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Structure and seasonal dynamics of the protozoan community (heterotrophic flagellates, ciliates, amoeboid protozoa) in the plankton of a large river (River Danube, Hungary)

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This paper is dedicated to the occasion of the 70th birthday of Dr. Magdolna Cs. Bereczky, researcher on ciliates in the Danube

Abstract

Seasonal dynamics of all major protozoan groups were investigated in the plankton of the River Danube, upstream of Budapest (Hungary), by bi-weekly sampling over a 1-year long period. Sixty-one heterotrophic flagellate, 14 naked amoeba, 50 testate amoeba, 4 heliozoan and 83 ciliate morphospecies were identified. The estimated abundance ranges of major groups throughout the year were as follows: heterotrophic flagellates, $0.27–7.8 \times 10^6$ ind. l^{-1}; naked amoebae, max. 3300 ind. l^{-1}; testaceans, max. 1600 ind. l^{-1}; heliozoans, max. 8500 ind. l^{-1}; ciliates, 132–34,000 ind. l^{-1}. In terms of biovolume, heterotrophic flagellates dominated throughout the year (max. 0.58 $mm^3 l^{-1}$), and ciliates only exceeded their biovolume in summer (max. 0.76 $mm^3 l^{-1}$). Naked amoeba and heliozoan biovolume was about one, and testacean biovolume 1–3, orders of magnitude lower than that of ciliates. In winter, flagellates, mainly chrysomonads, had the highest biomass, whilst ciliates were dominated by peritrichs. In 2005 from April to July a long spring/summer peak occurred for all protozoan groups. Beside chrysomonads typical flagellates were choanoflagellates, bicosoecids and abundant microflagellates (large chrysomonads and *Collodictyon*). Most abundant ciliates were oligotrichs, while *Phascolodon*, *Urotricha*, *Vorticella*, haptorids, Suctoria, *Climacostomum* and *Stokesia* also contributed significantly to biovolume during rapid succession processes. In October and November a second high protozoan peak occurred, with flagellate dominance, and slightly different taxonomic composition.

Keywords: Heterotrophic flagellates; Naked amoebae; Testate amoebae; Ciliates; Seasonal succession; River protozoa

Introduction

Heterotrophic protists (protozoa) play an important role in matter and energy flow in most aquatic ecosystems. Their potential function in classical herbivore food webs has been known for a long time, while understanding of their essential role in the microbial loop is more recent (Azam et al. 1983; Pomeroy 1974). Since the recognition of the microbial loop, system model investigations encouraged quantitative studies of microbial loop components, especially heterotrophic

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nanoflagellates (Berninger et al. 1991; Gasol and Vaque 1993) and ciliates (Beaver and Crisman 1989). However, most quantitative surveys only took these two protozoan groups into account (Sanders et al. 1989; Sommargua and Psenner 1995), while other groups were neglected. There have been relatively few investigations which provided quantitative data from every major protozoan group (Garstecki et al. 2000; Kopylov et al. 2002; Mathes and Arndt 1995), thereby allowing direct comparison of the potential role of different groups. Most of the quantitative data from the 1980s and early 1990s lack details of taxonomic composition, especially on heterotrophic flagellates. Since then it has become known that protozoan functional diversity, trophic relations and niches in aquatic habitats are related to different taxonomic levels: from higher taxonomic groups to morphospecies (Arndt et al. 2000), and in some cases to cryptic species (Scheckenbach et al. 2006) and ecotype (Weisse and Montagnes 1998) levels. Thus, a community ecology with a fine taxonomic resolution is sorely needed in protistan ecology to overcome problems that are untreatable by using big black boxes, such as 'bacteria', 'flagellates' and 'ciliates' in ecosystem models. On the other hand, every quantitative study has to make compromises in taxonomic resolution, since it is not practicable to identify as many species as a taxonomic/faunistic survey using enrichment cultures. There are some methodological problems too: fixed-sample direct counting, live counting and MPN-based techniques have different efficiencies in quantitativity and identification possibilities for different protozoan groups (Arndt et al. 2000; Smirnov and Brown 2004).

Planktonic protozoan communities in rivers have received less study than those in lakes and oceans, and there is little information on community structure and the relative quantitative importance of different protozoan groups. It is also difficult to decide what components of the protistan assemblage that can be captured by sampling the water column are euplanktonic, since, at least in smaller rivers, a majority of the protists carried in the water flow have benthic origins. Heterotrophic flagellates (HF) may reach a high abundance in rivers (Basu and Pick 1997; Carlough and Meyer 1989; Jochem 2003; Lair et al. 1999; Sorokin 1990), and a few investigators have given both quantitative data and species composition (Kopylov et al. 2006; Kosolapova 2007). A modern conceptual work revealed the annual quantitative changes of higher taxa in the River Rhine (Weitere and Arndt 2003). Occurrence data on many species are available for the River Volga (Zhukov et al. 1998) and the River Tisza (Danube tributary, e.g. Hamar 1979), but without any quantitative indications. Regarding ciliates, a considerable number of investigations have been performed (Carlough and Meyer 1989; Sorokin 1990), and in many instances community structure was also analysed (Lair et al. 1998; Madoni and Bassanini 1999; Mordukhai-Boltovskoi 1979; Primc-Habdija et al. 1996; Tirjakova 2003). Furthermore, Foissner et al. (1999) list many other papers on ciliates in riverine plankton, most of them containing faunistic and quantitative data. There are several reports about testate amoebae in riverine plankton, most of them containing quantitative data (Bini et al. 2003; Bonecker et al. 1996; Green 1963; Velho et al. 1999). Gál (1966) also provided some semiquantitative data on testate and naked amoebae in the plankton of the River Tisza. In many of the mentioned investigations on testate amoebae, samples were collected with large mesh size plankton nets (up to 70 μm), and the zooplankton community was monitored in parallel in the same samples, indicating a selection for larger testacean forms. Planktonic naked amoebae are still a very neglected protist group, although evidence is increasing about their potential role in planktonic habitats (Murzov and Caron 1996; Rogerson and Gwaltney 2000; Rogerson et al. 2003). There are detailed data on abundance and dynamics of amoebae in estuarine waters (Anderson 2007; Rogerson and Laybourn-Parry 1992; Zimmermann-Timm et al. 1998), while in rivers, data are scarce (plankton and benthos: Ettinger et al. 2003; only benthos: Mrva 2003; periphyton: Baldock et al. 1983). Similarly, there is very little quantitative information on the role of heliozoa: most investigations focus on lakes (Bell and Weithoff 2003; Bell et al. 2006; Biyu 2000; Packroff 2000; Zimmermann et al. 1996), but a few indications on river benthos are in Aguilera et al. (2007).

Protozoological investigations in the River Danube have been made by a number of authors, although there is no detailed comprehensive picture on all constituent groups. Heterotrophic flagellate data comprise nanoflagellate counts (Hoch et al. 1995; Kasimir 1992; Vörös et al. 2000). In contrast, ciliates have been well investigated. In addition to the data on the Slovakian (Matis and Tirjaková 1995), Yugoslavian (Pujin 1994) and Bulgarian (Naidenow 1962) sections, Bereczky has contributed altogether 28 publications on planktonic ciliates in the Hungarian section of the River Danube. Few investigations have been made on testate amoebae in the Danube plankton (Slovakia: Ertl 1954; Hungary: Bereczky 1978, 1979). Sporadic species records without quantitative data are available on naked amoebae and heliozoa, except for the limited abundance data on naked amoebae by Bereczky (1978).

Since quantitative data for different protozoan groups in large rivers are either lacking or very limited, there is now an urgent need for investigations with high taxonomic resolution in protozoan ecology. This work is aimed to obtain a comprehensive overview of the protozoan community in the plankton of the River Danube during a 1-year long period. Major aims