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The influence of a dam reservoir on caddisflies (Trichoptera) of an upland river on the example of the River Bystrzyca (south-eastern Poland)

Wpływ zbiornika zaporowego na chruściki (Trichoptera) rzeki wyżynnej na przykładzie Bystrzycy (południowo-wschodnia Polska)

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Słowa kluczowe: Trichoptera, zbiornik zaporowy, Zalew Zemborzycki, Bystrzyca

Abstract
The aim of the paper was to investigate the impact of the eutrophic dam reservoir on the fauna of Trichoptera of the medium-sized River Bystrzyca in the area of the Lublin Upland. Material collected at three sites above and three sites below the reservoir was analyzed with respect to: species composition and diversity, dominance and trophic structures, essential physical and chemical parameters of water, both at the species as well as assemblage level. The obtained results indicated the unfavorable influence of the reservoir on Trichoptera which was expressed by the decrease in the number of species and diversity below the dam, the disturbances of dominance and trophic structures as well as the increase in the number of specimens of the species insensitive to pollution. The more detailed characteristic of the representatives of the family Hydropsychidae is also given – their distribution and preferences against habitat conditions in the arrangement: river-reservoir-river.

Streszczenie
Celem pracy było prześledzenie wpływu eutroficznego zbiornika zaporowego na faunę Trichoptera średniej rzeki Bystrzycy na terenie Wyżyny Lubelskiej. Materiał pobrany z trzech stanowisk powyżej i trzech poniżej zalewu przeanalizowano pod kątem: składu gatunkowego i różnorodności gatunkowej, struktury dominacji oraz troficznej, istotnych czynników fizyczno-chemicznych wody, zarówno na poziomie gatunkowym jak i poszczególnych zgrupowań. Otrzymane wyniki wskazały na niekorzystny wpływ zalewu na Trichoptera co wyraziło się: spadkiem liczby gatunków i różnorodności gatunkowej poniżej zapory, zaburzeniem struktury dominacji i struktury troficznej oraz wzrostem liczby osobników gatunków niewrażliwych na zanieczyszczenia. W pracy zamieszczono także bardziej szczegółową charakterystykę przedstawicieli rodziny Hydropsychidae – ich rozmieszczenie i preferencje na tle warunków siedliskowych w układzie: rzeka-zalew-rzeka.

1. INTRODUCTION

Dam reservoirs serve a number of different functions: energetic, shipping, flood control, recreation, municipal or industrial ones. The creation of a dam reservoir changes hugely the whole ecosystem of a river. Except for habitat and landscape transformations associated with the creation of a reservoir itself, the most common and often negative phenomena connected with a river are: changes in sediment and flow regimes, the release of excessive amount of nutrients leading to eutrophication, increase in water temperature, decrease in dissolved oxygen and slow current [Giller, Malmqvist 1998]. All of this has impacts on living organisms inhabiting a river, both upstream from the dam and downstream. Particularly sensitive to these changes are aquatic invertebrates, including amphibiotic insects. They respond quickly to changes of habitats and water parameters in a certain way, either at a cellular, species or assemblage levels [Rosenberg, Resh 1993]. Natural systems that may serve as a reference point for observing changes in riverine invertebrate fauna caused by the presence of a water body are the rivers of lake districts with flow through numerous lakes although care must be taken in interpreting the results due to the regional differences in trichopterofauna.

The aim of this paper was to determine the impact of the Zemborzyce Reservoir on the fauna of Trichoptera of the River Bystrzyca by comparing the species composition and assemblages of these insects at sites above and below the reservoir against habitat conditions.

2. MATERIAL AND METHODS

The River Bystrzyca is a left tributary of the River Wieprz and the main river of the Lublin Upland. In 1974 in the area of Lublin city the dam reservoir called the Zemborzyce Reservoir was built, with the area of 280 ha and the average depth of 1.6 m. The role of this shallow reservoir is mainly recreational and flood prevention [Michalczyk, Wilgat 1998]. The character influencing its usability as well as living organisms of the reservoir and the river is the fact that during digging the basin, no peat from the bottom of river valley was picked out which aggravated water quality and accelerated the process of eutrofication. From the river itself and its catchment, high amounts of phosphorus and nitrogen infiltrate to the reservoir; moreover, in the last few years the massive blooms of green algae, diatoms and – the most toxic ones for animal organisms – blue-green algae were observed [Pawlik-Skowrońska et al. 2004; Smal, Ligęza 2006; Stani 2005].

In order to compare the fauna of Trichoptera of the River Bystrzyca up and downstream of the Zemborzyce Reservoir, 6 sampling sites very similar in hydromorphology and surroundings were selected:

three above the reservoir – 1. Prawiedniki (38,1 km to the mouth), 2. Prawiedniki, near small fish ponds (37,8 km), 3. Lublin-Zemborzyce, Cienista Street (35,7 km); and three below the reservoir – 4. Lublin, below the dam (26,8 km), 5. Lublin, Janowska Street (railway bridge) (23,8 km), 6. Lublin, Krochmalna Street (road bridge) (23,4 km). Insects were collected in the years 2001–2003 during vegetation seasons – aquatic stages with the use of a hydrobiological sampler and by picking up by hand while imagines were caught to an entomological net directly above water surface, on herbaceous vegetation or trees growing on banks or from the constructions like bridges, dams etc.

In data analyses, two ecological indices were used: dominance with the division into the following classes according to Biesiadka [1980]: eudominants > 10%, dominants 5,01–10%, subdominants – 2,01–5%, recedents < 2% while species diversity was calculated using PIE Index – according to Hurlbert's formula [Lampert, Sommer 1998]. Faunistic similarities between the species of the studied habitats according to formulas of Bray-Curtis and Jaccard were presented with the use of BioDiversity Pro programme as well as co-occurrence of the species [McAleece et al. 1997]. Statistical analyses (ANOVA Kruskal-Wallis test) were performed in Statistica 10.0 program. Feeding type categories of the species as well as the longitudinal distribution of Hydropsychidae in rivers were given after Graf et al. [2008].

3. RESULTS AND DISCUSSION

At the studied sites, 1742 specimens of caddisflies belonging to 18 species (22 taxa) were collected in total – Tab. 1. The largest numbers of individuals were found at sites 5 and 3 (895 and 318); the least at site 1 (95), and at sites 2, 4 and 6 those numbers were very similar, i.e. 147, 146 and 141 respectively. Comparing sites above and below the reservoir, 560 specimens (17 taxa) and 1182 specimens (10 taxa) were caught, respectively. The values of PIE Index ranged from 0.48 to 0.82; they were significantly higher above the reservoir than below (Fig. 1).

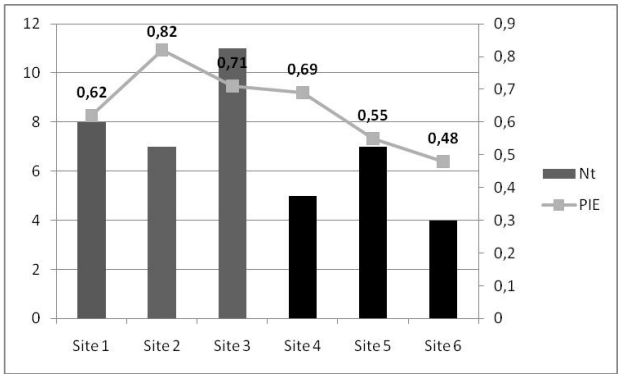

Fig. 1. The number of taxa of Trichoptera (Nt) against the value of PIE Index at sites on the River Bystrzyca above (gray bars) and below (black bars) the Zemborzyce Reservoir.

The analysis of qualitative faunistic similarities between the examined sites (Fig. 2) confirms the separateness of the faunas up and downstream of the reservoir; however, higher values of similarities were noted below the dam which is related to uniformed species composition of Trichoptera at sites 4–6. Site 3 serves as the link between the faunas above and below the reservoirs and has the mixed character. Quantitative analysis (Fig. 3) is slightly different: site 3 groups with the sites below the reservoir (sites 1 and 2 forms separate and clear block again) – this may indicate that the waters of the reservoir can have modifying impact on the fauna inhabiting the closest stretch of the river above (phenomenon of backwater).

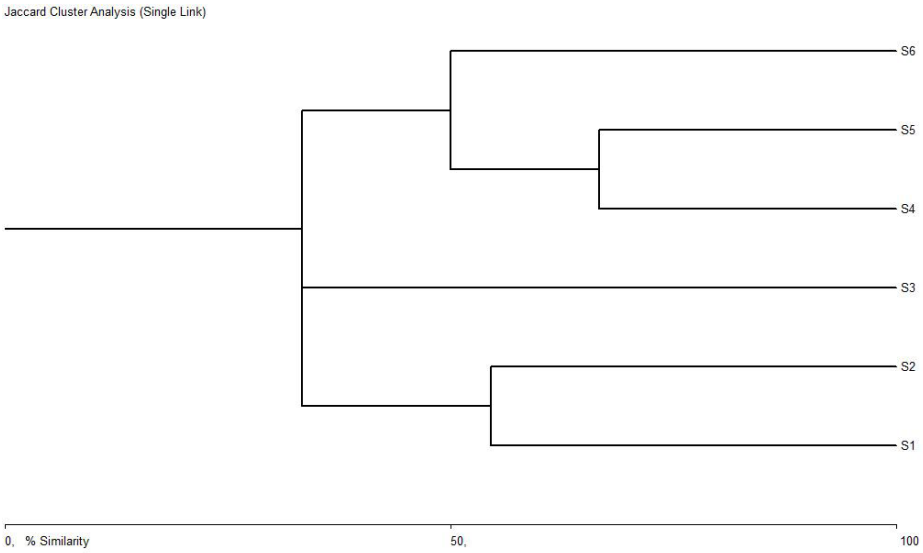

Fig. 2. Dendrite of qualitative faunistic similarities of Trichoptera between the studied sites of the River Bystrzyca.

Taking into consideration the dominance structure of Trichoptera above and below the reservoir it can be found that in the first case it is very balanced – all of the classes, except for dominants, were almost equally represented and the two highest classes encompassed the following taxa: eudominants – *Hydropsyche angustipennis*, *Anabolia* sp., *H. pellucidula* and *Limnephilidae* (juv.); dominants – *Chaetopteryx villosa*. This arrangement may indicate that the fauna of this river stretch is hardly disturbed; moreover, it may be also emphasized by the balance between the two most important trophic groups – shredders (46,1%) and filter feeders (45,8%). However, the dominance structure at the sites below the dam was clearly disturbed – the most taxa were recedents, there were no dominants, one subdominant only, and the class of eudominants consisted of three species: *H. angustipennis* (55%), *H. contubernalis* (33%) and

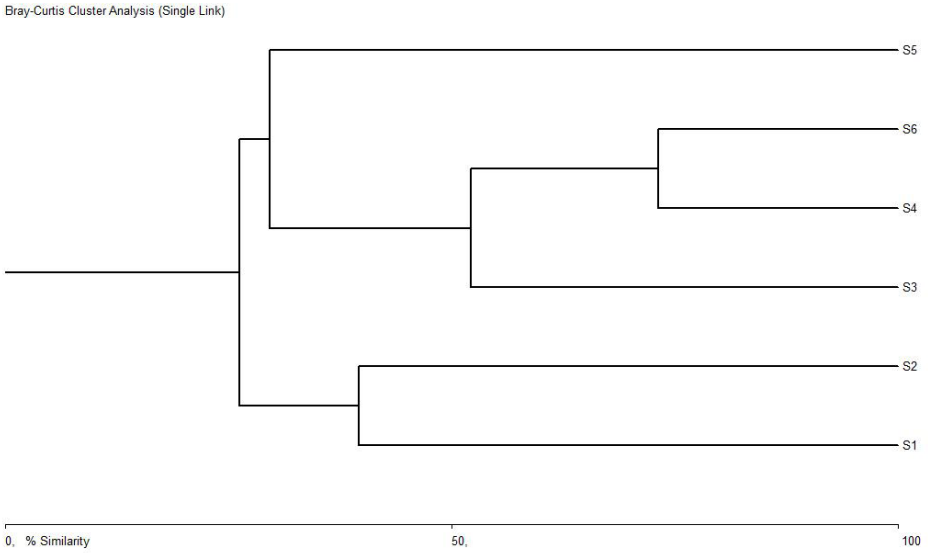

Fig. 3. Dendrite of quantitative faunistic similarities of Trichoptera between the studied sites of the River Bystrzyca.

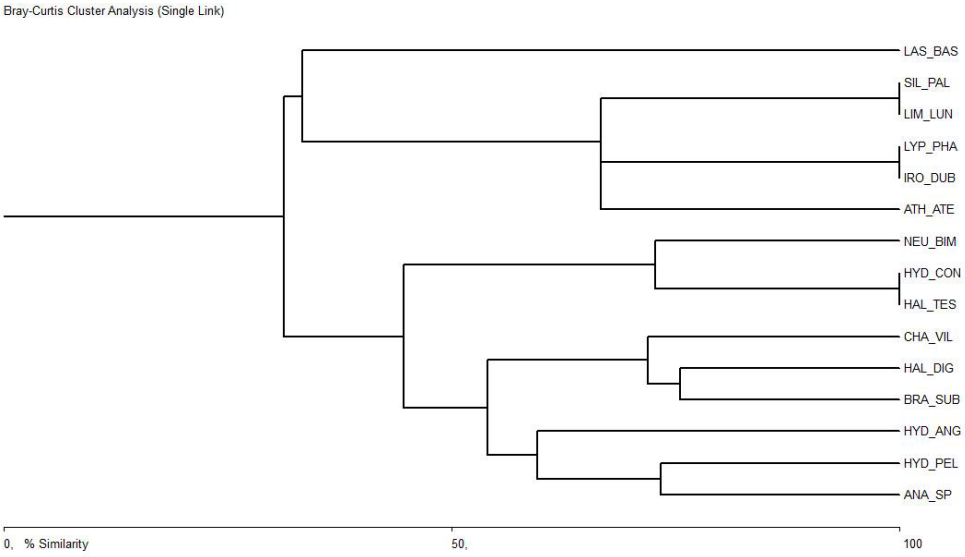

Fig. 4. The diagram of co-occurrence of caddisfly species above the Zemborzyce Reservoir. Abbreviations of species/taxa – see Table 1.

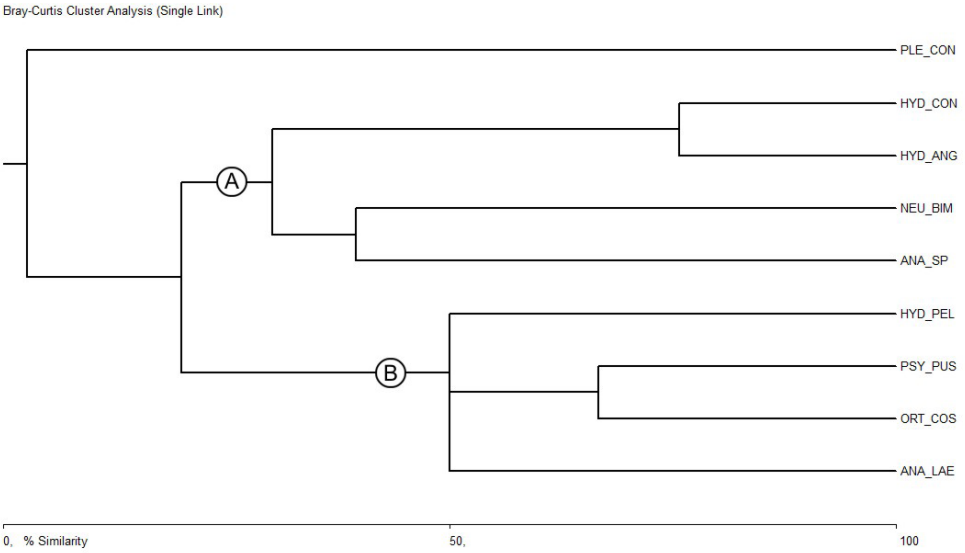

Fig. 5. The diagram of co-occurrence of caddisfly species below the Zemborzyce Reservoir. Abbreviations of species/taxa – see Table 1.

Neureclipsis bimaculata (6%). Statistical methods (ANOVA Kruskal-Wallis test) confirmed that the differences in numbers of those eudominants above/below the reservoir were statistically important (*H.a.* – H (1, N = 34) = 16,56834 p <,0001, *H.c.* – H (1, N = 34) = 5,859756 p =,0155), *N.b.* – H (1, N = 34) = 6,995420 p =,0082).

Due to the confirmed differences between the faunas up and downstream of the reservoir, in order to distinguish caddisfly assemblages typical of a medium-sized upland river, two separate co-occurrence analyses were performed. At the sites above the reservoir (Fig. 4) many species form groups with high or medium values of similarities; however, it is hard to find clear relationships associated with habitat parameters (together with the distribution in longitudinal profile of a river) or type of feeding between the taxa. In turn, in the analysis performed for the sites below the dam (Fig. 5), characteristic assemblages can be evidently distinguished: the strongest similarity was between *Hydropsyche contubernalis* and *H. angustipennis*. Together with *Neureclipsis bimaculata* and *Anabolia* sp. they form the separate block of taxa (A at the diagram) strongly connected with stony substratum in the studied river. The second group is composed of the species more diversified with respect to the feeding type and microhabitat distribution (B) – essential is the fact of the occurrence of the third filter feeder from the genus *Hydropsyche* which indicates its slightly different preferences from the species from the assemblage A. An entirely separated species is crenophilous *Plectrocenmia conspersa* – its occurrence may result from the fact that in the past side springs of the River Bystrzyca were situated at site 6.

Some data presented above indicate that the fauna of caddisflies above the reservoir is more diversified while below the dam the number of taxa decreases but at the same time the number of specimens of the species little sensitive to the changes described in the introduction increases, often significantly. In the literature, there are a number of very similar results referring to the fauna inhabiting the river stretches below and above reservoirs: for example, Dukowska [2000] analyzing the selected groups of macrobenthos, including caddisflies, in the similar arrangement on the River Warta found that in the stretch above the reservoir more diverse group of organisms appeared than below, where, in turn, high densities of insects such as Trichoptera and Simuliidae occurred but the number of taxa declined significantly. In similar but more detailed studies of the River Saranac (USA), Hartman and Mihuc [2008] found above the dam reservoir 10 genera of Trichoptera which comprised just over ¼ of all collected aquatic invertebrates while below the dam the number of genera dropped by half and the number of specimens was more than half of all collected invertebrates. What is more important, the number of filter feeding Trichoptera increased from 23% above the reservoir to 52% below. In the River Bystrzyca the trophic structure of caddisflies was as follows: in general 6 trophic groups according to the way of obtaining the food were distinguished (Tab. 1). The percentage shares of particular groups above/below the reservoir were: predators 3.7/6.2, filter feeders 45.8/91.7, shredders 46.1/1.7, xylophages 0.1/0, scrapers 0.3/0.08, algal piercing species 0/0.16. On the basis of these data it is clearly seen that just like in the American studies, in the River Bystrzyca the number of filter feeders increased by half (total number of filter feeders up and downstream of the dam is also statistically important (H (1, N= 34) = 11,19239 p =,0008); however, at the same time a drastic decrease in number of shredders below the reservoir was

Tab. 1. Caddisflies (Trichoptera) of the River Bystrzyca upstream (sites S 1-S 3) and downstream (sites S 4-S 6) of the Zemborzycki Reservoir, dominance (%) at particular sites. FT (feeding type): F – filter feeder, P – predator, SC – scraper, SH – shredder, A – algal piercing species, X – xylophagous species.

No.	Species/Taxon	S 1	S 2	S 3	S 4	S 5	S 6	FT
1.	*Hydropsyche angustipennis* (Curt.)	-	2.04	45	48.6	54.4	67.4	F
2.	*H. contubernalis* McL.	-	-	3.77	14.4	38.5	22.7	F
3.	*H. pellucidula* (Curt.)	9.47	16.3	12.6	-	0.34	-	F
-.	*Hydropsyche* sp. juv.	-	-	-	7.53	1.9	2.3	F
4.	*Neureclipsis bimaculata* (L.)	-	-	6.6	15.8	4.47	7.09	P
5.	*Plectrocnemia conspersa* (Curt.)	-	-	-	-	-	0.71	P
6.	*Psychomyia pusilla* (Fabr.)	-	-	-	-	0.11	-	SC
7.	*Lype phaeopa* (Steph.)	-	-	0.31	-	-	-	SC
8.	*Orthotrichia costalis* (Curt.)	-	-	-	0.68	0.11	-	A
9.	*Athripsodes aterrimus* (Steph.)	1.05	-	0.31	-	-	-	SH
10.	*Silo pallipes* (Fabr.)	1.05	-	-	-	-	-	SC
11.	*Ironoquia dubia* (Steph.)	-	-	0.31	-	-	-	SH
12.	*Chaetopteryx villosa* (Fabr.)	1.05	25.2	-	-	-	-	SH
13.	*Anabolia laevis* (Zett.)	-	-	-	1.37	-	-	SH
-.	*Anabolia* sp.	20	19.7	24.5	11.6	0.11	-	SH
14.	*Limnephilus lunatus* Curt.	1.05	-	-	-	-	-	SH
-.	*Limnephilidae* juv.	56.8	6.8	-	-	-	-	SH
15.	*Halesus digitatus* (Schrank)	7.37	12.2	0.63	-	-	-	SH
16.	*H. tesselatus* (Ramb.)	-	-	3.77	-	-	-	SH
-.	*Halesus* sp.	-	-	1.26	-	-	-	SH
17.	*Brachycentrus subnubilus* Curt.	-	15.6	0.94	-	-	-	F
18.	*Lepidostoma basale* (Kol.)	2.11	2.04	-	-	-	-	X
-.	PIE Index	0.62	0.82	0.71	0.69	0.55	0.48	-

noted which may be related with the less developed zone of swamp vegetation below the dam at the studied sites.

The phenomenon of the increase in number of individuals of the genus *Hydropsyche* in the rivers below dam reservoirs confirmed in the case of the River Bystrzyca is explained above all by increased availability of high quality suspended food particles for these filter feeders as well as favorable thermal conditions for some species [Giller, Malmqvist 1998; Poff et al. 1997; Wiederholm 1984]. The content of suspended solids given by Regional Inspectorate of Environment Protection (WIOŚ) in Lublin in the years of the studies [Bańkowska-Królikowska et al. 2002; Bańkowska-Królikowska et al. 2003; Burdzicki et al. 2004] above and below the reservoir, clearly indicated increased values of this parameter below the dam. Not without significance may also be a matter of algal and cyanobacterial blooms in the reservoir [Pawlik-Skowrońska et al. 2004] – for filter feeders and algae piercers, including the genus *Hydropsyche*, this may be the additional food base.

The obtained results can be compared with available trichopterological data from the rivers flowing through lakes in the Masurian Lake District [Czachorowski 1988] and the Pomorskie Lake District [Raczyńska et al. 2000]; however, the comparisons must be of general nature because these data refer to lowland rivers with different species composition associated with regional diversity of caddisfly fauna. For example, in the River Pasłęka, above and below Lake Isąg, the number of taxa was 18 and 34 respectively, and the number of filter feeding species was significantly higher below the lake. However, in the case of the second lake on this river – Lake Sarąg – the results were different: the number of taxa above and below the lake was similar (34 and 32) but only *Hydropsyche siltalai* increased in number below the lake while *H. pellucidula* remained at the same level and *H. angustipennis* disappeared below the lake. These results may suggest that natural lakes have less impact on the fauna than dam reservoirs. A similar study arrangement in the second lake-district in the case of the River Rurzyca showed similar number of species above and below Lake Trzygłowskie, but the increase in the number of *H. angustipennis* below the lake was significant (77 times). In the River Tywa, two lake complexes were studied: in the first case the number of taxa decreased below the lake (4 times), in the second it increased (5 times). The number of *H. angustipennis* below the lakes – similarly – dropped 23 times, and in the second case it increased three times. These results may suggest that natural lakes have less impact on the fauna than dam reservoirs and it depends on many additional parameters in particular cases.

Caddisflies are good indicators of many unfavorable processes in aquatic environments due to their high diversity – they are numerous, occupy different habitat (microhabitat) and trophic niches [de Moor, Ivanov 2008]. The creation of a dam reservoir interferes and reduces the stability of ecological systems [Jankowski 2004]; this is also confirmed at smaller scale, at the level of an order or even species assemblages of Trichoptera. Therefore the family *Hydropsychidae* – most visibly and rapidly responsive to the changes that took place in the River Bystrzyca – is worth analyzing in detail. The general distribution of its representatives in a longitudinal profile of a river (starting from a spring to a mouth) is as follows: *H. pellucidula* (rhithral and epipotamal zone), in the farther course of a river *H. contubernalis* (most numerous in hyporhithral and epipotamal) with widespread *H. angustipennis* (lower rhithral, epi and metapotamal) [Edington, Hildrew 1995, Graf et al. 2008]. Two last species are regarded as typical of stretches below lakes and reservoirs [Wallace 1991]. The number of *H. angustipennis* below the dam increased 4.5 times in comparison to the sites above the reservoir, while *H. contubernalis* increased 33 times. All the examined sites of the middle River Bystrzyca represent epipotamal zone where three species occur together which corresponds with the cited literature data.

The family *Hydropsychidae* is regarded as one of the most resistant to pollution families among Trichoptera [Bonada 2004]. Tolerances of individual species of *Hydropsychidae* relating to physical and chemical water parameters as well as pollutants are closely associated with their distribution in the studied arrangement: river-reservoir-river. Typical for faunas below dam reservoirs is the presence of pollution tolerant taxa [Hartman, Mihuc 2008]. Below the dam, the two most resistant of the three identified hydropsychids in the River Bystrzyca occurred numerously, i.e. *H. angustipennis* and *H. contubernalis*: the first one is the indicator of moderate organic pollution of a river, and the second one of anthropogenic pollution [Becker 1987; Dohet 2002; Edington, Hildrew 1995]. In the River Bystrzyca during the studies, to the factors influencing negatively water quality below the dam belonged the concentration of chlorophyll “a” and BOD5 (organic matter loads), slightly less important were phosphates [Bańkowska-Królikowska et al. 2002; Bańkowska-Królikowska et al. 2003; Burdzicki et al. 2004]. *H. angustipennis* is a species resistant to high temperatures of water, low oxygen concentrations and slow current [Edington, Hildrew 1995, Stuijfzand et al. 1999]. H. contubernalis is well adapted to the decrease in oxygen content and relatively slow current [Becker 1987]. Similar preferences of these species resulted in the fact that they were in the same assemblage with high values of similarity (Fig. 5, assemblage A). In turn, third species, *H. pellucidula*, is clearly typical of the stretch above the reservoir; however, it cannot be regarded as a characteristic one for the entire rhithral zone in this river because in the studies of Kornijów and Lachowska [2002] on the invertebrates of epirhitral of the River Bystrzyca it was not recorded (*Hydropsychidae* were not found at all). During the discussed studies this species was found above the reservoir not numerously but regularly – the reason for the decrease in its abundance below the dam is obviously the reservoir which became a barrier for it probably due to the changes of water properties below the dam. The same results were obtained by Czachorowski [1988] while studying caddisflies in the River Pasłęka, above and below a dam reservoir – Pierzchalskie Lake; however, the results obtained for *H. angustipennis* which was also found in this river are completely different – it was absent in Pasłęka below the dam. *H. pellucidula*, in comparison to *H. contubernalis*, needs higher current velocity and higher oxygen content [Becker 1987]; moreover, it is sensitive to phosphates and ammonium but tolerant to suspended solids [Bonada et al. 2004] which also corresponded with the data on water quality of Regional Inspectorate of Environment Protection. At sites below the reservoir, especially 5 and 6, the influence of the city can worsen the habitat conditions of living organisms of the River Bystrzyca. Studies on caddisflies of the farther urban stretch of the river would undoubtedly bring a lot of valuable information about the condition of this river in its lower course.

4. CONCLUSIONS

On the basis of obtained results it can be concluded that:

1. fauna of Trichoptera of the River Bystrzyca has been clearly modified by the dam reservoir although some changes are also visible at the site above the dam which can result from the phenomenon of backwater,

2. comparing the sites up and downstream of the Zemborzyce Reservoir the following results were found below the dam: decrease in number of taxa and biodiversity, increase in number of specimens of pollution tolerant species, disorder of dominance and trophic structure – the increase in the number of filter feeders by 50% and almost complete disappearance of shredders,
3. the phenomena mentioned above result from the presence of a dam reservoir but not the character of particular sites which are hydromorphologically very similar,
4. the discussed disturbances of the fauna are visible at the level of assemblages and species, and caddisflies as bioindicators can be a visible signal of negative changes for the whole riverine biocenosis.

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