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Use of the preliminary Jedlice Reservoir for water protection in the Turawa Reservoir on the Mała Panew River

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Key words: preliminary reservoir, physico-chemical parameters, macroinvertebrates, water quality

Abstract

Physico-chemical variables of water quality and benthic community structure were assessed in order to evaluate the need for reinstating the use of the preliminary Jedlice Reservoir. The waters of the Mała Panew River carry a significant load of nutrient compounds, particularly nitrates and phosphates. Deteriorating water quality results in permanent algal blooms and changes in the macrofauna structure. It was confirmed that the use of a preliminary reservoir could contribute to the protection of the Turawa Dam Reservoir against pollutants transported by the waters of the Mała Panew River.

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INTRODUCTION

The Turawa Reservoir is one of three dam reservoirs located within the Oder River basin in Opole Province. Created in the lower course of the Mała Panew River, it has been functioning since 1948 as a multipurpose reservoir. The reservoir water is used for, among other purposes, river navigation, hydro-power engineering, fishery, and recreation. Similarly to other lowland reservoirs, the Turawa Reservoir has been subjected to marked nutrient enrichment (Kasza 1995). According to Kajak (1995), this results from the high ratio of the reservoir basin area to the reservoir water-table. One solution to improve water quality is the use of a preliminary reservoir. The purpose of a pre-impoundment is to cumulate contamination transported by river waters and enhance self-purification processes. Consequently, waters flowing into the main dam reservoir contain a lower pollutant load as well as lesser amounts of suspended matter and bed traction load (Benndorf et al. 1975, Gołdyn 1994, Paul 1995). The Jedlice preliminary reservoir has not been functioning properly for many years. Due to its poor technical condition, the diversion weir is no longer operational, which means that water lifting is impossible during low river stages.

The aim of the study was (1) to assess the physico-chemical water quality, (2) assess the macroinvertebrate community structure and its changes in relation to water characteristics, (3) to evaluate possibilities of reactivating the use of the preliminary Jedlice Reservoir to assist in water pollution control in the Turawa Reservoir.

MATERIALS AND METHODS

For the purpose of the study, four sampling sites were located in the vicinity of the Turawa and Jedlice reservoirs and at the inflow of the Mała Panew River into the pre-impoundment (Fig. 1). The Mała Panew River and its tributaries drain an area of 2,037.4 km^2 of which about 51% is forested. The drainage basin of the Turawa is 1,424 km^2 and the ratio of the reservoir water-table to its drainage area is 1:69. The basic morphometric parameters of the investigated reservoirs are presented in Table 1. The Mała Panew River, 30 km upstream of the reservoirs, is characterized by a medium pollutant load. The mean values of nutrient compounds in the 2002-2005 period corresponded to classes II – III. However, temporary increases in the amount of nutrient compounds have also been recorded. Total phosphorus and ammonium nitrogen reached maximum concentrations of 1.10 and 1.82 mg dm^{-3}, respectively (Report 2005).

Surface water samples were collected monthly from April to September 2006. The analysis of 11 physical and chemical parameters was performed

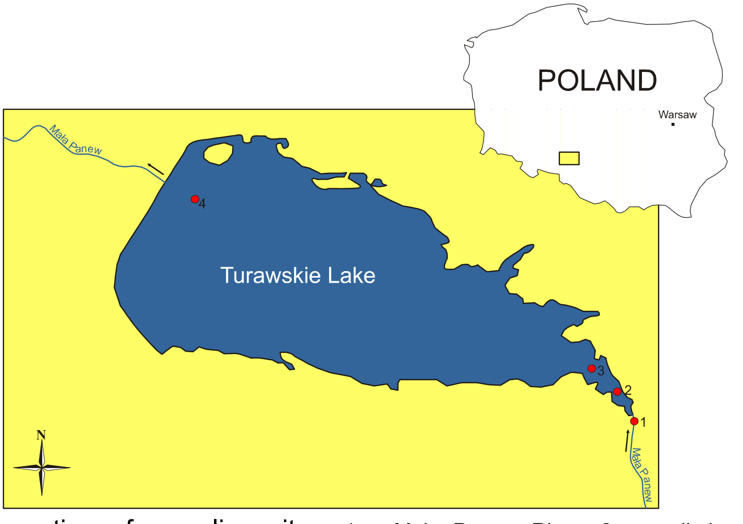

Fig. 1. Location of sampling sites: 1 – Mała Panew River; 2 – preliminary Jedlice Reservoir; 3 – Turawa Reservoir, near the diversion weir; 4 – near the dam.

Table 1

Morphometric and hydrological data of the investigated reservoirs.

Parameters	Turawa reservoir	Jedlice pre-reservoir
Datum of the highest water level [m a.s.l.]	177.03	177.48
Datum of the mean water level [m a.s.l.]	176.35	176.50
Max. water-table surface [ha]	2080	37.5
Mean water-table surface [ha]	1966	33.2
Max. capacity [mln m^3]	106.20	0.75
Mean capacity [mln m^3]	92.50	0.60
Mean depth [m]	5.1	1.8
Reservoir length [m]	7500	750
Reservoir width [m]	2500-4000	500
Water retention time [days]	151.6	0.98
Mean water discharge [$m^3 s^{-1}$]	7.06	

according to Polish Standard Methods (Hermanowicz et al. 1999). The following water quality variables were selected: temperature, pH, conductivity, suspended matter, dissolved oxygen (DO), biochemical (BOD) and chemical oxygen demand (COD), phosphates, nitrite, nitrate, and ammonium nitrogen. The physico-chemical water quality assessment was based on an ordinance by the Minister of the Environment (2004), according to the criterion of the worst value of particular variables.

Benthic macroinvertebrates were collected twice (July and September 2006) with an Eckman bottom sampler. Three replicates were collected at each site. The samples were rinsed over a sieve (mesh size 0.5 mm) and all macroinvertebrates were sorted carefully. Organisms were identified to the family (Trichoptera and Diptera) and species levels, except Oligochaeta and Hydracarina, which were treated as groups. The dominance structure was based on the assumption that the dominant taxa population constitutes at least 10% of the whole macroinvertebrate community.

RESULTS AND DISCUSSION

Physico-chemical analysis

The results of the analysis of physical and chemical water variables are presented in Table 2. The values obtained indicated a significant inflow of nutrient compounds with the waters of the Mała Panew River, particularly nitrate nitrogen and phosphates. The amount of both compounds was the highest at the river inflow into the pre-impoundment and gradually decreased towards the Turawa Dam. This tendency was noted nearly throughout the study period, although concentrations of both compounds displayed monthly variations. However, a significantly increased phosphate content at site 4 was recorded in September (Fig. 2). The mean amount of nitrate nitrogen and phosphates dropped by approximately 19% and 20%, respectively, in the Jedlice pre-impoundment (site 2) and by an additional 66% and 29% in the Turawa Reservoir (site 4). On the other hand, values of BOD and COD increased by 80% and 69%, respectively, from sites 1 to 4. Lower water nitrate and phosphate content in the Turawa Reservoir was accompanied by heavy algal blooms which occurred from July to September. Simultaneously, a remarkable increase in pH level up to a value of pH 9.9 at site 4 was recorded. It should be stressed that while phosphorus is a limiting factor for biomass production, the eutrophication process itself depends upon a great number of factors (Chróst 1995; Zalewski, Wagner 1995; Stambuk-Giljanovic 2001). From a management point of view, water retention time is an important aspect to consider when evaluating the degree of eutrophication of reservoir water. According to Bendorf et al. (1975), pre-impoundments have a positive effect on reservoir water quality, leading to a significant reduction in phosphate concentrations. Phosphate elimination efficiency obtained for 13 reservoirs in Germany, ranged from 14% to 66%, respectively, at 0.5-day and 12-day water retention times.

The percentage of analyzed parameters in particular water quality classes also revealed the gradual degradation of water quality from site 1 to 4 (Fig. 3). Although sediment characteristics were not included in the current study, it can

Table 2

Values of the physico-chemical parameters at particular sampling sites.

Parameter	Site 1			Site 2			Site 3			Site 4		
	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean
NO_3^- [mg dm^{-3}]	1.20	17.92	11.07	0.44	15.87	8.86	0.62	18.18	10.40	0.53	8.18	2.99
NO_2^- [mg dm^{-3}]	0.036	0.49	0.16	0.033	0.42	0.14	0.033	0.40	0.13	0.026	0.36	0.13
NH_4^+ [mg dm^{-3}]	0.11	0.95	0.40	0.22	0.84	0.49	0.20	0.82	0.46	0.06	0.87	0.33
PO_4^{3-} [mg dm^{-3}]	0.26	0.45	0.35	0.16	0.36	0.28	0.10	0.34	0.27	0.10	0.43	0.20
DO [mg dm^{-3}]	7.12	9.56	8.51	7.32	10.16	8.79	7.62	11.98	9.37	8.54	13.22	10.34
BOD_5 [mg dm^{-3}]	1.22	2.23	1.82	1.93	5.10	2.65	1.00	3.50	2.00	1.21	7.10	3.58
COD [mg dm^{-3}]	12.29	23.60	19.11	16.51	36.80	23.08	12.29	39.20	22.01	12.57	48.80	34.08
Susp matter [mg dm^{-3}]	1.0	12.0	4.8	2.0	36.0	15.7	3.0	21.0	7.8	8.0	31.0	18.5
pH	7.10	8.12	–	7.00	8.23	–	7.00	8.31	–	7.60	9.95	–
Conductivity [µS cm^{-1}]	328	460	399	351	431	389	343	453	391	294	385	319
Temperature [ºC]	8.5	25.2	17.5	9.2	27.0	18.6	9.4	25.0	18.4	9.9	24.9	18.9

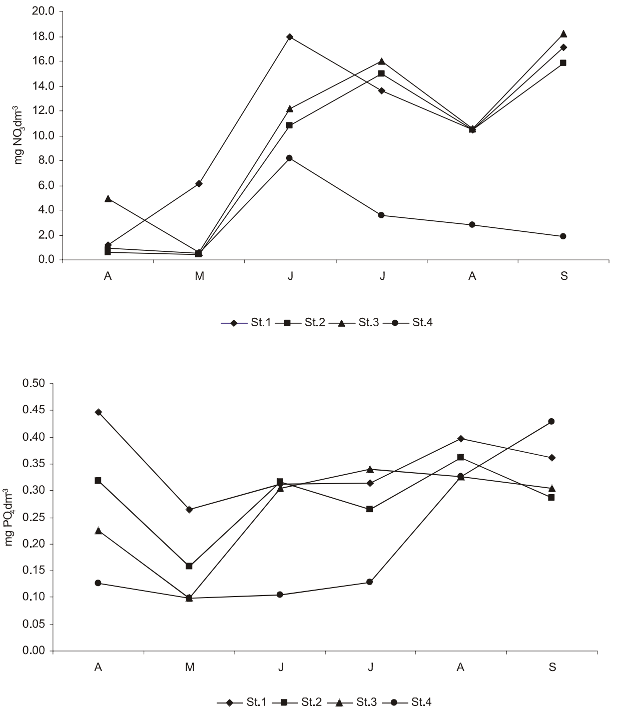

Fig. 2. Nitrate (a) and phosphate (b) content in water samples at sites 1-4 (April – September).

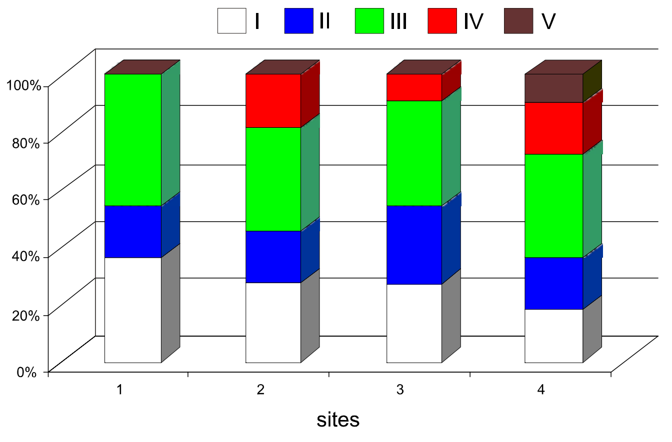

Fig. 3. Percentage of the analyzed parameters in particular water quality classes at sites 1-4

be anticipated that the intensity and duration of internal loading have a pronounced impact on the nutrient concentrations in water and subsequently on water quality in the Turawa Reservoir. Increasing temperatures and biological activity during spring and summer are likely to enhance phosphorus transport rates from deeper layers of the sediment (Kajak 1995). Enhanced temperatures also stimulate the mineralization of organic matter, thereby releasing inorganic phosphate into the interstitial water, and then, depending on the sorption capacity of the sediment, to the overlying water. Furthermore, photosynthetically elevated pH in eutrophic waters can increase release rates through the increased solubility of iron-phosphate compounds (Søndergaard et al. 1999).

Analysis of benthic macroinvertebrates

The benthic community was represented by the following groups of invertebrates: Oligochaeta, Hirudinea, Gastropoda, Trichoptera, Ephemeroptera, Odonata, Megaloptera, Coleoptera, Diptera, and Hydracarina. A total of 30 taxa were found. The results of qualitative and quantitative analysis revealed a reduction in biodiversity from sites 1 to 4. Sampling sites differed with respect to the type of sediments, as deposition within the reservoir involved two physically and genetically distinct processes including silting and sand-up (Teisseyre 1983). Thus, sandy sediments were typical for the river mouth and the preliminary Jedlice Reservoir, whereas black sapropelic mud occurred near the Turawa Reservoir Dam. Anoxia in mud drastically restricted macroinvertebrates. At site 4, macroinvertebrates were represented only by the larvae of *Chironomus f. thummi-plumosus*, and the density of its population varied from 50 to 110 ind. m^{-2}. The total number of taxa identified at sampling sites 1-3 was 17, 15 and 11. At the same time, the number of individuals increased from approximately 480 ind. m^{-2} (site 1) to 810 ind. m^{-2} (site 3). This resulted, firstly, from the increase in numbers of Chironomidae midges, which are known to be a pollution-tolerant taxa (Welch and Lindell 1992). Negative changes in the macroinvertebrate community were also revealed by the structure of the dominant taxa (Fig. 4) as well as the percentage of subfamilies belonging to Chironomidae (Fig. 5). The macrofauna at sites 1 and 2 was characterized by three dominant taxa. Caenidae mayflies and Brachycentridae caddies-flies that mainly inhabit woody debris, disappeared in the lower part of the preliminary Jedlice Reservoir (site 3). Only a few individual larvae of dipteran Simuliidae, which attach to higher plants in large quantities, were present at site 3. The only taxa dominating at the all investigated sites was Chironomidae. However, the percentage of particular subfamilies varied among the sites. The decrease in the number of Orthocladiinae and, concurrently, the increase of Chironominae, indicated not only changes in ecosystem features (potamic vs. lacustrine), but also in water quality (Kownacki et al. 2000).

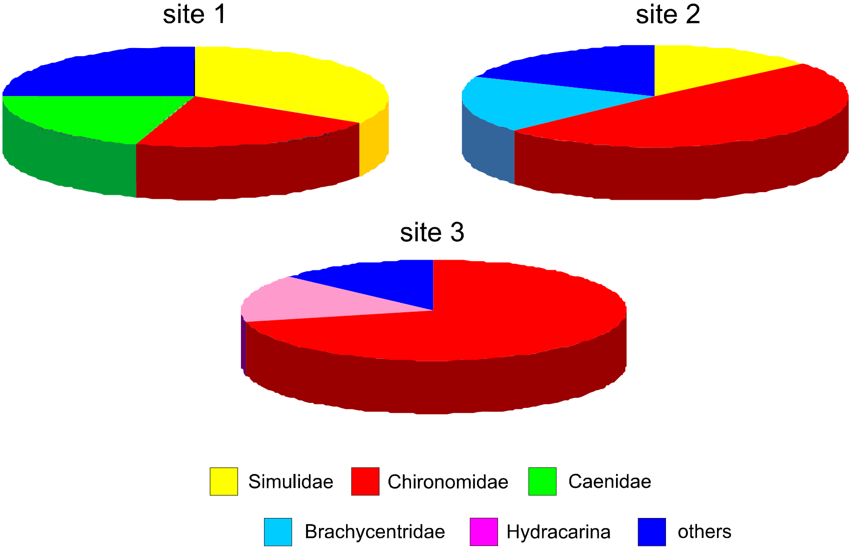

Fig. 4. The dominance structure of the macroinvertebrate communities at sites 1-3.

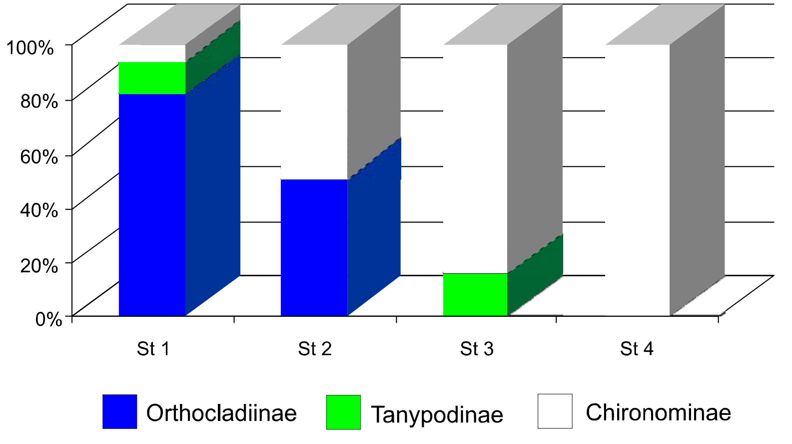

Fig. 5. Percentage of subfamilies belonging to Chirnomidae at sites 1-4.

CONCLUSIONS

In conclusion, the results indicate that the Turawa Dam Reservoir has been subjected to eutrophication due to substantial nutrient enrichment introduced by the waters of the Mała Panew River as well as by sewage inflows from tourist centers. Water quality deterioration has influenced changes in the benthic community structure. Increased pollution impoverished the macroinvertebrate variety, and even caused the disappearance of whole taxonomic groups. However, abundance increased due to the significantly higher contribution of pollution-tolerant taxa. Apart from improvements in water supply and sewage disposal in the reservoir basin, the reactivation of the preliminary Jedlice Reservoir could be extremely important for water quality improvement in the Turawa Dam Reservoir. Although the size of the preliminary Jedlice Reservoir seems rather small in comparison with river flow, its proper usage might help in eliminating at least some of the water pollutants. Of course, further study and water quality monitoring is required to estimate the efficiency of the preliminary Jedlice Reservoir.

REFERENCES

Benndorf J., Pütz K., Krinitz H., Henke W., 1975, *Die Funktion der Vorsperren zum Schutz der Talsperren vor Eutrophierung,* Wasserwirtschaft. Wassertechnik, 25 (1): 19-25

Chróst R., 1995, *Importance of microbiological processes for the intensity of the appearance of eutrophication symptoms* [in:] *Biological processes in the conservation and restoration of lowland reservoirs,* Ed. M. Zalewski, PIOŚ, Łódź, pp. 71-84, (in Polish)

Gołdyn R., 1994, *The role of preliminary reservoirs in the protection of the Maltański Reservoir*, Arch. Hydrobiol. Beih., 40: 253-62

Hermanowicz W., Dojlido J., Dożańska W., Koziorowski B., Zerbe J., 1999, *Physico-chemical analysis of water and sewage,* Warszawa, Arkady, pp. 556, (in Polish)

Kajak Z., 1995, *Eutrophication of lowland reservoirs* [in:] *Biological processes in the conservation and restoration of lowland reservoirs,* Ed. M. Zalewski, PIOŚ, Łódź, pp. 33-42, (in Polish)

Kasza H., 1995, *Eutrophication symptoms vs ecological succession in Goczałkowice Reservoir* [in:] *Biological processes in the conservation and restoration of lowland reservoirs,* Ed. M. Zalewski, PIOŚ, Łódź, pp. 143-54, (in Polish)

Kownacki A., Margreiter M., Kawecka B., Kwandrans J., 2000, *Effect of treated wastes on cyanobacteria, algae, and macroinvertebrate communities in an alpine stream*, Acta Hydrobiol., 42 (3/4): 215-30

Ordinance, 2004, *Ordinance of the Minister of Environment of February 11, 2004, concerning surface and groundwater quality classification, as well as methods of monitoring, data interpretation, and water quality state presentation*, Warszawa, pp. 1729-42, (in Polish)

Paul L., 1995, *Nutrient elimination in an underwater pre-dam,* Int. Rev. Hydrobiol., 80 (4): 579-94

Report, 2005, *Report on the environmental state in Opole Province*, Opole, Biblioteka Monitoringu Środowiska, pp. 184, (in Polish)

Sondergaard M., Jensen J.P., Jeppesen E., 1999, *Internal phosphorus loading in shallow Danish lakes,* Hydrobiologia, 408/409: 145-52

Stambuk-Giljanovic N., 2001, *The quality of water in the Busko Blato reservoir,* Envir. Mont. Ass., 71: 279-96

Teisseyre A.K., 1983, *Bottom sediments of Turawskie Lake: a geological study*, Geologia Sudetica, 18 (1): 21-60, (in Polish)

Welch E.B., Lindell T., 1992, *Ecological effects of wastewater,* Chapman & Hall, London, pp. 425

Zalewski M., Wagner I., 1995, *Potential impact of global climate warming on biological processes in reservoirs* [in:] *Biological processes in the conservation and restoration of lowland reservoirs,* Ed. M. Zalewski, PIOŚ, Łódź, pp. 177-88, (in Polish)