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Note

Grazing on Bacteria and Algae by Metazoans in the Lake-river Ecosystem (River Spree, Germany)

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Direct effects of zooplankton grazing activities on the natural assemblage of bacterioplankton and algae were evaluated at monthly intervals, from June to October of 2000, in the middle part of the River Spree, Germany. We quantified bacterioplankton, algae, zooplankton abundance and measured carbon ingestion rates (CIRs) by zooplankton according to two zooplankton size classes: (i) microzooplankton (MICZ), ranging in size from 30 to 150 μm and including rotifers and nauplii, excluding protozoans and (ii) macrozooplankton (MACZ), larger than 150 μm and including cladocerans and copepods. CIRs were measured using natural bacterial and algae communities in the zooplankton density manipulation experiments. Algae biomass (average± SD: 377±306 μgC L^{-1}, n=5) was always higher than bacterial biomass (36.7±9.9 μgC L^{-1}, n=5). Total zooplankton biomass varied from 19.8 to 137 μgC L^{-1}. Total mean biomass of zooplankton was 59.9±52.5 μgC L^{-1} (average±SD, n=5). Average MICZ biomass (40.2±47.6 μgC L^{-1}, n=5) was nearly twofold higher than MACZ biomass (19.6± 20.6 μgC L^{-1}, n=5). Total zooplankton CIRs on algae (average±SD: 56.6±26.4 μgC L^{-1} day^{-1}) were ~fourfold higher than that on bacteria (12.7±6.0 μgC L^{-1} day^{-1}). MICZ CIRs on bacteria (7.0±2.8 μgC L^{-1} day^{-1}) and algae (28.6±20.6 μgC L^{-1} day^{-1}) were slightly higher than MACZ CIRs. On average, MICZ accounted for 55.6 and 50.5% of total zooplankton grazing on bacteria and algae, respectively. Considering the MICZ and MACZ CIRs, the relative role of transferring carbon to higher trophic levels were nearly similar between both communities in the lake-river ecosystem.

Key words : zooplankton, algae, bacteria, CIRs, grazing, River Spree

INTRODUCTION

Changes in the biomass of grazing communities can cause dramatic changes in grazing pressure in aquatic environment, but few studies document the ecosystem-level impacts of these changes. Food web interactions within rivers, lakes and oceans plankton assemblages have received abundant attention (Ducklow, 1991; Hwang and Heath, 1999; Weitere *et al.*, 2005). In rivers too, a well established planktonic community can be found among the bacteria, algae, protozoans, and zooplankton (Reynolds and Descy, 1996; Lair *et al.*, 1999; Kim *et al.*, 2000; Weitere and Arndt, 2002). Many studies on the various aspects of river zooplankton dynamics have been conducted (Lair, 2006).

The influence of river hydrological changes can be responsible for dramatic shifts in community structure and function of plankton (Kim *et al.*, 2002). Although there is limited data available,

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the importance of microzooplankton in grazing and plankton community structure shifts has been reported in some river ecosystems (Kobayashi *et al.*, 1996). Moreover, the relative importance of bacteria versus algae as a food resource for microzooplankton and macrozooplankton has rarely been assessed in lake-river ecosystem. In this study, we compared microzooplankton and macrozooplankton grazing on bacteria and algae in the lake-river ecosystem, in order to provide information regarding plankton carbon dynamics.

MATERIALS AND METHODS

1. Study site and sampling

We examined the effects of zooplankton grazing on natural bacteria and algae in a series of bottle experiments conducted on water collected from Alt-Schadow in the middle part of the River Spree (Fig. 1). The sampling site (ca. 100 m below the lake outflow) was selected below Neuendorfer Lake. The width of the lower Spree at normal discharge varies between 25 and 40 m with a mean depth of between 1.5~2.5 m (Köhler, 1994). From June to October 2000, samples were collected monthly. Water samples were collected at 0.5 m depth with a 3.4 liter Rutter Sampler (Limnos^{TM}), placed in 20 liter sterile polyethylene bottles, and kept in the shade at ambient temperature until returned to the laboratory within 3 hrs after sample collection.

2. Biological variables

For bacteria enumeration, water samples (2~10 mL) were fixed with glutaraldehyde and stained with DAPI (4'6-diamidinoa-2-phenylindole; 0.001% final concentration). Concentration was by gentle vacuum filtration onto black, 0.2-μm Nucleopore polycarbonate membranes (Porter and Feig, 1980). Cell lengths and width (μm) were measured using micrometers. Bacteria carbon biomass was estimated using a conversion factor of 0.106 pgC μm^{-3} (Nagata, 1986). Algal samples were immediately preserved with Lugol's solution. Utermöhl's sedimentation method was used to identify and enumerate algae taxa present in the samples (Utermöhl, 1958). Cells were enumerated using a Zeiss IM inverted microscope at ×400 magnification. Algae carbon was calculated from measured biovolumes using cellular carbon contents. Cellular carbon content (μgC $cell^{-1}$) was estimated with a

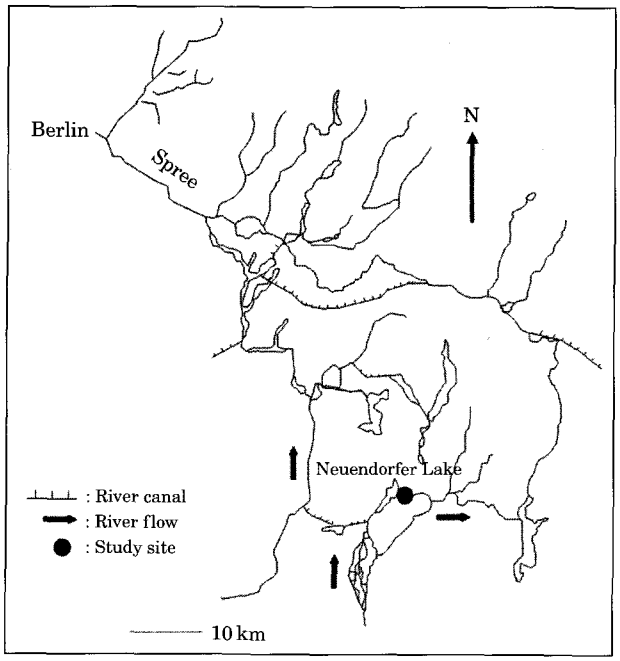

Fig. 1. Map showing the middle River Spree and study site (●: Study site was ca. 100 m after the outflow of the lake).

conversion factor of 0.11 pgC μm^{-3} (Rocha and Duncan, 1985). Zooplankton samples were taken with 3.4 l Rutter sampler from 0.5-m depth screened by a net of 30 μm and fixed in 4% (final concentration) formalin. Macrozooplankton biomass (μg dry weight L^{-1}) was estimated using length-weight regressions reported by Balushkina and Winberg (1979), Bottrell *et al.* (1976), and McCauley (in Downing and Rigler, 1984). Formulas of Ruttner-Kolisko (1977) were modified according to actual length relationships of rotifers in River Spree to determine rotifer biomass (μg dry weight L^{-1}). Zooplankton carbon contents were calculated using a conversion factor of 0.48 μgC per μg dry weight (Anderson and Hessen, 1991).

3. Quantification of carbon ingestion rates (CIRs)

Carbon ingestion rates (CIRs: μgC L^{-1} day^{-1}) of bacteria and algae were quantified experimentally by manipulating zooplankton grazer densities (1×, 4×, 8×, and 16× ambient levels). In each case, there were also controls with no zooplankton added. All carboys were incubated for 24 or 48 h under dark and 20°C conditions. Initial and final triplicate subsamples (25 mL) of bacteria

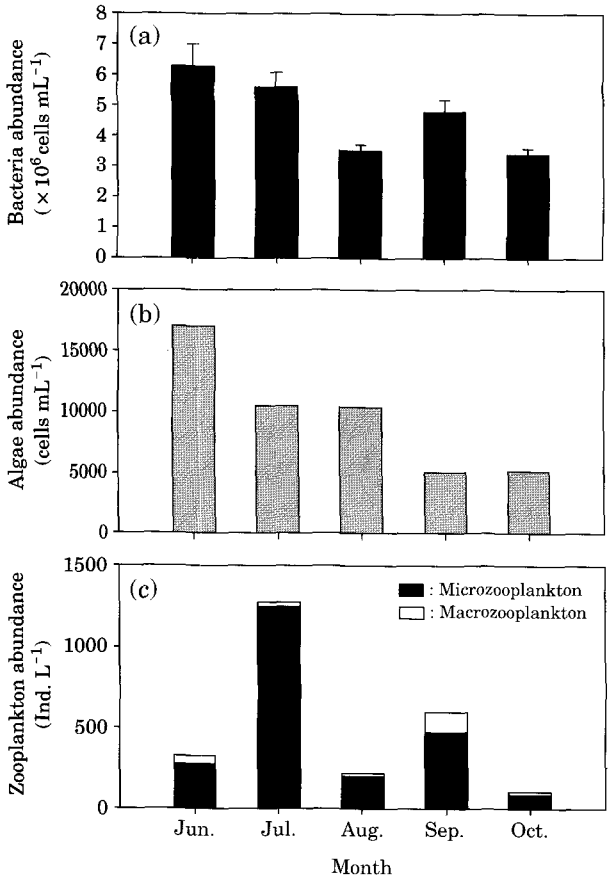

Fig. 2. Monthly variations in total bacteria (average ± SD, n=3), algae and metazoans abundances at the study site.

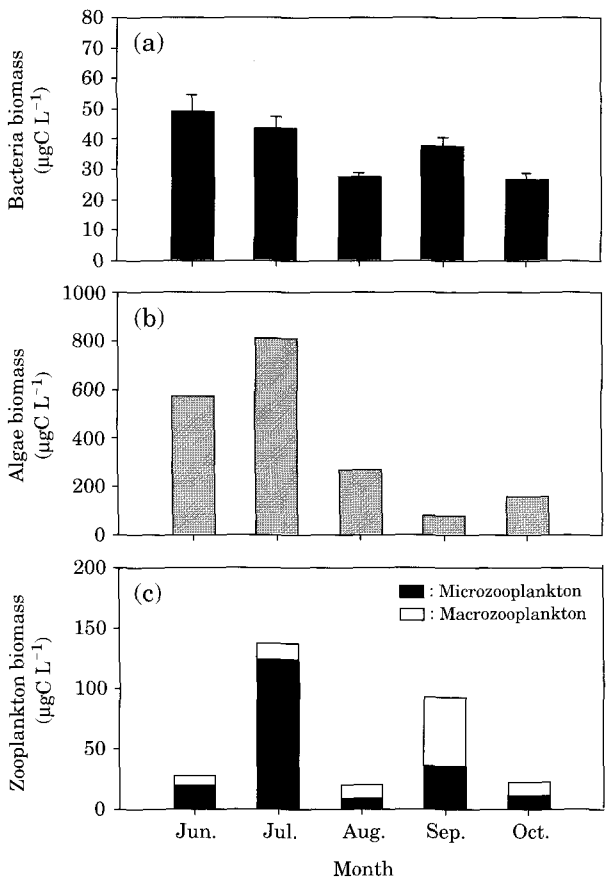

Fig. 3. Monthly variations in total bacteria (average ± SD, n=3), algae and metazoans carbon biomass (μgC L^{-1}) at the study site.

and algae were removed from the carboys, preserved, and enumerated as described above. The relationship between algal and bacterial growth rate and zooplankton biomass was assessed by least squares linear regression. The slope of this relationship provides an estimate of the biomass-specific clearance rate (CRs: mL μg dw^{-1} day^{-1}) of zooplankton on bacteria and algae (Lehman and Sandgren, 1985; Kim *et al.*, 2000).

RESULTS

1. Abundance and biomass

Bacterial abundance varied from 3.4 to 6.30 × 10^6 cells mL^{-1} (Fig. 2a). Mean abundance values were 4.72 ± 1.27 × 10^6 cells mL^{-1} (average ± SD, n=5). Maximal values of bacterial abundance coincided with maximal values of algae abundance during the study (Fig. 2b). Over the three months (June ~ August) of 2000, high algae abundance (> 1.0 × 10^4 cells mL^{-1}) was consistently present, while lower abundance with small changes occurred from September to October (< 0.5 × 10^4 cells mL^{-1}). Algal abundance peaks were observed in June 2000. At those times, the dominant algae taxa were diatoms. The monthly changes in microzooplankton (MICZ) abundance (e.g., *Keratella, Synchaeta,* and *Polyarthra* spp.) were nearly identical to that of total zooplankton as MICZ dominated the numbers, with the exception of September (Fig. 2c). In September, macrozooplankton (MACZ) abundance increased sharply (Fig. 2c). Average MACZ abundance (average ± SD: 43 ± 44 ind. L^{-1}, n=5) was lower than MICZ abundance (average ± SD: 463 ± 462 ind. L^{-1}, n=5). Among the MACZ, cladoceran abundance (e.g., *Daphnia cucullata* and *Diaphanosoma brachyurum*) was twofold higher than copepod abundance.

Bacterial biomass varied from 26.4 to 46.0 μgC

L^{-1} (Fig. 3a). Mean biomass values were 36.7±9.9 μgC L^{-1} (average±SD, n=5). Algae biomass (average±SD: 377±306 μgC L^{-1}, n=5) was always higher than bacterial biomass. Over the three months (June~August) of 2000, high algae biomass (>200 μgC L^{-1}) was consistently present, while lower biomass was observed in September (<80 μgC L^{-1}). The highest algae biomass occurred in July (811 μgC L^{-1}) (Fig. 3b). Total zooplankton biomass varied from 19.8 to 137 μgC L^{-1} (Fig. 3c). Total mean biomass of zooplankton was 59.9 ±52.5 μgC L^{-1} (average±SD, n=5). In September, macrozooplankton (MACZ) biomass increased sharply (Fig. 3c). Average MICZ biomass (average±SD: 40.2±47.6 μgC L^{-1}, n=5) was nearly twofold higher than MACZ biomass (average± SD: 19.6±20.6 μgC L^{-1}, n=5).

2. Biomass-specific clearance and carbon ingestion rates

The range of biomass-specific clearance rates (CRs: mL μg dw^{-1} day^{-1}) for metazoans on bacteria and algae varied from 0.13 to 3.4 and 0.19 to 4.05, respectively. The average CR of MICZ on bacteria (1.64±1.28 mL μg dw^{-1} day^{-1}) was nearly twofold higher than the average CR of MACZ (0.87±0.60 mL μg dw^{-1} day^{-1}), while the CRs of MICZ and MACZ on algae were approximately similar (MICZ: 1.88±1.35 mL μg dw^{-1} day^{-1}; MACZ: 2.18±1.09 mL μg dw^{-1} day^{-1}). Average algal carbon ingestion rates (56.6±26.4 μgC L^{-1} day^{-1}) to total metazoans were higher than average bacteria carbon ingestion rates (12.7±6.0 μgC L^{-1} day^{-1}) to total metazoans (Fig. 4). Average bacteria carbon ingestion rates to MICZ were slightly higher than those for MACZ (MICZ: 7.0± 2.8 μgC L^{-1} day^{-1}; MACZ: 5.6±3.5 μgC L^{-1} day^{-1}). Average algal carbon ingestion rates to MICZ were almost similar for MACZ (MICZ: 28.6±20.6 μgC L^{-1} day^{-1}; MACZ: 28.0±16.8 μgC L^{-1} day^{-1}).

DISCUSSION

The objective of this study was to examine the importance of metazoan groups (e.g., rotifers and crustaceans) in the carbon transfer from bacteria and algae to grazers in the plankton of a temperate lake-river system. In the middle reach of the River Spree, the relative role of transferring carbon to higher trophic levels of both communities

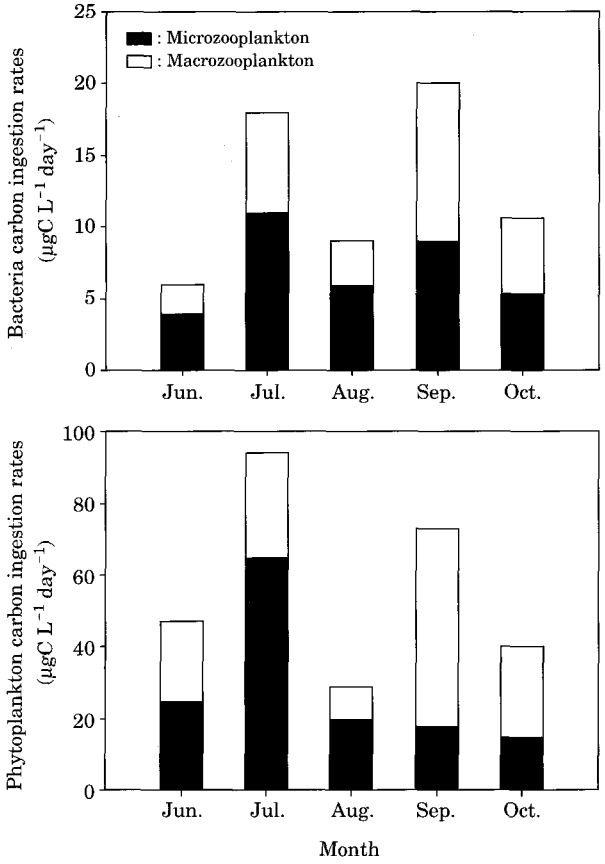

Fig. 4. Bacteria and phytoplankton carbon ingestion rates by microzooplankton and macrozooplankton.

(MICZ and MACZ) was almost similar. All together the carbon flux indicated a minor role of the planktonic metazoans in controlling the bacteria and algae in river ecosystems. This outcome is in contrast to the major role of these groups in controlling the planktonic food webs in lakes (Gaedke *et al.*, 2002). However, larger impacts of small metazoans on the bacteria and algae were found in other rivers (Servais *et al.*, 2000). Different results were observed the Nakdong, in a regulated river in South Korea, where the most important MICZ grazers, on both bacteria and algae, are rotifers (Kim *et al.*, 2000). MICZ community grazing appears to constitute an important process in altering the algal community structure in the river-reservoir hybrid type (Kim *et al.*, 2002).

An interesting result of the present study was the relatively high contribution of the MACZ (e.g., *Daphnia*) in the transfer of matter in the planktonic food web. With respect to hydraulic and geomorphologic features, habitat diversity

and the ability of individuals to avoid washout was examined, including the decrease in flow creating standing zones favourable to zooplankton development (Lair, 2006). As is true of most large and regulated rivers, the River Spree has experienced both cultural eutrophication and alterations to its natural hydrology. The zooplankton in rivers remains primarily governed by unpredictable physical processes and depends on the age of the water and the availability of habitats (Lair, 2006). In this ways, the eco-hydrology of river habitats need to be studied more with regard to their key role in the planktonic life and functions.

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