PROTOZOOPLANKTON IN THE DEEP OLIGOTROPHIC TRAUNSEE (AUSTRIA) INFLUENCED BY DISCHARGES OF SODA AND SALT INDUSTRIES

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Abstract. Traunsee is a deep oligotrophic lake in Austria characterised by an artificial enrichment of chloride in the hypolimnion (up to 170 mg L^{-1}) caused by waste disposal of soda and salt industries. Protists were collected monthly over one year, observed alive and after Quantitative Protargol Staining (ciliates) or via epifluorescence microscopy (heterotrophic flagellates). Three sites within the lake (0–40 m depths) were compared to deeper water layers from 60–160 m depths where chloride concentrations and conductivity were increased. In addition, we observed the protozooplankton of two neighbouring lakes, i.e. reference systems, during one sampling occasion. In Traunsee the abundance of ciliates was low (200–36 600 cells L^{-1}) in contrast to high species diversity (at least 60 different species; $H_S = 2.6$) throughout the year. The main pelagic species in terms of abundance were small oligotrichs and prostomatids like *Rimostrombidium brachykinetum/hyalinum*, *Balanion planctonicum* and *Urotricha* spp. throughout the investigation period. Among free-living heterotrophic flagellates, which occurred at densities of 40–2800 cells mL^{-1}, small morphotypes dominated in the pelagial. No differences at the community level between the three lakes could be observed and pelagic ciliates and flagellates seemed not to be affected by increased chloride concentrations or by enhanced conductivity.

Keywords: alkaline sludge discharge, chloride, ciliates, heterotrophic flagellates, oligotrophic lake, protists, temperate latitude, vertical distribution

1. Introduction

Salt mining in the area of the Salzkammergut has a long tradition starting around 1000 B.C. Since 1927 Traunsee has been used as dumping ground for industrial wastes from soda and salt plants. Every year up to 50 000 tons of solids (mainly calcite, gypsum and brucite) and 85 000 tons of dissolved compounds (mainly $CaCl_2$ and NaCl) are released into a basin in the south of the lake (for details see Ruttner, 1937; Pechlaner and Sossau, 1982; Jagsch *et al.* (2002)). This waste is highly alkaline and saline and leads to (1) an enrichment of chloride (45–170 mg L^{-1}) coming along with an increase in conductivity (270–840 μS cm^{-1}) in the aerobic hypolimnion, (2) the absence of a vertical pH gradient as known for com-

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parable lakes and (3) a local accumulation of sludge with a height of up to 47 m. For details on longitudinal and vertical distribution of solids see Müller *et al.* (2002), and Griebler *et al.* (2002). Based on recent national and international standards and directives in water laws (e.g. ÖNORM M 6232; European Water Framework Directive), the government of Upper Austria ordered an assessment of the ecological integrity of Traunsee. Ecological integrity is estimated via the comparison of the actual status of an ecosystem and its status prior to an anthropogenic impact. Data from the affected system are then compared with unaffected, so-called 'reference systems' of similar character and literature data.

The important role of protists in terms of nutrient cycling in aquatic and marine food webs has been well described in the past decades (e.g. Azam *et al.*, 1983; Weisse and Müller, 1998; Foissner *et al.*, 1999). Short generation times and physiological diversity allow microorganisms to react immediately on changing environmental conditions. Especially ciliates can be used as indicator organisms for trophic and saprobic conditions and for salinity in running waters under the presumption that they are determined to the species level (e.g. Sladecek, 1979; Berger *et al.*, 1997; Foissner *et al.*, 1991, 1999; Ziemann *et al.*, 1999 and references therein). Nevertheless, data on microorganisms prior to an anthropogenic impact on an ecosystem are not available in most cases.

In this study, we present data on ciliates and flagellates in the water column of Traunsee in regard to the alkaline and saline industrial waste discharge. We observed seasonal and spatial dynamics of protists at three sampling sites within the lake. As long-term studies on ciliates and flagellates from oligotrophic clear-water lakes in temperate latitudes are still scarce (Laybourn-Parry, 1994) we compared Traunsee with ecologically intact reference systems of similar trophic status, morphometric and physico-chemical characters of the same region, i.e. Attersee and Hallstättersee (Figure 1). Live examinations of protists were performed as a first step. Furthermore, we used a Quantitative Protargol Stain (QPS, modification after Pfister *et al.* (1999)) for ciliates' abundance, biovolume and identification and formaldehyde-fixation with additional DAPI – staining to determine heterotrophic flagellates' abundance and biovolume.

2. Material and Methods

2.1. SITE DESCRIPTIONS

The oligotrophic Traunsee is the second largest and the deepest lake situated in the north of the Austrian limestone Alps. Aerobic conditions down to the lake bottom prevail throughout the year (Jagsch *et al.*, 2002). The Traun River is the main tributary and drains the lake about once per year. As a consequence, temperature in Traunsee is generally low (for hydrological details see Pechlaner and Sossau (1982) and Jagsch *et al.* (2002)). The main anthropogenic impact on the pelagic zone is an

TABLE I

Annual means of temperature, pH, O_2, conductivity and chloride concentrations at three sampling sites in Traunsee, i.e. EB (0–40 m), RB (0–40 m), VI (0–40 m and 60–160 m, respectively) and, data from a single vertical sampling profile in May 1999 in Traunsee (0–180 m), Attersee (0–160 m) and Hallstättersee (0–120 m). Minimum and maximum values are given in brackets

Parameter	EB 0–40 m	RB 0–40 m	VI 0–40 m	VI 60–160 m	Traunsee 0–180 m	Attersee 0–160 m	Hallstättersee 0–120 m
T (°C)	8.5	8.3	8.4	6.0	6.3	6.5	6.4
	(4.3–20.2)	(4.5–20.0)	(4.2–19.6)	(4.6–8.8)	(5.6–10.0)	(5.4–12.7)	(5.3–9.4)
pH	8.4	8.3	8.4	8.5	8.4	8.2	8.0
	(8.1–9.8)	(6.9–9.1)	(7.9–8.7)	(8.2–8.8)	(8.3–8.4)	(8.1–8.3)	(7.9–8.2)
O_2 (mg L^{-1})	10.9	11.1	10.8	9.5	9.3	10.6	9.9
	(8.7–13.1)	(8.7–14.0)	(8.3–15.0)	(7.3–12.4)	(8.5–11.2)	(10.3–11.3)	(9.1–10.9)
Cond (μS cm^{-1})	522	481	500	652	652	281	250
	(272–840)	(285–774)	(335–732)	(409–763)	(455–711)	(276–284)	(238–255)
Cl^- (mg L^{-1})	95.4	81.2	79.7	126.5	87.9	3.6	6.1
	(48.7–171.7)	(45.7–154.2)	(48.1–119.4)	(121.3–132.2)	(57.5–123.4)	(3.5–3.6)	(5.3–6.6)

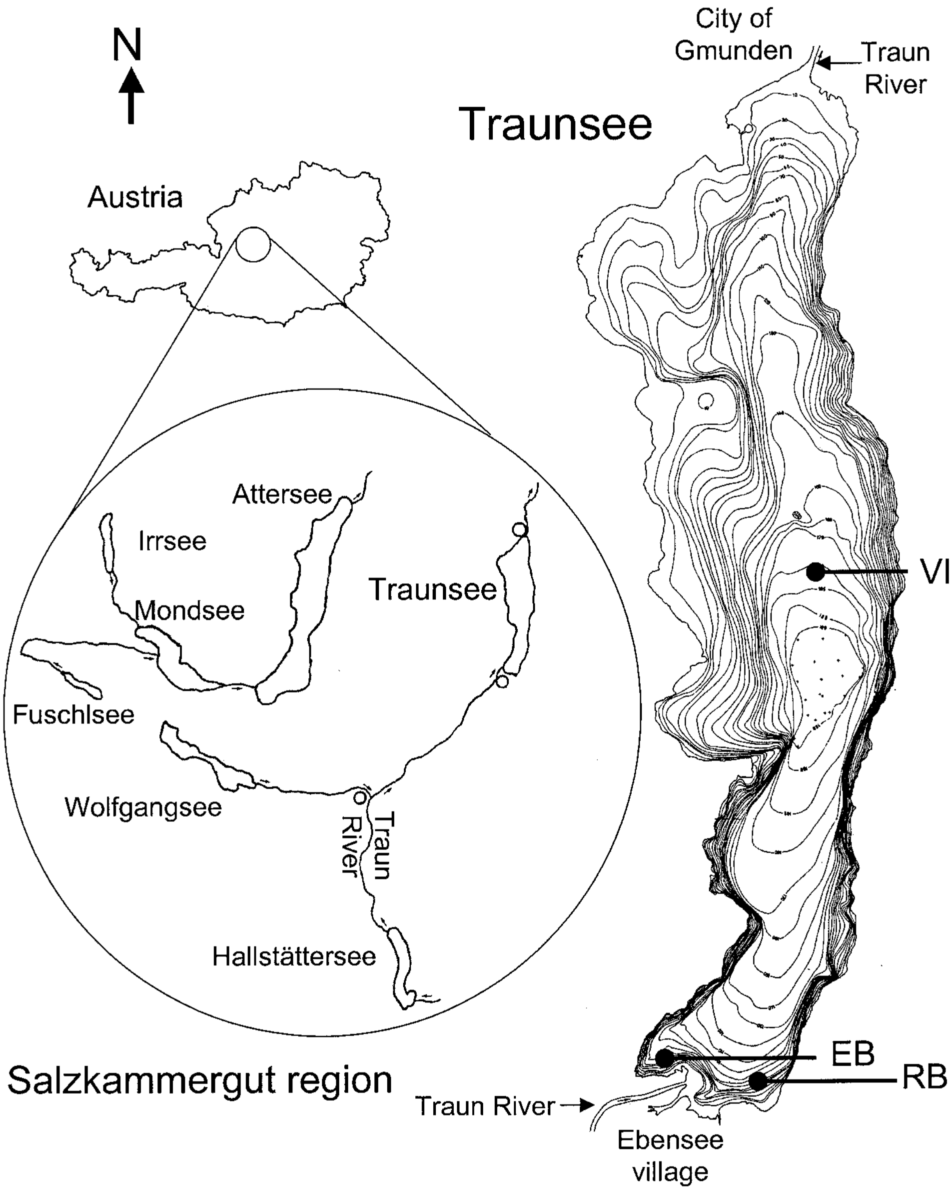

Figure 1. Geographical position and bathymetric map of Traunsee showing the three sampling sites EB, RB and VI, respectively. Modified from Müller and Schneider (1984) and Griebler *et al.* (2002).

artificial accumulation of chloride in the hypolimnion caused by industrial input. This enrichment has led to a short period of man-made meromixis in the 1930s–1950s. At present, the lake is characterised as holomictic and warm-monomictic. Increased chloride concentrations with depth are also the cause for a relatively warm hypolimnion (temperatures were always >4 °C; Table I). Hydroxides like

$Mg(OH)_2$ and $Ca(OH)_2$ in the alkaline waste bind free CO_2 in the water which leads to an unnatural increase of pH (Ruttner, 1937) in contrast to Attersee and Hallstättersee where pH decreased with depth. For further abiotic details see Jagsch *et al.* (2002), Teubner and Dokulil (2002), and Müller *et al.* (2002).

Three sampling locations were chosen at Traunsee (Figure 1): (1) Ebensee bay (EB), located in the south-western basin where the industrial waste is released, (2) Viechtau (VI), the deepest site supposed not to be directly influenced by the industrial sludge and (3) Rindbach bay (RB), located in the south-eastern basin influenced by allochthonous material of the Traun River but not by industrial waste. Furthermore, we took samples from two neighbouring lakes, Attersee (oligotrophic, supposed to represent the geogenic chloride background of the region) and Hallstättersee (oligo-mesotrophic, influenced by chloride since prehistoric salt mining up to the 1990s) at one occasion in May 1999 (Figure 1). For morphological and abiotic details on the three lakes see Table I, Jagsch *et al.* (2002), and Klammer *et al.* (2002).

2.2. SAMPLE COLLECTION AND HANDLING

Water samples were collected monthly from November 1997 through October 1998 from depths of 0, 10, 20, 40 m at locations EB, RB and VI. At location VI additional samples were taken at 60, 80, 120, 160 m depths. A 5-L Schindler-Patalas-sampler was used. Relocation of sampling sites was managed by using a GPS (global positioning system, Trimble, U.S.A.). Water samples from Attersee and Hallstättersee were collected at the deepest sites each at 0, 20, 40 and 80 m depths.

Abiotic parameters were measured immediately after sampling: pH (pH 340-A/SET-2, WTW, Germany), oxygen (Oxi 340-A/SET, WTW, Germany), conductivity and temperature (LF 340-A/SET, WTW, Germany).

For live observations small aliquots of water samples of the different depths were pooled directly into clean, HCl-rinsed (30% technical grade) 1-L plastic boxes (one box per each site). Net-plankton (10 μm net-size; 5–10 L per depth) was added due to low abundance of protists in the pure water samples. For transport, live samples were stored in a cooling box until examination within 24 hr. Additionally, we fixed 100 mL each for ciliates (5% Bouin's solution) and flagellates (2% formaldehyde) from each depth. Bouin's solution as recommended by Montagnes and Lynn (1987) for freshwater ciliates consisted of a mixture of 15 parts saturated picric acid plus five parts borax-buffered formaldehyde (36%) plus one part glacial acetic acid prepared fresh on the day of sampling. In the laboratory, ciliate samples were stained by a Quantitative Protargol Stain (QPS, developed by Montagnes and Lynn (1987); modified by Skibbe (1994) and Pfister *et al.* (1999)). Fixed flagellates were processed within one month. Prior to counts flagellate samples were stained with DAPI (4$'$, 6-diamidino-2-phenylindole, Sigma). For further details see Porter and Feig (1980), Sherr and Sherr (1993) and Sonntag *et al.* (2000). We used a Zeiss Axiophot II microscope equipped with differential interference contrast (DIC), brightfield, phase contrast and epifluorescence (filtersets for UV excitation: BP 360 nm, FT 395 nm, LP 397 nm and for green light excitation: BP 510 nm–560 nm, FT 580 nm, LP 590 nm). Ciliates and flagellates were identified morphologically based on publications of Foissner *et al.* (1991, 1992, 1994, 1995, 1999), Krainer and Müller (1995) and Patterson and Larsen (1991, and references therein). Fixed flagellates were split into two size-classes for biovolume estimations (<5 μm and >5 μm length). Before the measurement, each flagellate sample was counted to estimate the appropriate fraction of 'small' and 'large' cells. Then, length and width of 50 individuals per sample were measured by a semi-automatic image analysis system (software: LUCIA D V3.52, Laboratory Imaging, Prague, Czech Republic). Analyses of length and width of ciliates were either performed on living specimens or from QPS preparations with an eyepiece micrometer. Cell volumes of ciliates and flagellates were calculated from appropriate geometric shapes. Population biovolumes were determined by multiplying abundance with cell volume. We did not correct biovolumes for possible species-specific shrinkage because the majority of ciliate measurements were performed on fixed specimens (see also Pfister *et al.*, 1999).

To compare the three sampling sites within Traunsee statistical analyses were performed with the software SigmaStat 5.0. A non-parametric Kruskal-Wallis ANOVA based on ranks was applied. Abiotic and biotic parameters were compared via non-parametric Spearman Rank Correlation with the software SPSS 8.0 for Windows. A Shannon-Weaver diversity index (H_S) was calculated for the ciliate species in Traunsee (Mühlenberg, 1993).

Abundance of *Dinobryon* spp. and *Gymnodinium helveticum*, known as important members of the microbial food web, as well as phytoplankton and chlorophyll *a* data were determined by Teubner and Dokulil (2002). Bacterial parameters were provided by Klammer *et al.* (2002) and data on sediment characteristics by Müller *et al.* (2002).

3. Results

3.1. ABIOTIC PARAMETERS

Table I summarises the abiotic parameters of Traunsee for each sampling site from November 1997 through October 1998, and of Attersee, Hallstättersee and Traunsee for a single vertical profile in May 1999. In Traunsee, we observed a fully oxygenated water column down to maximum depth (191 m), an accumulation of chloride and an increase of conductivity in the hypolimnion throughout the investigation period. No significant differences among the three sampling sites (0–40 m depths) in respect to T, pH, O_2, conductivity and chloride concentrations could be observed ($p > 0.05$). Within the 60–160 m depths significant differences to the top 40 m were detected in respect to chloride concentrations and conductivity ($p <$

0.05). In Hallstättersee around 6 mg $Cl^- L^{-1}$ were measured in the water column in contrast to elevated concentrations of up to 30 mg $Cl^- L^{-1}$ in the past (Schwarz and Jagsch, 1998). In Attersee, chloride concentrations were below 4 mg L^{-1}.

3.2. CILIATES AND FLAGELLATES

Seasonal and vertical abundance and biovolume of ciliates ranged between 200–37 000 cells L^{-1} and from 0.002–0.973 $mm^3 L^{-1}$, respectively, with annual means of 3300 cells L^{-1} and 0.069 $mm^3 L^{-1}$ in the top 40 m and 1400 cells L^{-1} and 0.009 $mm^3 L^{-1}$ in the 60–160 m depths (Figure 2). Abundance and biovolume were not significantly different between the three sampling locations EB, RB and VI from 0–40 m depths ($p > 0.05$). Three peaks in ciliate abundance and biovolume were observed, i.e. in March with highest values at location VI, in May at the time of the phytoplankton maximum and, a major peak, in autumn (Figure 2). Additionally, we also observed greatest species richness in autumn (data not shown, Sonntag *et al.*, in prep.). At least 60 pelagic ciliate species were identified and ciliate diversity decreased with depth. Within the 0–40 m layers ciliate species diversity resulted in $H_S = 2.6$ (Evenness = 0.7) at all three sampling sites. At station VI ciliate diversity was lower in the 60–160 m depths ($H_S = 1.7$, Evenness = 0.5). The relative contribution of different orders to total ciliate abundance from November 1997 through October 1998 is shown in Figure 3. The dominant orders in the top 40 m were Oligotrichida, followed by Prostomatida > Hymenostomata > Gymnostomatea/Peritrichia, whereas the composition changed in the 60–160 m layers where Hymenostomata dominated over Oligotrichida > Gymnostomatea > Prostomatida > Peritrichia. The most important species in terms of abundance were *Rimostrombidium brachykinetum/hyalinum* (not recorded separately), *R. humile* and *Balanion planctonicum* in the surface waters. With depth a yet unidentified scuticociliate increased in abundance. In Table II we present the dominant ciliate species throughout the investigation period. Detailed information about the species–specific composition of the ciliate community will be published elsewhere (Sonntag *et al.*, in prep.).

Seasonal and vertical abundance, and biovolume of free-living flagellates ranged between 40–2800 cells mL^{-1} and 0.001–0.085 $mm^3 L^{-1}$, respectively, with annual means of 590 cells mL^{-1} and 0.014 $mm^3 L^{-1}$ in the top 40 m and 380 cells mL^{-1} and 0.010 $mm^3 L^{-1}$ in the 60–160 m depths (Figure 4). Abundance and biovolume in the top 40 m were not significantly different between the three sampling locations EB, RB and VI ($p > 0.05$). The maximum abundance and biovolume of flagellates was observed in May during the phytoplankton bloom. A second peak could be detected in autumn. Throughout the year, small heterotrophic flagellates accounted for 88% on total abundance (Figure 4). With depth we observed an increase of a ‘large’, yet unidentified kinetoplastid flagellate (data not shown).

TABLE II

List of the dominant ciliate species detected in Traunsee from November 1997 through October 1998 (TS 97–98), from a single vertical sampling profile in May 1999 from Traunsee (TS 99), Attersee (AS 99) and Hallstättersee (HS 99), and from Ruttner (1937)

	TS 97-98	TS 99	AS 99	HS 99	Ruttner (1937)
Oligotrichida					
Codonella cratera (Leidy, 1877)	x		x	x	x
Limnostrombidium pelagicum (Kahl, 1932)	x	x	x	x	x
Pelagohalteria cirrifera (Kahl, 1932)	x	x	x	x	
Pelagohalteria viridis (Fromentel, 1876)	x		x	x	
Pelagostrombidium fallax (Zacharias, 1895)/ *P. mirabile* (Penard, 1916)	x		x	x	
Rimostrombidium brachykinetum (Krainer, 1995/ *R. hyalinum* (Mirabdullaev, 1985)	x	x	x	x	
Rimostrombidium humile (Penard, 1922)	x	x	x	x	
Rimostrombidium lacustris (Foissner, Skogstad and Pratt, 1988)	x	x	x	x	
Tintinnopsis cylindrata Kofoid and Campbell, 1929	x	x		x	
Tintinnidium pusillum Entz, 1909	x			x	
'*Strobilidium/Halteria*'-group					x
Prostomatida					
Balanion planctonicum (Foissner, Oleksiv and Müller, 1990)	x	x	x	x	
Coleps spetai Foissner, 1984	x		x		
Urotricha spp. (at least 4 species)	x	x	x	x	
Gymnostomatea					
Askenasia chlorelligera Krainer and Foissner, 1990	x		x	x	
Askenasia sp.	x	x			
Askenasia volvox (Eichwald, 1852)/ *A. acrostomia* Krainer and Foissner, 1990	x		x	x	
Lagynophrya acuminata Kahl, 1935	x		x	x	
Mesodinium sp.	x	x	x	x	
Monodinium chlorelligerum Krainer, 1995	x				
Rhabdoaskenasia minima Krainer and Foissner, 1990	x	x	x	x	
'*Askenasia*'-group					x
Hymenostomata					
Histiobalantium bodamicum Krainer and Müller, 1995	x	x	x	x	
Scuticociliata (single unidentified species)	x	x	x	x	
'*Stokesia vernalis* (2 different morphotypes in Traunsee)'					x
Peritrichia					
Pseudohaplocaulus infravacuolatus Foissner and Brozek, 1996	x				x
Vaginicola ingenita (Mueller, 1786)	x	x			
Vorticella vernalis Stokes, 1887	x	x			x
Suctoria					
Gajewskaiophrya melosirae (Gajewskaja, 1933)	x	x	x		

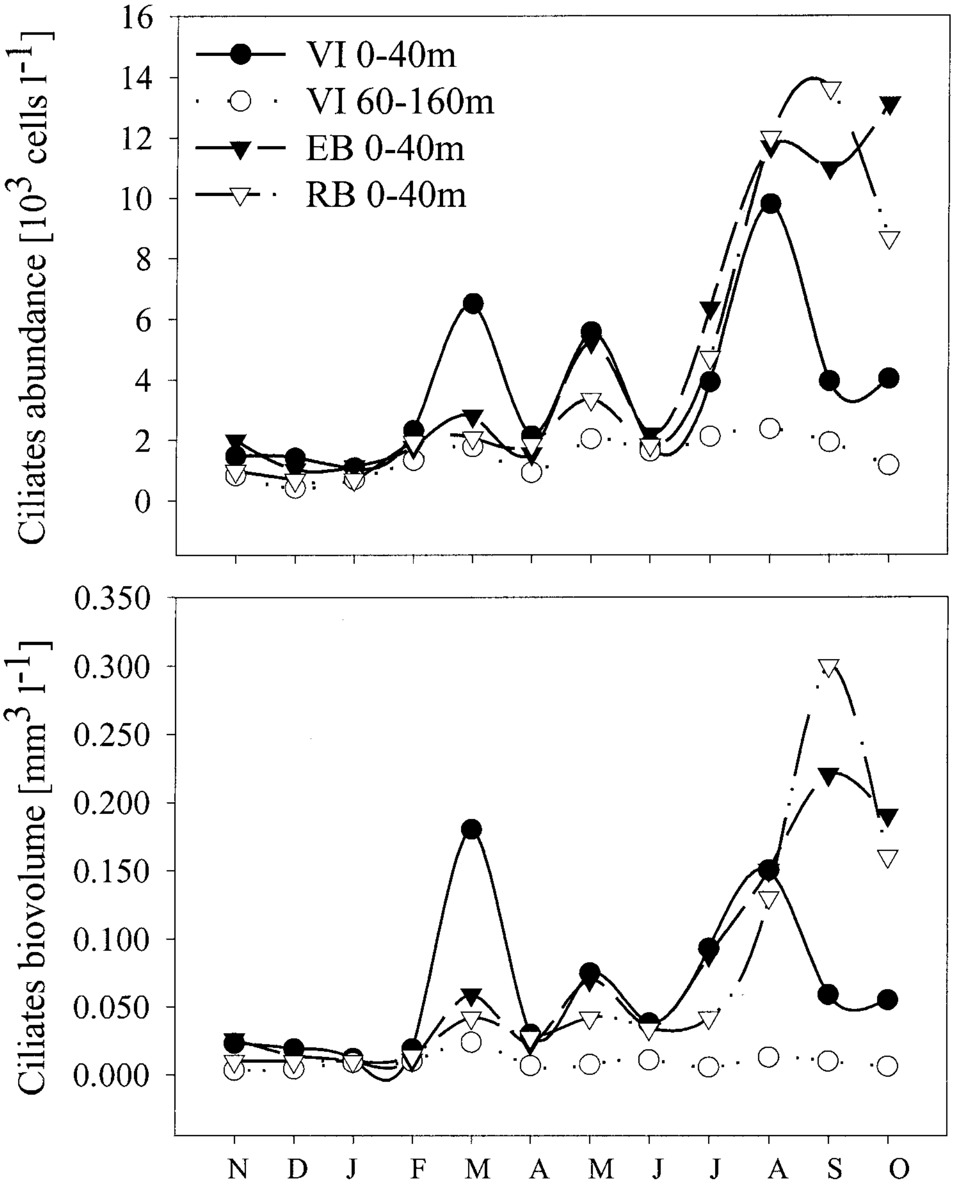

Figure 2. Mean abundance (upper panel) and biovolume (lower panel) of ciliates at the three sampling sites EB, RB and VI from November 1997 throughout October 1998. Values were integrated over depths 0–40 and 60–160 m, respectively.

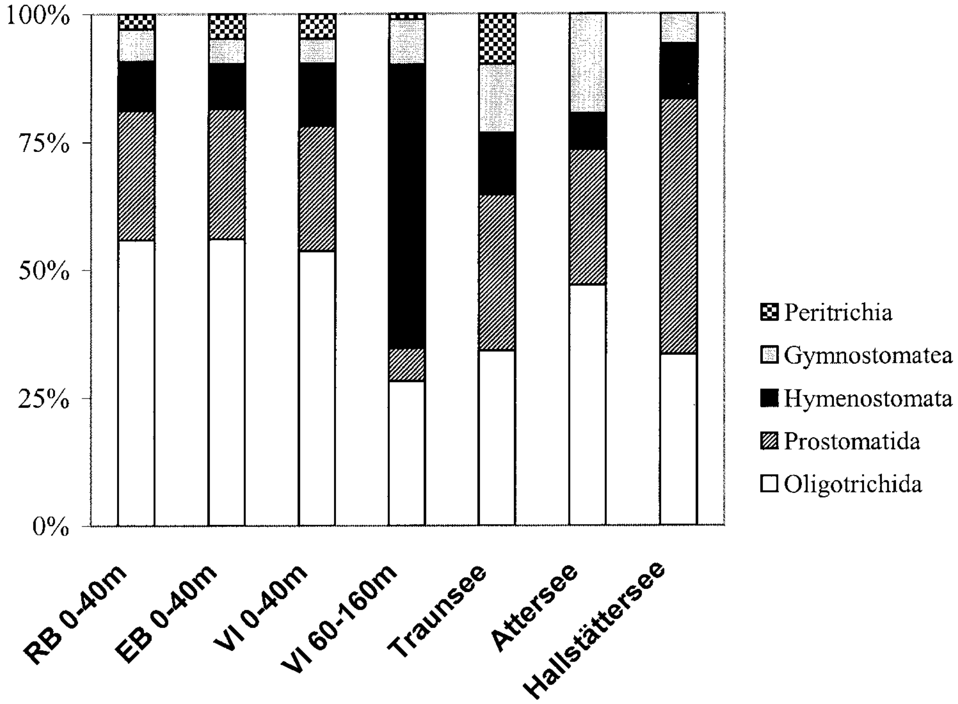

Figure 3. Mean annual percentages of the different ciliate orders at the three sampling sites EB, RB and VI in Traunsee over depths 0–40 and 60–160 m, respectively, and from a single sampling occasion in May 1999 (mean from depth profiles) for Traunsee, Hallstättersee and Attersee.

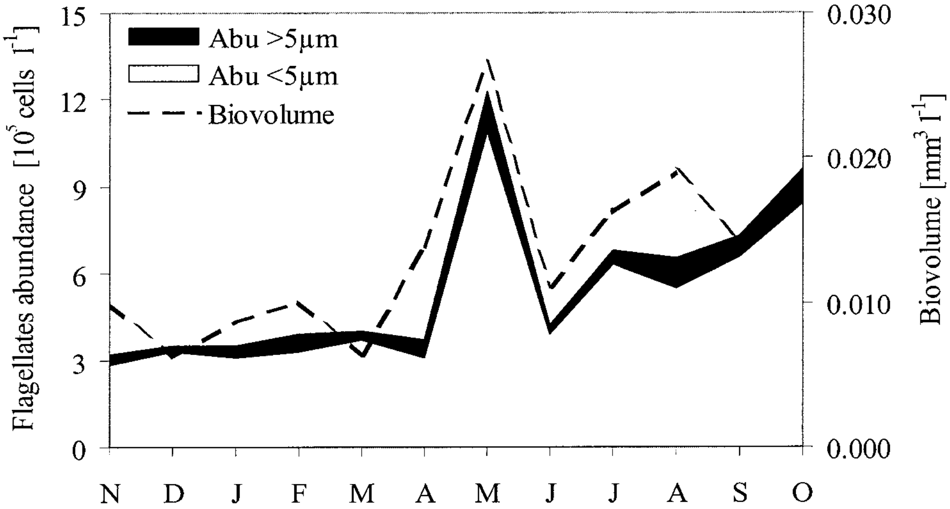

Figure 4. Mean abundance and biovolume of free-living heterotrophic flagellates of different size classes from November 1997 throughout October 1998. Values are means over depths 0–40 m from station RB representative for all sampling locations.

3.3. 'INTER-LAKE' COMPARISON

Abundance and species diversity of ciliates and flagellates decreased with depth in the three lakes observed. Traunsee, Hallstättersee and Attersee showed similar compositions of the ciliate community in the vertical profile (Figure 3, Table II). Ciliates were present in numbers ranging from 900–5500 cells L^{-1} (mean 3300) in Attersee, 1300–12 500 cells L^{-1} (mean 5600) in Hallstättersee and 1200–10 000 cells L^{-1} (mean 5600) in Traunsee. Flagellate numbers ranged between 296–845 cells mL^{-1} (mean 451) in Attersee, between 284–1195 cells mL^{-1} (mean 774) in Hallstättersee and between 198–2660 cells mL^{-1} (mean 1063) in Traunsee. With depth, the formerly mentioned unidentified scuticociliate and the heterotrophic kinetoplastid flagellate increased numerically in all three lakes observed. We identified several ciliate species (Table II: columns TS 99, AS 99, HS 99). No sessile peritrichs were detected in Attersee and Hallstättersee.

At all three sampling locations ciliate and flagellate numbers were significantly correlated to each other, to temperature, bacterial numbers, bacterial production and cyanobacterial abundance (for values see Table IV in Klammer *et al.*, 2002).

4. Discussion

Ciliates and flagellates play a pivotal role in the indication of pollution degree in running waters (e.g. DIN 48410) and lakes. Unfortunately, protists were often neglected in studies dealing with anthropogenic impacts on diverse ecosystems. Especially for planktonic ciliates, high standards in terms of methods, user-friendly literature and supplementary autecological data were sparse until nowadays.

In general, ecological integrity is assessed via the comparison of the actual status of an ecosystem with an expected status. Unfortunately, no data on the protist community of Traunsee prior to its anthropogenic impact (>100 yr ago) are available. Therefore, we compared the actual situation of Traunsee with data from one unaffected and a formerly affected system of similar characteristics, i.e. Attersee and Hallstättersee (Figure 1, Table I). However, Traunsee is quite different from these lakes, especially in respect to chloride concentrations and conductivity (Table I). Changes in salt concentrations may have pronounced effects on microbial communities, including variations in generation times, morphology, osmotic stress, physiology and community composition (e.g. Ziemann, 1973). In Traunsee we detected a diverse ciliate community with ubiquitous freshwater species tolerant against changes in pH, chloride concentrations and salinity. According to literature, the species observed were able to tolerate chloride concentrations within a range of 0–400 mg Cl^{-} L^{-1} corresponding to a salinity of 0–1‰ (salinity terminology after Albrecht, 1984). Hence, changes in nutrient concentrations and trophic status of the lake seemed to have had a greater influence on abundance and composition of the protist community (Sonntag *et al.*, in prep.). Furthermore, without the strong influence of the Traun River (theoretical water retention time of 1.1 yr), differences in abiotic and biotic parameters at the three sampling sites would have been more significant. Most likely, no other lake in the Salzkammergut region would have been able to tolerate such large amounts of saline and alkaline wastes.

Foissner *et al.* (1991) described the planktonic ciliate community as 'Oligotrichetea' dominated by organisms very well adapted to planktonic life. Predominance of Oligotrichida in Traunsee agreed with findings for other oligotrophic lakes (e.g. Beaver and Crisman, 1989; James *et al.*, 1995; Félip *et al.*, 1999). Furthermore, most important in terms of abundance were small rimostrombidiids and *B. planctonicum* (Sonntag *et al.*, in prep.). A vertical change in the ciliate community from oligotrichs/prostomatids to hymenostomatids, especially scuticociliates, seems to be characteristic for deep lakes with aerobic hypolimnia (Figure 3; Müller *et al.*, 1991b; Carrias *et al.*, 1996). In Traunsee, we detected an increase in abundance of a yet unidentified scuticociliate with depth. Moreover, we observed a significant correlation of this ciliate species with chloride concentrations but this species was also present in samples from Attersee and Hallstättersee and seemed to be a common species in lakes of this area, as did the unidentified kinetoplastid flagellate. We could not find any sessile peritrich ciliates in Attersee and Hallstättersee. This might be due to a lack of appropriate attachment sites, i.e. colonial diatoms.

Ruttner (1937) made first attempts to specify the ciliate communities of some Salzkammergut lakes with the help of a ciliate taxonomist (A. Kahl, Hamburg, Germany) at the beginning of the last century. In respect to the knowledge about ciliate species descriptions and methodologies at these times, Ruttner (1937) recorded several taxa from Traunsee (Table II). For all the lakes observed, he supposed *Limnostrombidium pelagicum* (identified as *Strombidium viride* forma *pelagica* by Kahl) to be a regular component of Alpine lakes. We also detected this species in Traunsee, Attersee and Hallstättersee, and in the broadest sense Ruttner's (1937) findings agree with the dominant ciliate taxa we detected in the late 1990s.

Abundance of ciliates and flagellates in Traunsee was generally low throughout the year and within the range of oligo-to mesotrophic lakes (Müller *et al.*, 1991a; Weisse, 1991; Salbrechter and Arndt, 1994; Sommaruga and Psenner, 1995; Carrias *et al.*, 1998a, b). Throughout the investigation period these protists showed two distinct peaks within the 0–40 m depths, one with the phytoplankton bloom in May and another one in autumn (Figures 2 and 4). Müller *et al.* (1991a) described similar peaks for Lake Constance although the ciliate maximum had been observed along with the phytoplankton maximum. A conspicuous, third peak in ciliate abundance and biovolume could be observed in March. Correspondingly, numbers of cyanobacteria, cryptomonads and diatoms as well as phosphorous and chlorophyll *a* values were increased. Very likely, this peak was the result of a short-time nutrient input by the Traun River as temperatures ranged between 4–5 °C.

Flagellate dynamics in Traunsee were similar to investigations in Lake Constance (Figure 4; Cleven and Weisse, 2001). The time of the phytoplankton bloom in May was also the time of highest bacterial numbers. Known as efficient bacterivores, flagellates correlated significantly to bacterial parameters (Klammer *et al.*, 2002; Weisse, 1991; Carrias *et al.*, 1998b). In Traunsee 'small, colourless flagellates, obviously belonging to several taxa' were already observed within 0–85 m depths by Ruttner (1937). During our study, small flagellates <5 μm in length, probably cryptomonads accounted for about 90% of total flagellate abundance (Figure 4). In Lake Pavin (Carrias *et al.*, 1996, 1998b) and Lake Huron (Carrick and Fahnenstiel, 1989) the proportion of such small flagellates on total abundance was around 70%.

5. Conclusions

Throughout the investigation period from November 1997–October 1998, we detected an unusual, man-made situation in Traunsee, concerning abiotic parameters, especially chloride concentration, conductivity and pH. However, after a detailed analysis of ciliates and heterotrophic flagellates we could not find any significant deviation in abundance and composition of the protistan community as described so far from similar lakes. Nevertheless, significant differences within the lake might have been prevented for various reasons: (1) the strong influence of the Traun River which leads to a short theoretical water retention time (1.1 yr) and, (2) the relatively large sampling intervals (i.e. one month, corresponding to every 10th to 20th protist generation). Another deficiency in data analysis is the lack of long–term data sets on microbial parameters of Austrian lakes.

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