

The Importance of Pelagic and Benthic Microfauna in a Shallow-Water Community of the Darss-Zingst Estuary, Southern Baltic, During Mesocosm Experiments

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With 4 Figures

Abstract

During enclosure experiments (3.1 m²) in the shallow coastal waters south of the Darss-Zingst in June/July 1985 and 1986, respectively, the impact of nutrient loading (P, N) on ecosystem structure and functioning was studied. As a part of these studies the relative importance of protozoans (esp. ciliates) and micrometazoans (esp. small rotifers) in the pelagic as well as in the benthic habitat was investigated by estimation of their biomass and calculation of their activity using specific metabolic rates from literature. The results showed that zooplankton which passes common used plankton nets (56 µm mesh size) was the most active part of the whole animal community during the investigation period. In benthic habitat (muddy sand) microzoans were of minor importance compared to meiozoobenthos. Although the investigation site was very shallow (0.5–0.7 m depth) there was a clear difference in species composition of pelagic and benthic fauna. Apart from the dominance of different species in different enclosures nutrient loading had no considerable influence on total animal biomass. This points to the stability of the ecosystem. Pelagic ciliates were the metabolic most active faunal component of the investigated eutrophic waters. Their dynamics were characterized by short-term succession of species (in a few days) and by the cooccurrence of different functional groups like algivores, bacterivores, and omnivorous predators. Our results underline the demand for more protozoological studies to explain ecosystem functioning in estuaries.

Introduction

Though the knowledge on microfauna in pelagic and benthic estuarine habitats has increased much during the last decades, there are only a very few studies, where dynamics of micro-, meso-, and macrofauna have been registered simultaneously in the plankton and the benthos community as well. Results of studies dealing with benthic habitats have shown that biomass of microfauna is mostly of minor importance compared to meio- and macrofauna, but that microfauna production is often in the same range of that of meio- and macrofauna depending on the quality of substrate (e.g. FENCHEL 1967; JANSSON et al. 1984; SCHARF & SCHNESE 1984). Data on pelagic estuarine microfauna are rather rare. The microfaunal component is mostly characterized by strong seasonal and short term changes ranging from overall importance to negligible importance in relation to total zooplankton biomass (e.g. BURKILL 1982; HAGSTRÖM & LARSSON 1985; ARNDT 1986).

In the shallow coastal waters south of the Darss-Zingst peninsula (southern Baltic) we carried out a series of mesocosm experiments in order to determine the influence of additional nutrient loading on functioning and stability of eutrophic estuarine ecosystems. Results regarding dynamics of nutrients, phytoplankton, zooplankton, and zoobenthos, respectively, have al-

ready been published (e.g. SCHIEWER & BAADER 1982; SCHIEWER et al. 1986; SCHLUNGBAUM et al. 1983; BÖRNER & KELL 1982; WASMUND 1988; SCHARF et al. 1984; SCHIEWER et al. 1989). In this paper we present results on the relative importance of microfauna within the pelagic and benthic animal community.

Material and Methods

From the beginning of June till the end of July in both years, 1985 and 1986, respectively, three enclosures were exposed in the shallow waters of the Kirr-Bight (Darss-Zingst estuary, 3–7‰ S; a description of the aquatorium is given by SCHIEWER et al. 1985). Enclosures consisted of polyethylene foile with a polyester filled ring at the upper part (cf. Fig. 1). The lower part is deepened into the sediment (muddy sand: medium corn size 0.2–0.5 mm; organic content of dry matter 1–2%; NAUSCH unpubl.). Each enclosure covers an area of about 3.1 m² with a mean water level of 0.55 m in 1985 and 0.72 m in 1986, respectively. In the course of the 8-week experimental period following nutrient supplies were given: 1985: enclosure A 10.6 gN · m⁻³, B no additions, C 12.6 gN · m⁻³ and 1.7 gP · m⁻³; 1986: enclosure A no additions, B 5.5 gN · m⁻³ & 2.6 gP · m⁻³, C 23.0 gN · m⁻³ & 2.9 gP · m⁻³. Dynamics of abiotic and biotic parameters were measured during the whole investigation period in all three enclosures and the surrounding water (Kirr). Most abiotic parameters were investigated nearly every day (e.g. temperature, turbidity, pH, dissolved nutrients), whereas biotic parameters were collected one time but mostly two times per week (e.g. chlorophyll content, biomass and production of phytoplankton, bacteria, protozoans, mesozooplankton, and meiofauna, respectively). In Fig. 2 and Fig. 3 only weekly mean values are shown. Some parameters were measured only occasionally like biomass and activity of microphytobenthos, macrophytes, and macrofauna, respectively. For other details of experiments see SCHIEWER et al. (1988, 1989).

Following methods were applied for the analysis of the shallow-water fauna:

- 1) Benthic macrofauna was sampled by means of an EKMAN-grab (0.025 m²). Five parallel samples were taken from all compartments at the beginning and at the end of experiments. All animals which were retained on a 0.5 mm sieve were counted after formalin fixation (4%) under a stereomicroscope. For each sample animal wet weights, dry weights (after 24 h at 60 °C), and ashfree dry weights (24 h at 500 °C) were determined.
- 2) Benthic meiofauna was sampled by means of a core sampler according to ARLT (1984) (core area 3 cm³). The upper two centimeters were taken from three parallel samples and pooled together. 1985 formalin fixed samples (4%) were analyzed in a BOGOROV-chamber under a stereomicroscope. 1986 subsamples were investigated by means of the living droplet method. Generally at least 20 length measurements were carried out for each species and bio-volumes were estimated by approximations of body shapes to simple geometrical forms.
- 3) Mesozooplankton was collected by sieving 5 one-litre samples per enclosure through a plankton net (56 µm mesh size). Zooplankters were fixed with formalin (4%) and subsamples were analyzed in a

microscopic chamber (ARNDT 1985). Biovolumes were estimated as was done with meiofauna.

4) Microfauna (ciliates, rhizopods, small rotifers) was investigated by analysis of living samples. Benthic samples were taken like those for meiofauna analysis. A volume of 182 ml filtered biotope water was immediately added to three core samples ($3 \times 3 \text{ cm}^2$; 18 cm^3). Subsampling was carried out by means of an automatic calibrated pipette during stirring of the sample. Plankton mixed samples consisting of 5 single samples were subsampled in the same way without dilutions. Abundant species were counted in a 0.35 ml microscopic chamber; scarcer species were counted by the living droplet method (cf. DALE & BURKILL 1982). Care was taken during manipulation of samples to reduce the time for stirring and counting of samples. Biovolumes were estimated like those for meiofauna. Length measurements were done to the nearest $5 \mu\text{m}$ interval.

5) Flagellates were analyzed only semiquantitatively by counting subsamples from benthic and pelagic microfauna in blood cell chambers without concentrations. Individuals were differentiated for pigmented and nonpigmented forms under a light microscope. Individuals were counted for size classes. By this procedure the amount of flagellates is probably underestimated.

Results and Discussion

1. Ecosystem structure

A view on the biotic structure within the enclosures is shown for the situation during the fourth week of July 1986 in the untreated control A for an example (Fig. 1). Since there are only a very few data for a nearly complete analysis of ecosystem structure (including microfauna) in literature we present estimations of all ecosystem components though our estimates are sometimes very rough and are typical only for the actual situation. As clearly to be seen phytoplankton and phytobenthos reach nearly the same production and even under the high turbidity (0.4 m Secchi depth) the microphytobenthos

contributes significantly to total primary production. In June in both years phytoplankton consisted mainly of chlorophyceans and blue-greens. In the first phase chlorophyceans like *Scenedesmus* and *Crucigenia* and later coccal blue-greens like *Gomphosphaeria* and *Microcystis* and the filamentous *Lyngbya contorta* dominated phytoplankton biomass. High nutrient loading leads sometimes to specific blooms (cf. WASMUND 1989). Growth of macrophytes was of no importance in 1985, but was of high importance in 1986 when community was dominated by *Potamogeton pectinatus* and *Chara* spp. Microphytobenthos consisted mostly of sedimented but still active phytoplankters.

Regarding their metabolic activity bacteria were the most important heterotrophic component within the pelagic as well as within the benthic community. This points to the high level of eutrophication in Kirr-Bight. Total bacteria population could reach turnover times up to 4 d^{-1} .

Meiofauna was the most important animal component regarding its biomass but production compared to zooplankton was low. Meiofauna was dominated in both years by ostracods (mainly *Cyprideis litoralis*), oligochaetes, nematodes and harpacticoid copepods (mainly *Microarthridion littorale* and *Halectinosoma curticorne*). In addition turbellarians, hydrozoans (*Protohydra* sp.), cladocerans (mainly *Chydorus sphaericus* and *Alona rectangularis*), bdelloids, and monogonont rotifers (mainly *Euchlanis*, *Colurella*, and *Lecane*).

Macrofauna was dominated by chironomid larvae. Of reduced importance were large oligochaetes, nemertines (*Prostoma obscura*), polychaetes (mainly *Hediste diversicolor* and *Spio* sp.), and crustaceans (mainly Gammaridae and *Sphaeroma*).

Though of minor importance regarding its biomass microfauna contributes to a significant part to benthic

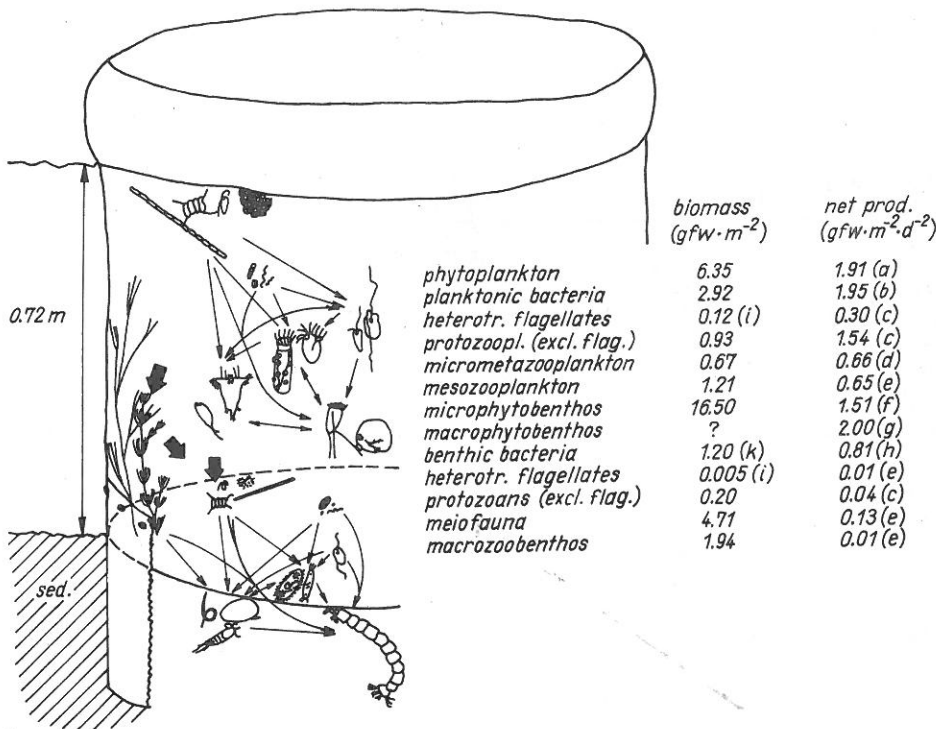


Fig. 1. Structure, biomass, and estimated production in the pelagic and benthic zone of brackish shallow-water enclosure A (without nutrient additions, fourth week of July 1986; small arrows stand for trophic interactions, large arrows point to the importance of sedimentation; a: ¹⁴C-method; b: ³H-thymidine incorporation method; c: assumed P/B-value from literature; d: egg-ratio method; e: assumed P/B-value derived from in situ growth rates; f and g: O₂-method, in situ incubation; h: specific production assumed to be the same as for planktonic bacteria; i: life counting in blood cell chamber; k: assumed specific biovolume)

animal production. Heterotrophic flagellates were very abundant but have only low biomasses. There were strong short term changes in abundances of flagellates. Ciliates were the most important component of microfauna, dominated by amphileptids, hymenostomes, and oxytrichids. Testaceans were generally of minor importance, but naked amoebae could reach very high abundances for short periods corresponding to high sedimentation rates from plankton.

Within the plankton community mesozooplankton dominated animal biomass. Rotifers were the most important group (mainly *Filinia longiseta*, *Keratella cochlearis*, *Brachionus quadridentatus*, *B. angularis*, *B. plicatilis*). Sometimes cladocerans (mainly *Chydorus sphaericus* and *Alona rectangula*) and copepods (*Eurytemora affinis* and *Acartia tonsa*) could significantly contribute to zooplankton biomass. Pelagic macrofauna (mysids, fishes) were excluded during experiments. Their metabolic activity would have been low relative to the other components, but their contribution to ecosystem functioning could have been of importance (cf. ARNDT et al. 1984; ARNDT 1986, in press).

We use the term micrometazooplankton for metazoans which pass common used zooplankton nets (e.g. 56 μm mesh size). These are generally very delicate rotifers (during experiments e.g. *Synchaeta kitina*, *S. cecilia*, *Trichocerca* cf. *dixon-nutalli*) difficult to register and determine in fixed samples. We investigated the delicate forms in living samples (droplet method). These small rotifers can be very productive (abundances $> 10,000 \text{ ind.} \cdot \text{l}^{-1}$) for short periods during summer in rivers, lakes, and estuaries (ARNDT, unpubl.). According to our opinion these delicate forms have been overlooked in many recent studies. Possible reasons are their small size, their delicate bodies, their generally short term occurrence in plankton,

and their difficult taxonomy, respectively. During early summer these microzooplankters can compose the major part of zooplankton biomass in Kirr-Bight.

Protozooplankton often excluded from traditional plankton studies up to now was the most important component of the whole animal community regarding its metabolic activity during the investigation period. Numbers of heterotrophic flagellates like those of benthic flagellates showed strong short term changes in abundances. A more detailed analysis is necessary to have a realistic view on their importance in the shallow coastal waters south of the Darss-Zingst estuary. There are only a few reports in literature regarding the importance of heterotrophic flagellates in estuarine waters, but those which are available point to their high significance for ecosystem functioning (e.g. ANDERSON & FENCHEL 1985). The biomass of planktonic ciliates was dominated by gymnostomes (e.g. *Mesodinium*, *Monodinium*) and oligotrichs (e.g. *Strombidium*, *Strobilidium*, *Halteria*, *Tintinnidium*) (see Fig. 4).

Besides the pelagic and benthic habitat sometimes microflora and microfauna on macrophytes was an additional important compartment for ecosystem functioning. When sedimentation rates were high leaves of macrophytes were covered with a thin layer of sedimented planktonic algae. Within one day this layer could be very densely populated by naked amoebae and soon after it benthic ciliates and rotifers show high abundances (ARNDT, unpubl.). This epiphytic community has only a short life span till the next wind induced turbulence but can contribute to a fast degradation of sedimented phytoplankton especially due to the activity of naked amoebae. When sedimentation rates were high there was also found an enormous increase of naked amoebae populations (but other species than on macrophyte

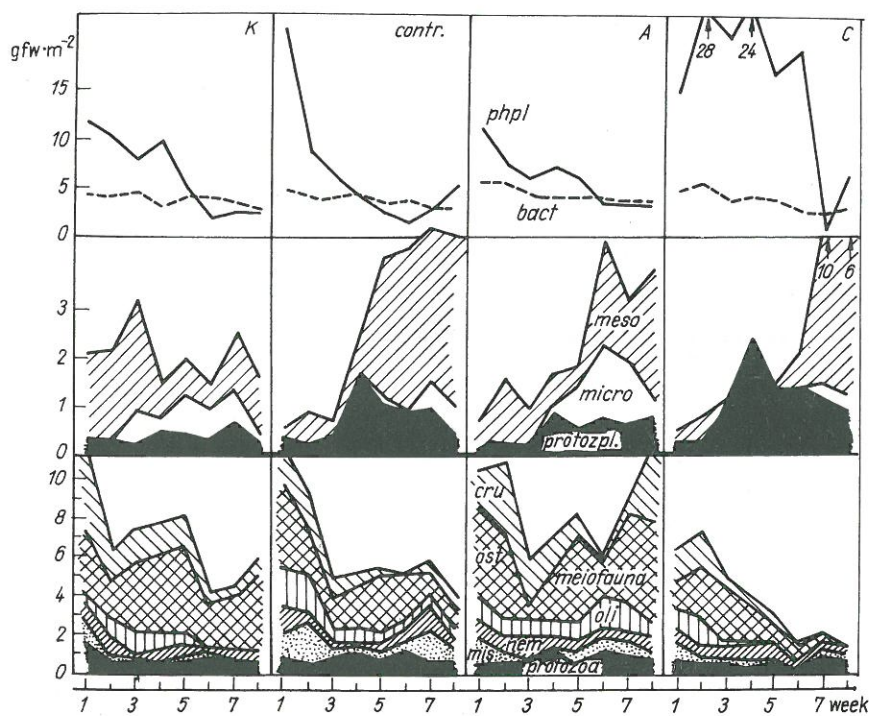


Fig. 2. Weekly fluctuations of animal biomass in the pelagic and benthic zone of four compartments in Kirr-Bight, Darss-Zingst estuary, in June/July 1985 (K: surrounding water; contr.: untreated control; A: stepwise addition of $10.6 \text{ gN} \cdot \text{m}^{-3}$; C: stepwise addition of $12.3 \text{ gN} \cdot \text{m}^{-3}$ and $1.7 \text{ gP} \cdot \text{m}^{-3}$; upper panel: biomass of phyto- and bacterioplankton; middle panel: biomass of zooplankton incl. protozoopl., microzoopl. and mesozoopl.; lower panel: biomass of protozoans and microfauna incl. cru — crustaceans, ost — ostracodes, oli — oligochaetes, nem — nematodes, and mis — miscellaneous)

leaves) in the upper thin layer of sediment (esp. 8th week in 1986, about 2,080 naked amoebae per cm^2). Of course, there was also sessile fauna (e.g. peritrichs, hydrozoans) and flora (esp. pennate diatoms) but their contribution to ecosystem functioning during the investigation period seemed not to be of importance.

2. Influence of nutrient loading

As indicated in Fig. 2 and Fig. 3 dynamics of ecosystem components behave similarly in Kirr-Bight, control enclosure, and the enclosure with lower nutrient supply, respectively. The development of some special species in distinct enclosures (cf. WASMUND 1988) indicates that this similarity was not the result of exchange processes. Most similarities were found between surrounding water and the enclosure with low nutrient additions (enclosure A in 1985, B in 1986). This may be due to the continuous nutrient supply of the surrounding water by horizontal water exchange with Zingster Strom.

The general decline of phytoplankton biomass after the second and third week was most probably the combined effect of abiotic factors (e.g. nutrient depletion, irradiance, sedimentation, temperature). This decline was followed by increasing bacterial production (^3H -thymidine incorporation method, JOST unpubl.) which was nearly fully consumed by bacterivorous microzooplankton (see next chapter). From then microzooplankton was the metabolic most active component. In the last weeks in 1985 rotifers reached especially high abundances and were able to control phytoplankton production which had been already reduced by sedimentation processes.

The high degradation rates within the plankton com-

munity explains the reduced effect of phytoplankton production on benthic fauna. Exceptions were the short term pulses of naked amoebae and heterotrophic flagellates (see above) as well as the increase in epibenthic cladocerans in enclosures C. The decreasing number of meiofauna and ciliates from late spring to summer is a typical phenomenon of the brackish waters south of Darss-Zingst (cf. ARLT 1984; SCHARF & SCHNESE 1984).

Only very high nutrient additions in enclosure C led to exceptionally high rates of primary production especially in 1985 where irradiance was higher than in 1986. In the first weeks in 1985 a dense bloom of *Scenedesmus* was established which collapsed in the sixth and seventh week by a sudden increase in temperature (cf. SCHIEWER et al. 1988). Thereafter high grazing pressure by rotifers prevented intensive phytoplankton growth. In 1986 a bloom of *Synedra* sp. was built up during the last weeks after a change in the relation of added nutrients (cf. WASMUND 1988). This very uncommon *Synedra* peak seems not to be a suitable food source for zooplankton. Detritus consuming cladocerans (*Chydorus*, *Alona*) made probably use of the sedimented algae.

In all enclosures the increase in the amount of sedimented material was not as high as would be expected from primary production (SCHIEWER & WASMUND, unpubl.). This was most probably due to the high activity of bacteria and microfauna. The low rate of increase in sedimented material in the shallow inner coastal waters (SCHLUNGBAUM & ARLT, pers comm.) was formerly mostly explained by the transport of sedimented material via water currents to the outer part of the estuary. In this respect our results underline the importance of fast degradation in the area itself supported by oxygenation and resuspension of presediment due to wind induced turbulences.

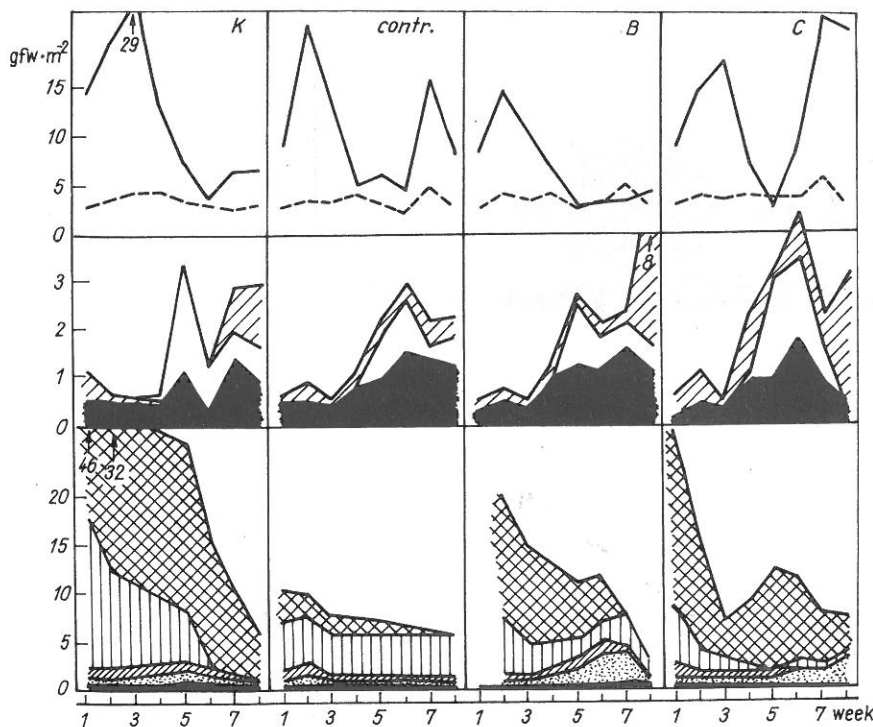


Fig. 3. Weekly fluctuations of animal biomass in the pelagic and benthic zone of four compartments in Kirr-Bight in June/July 1986 (K: surrounding water; contr.: untreated control; B: stepwise addition of $5.5 \text{ gN} \cdot \text{m}^{-3}$ and $2.6 \text{ gP} \cdot \text{m}^{-3}$; C: stepwise addition of $23.0 \text{ gN} \cdot \text{m}^{-3}$ and $2.9 \text{ gP} \cdot \text{m}^{-3}$; for description of graphs see Fig. 2)

3. Species diversity and ecosystem elasticity

Regarding species richness and diversity among the animal community protozoans (excl. flagellates which were not investigated into detail) were far the most diverse group. More than 50 benthic species and more than 40 pelagic species were occasionally abundant during the 8-week investigation period (ARNDT, unpubl.). Probably one major cause of the elasticity of many eutrophic ecosystems (cf. NILSSEN 1978) is microfauna diversity, a component which has been mostly excluded from ecosystem analysis up to now.

On the other hand, it seems that the dominance of euryphagous species in this highly eutrophic waters replaces the function of species diversity for achieving a certain level of ecosystem elasticity. Derived from our own observations (ARNDT & BURCKHARDT, unpubl.) each

zooplankton group serves as a food source for the other (cf. small arrows in Fig. 1). Our knowledge on benthic interactions is not as good as for the pelagic habitat but derived from literature interactions should also be very intensive. There are also some interactions between benthic and pelagic fauna in the investigation area supported by migration patterns (cf. ARNDT et al. 1984) as well as due to resuspension especially of benthic bacteria. Furthermore, bioturbation especially by the activity of macrofauna should be of certain importance.

4. Temporal changes of planktonic ciliates

Since planktonic ciliates reach the highest production of secondary producers (excl. heterotrophic flagellates) during the investigation period their dynamics are

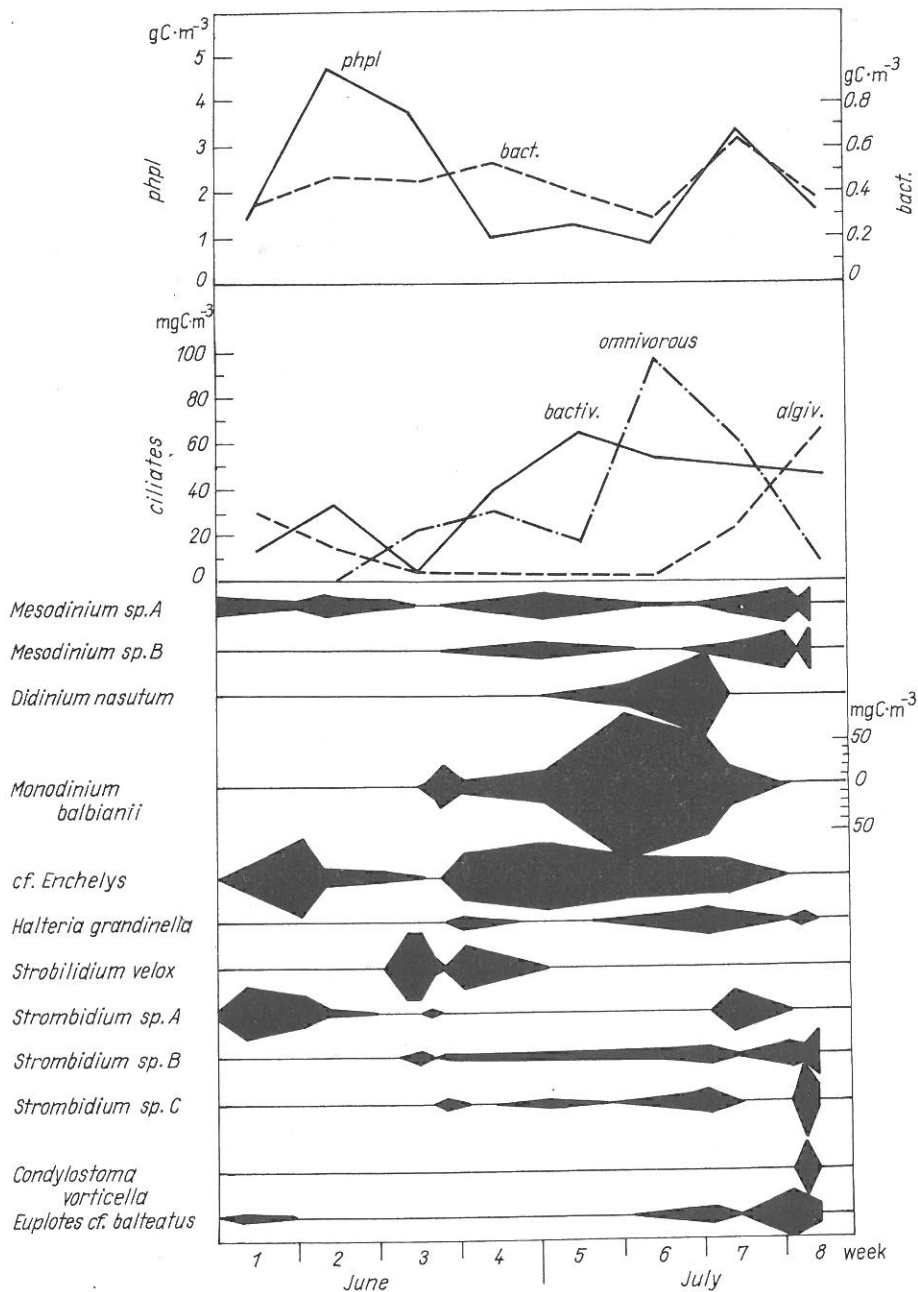


Fig. 4. Weekly fluctuations in biotic components in the pelagic zone of enclosure A (untreated control) in 1986 (upper panel: biomass of phytoplankton and planktonic bacteria; middle panel: biomass of planktonic ciliates separated for functional groups according to PRATT & CAIRNS (1985); lower panel: biomass of single ciliate species)

shown in more detail. For example, Fig. 4 presents the results of the control enclosure (1986). As already mentioned, the diversity of ciliates was much higher than total metazooplankton diversity. In Fig. 4 (lower part) the successions only of the dominant species are shown. The most interesting fact is the dominance of different functional groups. During degradation of phytoplankton and registered accompanying high production of planktonic bacteria numbers of bacterivorous ciliates increased remarkably. Calculated feeding rates of bacterivorous ciliates and heterotrophic flagellates were in the same range of the bacterial production (cf. ARNDT et al. 1988). Thus the production of bacteria should be under the control of microzooplankton. This perhaps may explain the relatively constant bacterial biomass.

From the third till the 7th week there were found high biomasses of omnivorous ciliates (*Strobilidium velox*, *Didinium nasutum*, *Monodinium balbianii*, *Condylostoma vorticella*) which are most probably able to control abundances of the small bacterivorous and algivorous species.

Thus the relatively stable ciliate biomass seems to be caused by the succession of several different species within short time intervals as well as the fact that the complexity of possible trophic relationships is already present within the Ciliophora.

The results point to the high importance of the matter flux via bacteria and microzooplankton in this eutrophic shallow waters and underline the necessity of more protozoological work for future ecosystem analysis in estuarine waters.

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