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Ecological succession of zooplankton species in a temporary river in a semi arid region of Brazil

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Abstract. In the semi arid region of Brazil, the rivers and reservoirs are temporary, existing at times, even years, without water. The animal communities have to develop special strategies to survive when the environment is dry and to multiply, when water arrives. This study analyzed the zooplankton community upon the beginning of the rainy season in a temporary river (in remaining ponds) in Northeast Brazil. Ecological succession of species was analyzed throughout 9 months during which there was water in the river. During this period, samples were collected on days 15, 28, 37 and 43 after the start of raining and monthly afterwards. From diapause 28 rotifer species and 5 subspecies; 8 cladoceran species and 8 copepod species ecloded. The first cladoceran to appear was *Moina minuta*, which reached high densities, 1,234 ind.L^{-1}, followed by *Ceriodaphnia comuta*, observed on day 28, and by *Diaphanosoma spimilosum* observed 37 days after the rain event. The first copepods to appear were *Mesocyclops meridianus* and *Muscocyclops* sp., both in the first sample (day 15). Of all the species, 21 were observed only once. Among the rotifers 10 species were observed in the first sample. This group was present in high densities e.g. *Conochilus* sp., with 20,403 ind.L^{-1}, *Keratella tropica* with 9,392 ind.L^{-1} and *K. lenzi* with 1,149 ind.L^{-1}. Species densities were correlated with chlorophyll *a*, nitrate and ammonium. New ephippia production was related with total zooplankton densities, chlorophyll-a, nitrate and ammonium.

Keywords: Ecological succession, zooplankton, temporary habitat, semi arid region.

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Introduction

Ecological succession is an ordered process of community development involving alterations in the specific structure and community process, in time. These successions occur due to modifications in the physical environment occasioned by the community, culminating with a stable one (Odum, 1988). As drought is a cyclical phenomenon (Barbosa et al., 2012), the organisms have to develop strategies of life that allow them to survive when the environment is adverse. Diapause is the strategy used by crustaceans (Fryer, 1996; Rossi et al., 1996; Crispim and Watanabe, 2001; Crispim et al., 2003) and rotifers (King and Snell, 1980; Gilbert, 1995) to survive such periods. Diapause in some studied crustacea lasted from some months to about 55 years (Hairston and Cáceres, 1996). The species adapted to this kind of environment, must have the ability to use the little time the habitat has water to rapidly multiply and to produce a diapause stage again. When organisms hatched from resting eggs, e.g. daphnids, they exhibited a significantly higher reproductive effort in the adult instars 1 and 2. The first clutch size was twice that compared to exephippial females (Arbaciauskas, 1998), allowing the population to rapidly attain high densities. The recruitment of zooplankton in temporary water-bodies from their resting stages is governed by a complexity of factors which regulate their production, distribution, hatchability, viability and survival during the dry periods (Chatterjee and Gopal, 1998). Hatching in arid regions is not only stimulated by the presence of water, but by a rise in temperature as well (Fryer, 1996).

Temporary rivers undergo great changes through a hydrological cycle. They go from a completely dry period to a running water period. When the rains fall, the rivers receive water, but as soon as the rain stops, most of them become shallow little ponds in some deeper places. At this time the chemical environmental conditions change, and the water becomes eutrophic and hypereutrophic until complete disappearance in some aquatic systems.

Zooplankton species only eclode when the environment is suitable, and not all at the same time. Since the special requirements are not the same for all species, it is possible to observe an ecological succession among the species along the period the river remains with water.

As these environments are strongly related with the water cycle, their hydrological fluctuations can be so large that a pond rarely remains the same from one year to the next. Wherefore it is difficult to find, clear annual patterns in zooplankton communities (Serrano and Toja, 1998). Ponce-Palafox and Arredondo-Figueroa (1998) noted that the metabolism of the water column in four temporary tropical freshwater ponds depended largely on the fluctuations in water volume and on the relation between this and dissolved substances, organic matter and the quantity of phytoplankton.

This work describes the ecological succession observed on the zooplankton community, in a temporary river in northeast Brazil, during a period of 9 months.

Study Site

Taperoá River is located in the Cariri Region in Paraíba State, in Brazil. The sampling site is located near São João do Cariri town in the coordinates 07° 43’ S and 36° 31’ W, at an altitude of 460 m. Water was never enough to make the river flow so the results are related to a little pond created by the rain.

Methodology

Samples were collected from the river 15, 28, 37, 43 daysafter the rainfall and monthly afterwards for nearly 9 months.

Zooplankton

40 liters of water were filtered in a 50 μm mesh filter and fixed in a 4% formol solution saturated with sugar. Three samples were collected on each date. Density results presented in the work are average values of the three samples. Densities were estimated by counting in a Sedgewick Rafter chamber, of at least 100 individuals for sample, and numbers were placed in the following formula:

$$D = \frac{s.v. \times N}{c.v.} / f.v$$

Were D = densities
s.v = sample volume
N = species number
c.v = counted volume
f.v = filtered volume

Chlorophyll-*a* and phytoplankton biomass

Chlorophyll *a* and phytoplankton biomass were analyzed as described by Golterman et al. (1978).

Table 1. Chemical parameters in the Taperoá River along the study period.

Days	15	43	69	99	140	170	193	211	255
alc (µg.L^{-1})	75.0	146.0	42.0	98.0	115.0	125.0	186.0	-	-
har (µg.L^{-1})	180.0	240.0	190.0	220.0	110.0	298.0	300.0	-	-
am (µg.L^{-1})	412.0	133.3	183.4	322.0	260.8	54.5	93.3	-	-
nit (µg.L^{-1})	309.7	599.7	816.3	149.7	106.3	69.7	-	-	-
Pt (µg.L^{-1})	5.0	15.0	19.9	6.3	8.9	20.0	-	66.8	61.9

alc = alkalinity; har = hardness; am = ammonium; nit = nitrate; Pt = phosphorus total.

Chemical factors

Alkalinity was analyzed following Golterman et al. (1978). Water hardness as described in Standard Methods (Eaton et al., 1995). Nitrate, nitrite and ammonium was determined by the colorimetric method, described by Rodier (1975), and total phosphorus was analyzed following Standard Methods (Eaton et al., 1995).

Correlations

Pearson's correlations were used in a SPSS computing Program.

Results

Cladocera

During the study period 9 species of Cladocera were found in the Taperoá River: *Moina minuta*, *Ceriodaphnia comuta*, *Diaphanosoma spinulosum*, *Macrothrix* sp., *Alonella hamulata*, *Alona poppei*, *Ilyocryptus spinifer*, *Chydorus sphaericus*, and *Chydorus eurynotus*. *M. minuta* was the first cladoceran to appear after the initiation of rainfall. This species was observed in days 15 and 28, with high densities (115.5 and 1,234.7 ind.L^{-1}), being observed with very low densities (0.18 ind.L^{-1}) in day 69, and was not observed again (Figure 1). *C. cornuta* was the second species to appear, on day 28. It attained its highest density on day 37 (30.0 ind.L^{-1}) and afterwards was only present at very low densities (0.02 and 0.03 ind.L^{-1}) respectively on days 69 and 140. It lived together with *M. minuta* (day 28) and with *D. spinulosum* that was observed on day 37. The latter species was only observed on two dates, appearing in day 69 at very low densities (0.17 ind.L^{-1}), *A. hamulata* and *Macrothrix* sp. were only observed on day 69, both with very low densities. *A. poppei* was also observed on day 69, but achieved its highest density on day 99 with 5.2 ind.L^{-1}. *I. spinifer* appeared only on day 170, with 0.7 ind.L^{-1} and *C. sphaericus* on day 193, with 0.5 ind.L^{-1}. Thus, the sequence of cladocerans observed was as follow:

M. minuta ➔ *C. cornuta* ➔ *D. spinulosum* ➔ *A. hamulata* = *Macrothrix* sp. = *A. poppei* ➔ *I. spinifer* ➔ *C. sphaericus* ➔ *C. eurynotus.*

The species of this group were present in the water for a few days. They hatched from the sediments in isolated pools as the river did not run this year, increased their populations and then disappeared again, probably after producing diapausing stages once again.

Chemical parameters are described on Table 1.

Diversity indices in this group reached the highest value on day 69 with $H' = 1.64$. On many dates this index was 0.0 due the presence of only one species (Figure 2).

The Pearson's coefficient correlation between cladocerans and chemical environmental factors was negative between *M. minuta* and alkalinity ($r = -0.757$, $N = 7$, $P < 0.05$).

Copepoda

Among the copepods 9 taxa were found during the study period. The cyclopoids *Mesocyclops meridianus*, *M. brasilianus*, *Muscocyclops* sp., *Metacyclops brauni*, *Thermocyclops crassus*, and 2 species unidentified, named here as cyclopoid sp.1 and cyclopoid sp.3; the Calanoida *Notodiaptomuns cearensis* and one species of Harpacticoida, not identified yet. The first copepod species to

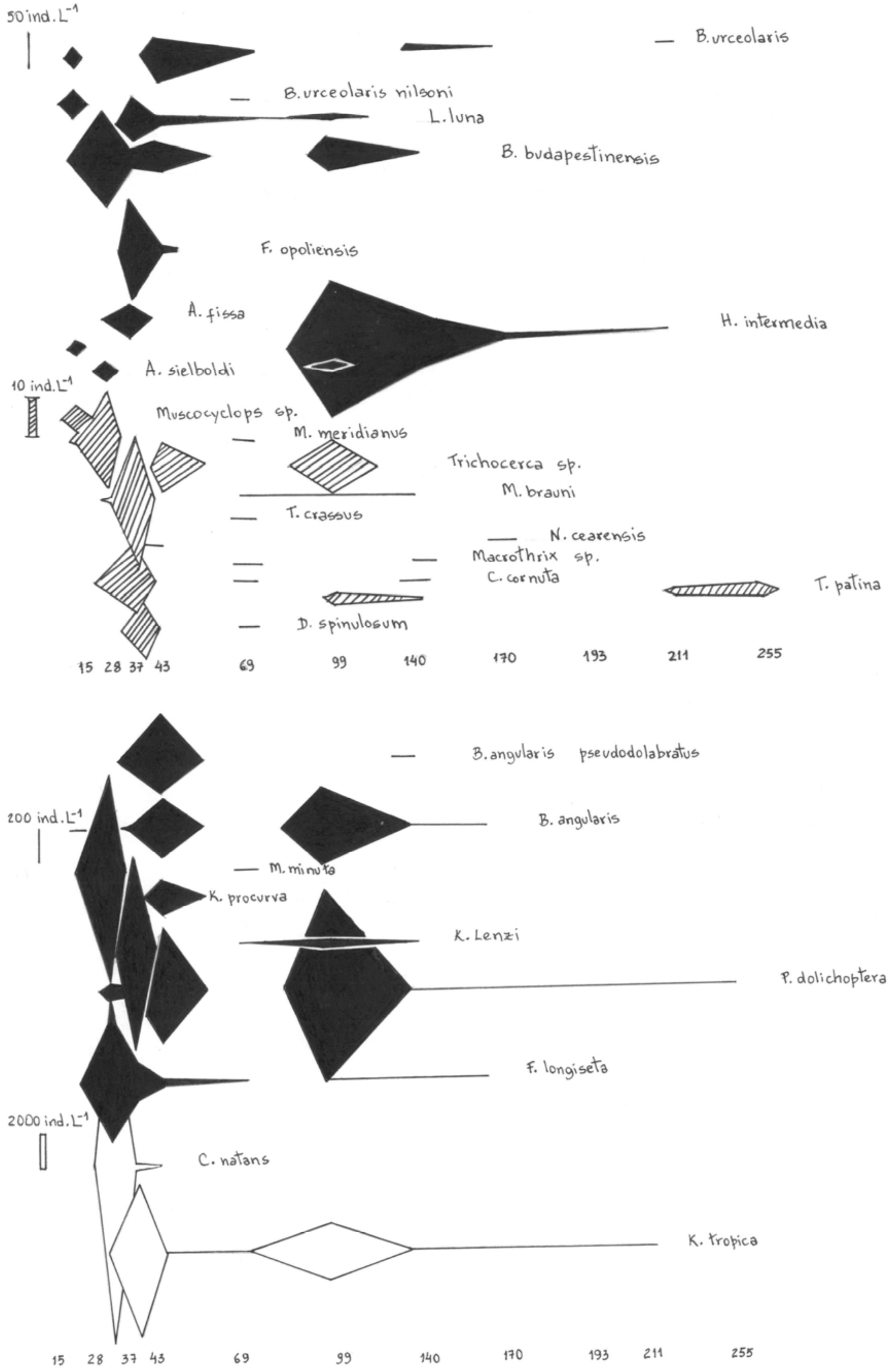

Figure 1. Densities of the more abundant species of Cladocera, Copepoda and Rotifera along the study period.

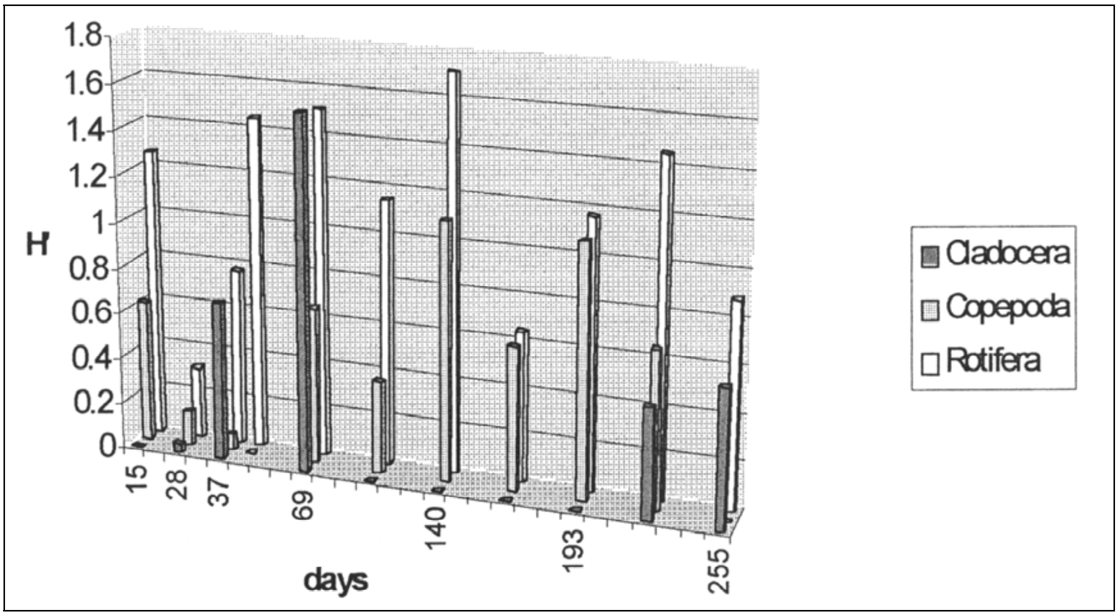

Figura 2. Diversity indices (H') along the study period.

be observed in Taperoá River was *M. meridianus* and *Muscocyclops* sp., both were observed on our first sample, 15 days after the beginning of the rain. *M. meridianus* attained its highest density on day 28 and then was only seen again on day 69 with very low densities (0.01 ind.L^{-1}) while *Muscocyclops* sp. was only observed in the first sample. The next species to appear was *M. brauni*, on day 28. This species reached its highest density values on day 37, with 35.8 ind.L^{-1}. Afterwards it was only present in very low densities ($\approx$ 0.3 ind.L^{-1}) on days 69 and 140. The calanoide *N. cearensis* was observed first on day 37, with very low densities (0.5 ind.L^{-1}) and then again on day 170 with similar densities. The cyclopoid sp.3 was noted on day 43 with very low density values, 0.03 ind.L^{-1}. This species was not found again. *T. crassus* was observed on day 69, also with low densities (0.4 ind.L^{-1}), and was not found again either. A cyclopoid harpacticoid was observed on day 99, with 2.9 ind.L^{-1} and on day 193 with 0.5 ind.L^{-1}. *M. brasilianus* and cyclopoid sp.1 were both found on day 140 with 0.8 ind.L^{-1}. *M. brasilianus* was seen until the day 193, but cyclopoid sp.1 only was observed again on day 170. Both species achieved almost the same densities along the study period. The ecological succession observed for copepods was:

M. meridianus = *Muscocyclops* sp. ➔ *M. brauni* ➔ *N. cearensis* ➔ cyclopoid sp.3 ➔ *T. crassus* ➔ Harpacticoida ➔ *M. brasilianus* = cyclopoid sp.1.

Similar to cladocerans, copepod species remained on the environment briefly, and then disappeared again.

Diversity index presented higher values on days 140 and 193, with H' = 1.12 and 1.10, respectively. Copepod values were only 0.00 on two sampling dates due to the presence of only one species. This group was always present during the study period.

Correlations were significantly negative between *M. meridianus* and alkalinity ($r = -0.757$, $N = 7$, $P < 0.05$) and between nitrate and cyclopoid sp.1 ($r = -0.845$, $N = 6$, $P < 0.05$).

Rotifera

This was the group most best represented in the river, with 36 species and sub-species present: *Anuaeropsis fissa*, *Asplanchna sieboldi*, *Brachionus angularis*, *B. angularis chelonis*, *B. angularis pseudodolabratus*, *B. bidentata*, *B. budapestinensis*, *B. calyciflorus*, *B. caudatus austrogenitus*, *B. havanaensis*, *B. patulus*, *B. urceolaris*, *B. urceolaris nilsoni*, *Colurela uncinata*, *Conochilus natans*, *Dipleuchnis propatula*, *F. longiseta*, *F. longiseta passa*, *F. longiseta saltitor*, *F. opoliensis*, *Hexarthra intermedia*, *Keratella americana*, *K. lenzi*, *K. procurva*, *K. tropica*, *Lecane hastata*, *L. leontina*, *L. luna*, *L.* (*Monostyla*) *brita*, *L.* (*M.*) *lunaris*, *Lepadella imbricata*, *Polyarthra dolichoptera*, *P. vulgaris*, *Testudinella patina*, *Trichocerca* sp., and a not loricated form unidentified.

These species were generally present in one or two sampling dates, not to be observed again. The other species did not displayed a defined pattern being present throughout the study period.

Significant negative correlations were found between hardness and *B. caudatus austrogenitus* ($r = -0.802$, $N = 7$, $P < 0.05$) and positive ones were observed between ammonium and *B. calyciflorus*, *B. urceolaris nilsoni*, *B. bidentata* and *F. longiseta passa* all with $r = 0.694$, $N = 7$, $P < 0.05$; alkalinity and *P. vulgaris* ($r = 0.690$, $N = 6$, $P < 0.05$); nitrate and *L. imbricata*, *D. propagula*, *L.* (*M.*) *bulla*, *L. leontina* and *K. americana*, all with $r = 0.767$, $N = 6$, $P < 0.05$. Positive correlations were also found between chlorophyll *a* values and *F. longiseta* ($r = 0.882$, $N = 7$, $P < 0.01$), *B. urceolaris* ($r = 0.876$, $N = 7$, $P < 0.01$), *B. budapestinensis* ($r = 0.674$, $N = 7$, $P < 0.05$), *C. natans* ($r = 0.957$, $N = 7$, $P < 0.01$), *L. luna* ($r = 0.789$, $N = 7$, $P < 0.05$), *F. opoliensis* ($r = 0.957$, $N = 7$, $P < 0.01$), *B. angularis pseudodolabratus* ($r = 0.957$, $N = 7$, $P < 0.01$), *K. procurva* ($r = 0.957$, $N = 7$, $P < 0.01$), *Trichocerca* sp. ($r = 0.730$, $N = 7$, $P < 0.05$), *B. angularis chelonis* ($r = 0.685$, $N = 7$, $P < 0.05$) and biomass and *F. longiseta* ($r = 0.881$, $N = 7$, $P < 0.01$), *B. urceolaris* ($r = 0.911$, $N = 7$, $P < 0.01$), *C. natans* ($r = 0.941$, $N = 7$, $P < 0.01$), *L. luna* ($r = 0.757$, $N = 7$, $P < 0.05$), *F. opoliensis* ($r = 0.941$, $N = 7$, $P < 0.01$), *B. angularis pseudodolabratus* ($r = 0.941$, $N = 7$, $P < 0.01$), *K. procurva* ($r = 0,941$, $N = 7$, $P < 0.01$) and *Trichocerca* sp. ($r = 0.693$, $N = 7$, $P < 0.05$).

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The peak of existent species occurred between the days 37 and 140 (halfway the study length) with 11 to 14 species present. The higher number of species (14) was found on day 99. Nevertheless the highest diversity index was found on day 140. This was due to the eveness index that was lower on day 99. The lowest number of species, (4) was found on day 193.

The following rotifers succession was observed:

B. ca1ycflorus / *B. bidentata* / *B. urceolaris nilsoni* / *F. longiseta passa* ➔ *A. fissa* / *C. natans* ➔ *K. lenzi* ➔ *K. procurva* / *B. angularis pseudodolabratus* ➔ *L. imbricata* / *L. leontina* / *L.* (*M.*) *bulla* / *D. propatula* ➔ *T. patina* / *L. lunaris* / *F. longiseta saltitor* ➔ *B. havanaensis* ➔ *P. vulgaris*.

Discussion

Succession of species occur when the environment undergoes changes due to chemical or physical interference, but succession can also occur in rotifer species in chemically stable environments, due to competition with cladocerans and predation (Urabe, 1992). Almost all species present in this work showed short life spans, being substituted one for another along the period the river had water. This was probably due to changes in chemical environment and resources, as well specific interference. In a specific time the habitat is suitable for some species but not to others, and when the environment changes becames suitable for the others. This allows, nevertheless their rapid succession in the environment, for the existence of a great number of species along a hydrological cycle. Hu and Tessier (1995) suggested that the emergence of *Daphnia galeata mendotae* as a superior competitor in late summer was related to a seasonal change in resource composition, at least when planktivory is low.

In a succession study of cladocerans in a ricefield in ltaly, it was observed that an increase in Chydoridae was associated with the growth and decomposition of a large biomass of weeds and microalgae during the summer (Ferrari et al., 1991). In our work Chydoridae species also increased on the second half period of the study when the river became eutrophic. Trophic conditions changed quickly from oligotrophic to hypereutrophic in almost 9 months.

Pearson's correlations observed between chemical factors and species, on this work, must be confirmed in other similar environments to conclude that those species are really sensitive to those factors. Chlorophyll *a* and biomass of phytoplankton were the main correlated factors for the greater number of rotifer species (10 and 8 respectively), showing that resources are more important in structuring the community than chemical factors. Nevertheless nitrate and ammonium values were correlated with 5 and 4 species respectively.

Diversity indices were higher for cladocerans on day 69 and for copepods and rotifers on day 140, although on day 193 copepods have the same H' value. On day 69, 6 cladoceran species were present. It seems that the environment became suitable for cladocerans earlier than for rotifers and copepods, although before day 69 only one or two species could be found in the water. Diversity indices, in Rotatoria, in two small rivers in Latvia, were related with trophic state and erosion in the river basin (Cimdins and Klavins, 1998). In our work rotifer diversity oscillated along the 9 months the river remained with water in the pond, showing 2 peaks: the first on day 140 and the second on day 211.

A high number of species was observed during the course of the study, 36 rotifers, 9 cladocerans and 9 copepod. An ecological succession was observed especially on the first 99 days. Generally the time that the species remaining in the pond formed on the river was very short. The species ecloded from diapausing stages, reproduced, produced new diapausing stages and disappeared again. The present work shows that some species, specially rotifers (e.g. *C. natans*) on early samplings, can disappear in less than 30 days, so the sampling period for these must be lower than a month.

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