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Vertical distribution and diel migration of rotifers in a Parana River floodplain lake

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Abstract

The vertical distribution of zooplankton rotifers in the open waters of Laguna El Tigre was investigated. Rotifers showed a relatively uniform distribution throughout the water column. This pattern of distribution was maintained during the year and did not show variations in relation to hydrologic phases of inundation and isolation of the lake. Diel vertical migration of rotifers from the limnetic and the littoral area was investigated too. In littoral area rotifers exhibited a reverse migration, whereas in the limnetic the movements weıe less conspicuous. Horizontal migration was observed too, and there were interactions between horizontal and vertical distribution. Predation and competition offer a possible explanation.

Introduction

Two of the most interesting aspects of zooplankton ecology are probably the vertical distribution and diel migration. These have been explained as responses to environmental factors such as light, temperature and oxygen (Hutchinson, 1967), metabolic and demographic advantages and avoidance of visual or nonvisual predation (Kerfoot, 1970, 1985; Zaret & Suffern, 1976; Enright, 1977; Gliwicz, 1986; Bayly, 1986; Bollens & Frost, 1989; Lampert, 1993). There are many studies on diel migration on crustaceans, in marine waters and lakes, but there are relatively few accounts of diel migration and vertical distribution of rotifers, even fewer in shallow lakes and ponds.

In South America the floodplain shallow lakes are the most abundant waterbodies. They show limnological features very different from those of classical lakes (Esteves, 1988). They are characterized by a fluctuating water level, with phases of inundation and isolation from the river. In most cases the lakes have a limnetic area and a well defined littoral area, ringed by floating and rooted vegetation. Though there is information about the zooplankton of these lakes from Orinoco (Vasquez & Rey, 1992), Amazonas (Robertson & Hardy, 1984) and Paraná River (Paggi & José de Paggi, 1990) there is only information on vertical distribution and diel migration of crustaceans (Fisher *et al.*, 1983).

This work intends to answer the following questions: (1) Does the vertical distribution of rotifers show changes related with the inundation and isolation phases which are typical of these environments? (2) Do rotifers migrate in this shallow lake? (3) Is the migration pattern the same in the limnetic and littoral areas?

Study site

Laguna El Tigre is a shallow lake, located in the floodplain of the Parana River, near Santa Fe city, at 31 41′S, 60 40′W, with 33 500 m^2 of surface (Fig. 1). The lake has a wide littoral area ringed by *Eichhornia crassipes, Paspalum repens* and *Typha* sp. El Tigre is indirectly connected with the Correntoso River; during the period of low waters the lake is completely isolated from the river and at high waters the river floods it.

The floodplain lakes of the Middle Parana River are in the climatic belt of the river valley, which permits the entry of tropical climate into a temperate region. The

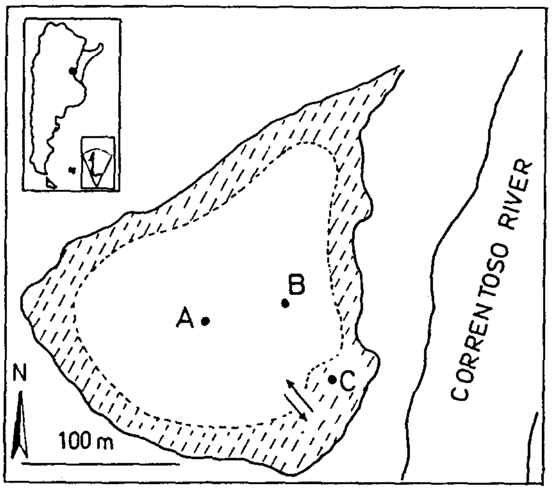

Fig. 1. El Tigre lake. Sampling sites for study of vertical distribution (A), vertical migration in limnetic area (B), and migration in littoral area (C). Shaded area indicates the vegetation of the littoral.

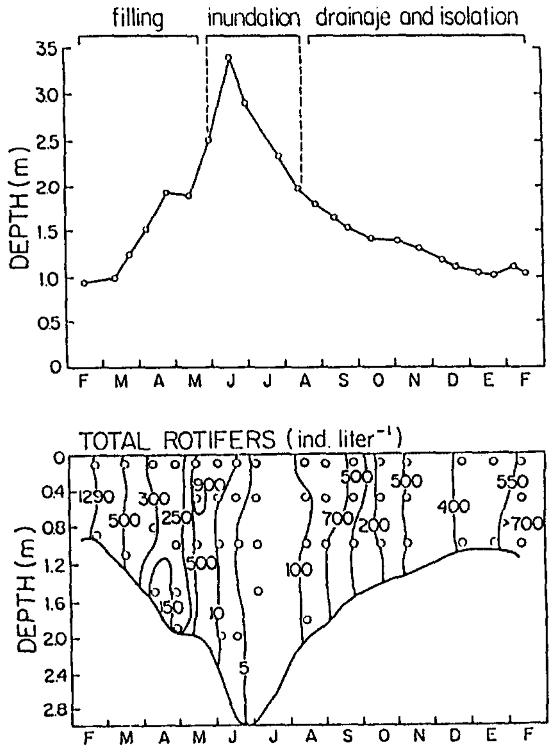

Fig. 2. Changes in stage height of the lake in time and vertical distribution of rotifer community. Hydrological phases of the lake are shown along the top.

temperature is as warm as in the tropical lakes, except for the winter months (Drago, pers. commun.).

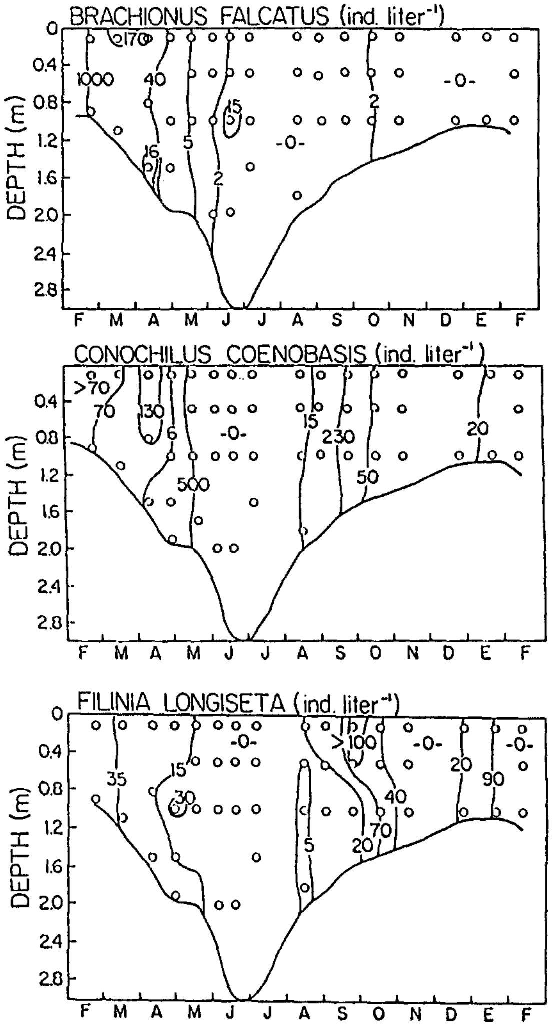

Fig. 3. Vertical distribution of the main rotifer species.

Material and methods

The vertical distribution of rotifers was investigated from February 1987 to February 1988. The samples were collected monthly, and fortnightly during the inundation period, with a Schindler-Patalas plankton trap, in a limnetic station, at different depths, in the morning between 10.00 and 11.00 hours.

The diurnal vertical distribution pattern was studied during two 24 hours period (4–5 May 1987 and 25–26 April 1989), in one limnetic station and one littoral station with *Paspalum repens*. In the littoral station the samples were taken in the free water between the vegetation.

The depth in both stations was always 1.20 (littoral) and 1.30 m. (limnetic). Duplicate samples were collected from fixed stations indicated by a buoy, with a pump, at 0.4 m depth intervals at different times. Water was filtered with nylon gauze of 45 μm mesh size and the organisms were counted using a microscope. Vertical distribution was expressed as the percentage of the total population in the whole water column present at each of the four depths sampled. Mean residence depth of the population was calculated as

$$D = \Sigma N_i d_i / \Sigma N_i$$

where N_i =number of individuals per liter at depth d_i (Hoffman 1975, Cruz Pizarro 1978). Gut content analyses of potential predators were made on material that was not fixed.

On the first data sunrise occurred at 7.48 hours and sunset was at 18.30 hours. On the second data sunrise was at 7.30 and sunset was at 18.30 hours. During the former period the weather was calm, with clear sky; during the second it was calm, but with a thick cloud cover.

In both dates the temperature and hydrologic stage were the same, the temperature at the surface ranged from 16.8 to 22.7°C. In both dates the oxygen shows weak diel stratifications with reductions during the night. In the first sampling date cladocerans and copepods were very abundant in the littoral station, as was *Chaoborus* (Ezcurra de Drago, pers. com.). In the second one the vegetation cover of the lake was wider than on the first occasion, and cladocerans and copepods were scarce. The lake showed a great amount of small fish and in the littoral, tadpoles were most abundant.

Results

Vertical distribution

The rotifers showed a relatively even distribution throughout the water column during the studied period, with a weak trend to a higher density near the surface, mainly during the isolation phase (Figs 2 and 3). The water column was homothermic, and the oxygen shows a similar concentration throughout the water column, except for some occasions (Table 1). There were no important changes in the rotifer vertical distribution in relation to the inundation and isolation phases. Nevertheless, *Filinia longiseta* and *Polyarthra trigla* showed a relatively uneven distribution during the inundation phase.

Table 1. Vertical distribution of some physical and chemical parameters.

Date	Depth (m)	Temp. (°C)	Conduct. (μS cm^{-1})	Oxygen (mg l^{-1})
25-02-87	0	25.0	250	6.6
	0.8	25.0	250	6.2
26-03	0	22.5	300	6.8
	1.2	22.0	300	6.8
17-04	0	23.5	300	6.5
	0.7	23.5	310	6.3
	1.5	23.3	310	5.5
29-04	0	20.0	262	3.2
	0.5	19.5	262	3.0
	1.0	19.5	262	2.7
	1.5	19.5	S/D	2.5
	1.8	20.0	S/D	2.0
12-05	0	16.7	240	6.6
	0.5	16.2	237	5.8
	1.0	15.8	235	5.7
	1.7	15.7	235	4.7
02-06	0	13.0	228	6.5
	0.5	13.2	220	6.2
	1.0	13.0	235	6.4
	2.0	13.0	260	5.4
17-06	0	11.7	81	8.3
	0.5	11.9	81	8.3
	1.0	11.9	80	8.4
	2.0	11.9	83	8.2
	3.0			
03-07	0	13.2	129	8.2
	0.5	13.2	130	7.8
	1.0	13.3	130	8.1
	1.5			
	2.5	13.2	13	7.7
28-07	0	12.0	126	8.3
	0.5	12.0	126	8.3
	1.0	12.0	126	8.3
	2.0	12.0	130	8.3
11-08	0	13.5	158	11.4
	0.5	13.0	158	10.8
	1.0	13.0	158	9.2
	1.8	12.8	160	6.7
24-09	0	17.0	144	8.0
	0.5	16.9	144	8.0
	1.0	16.8	144	8.1
13-10	0	20.2	163	7.1
	0.5	20.1	163	6.9
	1.0	20.0	163	6.9
05-11	0	26.3	181	4.9
	0.5	26.0	181	4.9
	1.0	25.0	174	4.8
28-12	0	25.7	173	4.8
	0.5	25.6	172	4.9
	1.0	25.6	172	4.8
12-01-88	0	28.6	196	5.3
	0.5	28.3	194	5.2

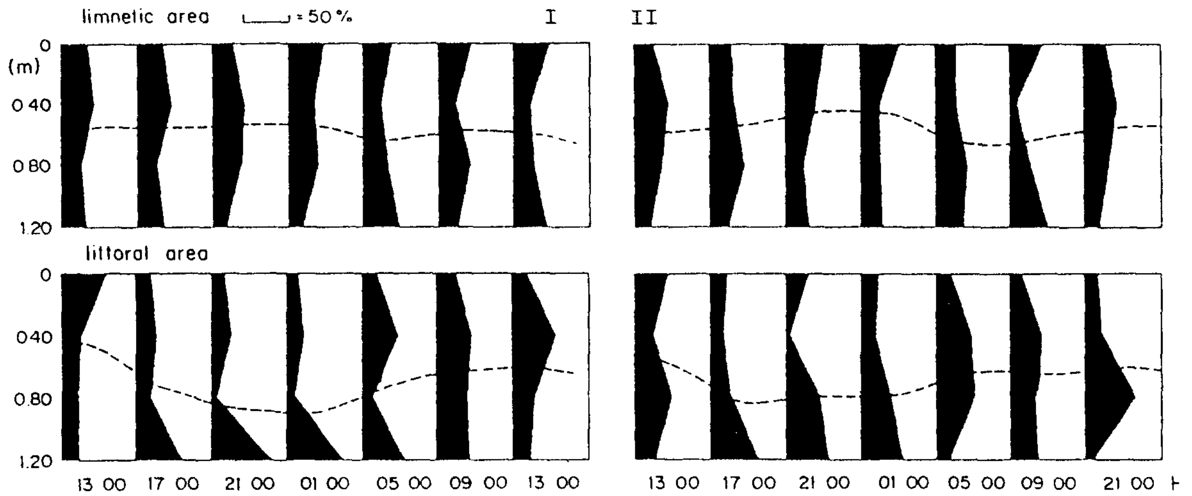

Fig. 4. Migration panels for total rotifer density during the first sampling (I) and second sampling (II). Depth scale in meters, time in local hours. The broken line connects the mean depth of the population at different sampling hours.

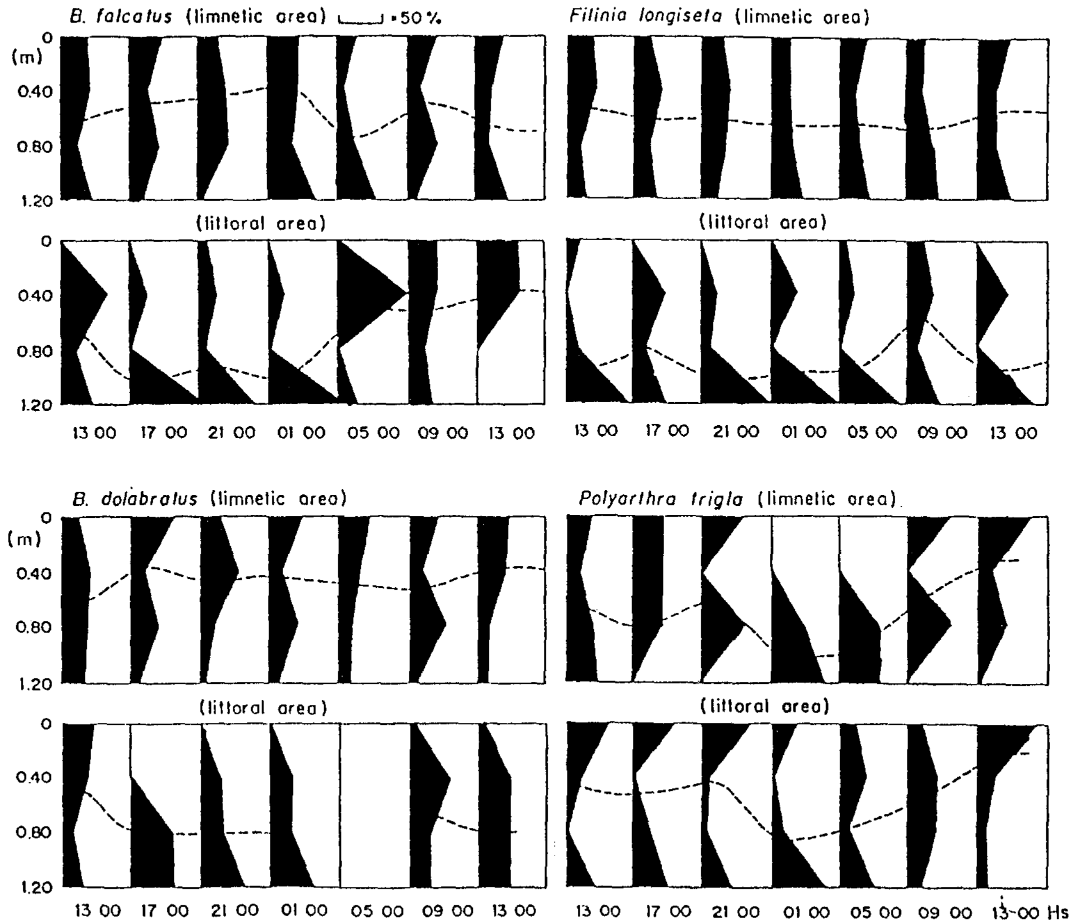

Fig. 5. First sampling. Vertical migration panels of the main rotifer species in the limnetic and littoral area. The broken line connects the mean depth of the distribution of each population.

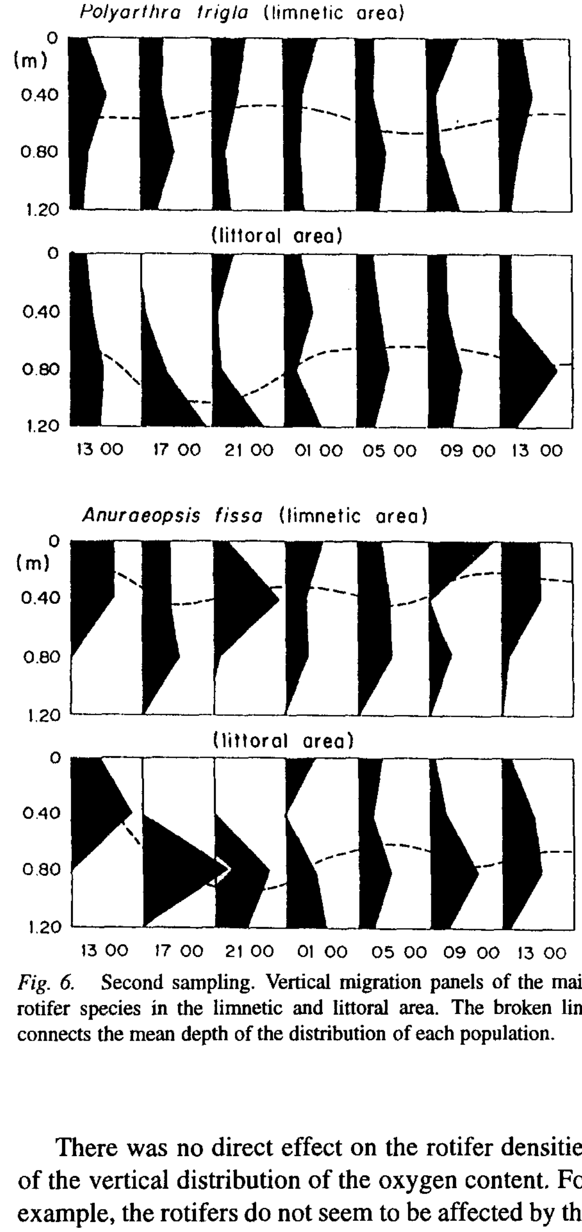

Fig. 6. Second sampling. Vertical migration panels of the main rotifer species in the limnetic and littoral area. The broken line connects the mean depth of the distribution of each population.

There was no direct effect on the rotifer densities of the vertical distribution of the oxygen content. For example, the rotifers do not seem to be affected by the with low oxygen content during May.

Diel vertical migration

First sampling

The littoral area was a little warmer than the limnetic area and the oxygen content was lower. However, the general pattern of vertical profiles of these factors was similar in the two areas: there were weak stratifications at midday and a relatively even distribution for the rest of the day. The phytoplankton from the limnetic area was dominated by Clorophycea which showed an even vertical distribution (Garcia de Emiliani, 1990).

Polyarthra trigla, Brachionus falcatus,; B. dolabratus and *Filinia longiseta* were the most abundant species in both stations. In the littoral area *Lecane* spp. were also abundant. Other species present showed negligible population densities.

In the limnetic station rotifers presented a similar vertical distribution throughout the day.

On the contrary, in the littoral area rotifers showed an upward movement in the morning, with the highest densities observed in the surface stratum at midday. During the night, rotifers migrated downwards (Fig. 4).

The total abundance of rotifers in the limnetic area was higher during the night, at 21.00 and 01.00 hours (more than twice at high as during the day). However, in the littoral area total numbers were more important during the morning, at 05.00, 09.00 and 13.00 hours, probably due to some changes in the horizontal distribution.

The diel movements of *B. falcatus* (Fig. 5) were less pronounced in the limnetic area than in the littoral area, where the animals migrated downwards during the night. *B. dolabratus* showed no clear pattern of movement but tended to stay at deeper waters in the littoral area. *F. longiseta* in the littoral area tended to aggregate close to the bottom, and only migrated upwards at 09.00 hours. *P. trigla* showed a similar pattern of movements in both stations, migrating downwards at night. In the littoral station *Lecane* spp remained close to the bottom during the night and showed a trend to ascend to the surface at 09.00 and 13.00 hours.

Second sampling

The water column was homothermic. A higher level of oxygen was registered in both stations. *Anuraeopsis fissa, B. caudatus, P. vulgaris* were the most abundant species. *B. quadridentatus* and several species of *Lecane* were abundant in the littoral area.

The total number of rotifers in the limnetic area was higher at 17.00 hours, while in the littoral station it was higher during the morning, at 05.00, 09.00 and 13.00 hours. This pattern is similar to that of the first sampling.

Comparing data of rotifers of the first sampling with the second sampling, the latter showed a greater degree of homogeneity in vertical distribution (Fig. 4). However, in the littoral station there was a degree of downward movements during the night. This trend was observed mainly in *P. trigla* and *A. fissa* (Fig. 6)

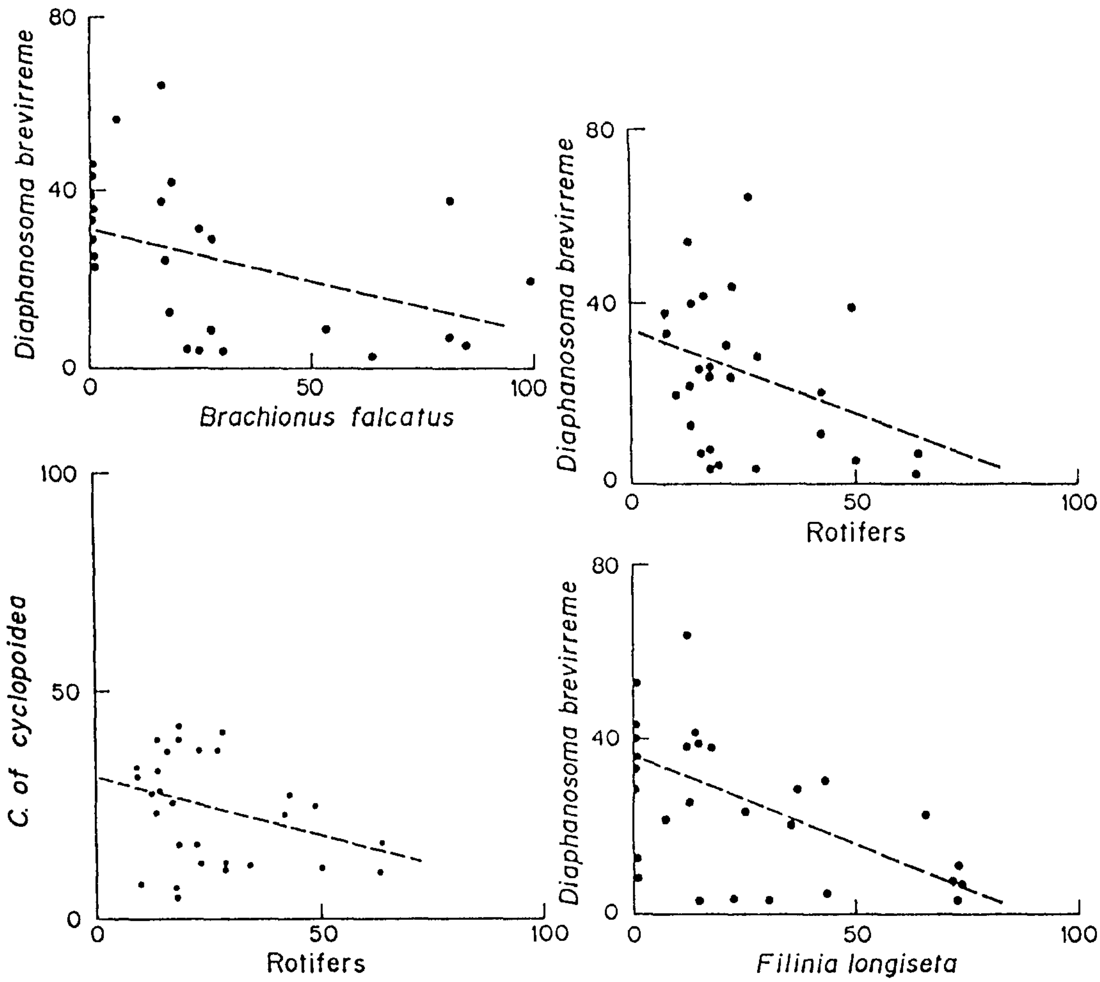

Fig. 7. Relationships between relative abundance of rotifers and cladocerans, and rotifers and cylopoid copepodites.

Discussion

In temperate lakes the vertical distribution of rotifers is closely related to the stratification and overturn periods of the water (Miracle, 1977). In El Tigre the lack of depth and the polymictic character of the lake contributed to an even distribution in the water column throughout the sampling period. The entry of lotic waters in the lake allows movements of water and dilution processes, but has no influence on the rotifer vertical distribution. In general the homogeneity of physical factors throughout the water column is striking. However, even at low oxygen rotifer vertical distribution did not change. The organisms showed a high tolerance to oxygen depletion of the bottom. On the other hand, low oxygen contents are frequent in tropical and subtropical environments (Esteves, 1988), so we can presume a strong adaptation of the species to this environmental characteristic.

Reversed migration has often been reported in rotifers, they remain in the surface during the day (George & Fernando, 1969; Dumont, 1972; Stewart & George, 1987) and have higher feeding rates during daytime than at night (Ardnt & Heerkloss, 1989). In the littoral area of El Tigre, the most common behaviour was reversed migration. In the limnetic area, there was not evidence of it, however, and the difference was more striking in the first sampling.

Reversed migration often involves a mechanism to avoid invertebrate predators (Fedorenko, 1975; Hairston, 1980). Turbellaria, *Chaoborus* and copepods are potential invertebrate predators (Karabin, 1978; Williamson, 1983, Moore & Gilbert, 1987; Fernando *et al.*, 1990; Rocha *et al.*, 1990). They are closer to the surface at night and many cyclopoids have their maximum feeding activity during the night (Arndt & Heerkloss, 1989). Roche (1990) found a negative correlation in vertical distribution between invertebrate predators and potential rotifer prey mainly with soft bodied species (*P. major* and *B. calyciflorus*). In our first sampling there was no evidence of vertical migration as a response to predation by copepods. Gut content analysis of adults and last stages of cyclopoids from the littoral area, at this time revealed consumption of rotifers, mainly *Brachionus, Filinia,* and *Trichocerca*. However, a negative relation between rotifers and adults of cyclopoids was not found, both swimming to deeper layers in the night. Such migratory behaviour of cyclopoids may have occurred in relation to *Chaoborus*, which was abundant at this time in the littoral zone of the lake. Neill (1990) shows this type of behaviour in *Diaptomus* as a response to *Chaoborus*.

Diaphanosoma brevireme was the most abundant crustacean in the littoral station (max. 400 ind. l^{-1} near surface at 21.00 hours) and showed a pattern of movement which was the reverse of that exhibited by rotifers (Fig. 7). The reversed migration of some rotifers can be a response to competition with cladocerans (Dumont, 1972).

In the second sampling, cladocerans and copepods were scarce, probably because of predation by small fish (26 to 48 mm of total length). The gut content of *Cheirodon piaba* and *Hyphessobrycon* sp. indeed showed an important amount of cladocerans and copepods, and some rotifers. The same trend to migrate downwards during the night in the rotifers remained in the littoral area. At that time, tadpoles seemed to be important predators of rotifers. Their gut contents showed an important consumption of rotifers (*Polyarthra, Filinia, Brachionus*), besides cladocerans (*Alona, Kurzia, Ilyocryptus* and *Chydorus*). Other potential predators, such as small Odonata (Anisoptera), showed in their gut only cladocereans (*Ceriodaphnia, Euryalona, Sarsilatona, Simocephalus*) and cyclopoids.

In the limnetic station, the presence of these predators was not observed. In the first sampling calanoid copepods were abundant and cladocerans showed low population densities. In the second sampling, crustaceans were scarce.

Rotifers density in the littoral was higher than in the limnetic during the morning. Inversely, a higher rotifer density was observed in the limnetic during the night (mainly *Polyarthra vulgaris, Brachionus falcatus* and *B. dolabratus*). This pattern of distribution could be interpreted as evidence of horizontal migratory movement. During light hours the zooplankton is more effectively captured by visual predators of the limnetic area. The visually heterogeneous environment of the littoral would be refuge available to organisms to decrease predation by small fish. However, 'immigrant' rotifers would able to inhabit only the upper layers, where phytoplankton congregates to fully use the limited light penetration in the littoral zone. Hence, a higher abundance of rotifers in the upper layers of the littoral during light time could be partially attributed to horizontal movement, at least for some species. Others, such as *Filinia*, showed no horizontal changes and showed an upward movement in the morning. It could be argued that rotifer'efficiency to move effectively over a 24 hours cycle is relative, but also that larval fishes, when present positively select the smallest zooplankton species (Lazzaro 1987) and this could induce a horizontal migration, particularly in small lakes.

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