

## Temporal fluctuation and reproduction of *Thermocyclops decipiens* (Copepoda, Cyclopoida) in an eutrophic lake of central Brazil

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Received 15-VII-2000. Corrected 19-III-2001. Accepted 17-X-2001.

**Abstract:** Lake Paranoá is an eutrophic reservoir situated in the urban region of Brasília. This study was carried out in a fixed collection station located in the Riacho Fundo branch of the reservoir. Zooplankton samples were collected at intervals of 3-5 d at 9:00 a.m. during two months in the dry and rainy seasons for two years (dry-1996, rainy-1997, dry-1997 and rainy-1998), using a 64 µm-mesh plankton net. The most predominant species was *Thermocyclops decipiens* (about 50% of the total zooplankton community), which during the whole period had a high reproductive rate. The highest densities were found in the dry-1996 season (1700 ind/l for nauplii), and also fluctuated widely overtime. Nauplii stages dominated during the four periods, comprising 50-75% of the total population density. Oviparous females peaked in the dry-1996 and rainy-1997 seasons, with 20-30% of the total females. The largest peak in egg production occurred during the dry-1996 season, and the total egg production was  $2.0 \times 10^3$  eggs/l. *Mesocyclops longisetus* is a first record for Lake Paranoá. The ecological factors that determine the success of *T. decipiens* in eutrophic systems are related to omnivorous feeding habits and prey-predator interactions.

**Key words:** *Thermocyclops decipiens*, temporal fluctuation, reproduction, Lake Paranoá, Brazil.

The population dynamics of zooplankton species in tropical lakes involves complex interactions among biotic and abiotic factors. Identification of the main factors that control ecological processes in tropical regions is essential to achieve detailed information about the temporal dynamics of the zooplankton community.

In tropical water bodies, the rate of the processes tends to be higher than in temperate ones, as suggested by Thornton *et al.* (1990). Tropical planktonic crustaceans have shown fast development and their generation time is usually less than one week (Berner-Fankhauser 1987). Seasonal analyses are the usual approach in temporal variation of the zooplankton. However, monthly sampling is not sufficient to obtain a realistic picture of population dynamics of zooplankton as well as

their importance in the ecosystem. The apparent stability in abundance of zooplankton species in tropical ecosystems disappeared when studies with different sampling intervals were carried out (Duncan and Gulati 1981, Twombly 1983, Twombly and Lewis 1989, Padovesi-Fonseca 1997). Annual and seasonal trends may be hidden by short-term irregular changes (Twombly 1983). Therefore, the sampling frequency has great influence on investigation of population dynamics in tropical water bodies.

Various factors have been pointed out as control mechanisms in tropical zooplankton communities. According to Saunders and Lewis (1988), there are two distinct sets of control that converge on the zooplankton herbivores: food and predation. Mixing and stability in water column affect the phytoplankton,

which in turn control herbivore populations through changes in food quality and/or quantity. The selective predation is a second set of control and determine the mortality and thus the composition and density of zooplankton populations.

Lake Paranoá is an eutrophic reservoir located in the city of Brasília, with the periodic occurrence of blooms of *Microcystis aeruginosa* and fish slaughter. Several studies in this reservoir have shown seasonal fluctuations of the plankton community. Seasonal phytoplankton variation was studied in the northern arm of the reservoir (Pinto-Coelho and Giani 1985). These studies showed a heterogeneous structure of phytoplankton community and its relation to nutrients inflow. Spatio-temporal variation of the zooplankton community was carried out in this part of the reservoir (Pinto-Coelho 1987). This study showed short-term fluctuations of rotifers and higher densities of zooplankton in rainy season. Branco and Senna (1996) analysed spatio-temporal variation of the zooplankton community in different parts of the lake. The zooplankton showed higher densities and lower diversity in parts with eutrophic conditions.

The genus *Thermocyclops* Kiefer, 1927 includes several species which are common and frequently numerous in the zooplankton of ephemeral, artificial and eutrophic waters (Reid *et al.* 1988). In the neotropical region, *T. decipiens* Kiefer, 1929 tends to dominate the crustacean zooplankton in eutrophic waters (Sendacz 1984, López 1994).

The aim of this study was to investigate the temporal fluctuation and reproduction of *T. decipiens* (Kiefer 1929) at one sampling station located in the Riacho Fundo branch of the reservoir, over two dry and rainy seasons.

## MATERIALS AND METHODS

Lake Paranoá (15°48' S, 47°47' W) is a large, relatively shallow, eutrophic reservoir (area 38.1 km<sup>2</sup>, volume 498.6 x10<sup>6</sup> m<sup>3</sup>, max. depth 40 m, mean depth 13 m), situated in the

urban region of Brasília, at an altitude of 1000 m. The regional climate is characterised by two seasons: a cool-dry season (May-September) and a warm-rainy season (October-April). Four main tributaries feed the reservoir: Ribeirão do Torto and Córrego do Bananal (northern part), and Ribeirão do Gama and Riacho Fundo (southern part). It has an irregular form, with a central area and four extended branches, corresponding to the former valleys of tributaries (Fig. 1). Riacho Fundo branch is the more eutrophic part of the reservoir because it receives the effluents of the south sewage treatment plant and the loads transported from the Riacho Fundo tributary. This branch has an area of 4.6 km<sup>2</sup>, a volume of 39.3 x10<sup>6</sup> m<sup>3</sup>, the maximum depth is 19 m, and the mean is depth 8.6 m (Mattos *et al.* 1992).

This study was carried out at a fixed collection station located in the Riacho Fundo branch of the reservoir. Zooplankton samples were collected at 9:00 a.m. at intervals of 3-5 d during two months in the dry and rainy seasons for two years (dry-1996, rainy-1997, dry-1997 and rainy-1998).

The samples were taken by vertical hauls (from 1 m to surface) of a 64 µm-mesh plankton net, and preserved in formalin-sucrose solution (Haney and Hall 1973). Studies of the primary production at many parts in Paranoá reservoir (PintoCoelho and Giani 1984) considered

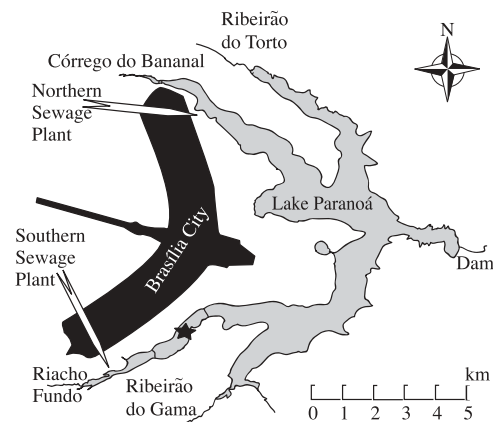


Fig. 1. Location of sampling point in Lake Paranoá.

this depth (1 m) the most productive of the euphotic layer.

Three 1 ml subsamples were counted in a Sedgwick-Rafter chamber to enumerate the naupliar stages of *T. decipiens*. Copepodites and adults were counted with a stereomicroscope at 25x magnification. Subsample size was chosen so that > 100 individuals of the population were counted. Subsamples were taken from a well mixed whole sample. This procedure was repeated until at least 100 specimens (Copepoda stages) were counted (Kurke *et al.* 1999). Ovigerous and non-ovigerous females, males, eggs, copepodites (I-II and III-IV) and nauplii were counted. According to Saunders and Lewis (1988), given the expected conformance of replicate counts to a Poisson distribution, a coefficient of variation of 10% is reached with density of 7.6 organisms/l for crustaceans. As *T. decipiens* is a common species in this lake, the average density is sufficient to place the coefficient of variation well below 10% for individual abundance estimates, with the exception of males and ovigerous females.

Coefficients of variation ( $CV = 100.Sx$ ) were used as a measure of temporal variation of the population.

Non-parametric Mann-Whitney U-Tests were used to test differences in density among dry and rainy seasons.

The population birth rate ( $b = [\ln(E_t + 1)/D_e]$ ) (Paloheimo 1974), population growth rate [ $r = (\ln N_{t_2} - \ln N_{t_1}) / (t_2 - t_1)$ ], and population death rate ( $d = b - r$ ; Polishchuk and Ghilarov 1981) were calculated for the species.  $E_t$  is the number of eggs/female; the egg development times ( $D_e$ ) used were those determined for the same species, and for tropical systems with temperatures comparable to those in Lake Paranoá (Rietzler 1995). These demographic parameters were calculated for the dry-1996 and rainy-1997 seasons.

## RESULTS

In the present study, the reservoir showed isothermal periods followed by stratified

profiles, during both dry and rainy seasons. The warm-rainy period showed higher temperatures in the surface layer (max. 30°C) and pronounced stratification, leading to oxygen decrease in the deepest water (min. 18% saturation). The conductivity varied from 85 to 109 mS/cm at 25°C, pH from 5.4 to 9.0, chlorophyll-*a* from 51.4 to 135.2 mg/l, and water transparency (Secchi depth) from 0.6 to 1.2 m.

*Thermocyclops decipiens* was the most predominant species, reaching about 50% of the total zooplankton community. The qualitative analysis of the zooplankton revealed another copepod species, *Mesocyclops longisetus*, which represents the first record for Lake Paranoá. This analysis was realised in various sites of the lake and its occurrence has been sporadic. No organism for *M. longisetus* was computed in the sample counting during this study. *Thermocyclops decipiens* was present during the whole period, and showed high rates of reproduction. Naupliar stages dominated during the four periods, comprising 50-75% of the total population density. Copepodites III-IV stages contributed 12-29%, copepodites I-II with 2-15%, and adults 10% of the total population density during the study.

**Temporal fluctuation:** Temporal fluctuations of *T. decipiens* population for dry-1996/1997 and rainy-1997/1998 seasons are shown in Figs. 2 and 3.

Males was scarce and remained with low densities during the whole period, reaching 8.2 ind./l in dry-1996 season. Ovigerous females showed high densities only during dry-1996 period, reaching 32.7 ind./l. Total females showed pronounced temporal variation throughout the study (50 to 78.5% CV), reaching 112.5 ind./l (dry-1996) to 46.3 ind./l (dry-1997). Ovigerous females comprised 21.6% (dry-1996), 16.9% (rainy-1997), 11.2% (dry-1997) and 52.7% (rainy-1998) of the total females.

Younger stages of *T. decipiens* fluctuated markedly overtime in this study, specially naupliar stages, ranging 73.9 to 110% CV. Higher peaks of naupliar abundance occurred in late

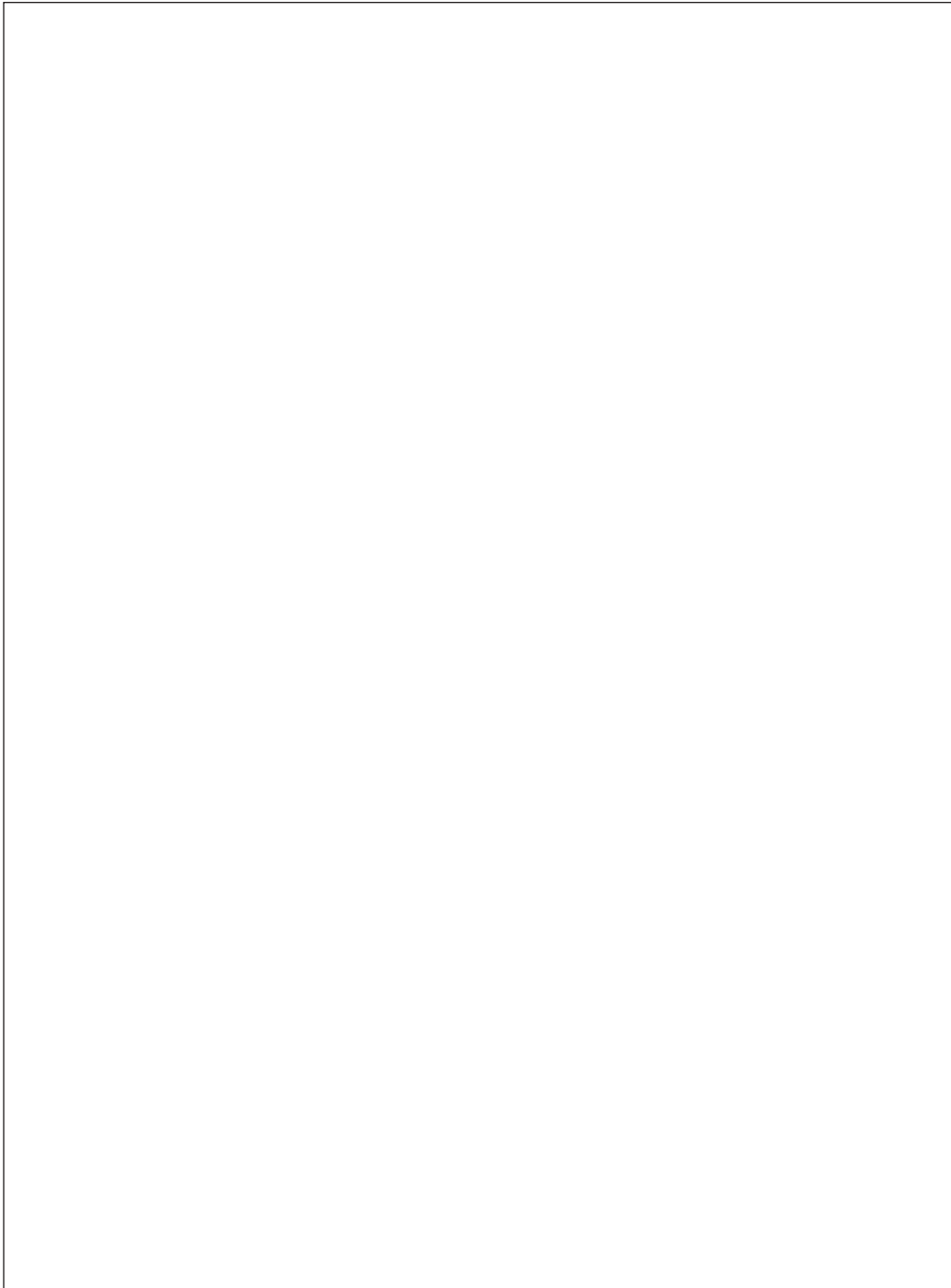


Fig. 2. Abundance of *Thermocylops decipiens* population during the dry-1996/1997 seasons in Lake Paranoá (Brazil). (a) and (c) total females. (b) and (d) nauplii, copepodites I-II and III-IV.

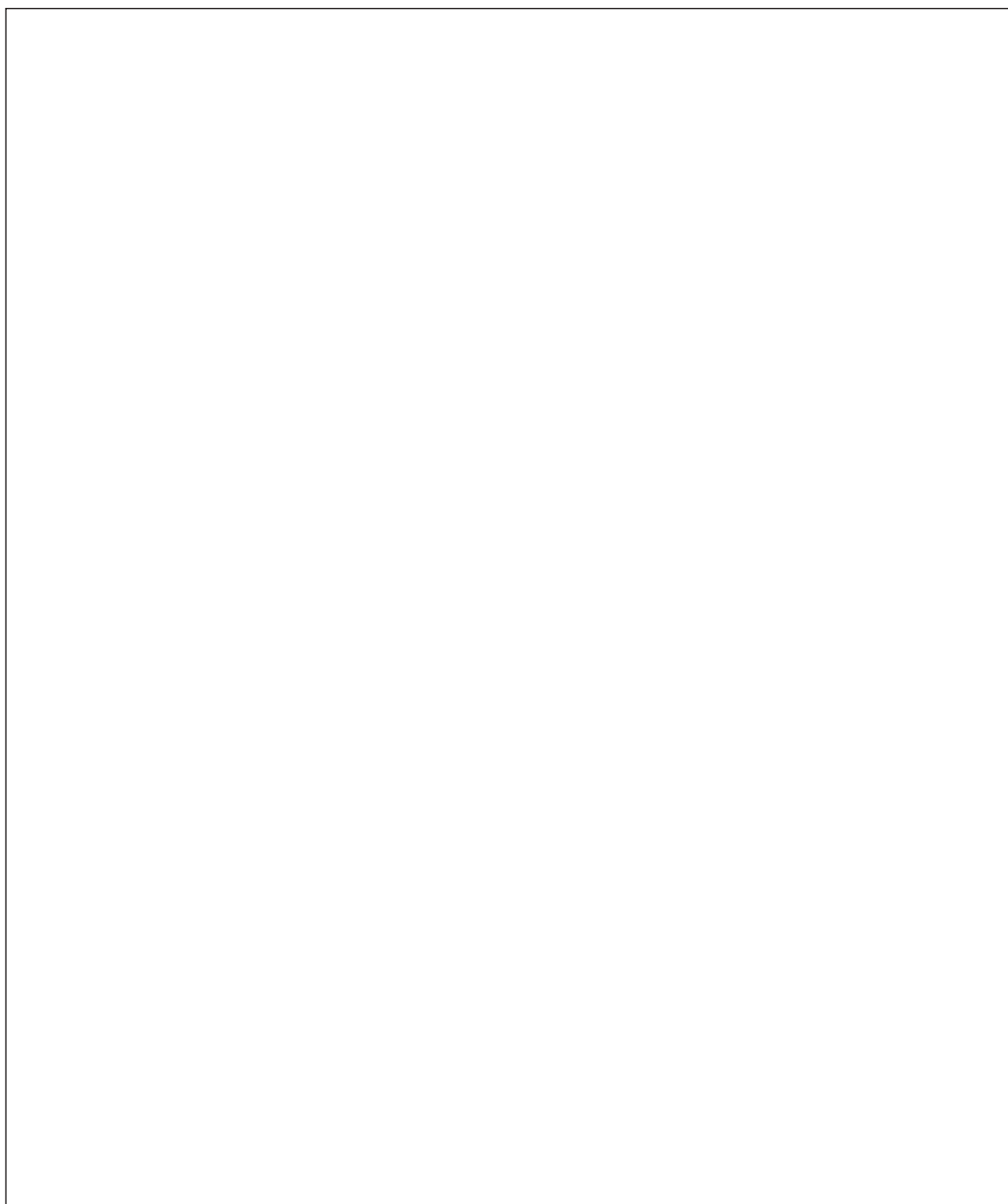


Fig. 3. Abundance of *Thermocylops decipiens* population during the rainy-1997/1998 seasons in Lake Paranoá (Brazil). (a) and (c) total females. (b) and (d) nauplii, copepodites I-II and III-IV.

September (dry-1996), with 1 675.3 ind./l, and in mid-January (rainy-1998), reaching 1 115.4 ind./l. In opposite situation, during dry-1997 and rainy-1998 periods, abundance of copepodites stages remained low, and the highest density was 89.3 ind./l for cIII-IV (rainy-1998).

#### **Comparisons between seasons:**

*Dry seasons (1996-1997):* Populations of *T. decipiens* were smaller throughout the dry-1997 period than during the preceding dry-1996 season. The population size in the dry-1997 period was only 20.2% of that during dry-1996, a significant difference (U-Test,  $P < 0.05$ )

TABLE 1

*Mann-Whitney test (U) for Thermocylops decipiens population in Lake Paranoá (Brazil) between dry-1996/97 seasons (n = 31) and between rainy-1997/98 seasons (n = 30)*

Categories	Dry-1996/97 seasons		Rainy- 1997/98 seasons	
	U	P	U	P
Total population	2.22	*	0.43	NS
Males	3.07	*	0.97	NS
Total females	3.21	*	1.60	NS
Ovigerous females	3.46	*	2.25	*
Copepodites III-IV	2.26	*	2.17	*
Copepodites I-II	2.80	*	0.75	NS
Nauplii	1.06	NS	2.37	*

\* P < 0.05, NS P > 0.05

(Table 1). This result was obtained for several population categories, as follows: males, total females, ovigerous females, and copepodites I-II and III-IV. In contrast, there was no significant difference in the number of nauplii stages between the two dry seasons (U-Test, P > 0.05) (Table 1).

*Rainy seasons (1997-1998):* The population sizes of *T. decipiens* were very similar between rainy seasons, and no significant difference in the population size was obtained between these periods (U-Test, P > 0.05) (Table 1). This result was obtained for several population categories, as follows: males, total females, and copepodites I-II. In contrast, there were significant differences in the number of ovigerous females, copepodites III-IV, and naupliar stages between the rainy seasons (U-Test, P < 0.05) (Table 1).

#### Demography:

*Dry-1996 season:* The population of *T. decipiens* fluctuated irregularly in August, with two successive peaks, and declined by late August. The population then increased in early September, and reached its highest peak at the end of the period (Fig. 4a). In August, the temporal variation of total egg production was similar to that of population size. In September there were two peaks in egg production, although the corresponding increase in population size was smaller than those in August (Fig. 4a). The last peak of total egg production occurred at the end of the period, before the

highest peak in population. This peak in population coincided with the highest abundance of naupliar stages (Fig. 2b).

Birth rates were high and relatively constant throughout the sampling period (Fig. 4b). Death rates were high and had a smooth temporal variation (Fig. 4b). Although birth rates remained high and constant, the high death rates resulted in low population growth rates.

*Rainy-1997 season:* Population size of *T. decipiens* also fluctuated irregularly, with two increases of abundance (Fig. 5a). Egg production varied widely, with two peaks coinciding with population size (one in early January and another in early February) (Fig. 5a). Egg stock remained lower than dry-1996 season (Fig. 5a).

Birth rates were high throughout this period, reaching higher rates than the preceding season (Fig. 5b). A slight decrease in birth rates occurred in early January. By mid sampling period, birth rates remained constant, and in late February increased slightly (Fig. 5b). Death rates were higher than dry-1996 period, and had a smooth temporal variation too (Fig. 5b). As in the preceding period, although birth rates remained high, high death rates resulted in low population growth rates (Fig. 5b).

#### DISCUSSION

The temporal fluctuation of *T. decipiens* was conspicuous throughout this study,



Fig. 4. Demographic analysis for *Thermocyclops decipiens* during the dry-1996 season in Lake Paranoá (Brazil). (a) total population and egg stock. (b) birth, growth and death rates.

although population density remained relatively high, contributing about 50% of the zooplankton community. This situation confirms the tendency to obtain more accurate results in relation to temporal fluctuation of the zooplankton in tropical areas, when samples are taken at shorter intervals. Sampling intervals in tropical areas should be commensurate with rapid zooplankton developmental rates. Seasonal trends can be interrupted by short-term irregular changes in

population size (Twombly 1983, Padovesi-Fonseca 1997).

This species was the single copepod reported in previous studies in Lake Paranoá (Starling 2000), showing high relative abundance of the community zooplankton at the Riacho Fundo branch (Branco and Senna 1996. Mattos *et al.* 1997). It showed densities between 50 and 600 ind./l, as documented by Branco (1991). However, Branco (*op. cit.*)

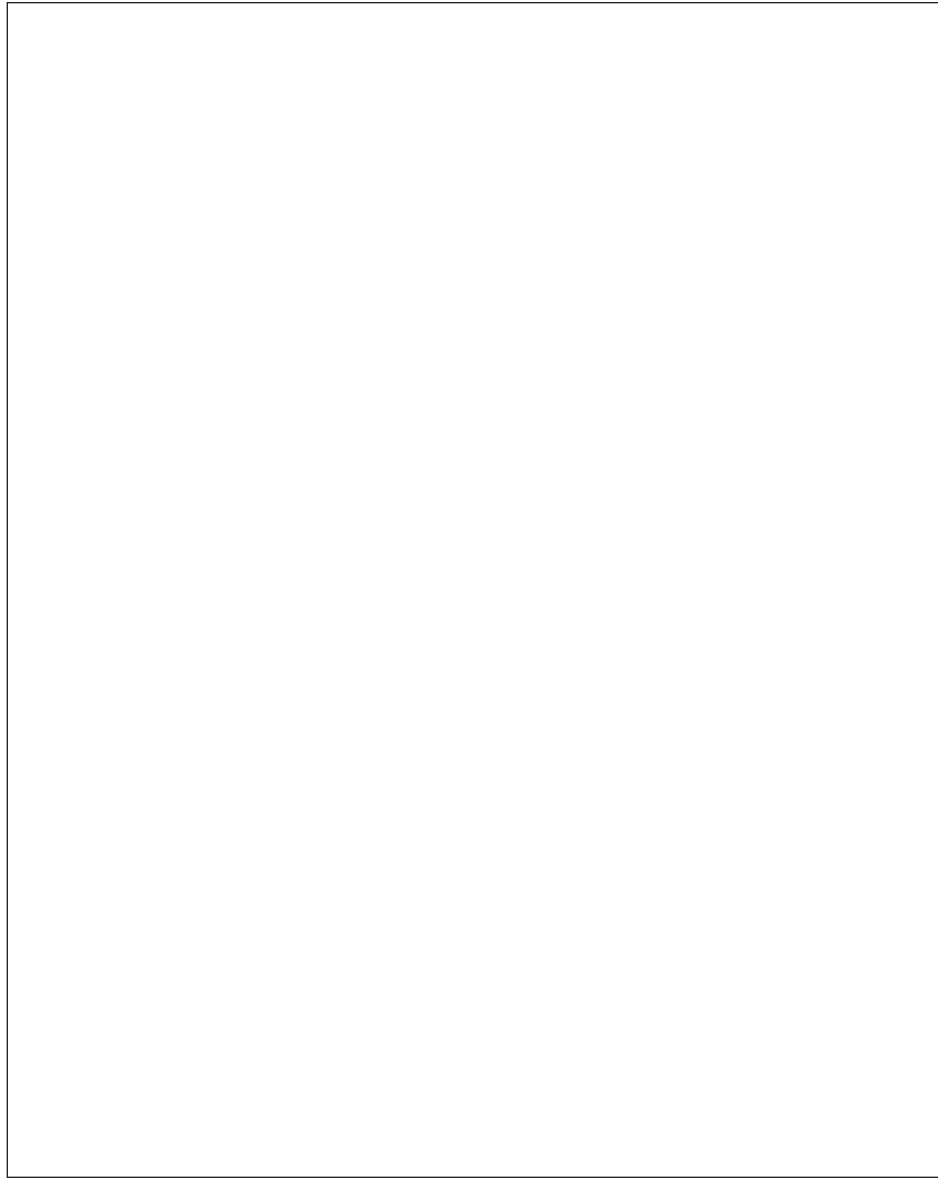


Fig. 5. Demographic analysis for *Thermocyclops decipiens* during the rainy-1997 season in Lake Paranoá (Brazil). (a) total population and egg stock. (b) birth, growth and death rates.

found that populations of *T. decipiens* were constant in the dry and rainy seasons, contrasting with the patterns of temporal fluctuation shown by this paper.

The predominance of this species is usually related with eutrophic systems (Reid *et al.* 1988, Carvalho *et al.* 1997), and may be an effective indicator of water quality. Lake

Paranoá has been considered an eutrophic system, because of the continuous inflow of nutrients, and this situation has been extensively reported (see, among others, Pinto-Coelho and Giani 1985, Mattos *et al.* 1992, Branco and Senna 1996). The Riacho Fundo branch is the part of the reservoir most affected by eutrophication. This segment is distinguished from the



remainder of the lake by the frequent occurrence of *M. aeruginosa* blooms as well as the development of banks of *Eichhornia crassipes*. Fish kills have occurred in this branch.

The regional climate is windy, producing total circulation in the reservoir, specially in the dry season, and the reservoir occasionally stratifies in the rainy season. However, we observed total mixing followed by stratification during dry and rainy periods (C. Padovesi-Fonseca *et al.* unpubl.). This confirms the influence of short-term environmental variations on physical processes in reservoirs, as emphasised by Tundisi (1996). In some cases, tropical zooplankton may have rapid developmental rates and shorter generation times, responding quickly to irregular physical changes.

The high densities and predominance of *T. decipiens* throughout this study in the Riacho Fundo branch evidenced the tolerance of this species to eutrophic conditions. There are also higher heterotrophic bacteria concentrations in this area (Branco and Senna 1996). Zooplankters in eutrophic systems can be efficient consumers of particulate food, such as detritus and bacteria (Pejler 1983, Pace 1986). Nevertheless, according to Rocha *et al.* (1997), eutrophic and productive Brazilian lakes such as Paranoá had lower zooplankton densities than mesotrophic lakes.

In this study, comparisons in population size between dry and rainy seasons over a two-year period showed a similar trend between rainy seasons, but there was a significant difference between dry seasons. During a 13-year (1982-1994) study of the zooplankton community in Lake Paranoá, Mattos *et al.* (1997) observed a higher amplitude of variation on the number of organisms in Riacho Fundo segment. However, there were no obvious alterations in the zooplankton community. For the present, the main factors which control the temporal variation in copepod abundance in Lake Paranoá (Riacho Fundo branch) remain unclear. There may be a complex interaction among conditions of trophic, suitable food, and the scarcity of large predators. More detailed investigations are need.

In more eutrophic systems, the food web is detritus-based, because of unsuitable quality of phytoplankton (Talamoni and Okano 1997). In this study, the phytoplankton community was dominated by *Cylindrospermopsis raciborskii*, a filamentous blue-green algae, with the occurrence of blooms of *M. aeruginosa* (C. Padovesi-Fonseca *et al.* unpubl.). These phytoplankton species have been considered unsuitable food for many zooplankton species (Talamoni and Okano *op. cit.*). Nevertheless, *T. decipiens* is one species with omnivorous feeding habits (Carvalho 1984) and with capacity to ingest and digest some cyanophyceans species (Infante 1978). In this study, there was no significant correlation between *T. decipiens* abundance and chlorophyll-*a* content (Spearman,  $P > 0.05$ ). Then, the reproductive activity of this species may have certain independence with respect to species composition and biomass of phytoplankton.

Fish community analysis in Lake Paranoá showed highest densities for tilapias (*Tilapia rendalli* and *Oreochromis niloticus*) in the Riacho Fundo segment (Grando 1989). These fish species are omnivorous by consuming various types of food, including organic matter from the sediment (Grando *op. cit.*). Stomach content analyses have revealed that sediment comprises 50%, in volume, of the food amount consumed by both tilapias in Lake Paranoá (Grando *op. cit.*). Another important fish species, "bluegill" (*Lepomis macrochira*), is considered visual predator and carnivorous, including the consume of juveniles and adults of *T. decipiens* (Grando *op. cit.*). Nevertheless, the Riacho Fundo segment has low water transparency (0.25 to 0.6 m) (C. Padovesi-Fonseca *et al.* unpubl.). Thus, the predation pressure by fish on *T. decipiens* population in the Riacho Fundo branch should be low, as result of low visual predation and the high food spectrum showed by predominant fish species in Lake Paranoá.

The invertebrate predation, mainly related by Chaoboridae larvae, has been considered to be low in this reservoir (Mattos *et al.* 1997).

Chaoboridae larvae were virtually absent in the present study, and this is a result of the sampling design, since these larvae usually hide in the deep and dark layers of the lake.

Birth rates of *T. decipiens* remained high throughout this study, even though the population size fluctuated widely. The coincidence of high birth rates with low population growth suggests that mortality controlled the species dynamics in Lake Paranoá during the study period.

According to Hutchinson (1967), variation in zooplankton abundance is related to temperature, suitable food, and predation. However, it is widely accepted that embryonic development of zooplankton species is regulated almost exclusively by temperature (Burgis 1970, Bottrell 1975, Herzig 1983). Many studies showed that food supply can affect the development time of zooplankton species (see, among others, Mullin and Brooks 1970, Woodward and White 1988, Hart 1991). These studies have revealed inverse relationships between development time and food supply; additionally, survival was higher when the food supply was enhanced.

#### ACKNOWLEDGMENTS

This study forms part of the research program on eutrophication of Lake Paranoá realised by NEL (Group of Limnological Studies). The authors thank FINATEC and Brazilian National Research Council (CNPq) for the financial support (CNPq proc: 420010/97-1) and grants to Mendonça-Galvão, (Master Scholarships). We thank Mariana Gomes Philomeno and Pedro O. Costa for technical assistance during the field work and laboratory analyses. We thank Firewarden Corporation of Brasília for field facilities.

#### RESUMEN

El lago Paranoá es una reserva eutrófica situada en la región urbana de Brasilia. Este estudio se llevó a cabo en

una estación de recolecta fija localizada en la rama Riacho Fundo de la reserva. Se recolectaron muestras de zooplankton a intervalos de 3-5 d a las 9:00 a.m. durante dos meses en las estaciones seca y lluviosa por dos años (seca-1996, lluviosa-1997, secca-1997 y lluviosa-1998), usando una red de plancton de 64 µm de poro. La especie más predominante fue *Thermocyclops decipiens* (cerca del 50% del total de la comunidad de zooplankton), la cual durante todo el período tuvo una tasa reproductiva alta. Las densidades más altas fueron encontradas en la estación seca-1996 (1700 ind/l para las nauplio), y también fluctuó ampliamente en el tiempo. Los estadios de nauplio dominaron durante cuatro períodos, comprendiendo 50-75% de la densidad de la población total. Las hembras ovígeras tuvieron picos en las estaciones seca-1996 y lluviosa-1997, con 20-30% del total de hembras. El pico más grande en producción de huevos fue durante la estación seca-1996, y la producción total de huevos fue de 2.0x10<sup>3</sup> huevos/l. *Mesocyclops longisetus* es un primer registro para Paranoá. Los factores ecológicos que determinan el éxito de *T. decipiens* en sistemas eutróficos están relacionados con los hábitos de alimentación omnívoros y las interacciones presa-depredador.

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