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CILIATES ON THE MACROPHYTES IN INDUSTRIALLY HEATED LAKES (KUJAWY LAKELAND, POLAND)

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Ciliates on the Macrophytes in Industrially Heated Lakes (Kujawy Lakeland, Poland). Babko R., Fyda J., Kuzmina T., Hutorowicz A. — The ciliate assemblage on the macrophytes was examined in 2005 during the vegetation period in the Konińskie Lakes which are heating by post-cooling waters from thermal electric plants. As a result of changed temperature regimen the alien thermophilic macrophyte *Vallisneria spiralis* is becoming increasingly common in the littoral zone. A total of 150 ciliate taxa belonging to 27 orders were found. Greater ciliate species diversity was found on architecturally complex, submerged forms such as *Ceratophyllum demersum* and *Myriophyllum spicatum*. By contrast the ciliate compositions on emergent macrophytes with simple architecture in their submerged parts, such as *Typha, Sparganium*, or *Acorus,* were less species rich. Despite the simple architecture of *Vallisneria* leaves, the ciliate diversity on them was high. The results show that replacement of native macrophytes by the alien form *V. spiralis* in heated lakes did not impoverish the ciliate diversity.

Key words: ciliate, macrophytes, diversity, lakes.

Ресничные простейшие на макрофитах в озерах, подверженных тепловому загрязнению (озерный край Куявы, Польша). Бабко Р., Фыда Я., Кузьмина Т., Хуторович А. — В течение вегетационного периода 2005 г. изучали ассамблею ресничных простейших на макрофитах в Конинских озерах, подверженных тепловому загрязнению, которое вызвано поступлением подогретых вод с теплоэлектростанции. Вследствие изменения температурного режима водоемов, в их литорали доминирующее положение среди макрофитов занял адвентивный вид *Vallisneria spiralis.* Всего на макрофитах было зарегистрировано 150 таксонов ресничных простейших, относящихся к 27 отрядам. Большее разнообразие видов ресничных простейших обнаруживалось на пространственно сложноорганизованных поверхностях таких макрофитов, как *Ceratophyllum demersum* и *Myriophyllum spicatum.* На макрофитах с простой архитектурой, таких как, например, *Typha*, *Sparganium* и *Acorus*, количество видов было меньшим. В то же время, несмотря на простую архитектуру листьев *Vallisneria*, разнообразие ресничных простейших на них было высоким. Таким образом, вытеснение аборигенных макрофитов адвентивным видом *V. spiralis* в условиях подогретых озер не приводило к снижению разнообразия ресничных простейших.

Ключевые слова: ресничные простейшие, макрофиты, разнообразие, озера.

Introduction

In freshwater lakes, periphyton communities develop mainly in the littoral zone on the submerged surfaces of water plants (Wetzel, 1983). Macrophytes differ strongly in the architecture of leaves and stems, as well as in the texture of plant surfaces and as a natural substrate for different periphytic species with both chemical and physical parameters of lake water, affect periphytic communities structure and species composition occurring on them (Raffaelli et al., 2000; Wetzel, 2001). Consequently the number of possible niches offered for a variety of periphytic species is enormous, so differences in species composition and density on different macrophytes are likely to occur (Messyasz, Kuczyńska-Kippen, 2006; Mieczan, 2007; Pals et al., 2006).

Periphytic communities are composed of a range of organisms including ciliated protozoa which are among the least studied, yet play an important role as consumers of bacteria, flagellates, and periphytic algae (Sleigh et al., 1992; Primc-Habdija, Radanowiĉ, 1998). Recent studies have demonstrated that the composition of ciliate periphyton communities in both marine and freshwater habitats is influenced by water chemistry, especially the availability of nutrients (Gong et al., 2005; Mieczan, 2005; Primc-Habdija et al., 2001; Wickham et al., 2004). However, it is uncertain whether it is the physicochemical parameters of the lake or the kinds of macrophyte present as a substrate for attachment that is most important in determining the periphyton species composition (Messyasz, Kuczyńska-Kippen, 2006).

In the lakes investigated during the present study, an increase in the water temperature caused a change in the hydrophyte composition, the most conspicuous being the appearance of an alien thermophile macrophyte *Vallisneria spiralis*, which appeared in lakes in the mid-1990s (Gąbka, 2002; Hutorowicz et al., 2006; Protasov et al., 1994). As *V. spiralis* becomes more abundant in Konińskie Lakes (Hutorowicz et al., 2006) and builds submerged mono-species water meadows, the native submerged macrophytes move to the deeper parts of lake. The effects of this process on the ciliate diversity in periphyton, however, are still unknown. The aim of this study was to determine the ciliate diversity and assemblage composition occurred in heated lakes both on alien (*V. spiralis, Eichhornia crassipes* (Mart.)) and native macrophytes.

Material and methods

The studied lakes Ślesińskie, Mikorzyńskie, and Licheńskie are situated in Central Poland in the Kujawskie Lakeland. These are typically postglacial, eutrophic lakes suffering from strong anthropopression. The main stressing factor is the introduction of post cooling, heated water from Pątnyw-Adamyw-Konin power plants to the lake system. As a result of industrial pressure, higher in comparison to other lakes in the region, there has been an observed increase in the mean water temperature of about 7.5–9.5°C (Socha, Zdanowski, 2001). These lakes also have a very short retention times (between 3 and 14 days on average in 1987–2000) and are connected to one another by a series of canals and locks. We chose three sampling stations located in those three lakes of the system. They were situated in shallow gulfs where the abundance and species richness of the macrophytes were both high.

In addition to the typical macrophytes originally found in these lakes and present in similar lakes, the invasion of the alien species *Vallisneria spiralis* has been observed since 1990 (Protasov et al., 1994). Currently in certain areas of the studied lakes, *V. spiralis* forms a mono-species, submerged water meadow up to 2.5 m in depth. Consequently most native, submerged macrophytes, with the exception of *Nuphar*, have either moved to deeper parts of the lakes or have disappeared.

An additional alien species *Eichhornia crassipes*, probably originating from nearby artificial garden ponds, was also noticed at the station on Lake Ślesińskie. *Eichhornia* did not occur at this station throughout the whole year. During the summer months, however, it was checked for ciliates as another potential alien species that may adjust to living there in the future. The native macrophytes such as *Ceratophyllum demersum* L., *Myriophyllum spicatum* L., *Potamogeton perfoliatus* L., *Najas marina* L., *Typha angustifolia* L., *Nuphar lutea* (L.), *Sparganium* sp., *Phragmites australis* (Cav.), and *Acorus calamus* L. were also checked for their ciliate composition.

Sampling was carried out over a 2-month period during the macrophyte vegetation period in 2005. The periphyton samples were taken from submerged parts of macrophytes using a glass tube (36 mm in diameter, 26 cm long, approximately 210 ml in volume), which was carefully placed on the leaves or shoots of the chosen plant. The top of the tube was closed with a cork. A sample of approximately 20 cm of the macrophyte, i. e. leaves of submerged macrophytes or stems of emergent macrophytes, was cut, and the bottom of the tube was closed with another cork. The number of samples taken from *Vallisneria spiralis* and other macrophytes reflect the frequency of occurrence of the plant at the sampling stations. In total, 38 samples from *V. spiralis*, nine from *Myriophyllum*, five from *Typha*, four from *Ceratophyllum,* three from *Najas* and *Nuphar*, and one sample from each of the remaining plants were taken. Among the three lakes 36 samples were taken from Lake Licheńskie, 12 from Lake Mikorzyńskie and 19 from Lake Ślesińskie.

All ciliated protozoa were identified by examining them *in vivo* under a microscope at appropriate magnification, although when necessary silver staining methods were applied in order to reveal the infraciliature, silverline system and other argentophilic features (Wilbert, 1975; Song, Wilbert, 1995).

Species identification was based on Kahl (1930, 1931, 1932, 1935), Foissner and Berger (1996) and Foissner et al. (1991, 1992, 1994, 1995). Nomenclature is according to Lynn (2008). The allocation of ciliate species to main feeding groups was according to Foissner et al., works.

The faunistic similarities among studied macrophytes were calculated by means of Jaccard's method. For statistical analysis the programs STATISTICA 8.0 and PAST 1.81 (Hammer et al., 2001) were used.

Results

During the study, 150 ciliated protozoa taxa in total, belonging to 27 orders and 84 genera, were found on submerged and emergent macrophytes. Among these, 53 species were known as typically periphytic, 81 species occurred mostly in benthos, and 16 were considered to be planktonic. Judging by the species frequency on macrophytes, 133 ciliates belonged to ubiquitous species (more than five records during the study), and 17 species were considered rare (table 1).

The average number of ciliate species varied depending on macrophytes (fig. 1). The highest number (20) of ciliate taxa was found on *Eichhornia*. On *Ceratophyllum* 18 ± 3.5 (mean, SD), and on *Myriophyllum*, an average of 16 ± 8.1 (mean, SD) taxa occurred. On *V. spiralis*, 16 ± 7.3 (mean, SD) species of ciliated protozoa were found. Surfaces of *Potamogeton, Najas, Typha, Nuphar, Sparganium*, and *Acorus* were less rich in ciliate taxa: on average, 9 to 11 species were found on them. Among emergent macrophytes, only on *Phragmites* the number of ciliate taxa was higher (15 species). The differences in species number were not significant ($p > 0.05$).

On *Myriophyllum* and *Vallisneria*, 24 and 25 orders of ciliated protozoa were found respectively, but representatives of only 9 orders occurred on *Phragmites*. The crawling Urostylida, Sporadotrichida and Euplotida dominated on *Najas* (31%) and on *Ceratophyllum, Myriophyllum*, and *Acorus* (27% each). Free-swimming Prorodontida were most abundant on *Sparganium* (31%) and *Acorus* (28%). The stems of *Phragmites* were dominated by Sessilida and small Philasterida (33% each). Ciliate species compo-

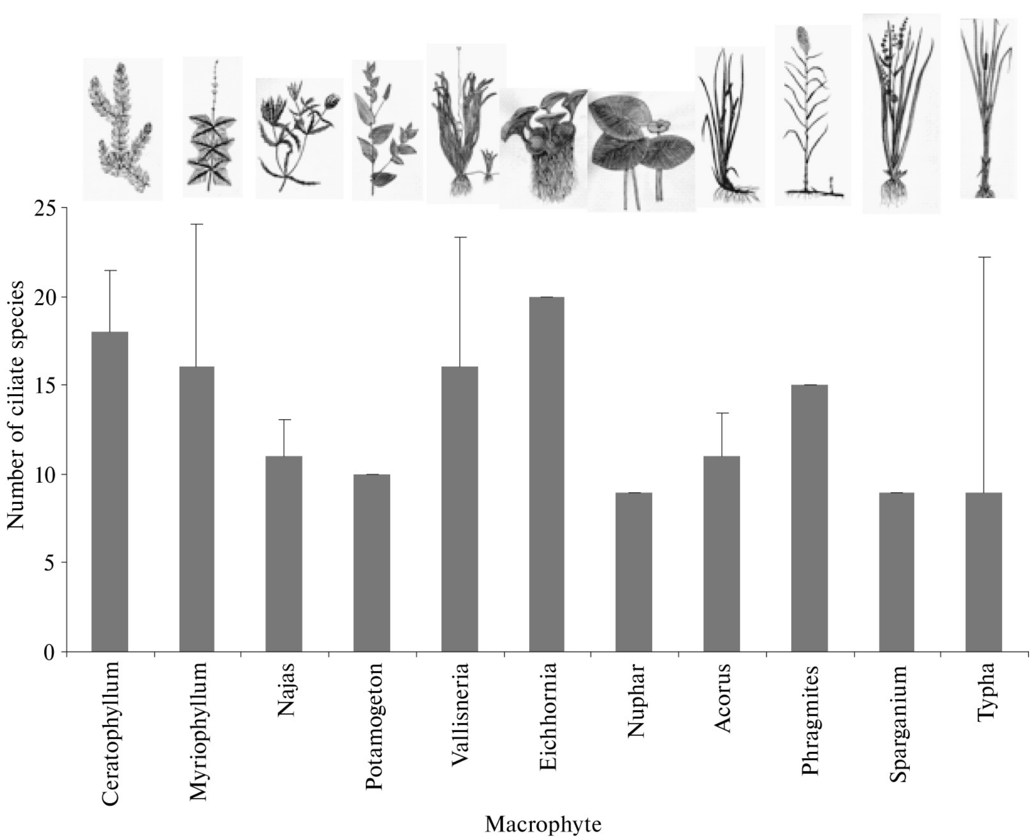

Fig. 1. Mean number of ciliate species found on different macrophytes (mean, SD, * lack of replications).

Рис. 1. Среднее количество видов ресничных простейших, обнаруженное на различных макрофитах (среднее, стандартное отклонение, *повторности отсутствуют).

Table 1. List of ciliated protozoa and their frequencies (% of samples) found on *Vallisneria spiralis* and other macrophytes in littoral zone of Konińskie Lakes (*according to Foissner. Berger, 1996, A — periphyton, B — benthos, Fs — anaerobic, P — planktonic, T — epizoic).

Таблица 1. Список ресничных простейших и их встречаемость (% проб) на *Vallisneria spiralis* и других макрофитах в литоральной зоне Конинских озер (*по: Foissner, Berger, 1996, A — перифитон, B — бентос, Fs — анаэробы, P — планктнеры, T — эпизоонты).

Taxon	Licheńskie L.		Ślesińskie L.		Mikorzyńskie L.		Preffered habitat*
	Vallisneria	Other macrophytes	*Vallisneria*	Other macrophytes	*Vallisneria*	Other macrophytes	
LOXODIDA JANKOWSKI, 1980							
Loxodes striatus (Engelmann,1862)	0	0	0	0	9	8	B, P
HETEROTRICHIDA STEIN, 1859							
Spirostomum teres Claparéde & Lachmann, 1858	0	3	0	0	0	0	P
Stentor coeruleus (Pallas, 1766)	22	17	0	5	18	17	B, A, P
Stentor igneus Ehrenberg, 1838	17	19	14	26	9	17	B, P
Stentor muelleri Ehrenberg, 1831	0	0	0	5	9	8	A
Stentor multiformis (Mueller, 1786)	0	0	0	21	0	0	B, A
Stentor polymorphus (Mueller, 1773)	17	11	0	0	0	0	B, A
Stentor roeseli Ehrenberg, 1835	30	28	14	42	18	17	B, A
EUPLOTIDA SMALL & LYNN, 1985							
Aspidisca cicada (Mueller, 1786)	43	36	29	42	36	33	B, A
Aspidisca lynceus (Mueller, 1773)	13	11	14	16	0	0	B, A
Euplotes affinis (Dujardin, 1841)	13	14	0	5	9	8	B
Euplotes moebiusi Kahl, 1932	4	6	0	0	9	8	B, A
Euplotes patella (Mueller, 1773)	26	33	29	42	27	25	B, A
Euplotes sp.	0	0	0	5	0	0	B, A
TINTINNIIDA KOFOID & CAMPBELL, 1929							
Codonella cratera (Leidy, 1877)	9	8	14	11	0	0	P, B
Tintinnidium semiciliatum (Sterki, 1879)	4	3	14	5	0	0	A, B
Tintinnidium sp.	0	0	14	5	0	0	P
CHOREOTRICHIDA SMALL & LYNN, 1985							
Rimostrombidium velox (Faure-Fremiet, 1924)	0	0	14	5	0	0	P, B
Strobilidium caudatum (Fromentel, 1876)	0	3	14	11	9	8	P, B
Strobilidium humile Penard, 1922	0	0	14	5	0	0	P, B
Strobilidium sp.	9	6	0	0	18	17	P
STICHOTRICHIDA FAURE-FREMIET, 1961							
Kerona pediculus (Mueller, 1773)	4	8	0	5	18	17	T, P
SPORADOTRICHIDA FAURE-FREMIET, 1961							
Gonostomum affine Stein, 1859	9	8	0	0	0	0	A, B
Halteria grandinella (Mueller, 1773)	13	8	0	0	9	17	P
Oxytricha bifaria Stokes, 1887	9	11	43	37	36	33	B
Oxytricha sp.	13	17	14	16	9	8	B
Paraurostyla weissei (Stein, 1859)	4	6	0	0	0	0	B
Sporadotrichida Gen. sp.	4	3	0	0	0	0	B
Stylonychia mytilus Ehrenberg, 1838	65	56	71	58	36	33	B, A
Stylonychia pustulata (Mueller, 1786)	22	19	14	11	0	0	B, A
Stylonychia putrina Stokes, 1885	4	3	0	0	0	0	B
Tachysoma pellionellum (Mueller, 1773)	35	28	43	47	18	17	B
UROSTYLIDA JANKOWSKI, 1979							
Diaxonella sp.	4	6	0	5	0	8	B
Holosticha monilata Kahl, 1928	17	14	0	0	0	0	B
Holosticha pullaster (Mueller, 1773)	22	22	29	32	45	42	B
Holosticha sp.	17	11	0	0	18	17	B
Paruroleptus caudatus Stokes, 1886	4	3	14	5	0	0	B
Uroleptus musculus (Kahl, 1932)	4	6	14	11	27	33	B, A
Uroleptus piscis (Mueller, 1773)	0	0	14	11	0	0	B, A
Uroleptus sp.	13	8	0	5	0	0	B, A
Urostyla grandis Ehrenberg, 1830	17	17	0	5	0	0	B
Urostyla sp.	0	0	0	0	9	8	B
STROMBIDIIDA PETZ & FOISSNER, 1992							
Limnostrombidium viride (Stein, 1867)	9	6	0	5	0	0	P
Strombidium sp.	4	3	0	0	9	8	A, B
HAPTORIDA CORLISS, 1974							

Table 1 (*continued*).
Продолжение таблицы 1.

Taxon	Licheńskie L.		Ślesińskie L.		Mikorzyńskie L.		Preffered habitat*
	Vallis-neria	Other macro-phytes	*Vallis-neria*	Other macro-phytes	*Vallis-neria*	Other macro-phytes	
Chaenea sp.	4	3	0	0	0	0	B, A
Enchelyodon fusidens Kahl, 1930	0	0	14	11	9	8	B, A
Enchelys gasterosteus (Kahl, 1926)	0	0	0	0	0	8	Fs, B
Homalozoon vermiculare (Stokes, 1887)	4	3	0	0	9	8	B, A
Lacrymaria filiformis Maskell, 1886	0	0	0	0	0	8	B, A
Lacrymaria olor (Mueller, 1786)	4	8	0	11	0	0	B, A
Phialina minima (Kahl, 1927)	4	6	0	0	0	0	B, A
Spathidium sp.	4	3	0	0	9	8	A, B, P
Trachelius ovum (Ehrenberg, 1831)	9	11	14	11	0	0	A, B, P
Trachelophyllum apiculatum (Perty, 1852)	4	3	0	0	0	0	A, B
PLEUROSTOMATIDA SCHEWIAKOFF, 1896							
Acineria incurvata Dujardin, 1841	0	0	0	5	0	0	A, B
Acineria uncinata Tucolesco, 1962	48	31	29	26	36	33	A, B
Amphileptus pleurosigma (Stokes, 1884)	22	14	14	11	0	0	A, B
Amphileptus procerus (Penard, 1922)	4	8	14	26	18	17	B
Amphileptus sp.	0	0	0		9	8	A, B
Litonotus anguilla Kahl, 1930	0	0	0	5	0	0	B, A
Litonotus crystallinus (Vuxanovici, 1960)	0	3	14	5	0	0	B, A
Litonotus cygnus (Mueller, 1773)	9	14	0	11	0	0	B, A
Litonotus lamella (Mueller, 1773)	17	22	14	16	18	17	B, A
Loxophyllum helus (Stokes, 1884)	9	6	0	0	0	0	A, B
Loxophyllum meleagris (Mueller, 1773)	13	14	0	5	9	8	A, B
CHLAMYDODONTIDA DEROUX, 1976							
Chilodonella uncinata (Ehrenberg, 1838)	48	39	29	32	18	17	A, B
Chlamydodon sp.	0	3	0	0	0	0	A, B
Gastronauta membranaceus Buetschli, 1889	0	0	14	5	9	8	A, B
Pseudochilodontopsis fluviatilis Foissner, 1988	0	3	0	0	0	0	A, B
Pseudochilodontopsis sp.	4	3	0	5	9	8	A, B
Trithigmostoma cucullulus (Mueller, 1786)	9	14	0	5	45	42	A, B
DYSTERIIDA DEROUX, 1976							
Dysteria fluviatilis (Stein, 1859)	4	6	0	11	0	0	A, B
Trochilia minuta (Roux, 1899)	17	14	14	21	27	25	A, B
ENDOGENIDA COLLIN, 1912							
Acineta tuberosa Ehrenberg, 1833	0	0	0	5	0	0	A, T
SYNHYMENIIDA PUYTORAC ET AL. IN DEROUX, 1978							
Chilodontopsis depressa (Perty, 1852)	9	14	0	0	0	0	A, B
Zosterodasys transversa (Kahl, 1928)	0	3	0	0	0	0	A, B
NASSULIDA JANKOWSKI, 1967							
Furgasonia trichocystis (Stokes, 1894)	0	3	0	0	0	0	P
Nassula picta Greeff, 1888	0	3	0	0	9	8	B, A, P
Nassula sp.	0	0	0	0	9	8	B, A, P
Obertrumia aurea (Ehrenberg, 1833)	0	3	14	11	9	8	B, P
MICROTHORACIDA JANKOWSKI, 1967							
Pseudomicrothorax sp.	0	0	0	0	9	8	A, B
BURSARIOMORPHIDA FERNANDEZ-GALIANO, 1978							
Bursaridium pseudobursaria (Faure-Fremiet, 1924)	0	0	0	5	0	0	P
CYRTOLOPHOSIDIDA FOISSNER, 1978							
Cyrtolophosis mucicola Stokes, 1885	0	0	0	0	18	17	B
PRORODONTIDA CORLISS, 1974							
Coleps hirtus (Mueller, 1786)	74	69	57	53	64	67	A, B, P
Coleps spetai Foissner, 1984	26	19	0	5	18	17	P
Holophrya discolor Ehrenberg, 1833	9	8	29	16	9	8	B, P
Holophrya teres Ehrenberg, 1833	4	6	0	0	0	0	B, P
Placus luciae (Kahl, 1926)	4	3	0	0	0	8	B, A
Prorodon niveus Ehrenberg, 1833	0	0	0	5	0	0	B

Table 1 (*continued*).
Продолжение таблицы 1.

Taxon	Licheńskie L.		Ślesińskie L.		Mikorzyńskie L.		Preffered habitat*
	Vallisneria	Other macrophytes	*Vallisneria*	Other macrophytes	*Vallisneria*	Other macrophytes	
Urotricha agilis (Stokes, 1886)	0	3	0	0	0	0	B, P
Urotricha armata Kahl, 1927	4	8	0	0	0	0	B, A
Urotricha furcata Schewiakoff, 1892	4	6	0	0	9	8	P
Urotricha ovata Kahl, 1926	13	11	0	5	9	8	B, P
Urotricha sp.	13	11	0	0	9	8	B, P
PENICULIDA FAURE-FREMIET IN CORLISS, 1956							
Frontonia acuminata (Ehrenberg, 1833)	13	11	14	11	18	17	B, A, P
Frontonia angusta Kahl, 1931	9	11	0	5	18	25	B, A, P
Frontonia atra (Ehrenberg, 1833)	9	11	0	0	9	8	B, P
Frontonia leucas (Ehrenberg, 1833)	0	0	0	5	0	0	B, A, P
Frontonia roquei Dragesco, 1970	9	6	0	0	9	8	B, A, P
Lembadion lucens (Maskell, 1887)	4	14	0	0	0	0	B, P
Paramecium aurelia complex Sonneborn, 1975	4	8	0	0	0	0	B, P
Paramecium bursaria (Ehrenberg, 1831)	9	6	0	0	0	0	A, B, P
Paramecium caudatum Ehrenberg, 1833	9	8	0	0	9	8	B, A, P
Stokesia vernalis Wenrich, 1929	0	3	0	0	0	0	P
Urocentrum turbo (Mueller, 1876)	4	3	0	0	0	0	B, A, P
PHILASTERIDA SMALL, 1967							
Cinetochilum margaritaceum (Ehrenberg, 1831)	35	39	43	53	55	58	A, B, P
Dexiotricha granulosa (Kent, 1881)	9	6	14	5	0	8	B, A
Philasterida Gen. sp. 1	0	0	0	11	18	17	B, P
Philasterida Gen. sp. 2	0	0	0	5	9	8	B, P
Philasterida Gen. sp. 3	0	0	14	5	9	8	B, P
Pseudocohnilembus pusillus (Quennerstedt, 1869)	13	19	14	16	64	67	B, P
Uronema nigricans (Mueller, 1786)	26	22	14	5	0	8	B, A, P
Urozona buetschlii Schewiakoff, 1889	0	3	0	0	0	0	B, P
PLEURONEMATIDA FAURE-FREMIET IN CORLISS, 1956							
Ctedoctema acanthocryptum Stokes, 1884	13	17	0	11	73	75	B
Cyclidium glaucoma Mueller, 1773	48	42	29	32	64	67	B, A, P
Cyclidium versatile Penard, 1922	0	0	0	5	27	25	B, A, P
Cyclidium sp.	4	8	0	5	0	0	B, A, P
Pleuronema coronatum Kent, 1881	0	3	0	0	9	8	B
TETRAHYMENIDA FAURE-FREMIET IN CORLISS, 1956							
Colpidium colpoda (Losana, 1829)	0	3	0	0	0	0	B
Dexiostoma campylum (Stokes, 1886)	4	3	0	0	0	0	B
Tetrahymena pyriformis complex Nanney& McCoy, 1976	22	17	14	26	9	8	B
OPHRYOGLENIDA CANELLA, 1964							
Ophryoglena flava (Ehrenberg, 1833)	13	11	0	11	9	8	B
Ophryoglena utriculariae Kahl, 1930	0	3	0	0	0	0	B
SESSILIDA KAHL, 1933							
Campanella umbellaria (Linnaeus, 1758)	4	3	0	5	0	0	A, B, T
Carchesium polypinum (Linnaeus, 1758)	4	6	0	0	0	0	B, A, T
Cothurnia sp.	0	0	14	5	9	8	A, B, T
Epistylis chrysemydis Bishop & Jahn, 1941	0	0	14	5	0	0	A, T
Epistylis keronata Nusch, 1970	0	0	0	0	27	25	A, T
Epistylis hentscheli Kahl, 1935	4	8	14	5	0	0	A, B
Epistylis plicatilis Ehrenberg, 1831	0	0	0	0	9	8	A, B, T
Opercularia articulata Goldfuss, 1820	0	0	0	0	18	17	A, T
Opercularia nutans (Ehrenberg, 1831)	17	14	0	0	0	0	A, T
Platycola decumbens (Ehrenberg, 1830)	0	0	0	11	0	0	A
Pyxicola sp.	0	0	0	0	9	8	A
Sessilida Gen. sp.	0	0	0	0	18	17	A, B
Thuricola folliculata Kent,1881	0	0	0	11	0	0	A

Table 1 (*continued*).
Окончание таблицы 1.

Taxon	Licheńskie L.		Ślesińskie L.		Mikorzyńskie L.		Preffered habitat*
	Vallis-neria	Other macro-phytes	*Vallis-neria*	Other macro-phytes	*Vallis-neria*	Other macro-phytes	
Thuricola kellicottiana (Stokes, 1887) Kahl, 1935	4	3	0	0	0	0	A
Vagnicola ingenita (Mueller, 1786)	0	0	0	21	9	8	A, T
Vagnicola sp.	4	3	0	0	0	0	A, T
Vorticella aquadulcis Stokes, 1887	4	6	14	21	9	8	A, B
Vorticella campanula (Ehrenberg, 1830)	78	78	100	89	73	67	A, B, T
Vorticella convallaria Linnaeus, 1767	52	61	14	53	73	75	A, B, T
Vorticella marginata Stiller, 1931	4	3	0	0	0	0	A, B
Vorticella octava Stokes, 1885	0	3	0	0	0	0	A, B
Vorticella picta Ehrenberg, 1838	4	3	0	0	18	17	A, B
Vorticella sp.	4	3	0	0	0	0	A, B
Zoothamnium arbuscula Ehrenberg, 1838	9	6	14	5	0	0	A
Zoothamnium procerius Kahl, 1935	4	3	0	0	0	0	A, B, T
Zoothamnium simplex Kent, 1881	4	3	0	5	0	0	A, B, T
MOBILIDA KAHL, 1933							
Trichodina pediculus Ehrenberg, 1831	0	0	0	5	9	8	T, P
Total number of taxa	**96**	**112**	**48**	**85**	**74**	**80**	
				150			

sition on *Potamogeton* was not rich, but represented by 10 orders and 14–15% of total species found.

Representatives of sessile, crawling, and free-swimming ciliates occurred on all macrophytes. On *Phragmites* and *Sparganium*, the free-swimming ciliates were dominant (50–68% of species present), while on *Myriophyllum*, *Ceratophyllum*, *Acorus*, and *Najas*, the crawling ciliates were the most numerous and reached, respectively, 45, 52 56, and 59% of the total species present (fig. 2). The percentage of sessile species var-

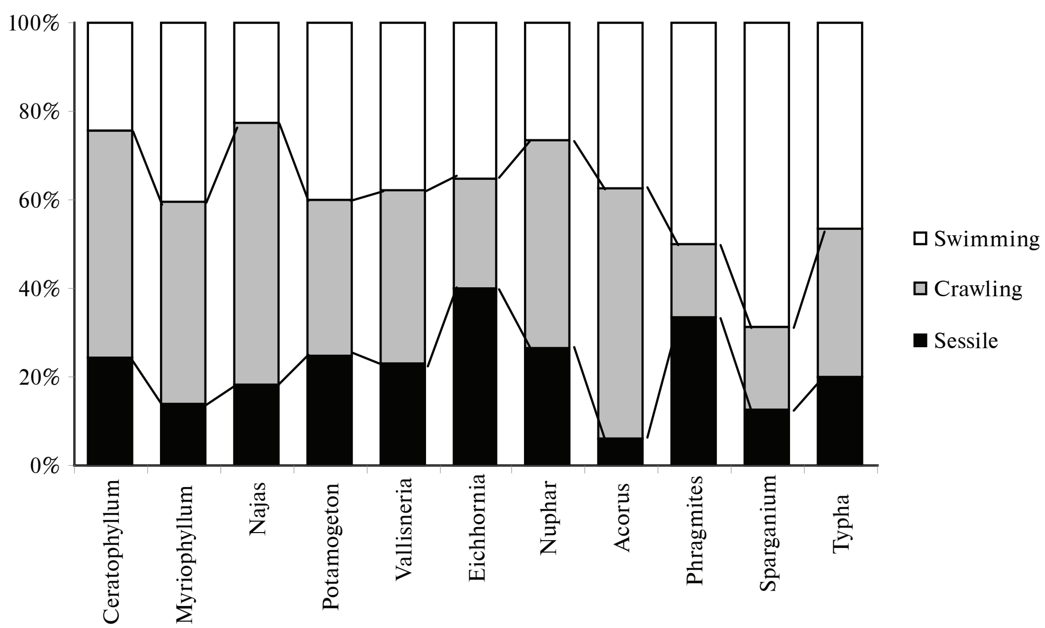

Fig. 2. Percentage of species number of sessile, crawling, and free-swimming ciliates on macrophytes.

Рис. 2. Процентное соотношение количества видов сессильных, ползающих и свободноплавающих цилиат на макрофитах.

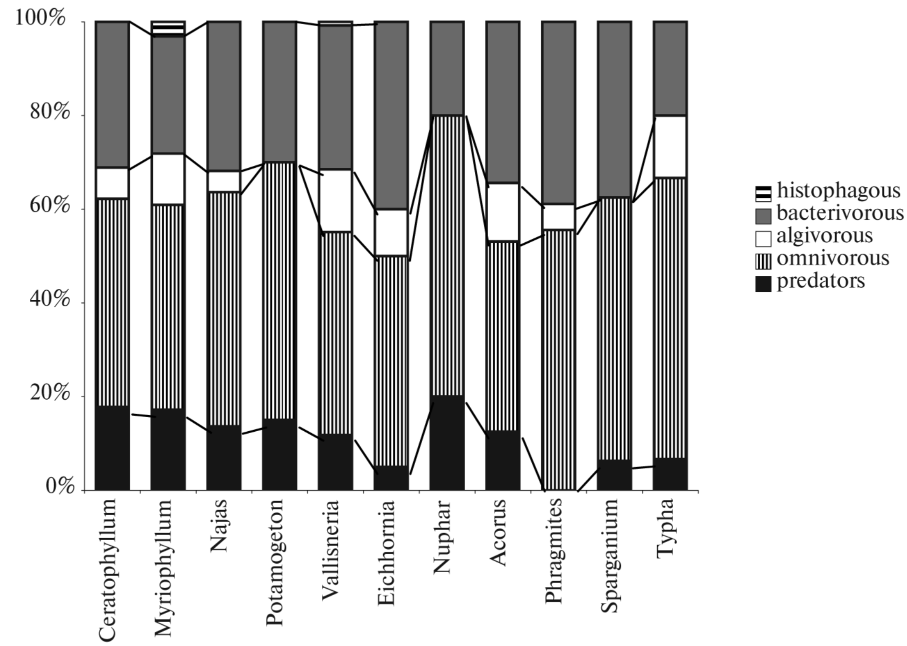

Fig. 3. Percentage of ciliate feeding groups on macrophytes.

Рис. 3. Процентное соотношение различных трофических групп цилиат на макрофитах.

ied among the macrophytes from 6% on *Acorus* to 40% on *Eichhornia,* which was a result of only two species on *Typha*, *Nuphar, Sparganium,* and *Acorus* and of eight sessile species on *Eichhornia*. The percentage of crawling ciliates had different pattern. On *Najas*, *Acorus*, *Ceratophyllum*, *Nuphar* and *Myriophyllum,* crawling species were dominant and reached from 59% to 45% respectively. On *Typha, Potamogeton* and *Vallisneria* crawling ciliates accounted for between 33 and 39% of the total species, and on *Sparganium* and *Phragmites* the percentage of crawling ciliate species was less than 20%. Sessile and crawling species considered as typically periphytic were the most abundant on *Nuphar*, *Myriophyllum* and *Ceratophyllum*.

The dominant group of ciliates living on macrophytes were bacterivorous (20-44%) or omnivorous (22-40%). They dominated on *Phragmites* and *Sparganium* (66% and 69% together, respectively) and on *Eichhornia* (40% bacterivorous). Predators comprised between 5% of ciliate species on *Eichhornia* to 18% on *Ceratophyllum*. Histophagous ciliates were rare and associated only with *Myriophyllum* (3%) and *V. spi-*

Table 2. Similarity of ciliate species composition among *Vallisneria spiralis* and other macrophytes.
Таблица 2. Сходство видового состава цилиат между *Vallisneria spiralis* и другими макрофитами.

Macrophyte	Jaccard index
Eichhornia crassipes (Mart.)	63,20
Ceratophyllum demersum L.	52,80
Myriophyllum spicatum L.	14,80
Potamogeton perfoliatus L.	5,88
Najas marina L.	41,67
Typha angustifolia L.	14,12
Nuphar lutea (L.)	6,60
Sparganium sp.	10,39
Phragmites australis (Cav.)	13,27
Acorus calamus L.	11,46

ralis (1%). All five trophic groups were present only on *V. spiralis* and *Myriophyllum* (fig. 3).

The Jaccard similarity index among ciliate composition on *V. spiralis* and other macrophytes was the highest for the alien form *Eichhornia* and the native form *Ceratophyllum*. The lowest similarity was among *Vallisneria* and native emergent and floating macrophytes (table 2).

Discussion

The composition of ciliate assemblages depends on habitat, water chemistry (especially nutrients), and surface of substrates. Number of species depends on the methods used, the surfaces studied and the habitat. Coppellotti and Matarazzo (2000), as an example, investigated ciliate colonization of glass slides in the Lagoon of Venice and found 45 species. In saline habitats in Jiaozhou Bay, China, the occurrence of 37 species of ciliates from 10 orders was noted on glass slides used as artificial surfaces (Gong et al., 2005), while 130 species of ciliates were reported on a combination of submerged objects and glass slides in the Caspian Sea (Agamaliev, 1974).

The results reported in the literature demonstrated strong affects of habitat structure and architecture of macrophyte leaf or stem on the spatial distribution and taxonomic composition of aquatic organisms (Duggan et al., 2001; Mieczan, 2007; Pals et al., 2006). Macrophytes strongly influence protozoan species composition by modifying protozoan food availability and increasing the spatial heterogeneity (Biyu, 2000). In a study of a macrophyte-abundant shallow lake in Eastern Poland, Mieczan (2007) found 23 ciliate species on *Chara* and *Ceratophyllum* stands and 10–14 species on *Phragmites* and *Typha*. In our study, the mean numbers of ciliate species found on *Ceratophyllum*, *Phragmites*, and *Typha* were similar to those reported by Mieczan (2007), i. e. 18, 15, and 9 species, respectively.

Ciliate assemblage on macrophytes in heated lakes is characterized by compex trophic structure composed of algivorous, bacterivorous, predators, omnivorous, and histophagous. Representatives of all trophic groups were found on native *Ceratophyllum* and *Myriophyllum*. At the simple surfaces of native macrophytes such as *Phragmites* or *Typha*, only the Sessilida and small bacterivorous forms from Prorodontida were abundant.

Although a well-developed periphyton community is supposed to occur on macrophytes with architecturally complicated structures, the results of our study showed that leaves of *V. spiralis*, in spite of their simple architecture, also had a rich ciliate assemblage with compex trophic structure. This is in contrast with the statement that ciliates prefer plants with complicated architecture, but supports the hypothesis that food availability and stable conditions play an important role for the ciliates. However, it should be noted that the dense patches of *Vallisneria* form peculiar space which is similar to macrophytes with complicated surface.

We found more ciliate species on leaves of the alien *V. spiralis* than on the submerged native macrophytes such as *Potamogeton* or *Najas*. This is even more clearly noticeable when compared with native emergent plants. Similar results for invertebrate communities associated with *V. americana* and Euroasian water-chestnut (*Trapa natans* L.) were reported by Strayer et al. (2003) who demonstrated, that the replacement of the native macrophyte (*V. americana*) by an alien (*Trapa*) in the Hudson River caused the increase in macroinvertebrate densities and probably increased the system-wide biodiversity.

The present study confirms that the average number of ciliate species on native macrophytes was higher on architecturally complex submerged forms such as *Ceratophyllum*, and *Myriophyllum* than on emergent macrophytes with simple architecture in their submerged parts such as *Acorus, Sparganium*, or *Typha*. In addition our results suggest that the replacement of the native macrophytes by monospecies water meadows of *Vallisneria* in the littoral of heated Konińskie Lakes did not negatively change the number of species and complexity of ciliate assemblage.

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