Teka Kom. Ochr. Kszt. Środ. Przyr. – OL PAN, 2012, 9, 125–133

CO-OCCURRENCE OF PSAMMONIC CILIATES AND ROTIFERS IN EUTROPHIC LAKE (ŁĘCZNA-WŁODAWA LAKELAND)

Dorota Nawrot, Tomasz Mieczan

Department of Hydrobiology, University of Live Sciences in Lublin
Dobrzańskiego str. 37, 20-262 Lublin, karolina.siczek@interia.pl

Summary. The aim of this study was to examine relationship between the density and species richness of ciliates and rotifers in eutrophic Lake Rotcze located in Łęczna-Włodawa Lake District. Also analyzed the influence of selected physical and chemical factors of psammolittoral waters on the formation of the structure of the studied groups of microorganisms. Psammon samples were collected during spring, summer and autumn of 2010 in three zones: euarenal, higroarenal, and hydroarenal. There were clear differences between the microhabitats in the qualitative and quantitative structure of organisms. The highest density of ciliates was observed in higroarenal zone, while rotifers in hydroarenal zone. Both the abundance of ciliates and rotifers significantly correlated with physical and chemical properties of water ($N\text{-}NH_4$, P_{tot} and TOC). There was also a significant negative correlation ($r = -0.56$, $p = 0.05$) between the abundance of ciliates and rotifers in the studied microhabitats. This may indicate a clear trophic relationship between this group of organisms.

Key words: lake, psammon, ciliates, rotifers

INTRODUCTION

The psammon is an assemblage of organisms living in the costal zones of lakes and rivers [Ejsmont-Karabin 2003]. Depth colonization of the coastal zone by organisms belonging to this group depends on the type of water ecosystems. In lakes, the psammlittoral zone does not exceed more than 2 cm deep into sand, in seas – up to a few centimeters, and in rivers it can reach more than 40 cm [Wiszniewski 1937]. Taxonomically, psammon is very differentiated. The composition of psammon includes bacteria, flagellates, algae, protozoa, rotifers, and nematodes. Psammon is a diversified and dynamic structure, unfortunately, been recognized in a very small extent. So far, the majority of information has been obtained from studies on rotifers, and they are the best known group of organisms belonging to psammon [Bielańska-Grajner 2001, Ejsmont-Karabin 2003]. In psammolittoral the relationships between physical and chemical parameters and animal communities (particularly small Metazoa) are well known [Ejsmont-Karabin 2008]. By contrast, little or no attention is given to abundance and biomass of protozoans and their relationships to food resources and predator pressure in these specific ecosystems. These microorganisms are important consumers of bacteria, flagellates and algae; they also participate in the decomposition of organic matter and nutrient cycling [Madoni 1990, Dragesco and Dragesco-Kernéis 1991, Obolkina 1995, Cleven and Weisse 2001, Kalinowska 2008]. Rotifers also constitute one of the main components of plankton, periphyton and psammon as consumers of bacteria, algae and protozoa [Mathes and Arndt 1994]. So both ciliates and rotifers are very important element in trophodynamic of lakes [Radwan 1973, Mieczan 2003].

The detail aim of this study was to examine the community structure and horizontal distribution of ciliates and rotifers, as well as to assess the influence of potential food resources (Chl *a*) and predators (rotifers) on protozoa communities.

STUDY AREA

The study was undertaken in shallow, poor eutrophic, macrophyte-dominated Lake: Rotcze (area 45.8 ha, max. depth 4.3 m) located in Łęczyńsko-Włodawskie Lake District (Eastern Poland, 51ºN, 23ºE) with well developed belts of emergent (*Phragmites australis* (Car.) Trin.ex Stend) and *Typha latifolia* L.) and submerged (*Ceratophyllum demersum* L., *Elodea canadensis* L., *Chara hispida* L. and *Chara fragilis* Desvaux) macrophytes dominating in littoral.

METHODS

Ciliates were collected in spring, summer and autumn in 2010. The samples of psammon were taken from three zones of arenal: euarenal – exposed sand, 1 m of shoreline; higroarenal – at the shoreline; hydroarenal – under water, 1 m from the shoreline.

Samples were collected with a plastic sharp-edged tube, 60 mm in diameter at four points of each zone. Samples were taken to the depth of 2 cm. Each sample was shaken with saline solution and then filtering through a benthic mesh net and fixed immediately with Lugol's solution (0.2% final concentration). Ciliate density was calculated per 1 cm^3 of sand. Observation of life samples was used for the taxonomic identification. Species identification was based on Foissner and Berger [1996].

Rotifers were identified in the same samples. Observation of life samples was used for the taxonomic identification. Species identification was based on Radwan [2004].

Ciliate and rotifer biomass was estimated by the multiplying the numerical abundance by the mean cell volume calculated from direct volume measurements using appropriate geometric formulas. Ciliate biomass was calculated cell volumes were multiplied with a correcting factor of 0.4 [Finlayand Esteban 1998].

Every time the following physical and chemical parameters: pH, conductivity, temperature, total organic carbon (TOC), total phosphorus (P_{tot}), $P\text{-}PO_4$, $N\text{-}NO_3$, $N\text{-}NH_4$ and chlorophyll *a* were examined in three sites: euarenal (interstitial water), higroarenal and hydroarenal (water above the ground). Temperature, conductivity and pH were determined *in situ* using the multiparameter sensor 556 MPS (Envag). TOC was determined using the PASTEL UV, and the others parameters were analyzed in laboratory, according to Hermanowicz *et al.* [1976]. Chlorophyll *a* was determined by the spectrophotometric analysis of alcohol extracts of the algae retained on polycarbonate filters.

Statistical analyses of results were carried out using the STATISTICA 7.0 software (ANOVA). Pearson correlation coefficients were calculated between pairs of variables in order to determine the relationship between abundance of ciliates and rotifers and physical and chemical parameters.

RESULTS

Physical and chemical parameters

Concentrations of nutrients, total organic carbon and conductivity significantly fluctuated during the sampling period. The highest conductivity was noted in the euarenal (336.33 $\mu S\cdot cm^{-1}$) and the lowest in the higroarenal (209.67 $\mu S\cdot cm^{-1}$). Euarenal zone was also the richest in nutrients, and total organic carbon. The concentrations of total phosphorus reached the highest values in the higroarenal (0.52 mg $P\cdot dm^{-3}$). The lowest chlorophyll *a* content was recorded in the hydroarenal zone (12.47 $\mu g\cdot l^{-1}$), the other two zones, this content was at a similar level (Tab. 1).

Taxonomic composition and abundance of ciliates and rotifers

The highest significant abundance of ciliates occurred in the higroarenal zone (661 ind.·1 cm^{-3}). Lower numbers of ciliates were observed in euarenal zone (ANOVA $F = 0{,}095$, $p \leq 0.05$). Biomass of ciliate also indicated clear differences between the analyzed microhabitats. The highest biomass were noted in higroarenal zone (83.57 $\mu g\cdot cm^{-3}$), and the lowest in the hydroarenal (29.35 $\mu g\cdot cm^{-3}$) (ANOVA $F = 15{,}989$, $p \leq 0.05$) (Fig. 1).

The composition of ciliates changes in particular microhabitats. In the euarenal zone the most abundant was *Hymenostomatida*. In higroarenal zone the community was predominantly composed of *Scuticociliatida*. Species belonging to *Pleurostomatida, Oligotrichidia* and *Prostomatidia* dominated in the hygroarenal zone (Fig. 3).

Table 1. Physical and chemical characteristic of the psammon water of investigated lake (hydroarenal, higroarenal, euarenal)

Lake	Zone	Temp	pH	Conductivity $\mu S \cdot cm^{-1}$	N-NO_3 mgN $\cdot dm^{-3}$	N-NH_4 mgN $\cdot dm^{-3}$	PO_4 $mgPO_4$ $\cdot dm^{-3}$	P_{tot} mgP $\cdot dm^{-3}$	TOC mgC $\cdot dm^{-3}$	Chlorophyll *a* $\mu g \cdot l^{-1}$
Rotcze	Hy	19.88* 15.74- -25.23**	7.48 7.34- -7.69	257.67 229-256	0.30 0.017- -0.76	0.11 0.045- -0.2	0.01 0-0.2	0.06 0.035- -0.094	6.13 5.5- -7.0	12.47 6.52- -23.35
	Hi	20.15* 15.14- -25.60**	7.80 7.23- -8.73	209.67 163-287	0.29 0.17- -0.72	0.09 0.008- -0.173	0.01 0.001- -0.02	0.52 0.076- -1.4	6.28 5.5- -6.9	23.51 7.9- -33.89
	Eu	19.62* 15.25- -23.30**	7.37 6.75- -8.2	336.33 287-404	0.36 0.082- -0.8	1.3 0.881- -1.712	0.19 0.018- -0.47	0.37 0.03- -0.883	15.86 6.9- -25.6	21.11 7.2- -39.09

*average and **range

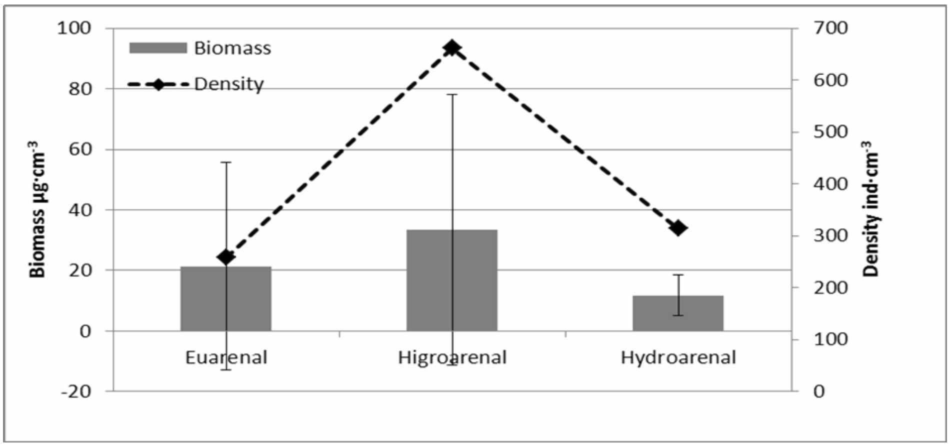

Fig. 1. Density and biomass (± standard deviation) of psammonic ciliates in investigated lake

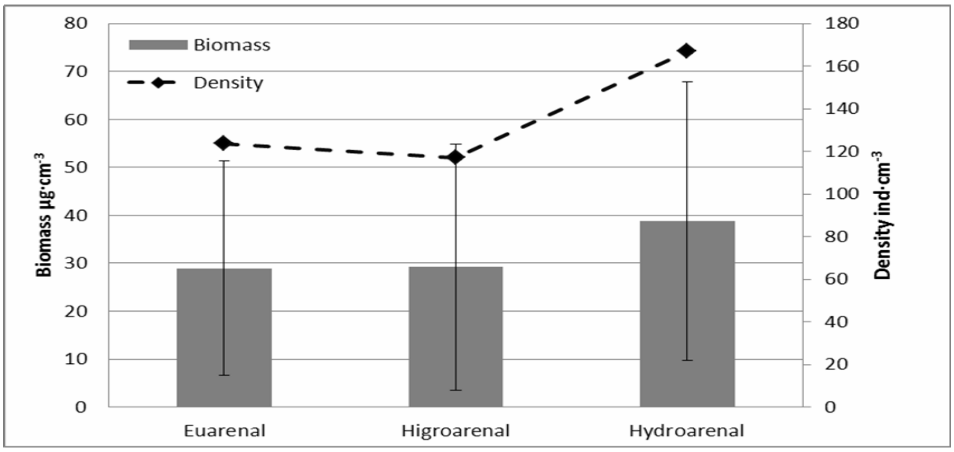

Fig. 2. Density and biomass of psammonic rotifers in investigated lake (± standard deviation)

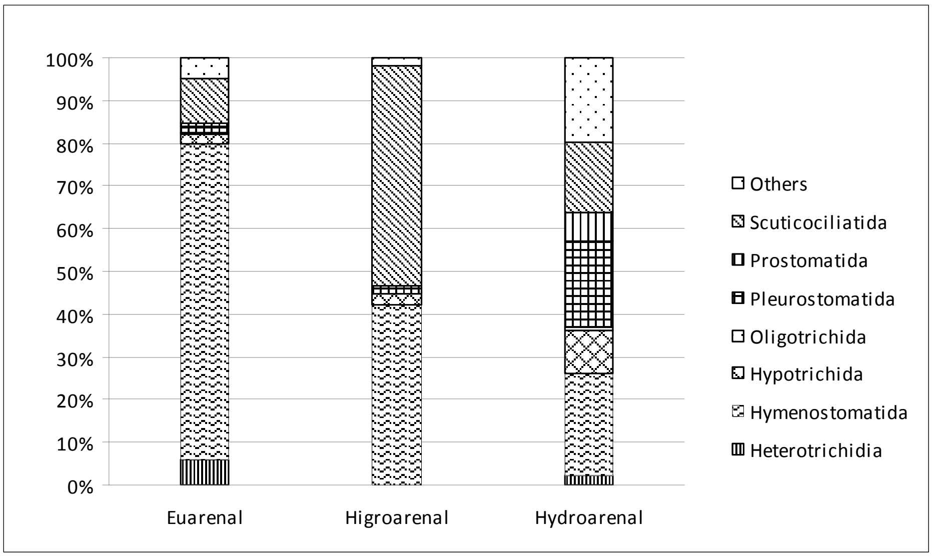

Fig. 3. Domination structure of psammonic Ciliata orders in psammolittoral (% of total numbers)

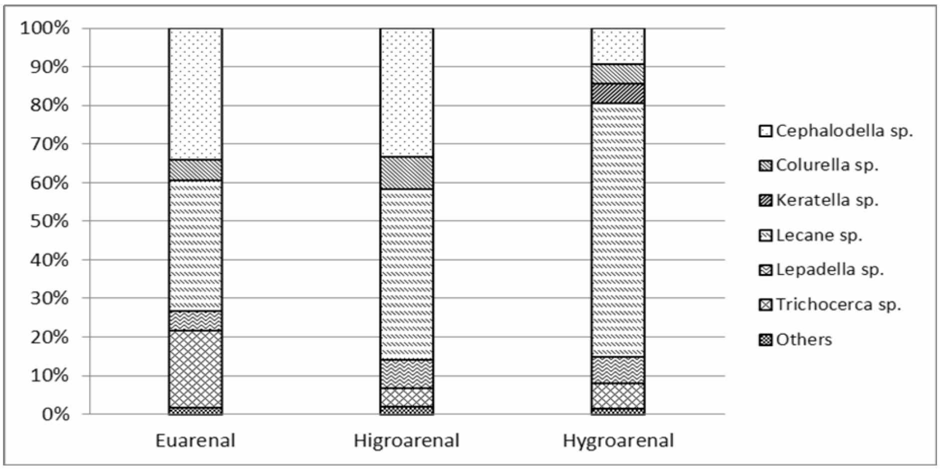

Fig. 4. Domination structure of psammonic Rotifera in psammolitoral (% of total numbers)

The quantitative structure of rotifers has not been reported significant differences between the eu- and higroarenal zone (ANOVA $F = 1.586$, $p \leq 0.05$). The highest density of rotifers was noted in hygroarenal (167 ind·cm^{-3}) and biomass of these organisms showed the same distribution (Fig. 2). The qualitative structure showed no significant differences between the eu- and higroarenal zone. In both these zones dominated *Cephalodella sp.* and *Lecane* sp. The hydroarenal zone was dominated by *Lecane* sp. (Fig. 4).

Relationship between chemical parameters and abundance of ciliates and rotifers

Certain physical and chemical properties of water had a clear effect on the community structure of microorganisms. In investigated lake ciliates and rotifers densities were correlated with the temperature, pH, content of $N\text{-}NH_4$ and TOC. In the eu- and hydroarenal zone the content of P_{tot} and chlorophyll *a* correlated positively with the total numbers of ciliates and rotifers. Moreover, in the same

Table 2. Pearson correlation between ciliate and rotifer density and physical and chemical factors of investigated lake ($p \leq 0.05$)

	Zone	Temp	pH	Conductivity	$N\text{-}NO_3$	$N\text{-}NH_4$	$P\text{-}PO_4$	P_{tot}	TOC	Chlorophyll *a*
Ciliates	Euarenal		-0.31		0.67		0.67	-0.30	0.65	-0.59
	Higroarenal	0.43	-0.36			0.43			-0.34	
	Hydroarenal	0.37	-0.57	-0.59	-0.56	0.38	-0.57	0.46	-0.58	0.51
Rotifers	Euarenal	-0.55	0.55	-0.48		-0.54		-0.33	-0.34	0.45
	Higroarenal	-0.46	0.40			-0.46			0.33	
	Hydroarenal	-0.39				-0.39		-0.37		-0.35

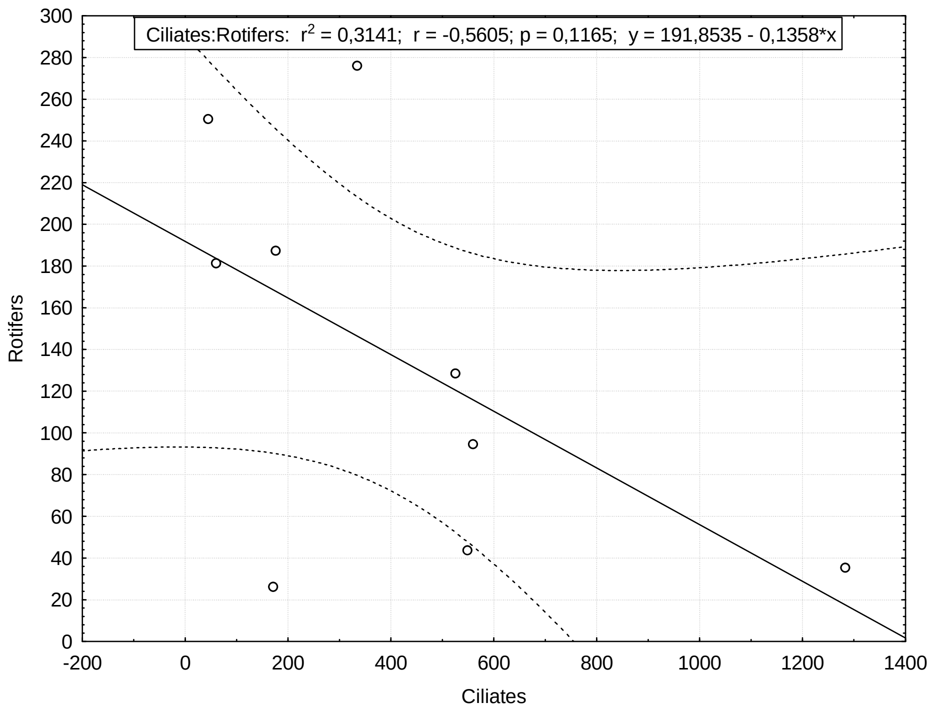

Fig. 5. Correlation between abundance of ciliates and rotifers in psammolittoral

zones ciliates were additionally affected by the content of phosphate phosphorus and nitrate nitrogen (Tab. 2). Generally, the abundance of ciliates was correlated with the abundance of rotifers (Fig 5). However, the number of significant correlations between these groups of microorganisms was different in particular microhabitats. Results showed that protozoa abundances were more dependent on rotifers abundances in the hydro- and higroarenal zone (Pearson coefficient of correlation from $r = -0.53$ to $r = -0.99$, $p \leq 0.05$). In eu- and higroarenal zone, concentrations of chlorophyll *a* were correlated with abundance of ciliates.

DISCUSSION

The similar taxonomic composition of ciliates and rotifers in our study sites and other European sites is not surprising, given the cosmopolitan distribution of many taxa [Radwan and Bielańska-Grajner 2001, Cleven and Weisse 2001]. The average numbers of psammonic ciliates in the investigated lake were similar to those recorded in the eutrophic lake Mikołajskie [Kalinowska 2008] and eutrophic Lake Sumin [Mieczan and Nawrot in press]. The present study found clear differences in the horizontal distribution of ciliates which is consistent with reports from lakes of different trophic status [Mieczan and Nawrot in press]. The highest abundance of ciliates occurred in the higroarenal zone. Lower numbers of ciliates were observed in euarenal zone. These differences were probably the results of local weather conditions such as temperature, rain, wind, and waves action. Taxonomic composition and abundance of ciliates in a horizontal approach are very similar to those of eutrophic lakes [Mieczan and Nawrot, in press].

In the present study the highest abundance and biomass of rotifers were noted in the hydroarenal zone. Similar results were observed in mesotrophic lakes [Radwan and Bielańska-Grajner 2001]. According to Ejsmont-Karabin [2008] lake hydroarenal is physically more stable than higro- and euarenal. Waves and currents affect sand near the water line, whereas more lake-ward stations are relatively stable and contain the highest numbers of different organisms in upper layers of sand. The results of the study confirmed this observation. The abundance of rotifers in the investigated habitats is closely connected with the physico-chemical parameters of water and potential food resources. Also important may be the granulometric composition of sand creating a habitat and having a direct impact on rotifer taxonomic composition of this zone [Radwan and Bielańska-Grajner 2001, Ejsmont-Karabin 2004].

The influence of food abundance seems to be more significant (correlation between numbers of ciliates and rotifers and chlorophyll *a* concentration). Significant correlations between numbers of psammonic ciliates and nutrient concentration in the less eutrophic lake Rotcze also suggest a considerable importance of the food source for the occurrence of these microorganisms. Both TOC and nutrients influence bacteria abundance. Therefore, they may have direct impact on the occurrence of protozoa and small metazoa [Mieczan 2003, 2005].

Organic matter content in the psammolittoral may be important, influencing both the growth, activity, and structure of bacteria. As studies by Mudryk and Podgórska [2007] revealed, numbers of microorganisms on a sea beach was much higher at higher contents of organic matter. This explains substantially higher numbers of ciliates in the surface layer of the eu- and higroarenal, where also the highest total organic carbon concentrations were recorded. The strong decline of ciliate numbers in the higro- and hydroarenal zone, which was observed in the present study, coincided with higher rotifers abundance. A clear influence of metazoa on the occurrence of ciliates is also confirmed by Cleven and Weisse [2001].

CONCLUSIONS

In conclusion, the present study showed clear horizontal-distribution patterns of ciliates and rotifers. The highest abundance and biomass of protozoan were observed in higroarenal, while the lowest values were noted in hydroarenal. The highest abundance and biomass of rotifers were observed in hydroarenal. The influence of Chl-*a* was particularly clear in euarenal. Metazoan predators could be the main regulators of protozoa communities in the higro- and hydroarenal.

REFERENCES

Bielańska-Grajner I., 2001.The psammic rotifer structure in three Lobelian Polish lakes differing in pH. Hydrobiologia, 446/447, 149–153.

Cleven E.J., Weisse T., 2001. Seasonal succession and taxon–specific bacterial grazing rates of heterotrophic nanoflagellates in Lake Constance. Aquatic Microb. Ecol., 23, 147–161.

Dragesco J., Dragesco-Kernéis A., 1991. Free-living ciliates from the coastal area of Lake Tanganyika (Africa). Eur. J. Protistol., 26, 216–235.

Ejsmont-Karabin J., 2003. Rotifera of lake psammon: community structure versus trophic state of lake waters. Pol. J. Ecol., 51, 5–35.

Ejsmont-Karabin J., 2004. Are community composition and abundance of psammon rotifera related to grain-size structure of beach sand in lakes? Pol. J. Ecol., 52, 363–368.

Ejsmont-Karabin J., 2008. Vertical microzonation of psammon rotifers (Rotifera) in the psammolittoral habitat of an eutrophic lake. Pol. J. Ecol., 56, 351–357.

Finlay B.J., Esteban G.F., 1998. Freshwater protozoa: biodiversity and ecological function. Biodivers Conserv. 7, 1163–1186.

Foissner W., Berger H., 1996. A user-friendly guide to the ciliates (Protozoa, Ciliophora) commonly used by hydrobiologist as bioindicators in rivers, lakes and waste waters, with notes on their ecology. Freshwater Biol., 35, 375–470.

Hermanowicz W., Dożańska W., Doilido J., Koziorowski B., 1976. Physical and chemical investigation methods of waterand sewage (in Polish). Arkady, Warszawa, 846 pp.

Kalinowska K., 2008. Psammon ciliates: diversity and abundance in hygroarenal of eutrophic lake. Pol. J. Ecol., 56, 259–271.

Madoni P., 1990. The ciliated protozoa of the monomictic Lake Kinneret (Israel): species composition and distribution during stratification. Hydrobiologia, 190, 111–120.

Mathes J., Arndt H., 1994. Biomass and composition of protozooplankton in relation to lake trophy in north German lakes. Protozooplankton Ecology, Metods and Seasional Succession. pp. 357–375.

Mieczan T., 2003. Dynamika sezonowych zmian peryfitonowych orzęsków (Ciliata) w eutroficznym jeziorze Rotcze. Acta Agropysica, 1(3), 471–477.

Mieczan T., 2005. Periphytic ciliates in littoral zone of three lakes of different trophic status. Pol. J. Ecol., 53, 105–111.

Mieczan T., Nawrot D., 2012. Horizontal zonation of psammonic ciliates in two lakes of different trophic status: relationship to physical and chemical parameters, in press.

Mudryk Z., Podgórska B., 2007. Abundance and distribution of culturable microorganisms in sandy beaches in south Baltic Sea. Pol. J. Ecol., 55, 221–231.

Obolkina L.A., 1995. New species of the family Colepidae (Prostomatida, Ciliophora) from Lake Baikal (in Russian). Zool Zh., 74, 3–19.

Radwan S., 1973. Wrotki pelagiczne jezior Pojezierza Leczyńsko-Włodawskiego, Studium faunistyczno-ekologiczne. Skrót rozprawy habilitacyjnej. Wyd. AR. Ser. Rozpr. Hab., 8, 57.

Radwan S., Bialańska-Grajner I., 2001. Ecological structure of psammic rotifers in the ecotonal zone of Lake Piaseczno (estern Poland). Hydrobiologia, 446/447, 221–228.

Radwan S. (red), 2004. Wrotki (Rotifera). Fauna słodkowodna Polski. OWT Łódź.

Wiszniewski J., 1937. Differenciation ecologique des Rotiferes dans le psammon d'eaux douces (in French). Ann. Mus. Zool. Pol. 13, 1–13.

WSPÓŁWYSTĘPOWANIE ORZĘSKÓW I WROTKÓW PSAMMONOWYCH W JEZIORZE EUTROFICZNYM (POJEZIERZE ŁĘCZYŃSKO-WŁODAWSKIE)

Streszczenie. Celem pracy było poznanie struktury jakościowej i ilościowej orzęsków i wrotków psammonowych w eutroficznym jeziorze Rotcze, położonym na terenie Pojezierza Łęczyńsko-Włodawskiego. Analizowano również wpływ wybranych czynników fizyczno-chemicznych wód psammolitoralu na kształtowanie się struktury badanych grup mikroorganizmów. Próby psammonu pobierano wiosną, latem oraz jesienią 2010 roku, z trzech stref: euarenalu, higroarenalu oraz hydroarenalu. Odnotowano wyraźne różnice w strukturze jakościowej i ilościowej analizowanych organizmów pomiędzy badanymi mikrosiedliskami. Największe zagęszczenie orzęsków stwierdzono w strefie higroarenalu, zaś wrotków w strefie hydroarenalu. Zarówno obfitość orzęsków, jak i wrotków istotnie korelowały z właściwościami fizyczno-chemicznymi wody, głównie stężeniami N-NH_4, P_{tot} oraz TOC. Wystąpiła także istotna ujemna korelacja ($r = -0.56$, $p = 0,05$) pomiędzy obfitością orzęsków i wrotków w badanych mikrosiedliskach. Może to świadczyć o ścisłej zależności troficznej pomiędzy tymi grupami mikroorganizmów.

Słowa kluczowe: jezioro, psammon, orzęski, wrotki