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INFLUENCE OF WATER CHEMISTRY ON THE STRUCTURE OF PLANKTONIC CILIATE COMMUNITIES ACROSS A FRESHWATER ECOTONE IN THE EUTROPHIC DAM RESERVOIR (EASTERN POLAND)

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Abstract: The aim of the present study was to examine changes in species composition and density of ciliates in an adjacent river, ecotone and reservoir zone (Zemborzycki Reservoir, Eastern Poland). Quality and quantity structure of planktonic ciliates showed visible differences between studied zones; the highest species diversity and abundance were observed in the ecotone (water/water). The lowest species diversity and abundance were noted in the Bystrzyca River. Independent on the zone, ciliates community was dominated by bacterivorous species with the lowest proportions of algivorous taxa. The present study showed that density of protozooplankton rose with the increase of nutrients delivery and TOC concentration in water.

INTRODUCTION

Ecotones are transition zones between relatively homogenous areas or patches. They are zones in which environmental gradient are steepened, where rates of change in ecological patterns and processes are increased relatively to the surrounding. The river – reservoir system may thus be perceived a spatial system of two kinds of ecosystems or patches. Ecotonal zones of these patches would be formed by the zones of mixing the reservoir water with river water [7]. The zone of river inflow to a reservoir functions as a barrier system and filter of incoming organic matter, nutrients and mineral suspension. The studies of the effect of ecotones on zooplankton communities have been concentrated on rotifers [3] and bacteria and periphyton communities [4]. However, very little is known about large-scale protozoan density and their function in the ecotones of freshwater systems. Protozoa communities are integrally linked to aquatic habitats and their abundance and community structure are related to both chemical and physical conditions in lake and river, making them useful bioindicators [16]. Because of their small size and high metabolic rate, protozoa play a substantial role in nutrient regeneration in the water column. Among protozoan, ciliates are most striking and important; they generally dominate the protozoan biomass with substantial numbers and large size. As the main consumers of bacteria, picoplankton and nanoplankton, ciliates serve as an important trophic link and

play a significant role in freshwater ecosystems [1]. The first step in understanding the structural and functional significance of these microorganisms is the analysis of density and biological diversity between different zones.

The aim of the present study was to examine changes in species composition and density of ciliates in an adjacent river, ecotone and reservoir zone in which water depth, velocity, and chemical water properties significantly differed.

STUDY AREA, MATERIALS AND METHODS

Zemborzycki dam reservoir constructed on the Bystrzyca River 30 years ago is situated on the periphery of Lublin city (Eastern Poland). It has a great significance for Lublin – it reduces a flood wave and feeds the middle course of the Bystrzyca River with water. Moreover, it functions as recreational reservoir and it is used for angling and fishing purposes. The reservoir is relatively small (surface area of 230 ha, capacity 6.34 mln m^3). Water exchange rate in the reservoir is about 28-times per year. High concentrations of chlorophyll *a* (115 $\mu g \cdot dm^{-3}$) and $P_{tot.}$ (43 $\mu g \cdot dm^{-3}$) in summer confirm eutrophic status of the reservoir [12]. The protozooplankton was studied in three sites: 1 – the Bystrzyca River (at the depth of 1 m), 2 – ecotone water/water with well developed belts of emergent (*Glyceria aquatica* Wahlenb.) and submerged (*Potamogeton perfoliatus* L. and *Potamogeton pectinatus* L.) macrophytes (1–1.5 m) and 3 – reservoir open water (4.0 m) (Fig. 1). Samples were collected in spring (April), summer (July) and autumn (October) 2004–2005. On each site, samples were collected every 0.5 meter using 5 dm^3 Bernatowicz apparatus. Samples from all layers were pooled together, carefully mixed and 500 cm^3 sample was fixed with Lugol's liquid (0.2% final concentration). Densities of ciliates were determined with an inverted microscope using the settling chamber technique: 50 cm^3 of sample was left for sedimentation for at least 24 h and half of the bottom of the chamber was counted at 300× magnification. Four microscopic slides were prepared from each sample and examined. Taxonomic identifications were based especially on Foissner and Berger [5].

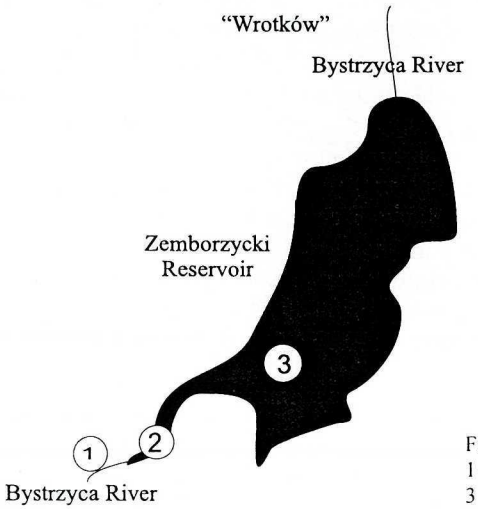

Fig. 1. Location of investigated sites: 1 – the Bystrzyca River, 2 – ecotone, 3 – Zemborzycki Reservoir

Ciliate biomass was estimated by multiplying the numerical abundance by the mean cell volume calculated from direct volume measurements using appropriate geometric formulas.

The water samples for chemical analysis were taken simultaneously with the ciliate samples. The following physical and chemical factors were examined: conductivity, total organic carbon (TOC), phosphates and total phosphorus [6]. Total organic carbon (TOC) was determined by using the PASTEL UV.

All data collected were analyzed statistically by means of GLM and CORR procedures of SAS Programme. The significance of differences between mean densities of ciliates was verified by means of ANOVA. Correlation between physical and chemical parameters and ciliate density were analyzed by calculating Pearson's correlation.

RESULTS

From all the studied zones, the highest conductivity values were noted in ecotone (440 $\mu S \cdot cm^{-1}$) and the lowest in reservoir (130 $\mu S \cdot cm^{-1}$). Concentrations of P_{tot} and $P\text{-}PO_4$ showed decreasing tendency along the transect with a maximum in the river and ecotone zones (0.30–0.23 mg $P \cdot dm^{-3}$ and 0.60–0.23 mg $P \cdot dm^{-3}$, respectively). Regarding total organic carbon (TOC) the highest mean concentration was found in the ecotone zone (> 10 mg $C \cdot dm^{-3}$).

The total number of ciliates taxa amounted 21. The highest number – 20 taxa was noted in the ecotone zone. At the remaining sites the number of taxa ranged from 3 to 9 (Tab. 1). The highest species diversity was usually observed in summer, the lowest in spring.

The density of ciliates showed visible changes among studied zones. It was significantly higher at the flow of the Bystrzyca River to the reservoir (water/water ecotone) – above 80 ind.$\cdot cm^{-3}$ and significantly lower in the Bystrzyca River – 23 ind.$\cdot cm^{-3}$ (ANOVA $F_{(4.32)} = 23$, $P < 0.001$) (Fig. 2A). Independent of the zone significantly higher densities was noted in spring. The lowest densities were observed in summer – 23 ind.$\cdot cm^{-3}$. Also the biomass of ciliates showed a significant differentiation across the river-reservoir transect with maximum values in the ecotone zone – 117 ng$\cdot cm^{-3}$ and minimum in the river – 47 ng$\cdot cm^{-3}$ (ANOVA $F_{(2.1)} = 13$, $P < 0.001$) (Fig. 2B).

The domination structure of planktonic ciliates differed markedly between studied zones. In the river the highest proportions reached mixotrophic Oligotrichida (*Strombidium viride* Stein, *Codonella cratera* Leidy) – 28% of total protozoan density. In the ecotone zone we observed the increasing share of bacterivorous Scuticociliatida (mainly *Cinetochilum margaritaceum* Ehrenberg), the taxa typical for eutrophic waters, this reached up to 50% of total density. In the reservoir instead of Scuticoliliatida (35–49%), the high proportion showed ciliates from *Vorticella* genus (14–20%) (Fig. 3). The domination structure of planktonic ciliates showed seasonal changes, independent of the zone, in spring dominated bacterivorous Scuticociliatida, in summer increased the proportion of mixotrophic Oligotrichida.

The strongest positive influence on ciliates density in particular zones showed concentration of total organic carbon (TOC) in water (r = 0.42–0.69). In the ecotone we noted the highest number of significant correlations between ciliates density and physical or chemical properties of water. The ciliates density positively correlated with concentrations of TOC ($r = 0.69$, $p \leq 0.01$), P_{tot} ($r = 0.45$, $p \leq 0.05$) and $P\text{-}PO_4$ ($r = 0.36$, $p \leq 0.05$) (Tab. 2).

Table 1. The composition of major planktonic ciliate taxa found in investigated zones

Takson	River	Ecotone water/water	Reservoir
HAPTORIDA			
Actinobolina radians Kahl		+	+
Didinium nasutum Stein		+++	
Spathidium sensu lato		+++	
HETEROTRICHIDA			
Caenomorpha spp.			
Stentor amethystinus Leidy		++++	
Stentor coeruleus Pallas		+++	+++
HYMENOSTOMATIDA			
Disematostoma tetraedricum Faure-Frem		+	
Lembadion sp.		+	+
Paramecium caudatum Ehrenberg		+++	+++
OLIGOTRICHIDA			
Codonella cratera Leidy		+++	+++
Halteria gradinella Mueller		+++	
Strombidium viride Stein	++++	+++	+++
PERITRICHIDA			
Vorticella convallaria – Komplex		++++	
Vorticella microstoma – Komplex		++++	
Carchesium sp.			++
PLEUROSTOMATIDA			
Litonotus sp.		+++	
PROSTOMATIDA			
Bursellopsis sp.		+++	
Coleps hirtus Mueller	+++	++++	
Coleps spetai Foissner		+++	+++
SCUTICOCILIATIDA			
Cinetochilum margaritaceum Ehrenberg	++++	++++	++++
SUCTORIDA			
Acineta sp.		++	
No. of taxa: 21	3	20	9

+ – < 0.1 ind.·cm^{-3}, ++ – 0.1–1 ind.·cm^{-3}, +++ – 1–10 ind.·cm^{-3}, ++++ – >10 ind.·cm^{-3}

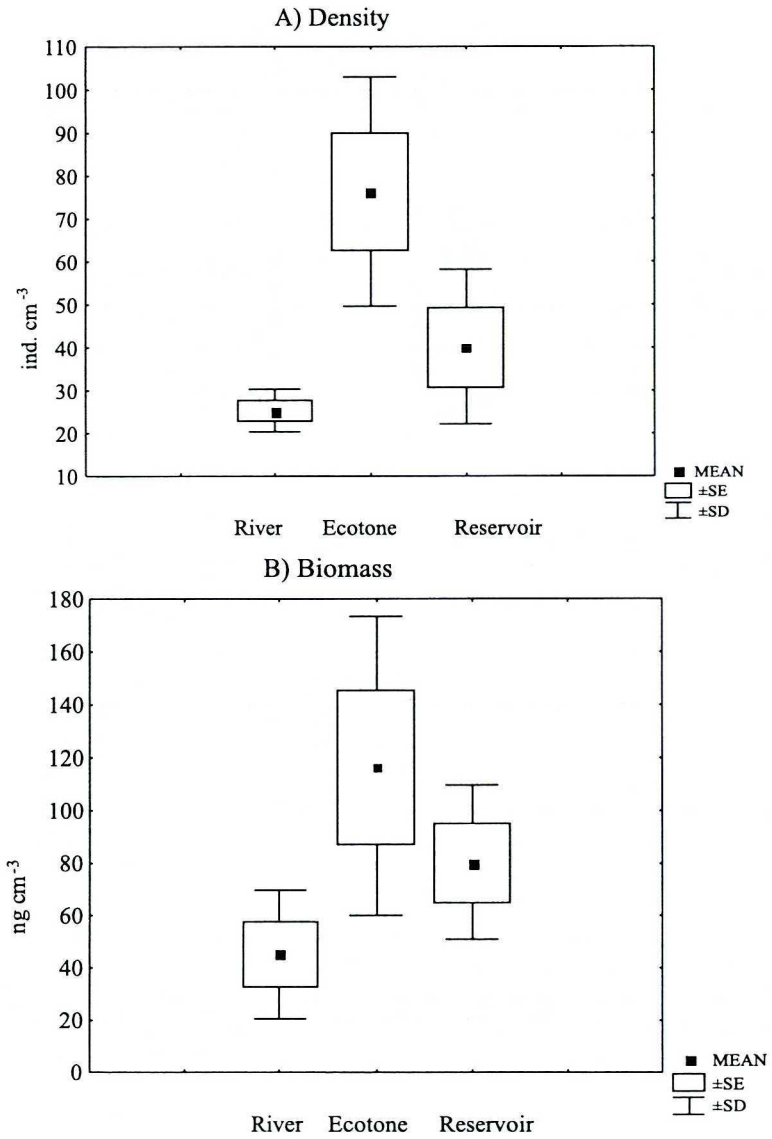

Fig. 2. Average density (A) and biomass (B) of planktonic ciliates in investigated zones

Table 2. Linear correlation coefficients between ciliate density and physical, chemical and biological factors in investigated lake (n = 23)

Zone	Conductivity [$\mu S \cdot cm^{-1}$]	P-PO_4 [mg $P \cdot dm^{-3}$]	$P_{tot.}$ [mg $P \cdot dm^{-3}$]	TOC [mg $C \cdot dm^{-3}$]
River	–	–	0.45**	0.42**
Ecotone water/water	–	0.36*	0.41**	0.69*
Reservoir	–	0.53*	0.40**	0.51*

* – $P \leq 0.01$, ** – $P \leq 0.05$, – not significant

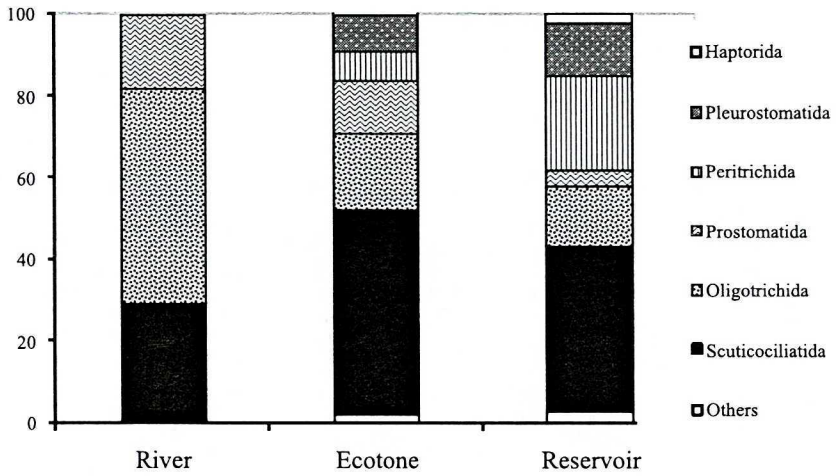

Fig. 3. Domination structure of planktonic ciliata orders in investigated zones

DISCUSSION

Species diversity and abundance of planktonic ciliates showed great differences in particular zones. A visible increase of the number of taxa usually occurred in water/water ecotone, the lowest diversity was observed in the Bystrzyca River and in Zemborzycki Reservoir. The most species, found in all stations, were eurytope species which have a rapid ecological adaptability and whose tolerance limits to environmental changes are wide. *Cinetochilum margaritaceum* Ehrenberg belonging to Scuticociliatida should be considered a typical example of this group of ciliates. The small Scuticociliatida are frequently observed in productive systems. This group of ciliates presents an opportunistic bacterivorous behavior [5, 9, 10]. In the river the highest proportions reached mixotrophic *Strombidium* (Oligotrichida). Oligotrichs are often reported as relatively common component of protozooplankton especially in low productive systems [10].

In the river we observed very low species diversity, probably as a consequence of current velocity, which confirms the studies of Primc-Habdija *et al.* [11]. Whereas, in ecotone (water/water contact zone) we noted very high number of ciliates taxa. Due to the presence of "contact zone"– ecotone zone is usually inhabited by a large number of species. At particular sites some physical or chemical water properties influenced the quality and quantity structure of planktonic ciliates. Along the increase of organic matter and nutrients concentrations we observed a higher number of taxa and abundance of ciliates. Similar relationships were noted in eutrophic lakes [13]. Higher abundances of ciliates at the flow of the Bystrzyca River to Zemborzycki Reservoir were caused probably by high nutrients concentration. Besides, in this particular zone, the total organic carbon (TOC) concentration in water positively correlated with the density of ciliates. It is in agreement with the results obtained during studies on protozooplankton in lakes [2, 9, 10, 14, 15]. These factors may additionally influence the rate of bacteria growth. It seems that the increase of ciliates density (especially Scuticociliatida) can be a reflection of food conditions. Also the presence of emergent vegetation in the ecotone zone may influence the

abundance of ciliates through slowing of the current and development of microniches. The similar tendencies were observed in phyto- and zooplankton in the river-lake system of the Krutynia River [7]. Planktonic ciliates community was dominated by bacterivorous taxa, predatory species reached the lowest proportions. The effect of organic load on the structure of the ciliate communities thus appears to be well depicted by the trophic categories, algivorous ciliates (Oligotrichida) being dominant in the unpolluted rearch and bacterivorous ciliates in the polluted ones [2]. The share of bacterivorous species increased visibly in the water/water ecotone. It can suggest that feeding on bacteria ciliates become an important link in the flow of matter and energy between bacteria and higher trophic levels [8]. The very small amount of algivorous ciliates found during our research was probably a consequence of food availability. During the whole studied period the phytoplankton community was dominated by blue-green algae, unavailable or indigestive for ciliates.

CONCLUSIONS

Quality and quantity structure of planktonic ciliates showed visible differences between studied zones; the highest species diversity and abundance were observed in the water/water ecotone. The lowest species diversity and abundance were noted in the Bystrzyca River. Independent on the zone, ciliates community was dominated by bacterivorous species with the lowest proportions of algivorous taxa. The highest percentage of bacterivorous species was usually noted in a water/water ecotone. The present study showed that density of protozooplankton rose with the increase of nutrients delivery and TOC concentration in water.

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WPŁYW WŁAŚCIWOŚCI CHEMICZNYCH WÓD NA WYSTĘPOWANIE ZESPOŁÓW ORZĘSKÓW PLANKTONOWYCH W EKOTONIE SŁODKOWODNYM EUTROFICZNEGO ZBIORNIKA RETENCYJNEGO (WSCHODNIA POLSKA)

Celem pracy była analiza zróżnicowania gatunkowego oraz liczebności orzęsków planktonowych w układzie: rzeka – ekoton (woda/woda) – zbiornik retencyjny (Zbiornik Zemborzycki, Wschodnia Polska). Zarówno bogactwo gatunkowe jak i obfitość orzęsków planktonowych były wyraźnie zróżnicowane w poszczególnych badanych strefach. Najwyższą różnorodność i liczebność orzęsków stwierdzono w strefie ekotonowej. Najbardziej uboga jakościowo i ilościowo okazała się natomiast rzeka Bystrzyca. Niezależnie od strefy, w strukturze troficznej dominowały gatunki bakteriożerne, najniższy zaś udział miały gatunki glonożerne. Czynnikami w największym stopniu wpływającymi na występowanie protozooplanktonu były stężenia w wodzie fosforu ogólnego, fosforanów oraz całkowitego węgla organicznego.