Feeding Behaviour of Two Planktonic Freshwater Ciliates Coexisting during Spring Time in the Eutrophic Belauer See (Bornhöveder Seenkette, North Germany)*

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With 4 Figures and 2 Tables

Key words: Ciliates, pico- and nanoplankton, phytoplankton, spring, nutrition

Abstract

In spring 1991, we investigated the development of the planktonic community of a eutrophic lake (Belauer See, North Germany), focusing on the feeding behaviour of *Vorticella rhabdostyloides* and *Tintinnidium fluviatile*, the two most abundant ciliate species in the pelagic zone of this lake during spring. Experiments on the uptake of fluorescently labelled particles in different size classes and fluorescently labelled bacteria and algae permitted the determination of the importance of those kinds of food. *Vorticella rhabdostyloides* ingested particles about 1.0 μm and 3 μm long and autotrophic picoplankton (APP). *Tintinnidium fluviatile* preferred particles 0.5 μm to 1.0 μm and 5.0 μm long, APP and diatoms in the genus *Nitzschia*. Ingestion rates ranged between 100 and 120 particles h⁻¹ for each *Tintinnidium fluviatile* and 60 to 230 particles h⁻¹ for each *Vorticella rhabdostyloides*. APP, bacteria, centric diatoms and nanoprotozoans were evaluated as foods for both ciliates. *Tintinnidium fluviatile* was found to exert a strong short-term control on picoplankton ($r_s = -0.941$, $n = 6$, $p < 0.05$) and small centric diatoms ($r_s = 0.700$, $n = 6$, $p < 0.05$). The different diets of both ciliates may explain the coexistence of both species during spring.

Materials and Methods

To obtain the ciliates plankton samples were collected in a 3.6 l Haney chamber (HANEY 1971) weekly from March to May at a depth of 1 m in the Belauer See, which is part of the Bornhöveder chain of lakes in North Germany. Belauer See is a holomictic, dimictic eutrophic lake with an area of 1.13 km² and a maximal depth of 29.6 m (MÜLLER 1981).

Samples of 0.2 l collected to investigate the ciliates and phytoplankton were fixed immediately after sampling by adding 0.06% HgCl₂ to preserve ciliates and Lugol’s solution to preserve the phytoplankton. Organisms were counted under the Utermöhl inverted microscope (ÜTERMÖHL 1958). Subsamples of 0.01 l were allowed to settle for 24 h. Then the entire surface of the settling chamber was examined at 200× or 400× magnification (ZIMMERMANN 1996).
Another 0.2 l sample of lake water was fixed in 4% formalin, stained with the fluorochrome, 4'-diamidino-2-phenylindole (DAPI), according to PORTER & FEIG (1980) and filtered onto black membrane filters (0.2 μm, Nucleopore). Between 400 and 500 bacteria were counted at 1600× using epifluorescence microscopy (ZIMMERMANN 1996). Picocyanobacteria were counted similarly to bacteria, but autofluorescence of phycoerythrin was used to detect the cells (BARKMANN 2000).

Production of picoplankton and nanoplanckton: Growth rates of APP, mainly picocyanobacteria (BARKMANN 2000), were calculated at a depth of 1 m on several occasions in 1992 and 1993 in the Belauer See using the frequency of dividing cells method (MC DUFF & CHISHOLM 1982) and the dilution technique (LANDRY & HASSET 1982). Considering the fact that the APP in this lake showed negligible seasonal differences in abundance (BARKMANN 2000), the results from 1992 were standardized and calculated for 1991, yielding a value of 0.89 μg C l-1 d-1 for April and May.

In 1991, the production by bacteria was calculated in situ from thymidine incorporation using the method of FURSIEMAN & AZAM (1980). Three bottles were filled with water from depths of 3, 10 and 20 m and inoculated with 15 nM of methyl-3H-thymidine from Amersham. The bottles were exposed for 1 h around midday at the depth from which the samples had been taken. Formaldehyde was added to produce a final concentration of 1.5%, and subsamples were collected on 0.2 μm Nucleopore filters, which were washed three times with 5 ml of 5% cold trichloracetic acid. The filters were dissolved in a Dioxan scintillation cocktail. The samples were then counted in a liquid scintillation counter using an external standard and quench correction.

Primary production by nanoplankton was determined using the radiocarbon method (STEEMANN NIELSEN 1952; VOLLENWEIDER 1974). Determinations of phytoplankton production were carried out every 2 weeks. Clear and dark 120 ml glass bottles were filled with water from depths of 0 to 5 m either unsieved and sieved through a 30 μm mesh (NITZSCH et al. 1990). They were inoculated with NaH14CO3, to produce a final concentration of about 12.5 μCi l-1. The bottles were exposed at the depths from which the samples had been taken for four hours around midday. They were then transported to the laboratory while kept in the dark in boxes. Aliquots of 5 ml were acidified and aerated by bubbling for 25 minutes to remove inorganic 14C (SCHINDLER et al. 1972). A scintillation cocktail (12 ml Pico-Aqua, Canberra Packard) was added the following day, and the radiation counted 2 h later in a Canberra Packard Tri-Carb 2500 TR liquid scintillation analyser with quench correction. To determine the total specific activity in each individual bottle after exposure, a 0.1 ml aliquot was mixed with 1 ml of Carbo-Sorb (Canberra Packard) and 5 ml of Pico-Aqua scintillation cocktail, and the radiation was counted (GESSNER et al. 1996).

The production by nanoprototozooplankton was determined during an intensive investigation of Lake Belau in 1991 and again in 1993. The size fractionation technique was used to eliminate predators from the samples (LANDRY 1994). To remove the species at the highest trophic levels from the plankton, the water was filtered through 150, 44 and 15 μm sieves. Filtered and unfiltered water as well as water enriched with zooplankton (3×1 l ± 150 μm) was placed in 1 l glass bottles and exposed under in situ conditions at a depth of 1 m. All procedures were performed on triplicate samples. The bottles were exposed on a rotating wheel under ambient conditions. Samples were taken once or twice daily. In each sample, 50 to 100 cells of the nanoprototozooplankton were counted (MULLER 1994; ZIMMERMANN 1994, 1996). From the time intervals (t) during which maximum growth was observed, net growth rates (r) were calculated according to the equation:

\[ r = \left( \ln N_f - \ln N_i \right) \times r \]

where \( N_i \) and \( N_f \) are cell numbers observed at the beginning and the end of the time interval (t).

The sizes of the protozoans were measured under the microscope, and the volume was calculated using appropriate formulas (MULLER 1994; RUTTNER-KOLESKO 1977; ZIMMERMANN 1994). The mean daily production (P) has been roughly estimated according to the equation:

\[ P = r \times V \]

where \( V \) is the biovolume.

The number of cells and their biovolumes were used to calculate the amount of carbon using the following conversion factors: for bacteria 15 fg C cell-1 (SIMON & TILZER 1987), APP 220 fg C μm-3 (WATERBURY et al. 1986), nanoflagellates 220 fg C μm-3 (BORSHEIM & BRATBACK 1987), ciliates 110 fg C μm-3 (TURLEY et al. 1986). Phytoplankton at a depth of 1 m was calculated by the method of ROCHA & DUNCAN (1985) according to the equation:

\[ C = -2.117 + 1.05 \ln V \]

where \( C \) is the carbon content per cell [pg cell-1], and \( V \) is the volume [μm3].

Protozoan grazing was measured in short-term direct-uptake experiments on fluorescently labelled prey. Two types of stained prey were prepared: fluorescently labelled organisms and fluorescently labelled particles (FLP). 9-10 l bacteria from 1 m depth were taken from the Plussee and concentrated on 130-180 ml with an Amicon Hollow Fiber Concentrator CH4A (cartridge types H1P100-15, H1MP01-43; MEYER 1991). Bacteria and a strain of Syndecoccus sp., Nitzchia palea and Scenedesmus acutus were harvested by centrifugation, heat killed and stained with 5-[4,6-dichlorotiazin-2-yl]amino amino fluorescin (DTAF) according to SHERR & SHERR (1993). Grazing experiments were performed on each sampling date using 100 ml of sample in 1 l acid-washed glass bottles. Two sets of experiments were carried out to calculate selectivity independently for fluorescently labelled organisms and FLPs. To calculate ingestion rates prefiltered lake water was enriched with fluorescently stained particles or food. After the sample had been allowed a 15 min adaptation period at in situ temperature, food items were added at a concentration of 30% of the natural abundance of picoplankton and up to a maximum of 15% of the algal abundance (Table 1). Subsamples of 0.005 l were taken after 5, 10, 20 and 30 min and 1 h and 12 h, fixed in alkaline Lugol's solution (0.5% final concentration) and placed in borate buffered formalin, previously filtered through 0.2 μm membranes, at a final concentration of 3%. Samples were processed within 24 h after fixation. As the uptake was generally slow, so the subsamples taken after 20 min and 30 min were used to count ingested particles. Subsamples were stained with DAPI, filtered through a 1 μm black filter from Poretics and examined using epifluorescence microscopy. At least 50 ciliates were checked for tracer uptake in each sample. Hourly uptake rates were estimated from the ingested tracer cells and feeding period assuming a linear ingestion rate. On average 80% of the ciliates were found to contain ingested food after 30 min. The grazing rates on food items by pro-
Table 1. Specifications of prey in the grazing experiments.

<table>
<thead>
<tr>
<th>Prey</th>
<th>Approx. size [μm]</th>
<th>Mean biovolume [μm² ind⁻¹]</th>
<th>Concentration in the cocktail [food ml⁻¹]</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.2 μm</td>
<td>0.2</td>
<td>0.03</td>
<td>15×10⁶</td>
</tr>
<tr>
<td>0.5 μm</td>
<td>0.5</td>
<td>0.07</td>
<td>19×10⁶</td>
</tr>
<tr>
<td>1.0 μm</td>
<td>1.0</td>
<td>0.52</td>
<td>13×10⁶</td>
</tr>
<tr>
<td>2.0 μm</td>
<td>2.0</td>
<td>4.18</td>
<td>20×10⁶</td>
</tr>
<tr>
<td>3.0 μm</td>
<td>3.0</td>
<td>14.13</td>
<td>71×10⁶</td>
</tr>
<tr>
<td>4.0 μm</td>
<td>4.0</td>
<td>33.49</td>
<td>29×10⁶</td>
</tr>
<tr>
<td>5.0 μm</td>
<td>5.0</td>
<td>65.42</td>
<td>17×10⁶</td>
</tr>
<tr>
<td>FLB (fluorescently labelled bacteria)</td>
<td>0.2-0.5×0.8–1.2</td>
<td>0.12</td>
<td>22×10⁳</td>
</tr>
<tr>
<td>APP (Synechococcus elongatus)</td>
<td>2.0</td>
<td>3.14</td>
<td>14×10⁵</td>
</tr>
<tr>
<td>FLA (Scenedesmus acutus)</td>
<td>2.5-3.0×12.0-18.0</td>
<td>113.0</td>
<td>14×10⁵</td>
</tr>
<tr>
<td>FLA (Nitzschia palea)</td>
<td>3.0-5.0×10.0-25.0</td>
<td>200.0</td>
<td>43×10³</td>
</tr>
</tbody>
</table>

Results

The seasonal cycle of protozoan activity in Belauer See is characterized by a great abundance of protozoans during spring. At 1 m, the depth where the experiments were carried out, the abundance of protozooplankton was characterized by a spring peak of 23×10² ciliates 1⁻¹ in mid-April and a drastic decline at the end of April. The ciliate community consisted primarily of 2 ciliate species, *Tintinnidium fluviatile* (Stein 1863) Kent 1881 reached an abundance of 11 × 10² cells 1⁻¹, and *Vorticella rhabdostyloides* Kellicott 1885 reached 2×10² cells 1⁻¹. The sessile ciliate, *Vorticella rhabdostyloides*, was attached to centric diatoms. Almost no free swimming species were found in the water column of the lake. Ciliates became abundant during the first phytoplankton bloom (Fig. 1), which was produced by diatoms. Algae produced chlorophyll a values between 14 μg 1⁻¹ and 62 μg 1⁻¹ at a depth of 1 m (Fig. 1).

Nanoflagellates were not numerous during spring. Amoeboae and heliozoans were generally of minor importance (see Zimmermann 1996).

In early spring, the predominant algae in the eutrophic Belauer See were Bacillariophyceae, followed in abundance by Chrysophyceae. The centric diatoms, *Cyclotella radiosa* (Grunow) Lemmermann 1900, *Stephanodiscus minutulus* (Kützing) Cleve and Müller 1878, *Stephanodiscus parvus* Stoermer and Häkansson 1984 and some unidentified species were most numerous until the middle of April. At a depth of 1 m, small unidentified centric diatoms were most numerous at 2.7 × 10⁶ to 9.78 × 10⁶ 1⁻¹. Planktonic bacteria showed much less variability in abundance. At 1 m depth, between 4.80 and 9.1 × 10⁶ bacteria 1⁻¹ or 42 and 129 μg C 1⁻¹ were found (Fig. 1). APP was not significantly represented during spring (see Barkmann 2000).

The experiments were carried out to characterize the diets of the two coexisting ciliates, *Tintinnidium fluviatile* and *Vorticella rhabdostyloides*, according to size and kinds of item consumed and to compare their impacts on representa-
Fig. 1. Seasonal changes in the biomass and abundance of plankton in the eutrophic Belauer See with the biomass of chlorophyll a [μg l⁻¹], small centric diatoms [μg C l⁻¹], pico- and nanoprototzooplankton [μg C l⁻¹] in 1991.

Tintinnidium fluviatile showed a significant preference for 0.5 μm particles (D_Jacobs = +0.80) over 0.2 μm, 2.0 μm, 3.0 μm and 4.0 μm particles. It preferred 1.0 μm particles (D_Jacobs = +0.75) over 0.2 μm, 2.0 μm and 4.0 μm particles, it favoured 5.0 μm particles (D_Jacobs = +0.20) over 0.2 μm, 2.0 μm and 4.0 μm particles (Fig. 2). Vorticella rhabdostyloides ingested particles of 1 μm (D_Jacobs = +0.56) and 3 μm in diameter (D_Jacobs = +0.25; Fig. 2). Preference for 1.0 μm was more pronounced in Tintinnidium fluviatile than in Vorticella rhabdostyloides.

tives of the different compartments of the microbial food web. The selectivity coefficient for the food items and the ingestion and filtration rates were estimated for both species (Table 2). To check the optimal incubation time, fluorescently prey was offered to the species, and samples were taken after 5, 10, 15, 20, 30 and 60 minutes. A sharp increase in the labelled picoplankton during the first 15 min was followed by a peak. A similar increase and peak of the nanoplanckton occurred after 20 minutes. Therefore, samples were taken after 15 and 20 min to count ingested food particles.
Table 2. Ingestion and filtration rates of *Tintinnidium fluviatile* (n = 50) and *Vorticella rhabdostyloides* (n = 50).

<table>
<thead>
<tr>
<th>Organisms</th>
<th>Food</th>
<th>Ingestion rate [particles cell⁻¹ h⁻¹]</th>
<th>Filtration rate [µl cell⁻¹ h⁻¹]</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Tintinnidium fluviatile</em></td>
<td>0.2 µm</td>
<td>110–120</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td>0.5 µm</td>
<td>111–119</td>
<td>5.26–5.32</td>
</tr>
<tr>
<td></td>
<td>1.0 µm</td>
<td>110–115</td>
<td>0.76–0.90</td>
</tr>
<tr>
<td></td>
<td>2.0 µm</td>
<td>113–120</td>
<td>0.50–0.60</td>
</tr>
<tr>
<td></td>
<td>3.0 µm</td>
<td>100–101</td>
<td>1.41–1.69</td>
</tr>
<tr>
<td></td>
<td>4.0 µm</td>
<td>101–110</td>
<td>3.45–4.14</td>
</tr>
<tr>
<td></td>
<td>5.0 µm</td>
<td>102–108</td>
<td>5.88–7.06</td>
</tr>
<tr>
<td></td>
<td>bacteria</td>
<td>100–120</td>
<td>4.55–5.45</td>
</tr>
<tr>
<td></td>
<td><em>Synechococcus elongatus</em></td>
<td>110–120</td>
<td>7.14–8.57</td>
</tr>
<tr>
<td></td>
<td><em>Scenedesmus acutus</em></td>
<td>105–110</td>
<td>7.14–8.57</td>
</tr>
<tr>
<td></td>
<td><em>Nitzschia palea</em></td>
<td>100–110</td>
<td>2.33–2.79</td>
</tr>
<tr>
<td><em>Vorticella rhabdostyloides</em></td>
<td>0.2 µm</td>
<td>145–229</td>
<td>0.02–0.02</td>
</tr>
<tr>
<td></td>
<td>0.5 µm</td>
<td>146–200</td>
<td>3.14–12.11</td>
</tr>
<tr>
<td></td>
<td>1.0 µm</td>
<td>145–213</td>
<td>0.46–1.77</td>
</tr>
<tr>
<td></td>
<td>2.0 µm</td>
<td>147–230</td>
<td>0.30–1.15</td>
</tr>
<tr>
<td></td>
<td>3.0 µm</td>
<td>60–100</td>
<td>0.85–3.24</td>
</tr>
<tr>
<td></td>
<td>4.0 µm</td>
<td>70–99</td>
<td>2.07–7.93</td>
</tr>
<tr>
<td></td>
<td>5.0 µm</td>
<td>60–88</td>
<td>3.53–13.53</td>
</tr>
<tr>
<td></td>
<td>bacteria</td>
<td>145–230</td>
<td>2.73–10.45</td>
</tr>
<tr>
<td></td>
<td><em>Synechococcus elongatus</em></td>
<td>145–230</td>
<td>4.29–16.43</td>
</tr>
</tbody>
</table>

Both organisms actively selected the APP: *Tintinnidium fluviatile* ($D_{secb} = +0.95$) and *Vorticella rhabdostyloides* ($D_{secb} = 0.70$). Fluorescently labelled bacteria (FLB) and *Scenedesmus* were negatively selected. The alga *Nitzschia* was selected positively by *Tintinnidium fluviatile* and negatively by *Vorticella* (Fig. 3).

Feeding rates of *Tintinnidium fluviatile* ranged between 100 and 120 particles cell⁻¹ h⁻¹ (Table 2). The filtration rate of each ciliate ranged between 0.01 µl cell⁻¹ h⁻¹ and 8.57 µl cell⁻¹ h⁻¹ (Table 2). Feeding rates of *Vorticella rhabdostyloides* ranged between 60 and 230 particles cell⁻¹ h⁻¹. The filtration rate of each ranged between 0.02 µl cell⁻¹ h⁻¹ and 16.43 µl cell⁻¹ h⁻¹ (Table 2).

After one hour of feeding, *Vorticella* contained only APP and FLB but no inert fluorescent particles, which were supplied at the same time. This indicates that after a few minutes, *Vorticella* is able to distinguish between edible and non-edible particles before ingestion. *Tintinnidium fluviatile* did not show that it could distinguish between edible and non-edible items.

![Fig. 2. Selective feeding ($D_{secb}$) by *Tintinnidium fluviatile* and *Vorticella rhabdostyloides* on FLP (fluorescently labelled particles) in the size range 0.2, 0.5, 1.0, 2.0, 3.0, 4.0, and 5.0 µm. The center of the selectivity was characterized using the the median (n = 50), and the range was calculated according to the standard deviation method of the median. In some cases the range was very small.](image1)

![Fig. 3. Selective feeding ($D_{secb}$) by *Tintinnidium fluviatile* and *Vorticella rhabdostyloides* on fluorescently labelled food (FLB = fluorescently labelled bacteria, APP = autotrophic picoplankton, Sce = *Scenedesmus*; Nit. = *Nitzschia palea*). The center of the selectivity was characterized using the the median (n = 50), and the range was calculated according to the standard deviation method of the median. In some cases the range was very small.](image2)
Several important points should be considered if FLPs are used as markers of protozoan food. Active selection by protozoa of fluorescently labelled natural food instead of FLP has been previously reported (Pace & Bailiff 1987; Sherr et al. 1987; Nygaard et al. 1988; Simek et al. 1990b). FLPs differ in some features from natural food. Though their size frequency distribution in our experiment was similar to that of natural plankton (Zimmermann 1994), their shapes were somewhat different, and their surfaces and their taste may cause them to be rejected by protozoa. Due to the preservative used (Sieracki et al. 1987) an eggestion of the particles can be ruled out in these experiments (Zimmermann 1994). The rejection of FLP by ciliates, as observed in the experiment on Vorticella rhabdostyloides, appeared to be a more serious problem. Vorticella was able to “learn” to distinguish between FLPs and natural stained food after 60 minutes of exposure to food suspension. Pace & Bailiff (1987) found that Cyclidium sp. did not reject inert beads, whereas some other ciliates ingested FLP at much higher rates (Sherr & Sherr 1987; Sherr et al. 1989). The ingestion rates found for ciliates seem to fall in the range reported for those in other marine and lacustrine systems, except for the ingestion rate of Tintinnidium fluviatile, which will be discussed later (Table 2).

The calculated selectivity indices showed that both ciliate species were able to ingest food particles, dependent from the handling. Tintinnidium fluviatile ate particles between 0.5 μm and 1.0 μm and those of 5.0 μm in diameter more efficiently than those of 0.2 μm, 2.0 μm and 4.0 μm in diameter, while Vorticella rhabdostyloides ingested particles between 0.5 and 3.0 μm. In the experiments on stained food, Tintinnidium fluviatile ate Nitzschia palea and APP, whereas Vorticella ate only food in the picoplankton size range. Because they showed selectivity between APP and bacteria, not only the size, but also taste seems to be an important feeding criterium. It seems that both ciliates had a similar diet, but they differ in that Tintinnidium actively rejects relatively large particles. From an ecological point of view, it is not the size that counts but rather the volume of the prey. If the volume of the small centric diatoms ingested by Tintinnidium is calculated, it is found that a volume of bacteria 19 times greater will be consumed if their concentration in the medium is the same. An essential difference is that Tintinnidium actively rejects larger FLPs, which may explain the strange decrease in the clearing rate of particles ≥1 μm.

The finding that Tintinnidium is able to feed on food items in the lowest and in the upper size ranges of different items suggests, that there are two feeding modes: filter-feeding on pico-sized particles and encounter-feeding on suitable large particles which enter the mouth region during filtration. In the opinion of Spittler (1973) and Heinbockel (1978 a, b), tintinnids only eat particles larger than 2.0 μm. Heinbockel (1978a) stated a general rule that tintinnids are able to ingest food particles with a diameter of up to 43% of their own lorica opening. They therefore accept particles about 19 μm in diameter. In our study, all tintinnids also ingested smaller particles, the lower limit being 0.2 μm. Heinbockels (1978a) upper limit seems to agree with our results. Blackburn (1974) also found high ingestion rates for 1 μm particles. Kivi & Setäle (1995) found Tintinnidium fluviatile with ingested particles in size ranges between 1.8 to 8.4 μm. The most popular particle size in their study was 4.2 μm.

A potential explanation for the high filtration rate of 100 to 120 particles ciliate⁻¹ h⁻¹ is the fact, that the filter is relatively rough and that the filtration rate is not reduced by aggregated small particles. The clearing rates for picoplankton-sized particles which were found in these experiments are high for a tintinnid. These high rates indicate that capture of small particles is accomplished by sieving alone since it would be hydrodynamically difficult to explain a flow of 8.57 μl cell⁻¹ h⁻¹ through a filter with a pore size less than...
0.5 μm, assuming a pressure drop of ca 15 dyne cm⁻², which is
typical of ciliary filters (Per Jonsson, Strömstad, personal
communication). For this work Tintinnidium would have to
possess a filter about 2000 μm² in area, which would imply
the possession of membraelles 70 μm long. A possible ex-
planation may be that the filter is coarser and that electrostat-
ic forces greatly enhance impact capture on ciliary filaments.
Besides this it should be taken into account, that the FLP
concentration for 0.2 and 0.5 μm particles was much higher
than the natural bacterial concentration. May be, that values
of uptake in such high concentrations are a rather passive
side effect of ingesting some larger prey items. But the lower
picoplankton concentrations (APP and FLB; Table 1) and the
high ingested picoplankton values (Table 2) underline the
first explanation.

Many qualitative analyses of tintinnid food have been
conducted (Beers & Stewart 1967; Blackburn 1974;
Campbell 1926; Hollibaugh et al. 1980; Gold 1968;
Stoecker et al. 1981), and correlations between tintinnids
and potential food items have been made (Barnes et al.
1976; Kimor & Gollandsky 1977; Sorokin 1977). While
quantitative investigations of the feeding behaviour of
Tintinnidium in marine and estuarine environments have
been completed (Blackburn 1974; Capriulo & Carper-
Spittler 1973, information about their role in fresh water is
scarce (Cleven 1996). Pratt & Cairns (1985) described
Vorticella as a consumer of bacteria and detritus. Our
own investigations confirm the finding that Vorticella favours
on bacteria. The feeding behaviour of Vorticella has been
studied in only one experiment on protozoan grazing in the epi-
limnion and metalimnion of the eutrophic Rimov Reservoir
in southern Bohemia (Simek et al. 1995). The authors ob-
served the Vorticella aquadulcis complex and found that
their rates of ingesting picoplankton were twice as high as
those reported here.

The influence of grazing by ciliates on bacteria and algae
during the year. Tintinnidium fluviatile is important
during spring as “herbivorous” organism, while metazo-
oplankton with a longer generation time occupies this ecolog-
ic niche later. During spring Tintinnidium fluviatile is able
to use the small centric diatoms as food, and it reduces the
nanoplankton production (nearly 52%) and sometimes elimi-
nates whole populations. In our own microscopic investiga-
tions, they favoured centric diatoms and flagellates. Howev-
er, the calculations (Fig. 4) show that the nanoplanktonic diet
is insufficient. A few days later, their influence greatly de-
creased because of the grazing by Synchaeta on diatoms and
their direct predation on Tintinnidium (Zimmermann 1996).
Landry & Hassel (1982) found around the coast of Hawai,
that 17-52% of the phytoplankton production were con-
sumed by tintinnids and nauplii, while tintinnids in the sea
and in estuaries consumed about 4 to 41% of the daily prima-
ry production (Heinbockel & Beers 1979; Capriulo &
grazing losses due to Codonella and Tintinnidium sp. in
Lake Constance to be about 17% of the total community.

Ciliates graze considerably on picoplankton during cer-
tain seasons (Simek et al. 1990 a, b). Such grazing occurs in
the estuarine and coastal environment, where ciliates can
eliminate 100% of the bacterial production (Sherr et al.
1986; Sherr & Sherr 1987). During this study, their impact
on bacteria was of less severe.

Distinct ecological niches seem to be produced by particle
selection facilitated by differences in the mouth structure
(Fenchel 1980). There is evidence that Tintinnidium grazes
effectively only on some of the potential prey available. The
two planktonic ciliates coexisting during the spring bloom in
Belauer See seem to be well separated ecologically by the
ability of Tintinnidium fluviatile to ingest voluminous algae.

Zusammenfassung

Im Frühjahr 1991 wurde das plankton des eutrophen Belauer Sees
(Bornhöver Seenkette, Norddeutschland) untersucht, wobei die
das Frühjahrsplankton beherrschenden Ciliaten, Tintinnidium flu-
viatile und Vorticella rhabdosostyloides, hinsichtlich der Nahrungs-
aufnahme besonders bearbeitet wurden. Um die Nahrungsaufnahme
qualitativ und quantitativ bestimmen zu können, wurden im Wasser
suspendierte fluoreszierende Partikel unterschiedlicher Größe und
mit Fluoreszenzfärbstoffen gefärbte natürliche Futterpartikel den
den Ciliaten unter in situ-Bedingungen als Nahrung angeboten. Vorticella rhabdo-
stoysioie (1 μm-Partikel und APP auf. Tintinnidium fluviatile bevorzog Partikel in der Größenordnung
von 0,5 bis 1,0 μm und 5,0 μm, APP und die Diatomee Nitzschia pelast. Die Ingestionsraten
lagen bei Tintinnidium fluviatile im Bereich von
100-120 Partikeln Individuum⁻¹ Stunde⁻¹ 
bei Vorticella rhabdo-
stoysioie zwischen 60 und 230 Partikeln Individuum⁻¹ Stunde⁻¹.
Das unterschiedliche Futterpektrum ermöglichte die Koezistenz
beider Ciliatenarten im Frühjahr.

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