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# Comparison of Plankton Composition in Two Reservoirs with Different pH-Conditions

*keywords*: plankton community, oligotrophic, acidic, food web, microbial loop

## Abstract

Two small, oligotrophic to mesotrophic reservoirs with softwater character, differing in acidity, were investigated comparatively. Special emphasis was placed on the microbial plankton groups such as bacteria, heterotrophic flagellates and ciliates, which were determined within in a general investigation programme on zooplankton. Both of the reservoirs showed negligible influence of fish on the planktonic food webs.

The circum-neutral Kleine Kinzig reservoir has a food web with changing importance of the microbial components. In spring and autumn, recycling of nutrients and the pathway through the microbial groups is most important, while during summer *Daphnia* dominates the plankton system. In the acidic Sosa reservoir, higher trophic levels are lacking and therefore the microbial components are most important throughout the year.

## 1. Introduction

Microbial plankton analysis has become important in understanding the food webs and the cycling of matter in lakes as well as in reservoirs. There is a lack of knowledge concerning these matters for oligotrophic and acidic reservoirs because of their rareness in central Europe and because of the difficulty in investigating low productive waters. In geological regions with bunter sandstone or granitic bedrock low buffered waterbodies are common, which often tend to acidify by the influence of acid rain.

Two reservoirs with softwater character and with oligotrophic to slithly mesotrophic conditions were compared during this study concerning their planktonic components and their possible planktonic food webs. The goal of this contribution is to show which changes the food web will undergo in case of increasing acidification of a reservoir from pH-neutral to below pH 5.

SCHMIDT-HALEWICZ (1994) introduced the oligotrophic and circum-neutral reservoir Kleine Kinzig concerning it's heterotrophic plankton composition of the year 1990. In this contribution 2 more years of investigation confirmed the knowledge of Kleine Kinzig reservoir. The acidic reservoir Sosa has been introduced only poorly (HORN and HORN, 1995) and it's plankton composition will demonstrate which changes can be expected for an increase in acidification of the reservoir Kleine Kinzig.

## 2. Material and Methods

Two reservoirs situated in southern and eastern Germany were investigated and sampled comparatively with special emphasis on the microbial plankton groups. That means bacteria, heterotrophic nanoflagellates, ciliates and autotrophic picoplankton were included within a general investigation of zooplankton and phytoplankton (HOEHN, 1993). Both of the reservoirs have canyon-shaped valleys and were oligotrophic to slithly mesotrophic concerning nutrient conditions.

Study site and sampling methods for the reservoir Kleine Kinzig in Northern Black Forest were introduced in SCHMIDT-HALEWICZ (1994) and HOEHN and SCHMIDT-HALEWICZ (1995). General data, the times of investigation and comparable values of reservoir Sosa in Erzgebirge are given in Table 1. Further information on the reservoir Sosa is given by HORN and HORN (1995). Basic chemical data for both study sites introducing the acidic characters are given in Table 2.

The methods for sampling, fixation, creation of size classes and microscopic counting of the organisms were given in detail by SCHMIDT-HALEWICZ (1994). The same convertion of biomass to carbon units were used with exception for bacteria. Small bacteria (0,065 $\mu m^3$) were converted with 0,016 pg per cell C, and large bacteria (0,30 $\mu m^3$) with 0,044 pg per cell C (SIMON and AZAM, 1989). Four seasonal phases were found to be typical for both of the reservoirs. The phases were separated using the stability. Phase 1 covers the period of no or invers stratification, phase 2 the time of increasing stability. Phase 3 starts with the time of clearwater and embraces the part of highest stability, while the phase 4 contains the time of decreasing stratification up to total mixing.

Table 1. General data upon the reservoirs Kleine Kinzig and Sosa.

| | Kleine Kinzig | Sosa |
|---|---|---|
| Max. volume [$10^6 \cdot m^3$] | 12,4 | 6,3 |
| Retention time [a] | 0,4-0,6 | 0,45 |
| Max. depth [m] | 57 | 48 |
| Altitude [m] | 605 | 639 |
| Geology | bunter sandstone | tourmaline granit |
| P-load [o-$PO_4$-P $g \cdot m^{-2} \cdot a^{-1}$] | max. 0,21 | 0,3-0,48 |
| Catchment area %forested | 98 | 94 |
| Ann. rainfall [$mm \cdot a^{-1}$] | 1600 | 1200 |
| Wet deposition $SO_4$ [$mg \cdot l^{-1}$] | 1,4-2,4* | 2,8-3,1** |
| Times of investigation | Jan.1990-Mar.1993 | Apr.1992-May 1993 |

Sources: * = HOEHN (unpubl. data); ** = Saxonian authority of geology (unpubl. data).

Table 2. Parameters describing the acidity of two german reservoirs.

| | | Kleine Kinzig | Sosa |
|---|---|---|---|
| Conductivity | [$\mu S \cdot cm^{-1}$] | 39-63 | 84-93 |
| Alkalinity | [$\mu mol \cdot l^{-1}$ $HCO_3$] | 59-352 | 21-48 |
| pH | | 5,8-10 | 4,6-5,9 |
| $Al_{total}$ | [$\mu g \cdot l^{-1}$] | 4,5-115 | 200-1700 |
| $NO_3$ | [$mg \cdot l^{-1}$] | 2,5-7,1 | 2,0-5,6 |
| $SO_4$ | [$mg \cdot l^{-1}$] | 2,1-5,5 | 25-71 |
| DOC | [$mg \cdot l^{-1}$] | 0,6-3,6 | 1,1-3,9 |

Table 3. Relations of production to biomass (P/B) in different seasonal periods for taxonomic groups in Kleine Kinzig reservoir, used for calculation of secondary production. Source of data beside bacterial production are growth rates from direct measurements of secundary production in Lake Constance (after GAEDKE and STRAILE, 1994).

| $d^{-1}$ | Winter(I) | spring (II) | summer(III) | autumn (IV) |
|---|---|---|---|---|
| bacteria | 0,002 | 0,13 | 0,67 | 0,19 |
| heterotrophic nanoflagellates | 0,38 | 0,47 | 0,61 | 0,50 |
| ciliates | 0,13 | 0,31 | 0,18 | 0,10 |
| rotifers | 0,10 | 0,15 | 0,13 | 0,11 |
| herbivorous crustacea (*Daphnia*) | 0,02 | 0,05 | 0,07 | 0,05 |
| carnivorous crustacea (*Cyclops* CIV upwards) | 0,05 | 0,10 | 0,07 | 0,07 |

In the Kleine Kinzig reservoir bacterial production was measured at 10 dates 1991 via $^3$H-thymidine incorporation. The following assumptions were included: 25% thymidine content of DNA, no isotope dilution, 100% incorporation of thymidine, $3 \cdot 10^{18}$ cells production per mole thymidine and 16 fg C per bacterial cell. Detailed results were presented by HOEHN and SCHMIDT-HALEWICZ (1995). For the first and third year the theoretical production rates were calculated using the production-to-biomass relation (P/B) from 1991. Bacterial production in the acidic reservoir was calculated with P/B-values derived from direct measurements in acidic Šumava lake Schwarzsee (STRAŠKRABOVÁ, unpubl.). Rates per day used for calculation were 0.002 for winter, 0.07 for spring, 0.2 for summer, and 0.01 for autumn respectively. Secondary production was roughly calculated using group-specific, seasonal P/B-values retained from a great number of direct production measurements in Lake Constance (after GAEDKE and STRAILE, 1994) (Table 3). Ingestion rates for calculation of bacterial grazing were derived from literature data.

## 3. Results and Discussion

Both of the reservoirs have food-webs which are unaffected by planktivorous fish. *Daphnia longispina* is the key-stone organism and top consumer in Kleine Kinzig reservoir during the 3 years, as was stated already for the single year of 1990 (SCHMIDT-HALEWICZ, 1994). During the summer season *Daphnia* dominates the plankton system (Fig. 1). Its efficient grazing leads to high transfer efficiency of energy by a short pathway through the food web, *Daphnia* as a key-stone organism is believed to be common in more productive oligotrophic waters (STEINBERG and GELLER, 1993).

Autotrophic procaryotic picoplankton is, concerning the oligotrophic character of the reservoir, unexpectedly unimportant (Table 4). This is probably due to the pH-conditions or the low conductivity (BROCK, 1973), or for the reason of other perturbations (STEINBERG et al., in press). In contrast to other oligotrophic lakes, where picoplankton can dominate the primary production and is abundant throughout the year (STOCKNER and SHORTREED, 1991), *Synechococcus*-like picoplankton seems to play at best any role in Kleine Kinzig reservoir during the warm season. The abundances range from near zero up to 60 million cells per liter, but the mean abundance is low (Table 4).

Table 4. Annual mean values of abundance and fluctuation in Kleine Kinzig reservoir, 0-20m or bottom-surface for crustacea respectively.

| | 1990 | | 1991 | | 1992/93 | |
|---|---|---|---|---|---|---|
| | x | min - max | x | min - max | x | min - max |
| bacteria [$10^6$/ml] | 2,2 | 1,0 - 3,6 | 1,7 | 0,8 - 3,7 | 1,8 | 1,0 - 2,8 |
| APP [$10^5$/ml] | 2,2 | 0,02 - 32,7 | 5,1 | 0 - 40,2 | 3,3 | 0 - 59,2 |
| HNF* [$10^3$/ml] | 0,6 | 0,1 - 2,0 | 0,5 | 0,1 - 1,6 | 0,5 | 0,1 - 1,3 |
| ciliates [/ml] | 2,5 | 0,1 - 25,4 | 5,6 | 0,5 - 23,9 | 7,8 | 0,5 - 49,0 |
| rotifers [/l] | 49,0 | 1,8 - 278 | 74,3 | 1,9 - 324 | 1242 | 0 - 1576 |
| crustacea [/l] | 4,7 | 0,7 - 10,1 | 15,4 | 2,1 - 67,5 | 12,8 | 0,5 - 43,0 |

* HNF = heterotrophic nanoflagellates

The spectrum of heterotrophic nanoflagellates is divers, although clearly dominated by *Chrysomonadida*. Attached flagellates are rare and were detected only within the decay of a diatom bloom. Some phytoplankton species are typical acid-tolerant species (*Gymnodinium uberrimum* and *Peridinium inconspicuum*). The production of bacteria is high during the summer season (up to 1:1 with primary production, see HOEHN and SCHMIDT-HALEWICZ, 1995). It is thought to be stimulated by *Daphnia* grazing and their faeces, as well as by allochtonous carbon sources. In spring and autumn the recycling of carbon via microbial loop prevails. A calculation with ingestion rates based on literature values indicates besides just abundances that daphnids can be responsible for as much as 41% loss equal to the bacterial production in summer. In spring and autumn heterotrophic and mixotrophic phytoplankton are the most important bacterial consumers and the influence of daphnids on bacterial mortality is negligible. Ciliates and rotifers are unimportant for bacterial mortality throughout the year in that reservoir.

The heterotrophic plankton in Sosa reservoir is dominated by protozoans, in termes of biomass especially by ciliates (Fig. 2). Higher trophic levels (fishes, daphnids) are lacking due to the pH- and aluminum-toxicity. They are partly replaced by litoral invertebrates (HORN and HORN, 1995) (*Glaenocorisa propinqua*). The bacteria are divers in size and shape most of the year, and filamentous forms are common. This fits well to the theory of grazing-resistant bacteria (JÜRGENS and GÜDE, 1994). Autotrophic picoplankton is absent, but coccoid green algae (*Choricystis* cf.*minor, Chlorella* sp.), are common in acidic environments (HEHMANN and KRIENITZ, 1996). They reach abundances as high as 46 million cells per liter, which is in the same range than APP in Kleine Kinzig reservoir (Table 5). But the smallest autotrophic phytoplankton (SAP) of the acidic reservoir is larger (4 $\mu m^3$) in volume than its procaryotic represents (about 1 $\mu m^3$). This is in accordance with the findings of STEINBERG et al., (in press) and NIXDORF, (in press), who did not find picoplanktic prokaryotes in acidified and geogenically acidic lakes.

Other acid tolerant species within the phytoplankton community are *Gymnodinium uberrimum, Peridinium inconspicuum*, both potentially mixotrophic. Within the zooplankton *Microcodon clavus, Brachionus urceolaris, Acanthocyclops vernalis, Chy-*

Table 5: Annual mean values of abundance and fluctuation in Sosa reservoir, 0-20m or bottom-surface for crustacea respectively.

| | | May 1992 - April 1993 | |
|---|---|---|---|
| | | x | min - max |
| bacteria | [$10^6$/ml] | 1,34 | 0,86 - 1,77 |
| SAP* | [$10^3$/ml] | 10,6 | 0,96 - 46,1 |
| HNF* | [$10^3$/ml] | 0,25 | 0,01 - 0,76 |
| ciliates | [/ml] | 6,26 | 1,74 - 13,3 |
| rotifers | [/l] | 29,8 | 3,8 - 127 |
| crustacea* | [/l] | 3,18 | 0,34 - 11,0 |

* SAP = smallest autotrophic phytoplankton; HNF = heterotrophic nanoflagellates; crustacea = September1992 to August 1993

*dorus sphaericus* are typical acid tolerant species. Heterotrophic nanoflagellate were reduced to the order *Chrysomonadida* and are rare in abundance. Pigmented flagellates (*Dinobryon, Peridinium, Gymnodinium*) are probably the more important flagellate grazers. In acidic Šumava lake Schwarzsee 40% of bacterial grazing was due to pigmented flagellates (VRBA et al., 1997).

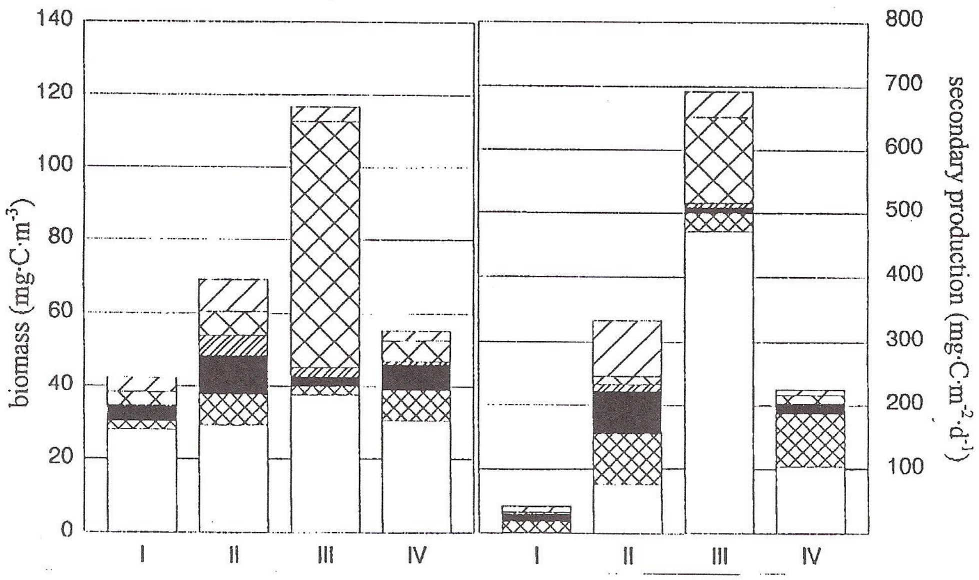


Figure 1: Biomasses of heterotrophic plankton components (left panel) and secondary production (right panel) in Kleine Kinzig reservoir in 4 averaged seasonal phases of 3 years. Values from upper 20m, except for crustacea (bottom to surface). I = winter, II = spring, III = summer, IV = autumn. Hatches: white = bacteria; small cross-hatched = HNF; black = ciliates; 45°angle double lined = rotifers; large cross-hatched = daphnids; 45°angle single lined = copepods

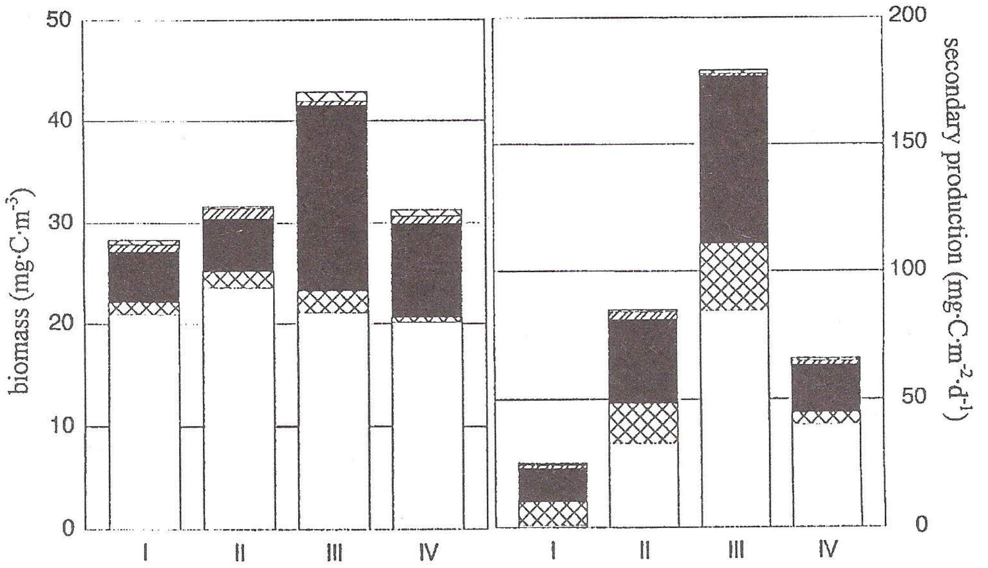


Figure 2: Biomasses of heterotrophic plankton components in the upper 20 m of Sosa reservoir for April 1992 to May 1993 in 4 seasonal phases: I = winter, II = spring, III = summer, IV = autumn. Values from upper 20m, except for crustacea (bottom to surface). Hatches: white = bacteria; small cross-hatched = HNF; black = ciliates; 45°angle double lined = rotifers; large cross-hatched = daphnids; 45°angle single lined = copepods

Ciliates were found to be dominated by a *Paramecium*-like organism of >100µm in Sosa reservoir and these protozoans dominate biomass as well as secondary production most of the year (Fig. 2). BIENERT et al. (1991) found in an acidic lake a biomass maximum of 37 µg C per liter, which was due to a volumenous, mixotrophic ciliate. Other investigations indicate in contrast, ciliates may play a reduced role in acidified lakes (VRBA et al., 1997).

The majority of the heterotrophic community in Sosa reservoir feeds on bacteria and pico-sized particles. On the other hand, bacteria and the smallest phytoplankton produce the highest biomasses.

## 4. Conclusions

The following changes within the plankton community and the food web can be attributed to an increasing acidification of a clear-water reservoir (low DOC), where fish are not affecting the plankton:

- Change of species to more acid tolerant forms
- Lack of procaryotic autotrophic picoplankton (*Synechococcus*-type)
- Coccoid green algae (*Choricystis minor*) replace procaryotic forms (SAP)

- Bacteria more divers in volume with filamentous forms
- Lack of daphnids (> 1 mm)
- Increase of carnivorous invertebrates
- Increase in litoral species
- Increase of smaller filter feeders (*Chydorus, Ceriodaphnia*)
  and / or other less efficient non crustacean filter feeders (ciliates, rotifers)
- Reduction of heterotrophic flagellates to Chrysomonads

The consequences are less reduction of spring algae bloom, less seasonal dynamic of plankton succession and a less efficient energy tranfer through the food web. The microbial loop and recycling of carbon prevails, because highly efficient filter feeders do not appear.

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