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Phytoplankton species diversity of the Lower Vistula from Wyszogród to Toruń

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Key words: phytoplankton, diatoms, green algae, the Vistula River, the Włocławek Reservoir, species diversity

Abstract

In this paper, the results of research on phytoplankton species composition along the 145 km section of the Lower Vistula are presented. The research was carried out during the growing season in 1998. All sites were located in the mainstream, both in the river and in the dam reservoir, which is situated in the middle part of the studied river section. As regards the number of species, diatoms and green algae were the most numerous. Most of the species were identified at the site located above the dam reservoir. The fewest number of species were identified at the sites below the reservoir. Damming the river, and therefore changing the water flow velocity, had a clear effect on the species composition and diversity of plankton algae.

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INTRODUCTION

Biodiversity is one of the essential characteristics of ecosystems. In rivers, the species diversity of phytoplankton is usually high, affected by numerous species of diatoms coming from periphyton and benthic communities. Lakes, through which a river flows, as well as meanders, dead river arms and artificial reservoirs built on rivers are all frequent sources of plankton. These kind of "nurseries" enrich a river with new species. Dam reservoirs of long retention time are particularly important, as rich and diverse plankton communities develop there. In reservoirs of short retention time and high water turbulence, poor development of phytoplankton is recorded (Kawecka and Eloranta 1994).

The aim of the present paper was to describe the phytoplankton species composition of the Lower Vistula and ascertain whether the rheolimnic reservoir, existing since 1970, induces changes in phytoplankton. Quantitative issues are treated in a separate publication.

Description of the study area

The Vistula River is the biggest river in Poland; its total length amounts to 1068 km, whereas the drainage area is about 194,000 km^2. Circa 170,000 km^2 are situated within the borders of Poland, which constitutes approximately 55% of the country's area (Jarzębińska and Majewski 1994, Głogowska 2000). The distribution of the drainage area is outstandingly asymmetrical – about 73% falls to right-bank tributaries (Fig. 1). The Vistula is a lowland river throughout almost its entire course.

The Lower Vistula is the longest section at 391 km long, between 550 and 941 km of the river course. Average annual flows range from 900 to 1050 m^3 s^{-1}.

The Włocławek Reservoir was built in 1970. Although plans called for a cascade of reservoirs on the Lower Vistula, this was the only one built. It is the biggest dam reservoir in Poland with respect to area, and the second largest (after the Soliński Reservoir) with respect to capacity (Głodek 1985). The Vistula brings more than 98% of the water falling into the reservoir, so the inflow is basically equal to the outflow. A short retention time, regular shape, a considerable length and small width of the reservoir emphasize its fluvial, channel character (Giziński et al. 1993). It is a specific superrheolimnic reservoir, more similar to a somewhat slowed down river rather than to a typical dam reservoir (Giziński and Falkowska 2003).

A characteristic feature of the Włocławek Reservoir is a significant hydrological variation (Giziński et al. 1989). It results from the variation in flows during the year as well as in the long-term cycle, but also from the cyclic

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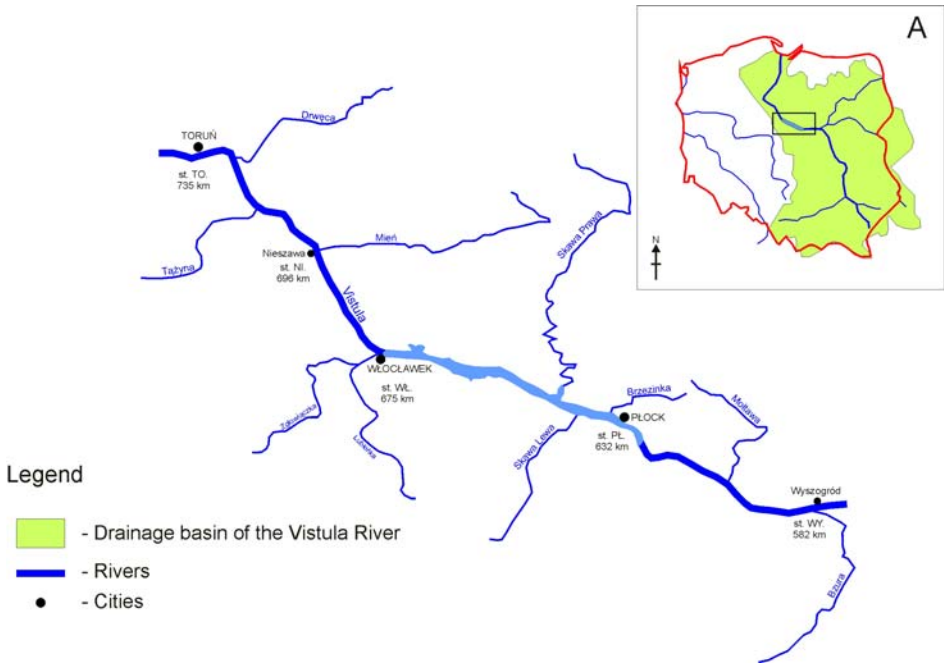


Fig. 1. Map of the Lower Vistula, the section from Wyszogród to Toruń. **A-** Map of Poland with the drainage basin of the Vistula River (marked green).

operation of the Włocławek hydroelectric power plant (twice a day) as well as from the particular susceptibility to weather conditions. The main axis of the reservoir runs from east to west, in line with the prevailing winds which blow from the west, increasing their influence on the dynamics of water masses.

Results of chemical studies on the water and bottom sediments of the Włocławek Reservoir are presented in the papers by Kentzer and Giziński (1995) and Kentzer et al. (1999), as well as Kentzer (2000). In the eighties, concentrations and loads of biogens in the water of the Vistula River were very high. This significant overload of the Vistula water classified this river among hypertrophic watercourses. In the nineties, a noticeable improvement followed in the water quality of the reservoir, as a result of improvements in the water and wastewater management in the entire river basin (including the construction of new wastewater treatment plants and modernization of existing treatment plants).

Slowing down of the flow brings about deterioration of conditions in the Włocławek Reservoir only with respect to oxygen concentration. Along the section from Płock to Włocławek, the oxygen content decreases, and yet even in

summer, when the drops are highest, dangerously low concentrations were seldom recorded. More severe deficiencies of oxygen, causing even local anoxias, take place at high temperatures, low flows and in windless weather but only in the shallow pool zone. Below the dam, the oxygen content in the water increases (Kentzer 2000).

MATERIALS AND METHODS

The data presented in this paper came from 5 sites located along the Lower Vistula, between kilometers 582 and 727 of the river course. Location of the sites is presented in Fig. 1.

1. Wyszogród (WY): the site above the reservoir, at 582 km of the river course (50 km. upward from the site Płock), representing the mainstream zone of the freely flowing river above the Włocławek Reservoir; depth 2 m.
2. Płock (PŁ): - the upper part of the Włocławek Reservoir, at 632 km of the river course, 12 – 14 km downward from the maximum range of the reservoir's backwater; depth 3 – 5 m, the flow velocity about 0.6 m s^{-1}.
3. Włocławek (WŁ): the dam, at 675 km of the river course, on the premises of the reservoir, in the vicinity of the dam; depth of 12 – 13 m, the flow velocity about 0.2 m s^{-1}.
4. Nieszawa (NI): 21 km below the dam (696 km of the river course); depth 2 m.
5. Toruń (TO): 55 km below the dam (727 km of the river course); depth 3.5 m.

The research, the results of which are presented in this paper, was conducted during the months of April, June, July, August and November of 1998.

Qualitative samples of phytoplankton were collected from the surface layer, i.e. from the depth of ca. 0.5 – 1.0 m with a plankton net no. 25 through multiple horizontal and vertical hauls. Collected samples were poured into a dark glass bottle and preserved with 4% formalin.

Qualitative determinations were carried out under the light microscope Nikon Alphaphot-2 at ×750 magnification. Diatoms were determined at ×1000 magnification, on the basis of the cell wall structure. To this end, permanent preparations were prepared after burning the cell content and organic admixtures present in the material. The material was boiled in 30% perhydrol (H_2O_2). From the material treated that way, permanent preparations were prepared in the synthetic resin Styrax (Gum Storax) of Sigma – Aldrich production.

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RESULTS

During the research in the Lower Vistula, along the distance from Wyszogród to Toruń, 279 phytoplankton taxa (mainly species) were recorded: Cyanoprocaryota – 24, Cryptophyta – 3, Dinophyta – 2, Chrysophyceae – 5, Bacillariophyceae – 129, Euglenophyta – 9, Chlorophyta – 107. Forty taxa were identified exclusively within the reservoir, i.e. they were not recorded at the sites in Wyszogród, Nieszawa and Toruń.

The species most frequently encountered (frequency from 75 to 100%) in the Lower Vistula are presented in Table 1.

Table 1

The most frequently encountered species (75 - 100%) in the Lower Vistula.

Species	An average count (1000 ind. dm^{-3})	Ecological characteristic
Blue-green algae		
Microcystis aeruginosa	3.996	cosmopolitan. pelagic
M. incerta	0.378	cosmopolitan. pelagic
Diatoms		
Achnanthes lanceolata	0.001	cosmopolitan
Asterionella formosa	17.179	cosmopolitan. pelagic
Aulacoseira granulata	118.039	cosmopolitan. pelagic
Cocconeis placentula	0.001	epontic
Cyclotella bodanica	51.141	pelagic
C. meneghiniana	1628.330	cosmopolitan. littoral. seldom in plankton
Cymatopleura solea	0.001	cosmopolitan. littoral. sometimes in plankton
Diatoma vulgaris	0.0011	cosmopolitan. littoral.
Fragilaria crotonensis	504.941	cosmopolitan. pelagic
F. ulna var. *ulna*	15.835	littoral. sometimes in pelagic zone of eutrophic waters
Navicula capitatoradiata	0.001	benthic
N. halophila	0.001	benthic
N. lanceolata	0.001	cosmopolitan
Nitzschia recta	0.001	benthic
Stephanodiscus hantzschii	478.223	cosmopolitan. pelagic
Green algae		
Actinastrum hantzschii	51.850	cosmopolitan. pelagic
Crucigenia quadrata	27.835	cosmopolitan. pelagic
Pediastrum boryanum	12.516	cosmopolitan. pelagic
P. duplex	7.364	cosmopolitan. pelagic
Scenedesmus acuminatus	60.653	cosmopolitan. pelagic
S. communis	845.348	cosmopolitan. pelagic and littoral

The highest number of taxa – 221 – was identified at Wyszogród (WY). The least number of taxa – 195 – was identified in Toruń (TO). However, values of the Shannon–Weaver index and the ecological equation „evenness"

were distributed inversely. The highest values were recorded in Toruń, the lowest ones in Wyszogród (Table 2). The Jaccard's taxonomic similarity was defined on the basis of the species composition. It turned out that sites located within the Włocławek Reservoir are most similar to each other (with a similarity of 77%). The least similarities are displayed by the site Wyszogród as compared with the site Włocławek (the dam) and the sites located below the dam – Nieszawa and Toruń (with similarities of 59 – 56%). Values of the taxonomic similarity (the Jaccard coefficient) for all sites are presented in Table 3.

Table 2

The number of species and values of the Shannon-Weaver index as well as evenness values.

Site	A number of taxa	The Shannon - Weaver index	Evenness
Wyszogród WY	221	1.708	0.32
Płock PŁ	213	2.474	0.46
Włocławek WŁ	196	2.917	0.55
Nieszawa NI	195	2.919	0.55
Toruń TO	194	2.998	0.57

Table 3

Taxonomic similarity (of the species composition) between sites, calculated on the basis of the Jaccard coefficient.

Site	PŁ	WŁ	NI	TO
Wyszogród WY	63	59	57	56
Płock PŁ	-	77	65	65
Włocławek WŁ	-	-	68	61
Nieszawa NI	-	-	-	69

DISCUSSION

During the studies in the Lower Vistula, from Wyszogród to Toruń, 279 phytoplankton taxa (mainly species) were recorded. Among them, diatoms (129 taxa) and green algae (107 taxa) predominated. A significant number of taxa were determined also from among blue-green algae (24) and euglenoids (9). The remaining phyla (Cryptohyta, Dinophyta, Chrysophyceae) were represented by few species (from 2 to 5). During the seven-year research period, as many as 491 taxa were recorded along this section of the Vistula River (Dembowska

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2002a). However, the number of taxa in each one-year season was similar (from 200 to 300). The Włocławek Reservoir, existing here since 1970, undoubtedly has some influence on the number of taxa in the studied section of the Vistula River.

In stagnant waters, the taxonomic composition of phytoplankton reflects, first of all, the degree of fertility, whereas in flowing waters (also in rheolimnic dam reservoirs) factors related to current velocity are significant as well, or perhaps first and foremost. High velocity of the flowing water causes the periphyton and benthic algae to break off the substrate and drift away into the water body. Even species not adapted to living in isolation from the substrate live for a while and contribute to the increase of phytoplankton species diversity in flowing waters. A slower flow enables the development of euplankton species. The slower the flow, the more apparent the dependence on the trophy degree becomes. Changes resulting from the partition of flowing waters are often significant (Allan 1998). As the river water flows into the dam reservoir, it loses velocity. If the retention time is sufficiently long (at least 10 days according to Round (1984)), autochthonous plankton develops in the reservoir.

In almost all prior studies on the Vistula River, along its entire length, diatoms were described as the most species-rich group (Starmach 1938; after Krzeczkowska–Wołoszyn 1991; Cabejszek et al. 1959; Kyselowa and Kysela 1966; Hanak–Schmager 1974; Klimowicz 1981; Praszkiewicz et al. 1983; Tyszka–Mackiewicz 1983; and Dembowska 1996, 2002a, 2002b, 2002c, 2005). The research presented here revealed that the Vistula River in its lower course has similar species composition of phytoplankton as compared with other sections of the River. A significant majority (94%) of the diatoms identified from the Lower Vistula are non-plankton forms. These diatoms got into the water depths by breaking off and washing away from epiphyton and benthic communities, e.g. during resuspension caused by strong water currents.

The second most species-rich group was comprised of green algae (mainly from the order coccal algae), recognized rather as plankton forms.

Studies on the Vistula River carried out by Uherkovich (1970) and Kowalczewski et al. (1985), revealed that green algae were then the most species rich group. One should emphasize, however, that Uherkovich (l.c.) as well as Kowalczewski et al. (l.c.) determined diatoms at the level of higher taxonomic units only (usually genera) and not species. Therefore, it is nearly certain that with the accurate determination the number of diatoms' taxa would be much higher. Also phytoplankton of other rivers consists, mainly, of diatoms and green algae, mostly coccal ones (Hötzel and Croome 1994, Ibelings et al. 1998, Kelly and Whitton 1998, Kiss 1987, Lair et al. 1999, Piirsoo 2001, Rojo et al. 1994, Yang et al. 1997). In phytoplankton of dam reservoirs, besides diatoms and green algae, other groups of algae also develop in large numbers –

blue-green algae, Dinophyta, Cryptohyta, Chrysophyceae (Al–Lami et al. 1996; Bucka 1985; Calijuri and Dos Santos 1996; Galicka 1996; Galicka et al. 1990; Galicka and Kruk 1999; Galicka, Lesiak 1996; Górniak and Grabowska 1994; Pająk 1986; Pająk, Kiss 1990; Puchalski 1994; Puchalski et al. 1995; Rakowska and Rakowski 1992; Wilk–Woźniak 1996; Wilk–Woźniak, Bucka 2000).

The influence of dam reservoirs on river plankton is often significant. It depends, to a large degree, on the abundance and dynamics of algae development, which in turn depends on the water exchange rate in a reservoir. The following factors have an influence on the high number of diatoms in dam reservoirs: morphometry (mainly a high share of shallow waters, where periphyton and phytobenthos develop abundantly) as well as physical instability (wavy motion, fluctuation in the water level, rapid water current related to a short retention time), which induces breaking off the algae and transportation to the water depths.

Recapitulating, one can confirm the opinion of Kawecka and Eloranta (1994) as well as of Puchalski (1994), that a similarly high quantitative share of diatoms and green algae taxa is characteristic of fluvial habitats rather than of lakes. It seems that within those two algae phyla the highest number of species tolerate considerable water movements, which enables them to exist in lotic (physically unstable) environments. One should remember, however, that many of them have periphytic and benthic origin, and the high adaptation degree enables them to exist in the water body. It is difficult to draw a line between euplankton and tychoplankton, since many species of sedentary origin still develop and reproduce in the water depths.

The earliest studies on phytoplankton in the Włocławek Reservoir, situated on the Lower Vistula, were conducted when filling the reservoir with water and directly after completing it (Praszkiewicz et al. 1983). However, the authors did not publish the complete taxonomic composition, but only the species occurring most frequently: *Asterionella formosa*, *Cyclotella comta, C. meneghiniana, Diatoma vulgare, Actinastrum hantzschii*, *Ankistrodesmus falcatus*, *Coelastrum microporum*, *Crucigeniella rectangularis*, *Pediastrum boryanum*, *Scenedesmus acuminatus*, *Selenastrum minutum*.

As regards the species composition, the sites located within the Włocławek Reservoir, i.e. Płock and Włocławek, were the most similar to each other. The similarity between those sites amounted to 77%. An unambiguous conclusion follows from the above, namely that the sites Płock and Włocławek (located 45 km from each other), reveal the highest habitat homogeneity of this river section, induced by backwater. The similarity of almost 70% was ascertained with reference to the sites Włocławek–Nieszawa and Nieszawa–Toruń. However, the differences between Włocławek and Toruń were definitely higher (with a similarity of 61%), which implies that changes in the species

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composition varied successively and proportionally with the increase in distance from the dam. The sites Wyszogród–Włocławek (59%), Wyszogród–Nieszawa (57%) and Wyszogród–Toruń (56%) were the least similar to each other. Also, the number of identified algae was the most diversified there. At the site Wyszogród, 221 taxa were present, and at the sites Włocławek and Nieszawa, 196 and 195 taxa, respectively, as well as 194 taxa in Toruń. The nature of the phytoplankton community below the dam still remains under the influence of changes occurring in the Włocławek Reservoir.

Taxa that determined the differences between the sites occurred sporadically and in small numbers. In most cases they were tychoplankton (pseudoplankton) species coming from periphyton and benthos. Those organisms, however, were not adapted to the strong flow and therefore they could not survive any longer either in the freely flowing river or in the superrheolimnic Włocławek Reservoir. They could survive here only for a short period of time. They did not reproduce and soon perished.

The Shannon-Weaver species diversity index and evenness have the smallest values in Wyszogród, i.e. at the site not influenced by backwater. A low value of the diversity index and evenness results from the exceptional domination of one species of centric diatom in the Vistula River – *Cyclotella meneghiniana.* Even though this species also dominated at the remaining sites, frequency proportions of *Cyclotella meneghiniana* in relation to other species still underwent a change. Along the distance from Włocławek to Toruń the Shannon-Weaver species diversity index and evenness do not undergo any major changes, which indicates the significant effect of algae sedimentation in the reservoir for 55 km below the dam.

The Włocławek Reservoir, situated within the Lower Vistula, differs from typical dam reservoirs, where retention time is measured in weeks or months. In the Włocławek Reservoir, the retention is about 5 days and thereby, conditions for phytoplankton are similar to those in the river. The Włocławek Reservoir is subject to strong influence from the river. Although the reservoir has a short retention time and high water flow rate, it exerts a distinct influence on the species composition and diversity of plankton algae in the river below the dam.

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