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Planktonic ciliates in Western Basin of Lake Ringsjön, Sweden: community structure, seasonal dynamics and long-term changes

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Summary

Temporal changes in species composition, abundance and biomass of planktonic ciliates in Western Basin of Lake Ringsjön, Sweden, were studied in 1988-1990 and 1998-2000. In total, 49 species were found. The most common species were *Tintinnidium* spp., *Halteria grandinella, Strombidium* spp., *Strobilidium* spp., *Coleps hirtus* and *Vorticella* spp. The planktonic ciliates ranged in abundance from 1.2 and 1.6 to 82.0 and 41.0 cells $l^{-1}\times10^3$ during the investigation, with a mean of 16.38 and 9.74 cells $l^{-1}\times10^3$, respectively. Biomass of the ciliate communities ranged from 27.6 and 50.0 to 1939.3 and 2182 μg l^{-1}. In terms of abundance and biomass, small Oligotrichida species were very important for the lake. The seasonal dynamics of the ciliates in Lake Ringsjön had a pattern typical of eutrophic lakes. Species composition in 1988-1990 and in 1998-2000 was very similar. The annual mean abundance and biomass of ciliates decreased at a large scale. The patterns of temporal distribution of some dominant species showed some changes.

Key words: ciliates, species composition, abundance, biomass, seasonal dynamics, Lake Ringsjön

Introduction

In freshwater environments, planktonic ciliates provide an important intermediate link between primary producers (algae and bacteria) and higher trophic levels (metazooplankton and fishes). As a significant fraction of the total primary production in aquatic environment is taken up by bacterioplankton (Bark, 1981; Gates, 1984; Hwang and Heath, 1997; Laybourn-Parry, 1992), the bacterivory of ciliates transfers much of this reduced carbon and nutrients up the food chain via protist – zooplankton – fish coupling (Sherr et al., 1991; Ambland et al. 1995, Weisse and Müller, 1998). In addition, ciliates are major consumers of algal picoplankton (Laybourn-Parry, 1992; Mathes and Arndt, 1995), which are often the dominant primary producers in the lakes. Protozoa account for 30% or more of the zooplankton biomass in some lakes, and most of them are ciliates (Hunt and Chein, 1983; Mathes and Arndt, 1995).

There is some evidence that ciliates are involved in bio-geochemical cycling of phosphorus and nitrogen and can increase the availability of nutrients for phytoplankton growth (Berman et al., 1987). Ciliate ecology in freshwater lakes has been extensively studied (Hecky and Kling, 1981; Pace and Orcutt, 1981; Taylor and Heynen, 1987; Beaver et al., 1988; Carrick and Fahnenstiel, 1990; Laybourn-Parry et al., 1990; Carrias et al., 1994; James et al., 1995; Xu and Nauwerck, 1996; Zingel, 1999; Xu and Zheng, 2000), in the different regions and in lakes with different trophic status (Zingel et al., 2002; Graham et al., 2004; Yasindi and Taylor, 2006; Obolkina, 2006; Huber and Gaedke, 2006; Macek et al., 2006; Conty et al., 2007; Agasild et al., 2007; Mieczan, 2007; Munawar et al., 2006; Sinistro et al., 2007; Zingel et al., 2007). In Sweden, however, such investigations have been rare. There is only one paper dealing with ecology of ciliates within a complex limnological study (Ulrika, 1999).

Lake Ringsjön (55°52′N, 13°32′E) is situated at the geographical mid-point of the southernmost county in Sweden, Scania. It has been of interest to limnologists for more than a century, and is one of the best-studied Swedish lakes. There are many limnological reports on this lake (Hansson et al., 1999; Bergman, 1999; Cronberg, 1999), but the ciliate community in the lake has so far not been investigated.

The aim of this study was to describe community structure, abundance and seasonal dynamics changes of ciliates in the Lake Ringsjön.

Material and methods

Sampling site

The sampling site was located in the Western Basin of Lake Ringsjön. The Lake is situated in southern Sweden and consists of three basins, Setofta Basin, Eastern Basin and Western Basin (Fig. 1). Eastern Basin and Western Basin are connected with each other through a small canal. Western Basin is about 15 km^2, and the maximum and mean depths are 5.4 and 3.1 m, respectively. The retention time in this basin is between 0.2 to 0.5 years (Enell and Fejes, 1996). The turnover time in this basin should be 0.18 to 0.39 years (Hansson et al., 1999).

Sampling

Both quantitative and qualitative planktonic ciliate samples were collected monthly during the investigation period. At the deepest part of the Western basin of Lake Ringsjön, the samples were taken with a 2 m tube sampler at several sites. The samples were pooled together in a bucket and samples for ciliates and phytoplankton quantitative analyses, chlorophyll a and water chemistry were collected from these integrated samples. Qualitative ciliate samples were collected with 10 μm plankton net. Quantitative and qualitative samples were preserved with formalin to 1 and 4% final solution, respectively.

Abiotic and biotic variables

Water temperature and dissolved oxygen were measured with a multiparameter probe. The water transparency was estimated with the use of the Secchi disc. The content of chlorophyll *a* in water samples was determined by spectrophotometry after extraction in acetone. The dissolved organic matter concentration was determined after filtration through a 0.2 μm polycarbonate membrane (Millipore). Total P, N and $NO_3 + NO_2$-nitrogen concentrations were analyzed as well.

The annual mean values of some abiotic and biotic variables in Western Basin of Lake Ringsjön are shown in Table 1.

Quantitative analysis of ciliates

Ciliates was counted in sedimentation chambers (5 and 10 ml) with an inverted Nikon phase contrast microscope at 200 and 400× magnification. Sedimentation time was more than 24 h. The whole chamber was observed.

Qualitative analysis of ciliates

The qualitative analysis of ciliates was carried with a Nikon light microscope (Type 104) at 200, 400 and 1000× magnification, after the samples were stained with Protargol. The staining was performed according to Foissner (1991). The ciliate species were identified on the basis of the descriptions of Kahl (1930-1935) and Foissner et al. (1991-1995, 1999). The taxonomic system of ciliates mainly followed the scheme of Corliss (1979).

Biomass and biodiversity index of ciliates community

The conversion of abundance to biomass for each species of ciliates was based upon the data given by Foissner et al. (1995).

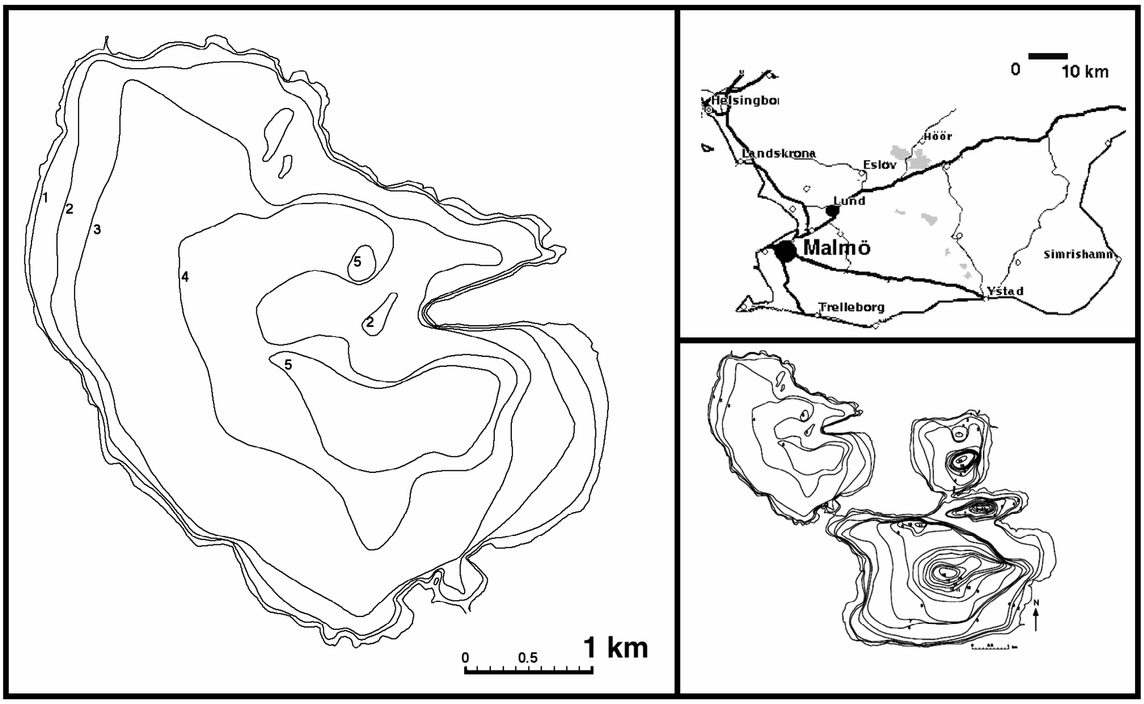

Fig. 1. Map of Western Basin in Lake Ringsjön, Sweden.

The biodiversity index (*d*) was calculated with a formula given by Margalef (1951) as follows:

$$d = (S-1) / \ln N$$

in which d is diversity index; *S* is species number of community and *N* is density of ciliates community (cells l^{-1}).

Results

The ciliate community composition

During the investigation period (1988—1990 and 1998 to 2000), a total of 49 species of ciliates was found, with 5 additional species from the fresh samples taken in 2001. Among them, 10 species were from Oligotrichida, 7 species from Prostomatida, 10 species from Hymenostomata, 7 species from Peritrichia, 8 species from Haptorida and 12 species from other orders (Table 2).

The most common ciliate species were *Tintinnidium* spp., *Halteria grandinella, Strombidium* spp., *Strobilidium* spp., *Coleps hirtus* and *Vorticella* spp. Within the 6 year period, the greatest species diversity was observed in August and September. The ciliate community consisted of 41 species in 1988-1990 and 40 species in 1998-2000. Among all

Table 1. Mean values of physicochemical parameters in Western Basin of Lake Ringsjön.

Years	1988	1989	1990	1998	1999	2000
Secchi depth (m)	0.93	0.97	1.21	1.4	1.2	1.1
Conductivity (mS m^{-1})	26.5	28	28.2	30.1	26.6	26.8
pH	8.55	8.42	8.4	8.3	8.3	8.4
Alkalinity (mekv l^{-1})	1.53	1.88	1.71	1.8	1.6	1.6
O_2 (%)	103	105	105	93	91	106
PO_4-P (μg l^{-1})	21	9	6	7	15	10
Total-P (μg l^{-1})	86	72	60	69	89	84
Particle-P(μg l^{-1}l)	50	46	42	53	65	67
NO_3+NO_2-N (mg l^{-1})	0.64	0.24	0.28	0.609	0.608	0.528
Total-N (mg l^{-1})	1.99	1.61	1.48	1.877	2.033	1.983
Chlorophyll *a* (mg m^{-3})	29.9	38.1	36.8	34	39	31.8

Table 2. Species list of ciliated protozoa found in Lake Ringsjön, Sweden, during 1988-1990 and 1998-2000.

Ciliates	1988	1989	1990	1998	1999	2000	Suppl.*
Prostomatida							
Coleps hirtus	+	+	+	+	+	+	
Holophrya discolor	+	+	+	+	+	+	
Urotricha agilis	+	+	+	+	+	+	
Urotricha apsheronica	+	+	+		+	+	
Urotricha castalia	+	+	+	+	+	+	
Urptricha furcata	+	+		+	+	+	
Urotricha farcta	+	+					
Haptorida							
Askenasia acrostomia	+	+	+	+	+	+	
Askenasia chlorelligera	+						
Didinium nasutum						+	
Dileptus anser	+	+		+	+	+	
Mesodinium pulex	+		+	+	+	+	
Monodinium balbianii			+	+	+	+	
Spathidium sp.	+	+	+				
Enchelys sp.	+	+	+	+	+	+	
Pleutostomatida							
Hemiophryas sp.	+	+	+			+	
Lagynophrya sp.				+		+	
Litonotus fasciola	+	+		+	+	+	
Nassulida							
Nassula sp.			+				
Cyrtophorida							
Phascolodon vorticella				+		+	
Chlamydonellopsis plurivacuolata							+
Pseudochilodonopsis piscatoris							+
Hymenostomatida							
Cinetochilum margaritaceum	+	+	+	+	+	+	
Ctedoctema acanthocrypta	+	+	+	+	+	+	
Cyclidium glaucoma	+	+	+	+	+	+	
Cyclidium elongatum					+		
Histiobalantium bodamicum	+	+	+	+	+	+	
Lembadion lucens				+		+	
Pleuronema sp.		+					
Pseudocohnilembus pusillus	+	+	+				
Tetrahymena sp.					+		
Epenardia myriophylli							+

Table 2. (Continuation).

Ciliates	1988	1989	1990	1998	1999	2000	Suppl.*
Peritrichida							
Rhabdostyla sp.						+	
Cothurnia sp.	+	+	+	+		+	
Epistylis sp.	+	+	+	+	+	+	
Epistylis sp.**	+	+				+	
Vaginicola sp.	+	+	+	+			
Vorticella cupifera	+	+		+	+	+	
Vorticella convallaria	+	+	+	+	+	+	
Heterotrichida							
Stentor polymorphus	+			+		+	
Stentor roeseli	+	+					
Hypotrichida							
Aspidisca castata							+
Holotricha kessleri							+
Stichotricha aculeata	+			+	+	+	
Ologotrichida							
Halteria grandinella	+	+	+	+	+	+	
Strobilidium humile	+	+	+	+	+	+	
Strobilidium caudatum	+	+	+	+	+	+	
Strobilidium velox	+	+	+	+	+	+	
Strombidium coronatum	+	+	+			+	
Strombidium crassulum						+	
Strombidium viride	+	+	+				
Tintinnidium fluviatile	+	+	+	+	+	+	
Tintinnidium pusillum	+	+	+	+	+	+	
Tintinnopsis sp.	+	+	+	+	+	+	
Stichotricha aculeata	+			+	+	+	
Ologotrichida							
Halteria grandinella	+	+	+	+	+	+	
Strobilidium humile	+	+	+	+	+	+	
Strobilidium caudatum	+	+	+	+	+	+	
Strobilidium velox	+	+	+	+	+	+	
Strombidium coronatum	+	+	+			+	
Strombidium crassulum						+	
Strombidium viride	+	+	+				
Tintinnidium fluviatile	+	+	+	+	+	+	
Tintinnidium pusillum	+	+	+	+	+	+	
Tintinnopsis sp.	+	+	+	+	+	+	

* Supplement species found from the living sample taken in 2001.
** Species epizoite on copepoda.

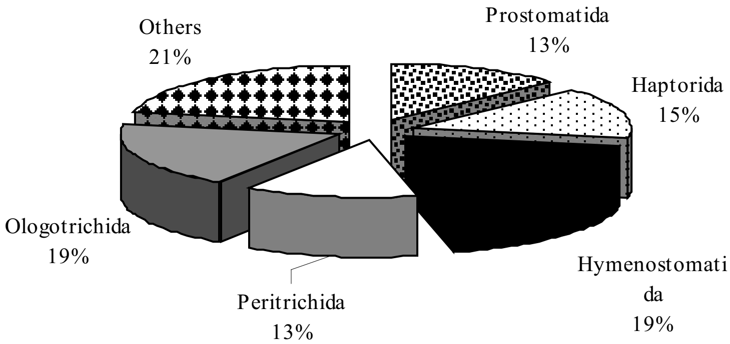

Fig. 2. Percentage of species composition from different groups of ciliated protozoa.

species, there were 15 species present only in 1988-1990 or in 1998-2000.

The percentage of species from different groups of ciliates in Western Basin of Lake Ringsjön during the investigation period is shown in Fig 2.

Abundance, biomass and seasonal dynamics of ciliates

Seasonal dynamics of total abundance of ciliate community during the investigation period is shown in Fig. 3, and the percentage distribution of abundances of 5 major ciliate groups with the seasonal changes is shown in Fig. 4.

In 1988-1990, the mean abundance of ciliates was 16.38 cells $l^{-1}\times10^3$, while the maximum density was recorded in September, 1990 (82.0 cells $l^{-1}\times10^3$); in 1998—2000, the mean abundance was 9.74 cells $l^{-1}\times10^3$, while the maximum density was recorded in July, 2000 (42.0 cells $l^{-1}\times10^3$). The patterns of annual change of ciliate abundance in the lake had two peaks: the smaller one between March to April, and the larger one from July to September. Statistical analysis with SPSS showed that there was a significant difference between the abundance means of different periods (Mann-Whitney U-test, $p < 0.01$).

The contribution from different ciliate groups to the abundance varied. The most important group was Oligotrichida, contributing about 41% of the total abundance. All year round, except in autumn, the species from this group contributed most of the total abundance. Next to it was Hymenostomatida, accounting for about 26% of total abundance, but the species from this group could have the greatest abundance in autumn.

During the investigation, the mean biomass of planktonic ciliates community from 1988 to 1990 was 0.42 mg l^{-1} with a maximum value of 1.939 mg l^{-1} in July, 1989; from 1998 to 2000, the mean biomass of the planktonic ciliate community was 0.321 mg l^{-1} and the maximum of 2.182 mg l^{-1} appeared in June, 2000 (Fig. 5).

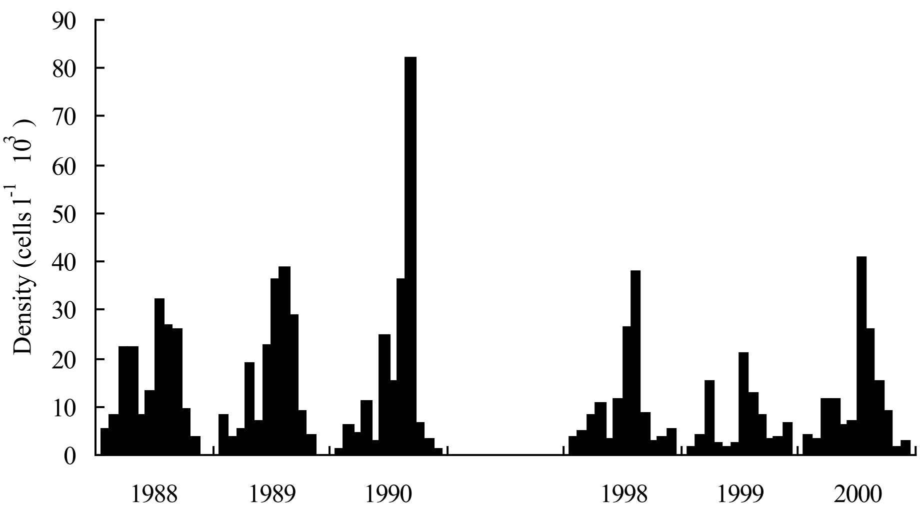

Fig. 3. Seasonal and long-term changes of total ciliated protozoa abundances.

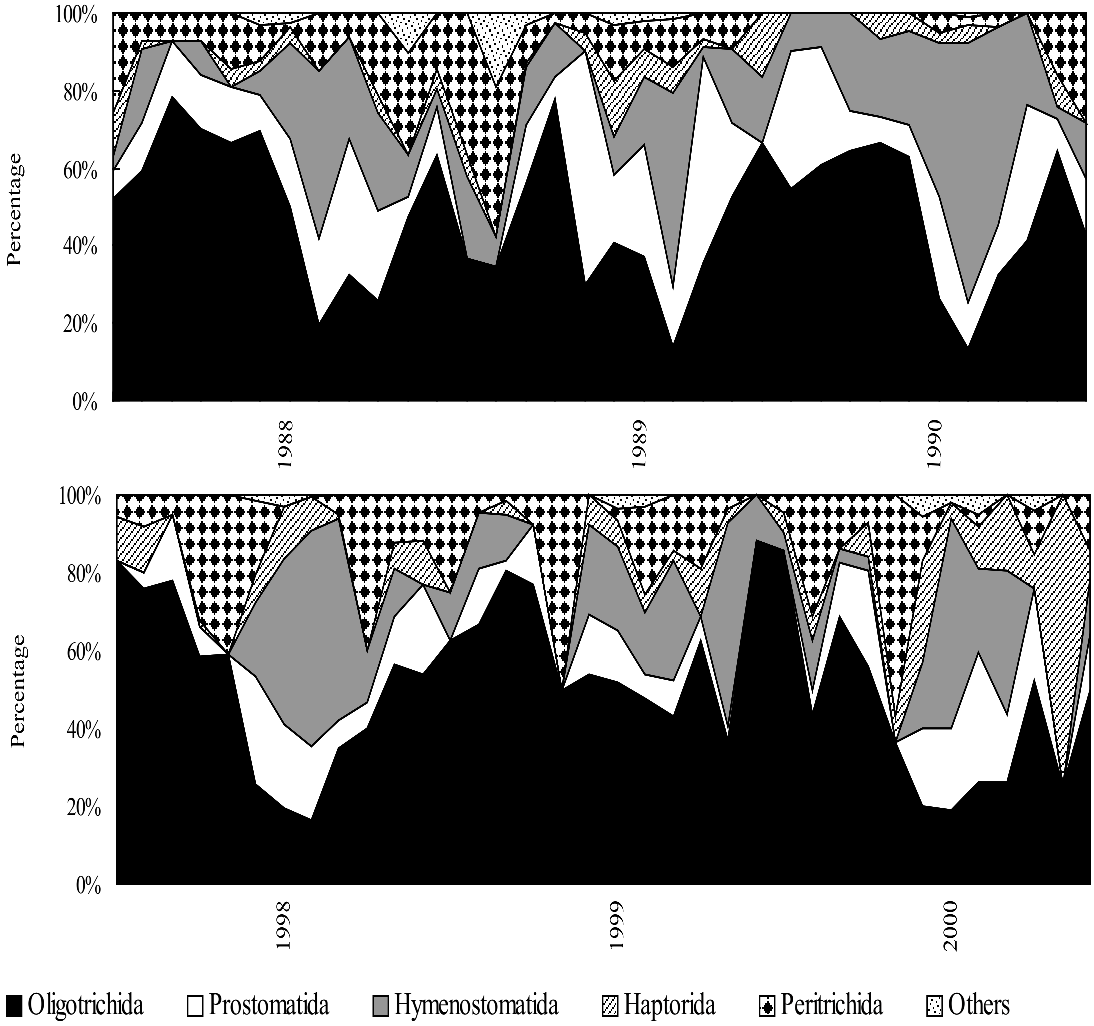

Fig. 4. Seasonal and long-term changes of abundance percentage distribution of 5 major ciliated protozoan groups.

Annual patterns of biomass change had a double peak, but not as regular those of abundance change. Except in 1988, the small biomass peaks of planktonic ciliates occurred between March to May, and the second large peak existed from July to September. In 1988, due to the presence of larger-size ciliates in the community, the highest peak of biomass was found in March to April.

The contribution of biomass from different ciliate groups is demonstrated in Fig. 6.

Similarly to abundance, the role of Oligotrichida in total biomass was also the most important one. This group accounted for 50% of the total biomass of the community from 1988 to 1990. Although the significance of this group slightly decreased from 1998 to 2000 (33.7% of total biomass), it was still the most important group to total biomass. This could be explained by the large body size of species like *Dileptus* sp. and *Stentor* spp., which could contribute greatly to the total biomass, even though, sometimes, there was no significant abundance.

Compared with abundance, the biomass significance from different groups in two periods, from 1988 to 1990 and from 1998 to 2000, had some changes. For instance, the biomass percentage from Prostomatida has doubled as compared with the former period. On the contrary, the biomass percentages from other groups decreased.

Seasonal dynamics of dominant ciliate species in Western Basin of Lake Ringsjön

Considering the contributions to both abundance and biomass, dominant species in the lake were *Halteria grandinella, Tintinnidium pusillum, T. fluviatile, Strobilidium humile, Tintinnopsis* sp.,

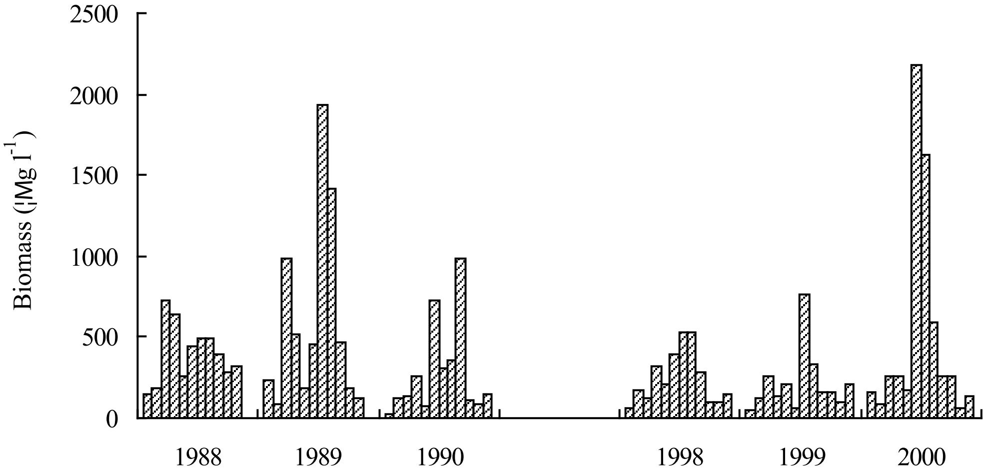

Fig. 5. Seasonal and long-term changes of total ciliated protozoan biomass.

Coleps hirtus and *Vorticella cupifera*. Their seasonal dynamics is demonstrated in Figs 7 to 13.

The annual abundance changes of *Halteria grandinella* and *Tintinnidium pusillum* had a very consistent pattern. The abundance and biomass of these two species were higher in the first three years than in the later period. Their peaks of abundance appeared during the summer every year.

T. fluviatile was similar to *Halteria grandinella* and *Tintinnidium pusillum* in the fact that its density decreased within long-term scale, but its seasonal peak normally occurred in spring or autumn each year.

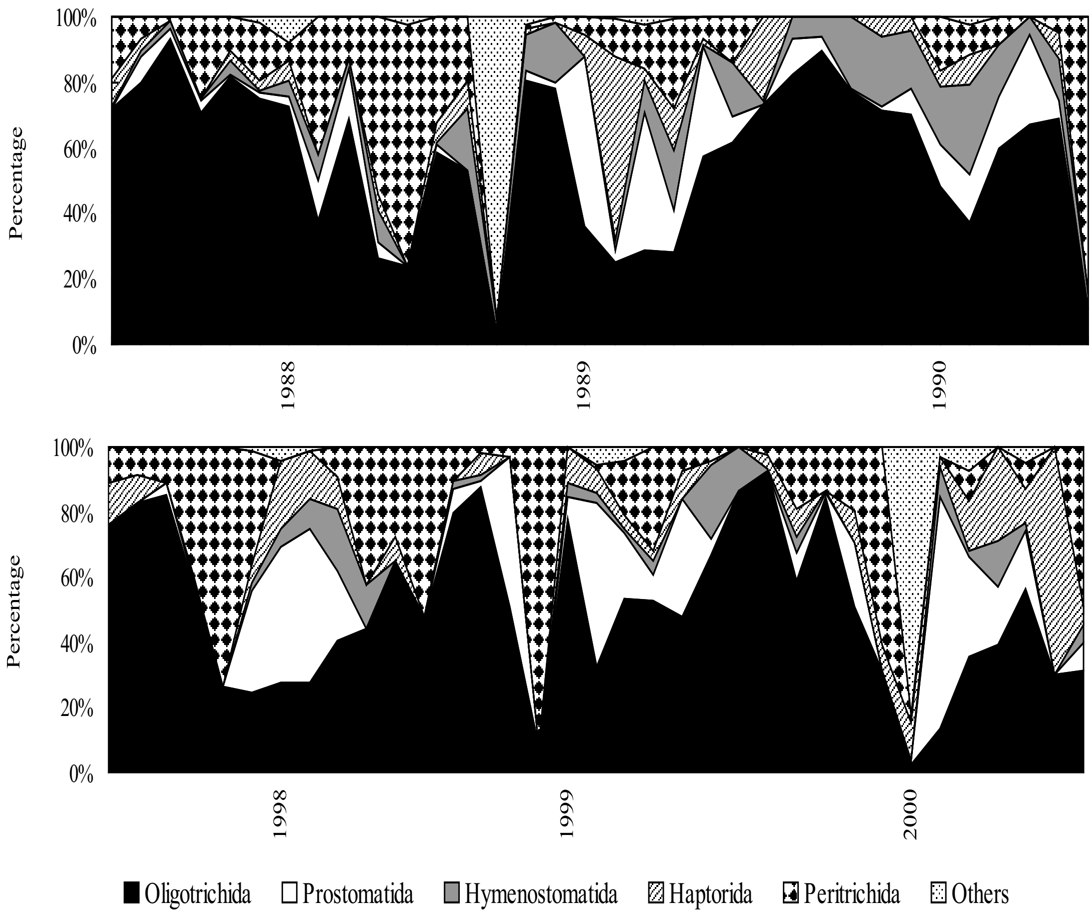

Fig. 6. Seasonal and long-term changes of 5 major ciliated protozoan groups.

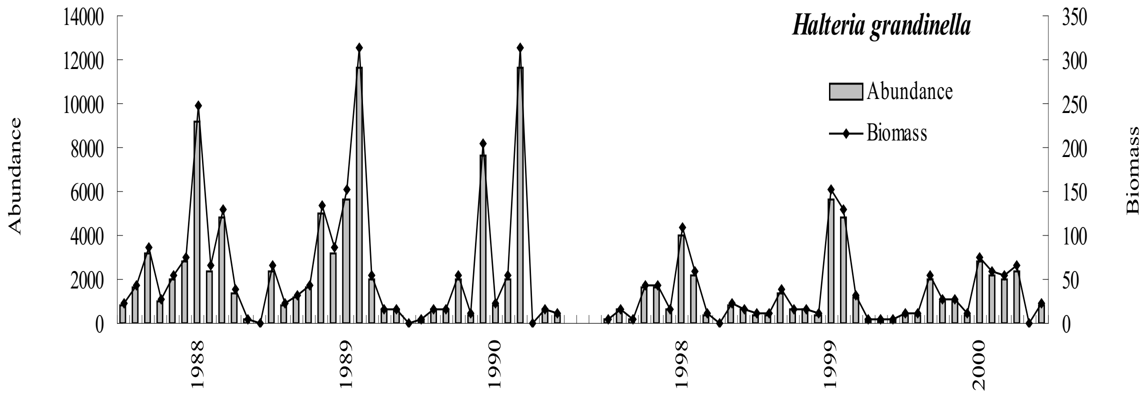

Fig. 7. Abundance and biomass seasonal changes of *Halteria grandinella*.

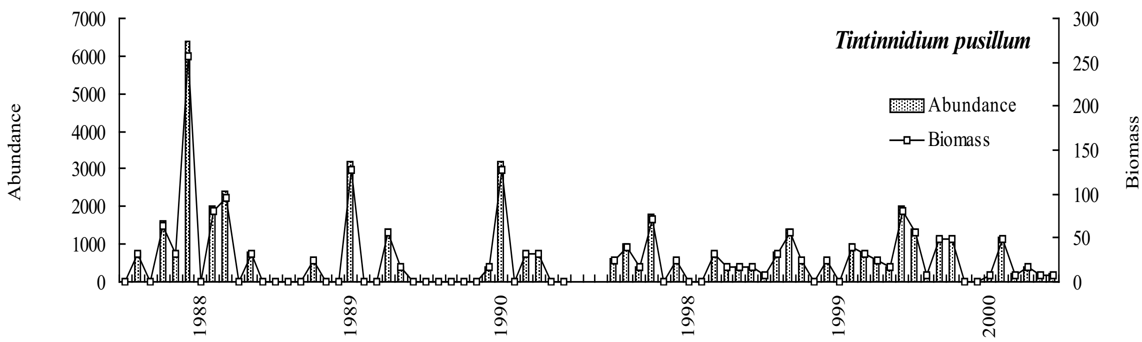

Fig. 8. Abundance and biomass seasonal changes of *Tintinidium pusillum*.

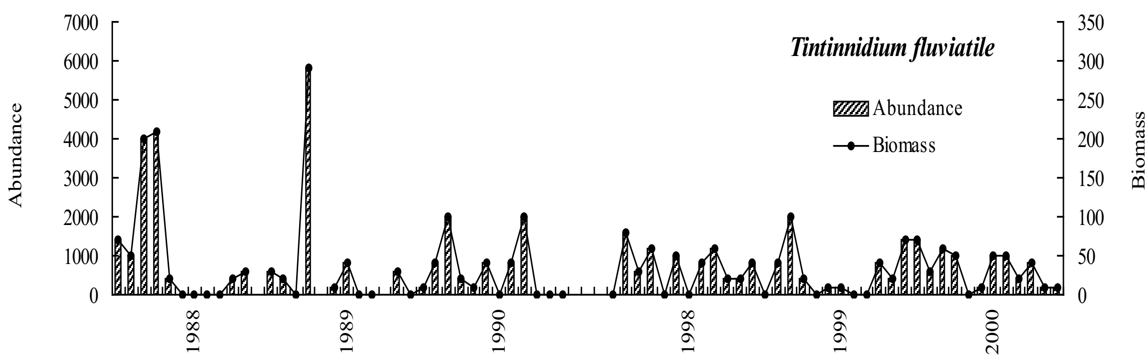

Fig. 9. Abundance and biomass seasonal changes of *Tintinnidium fluviatile*.

With the decreasing density of three oligotrichs from 1988 to 2000, the density of *Strobilidium humile* increased.

Frequency of occurrence of *Tintinnopsis* sp. was different between the two periods. During the first three years, is was present in some months each year, but during the last three years, it could be found each month, and the peak appeared irregularly.

Coleps hirtus was only species from Protostomatida that had contributed a lot in terms of both abundance and biomass to the community in the lake. Trend in abundance variation of this species was not regular between years, and each year the peak of density occurred in spring to summer.

Vorticella cupifera had its peak in spring or autumn each year except 1989.

Biodiversity index of ciliates community

The Margalef's biodiversity indices were from 0.49 (in May, 1998) to 2.37 (in June, 2000) (Fig. 14). Changes of this index showed a similar trend each year. During summers the community had a high biodiversity value, with the lower index characterizing winter or spring.

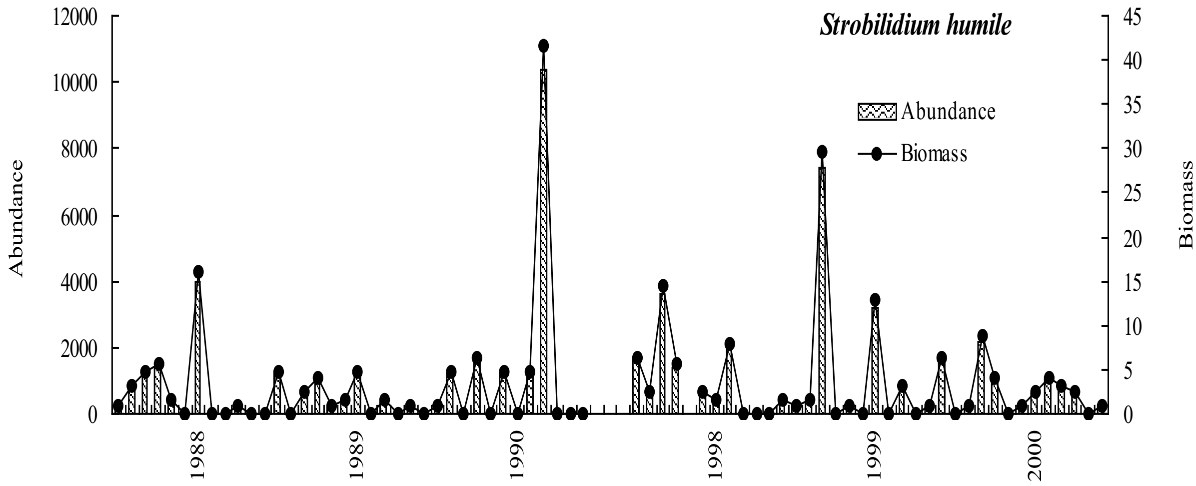

Fig. 10. Abundance and biomass seasonal changes of *Strobilidium humile*.

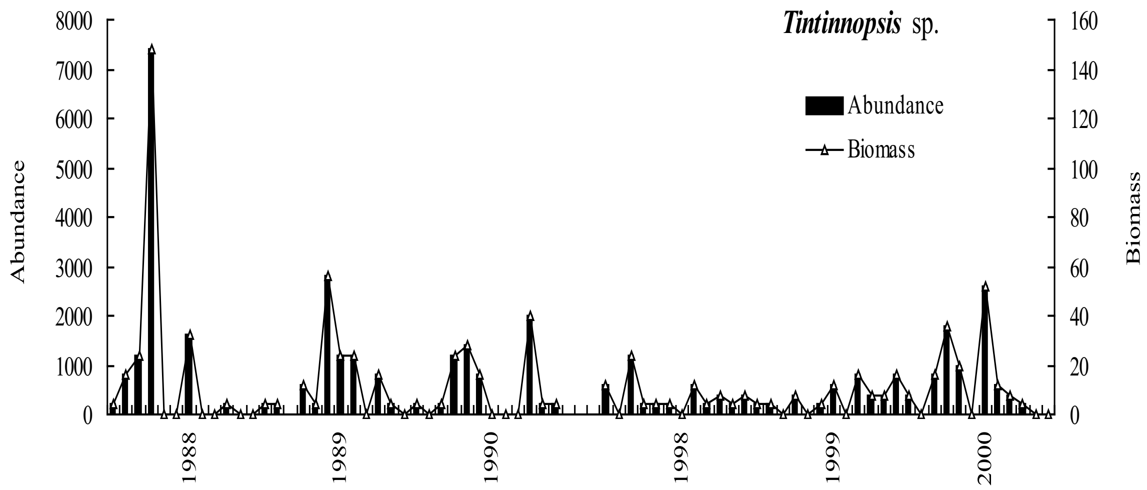

Fig. 11. Abundance and biomass seasonal changes of *Tintinnopsis* sp.

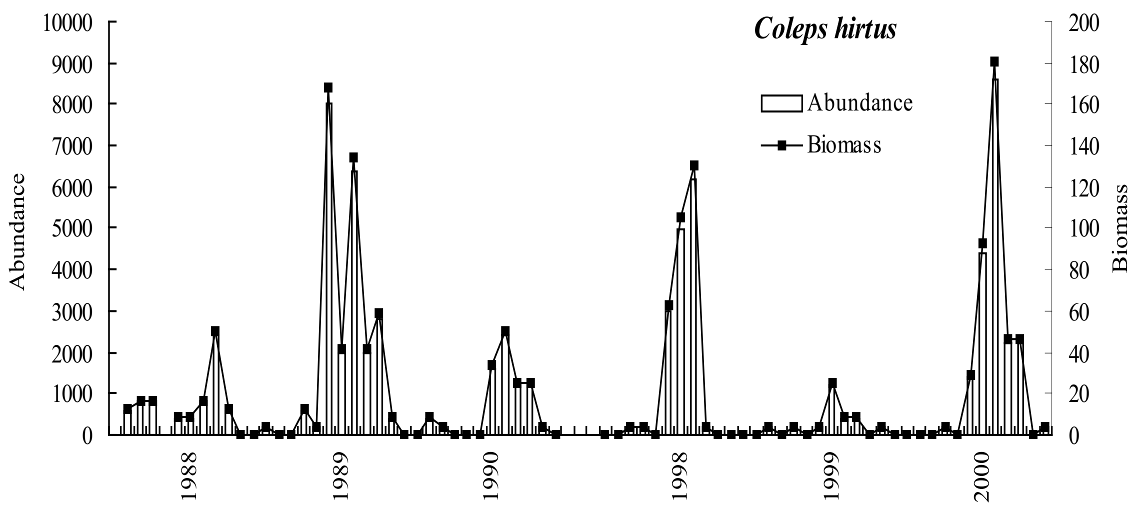

Fig. 12. Abundance and biomass seasonal changes of *Coleps hirtus*.

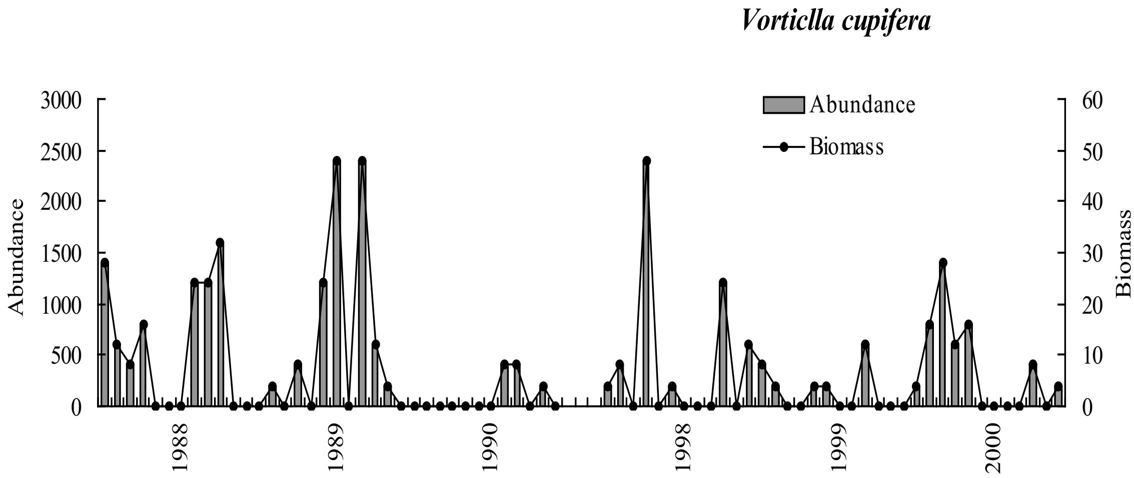

Fig. 13. Abundance and biomass seasonal changes of *Vorticella cupifera.*

Discussion

Species composition

The distributions of most free-living ciliates are global (Finlay et al., 1999). However, the species composition of ciliates in a specific water body could be very different from that in others due to differences the hydrochemical composition, even if those water bodies are in the same latitude or region (Laybourn-Parry, 1992).

From the viewpoint of species composition, most ciliate species from Lake Ringsjön are characteristic of typical temperate lakes. Ciliate communities in this lake were dominated by Oligotrichida, Hymenostomatida and Prostomatida. All of these groups are often reported as relatively common in lacustrine ciliate communities, for instance, in Lake Huron and Michigan (Carrick and Fahnenstiel, 1990), Lake Esthwaite (Laybourn-Parry et al., 1990), Lake Loch Ness (Laybourn-Parry et al., 1994), Lake Vxrtsjдrv (Zingel, 1999), Lake Peipsi (Zingel, 2001), Lake Windermere (Laybourn-Parry and Rogerson, 1993), and even in southern temperate lakes (James et al., 1995).

The number of ciliate species present in Lake Ringsjön is almost equal to that in some temperate lakes (Schlott-Idl, 1984; Laybourn-Parry et al., 1990 and Zingel, 1999), but is only a half of that in some subtropical lakes in China (Gong, 1986, Xu and Zheng, 2000).

Species composition of ciliates in a lake could change in accordance with variation of the aquatic environment during relatively long periods. For example, in Lake Donghu, a eutrophic shallow lake in China, the ciliate community succeeded the community dominated by larger carnivorous and herbivorous species to smaller bacterivorous species from 1960s to 1980s, due to eutrophication (Gong, 1986). The concentrations of total P and N in Western Basin of Lake Ringsjön had not significantly changed from 1988 to 1996, and it did not seem to be affected by a fish reduction program for improvement water quality in the lake (Bergman, 1999). After that, some increase of PO_4-P and Total N happened in Western Basin of Lake Ringsjön (Table 1). However, in the ecosystem context, the changes of some hydrochemical parameters mentioned above were minor.

The results of this study indicate that the changing of biodiversity index and abundance followed the same pattern, that is, had two peaks a year. This may be associated with the fact that in spring and summer/autumn, the ciliates have more food and other resources. Comparison of the ciliate species composition in different periods (1988-1990 and 1998-2000) shows that their species composition also did not change significantly. Bray-Curtis similarity index (Hubbell, 1997) for the ciliate communities from 1988–1990 to 1998–2000 in the lake is 0.805 ($p < 0.01$).

Species abundance and biomass

Small species like *Halteria grandinella*, *Tintinnidium* spp., *Strobilidium* spp., *Urotricha* spp. and *Cyclidium glaucoma* in Lake Ringsjön has accounted for over 90% to total abundance in the community. Beaver and Crisman (1990), who investigated 20 freshwater lakes along a trophic gradient, found that in eutrophic lakes, oligotrichs, haptorids and scuticociliates made up 28, 11 and 33 % of total abundance, respectively, and that the large, algivorous species were progressively replaced by small bacterivorous ciliates with increasing Chl-*a* concentrations. That conclusion is supported by the observation that eutrophic status in Western Basin of Lake Ringsjön did not change significantly within the last decade.

The maximum abundances of ciliates recorded in Lake Ringsjön were within the range reported for eutrophic lakes (Beaver and Crisman, 1990; Pace

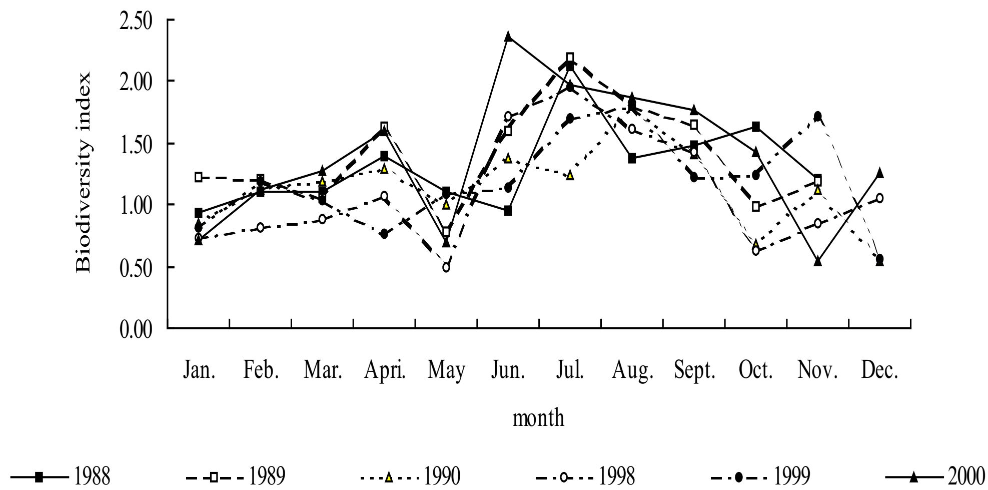

Fig. 14. Seasonal changes of ciliated protozoan community biodiversity indexes.

and Orcutt, 1981; Zingel, 1999 and 2001; Xu and Zheng, 2000) (Table 3). Similar to other eutrophic lakes, the maximum abundance in Lake Ringsjön is higher than in most reports from in oligotrophic and mesoeutrophic lakes.

The seasonal changes of ciliate abundance in Lake Ringsjön had two peaks each year, which is in agreement with the data reported from other eutrophic lakes. The patterns of seasonal changes in ciliate abundance in Lake Ringsjön confirm the conclusion of Laybourn-Parry (1992), who suggested that in a eutrophic lake there are two peaks of seasonal changes in ciliate abundance. The seasonal succession of ciliates has been documented in quite a number of lakes with varying trophic status and latitude, as summarized by Laybourn-Parry (1992). According to the cited review, a bimodal pattern with ciliates abundance in spring and summer/autumn for Western Basin of Lake Ringsjön is typical of eutrophic lakes from temperate latitudes.

The biomass of ciliates in Lake Ringsjön is also within the range reported from eutrophic lakes (Table 4).

According to the Amblard et al. (1994), Mayer et al. (1997), Hunt and Chein (1983) and Mathes and Arndt (1995), the contributions of total zooplankton abundance and biomass from ciliates could be very important. Sometimes, this contribution can reach 40 to 64 % of total zooplankton abundance and biomass (Zingel, 1999). There is evidence that the role of Oligotricha should be significant in shallow lakes. In Lake Peipsi, a large freshwater lake in Estonia, Oligotrichas contributed about 50% of the total ciliates abundance (Zingel, 2001). The same

Table 3. Comparison of the maximal ciliated protozoan abundances in the lakes with different trophic status.

Lakes	Trophic Status	Ciliate Abundance (10^3 l^{-1})	Sources
Lunzer Unterzee Lake	oligotrophic	1.8	Schlott-Idl, 1984
Pavin Lake	oligomesotrophic	24.2	Carrias et al., 1998
Tohopekaliga Lake	mesotrophic	86.1	Beaver and Crisman, 1990
Peipsi Lake	mesotrophic	18.64	Zingel, 2001
Vassivière Lake	eutrophic	4.8	Amblard et al., 1995
Nantua Lake	eutrophic	12.7	Amblard et al., 1999
Esthwaite Lake	eutrophic	9.2	Laybourn-Parry et al., 1990
Ringsjön Lake, Western Basin	eutrophic	82.0 42.0	1988 to 1990, this work 1998 to 2000, this work
Oglethorpe Lake	eutrophic	100–200	Pace and Orcutt, 1981
Scott lakes Lake	hypertrophic	355.5	Beaver and Crisman, 1990
Dongshan Lake	hypertrophic	164.7	Unpublished
Yuexie Lake	hypertrophic	69.1	Xu and Zheng, 2000

Table 4. Comparison of the maximal ciliated protozoan biomass in the lakes with different trophic status.

Lakes	Trophic Status	The max. Biomass (mg l^{-1})	Sources
Norris Lake	oiligotrophic	0.08	Beaver and Crisman, 1988
Holden Pond	oligotrophic	0.33	Beaver and Crisman, 1988
Tohopekaliga Lake	mesptrophic	0.4068	Beaver and Crisman, 1990
Peipsi Lake	mesptrophic	0.5874	Zingel, 2001
Ringsjön Lake, Western Basin	eutrophic	1.939 2.182	1988 to 1990, this work 1998 to 2000, this work
Scott Lake	hypertrophic	4.4136	Beaver and Crisman, 1990
Dongshan Lake	hypertrophic	11.230	Unpublished
Yuexie Lake	hypertrophic	7.16	Xu and Zheng, 2000

results were from Lake Neumühler in Germany (Mathes and Arndt, 1995) and Lake Vassivière in France (Amblard et al., 1995). The Oligotrichas in Lake Ringsjön also had an important role in abundance and biomass.

Seasonal successions of dominant ciliates species

Although there were no significant changes of species composition in ciliates communities in Western Basin of Lake Ringsjön during 13 years, there were some varieties in temporal distribution of abundance of some predominant species.

Due to the decrease in the total ciliates abundance, the mean abundance levels of dominant species, for instance, *Halteria grandinella, Tintinnidium pusillum, T. fluviatile*, also decreased during the decade. In contrast, the mean abundance of *Coleps hirtus* and *Strobilidium humile* increased in a small scale. The position of *Halteria grandinella* as the first predominant species in the lake was retained during the investigation period. In terms of biomass contribution, the importance of *Halteria grandinella* for whole community became slightly less in 1999-2000 as compared with 1988-1990.

In addition, the temporal distribution patterns of some species underwent some changes. From 1988 to 1990, the peaks of *Tintinnidium pusillum* and *Vorticella cupifera* appeared in May to July, but in 1998 to 2000 the density peaks occurred earlier in spring or later in autumn.

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