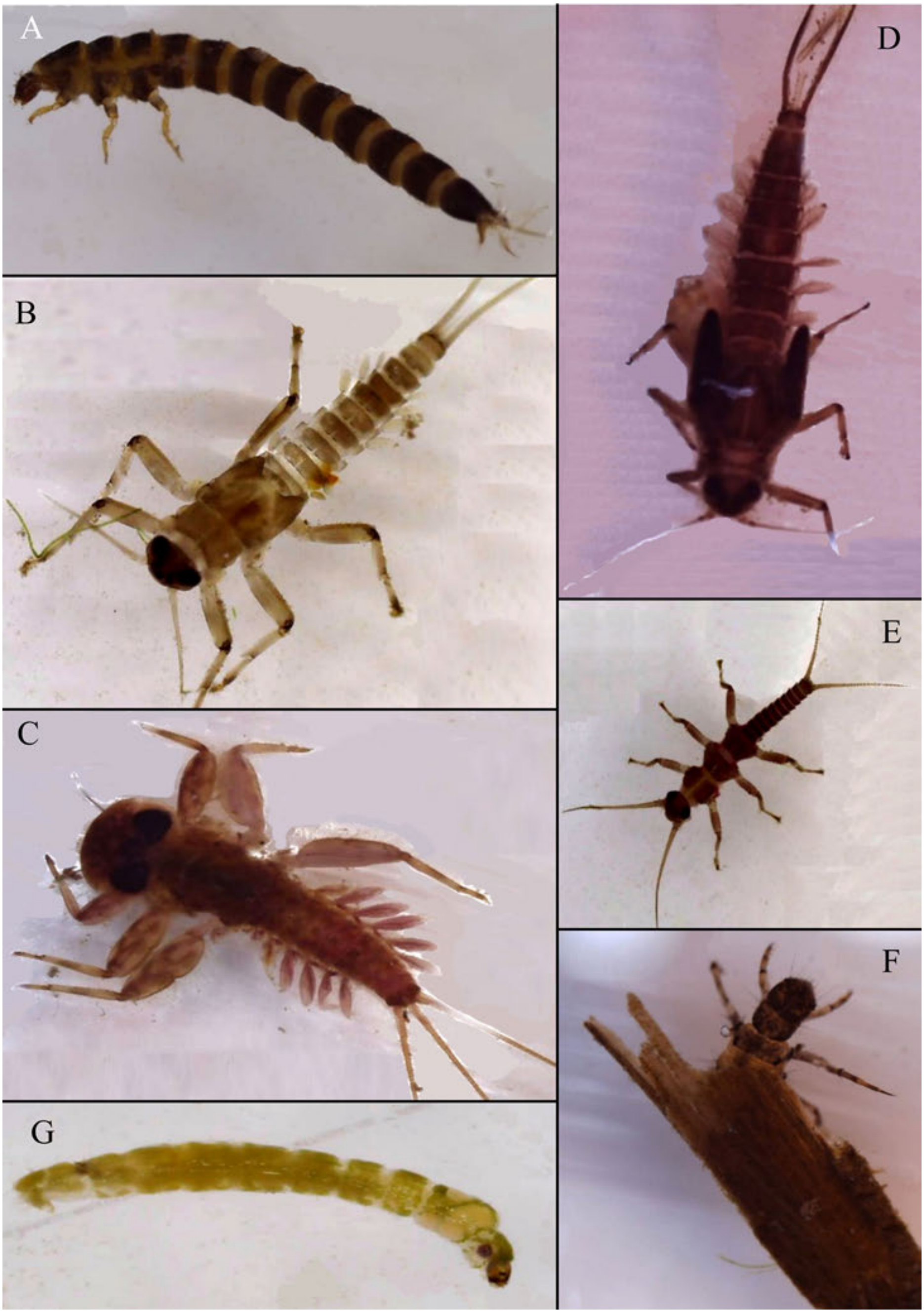

Fig. 3. Taxa recorded in spring at the S1 site (Sucha Beskidzka): A – larva *Hydrous piceus* from the Hydrophilidae family (Coleoptera), B – larva of the *Baetis* sp. (Baetidae family), C – larva *Rhithrogena semicolorata* from the Heptageniidae family, D – larva Ephemeroptera, (*Cloeon dipterum*), E – larva *Capnia* sp. from the Capniidae family, F – larva from the Limnephilidae family; taxa recorded in autumn at the S1 site (Sucha Beskidzka): G – larva from the Chironomidae family (Diptera) (Photo. A. Sadlak, 2023)

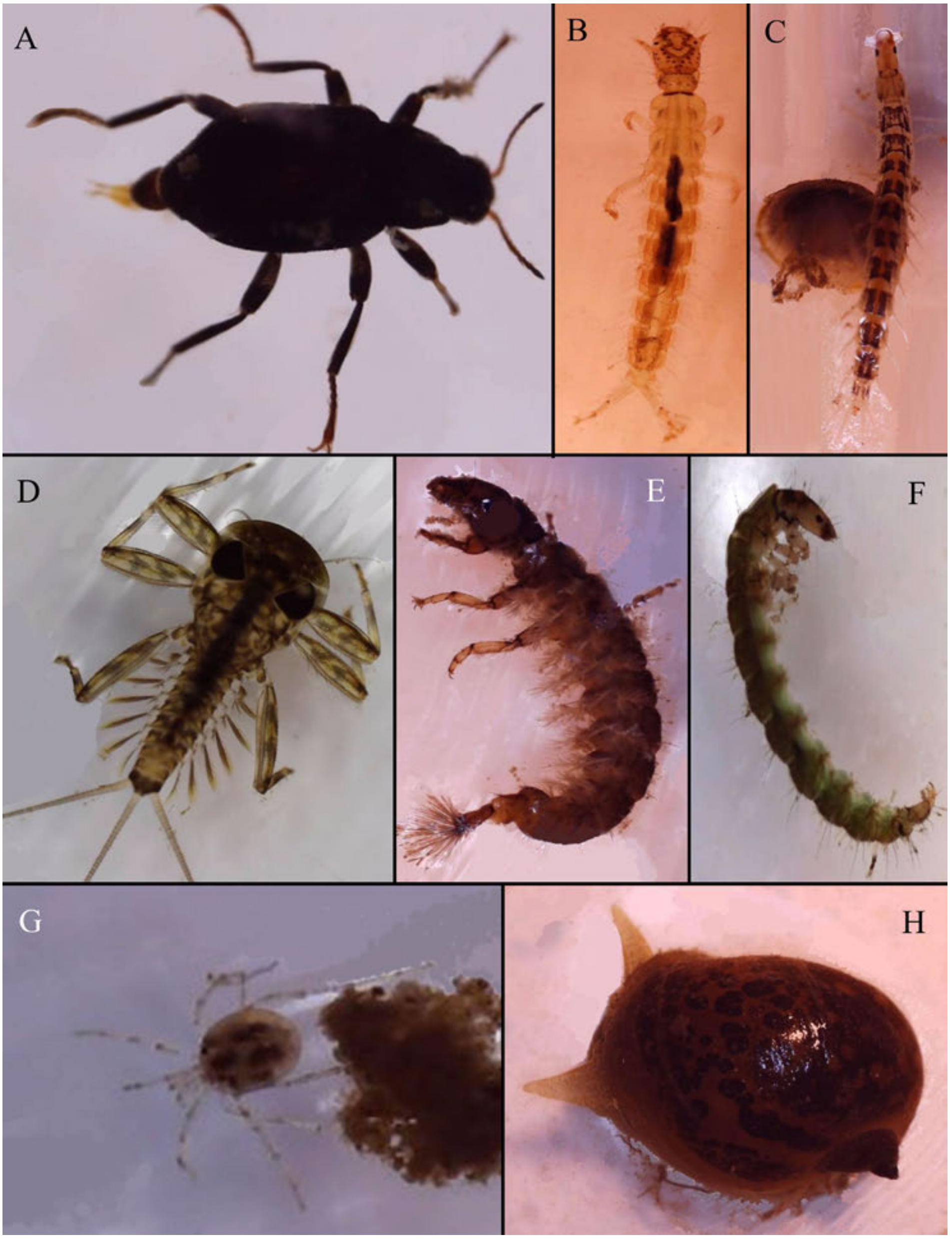

Fig. 4. Taxa recorded in autumn at the S1 site (Sucha Beskidzka): A – imago *Elmis maugei* from the Gyrinidae family, B – larva *Dytiscus marginalis* from the Dytiscidae family, C – larva from the *Agabus* sp. (Dytiscidae), D – larva *Heptagenia* from the Heptageniidae family, E – Larva *Hydropsyche* sp. (Hydropsychidae family), F – larva *Polycentropus flavomaculatus* from the Polycentropodidae family, G – adult form from the Hydrachnellae (Acari), H – adult form *Theodoxus fluviatilis* of the Gastropoda, (Photo. A. Sadlak, 2023)

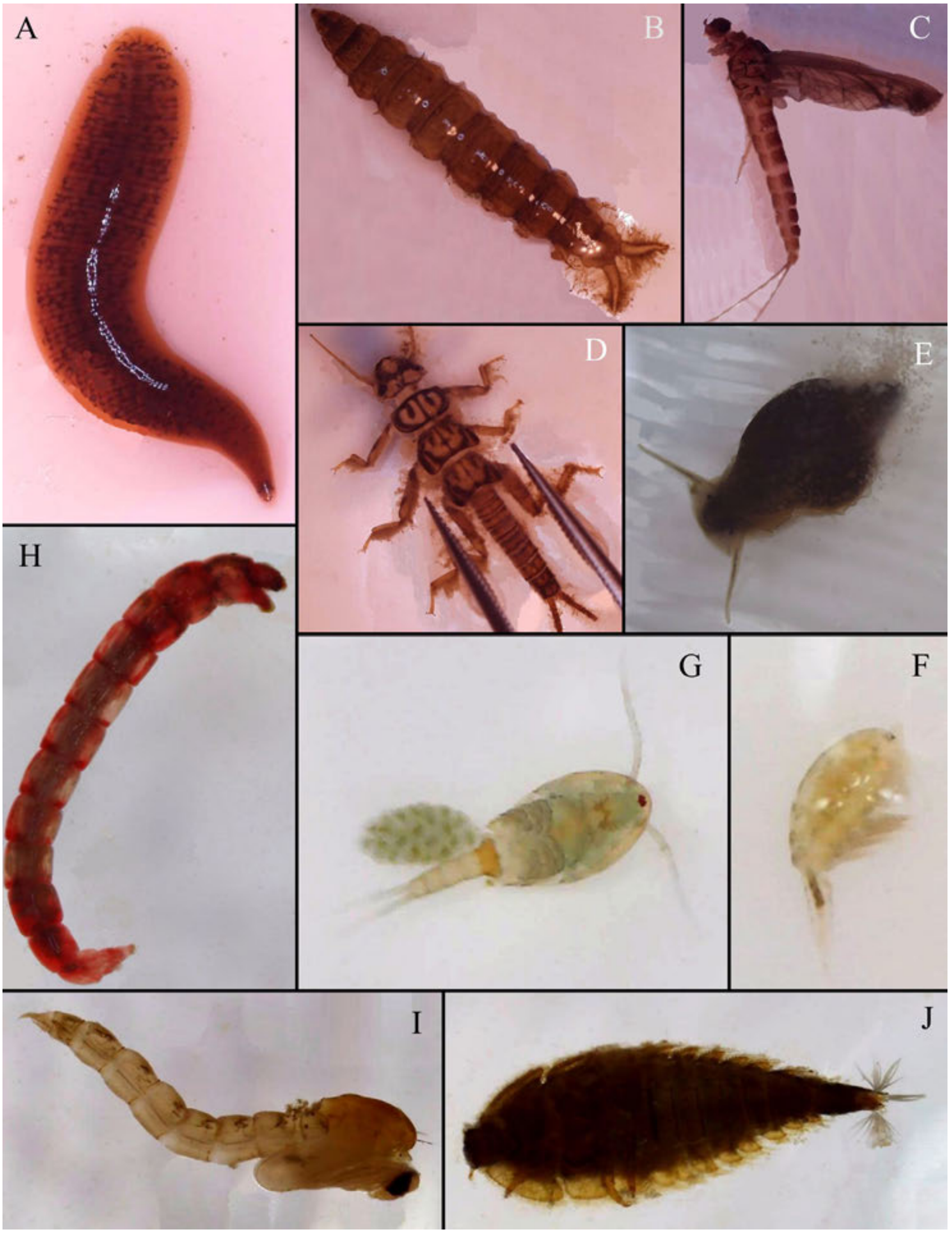

Fig. 5. Taxa recorded in autumn at the S1 site (Sucha Beskidzka): A – leech *Haementeria* sp. from the Glossiphoniidae family; taxa recorded in spring at the S2 site (Zembrzyce): B – larva from the Athericidae family (Diptera), C – *Ephemera* sp. from the Ephemeridae family (Ephemeroptera), D – larva Pleocoptera from the Perlidae family, E – snail *Lymnaea stagnalis* from the Lymnaeidae family; taxa recorded in autumn at the S2 site (Zembrzyce): F – adult form the *Daphnia* sp. (Cladocera), G – Cyclopoida (with egg sac) from the Copepoda, H – larva from the Thaumaleidae family (Diptera), I – pupa *Chaoborus* sp. from the Chaoboridae family (Diptera), J – larva *Elmis maugei* from the Gyrinidae family (Photo. A. Sadlak, 2023)

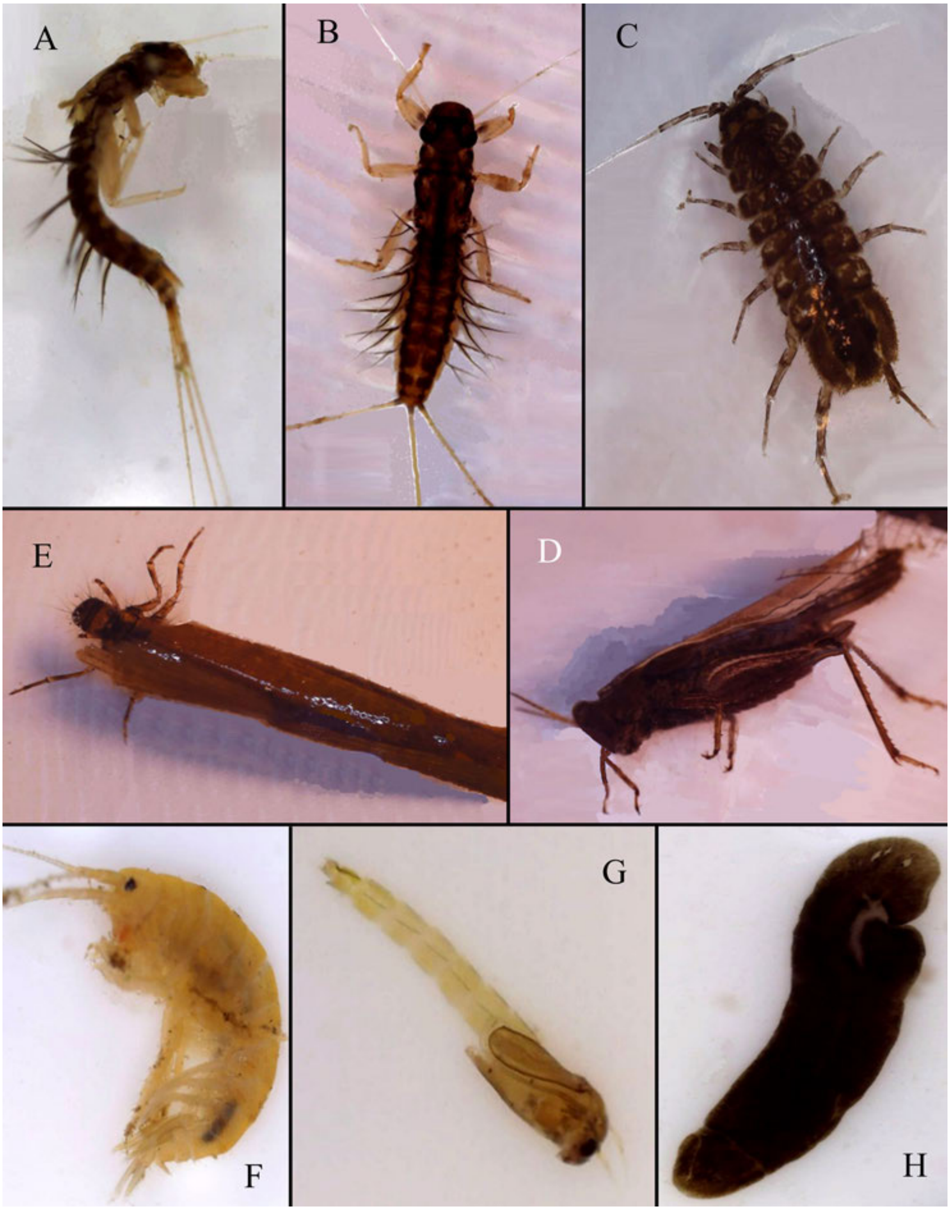

Fig. 6. Taxa recorded in autumn at the S2 site (Zembrzyce): A – pupa from the *Leptophlebiidae* family during metamorphosis, B – larva from the *Leptophlebiidae* family, C – adult form *Asellus aquaticus* (from the Asellidae family); taxa recorded in spring at the S3 site (Dąbrówka): D – imago Orthoptera (Gryllidae family); taxa recorded in spring at the S6 site (Jaroszowice): E – larva from the Trichoptera (Sericostomatidae family); taxa recorded in autumn at the S6 site (Jaroszowice): F – adult form for the Amphipoda (Ostracoda), G – pupa from the Tipulidae family (Diptera), H – *Crenobia alpina* from the Planariidae family (Photo. A. Sadlak, 2023)

Appendix 2

Tab. 1. BMWP-PL Index acording to Kownacki, Soszka (2004)

Family		**Scoring**
Ephemeroptera	Ameletidae	10
Trichoptera	Glossosomatidae, Molannidae, Beraeidae, Odontoceridae, Leptoceridae	
Diptera	Blephariceridae, Thaumaleidae	
Ephemeroptera	Behningiidae	9
Plecoptera	Taeniopterygidae	
Odonata	Cordulegastridae	
Trichoptera	Goeridae, Lepidostomatidae	
Crustacea	Astacidae	8
Ephemeroptera	Oligoneuriidae, Heptageniidae (genus *Epeorus*, *Rhithrogena*)	
Plecoptera	Capniidae, Perlidae, Chloroperlidae	
Trichptera	Philopotamidae	
Diptera	Athericidae	
Ephemeroptera	Siphlonuridae, Leptophlebiidae, Potamanthidae, Ephemerellidae, Ephemeridae, Caenidae	7
Plecoptera	Perlodidae, Leucridae	
Odonata	Calopterygidae, Gomphidae	
Trichoptera	Rhyacophilidae, Brachycentridae, Sericostomatidae, Limnephilidae	
Coleoptera	Elmidae	
Heteroptera	Aphelocheiridae	
Gastropoda	Viviparidae	
Bivalvia	Unionidae, Dreissenidae	
Hirudienea	Piscicolidae	6
Crustacea	Gammaridae, Corophiidae	
Ephemeroptera	Baetidae, Heptageniidae (except genus *Epeorus* i *Rhitrogena*)	
Plecoptera	Nemouridae	
Odonata	Platycnemididae, Coenagrionidae	
Trichoptera	Hydroptilidae, Polycentropodidae	
Diptera	Limoniidae, Simuliidae, Empididae	
Gastropoda	Neritidae, Bithyniidae	
Crustacea	Cambaridae	5
Trichoptera	Hydropsychidae, Psychomyidae	
Coleoptera	Gyrinidae, Dytiscidae, Haliplidae, Hydrophilidae	
Heteroptera	Mesoveliidae, Veliidae, Nepidae, Naucoridae, Notonectidae, Pleidae	
Diptera	Corixidae, Tipuliidae	
Gastropoda	Hydrobiidae	
Diptera	Ceratopogonidae	4
Gastropoda	Valvatidae, Planorbidae	
Bivalvia	Sphaeriidae	

Hirudinea	Glossiphonidae, Erpobdellidae, Hirudinidae	3
Crustacea	Asellidae	
Megaloptera	Sialidae	
Diptera	Chironomidae	
Gastropoda	Ancylidae, Physidae, Lymnaeidae	
Oligochaeta	all Oligochaeta	2
Diptera	Culicidae	
Diptera	Syrphidae, Psychodidae	1

Tab. 2. Range of BMWP-PL scores (Kownacki, Soszka, 2004)

BMWP-PL Class		Score Range
I	very good	above 100
II	good	70–99
III	moderate	40–69
IV	poor	10–39
V	bad	below 10

Tab. 3. Diversity of invertebrates at the S1 site in Sucha Beskidzka, spring/autumn 2023

Systematic group	Family, genus, species	Stage	Abundance	Total
Spring				
Branchiopoda	Cladocera, *Daphnia* sp.	adult form	4	50
	Cladocera, *Bosmina* sp.	adult form	3	
	Copepoda, *Cyclopoida*	adult form	27	
	Ostracoda	adult form	16	
Diptera	Culicidae	larva	4	81
	Culicidae	imago	4	
	Chironomidae	larva	56	
	Chironomidae	pupa	4	
	Chironomidae	imago	5	
	Chaoboridae, *Chaoborus* sp.	pupa	1	
	Thaumaleidae	larva	6	
	Limmonidae	larva	1	
Coleoptera	Hydrophilidae *Hydrous piceus*	imago	13	14
	Gyrinidae, *Elmis maugei*	imago	1	
Ephemeroptera	Ephemeridae *Ephemera* sp.	larva	15	20
	Baetidae	larva	3	
	Heptageniidae *Rhithrogena semicolorata*	larva	1	
	Baetidae *Cloeon dipterum*	larva	1	

Plecoptera	Perlidae	larva	4	5
	Capniidae	larva	1	
Odonata	Zygoptera, *Coenagrion* sp.	larva	1	1
Trichoptera	Limnephilidae	larva	3	3
Total number of individual organisms recorded in spring			174	
Autumn				
Branchiopoda	Cladocera, *Daphnia* sp.	adult form	12	35
	Copepoda, Cyclopoida	adult form	23	
Diptera	Chironomidae	larva	5	8
	Chaoboridae, *Chaoborus* sp.	pupa	1	
	Athericidae	larva	2	
Coleoptera	Dytiscidae, *Agabus* sp.	larva	1	4
	Gyrinidae, *Elmis maugei*	imago	1	
	Hydrophilidae	imago	1	
	Dytiscidae, *Dytiscus marginalis*	imago	1	
Ephemeroptera	Ephemeridae *Ephemera* sp.	larva	34	38
	Heptagenia	larva	2	
	Baetidae *Cloeon dipterum*	larva	2	
Trichoptera	Polycentropodidae, *Polycentropus flavomaculatus*	larva	1	26
	Hydropsyche sp.	larva	25	
Acari	Hydrachnellae	adult form	1	1
Gastropoda	*Theodoxus fluviatilis*	adult form	1	1
Hirudinea	Glossiphoniidae	adult form	1	1
Total number of individual organisms recorded in autumn			114	

Tab. 4. Diversity of invertebrates at the S2 site in Zembrzyce, spring/autumn 2023

Systematic group	Family, genus, species	Stage	Abundance	Total
Spring				
Branchiopoda	Cladocera, *Bosmina* sp.	adult form	1	43
	Copepoda, Cyclopoida	adult form	33	
	Ostracoda	adult form	9	
Diptera	Chironomidae	larwa	29	37
	Chironomidae	pupa	4	
	Chironomidae	imago	1	
	Thaumaleidae	larva	1	
	Limoniidae	larva	1	
	Athericidae	larva	1	
Ephemeroptera	Ephemeridae *Ephemera* sp.	larva	23	25
	Ephemeridae *Ephemera* sp.	imago	1	
	Baetidae	larva	1	

Plecoptera	Perlidae	larva	1	1
Trichoptera	*Limnephilidae* sp.	larva	2	2
Gastropoda	*Lymnae stagnalis*	adult form	1	1
Total number of individual organisms recorded in spring			109	
Autumn				
Branchiopoda	Copepoda, Cyclopoida	adult form	5	7
	Cladocera, *Daphnia* sp.	adult form	2	
Diptera	Chironomidae	larva	13	17
	Thaumaleidae	larva	1	
	Chaoboridae, *Chaoborus* sp.	pupa	2	
	Athericidae	larva	1	
Coleoptera	Dytiscidae, *Dytiscus marginalis*	imago	12	13
	Gyrinidae, *Elmis maugei*	larva	1	
Ephemeroptera	Ephemeridae *Ephemera* sp.	larva	10	17
	Leptophlebiidae,	larva	6	
	Leptophlebiidae	pupa	1	
Trichoptera	Polycentropodidae, *Polycentropus flavomaculatus*	larva	2	11
	Hydropsyche sp.	larva	9	
Crustacea	*Asellus aquaticus*	adult form	4	4
Hirudinea	Glossiphoniidae, *Haementeria*	adult form	2	2
Total number of individual organisms recorded in autumn			71	

Tab. 5. Diversity of invertebrates at the S3 site in Dąbrówka, spring/autumn 2023

Systematic group	Family, genus, species	Stage	Abundance	Total
Spring				
Branchiopoda	Copepoda, Cyclopoida	adult form	50	52
	Ostracoda	adult form	2	
Diptera	*Chironomidae*	larva	10	25
	Chironomidae	pupa	13	
	Culicidae	imago	2	
Orthoptera	Gryllidae	imago	1	1
Total number of individual organisms recorded in spring			78	
Autumn				
Branchiopoda	Copepoda, Cyclopoida	adult form	2	2
Diptera	Chaoboridae, *Chaoborus* sp.	pupa	1	7
	Chironomidae	larva	5	
	Culicidae	larva	1	
Coleoptera	Dytiscidae, *Dytiscus marginalis*	larva	2	2
Total number of individual organisms recorded in autumn			11	

Tab. 6. Diversity of invertebrates at the S4 site in Mucharz, spring/autumn 2023

Systematic group	Family, genus, species	Stage	Abundance	Total
Spring				
Branchiopoda	Cladocera, *Bosmina* sp.	adult form	1	14
	Copepoda, Cyclopoida	adult form	12	
	Ostracoda	adult form	1	
Diptera	Chironomidae	larva	4	18
	Chironomidae	pupa	9	
	Tipulidae	imago	5	
Collembola	Entognatha	adult form	1	1
Heteroptera	Anthocoridae, *Orius insidiosus*	imago	1	1
Total number of individual organisms recorded in spring			34	
Autumn				
Diptera	Chironomidae	larva	1	2
	Chironomidae	imago	1	
Total number of individual organisms recorded in autumn			2	

Tab. 7. Diversity of invertebrates at the S5 site in Zagórze, spring/autumn 2023

Systematic group	Family, genus, species	Stage	Abundance	Total
Spring				
Branchiopoda	Copepoda, Cyclopoida	adult form	11	11
Diptera	Chironomidae	larva	23	39
	Chironomidae	pupa	9	
	Tipulidae	imago	4	
	Simuliidae	imago	1	
	Culicidae	imago	2	
Trichoptera	Sericostomatidae	larva	1	1
Total number of individual organisms recorded in spring			51	
Autumn				
Branchiopoda	Copepoda, Cyclopoida	adult form	6	6
Diptera	Chironomidae	larva	2	6
	Athericidae	larva	1	
	Culicidae	imago	1	
	Thaumaleidae	larva	2	
Coleoptera	Dytiscidae, *Dytiscus marginalis*	larva	5	5
Total number of individual organisms recorded in autumn			17	

Tab. 8. Diversity of invertebrates at the S6 site in Jaroszowice, spring/autumn 2023

Systematic group	Family, genus, species	Stage	Abundance	Total
Spring				
Branchiopoda	Copepoda, Cyclopoida	adult form	12	12
Diptera	Culicidae	imago	2	2
Trichoptera	Leptoceridae, *Mystacides* sp.	larva	2	2
Total number of individual organisms recorded in spring			16	
Autumn				
Branchiopoda	Copepoda, Cyclopoida	adult form	4	9
	Amphipoda	adult form	5	
Diptera	Thaumaleidae	larva	2	10
	Psychodidae	larva	1	
	Tipulidae	larva	7	
Trichoptera	Leptoceridae, *Mystacides* sp.	larva	2	12
	Polycentropodidae, *Polycentropus flavomaculatus*	larva	10	
Ephemeroptera	Leptophlebiidae	larva	6	6
Crustacea	*Asellus aquaticus*	adult form	15	15
Coleoptera	Hydropsychidae, *Hydropsyche* sp.	larva	1	3
	Dytiscus marginalis	larva	2	
Hirudinea	Glossiphoniidae, *Glossiphonia* sp.	adult form	2	2
Turbellaria	*Crenobia alpina*	adult form	4	4
Total number of individual organisms recorded in autumn			61	

Tab. 9. BMWP-PL scores at the S1–S6 sites, spring/autumn 2023

Systematic group	Family	BMWP-PL scores					
		S1 Sucha Beskidzka	S2 Zembrzyce	S3 Dąbrówka	S4 Mucharz	S5 Zagórze	S6 Jaroszowice
Spring 2023							
Diptera	Thaumaleidae	10	10				
	Athericidae		8				
	Limoniidae	6	6				
	Simuliidae	6				6	
	Tipuliidae	5			5	5	
	Chironomidae	3	3	3	3	3	3
	Culicidae	2		2		2	2
Plecoptera	Capniidae	8					
	Perlidae	8	8				

Coleoptera	Gyrinidae	5					
	Hydrophilidae	5					
Ephemeroptera	Heptageniidae	9					
	Ephemeridae	7	7				
	Baetidae	6	6				
Gastropoda	Lymnaeidae		3				
Trichoptera	Leptoceridae						10
	Limnephilidae	7	7				
	Sericostomatidae					7	
Odonata	Coenagrionidae	6					
BMWP-PL total score		93	58	5	8	23	15
Autumn 2023							
Diptera	Thaumaleidae		10			10	10
	Athericidae	8	8			8	
	Psychodidae						1
	Tipuliidae						5
	Chironomidae	3	3	3	3	3	
	Culicidae			2		2	
Coleoptera	Gyrinidae	5	5				
	Hydrophilidae	5					
	Dytiscidae	5	5	5		5	5
Ephemeroptera	Heptageniidae	6					
	Ephemeridae	7	7				
	Leptophlebiidae		7				7
	Baetidae	3					
Trichoptera	Leptoceridae						10
	Hydropsychidae	5	5				5
	Polycentropodidae	6	6				6
Hirudinea	Glossiphonidae	3	3				3
Crustacea	Asellidae		3				3
BMWP-PL total score		56	62	10	3	28	55

Makrobezkręgowce jako bioindykatory jakości wód rzeki Skawy i Jeziora Mucharskiego (Południowa Polska)

Streszczenie

Makrobezkręgowce wodne to organizmy wrażliwe na zmiany w środowisku, w którym funkcjonują, dlatego służą do oceny jakości wód powierzchniowych. Celem niniejszej pracy była ocena jakości wody rzeki Skawy i Jeziora Mucharskiego na podstawie makrobezkręgowców bentonicznych, przy użyciu wskaźnika BMWP-PL. Do badań wykorzystano próbki wody z sześciu stanowisk badawczych – trzy na rzece Skawie i trzy na Jeziorze Mucharskim. W próbkach wody z miejsc badawczych zidentyfikowano różne makrobezkręgowce, takie jak: jętki, chruściki, widelnice, chrząszcze, skorupiaki, ślimaki i pijawki. Ocena jakości wody rzeki Skawy i Jeziora Mucharskiego, uwzględniająca wskaźnik BMWP-PL, wskazuje na ogólnie zły stan badanych wód. Wartości wskaźników BMWP-PL uzyskane na badanych stanowiskach były zróżnicowane i mieściły się w przedziale od 3 do 93 punktów. Ocena ta odpowiada czterem klasom jakości wody – II, III, IV i V. Dobrą i umiarkowaną jakością wody (klasa II i III) charakteryzowały się punkty S1, S2 i S6 na rzece Skawie. Natomiast złą jakość wody stwierdzono na Jeziorze Mucharskim (stanowiska S3 w Dąbrówce i S4 w Mucharzu).

Słowa kluczowe: bezkręgowce, monitoring środowiska, wskaźniki czystości wód

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