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Comparison of Direct Stream Bed and Artificial Substrate Sampling of Ciliates (Protozoa, Ciliophora) in a Mesosaprobic River

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With 3 Figures

Key words: Artificial substrate sampling; Ciliophora; Natural substrate sampling; River ecology; Sampling; Saprobic system; Water quality.

Summary

Species richness, species composition and individual abundance of ciliated protozoa were compared on 14 occasions in natural and artificial substrate (foam units, litter bags) samplings from a mesosaprobic river system near Munich, South Germany. The artificial substrates were allowed to be colonized for 2 – 3 weeks. Direct samples from natural substrates (mud, Aufwuchs, etc.) were taken when artificial substrates were harvested. A total of 209 ciliate taxa were identified. The foam units sampled significantly ($P < 0.05$) less species (122 taxa) than the natural substrates (174 taxa); no significant difference was found between litter bags (150 taxa) and natural collections. Edaphic species and alpha- to polysaprobic mud-dwellers were more common in the natural substrates. The latter caused significantly higher saprobic indices in the direct samples, indicating poorer water quality. Differences in individual abundances were sometimes great. However, averages were very similar for all methods due to the lack of a consistent trend. PRATT et al. (1987), in contrast, found a richer protist community in artificial substrates (foam units) than in collections from natural sites; however, their sampling strategy was evidently biased. It is concluded that artificial samplers are not as accurate and practical as natural substrate collections; the river's organic waste load is underestimated, the species richness is lower, two visits are required to obtain one sample (one to set the sampler and one to recover it), and some samples are usually lost by, e.g. floods and vandalism.

Introduction

The choice of the sampling method is not an entirely academic problem since incomplete and/or selective sampling may influence, e.g. water quality assessment considerably. Two principal techniques are available: either direct sampling of natural substrates or artificial substrate sampling. The advantages and disadvantages of these methods have been excellently reviewed by ROSENBERG & RESH (1982). They conclude that the correct use of artificial substrates, as with any other sampling method, requires that they be placed in similar macrohabitats if standardization is to be achieved. Thus, one of the most commonly claimed advantages of using artificial substrates, viz. that they permit standardized sampling, obviously does not hold.

Although there is a great deal of literature on sampling of macroinvertebrates (for reviews see BRAUKMANN 1987; DANECKER 1986; ROSENBERG & RESH 1982), data on protozoan collection are extremely sparse. These are usually sampled from natural substrates by collecting algal masses, mud, debris and leaves and by scraping off the Aufwuchs from stones, twigs and vegetation (HEUSS 1976; LIEBMANN 1962; STÖSSL 1987). Our paper specifically refers to a study by PRATT et al. (1987) suggesting that artificial substrate samplers yield many more protist species than direct stream bed sampling. The data provided by PRATT et al. (1987) do not appear very convincing in terms of both sampling strategy and from a general point of view as the number of species usually increases with biotope diversity (SCHWERDTFEGER 1975), and there can be no doubt that a natural river has a higher substrate diversity than any artificial sampler.

Material and Methods

Study sites

The investigations were performed between June and October 1991 on the River Amper and on a small tributary, the River Windach. The Amper is the outlet of the Ammersee (Lake Ammer) and located near Munich (Germany). Normal discharge in the outlet is about 20 m^3/s, this increases to 48 m^3/s about 100 km north-east of the Ammersee, where the Amper flows into the River Isar near the town Moosburg. The drainage basin is primarily agricultural. The river system receives 75 inputs from domestic sewage treatment plants with a total of 1,250.000 population equivalents. The river Amper is thus hypertrophic and has a saprobity index of 2.5 to 2.9, the higher values are usually encountered below plant effluents. The sediment contains much organic mud at all stations.

The Windach, a brooklet with a normal discharge of about 1.5 m^3/s, is, like the Amper, highly eutrophic and mesosaprobic.

Station 1: Amper, about 100 m after the outlet from Lake Ammer. Current velocity low, less than 0.5 m/s. River bed 50 m wide, water about 1.5 m deep. Samples were thus taken from the bank area only. Bottom coated with lime precipitates, algae and macrophytes during summer.

Station 2: Windach, about 50 m above a sewage disposal plant. Current velocity about 1 m/s. River bed 4 – 5 m wide, water about 50 cm deep. Bottom consists of coarse gravel, some larger stones and leaf-litter.

Station 3: Like station 2, but about 150 m below the plant effluent. Current velocity 0.5 – 1 m/s. River bed about 8 m wide, water 10 – 20 cm deep. Sediment consists of fine gravel and some big stones. Anaerobic patches occur in the sediment which sometimes contains dislodged sewage.

Station 4: Amper, about 1 km above the biggest sewage disposal plant of the catchment area. Current velocity high, i.e. 1 – 2 m/s. River bed about 40 m wide, water about 10 – 20 cm deep on right side, more than 70 cm on left. Bottom consists of coarse gravel and is densely overgrown with macrophytes (80%, summer) and mosses (10%, winter).

Station 5: Like station 4, but about 50 m below the plant effluent. Current velocity high, about 2 m/s since the river is regulated and reinforced with big stones. River bed about 25 m wide, water more than 1.5 m deep. Samples were thus taken from the bank area only.

Station 6: Amper, about 50 m above a dam. Current velocity hence very low, i.e. 0.1 – 0.2 m/s. River bed about 30 m wide, water more than 2 m deep. Samples were thus taken from the bank area which consists of sand and fine gravel and is overgrown with reeds.

Sampling

Direct (natural substrate) sampling: This sampling method was directed at the more obviously definable substrate types, and collecting procedures were varied slightly to obtain samples reflecting the variety of substrates (e.g., logs, twigs, rocks, vegetation, algal masses, mud, debris, leaves). An effort was made to collect each different type of substrate at each station and to collect from comparable substrates at all sites. Three samples were hereby obtained at each station and date: (1) logs, twigs and vegetation; (2) algal masses, mud, debris, detritus, litter and fine gravel; (3) Aufwuchs brushed off stones and coarse gravel.

Foam sampling: The method recommended by CAIRNS & HENEBRY (1982) was employed. However, we used natural sponge *(Euspongia officinalis)* instead of polyurethane foam (PF units) to avoid possible leaching of toxic substances. The sponges had a diameter of about 10 cm and were tied to a short line, anchored to a steel pole, so that they floated about 10 cm above the sediment surface.

Litter bag sampling: Litter bags with a size of 20 × 10 cm and a 1.5 mm mesh were filled with dried leaves from *Corylus avellana* L. and mounted as described for the foam unit.

Both artificial substrates were exposed for 2 – 3 weeks near the centre of the river (stations 1 – 4) or near the river bank (stations 5, 6). This exposure time is more than enough to reach equilibrium species number in eutrophic waters (CAIRNS & HENEBRY 1982). At each site and each sampling date one "normal" (direct) sample, one foam and one litter bag were collected in 0.5 l bottles and transported to the laboratory in a cooling box.

In the laboratory, the artificial substrates were harvested by slight, medium and strong squeezing of the substrate contents into three separate bottles. This sampling strategy was intended as correlating to the three collections used for the direct method.

Determination of the number and kinds of species, nomenclature

After a few minutes, when the coarse detritus had been settled, a coverslip (50 × 24 mm) was placed on the surface of each bottle. This is a very simple and highly effective method for collecting most of the vagile and sessile Aufwuchs species. The first coverslip was removed and investigated for the number and kind of species and individuals present after 30 min. A skilled person takes about 25 min. for the inspection of such a preparation. Thus, the following coverslips were removed from the sample surface after about 60 min. and 80 min., respectively. After the coverslips had been inspected, some drops of the sediment from each bottle were investigated for bottom dwellers. The evaluation of one series (three coverslips each from direct, foam and litter bag sample; sediment investigation) takes about 5 hours; two series were investigated at each sampling date.

Most species were pre-determined from silver impregnated slides using specific taxonomic literature and our recently published monograph on the ciliates of the saprobic system (FOISSNER et al. 1991). Nomenclature is according to the revisions by FOISSNER (1988), FOISSNER & FOISSNER (1988) and FOISSNER et al. (1991).

Estimation of individual numbers

A rating scale was used for estimating the individual abundance of species: 1 = very sparse, 2 = sparse, 3 = sparse to medium, 5 = medium, 7 = numerous, 9 = very numerous.

Calculation of the saprobic index

The saprobity was calculated according to PANTLE & BUCK (1955) and ZELINKA & MARVAN (1961). The saprobic classification of the ciliates was taken from the lists of FOISSNER (1988) and FOISSNER et al. (1991).

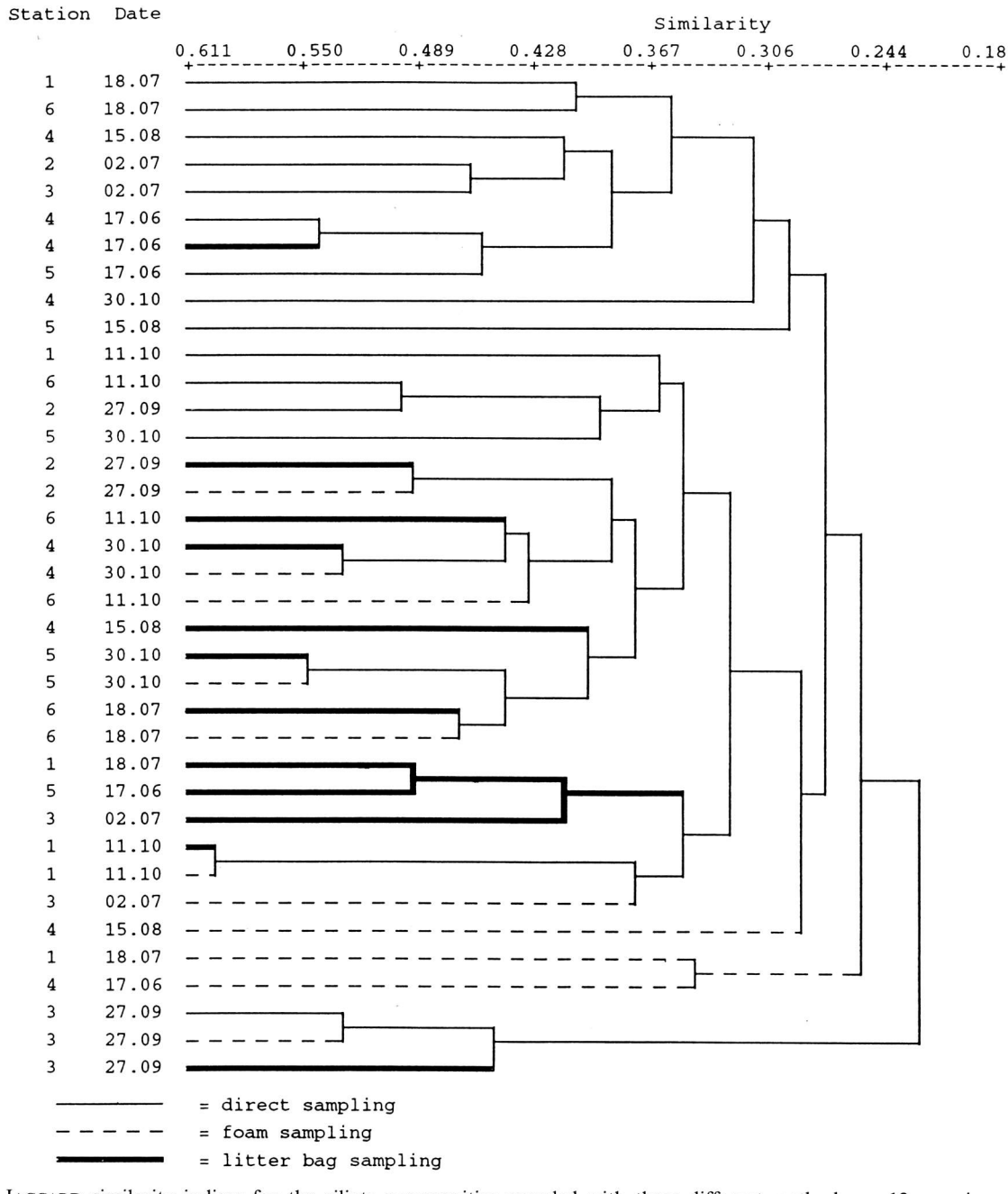


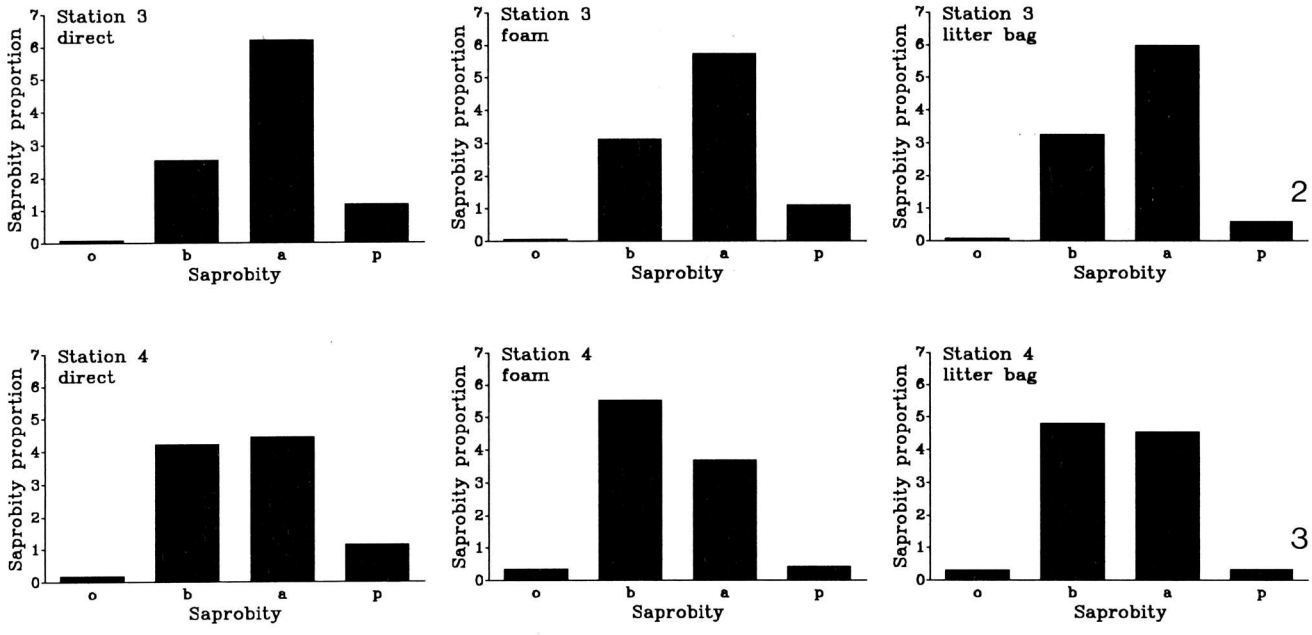
Fig. 1. Clusters of JACCARD similarity indices for the ciliate communities sampled with three different methods on 12 occasions at six stations.

Similarity analysis

Similarity between the ciliate communities at each station, sampling date and method was calculated with the indices suggested by JACCARD (1902) and BRAY & CURTIS (1957). The similarity values obtained were summarized by clustering using the UPGMA (unweighted group mean, average distance criteria; SNEATH & SOKAL 1973) algorithms of the CLUSTAN program.

Results

A total of 209 ciliate taxa were identified; 174 of these occurred in the natural stream bed samples, 150 in the litter bags and 122 in the foam units (Table 1). At all dates, with one exception, the species number was higher with direct and litter bag sampling than with foam; thus, direct



Figs. 2, 3. Examples for the saprobic levels obtained with the three sampling methods tested. Diagrams were constructed according to ZELINKA & MARVAN (1961). For each species the number unit found in the samples is multiplied separately by the factor for each quality class, and the products of each species are summed by quality class to give a relative ranking for each class. These are then reduced by normal proportional arithmetic to a class ratio, the sum of whose terms is ten. This ratio constitutes the water quality index for the sample. o = oligosaprobic, b = beta-mesosaprobic, a = alpha-mesosaprobic, p = polysaprobic.

stream bed and litter bag samples yield a significantly ($P < 0.05$, U-test) higher number of species than foam units. The difference between the means of species collected with the litter bags and the direct method is not significant ($P > 0.05$, U-test) since in 4 out of 12 samples most species occurred in the litter bags (Table 2).

There were often distinct differences in the individual abundances and sometimes even the dominant species differed. However, averages are very similar for all methods due to the lack of a consistent trend (Table 2).

The mean of the saprobic index is significantly higher ($P < 0.05$, U-test; indicating poorer water quality) in the direct samples than in the foam units and the litter bags. In contrast, the means of the saprobic index do not differ ($P > 0.05$, U-test) in the foam units and the litter bags (Table 2, Figs. 2, 3).

Direct and artificial substrate samples are well separated in the cluster calculated with JACCARD's species similarity index (Fig. 1); only on 27. 09. 1991 did the three sampling methods fall into the same cluster. In contrast, litter bag and foam units separate indistinctly. Usually, the difference between stations is larger than between methods (Fig. 1). The distinct separation of the direct samples is due to the many taxa which were recorded with this method only. Most belong to two ecological groups, viz., edaphic species (e.g., *Colpoda* spp., *Platyophrya* spp., *Pseudoplatyophrya nana*) and alpha- to polysaprobic mud-dwellers (e.g., *Colpidium colpoda*, *Dexiostoma campyla*, *Tetrahymena pyriformis*). The increased occurrence of mud-dwellers is apparently responsible for the higher saprobic indices in the direct samples (Tables 1, 2, Figs. 2, 3). Only few species were restricted to the foam units; most of these are sessile peritrichs *(Cothurnia annulata, Epistylis balatonica, E. major, E. nympharum, Thuricola folliculata)* whereas sessile suctorians *(Acineta compressa, A. tuberosa, Podophrya fixa, Tokophrya quadripartita)* occurred almost exclusively in the direct samples. These differences emphasize the separation of the direct samples in the cluster (Table 1, Fig. 1).

We also calculated a cluster using BRAY & CURTIS' index, which measures the similarity in species composition and individual abundance. The cluster was very similar to that obtained with JACCARD's coefficient, indicating that the distinct separation of the direct and artificial substrate samples is mainly caused by differences in species composition and species number.

Discussion

Our results agree with those of CHADWICK & CANTON (1983), who found that artificial multiplate samples provide less species of macroinvertebrates than direct surber samples. PRATT et al. (1987), in contrast, collected much higher numbers of protist species (ciliates, heterotrophic and autotrophic flagellates, amoebae) from artificial poly-

Table 1. Species found with direct, foam and litter bag sampling. B = bottom (mud) dweller, E = reliably recorded also from terrestrial biotopes, P = mainly planktonic, S = sessile Aufwuchs dweller, V = vagile Aufwuchs dweller; + = found, − = not found.

Species	Group	direct	foam	litter
Acineria incurvata Dujardin, 1841	V	+	−	+
Acineria uncinata Tucolesco, 1962	V	+	+	+
Acineta compressa Claparede & Lachmann, 1859	S	+	−	−
Acineta tuberosa (Pallas, 1766)	S	+	−	−
Amphileptus claparedii Stein, 1867	V	+	+	−
Amphileptus fusidens (Kahl, 1926)	V	+	−	+
Amphileptus pleurosigma (Stokes, 1884)	V	+	+	+
Amphileptus procerus (Penard, 1922)	V	+	+	+
Amphileptus punctatus (Kahl, 1926)	V	+	+	+
Aspidisca cicada (Müller, 1786)	E, V	+	+	+
Aspidisca lynceus (Müller, 1773)	E, V	+	+	+
Blepharisma bimicronucleatum Villeneuve-Brachon, 1940	E, B	−	−	+
Blepharisma hyalinum Perty, 1849	E, B	+	−	+
Calyptotricha lanuginosa (Penard, 1922)	S	+	+	+
Campanella umbellaria (Linnaeus, 1758)	S	+	+	+
Carchesium polypinum (Linnaeus, 1758)	S	+	+	+
Chaenea torrenticola Foissner, 1984	B	+	−	+
Chilodonella uncinata (Ehrenberg, 1838)	E, V	+	+	+
Chilodonellidae Gen. sp.	V	+	+	+
Chilodontopsis depressa (Perty, 1852)	V	+	+	+
Chlamydonella alpestris Foissner, 1979	V	+	−	+
Chlamydonella rostrata (Vuxanovici, 1963)	V	+	+	+
Chlamydonella sp.	V	+	+	+
Chlamydonellopsis plurivacuolata Blatterer & Foissner, 1990	V	+	+	+
Cinetochilum margaritaceum (Ehrenberg, 1831)	E, V	+	+	+
Codonella cratera (Leidy, 1877)	P	+	−	−
Coleps hirtus (Müller, 1786)	B	+	+	+
Coleps nolandi Kahl, 1930	B	+	+	+
Coleps spetai Foissner, 1984	P	+	+	+
Colpidium colpoda (Losana, 1829)	B	+	−	−
Colpoda aspera Kahl, 1931	E, V	+	−	−
Colpoda cucullus (Müller, 1773)	E, B	+	−	−
Colpoda henneguyi Fabre-Domergue, 1889	E, B	+	−	−
Colpoda inflata (Stokes, 1884)	E, B	+	−	−
Colpoda steinii Maupas, 1883	E, V	+	−	−
Cothumia annulata Stokes, 1885	S	−	+	−
Cristigera minor Penard, 1922	V	−	+	+
Ctedoctema acanthocrypta Stokes, 1884	V	+	+	+
Cyclidium glaucoma Müller, 1773	E, V	+	+	+
Cyclidium heptatrichum Schewiakoff, 1893	V	+	+	+
Cyclidium versatile Penard, 1922	V	+	+	+
Cyrtohymena citrina (Berger & Foissner, 1987)	E, V	+	+	+
Cyrtohymena muscorum (Kahl, 1932)	E, V	+	−	−
Cyrtolophosis mucicola Stokes, 1885	E, V	+	−	+
Dexiostoma campyla (Stokes, 1886)	B	+	−	+
Dexiotricha tranquillus (Kahl, 1926)	B	+	+	+
Didinium nasutum (Müller, 1773)	B	+	+	−
Dileptus anguillula Kahl, 1931	E, B	+	+	+
Dileptus margaritifer (Ehrenberg, 1833)	B	−	+	+
Dileptus monilatus (Stokes, 1886)	B	+	+	+
Dileptus visscheri Dragesco, 1963	E, B	+	+	+
Dysteria scultellum Wilbert, 1971	V	+	−	+
Enchelydium piliforme (Kahl, 1930)	B	−	−	+
Enchelydium sp.	B	−	+	+
Enchelyodon farctus Claparede & Lachmann, 1859	B	+	−	+
Enchelyodon sp.	B	+	+	+
Enchelys gasterosteus Kahl, 1926	B	+	−	−
Epistylis balatonica Stiller, 1931	S	−	+	−
Epistylis entzii Stiller, 1935	S	+	−	−
Epistylis major Nenninger, 1948	S	−	+	−
Epistylis nympharum Engelmann, 1862	S	−	+	−
Epistylis sp.	S	+	−	+
Euplotes affinis (Dujardin, 1841)	V	+	+	+
Euplotes eurystomus Wrzesniowski, 1870	V	−	−	+
Euplotes moebiusi Kahl, 1932	V	+	+	+
Euplotes patella (Müller, 1773)	V	+	+	+
Frontonia acuminata (Ehrenberg, 1833)	B	+	−	+
Frontonia angusta Kahl, 1931	B	+	+	+
Furgasonia blochmanni (Fauré-Fremiet, 1967)	B	+	+	+
Furgasonia rubens (Perty, 1852)	B	−	−	+
Furgasonia trichocystis (Stokes, 1894)	B	+	−	−
Fuscheria lacustris Song & Wilbert, 1989	B	+	+	+
Fuscheria nodosa Foissner, 1983	B	−	−	+
Gerda sp.	S	−	−	+
Glaucoma scintillans Ehrenberg, 1830	B	+	+	+
Gonostomum affine (Stein, 1859)	E, V	+	−	−
Halteria grandinella (Müller, 1773)	E, P	+	−	−
Histiobalantium natans (Claparede & Lachmann, 1858)	B	−	+	+
Holosticha (bergeri?) Foissner, 1987	E, V	−	−	+
Holosticha monilata Kahl, 1928	E, V	+	+	+
Holosticha multistilata Kahl, 1928	E, V	+	+	+
Holosticha pullaster (Müller, 1773)	V	+	+	+
Homalogastra setosa Kahl, 1926	E, V	+	−	−
Homalozoon vermiculare (Stokes, 1887)	B	+	−	+
Kahlilembus fusiformis (Kahl, 1926)	E, V	−	+	+
Kreyella minuta Foissner, 1979	V	+	+	+
Lacrymaria filiformis Maskell, 1886	B	+	+	+
Lacrymaria olor (Müller, 1786)	B	+	+	+
Lacrymaria vaginifera Song & Wilbert, 1989	S	+	+	+
Lacrymaria sp. 1	B	+	+	+
Lacrymaria sp. 2	B	−	+	+
Lembadion lucens (Maskell, 1887)	B	+	+	+
Lembadion magnum (Stokes, 1887)	B	−	−	+
Lepidotrachelophyllum sp.	V	+	+	+
Leptopharynx costatus Mermod, 1914	E, V	+	−	+
Litonotus alpestris Foissner, 1978	V	+	+	+
Litonotus cygnus (Müller, 1773)	V	+	+	+
Litonotus fasciola (Müller, 1773)	V	+	+	+
Litonotus lamella (Müller, 1773)	V	+	+	+
Litonotus trichocystiferus Foissner, 1984	V	−	−	+
Litonotus varsaviensis Wrzesniowski, 1870	V	+	+	+
Loxodes striatus (Engelmann, 1862)	B	+	−	+
Loxophyllum helus (Stokes, 1884)	V	+	+	−
Loxophyllum meleagris (Müller, 1773)	V	+	+	+
Loxophyllum utricullariae (Penard, 1922)	V	+	+	+
Mesodinium acarus Stein, 1863	P	+	+	+
Metacineta mystacina (Ehrenberg, 1831)	S	+	+	+
Microthorax bidentatus Kahl, 1926	V	−	−	+
Microthorax tridentatus Penard, 1922	V	+	−	−
Microthorax sp.	V	−	+	−
Myriocaryon lieberkuehni (Bütschli, 1889)	B	−	+	+
Nassula citrea Kahl, 1931	B	−	−	+
Nassula picta Greeff, 1888	E, B	+	−	−
Obertrumia aurea (Ehrenberg, 1833)	B	+	−	−
Odontochlamys alpestris Foissner, 1981	E, V	+	+	+
Opercularia articulata Goldfuss, 1820	S	+	+	−
Opercularia sp.	S	+	−	−

(Table 1 continued)

Species	Group	direct	foam	litter
Ophryoglena sp.	B	–	+	+
Ovalorhabdos sapropelica FOISSNER, 1984	B	–	+	+
Oxytricha haematoplasma BLATTERER & FOISSNER, 1990	V	+	+	+
Oxytricha setigera STOKES, 1891	E, V	+	+	+
Papillorhabdos carchesii FOISSNER, 1984	V	–	–	+
Paracolpidium truncatum (STOKES, 1885)	B	+	–	+
Paraenchelys spiralis FOISSNER, 1983	B	+	–	–
Paraholosticha muscicola KAHL, 1932	E, V	+	–	–
Paramecium aurelia-Complex	B	+	+	+
Paramecium bursaria (EHRENBERG, 1831)	B	+	–	+
Paramecium caudatum EHRENBERG, 1833	B	–	–	+
Paramecium putrinum CLAPAREDE & LACHMANN, 1859	B	+	+	+
Paranophrys sp.	V	+	+	–
Paraurostyla weissei (STEIN, 1859)	V	+	+	+
Paruroleptus caudatus (STOKES, 1886)	V	+	+	+
Phialina vermicularis (MÜLLER, 1786)	B	+	–	–
Placus luciae (KAHL, 1926)	V	+	+	+
Placus cf. *salina*	V	+	+	+
Plagiocampa rouxi KAHL, 1926	E, B	+	+	+
Platyophrya macrostoma FOISSNER, 1980	E, V	+	–	+
Platyophrya vorax KAHL, 1926	E, V	+	–	–
Pleuronema coronatum KENT, 1881	V	+	+	+
Podophrya fixa (MÜLLER, 1786)	S	+	–	–
Prorodon ovum (EHRENBERG, 1831)	B	+	+	+
Prorodon teres EHRENBERG, 1833	B	+	–	–
Pseudochilodonopsis algivora (KAHL, 1931)	V	+	–	–
Pseudochilodonopsis caudata (PERTY, 1852)	V	+	–	–
Pseudochilodonopsis fluviatilis FOISSNER, 1988	V	+	+	+
Pseudochilodonopsis polyvacuolata FOISSNER & DIDIER, 1981	V	+	–	–
Pseudochilodonopsis similis SONG & WILBERT, 1989	V	+	+	+
Pseudochlamydonella rheophila BUITKAMP, SONG & WILBERT, 1989	V	+	–	–
Pseudomicrothorax agilis MERMOD, 1914	V	+	–	–
Pseudoplatyophrya nana FOISSNER, 1980	E, V	+	–	–
Pseudoprorodon sp.	B	+	–	–
Pseudovorticella chlamydophora (PENARD, 1922)	S	+	–	+
Pseudovorticella monilata (TATEM, 1870)	S	+	–	–
Pseudovorticella sphagni FOISSNER & SCHIFFMANN, 1974	E, S	+	–	–
Sathrophilus muscorum (KAHL, 1931)	E, V	+	–	–
Spathidium spathula (MÜLLER, 1773)	E, V	+	–	–
Spathidium sp.	V	+	+	+
Spirostomum minus (ROUX, 1901)	B	+	–	+
Spirozona caudata KAHL, 1926	B	–	+	–
Stammeridium kahli (WENZEL, 1953)	E, V	–	–	+
Stentor coeruleus (PALLAS, 1766)	S	+	–	+
Stentor igneus EHRENBERG, 1838	S	+	+	+
Stentor muelleri (BORY DE ST. VINCENT, 1825)	S	+	+	+
Stentor multiformis (MÜLLER, 1786)	S	+	–	+
Stentor polymorphus (MÜLLER, 1773)	S	+	+	+
Stentor roeselii EHRENBERG, 1835	S	+	+	+
Sterkiella histriomuscorum (FOISSNER, BLATTERER, BERGER & KOHMANN, 1991)	E, V	+	–	–
Stichotricha aculeata WRZESNIOWSKI, 1866	E, S	–	+	+
Stichotricha secunda PERTY, 1849	S	+	–	–
Strobilidium caudatum (FROMENTEL, 1876)	S	+	+	+
Strobilidium humile PENARD, 1922	P	+	+	+
Strombidium rehwaldi PETZ & FOISSNER, 1992	P	+	–	+
Strongylidium sp.	V	+	–	–
Stylonychia mytilus-Complex	E, V	+	+	+
Stylonychia pustulata (MÜLLER, 1786)	V	+	+	+
Tachysoma pellionellum (MÜLLER, 1773)	V	+	+	+
Tetrahymena (corlissi?) THOMPSON, 1955	B	+	+	+
Tetrahymena pyriformis-Complex	B	+	–	–
Tetrahymena setosa (SCHEWIAKOFF, 1893)	B	+	–	–
Thigmogaster oppositevacuolatus AUGUSTIN & FOISSNER, 1989	V	+	–	+
Thigmogaster potamophilus FOISSNER, 1988	V	+	–	–
Thuricola folliculata KENT, 1881	S	–	+	–
Tintinnidium semiciliatum (STERKI, 1879)	S	+	+	+
Tokophrya quadripartita (CLAPAREDE & LACHMANN, 1859)	S	+	–	–
Trachelius ovum (EHRENBERG, 1831)	B	+	+	+
Trachelophyllum sigmoides KAHL, 1926	V	+	–	+
Trichodina pediculus EHRENBERG, 1831	S	+	+	+
Trichototaxis trimarginata (JANKOWSKI, 1979)	V	+	+	+
Trithigmostoma cucullulus (MÜLLER, 1786)	V	+	+	+
Trithigmostoma srameki FOISSNER, 1988	V	+	+	+
Trithigmostoma steini (BLOCHMANN, 1895)	V	+	+	+
Trochilia minuta (ROUX, 1899)	V	+	+	+
Trochilioides fimbriatus FOISSNER, 1984	V	+	–	–
Uroleptus gallina (MÜLLER, 1786)	V	+	+	+
Uroleptus limnetis STOKES, 1885	V	–	+	+
Uroleptus piscis (MÜLLER, 1773)	V	–	–	+
Uronema parduczi FOISSNER, 1971	B	+	+	+
Urosomoida agiliformis FOISSNER, 1982	E, V	+	+	+
Urosomoida agilis (ENGELMANN, 1862)	E, V	–	+	+
Urostyla grandis EHRENBERG, 1830	V	+	+	+
Urotricha armata KAHL, 1927	B	+	+	+
Urotricha farcta CLAPAREDE & LACHMANN, 1859	B	+	+	–
Vorticella campanula EHRENBERG, 1831	S	+	+	+
Vorticella citrina MÜLLER, 1773	S	+	+	+
Vorticella convallaria (LINNAEUS, 1758)	S	+	+	+
Vorticella infusionum DUJARDIN, 1841	E, S	+	+	+
Vorticella octava STOKES, 1885	S	+	–	+
Vorticella picta (EHRENBERG, 1831)	S	–	–	+
Zosterodasys transversa (KAHL, 1928)	V	+	–	–
Total number of taxa		174	122	150
% terrestrial species		21.3	15.6	17.3
% bottom dwellers		28.2	27.0	31.3
% sessile Aufwuchs dwellers		17.8	18.9	16.0
% vagile Aufwuchs dwellers		50.6	51.6	50.0
% planktonic species		3.4	2.5	2.7

urethane foam substrates than from natural stream bed samples (Table 3). However, their sampling strategy was apparently biased: "Average species richness from artificial substrate collections was less variable based on estimates of species equilibrium values but generally fell within a similar range as *total* species numbers from natural substrates. The sum of species numbers over time was greater for artificial substrates, primarily because of the greater number of samples examined. A few artificial substrate samples (three or four replicates) can provide an equivalent estimate of species richness at a site as 10–12 samples from several natural substrata". These statements are

Table 2. Species numbers (SN), average individual numbers (IN; ranked individual abundances divided by number of species) and saprobity indices (SI) with direct, foam and litter bag sampling. Samples were lost on 02.07 by a flood and on 17.06 and 15.08 by vandalism. $\bar{x}$ = arithmetic mean, M = median.

Station	Date	Direct sampling			Foam sampling			Litter bag sampling		
		SN	IN	SI	SN	IN	SI	SN	IN	SI
1	18. 07. 91	48	1.17	2.7	25	1.44	2.4	53	1.45	2.5
1	11. 10. 91	75	1.55	2.5	40	1.23	2.4	47	1.13	2.3
2	02. 07. 91	45	1.29	2.7	–	–	–	–	–	–
2	27. 09. 91	67	1.69	2.6	38	1.40	2.3	53	1.59	2.4
3	02. 07. 91	62	1.53	2.8	39	1.23	2.7	66	1.42	2.7
3	27. 09. 91	46	2.04	2.9	32	1.47	2.8	37	1.76	2.7
4	17. 06. 91	47	1.28	2.7	29	1.07	2.4	41	1.15	2.7
4	15. 08. 91	49	1.10	2.7	28	1.61	2.4	44	1.34	2.5
4	30. 10. 91	38	1.47	2.5	44	1.27	2.6	63	1.48	2.4
5	17. 06. 91	56	1.21	2.9	–	–	–	50	1.56	2.6
5	15. 08. 91	42	1.12	2.6	–	–	–	–	–	–
5	30. 10. 91	56	1.41	2.6	51	1.31	2.6	42	1.52	2.6
6	18. 07. 91	52	1.19	2.7	44	1.59	2.5	59	1.31	2.5
6	11. 10. 91	77	1.48	2.6	44	1.30	2.4	45	1.40	2.3
Average number of species per sampling date	$\bar{x}$	54.3			37.6			47.2		
	M	50.5			39			47		
Total number of species found at all stations and dates			174			122			150	
Average of individual abundances	$\bar{x}$		1.40			1.36			1.39	
	M		1.35			1.31			1.42	
Average of saprobity indices	$\bar{x}$			2.7			2.5			2.6
	M			2.7			2.4			2.5

Table 3. Total number of protozoan taxa collected, Flint River-Lake Blackshear, 1983 (from PRATT et al. 1987).

	Spring	Summer	Fall
Natural substrates	245	280	269
Artificial substrates	316	433	385

clearly contradicted by our data (Tables 1, 2). Likewise, we cannot support BAMFORTH's (1982) observation that foam units damp the number of attached species, although suctorians were less frequent, because peritrichs were more common in the foam units than in the natural collections.

The saprobic indices calculated from the ciliate communities of the foam substrates were significantly lower (indicating better water quality) than those from natural collections, which contained more alpha- to polysaprobic mud-dwellers (Tables 1, 2, Figs. 2, 3). This is a significant and reasonable difference: a floating substrate cannot representatively collect the mud fauna mainly because it is better aerated. However, the assessment of the river quality must include the bottom community as comprehensively as possible since the stream bed is the "ecological fabric" where most of the self-purification takes place.

Further disadvantages of artificial substrate samplers noted during this study and by others (e.g., PITTWELL 1975; ROSENBERG & RESH 1982) were the loss of samplers by floods and vandalism (Table 2) and the financial burden due to the two visits required to obtain one sample: one to set the sampler and one to recover it. We thus do not recommend artificial samplers for routine investigations of ciliated protozoa.

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