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Temporal dynamics of lipids in the zooplankton of two tropical reservoirs of different trophic status

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Introduction

Lipids make up the most important energy reserves of zooplankton (GOULDEN & HENRY 1988). In freshwater ecosystems, copepods, cladocerans and rotifers are the dominant groups and all are known to accumulate lipid as energy reserves (VIJVERBERG & FRANK 1976, KOKOVA et al. 1982). Lipids in zooplankton occur mostly as triacylglycerides, phospholipids, acetone mobile polar lipids, free fatty acids and sterols (VANDERPLOEG et al. 1992).

A vast literature exists on lipids from marine zooplankton (e.g. RAYMONT et al. 1971). More recently, some information on lipid dynamics of freshwater zooplankton from temperate regions has been published. These works are basically limited to a few studies on seasonal patterns (e.g. SIEFKEN & ARMITAGE 1968, HILL et al. 1992, WAINMAN & LEAN 1990, WAINMAN et al. 1993, VANDERPLOEG et al. 1992).

There is a great lack of information about the biochemical composition of zooplankton from tropical regions. Are the data on lipid content comparable to the existing data from higher latitudes? Can we isolate temporal patterns of energy storage in tropical zooplankton?

This study aimed to investigate the temporal dynamics of lipids of zooplankton in two reservoirs: a) the turbid and hypereutrophic Pampulha Reservoir ($A = 2.4\ km^2$, vol $= 14 \times 10^6\ m^3$, $Z_{max} = 16$ m, loc. = 19° 55′ S, 43° 56′ W), situated in the city of Belo Horizonte; and b) the oligo-mesotrophic Furnas Reservoir ($A = 1459\ km^2$, vol $= 21.0 \times 10^9\ m^3$, $Z_{max} = 88.5$ m, loc. = 20° 40′ S, 46° 19 W). This resorvoir is situated in south-eastern Minas Gerais State. The temporal dynamics of lipids was investigated at two different time scales: annual and diurnal cycles.

Methods

Zooplankton was collected monthly from February 1993 to December 1994 by means of vertical net tows using a 22 cm diameter net with 90 µm mesh size at a central sampling point in Pampulha Reservoir (Z = 10 m). Two diel cycles were investigated in Pampulha Reservoir: in April and August 1994, respectively. In Furnas Reservoir, two diel cycles were investigated: in July 1994 and in February 1995.

Zooplankton samples for counting were also taken. Organisms were immediately fixed u sing formalin (4 % of final concentration) buffered to pH 7. Counting was done using a stereo-microscope Zeiss microscope. Every specimen was measured and allometric equations were used for estimation of dry weights (PINTO-COELHO 1991 b).

Contents of net tows for biochemical analyses were placed in an insulated 5 L container filled with lake water from the epilimnion, and transported to the laboratory within 20 minutes. At the laboratory, organisms were filtered on an inox gauze with 160 µm mesh size. These filters were placed on 10 cm diameter Petri dishes and immediately stored in a freezer (−25 °C).

Zooplankton organisms were then freeze-dried according to the technique proposed by BERBEROVIC & PINTO-COELHO (1989). Dried organisms were transferred to small pre-weighed aluminium 'boats' and dry weight was determined using a Mettler high precision balance (0.000001 g). Weighed zooplankton was homogenized with 1.0 ml of distilled water using an electrical micro-homogenizer ELGIN.

Chemical digestion, as proposed by MEYER & WALTHER (1988), was applied to the homogenized material. Total lipids were determined spectrophotometrically (h = 546 nm) using the sulpho-phospho-vanillin reaction (ZÖLLNER & KIRSCH 1962).

Results and discussion

The biomass of total zooplankton of Pampulha Reservoir fluctuated between 1.0 and 4.0 mg $DW \cdot m^{-2}$ in 1994 (Fig. 1, top). This community was dominated by large cladocerans *Daphnia gessneri, D. laevis, Diaphanosoma* spp. were the most important organisms. Small cladocerans, such as *Bosmina* spp. and *Ceriodaphnia cornuta,* were occasionally abundant but their contributions to total biomass can be neglected. Copepods were dominated by *Thermocyclops decipiens*. Other cyclopoids, such as *Mesocyclops* spp., *Metacyclops* sp. and *Scolodiaptomus corderoi* were also occasionally present. Total zooplankton biomass peaked in June–July,

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DeBusk (1991) observed that microbial retention of phosphorus from macrophytes caused an acute reduction of C:P ratios of detrital biomass attached to the root zone of *E. crassipes* in the first 40 days of observations. Nevertheless, these microbial community attached to the root zone of *E. crassipes* is a key factor for the decomposition of these macrophytes, since decomposition rates are faster in the root zone of hyacinth mats than at the sediment water interface (Reddy & DeBusk, 1991). As an example, the microbial flora and fauna attached to young *E. crassipes* plants required only 26 days to recycle its biomass completely in other lakes (Singhol et al., 1993). The decomposition rate will depend strongly on the prevailing metabolism of the attached microbes: aerobic respiration, facultative anaerobic respiration and anaerobic respiration. The aerobic respiration, however, may be the major metabolic pathway of biomass decomposition of dead macrophyte tissue in the root zone (Reddy & DeBusk, 1991).

Conclusions

The higher excretion rates of zooplankton and biomass turnover rates of macrophytes found in this study indicate that the zooplankton community and the macrophyte *E. crassipes* may be the keystone organisms in the internal cycling of phosphorus in Pampulha reservoir. On some occasions, like at the end of the rainy season, both communities were able to recycle as much as 43% d^{-1} of the available phosphorus in lake water. Furthermore, it was also clear that there was a time lag between the maximum of return rates of phosphorus due to these communities. Zooplankton released more phosphorus during the dry season when its biomass was high, whereas the water hyacinths released more phosphorus at the end of their growing season when biomass turnover peaked. This period coincided with the end of the rainy season and a low zooplankton biomass.

The temporal differences in maximum P-release due to zooplankton and macrophytes possibly have important consequences. The regular monitoring program over several years has shown that the phosphorus concentrations in the water usually reach a minimum at the end of the rainy season (Pinto-Coelho, 1998). At this time, the water hyacinth population is recycling more phosphorus. Therefore, the decomposition of macrophyte biomass is not only a major source of phosphorus for the existing biota in the reservoir, but is possibly the most important source of regenerated phosphorus during some periods of the year.

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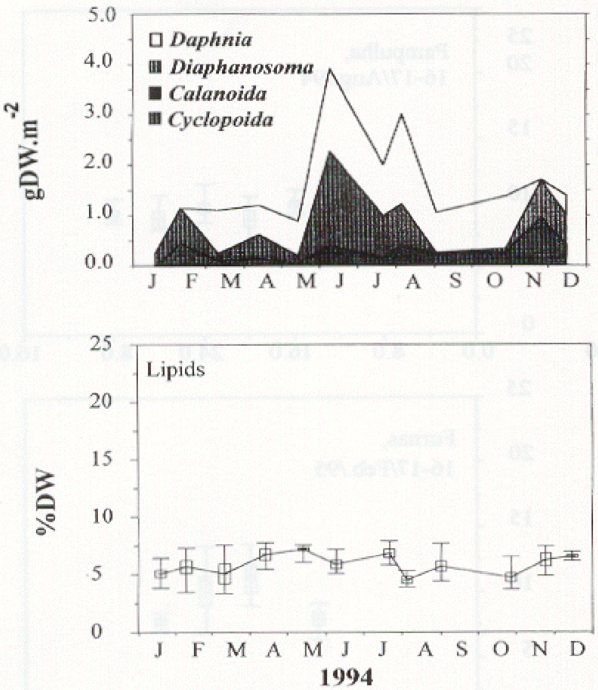

Fig. 1. Annual course of biomass and lipid content of zooplankton from Pampulha Reservoir, Brazil in 1994. Ranges, standard errors and mean values are indicated.

mostly due to an increase of cladoceran populations. Copepods were more abundant in the rainy season (November–March).

The lipid content of total zooplankton in 1994 remained always below 10 % of total biomass (Fig. 1, bottom). In spite of the seasonality observed in the biomass of cladocerans and copepods, seasonal fluctuations in the lipid content were minimal. The mean annual value for total lipids was 5.8 ± 0.8 % DW. Zooplankton of Furnas Reservoir also exhibited low values of lipid in its biomass. The overall mean values for the two diurnal cycles undertaken in 1994 were 8.4 and 9.2 % DW, respectively.

Freshwater zooplankton of higher latitudes has generally higher lipid values (Hill et al. 1992, Vanderploeg et al. 1992). The lipid contents of zooplankton also increases with depth in the oceans (Childress & Nygaard 1974). In both cases, it seems that zooplankton stores higher amounts of lipids in colder waters. Tropical zooplankton possibly has a higher energetic demand since they are living permanently in warmer waters (>18 °C). The oxygen consumed is positively affected by temperature increases (Toth & Drits 1991) and, therefore, tropical zooplankton would have to allocate more energy to basal metabolism and this should cause lower lipid storage patterns.

Poor food quality can also induce lower levels of lipid content (La Row et al. 1975). Phytoplankton in Pampulha Reservoir is dominated by Cyanobacteria (*Microcystis* spp.). Recent investigations have demonstrated that zooplankton in this lake mostly consumes detritus and small heterotrophs (Araújo 1995). It is well known that assimilation efficiency is very low in any detrital food chain (Margalef 1977).

The daily cycles of lipid content of zooplankton showed different results in each of the reservoirs studied. In Pampulha Reservoir, the two diel cycles showed different trends (Fig. 2, top). In the diel cycle of April/94, the coefficient of variation, c.v., was 15.5 %, higher than the c.v. obtained for the whole year of 1994 (c.v. = 14.4 %). Nevertheless, the same mean value of lipids (8.2 %) was observed in three different times of the cycle: at 20:00 hs, 24:00 hs and 08:00 hs, respectively. The maximum value (10.2 %) was measured at 20:00 hs.

In the diel cycle from August of 1994, lipid values remained quite comparable (c.v. = 5.6 %). The ANOVA confirmed the absence of a diel pattern (F-Ratio = 1.907, $P <= 0.122$, N = 37). The mean values varied within a narrow range: 8.8–10.1 % for all times (Fig. 2, top). The highest values of the diel cycle were 11.6 % and 11.5 %, observed at noon and midnight, respectively.

In Furnas Reservoir, there was a clear trend for higher lipid values at night in both dates (Fig. 2, bottom). In July 1994, the highest values (both mean and maximum values) occurred at 04:00 am. The mean value at 04:00 hs. am was 10.8 % clearly much higher than all mean values observed during the day (6.7–8.7 %). The c.v. of 17.8 % also indicates the existence of a marked diel fluctuation in the lipid content of zooplankton (F-Ratio = 4.232, $P <= 0.021$ N = 18).

Higher lipid values at night were again observed in February 1995. Night values of lipids were 11.1 % and 10.1 %, observed at 20:00 hs. and 24:00 hs., respectively. These values were clearly more elevated than the mean daily values (7.7–7.9 %). The c.v. calculated for the whole cycle was 15.5 % (F-Ratio 4.119, $P <= 0.026$, N = 19).

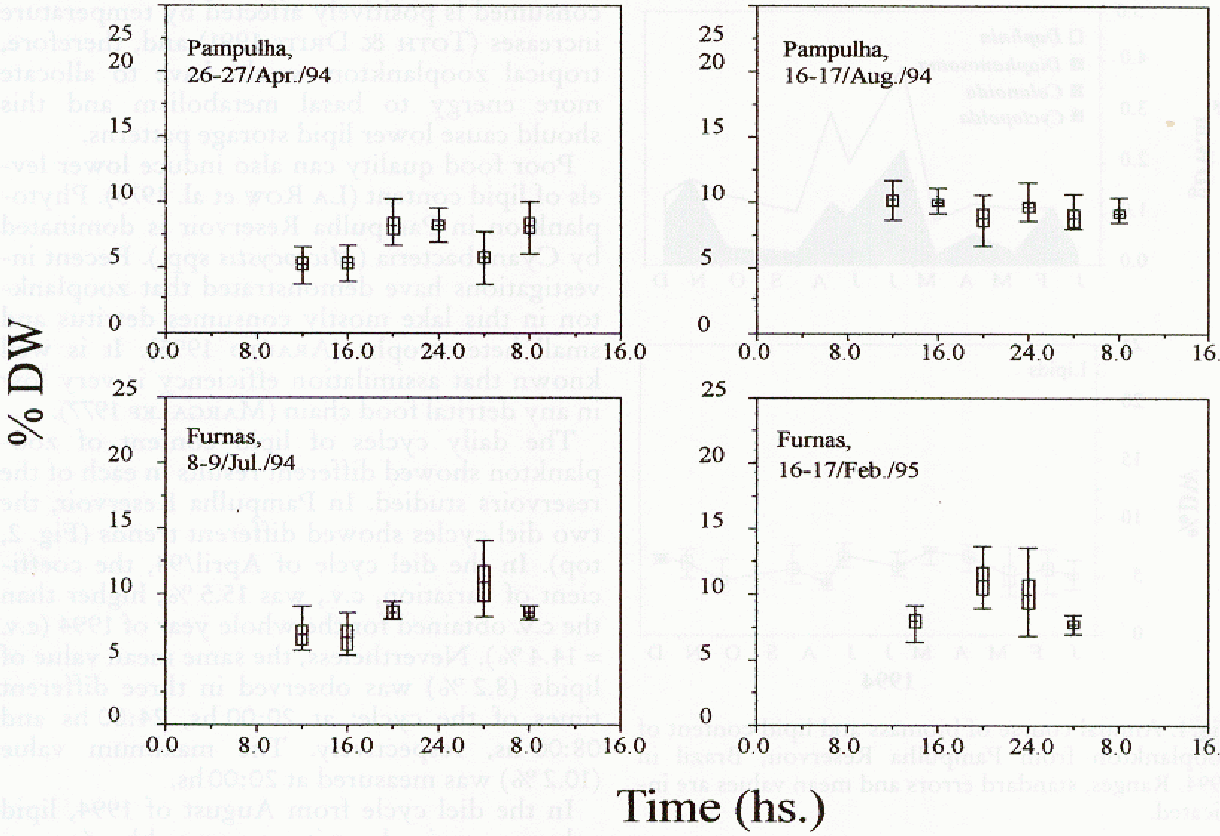

Fig. 2. Diurnal course of lipid values in zooplankton (% DW) in two reservoirs of Minas Gerais, Brazil. Ranges, standard errors are indicated.

Why has zooplankton in Furnas Reservoir higher lipid values at night, whereas this trend could not be ob served in Pampulha Reservoir? This survey was undertaken in an oligotrophic part of Furnas Reservoir, near the Turvo River Bridge. Herbivore zooplankton in this part of Furnas is largely dominated by the calanoids *Argyrodiaptomus furcatus, Notodiaptomus iheringi, Scolodiaptomus corderoi* and large cladocerans such as *Daphnia* and *Diaphanosoma* (Reid & Pinto-Coelho 1994). At least *S. coderoi* is known to be an efficient algal filter-feeder (Pinto-Coelho et al. 1988). Transparency of the water column at this point in Furnas is high (Secchi disk>4.0 m).

The higher lipid values of zooplankton at night suggest that the classic food chain (phytoplankton-zooplankton) plays a major role in this environment. Large herbivores are known to have higher filtering rates at night (Pinto-Coelho 1991 a). Consequently, they would stock lipids at night. On the other hand, Pampulha Lake is a very turbid reservoir (Secchi disk<1.5 m) and zooplankton nutrition is mostly based on heterotrophic organic carbon (Araújo 1995). The lack of a pattern in the diurnal rhythms of lipid dynamics would be expected in a detrital/heterotrophic food chain in a turbid reservoir since there would be no selective advantage for zooplankton to wait until dark to enhance filtering rates.

Conclusions

The lower lipid values of zooplankton found in different tropical ecosystems seem to confirm the latitudinal trends observed in the lipid content of zooplankton. Furthermore, the differences found in the diurnal cycles between Pampulha and Furnas reservoirs indicate that food quality possibly plays a major role in the dynamics of lipids in zooplankton. The comparison between diel and seasonal cycles of lipid contents of zooplankton seems to confirm the idea that short temporal variations are more important in most ecological processes occurring in the water column of tropical waters.

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