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Ecology Studies of Ciliated Protozoa in An Eutrophic Lake Lake Höllerersee, Austria
Ⅱ. Temporal and spatial distribution of abundance*

Xu Runlin[1] Nauwerck Arnold[2]
(1) Life Sciences of School Zhongshan University, Guangzhou, 510275;
2) Institute of Limnology, Austrian Academy of Sciences)

Abstract The planktonic ciliate abundance distribution pattern in Lake Höllerersee, a small eutrophic lake in Austria, was studied between June 1995 to February 1996. The most ciliate density peaked in July 1995 at 2m depth (133 600 ind./L). *Ctedoctema acanthocryptum*, *Cyclidium glaucoma*, *Halteria grandinella*, *Strombidium viride*, *Askenasis acrostomia*, *Histobalantium bodamicum*, *Cinetochilum margaritaceum*, *Coleps spetai*, *Monodiniium balbianii*, *Tintinndium pusillum*, *Strobilidium caudatum*, *Strobilidium lacustris*, *Spirostomum teres*, *Calyptotuicha lanuginosa* and *Dexiotricha granulosa* made more contributions in abundance. Based on the distribution pattern, ciliate species can be divided 3 groups in the lake. The relationships between the limnological characters and the distributions of ciliates in the lake are discussed in present paper.

Keywords Ciliates, abundance, temporal and spatail pattern, Lake Höllerersee
Classification number Q 178.1

The temporal and spatial distribution patterns of planktonic ciliates are the important contents in limnology, especially in the deep lakes with thermal stratification. Although some reports about the time and spatial patterns of zooplanktonic ciliates have been made[1], until now, we have only a limited knowledge of the spatial distribution patterns of deep lake ciliated zooplanktons. The aim of this work was, therefore, to study the temporal and vertical distribution of ciliated protozoan community in a small eutrophic lake, Lake Höllerersee, in Austria. We hope, with this study, to provide more detailed messages about zooplanktonic especially microzooplanktonic community in this small lake.

1 Materials and Methods

Quantitative examinations were done as the method of Skibbe[2].

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2 Results

2.1 Physical and chemical parameters

Data of water temperatures, pH, O_2 concentrations and saturations within the investigation period in Lake Höllerersee are showed in Fig. 1. During the investigaton, The highest temperature appeared in June and July of 1995 (20℃) and the lowest was in February 1996 (1.0℃) at surface (ice covered). Based on the thermal distribution, it was found in June and July there was a thermal stratification in the lake and the thermocline appeared at 4 to 6 m depths. Water turnover began in August. As a result, water was mixed completely in Februray. The pH showed a decreasing trend with depths in different months during the investigation. The pH of uppermost water were higher than 8 (except Feb. 1996), at 12 m depth, pH was about 7. The loss of stratification resulted in the pH of surface water become lower. The highest data of concentrations of O_2 and O_2 saturations were recorded at 0 and 1 m (18.0 mg/L and 142%, respectively). Below 10 m depth, concentrations of O_2 and O_2 saturations approached zero in different months during the stratification. Due to the temperature effects, the O_2 concentrations in different depth showed some changes, in fall, the water mixed resulted from temperature, leading to O_2 concentration and O_2 saturation became no clearly differences with depth.

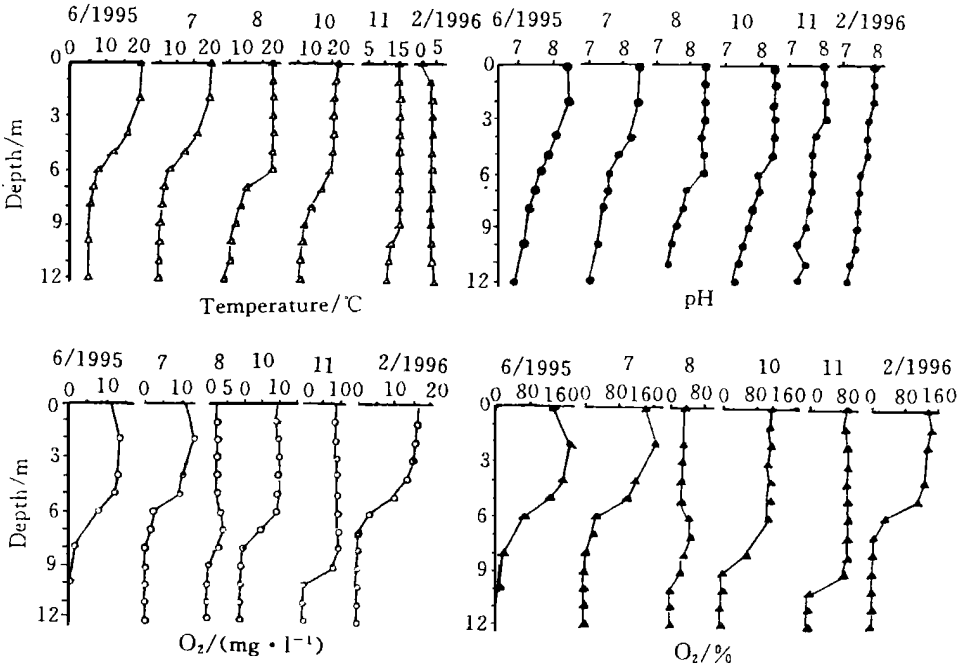

Fig. 1 Vertical distributions of temperature, pH, O_2 content and O_2 saturation in Lake Höllerersee

2.2 Ciliate total abundance

Ciliate total abundances in water column in different months are showed in Fig. 2. The highest ciliate concentration was recorded at 2 m depth in July 1995 (133 600 ind/L), the lowest abun-dance was found at 8 m depth in June 1995 and 12 m depth in February 1996 (1 040 and 1 060 ind/L, respectively). The number of ciliates was

decreased with the depth in June, July 1995 and February 1996. In August and October of 1995, the peaks of the abundance were at 8 and 6 m depth, separately. In November of 1995, the number of ciliates had no changed with the depth almost. The vertical distributions demonstrated the most abundances presented at epilimnion in June and July in 1995. With water mixture happened in August, the most abundance appeared under thermocline, and then the abundances showed less variant in whole water column.

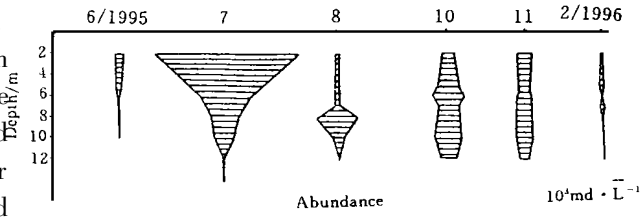

Fig. 2 Vertical distributions of total ciliate abundance in Lake Hollerersee

The temporal and spatial patterns of ciliate abundance in different months. The vertical distributions of 16 main ciliate species which are important to abundance are demonstrated in Fig. 3.

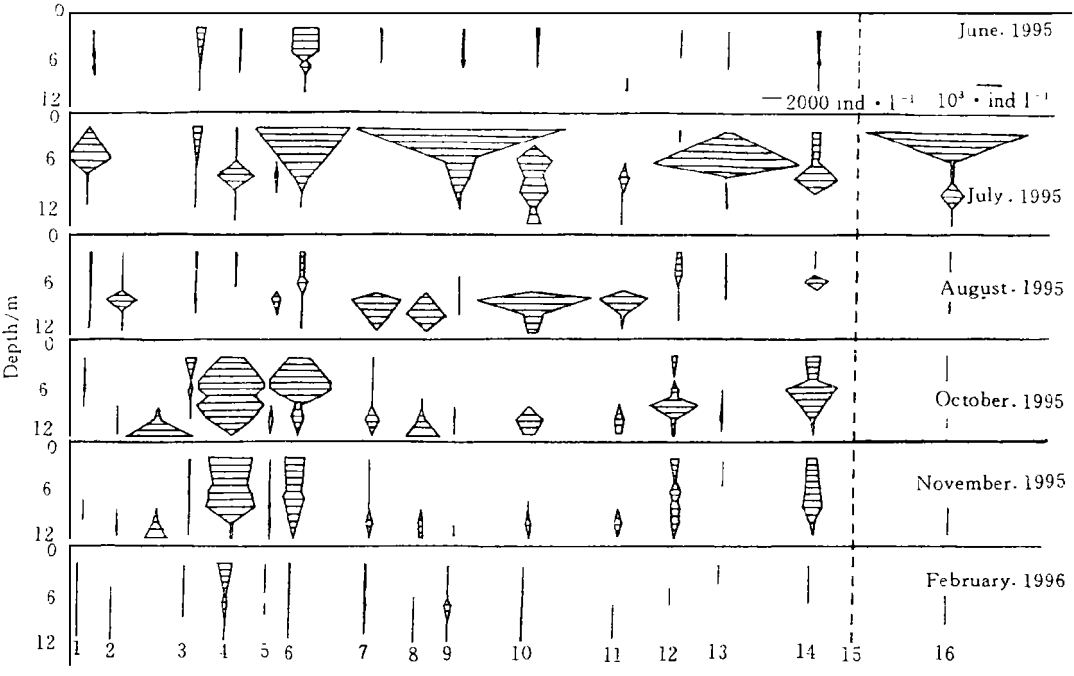

Fig. 3 Abundance vertical distributions of 16 main ciliate species in Lake Hollerersee

1 *Askenasia acrostomia*; 2 *Cinetochilum margaritaceum*; 3 *Calyptotricha lanuginosa*; 4 *Strombidium viride*; 5 *Coleps spetai*; 6 *Monodinium balbianii*; 7 *Halteria grandinella*; 8 *Histobalantium bodamicum*; 9 *Dexiotricha granulosa*; 10 *Cyclidium glaucoma*; 11 *Holophrya discolor*; 12 *Spirostomum teres*; 13 *Tintinnidium pusillum*; 14 *Strobilidium caudatum*; 15 *Strobilidium lacustris* and 16 *Ctedoctema acanthocrypta*

Based upon the shapes of figures, 3 kinds of distribution patterns could be divided. *Ctedoctema acanthocryptum*, *Cyclidium glaucoma*, *Halteria grandinella* and *Strombidium viride*, found at all depth and the most abundance appeared at 2 m depth belonged to the first one; *Askenasia acrostomia*, *Histobalantium bodamcium*, *Cinetochilum margaritaceum*, *Coleps spetai*, *Holophyra discolor*, *Monodiniium balbianii*, *Tintinndium pusillum*, *Strobilidium caudatum* and *Strobilidium lacustris* discovered at all water column but their most abundance presented at 6 to 8 m depth belonged to the second one; Therefore, *Spirostomum teres*, *Calyptotricha lanuginosa and Dexiotricha granulosa* found only at hypolimnion were the third one.

Out of ciliate species, the most important species for abundance should be *Ctedoctema acanthocryptum*. In July 1995, it reached 86 160 ind/L at 2 m depth, at the thermocline it has a sharp decline. Below the thermolimnion, the number appeared increase and has second peak at 10 m depth, then the species become less in number and from epilimnion moving to the hypolimnion from July 1995 to February 1996. Similar to *Ctedoctema acanthocryptum*, *Cyclidium glaucoma*, the density of which increased with the depth from 2 to 6 m and then decreased in June 1995, had the most abundance in July 1995, at 2 m depth (26 000 ind/L), At thermoline, it showed a sharply decreasing with the depth. From June to October, its abundance was not important to the total abundance of the community. In November 1995, it presented at hypolimnion, and spreaded to the epilimnion with a higher abundance at 6 m depth in February 1996 (1 200 ind/L). *Halteria grandinella*, showing its most density at 2 m depth in July 1995 (12 000 ind/L), had the second peak at 6 m depth in October 1995 (8 120 ind/L). From late autumn to next spring, the densities showed decreased.

In the second group, the members found at all depths, the density peaks of these species were not at epilimnion but under therocline. *Strobilidium caudatum* showed its density peak at 6 m depth in July 1995 (19 360 ind/L). *Askenasia acrostomia* had the most density at 6 m depth in July 1995 (5 760 ind/L) as well and then the densities became less with the time from August 1995 to February 1996. *Holophyra discolor*, *Cinetochilum margaritaceum* and *Histobalantium bodamicum* were observed the peaks of densities at 8 m depth in August 1995 (14 120, 3 760 and 6 520 ind/L, respectively). *Coleps spetai* and *Tintinndium pusillum* had the most abundance at 8 m depth in October 1995 (8 720 and 7 520 ind/L, separately), *Strobilidium lacustris* showed the highest density in same month at 6 m depth (6 680 ind/L). Compared with other species, *Monodiniium balbianii* had a less importance to the total abundance, its density reached 1 520 ind/L at 8 m depth in August 1995.

In the third group, only found under thermocline, Spirostomum teres, a ciliate species longer than 200 μm *in vivo*, was important to abundance. In August 1995, it reached 6 600 ind/L at 8 m depth. *Calyptotricha lanuginosa* had been discovered under 8 m depth and with the highest density at 12 m in October 1995 (8 160 ind/L). Dexiotricha granulosa presented below 6 m depth with the most abundance at 10 m depth in August 1995 (4 640 ind/L).

3 Discussions

Concerning the ciliated protozoan temporal and spatial distributions in freshwater

lakes, a few reviews have been made by some authors[3], but reports of ciliate distributions in deep lakes with thermal stratification are limited.

From the view of abundance, it is doubtless that *Ctedoctema acanthocryptum*, a small hymenostomata ciliate, which feeds on bacteria and presents in lakes with various trophic status in the world, should be the most important species for the ciliate community in Hollerersee. According to Bich & Bertram, this ciliate can live in the waters with wide range of O_2 (0.3~22.4 mg/L), but it has a trend to the water with higher temperature[4]. In July, the epiliomnonic temperature of Lake Hollerersee was the highest during the investigation. It could be comprehended easily why *Ctedoctema acanthocryptum* had so much high concentration at this period. In addition to, *Cyclidium glaucoma*, another small hymenostomata of global dispread species, *Strombidium viride*, a typical planktonic species of oligotrich ciliate, and *Halteria grandinella*, a oligotrich ciliate of global distribution was significant for abundance in the lake, too. It is identical with some reports in which they can live the wider ranges of condition[5]. The four species that mentioned above standed for the dominant species at epilimnion in planktonic ciliate community of Lake Hollerersee are smaller in sizes.

Oppositely, the ciliate species that had their higher concentrations at therocline or hypolimnion due to their bigger sizes, were less importance to whole abundances but perhaps more contributions to the total biomass of ciliate community in the lake. *Histobalantium bodamicum*, *Holophyra discolor*, *Strobilidium caudatum*, *Tintinndium pusillum* and *Coleps spetai* should be main members of this group in the lake. As literatures reported, these species generally presented in the water with higher concentration of H_2S and can resist to a wide ranges of the temperatures and O_2 contents changes in water[5].

In the group presented in hypolimnion of Lake Hollerersee, *Spirostomum teres*, a larger heterotricha ciliate, playing an important role in abundance, were found frenquently in the waters with higher H_2S and lower O_2 and considered as an indicated species for polysaprobia[5]. Its peak of number was considered corresponding to the conditions of the water. *Calyptotricha lanuginosa* and *Dexiotricha granulosa* were reported in Lake Piburgersee under the relatively adverse conditions[6]. In addition to these ciliate species mentioned above, some anaerobic ciliate species reported like *Caenomorphra medusula*, *Metopus* spp., *Plagiopyla nasuta* and *Lagynus elegans* were also discovered and made some contributions in abundances at hypolimnon in Lake Hollerersee. Based upon Fig. 2, a fact can be conformed that the ciliates with smaller size ($< 100\mu m$) had higher densities at surface and mid-water in the first half year (10^4 ind/L), the ciliates with larger size ($> 100\mu m$) were found density peaks between 8 to 12 m depths from July to November (10^4 ind/L). As predators, planktonic ciliate abundance and distributions are limited by the number and distributions of foods, especially bacterias and algae. In Hollerersee, the primary productions were contributed mainly from *Oscillatoria rubescens*, *Cryptomonas* sp., *Rhodomonas* sp., *Dinobryon* sp. and *Cyclotella* sp. The densities of algae appeared more from July to October in the lake[6]. Considered the vertical distributions of algae, the most phytoplankton density presented at 6 to 10 m depth during August to October. Corresponding, the algivorous ciliates like *Coleps spetai*, *Holophyra discolor*, *Strobilidium lacustris*, *Histiobalantium bodamicum* and *Spirostomum teres* also had higher densities in the same time and space. The ciliate species feeding on bacterias had more contributions in up-

permost water and in summer. Hypolimnionic ciliate species like *Calyptotricha lanuginosa* and *Dexiotricha granulosa* feed on bacterias mainly too. Additional, some anaerobic ciliate species discovered here like *Caenomorphra medusula*, *Metopus* spp., *Plagiopyla nasuta* and *Lagynus elegans* get their energy from the symbiotic bacterias in or on their cells. From the view of food distributions, and the ciliate distribution figure shapes in Fig. 3, the pattern of ciliate distribution in Lake Höllerersee should be that bacterivious ciliates present the epilimnion and have higher concentrations in summer, the algivorous ciliates live in the middle of the water column in early autumn, and anaerobic ciliates live in hypolimnion and have less importance to abundance.

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奥地利 Höllerersee湖的纤毛虫生态学研究
Ⅱ. 丰度的时空分布

徐润林* Nauwerck A

摘 要 报道了生存在奥地利 Höllerersee湖泊中的浮游纤毛虫的时空分布模式. 纤毛虫丰度的最大值出现在 1995年 7月水面上 2 m处 (133 600 ind/L); 在全部种类中, *Ctedoctema acanthocryptum*, *Cyclidium glaucoma*, *Halteria grandinella*, *Strombidium viride*, *Askenasia acrostomia*, *Histobalantium bodamicum*, *Cinetochilum margaritaceum*, *Coleps spetai*, *Monodiniium balbianii*, *Tintinndium pusillum*, *Strobilidium caudatum*, *Strobilidium lacustris*, *Spirostomum teres*, *Calyptotuicha lanuginosa* 及 *Dexiotricha granulosa* 在丰度中起重要作用. 根据分布的模式, 该水体中的纤毛虫可分为 3组. 对纤毛虫的分布模式与该湖泊湖沼学特点间的关系也进行了讨论.

关键词 纤毛虫, 丰度, 时空分布模式, Höllerersee湖

分类号 Q 178.1

* 中山大学生命科学学院, 广州 510275