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# Crustacean zooplankton of Lago Tupé, a neotropical black water lake in the Central Amazon

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ABSTRACT – The black water lake Lago Tupé in Central Amazonia was studied in 1974 and 2002 and the results are compared. 18 taxa of Cladocera and 12 taxa of Copepoda were encountered, with 6 taxa of Bosminidae and 9 taxa of diaptomid copepods. The high species diversity of these families remains unclear. Numerical dominant are copepod nauplia, *Bosminopsis deitersi* and *Oithona amazonica*. The examination of the vertical distribution in 2002 showed the phenomenon that many individuals were caught in the hypolimnion despite anoxic conditions. The ria-lake Tupé (drowned valley lake) has a dendritic shape and a high spatial heterogeneity for zooplankton. Nearly each side-arm has its own zooplankton composition. Cladocera all are of small body size whereas Copepoda especially Diaptomidae are bigger and are in the same range as Asian species.

KEY-WORDS – black water, zooplankton, abundance, vertical migration, spatial heterogeneity, body size, Central Amazonia

# Introduction

Zooplankton plays a central role in the food webs of lakes. On the one hand it feeds on the smaller phytoplankton (Arcifa *et al*. 1986), bacteria (Jürgens *et al*. 1994) and sometimes protozoa (Arvola & Salonen 2001) and on the other hand its been eaten by larger fish (Barbosa & Matsumura-Tundisi 1984; Carvalho 1984), insects (Nessimian & Ribeiro 2000) or their larvae (Bezerra-Neto & Pinto-Coelho 2002b). Zooplankton in a broader sense (Fernando 2002) contains mainly three predominating groups as Rotifera, Cladocera and Copepoda (Robertson & Hardy 1984) and few species from other groups such as Protozoa (Lansac Tôha *et al.* 1993), Ectoprocta (Wiebach 1970), Coelenterata, Plathelminthes (Rocha *et al.* 1990), Insecta (Bezerra-Neto & Pinto-Coelho 2002a), Ostracoda (Tundisi *et al*. 1997a), Hydracarina (Matveev & Martinez 1990) and Mollusca.

After the summary publication of Robertson & Hardy (1984) about the zooplankton of Amazonian lakes there are some papers that promote the knowledge of zooplankton from this region (Hardy 1992; Santos-Silva & Robertson 1993; Chu Koo 2000; Bozelli 2000; Espíndola *et al*. 2000; Pinto-Mendieta 2000).

On the other hand there is very little information about the zooplankton of the black water of which the Rio Negro is the most prominent representative as well as many of his affluents. Recently a whole book was been published about the black water lake Lago Tupé (Santos Silva *et al.* 2005). It brings information about the geomorphology, physico-chemical parameters and also occurrence data of phyto- and zooplankton species.

Because of its very poor nutritional status and the extremely low electrolyte content of the black waters the phytoplankton density and production is very low and so the secondary production is believed also very low (Fittkau *et al*. 1975), what is true for the benthos (Reiss 1977). Rai & Hill (1981) characterize Lago Tupé by a low to moderate chlorophyll-content, low zooplankton populations, lack of submerged and floating vegetation and low bacterial numbers. The chemical composition of the lake water in comparison to Rio Negro and the nearby Tarumã-Mirim is presented by Furch & Junk (1997). They confirm the low ionic content and the low pH, but point out that the lake water shows much lower concentration of major cations and much higher concentrations of major anions than the river water. In 1978 Brandorff made the first attempt to compare zooplankton from a white water and a black water lake. He concluded that the differences between black and white waters are not so significant.

The aim of this paper is to concentrate the information about the zooplankton of a black water lake in Amazonia, which is Lago Tupé.

# Study area and material and methods

Lago Tupé lays ca 28 km upstream Manaus on the left margin of the Rio Negro. The lake is about 3 km long with a maximal width of 0, 3 km and a surface area of about 68 ha (Reiss 1977). During the cold periods of the Pleistocene the sea level was about 100 meter lower and the rivers in the Central Amazon basin were considerably deepened. During the subsequent Holocene sea level rise the deep valleys were filled and the lower parts of the rivers were drowned forming lakes, called 'ria-lakes' (Irion 1976; Sioli 1957). Many of the black water lakes have therefore the typical dendritic form (Fig. 1).

The mouth of Lago Tupé is closed by a huge sand-bar leaving at low water level only a narrow channel opening to the Rio Negro. This channel is directed upstream of the Rio Negro probably due to local currents in the river. Just above Lago Tupé a layer of sandstones narrow the course of the Rio Negro to only 2, 2 km that afterwards widens in the Tarumã bay to 10 km. In this bay a back current along the left margin of Rio Negro has deposited the sand bar at the mouth of Lago Tupé (Reiss 1977).

As common for black water the pH was between 4,8 and 5,2; the conductivity varies between 6,4 and 10,5 µS/cm. Due to the brown water color the secchi disk readings were between 1,1 and 1,7 meter.

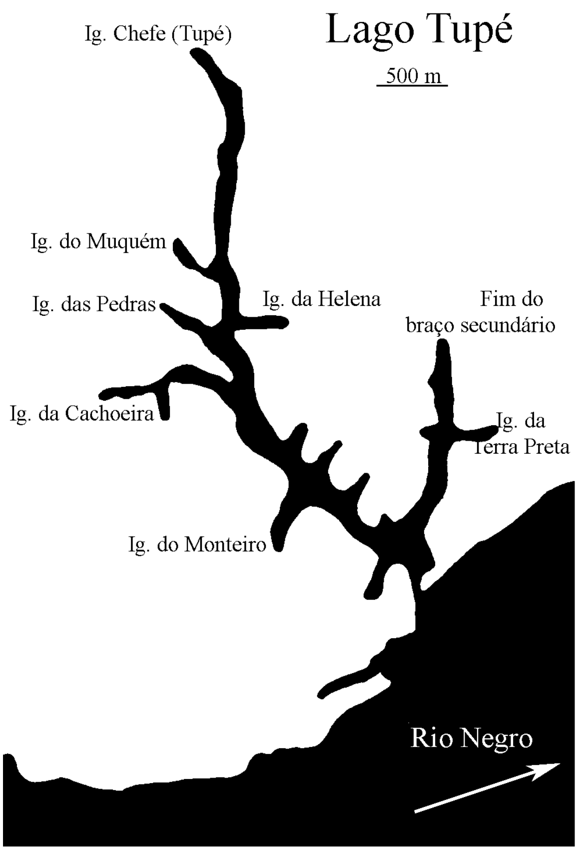


**Figure 1**: Outlines of Lago Tupé with flow direction of the Rio Negro. The subsidiary branches of the lake are named. Ig. = Igarapé (brook)

Zooplankton was sampled in 1974 from April to November corresponding to high to falling to low water level and in 2002 from September to November that is falling to low water phase. Samples were collected in 1974 by means of a water pump (Fa. Allweiler Nr. 2) and filtered trough a 56µm plankton net. The samples were concentrated to about 50 ml and fixed with formol. In 2002 we used a Schindler/ Patalas plankton trap containing 12 Liter. Samples were filtered through a 55 µm plankton net and fixed with formol. All samples were collected in the centre of the lake corresponding to sampling point ET 10 of Darwich *et al.* (2005). Water level in the lake is according to the water level fluctuations of the Rio Negro (Aprile & Darwich 2005).

# Results and discussion

## Taxonomic composition

Here we present all species encountered in 1974 and 2002 in Lago Tupé.

We found 18 taxa of Cladocera including 6 taxa of Bosminidae. This is a very high number of Bosminidae. 12 taxa of copepods were recorded with 9 taxa of Diaptomidae including two new not yet described species. In a comparison of an oligotrophic and an eutrophic reservoir in São Paulo State, Brazil (Sendacz *et al.* 2006) 4 species of Bosminidae were found in the oligotrophic lake whereas the eutrophic lake only hosted 2 species. In contrast the number of diaptomid copepods was higher in the eutrophic lake (4) than in the oligotrophic (1 species) (Table 2). In the black water reservoir Guri in Venezuela 5 species of diaptomid copepods were recorded (Weibezahn, 1994), but it seems that none of them is restricted to humic rich waters.

Two species of the Bosminidae are probably restricted to black waters or extreme nutrient poor waters. These are *Bosminopsis brandorffi* and *B. negrensis*. The same holds true for *Holopedium amazonicum*. Probably four diaptomid species from Lago Tupé are restricted to black waters: *Rhacodiaptomus retroflexus*, *R. nov. spec.*, *Aspinus acicularis* and *Diaptomus s.l. negrensis*. In a comparison of oligotrophic and eutrophic lakes in North and South America a clear preference of diaptomids to oligotrophic conditions were recorded (Pinto-Coelho *et al.* 2005). If the humic content of the waters or the oligotrophic conditions play the main role remains unclear. According to Steinberg (2003) only a few species can be used as humus indicators but only on a regional basis.

Up till now nearly only the pelagic species of the zooplankton community are sampled and identified in Lago Tupé. We are sure that sampling in the

**Table 1 -** Zooplankton taxa found in Lago Tupé

| Cladocera | Ctenopoda | Holopedidae | *Holopedium amazonicum* | Stingelin, 1904 |
|---|---|---|---|---|
| | | Sididae | *Diaphanosoma dentatum* | Herbst, 1968 |
| | | | *Diaphanosoma polyspina* | Korovchinsky, 1982 |
| | | | *Diaphanosoma brevireme* | Sars, 1901 |
| | Anomopoda | Bosminidae | *Bosminopsis deitersi* | Richard, 1895 |
| | | | *Bosminopsis brandorffi* | Rey & Vásquez, 1989 |
| | | | *Bosminopsis negrensis* | Brandorff, 1976 |
| | | | *Bosmina longirostris* | (O.F. Müller, 1776) |
| | | | *Bosmina tubicen* | Brehm, 1953 |
| | | | *Bosmina brehmi* | Lieder, 1962 |
| | | Daphniidae | *Daphnia gessneri* | Herbst, 1967 |
| | | | *Ceriodaphnia cornuta s.l.* | Sars, 1885 |
| | | Moinidae | *Moina minuta* | Hansen, 1899 |
| | | | *Moina rostrata* | McNair, 1980, |
| | | Ilyocryptidae | *Ilyocryptus spinifer* | Herrick, 1882 |
| | | Macrothicidae | *Streblocerus pygmaeus* | Sars, 1901 |
| | | Chydoridae | *Kurzia latissima* | (Kurz, 1875) |
| | | | *Chydorus pubescens* | Sars, 1901 |
| Copepoda | Cyclopoida | Cyclopidae | *Thermocyclops minutus* | (Lowndes, 1934) |
| | | | *Mesocyclops longisetus* | (Thiebaud, 1912) |
| | | Oithonidae | *Oithona amazonica* | Burckhard, 1912 |
| | Calanoida | Diaptomidae | *Rhacodiaptomus retroflexus* | Brandorff, 1973 |
| | | | *Rhacodiaptomus nov. spec.* | |
| | | | *Aspinus acicularis* | Brandorff, 1973 |
| | | | *Dactylodiaptomus pearsei* | (Wright, 1927) |
| | | | *Dasydiaptomus coronatus* | (Sars, 1901) |
| | | | *cf. Notodiaptomus nov. spec.* | |
| | | | *Diaptomus s.l. linus* | Brandorff, 1973 |
| | | | *Diaptomus s.l. negrensis* | Andrade & Brandorff, 1975 |
| | | | *Argyrodiaptomus azevedoi* | (Wright, 1935) |
| | Poecilostomatoida | Ergasilidae | | |
| Ostracoda | | | | |
| Insecta | | Chaoboridae | | |
| Rotifera | Monogononta | | | |
| Ectoprocta | (Bryozoa) | Cyphonauta | | |
| Protozoa | Rhizopoda | | | |
| | Ciliata | | | |

**Table 2 -** Comparison of number of zooplankton taxa found in some Brazilian lakes

| River basin | Rio Paraná | | Rio Tieté | | Rio Amazonas | Rio Negro |
|---|---|---|---|---|---|---|
| author | Lansac-Tôha et al.1997 | | Sendacz et al. 2006 | | Brandorff 1977 | This study |
| taxon / lake | Patos | Guaraná | Ponte Nova | Guarapiranga | Castanho | Tupé |
| *Diaphanosoma* | 3 | 1 | 1 | 1 | 2 | 3 |
| *Ceriodaphnia* | 1 | 1 | 2 | 2 | 3 | 1 |
| *Daphnia* | 1 | 1 | 2 | 2 | 1 | 1 |
| *Scapholeberis* | 1 | 1 | | | | |
| *Simocephalus* | 2 | | | | | |
| *Moina* | 1 | 1 | 2 | 1 | 3 | 2 |
| *Bosmina* | 2 | 2 | 3 | 1 | 2 | 3 |
| *Bosminopsis* | 1 | 1 | 1 | 1 | 1 | 3 |
| Chydoridae | 17 | 20 | ? | ? | ? | ? |
| Macrothricidae | 5 | 3 | ? | ? | ? | ? |
| Cyclopidae | 5 | 6 | 2 | 3 | 3 | 3 |
| Diaptomidae | 6 | 5 | 1 | 4 | 5 | 9 |

littoral and at high water between the trees the number of species will increase. In Norwegian lakes (Walseng *et al*. 2006) more than two-thirds of the total crustacean species numbers were accounted for by species with littoral preference.

Other taxa are left undetermined to species level are the poecilostomatoid Copepoda, Ostracods, larvae of chaoborid insects, rotifers and protozoans. Interesting is the larva of the Bryozoa called Cyphonauta. Their taxonomic assignment is not yet clear but possibly it could be *Hislopia corderoi* Mané-Garzon, 1959.

The secondary production of Amazonian black waters is believed to be very low (Fittkau *et al*. 1975). About secondary production of zooplankton in these waters we can only speculate. But the diversity and biomass is not very low, as already Brandorff (1978) stated. Also Freeman & Freeman (1984) suggested "that ideas concerning the unproductive nature of black water systems has to be re-examined". They came to this conclusion looking at fish and their potential prey production in Okeefenokee swamp, USA.

## Qualitative results from 1974

We have samples from 1974 from the central station of the lake but unfortunately not a year round (see table 3). Evaluable quantitative samples are only from a short period from end of July to mid of September. Lago Tupé in 1974 had a bloom of the dinoflagellate of *Peridinopsis amazonica* Meyer, 1997 (Meyer *et al*. 1997). To see if this is a common phenomenon in black water lakes we sampled two times many lakes on the left margin of the Rio Negro (see Brandorff & Andrade 1975). This bloom was only encountered in Lago Tupé, so we abandoned sampling this lake in November 1974. Nevertheless with the samples from 1974 and samples from 2002 we are able to throw some light on composition and numbers of the zooplankton of Lago Tupé.

The sampling period in 1974 covers high, falling and low water in the lake. That is from 14, 5 to 6 m water depth at the central station of the lake. The samples show that some species are found at many sampling dates, e.g. *Diaphanosoma polyspinum, Ceriodaphnia cornuta s.l., Moina minuta, Bosminopsis deitersi, and Bosmina sp*. of the Cladocera and *Oithona amazonica* and *Diaptomus s.l. negrensis* of the Copepoda.

Figure 2 shows the abundance of total zooplankton, nauplia, *Bosminopsis deitersi* and Cyclopoida, mainly *Oithona amazonica* in lago Tupé. As can be seen total zooplankton consists mainly of nauplia. The numbers increase with falling water with a maximum of about 1900 individuals per litre.

The zooplankton was vertically distributed only in the first three meters. There was a steep gradient in the oxygen content of the water; at 4m we found only 5 to 10 % of oxygen saturation. At 5m the smell of $H_2S$ could be detected. The highest numbers of zooplankton were at 1 and 2 meter depth. Only *Moina rostrata* was found at 6m depth on September $12^{th}$.

**Table 3 -** Qualitative abundance of zooplankton taxa in Lago Tupé in 1974 at Central station

| taxon | 11.04. | 22.05. | 29.07. | 05.08. | 09.08. | 13.08. | 23.08. | 05.09. | 12.09. | 26.09. | 10.10. | 28.10. | 07.11. | 21.11. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Diaphanosoma polyspinum* | xx | xx | | xx | xx | | | x | x | x | | xx | xx | |
| *Ceriodaphnia cornuta s.l.* | xx | xxxx | x | xx | xx | xx | | xxx | xxxx | xxxx | xxxx | xxxxx | xxxx | xxxx |
| *Moina minuta* | | xx | | | | | | | xxx | xxx | xxxx | xxxx | xxx | xxx |
| *Bosminopsis deitersi* | xxx | xx | xx | xx | xxxx | xxx | xxxx | xxxxx | xxxxx | xxxx | xxxx | xx | xxxx | xx |
| *Bosminopsis brandorffi* | | | x | x | | | | | | | | | | |
| *Bosmina rost.long.* | xx | xxxx | x | | xx | xx | xx | x | xx | | | | xx | |
| *Bosmina rost.curt.* | | | | | | | | | | | x | xx | xxxx | xxxx |
| *Bosmina rost.curv.* | | | | | | | | | | | | x | | |
| *Holopedium amazonicum* | | x | | | | | | | | | x | xxx | xx | xxxx |
| *Oithona amazonica* | xxxxx | xxx | xxx | xxxx | xxxxx | xxxx | xxxx | xxxx | xxxx | xxx | xxx | xxx | xxx | xxx |
| *Cyclopoida* | | | | | xx | | | | xx | x | xx | | | |
| *Aspinus acicularis* | | | | x | xx | | | | | | | | | |
| *Diaptomus negrensis* | | | | | | | | | xxxx | xxx | xx | xxxx | xxx | xxx |
| *Dasydiaptomus coronatus* | | | | | | | | | | | | x | | |
| *Rhacodiaptomus retroflexus* | | | | | | | | | | x | | | | |
| Bryozoa Cyphonauta | xx | x | | | xx | xxxx | xxxx | xx | | | x | xx | | |
| Rotifera | xxx | | xx | xxxxx | xxxxx | xxxx | xxx | xxxx | xxxx | xxx | xxx | | xxx | xxx |
| Dinoflagellata | | | xxxxx | xxxxx | xxxxx | xxxx | xxxx | xxxx | xxx | xx | | | | |
| Chaoborus | | | x | x | | | | | xx | | x | xx | x | xx |

x = single   xx = few   xxx = abundant   xxxx = very abundant

## Vertical distribution in 1974 and 2002

On September 14/15th we collected zooplankton with a 12 liter trap at the central station of the lake every meter at 15, 21, 3 and 9 hours. The aim was to see the vertical distribution of the different species and if the zooplankton undertakes vertical

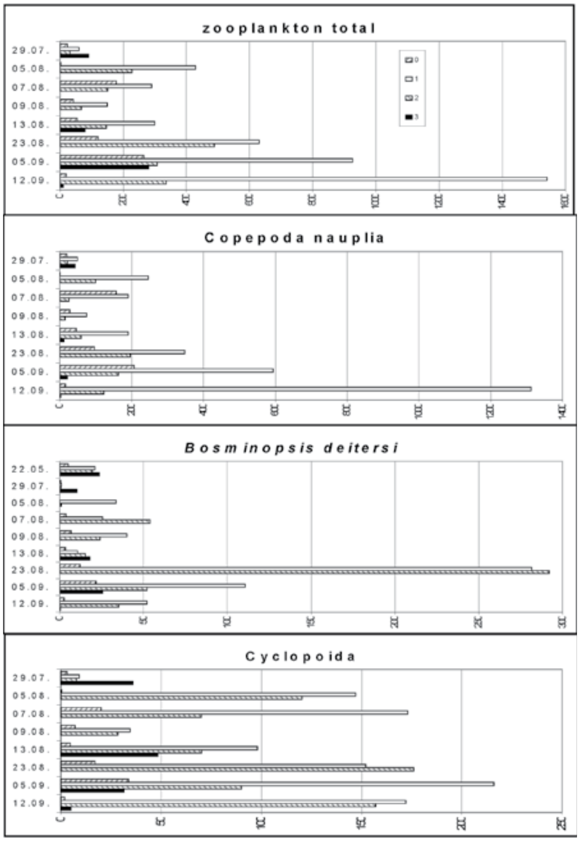


**Figure 2:** Lago Tupé 1974, abundance (x-axis: individuals per cubic meter) of total zooplankton, nauplia, Bosminopsis deitersi and Cyclopoida at sampling dates (y-axis) in the first three meters depth (0, 1, 2, 3 meter).

migrations. This behavior should derive benefits for the migrating animals. Zooplankton populations migrate at day to the dark to avoid predators that recognize their prey visually and migrate at night to near the surface to graze on phytoplankton (Lampert & Sommer 1997).

The vertical distribution of zooplankton in Lago Tupé between 1974 and 2002 is markedly different. In 2002 the zooplankton is distributed down to 11 meter just above the sediment (Fig. 3). As already mentioned in 1974 we did not found zooplankton under the depth of three to four meters, the limiting factor was oxygen. Oxygen in 2002 is also only distributed to four meters depth (Fig. 4). The vertical distribution of the other chemical data like conductivity, pH, and temperature give no hint why zooplankton in 2002 was found in depths greater than four meters (Fig. 4). A possible explanation is that the water level of the Rio Negro was lower in 2002 than in 1974. So the outflow from the lake in 2002 into the Rio Negro was remarkable and zooplankton from the subsidiary branches of Rio/Lago Tupé was washed into the deeper layers of the centre of the lake.

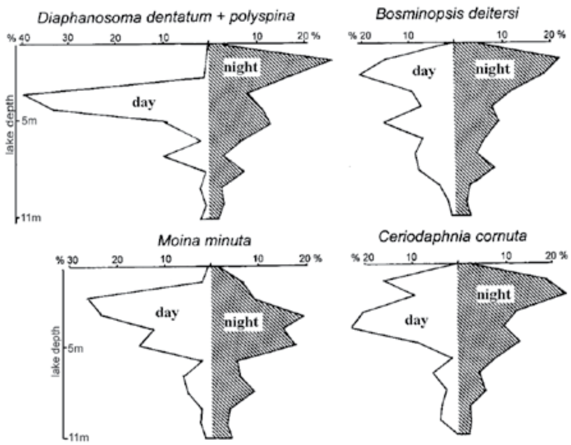


**Figure 3:** Vertical distribution of different species at 15 hours and 3 hours (shaded area) on 14th/15th of September 2002 in Lago Tupé. Shown is the percentage of the population at depth intervals

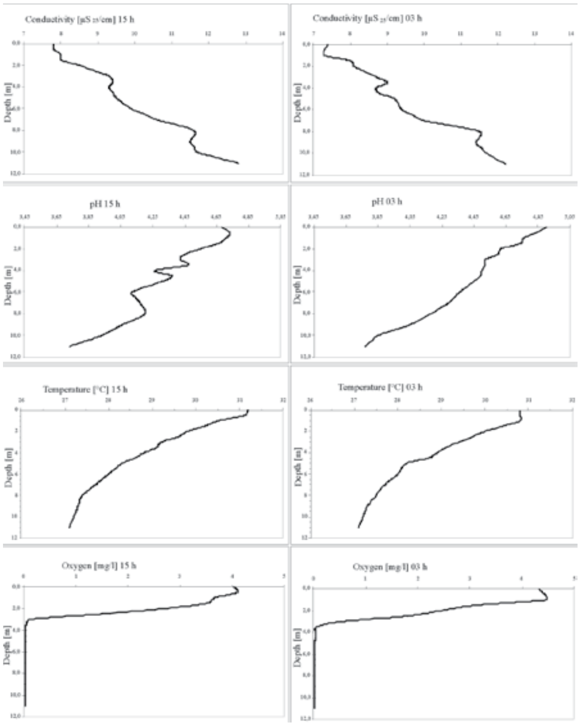


**Figure 4:** Vertical distribution of chemical data on 14th/15th of September 2002 in Lago Tupé at 15 hours (day) and 3 hours (night)

From Fig. 3 we cannot draw the conclusion that the depicted species undergo vertical migration. Much of the population of *Diaphanosoma* tends to the surface at night whereas *Moina* tends to deeper layers. In *Bosminopsis* and *Ceriodaphnia* no trend can be seen. The problem already mentioned cannot be solved: that below 4 meters is no oxygen but there live zooplankton species.

In November 2001 at a lake depth of about 4.5 meter Previatelli *et al.* (2005) investigated in Lago Tupé the vertical distribution of the zooplankton during one day at a three hour interval. From three meters on to ground there was practically no oxygen. Most taxa presented high abundances at three meters or below mostly during daytime. Especially *Holopedium amazonicum* is living between three an four meters depth during the whole investigation. So the question arises: what makes it attractive to live under unfavorable conditions? It is known that in humic waters bacteria play a central role (Hessen 1998). In a humic lake in Finland (Arvola *et al*. 1992) the highest bacterial biomass was found in the anoxic hypolimnion. Also mixo- and heterotrophic flagellates were found at that stratum and also a small proportion of *Daphnia longispina* which are efficient filtrators of bacteria. The lower boundary of edible particles is determined by the mesh width of the filtering apparatus of Cladocera and Copepoda (Lampert & Sommer, 1997). *Holopedium gibberum* is known to have coarse meshes, for *H. amazonicum* this is not known.

Dark field experiments (Daniel *et al*. 2005) have shown that zooplankton can grow and reproduce in humic waters independently from recent phytoplankton production. The food quality in humic lakes for zooplankton is high, measured as polyunsaturated fatty acids (Gutseit *et al*. 2007). It would be interesting to examine the biomass and vertical distribution of bacteria, flagellates and ciliates and their biochemical contents in Lago Tupé.

Some zooplankton species seem to undertake vertical migration in Lago Tupé as the diaptomid copepod *Aspinus acicularis* and his copepodites and *Bosmina longirostris* (Previattelli *et al*. 2005). *Bosminopsis deitersi* and *Holopedium amazonicum* did not show vertical migration.

Another interesting fact is that we caught in 2002 much more individuals (two to fivefold) at three hours at night than at 15 hours. This leads to the assumption that at night horizontal migration may take place. But this must be investigated experimentally.

Interesting is the larva of the Bryozoa, Gymnolaemata called Cyphonauta that are common in the plankton of lake Tupé but also in the Rio Negro. Larvae of that type are known from marine environments (Zimmer & Woollacott 1977) but not from freshwater. In an internet publication Timothy S. Wood (2005) reports on the discovery of *Hislopia* larvae in Thailand.

We found in 1974 up to nearly 50 individuals per Litre in Lago Tupé with a characteristic depth distribution (Fig. 5). Most of the larvae live in the first meter under the lake surface. The larvae from marine species are known to be planktotrophic animals (Zimmer & Woollacott 1977). Up to date nothing is known about the biology of the Amazonian larvae.

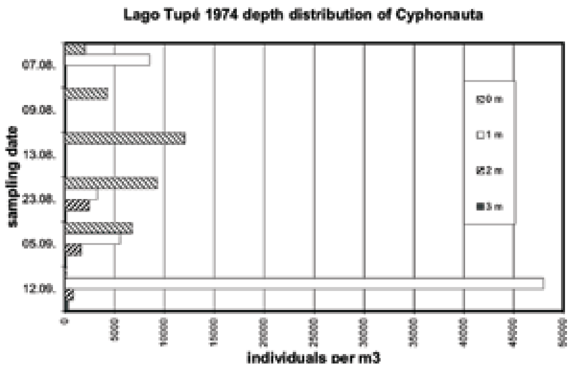


**Figure: 5** Depth distribution of bryozoan larvae in Lago Tupé 1974 at different data

## Spatial heterogeneity in 2002

Hutchinson (1967) annotated in his book about plankton that in large lakes or those with very irregular forms a considerable heterogeneity of horizontal zooplankton distribution can be predicted. A possible reason can be different water masses with different physical and chemical characteristics. Espíndola *et al.* (2000) sampled in the Tucuruí reservoir various stations that differed in morphometry and the presence of "flooded forest". The heterogeneity between the stations in regard to Cladocera and Copepoda was mainly quantitatively whereas in rotifers it was quantitatively.

The dendritic form of Lago Tupé (Fig. 1) resembles much of many man-made reservoirs by damming a river. As can be seen from table 4 the temporal and spatial heterogeneity is great. The sampling stations do not differ very much, except Central, Canal and Rio Negro. They were shallow (max. 30 cm depth) with woody debris and a soft bottom. There were no aquatic macrophytes; the main difference was the shading by the bank trees.

From the Cladocera *Diaphanosoma dentatum* and *D. polyspina*, *Bosminopsis deitersi*, *Bosmina longirostris, Ceriodaphnia cornuta s.l., Moina minuta* were found at all sampling stations of the lake. The same holds true for the copepods *Rhacodiaptomus retroflexus, Aspinus acicularis* and *Diaptomus s.l. linus*. But the temporal heterogeneity and the appearance of other species leads to the impression that zooplankton in each branch of the lake is considerably independent from each other.

A cluster analysis of the occurrence of the zooplankton species shows that we can distinguish five clusters (Fig. 6). The greatest group consists of Igarapés Pedras, Helena, Cachoeira and Chefe, the second is Ig. Monteiro and Fim do braço secundário and the third is Canal and Central. The sampling station of the Rio Negro differs from those of Lago Tupé, but astonishingly the Igarapé da Terra Preta is very different from the other lake and river stations. Neither the morphology of the sampling station (Aprile & Darwich 2005) nor the water chemistry (Darwich *et al.* 2005) can explain the differences in the biology to the other sampling stations.

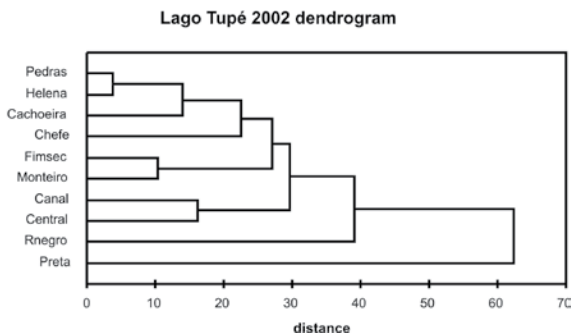


**Figure 6:** Dendrogram of the Euclidean distance of occurrence of zooplankton species in the subsidiary branches of Lago Tupé and the Rio Negro in 2002

**Table 4 -** Semi-quantitative data of zooplankton in Lago Tupé and its branches

| Lago Tupé 2002 | Ig. Chefe | | | | | Ig. Helena | | | | | Ig. das Pedras | | | | | Ig. da Cachoeira | | | | | Ig. do Monteiro | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 14.09. | 27.09. | 12.10. | 19.10. | 10.11. | 14.09. | 27.09. | 12.10. | 19.10. | 10.11. | 14.09. | 27.09. | 12.10. | 19.10. | 10.11. | 14.09. | 27.09. | 12.10. | 19.10. | 10.11. | 14.09. | 27.09. | 12.10. | 19.10. | 10.11. |
| *Holopedium amazonicum* | x | x | | | | | | | | | | | | | | | | | | | | x | | x | |
| *Diaphanosoma dentatum* | x | | | | | x | | | | | x | | | | | x | | | | | | | | x | |
| *D. polyspina* | x | | | | | x | | | | | x | | | | | x | | | x | | x | | | x | |
| *D. brevireme* | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Bosminopsis deitersi* | x | x | xx | xx | | x | x | | xx | x | x | | | xx | | x | | | xx | xx | x | | | x | x |
| *B. brandorffi* | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Bosmina longirostris* | x | x | | | | x | x | | x | | x | x | | x | | | | | | | x | x | | | |
| *B. tubicen* | | | | | | | | | | | | | | x | | | | | | | x | | | xx | |
| *B. brehmi* | | | x | | | | | | x | | | | | | | | | | | | | | | x | x |
| *Daphnia gessneri* | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Ceriodaphnia cornuta* | xx | xxx | | | | xx | x | | | | x | x | | | | xx | x | | | | x | xx | | x | |
| *Moina minuta* | | x | x | | | x | x | | | | x | | | | | x | | | x | | x | x | | | |
| *M. rostrata* | x | | | | | | | | | | | | | | | | | | | | | | | | |
| *Streblocerus pygmaeus* | | | | x | | | | | | | | | | | | | | | | | | | | | |
| *Chydoridae* | | | x | x | x | | | | | | | | | x | x | | | | | x | | | | | xx |
| *Kurzia latissima* | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Chydorus pubescens* | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Cyclopoida* | xx | x | xx | xx | x | x | x | | xx | x | x | x | | xx | x | xx | x | | xxx | xx | xx | x | | xx | xx |
| *Rhacodiaptomus retroflexus* | xx | xx | | | | xx | x | | x | | x | x | | x | | x | x | | xx | | x | x | | xx | |
| *R.* nov. spec. | | | | | | | | | | | | | | | | | | | xx | x | | | | x | |
| *Aspinus acicularis* | x | | x | | | x | | | | | x | x | | | | x | x | | x | | x | xx | | xx | x |
| *Dactylodiaptomus pearsei* | x | x | | | | | | | | | | | | | | | | | | | | | | | |
| *Dasydiaptomus coronatus* | | | | | | | | | | | | | | | | | | | | x | x | | | x | |
| *Diaptomus* nov. spec. | | x | | | | x | | | | | | | | | | x | x | | x | | | | | xx | |
| *Diaptomus linus* | x | | | | | x | | | x | | | | | x | | | x | | xx | | x | | | xx | |
| *Argyrodiaptomus azevedoi* | | | | | | | | | | | | | | | | | | | | | | | | x | |

x few individuals xx many individuals xxx very much individuals

| Lago Tupé 2002 | Fim braço secundário | | | | | Ig. Terra Preta | | | | | Central | | | | | Canal | | | | | rio Negro | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 14.09. | 27.09. | 12.10. | 19.10. | 10.11. | 14.09. | 27.09. | 12.10. | 19.10. | 10.11. | 14.09. | 27.09. | 12.10. | 19.10. | 10.11. | 14.09. | 27.09. | 12.10. | 19.10. | 10.11. | 14.09. | 27.09. | 12.10. | 19.10. | 10.11. |
| *Holopedium amazonicum* | x | | x | | | x | x | x | x | | | | | x | | | | | x | | | | x | | |
| *Diaphanosoma dentatum* | x | | x | | | x | | x | x | | x | | | | | | | | x | | | | | | |
| *D. polyspina* | x | | | x | x | x | x | x | x | x | x | x | | x | | xx | x | | x | | x | x | xx | | |
| *D. brevireme* | | | | | | | | | | | | | | | | | | | | | x | | | | |
| *Bosminopsis deitersi* | `x | | | x | x | x | x | | x | x | xx | x | x | x | x | x | x | | x | | xxx | x | xx | | |
| *B. brandorffi* | | | | | | | | | | | | | | | | | | | | | x | | | | |
| *Bosmina longirostris* | x | | x | xx | | x | x | xxx | | | x | x | x | x | | | x | | | | x | xx | xxx | | |
| *B. tubicen* | | | x | | | | | x | x | | x | | | x | | x | | | x | | x | | x | | |
| *B. brehmi* | | | | | x | | | | | | | | | x | | | | | | | | | | | |
| *Daphnia gessneri* | | | | | | | | | x | | | | | | | | | | | | | | | | |
| *Ceriodaphnia cornuta* | xxx | | xx | | | xxx | xx | xxx | x | | xx | xx | | | | xx | x | | | | | | | | |
| *Moina minuta* | x | | x | x | | xx | | x | x | x | x | x | | x | | x | | | xx | | x | | xx | | |
| *M. rostrata* | | | | | | x | | | | | x | | | | | | | | | | | | | | |
| *Streblocerus pygmaeus* | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Chydoridae* | x | | | | x | | x | | | | | x | | | | | | | | | x | x | | | |
| *Kurzia latissima* | | | | | | | | | | | x | | | | | | | | | | | | | | |
| *Chydorus pubescens* | | | | | | | | | | | x | | | | | | | | | | | | | | |
| *Cyclopoida* | x | | xx | xx | xx | x | | xx | xx | xx | xxx | x | x | xx | xx | x | x | | x | | xxx | x | x | | |
| *Rhacodiaptomus retroflexus* | xx | | xx | xx | | x | xx | xx | x | | x | xx | | x | | x | x | | x | | | | x | | |
| *R.* nov. spec. | | | | x | | | | | x | x | | | | | | | | | | | | | | | |
| *Aspinus acicularis* | x | | x | | | | | x | x | x | x | x | | x | x | | | | x | | | | x | | |
| *Dactylodiaptomus pearsei* | | | | | | | | x | x | | x | | | | | x | | | | | x | xx | | | |
| *Dasydiaptomus coronatus* | | | x | | x | | | x | | x | | | | | | | | | x | | | | | | |
| *Diaptomus* nov. spec. | x | | x | x | | x | x | x | xx | | | | | | | | x | | x | | | | | | |
| *Diaptomus linus* | | | x | xx | | | x | x | xx | x | | | | | | | | | | | | | | | |
| *Argyrodiaptomus azevedoi* | | | | | | | | x | x | | | | | | | | | | | | | | | | |
| | x | few individuals | | | | | | xx | many individuals | | | | | | xxx | very much individuals | | | | | | | | | |

## Body size distribution of zooplankton in 2002

Another fact that is striking in tropical zooplankton: “The species size and spectrum of limnetic Cladocera and Copepoda is markedly smaller in the tropical region than in the temperate regions” (Fernando 1980). This was also shown in a convincing manner by Gillooly & Dodson (2000) by comparing the Cladocera in water bodies from 77° south to 81° north over the American continents: “The mean body length of limnetic cladocerans was smallest in tropical regions, increasing to a maximum size in temperate regions (50-60°) in both Northern and Southern Hemispheres.” Fernando (2002) and others claim the small size of the zooplankton in the tropics due to year-round predation by fish. That predation plays its role (Gliwicz 2003), can be seen in the fishless lakes of the Nhecolandia lake district, Pantanal Matogrossense where the 2 mm big diaptomid copepod *Argyrodiaptomus nhumirim* has been found (Reid 1997) whereas in the other lakes smaller species of copepods were found. This is in accordance with the size-efficiency hypothesis (SEH) of Brooks and Dodson (1965).

Another factor discussed to explain the paucity of large cladocerans in the tropics is the ecophysiology of the animals that is the metabolic efficiency tenet of SEH (Hart 1996). Temperature regulates many physiological processes in animals such as feeding rate, food assimilation rates and the rates of further transformation of assimilated resources including the rate of their investment into reproductive larger cladocerans have a lower upper thermal tolerance (Gillooly & Dodson 2000). This could be one reason why they do not appear in tropical zooplankton communities. Lehmann (1988) showed that threshold food levels increase with water temperature. He hypothesized that food acquisition abilities for large-bodied crustacean zooplankton do not keep pace with metabolic costs as temperature rise. Larger animals may face the classic surface-to-volume dilemma. On the other hand larger daphnids have lower threshold food levels and, in the absence of predators, should be

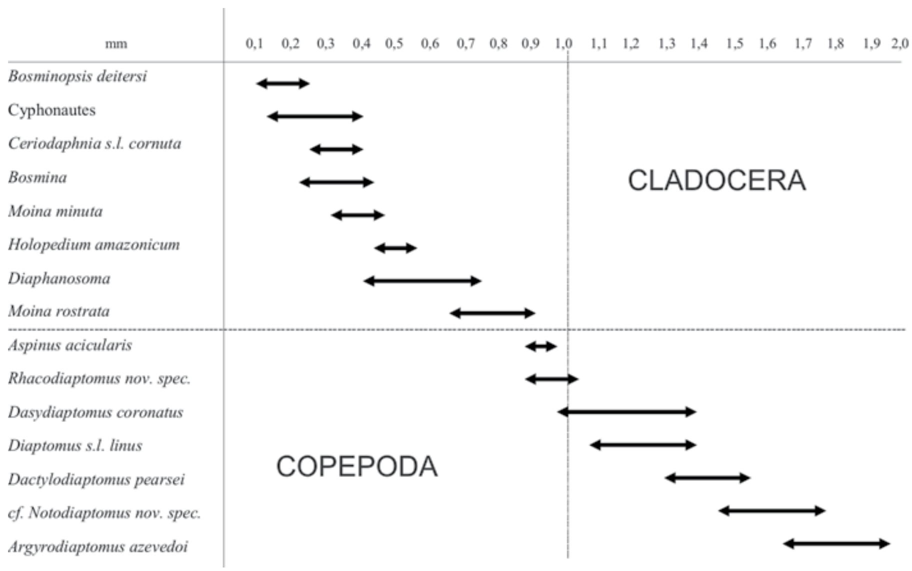


**Figure 7 -** Size distribution of zooplankton taxa in Lago Tupé, the dashed line at 1 mm is inserted for better visualization of the sizes

more successful competitors for food (Lampert & Sommer 1997; Gliwicz 2003).

"Zooplankton size structure will rarely be controlled exclusively by one or the other factor, but rather by their interaction" (Hart 1996). Gliwicz (2003) pointed out, that "The phenomenon of temperature selection for individual regulation of the pace of life needs to be studies more, and it could become an area of fascinating experimental work, at least for offshore ecologists".

Our data from Lago Tupé show that the smaller species are all cladocerans. This is in accordance with Fernando (1980): "The lower end of the size range is occupied in both regions by Cladocera." The biggest cladoceran species in Lago Tupé *Moina rostrata* lives in deeper layers just above the anoxic layer. There little light is present and therefore the animals are well protected to visible predators like fish. In temperate brown water lakes (Wissel *et al.* 2003) as in other fishless lakes the predation of *Chaoborus* species and other invertebrate predators is more important than fish predation and is followed by a shift in the zooplankton assemblage toward larger species (Gliwicz 2003). Nothing is known up till now about zooplankton predation by fish or invertebrate predators. *Chaoborus* exists in Lago Tupé but the predation effect on zooplankton is unknown.

Copepoda especially Calanoida in Lago Tupé are of the same size range as Calanoida from India and Southeast Asia (Ranga Reddy 1994). Lewis (1996) stated that calanoids, which are often among the largest of zooplankton in temperate lakes, are absent or rare in many tropical lakes. This applies perhaps to some Asian lakes.

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