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# Cladocera (Crustacea, Branchiopoda) of a temporary shallow pond in the Caatinga of Pernambuco, Brazil

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**Abstract** - The aim of this study was to describe the composition and structure of cladocerans of littoral areas with and without macrophytes from a temporary shallow pond in the Caatinga of Pernambuco state (Brazil). Samples were taken between June 2011 and August 2012. The sampling of cladocerans and environmental variables was performed at four fixed points, using a plankton net (45 µm) and a multiparameter probe. Twenty-two cladoceran species were recorded, with two new occurrences for Pernambuco state: *Chydorus* cf. *brevilabris* and *Macrothrix superaculeata*. The species richness of non-planktonic cladocerans (16) was higher than that of planktonic ones (4). The mean density was 186.7 ± 273.6 ind. $L^{-1}$. *Macrothrix elegans, Diaphanosoma spinulosum* and *Ephemeroporus hybridus* were the most abundant. The fluctuation index of the main species showed greater instability during the driest months or greater rainfall, a pattern not observed for the environmental data. However, the pond did not show limnological and cladoceran structure differences between the dry and rainy seasons and between the areas with and without macrophytes. With the exception of temperature and rainfall, the structure and richness of cladocerans was not related to the fluctuation of the other variables. Warmer months had higher densities and richness of cladocerans. On the other hand, months of greatest rainfall had lower richness, especially for the Chydoridae family. Although this Caatinga pond is maintained exclusively by rainwater, the richness of cladocerans is high when compared to other tropical and subtropical ecosystems. These results suggest that rainfall and temperature exert greater control on the dynamics of cladocerans in the Caatinga's temporary shallow ponds, and demonstrate the importance of these ecosystems to biodiversity in the semiarid region.

Key words: Cladocerans, fluctuation, macrophytes, Northeastern Brazil, Semiarid

Nauplius

## Introduction

Despite being within the Brazilian semiarid region, the Caatinga has thousands of small aquatic ecosystems spread across it (Maltchik, 2000). Some of these environments are formed naturally by rainfall and geomorphological characteristics of the area where they are found (Maltchik, 2000; Melo Júnior *et al.*, in press), most of them being totally unknown in terms of biodiversity of invertebrates. Consequently, the lack of extensive studies on the ecological processes underlying the Caatinga biome and its waterways, and the lack of knowledge about its biodiversity have led, until recently, to the erroneous perception that the aquatic biota is poor in species and endemism (see review by Maltchik and Medeiros, 2006).

Given the hydric irregularity characterizing the Brazilian semiarid region, temporary lagoons or ponds represent ecosystems of major importance, since they consist of natural environments that accumulate water during the rainy season, which may reduce its volume or even dry it during drought (Silva *et al.,* 2008), although in rainy season the rainfalls can be not sufficient to keep the lentic ecosystems flooded during a long period. These water bodies are widely distributed around the world and particularly in the northeast region of Brazil they play a role of great importance from the point of view of evolution, ecology and exploitation of wild fauna and flora (Maltchik, 2000; Tundisi and Matsumura-Tundisi, 2008), even sustaining high productivity and biodiversity (Cardoso *et al.*, 2012). However, the processes maintaining the species diversity at local and regional levels are still poorly understood, especially in tropical aquatic systems (Aranguren-Riaño *et al.,* 2011).

The cladocerans are consumers, like other zooplankton organisms, located at the base of the trophic webs of natural aquatic ecosystems with an important role in energy transfer synthesized by primary producers for other links in the food web and also in nutrient cycling (Melão *et al.,* 2005). These organisms have strategies that ensure the maintenance of diversity in the face of changes in the water volume of temporary ponds, contributing to the support of these important natural resources. This persistence of aquatic fauna is the result of complex interaction between biotic and abiotic features, which are still poorly known in tropical regions (Almeida *et al.*, 2012).

A greater diversity of cladocerans can be found in the littoral region of continental water bodies, areas of transition between aquatic and terrestrial environments (Castilho-Noll *et al.*, 2010), especially those occupied by aquatic macrophytes. Although the littoral areas have rich biodiversity, according to Nogueira *et al.* (2003), the biology and ecology of cladocerans in these areas are still poorly known, particularly when compared to organisms living in open waters (Maia-Barbosa *et al.,* 2008).

The large number of temporary aquatic environments in the Caatinga region, coupled with the high potential of these ecosystems to store rich biodiversity that is still unknown by science, means that expansion of knowledge about its biota is imminent. According to Crispin and Freitas (2005), studies on these ecosystems are important for understanding and protecting these unique and variable habitats. Thus, the present study aimed to describe the composition and diversity of cladocerans in a temporary shallow pond of the Mata da Pimenteira State Park, an area with a history of more than 20 years of conservation in the Caatinga of Pernambuco.

## Material and Methods

### *Study Area*

The temporary shallow pond of the Mata da Pimenteira State Park (7°53'48.96"S / 38°18'14.30"W) is located in Serra Talhada, in the semiarid region of Pernambuco state (Fig. 1), about 420 km from the capital Recife. It covers approximately 890 ha and for the most part corresponds to the tops of mountains and fragments of arboreal Caatinga. This area has a large complex of hills and rocky outcrops, providing a strikingly beautiful landscape. It consists of a stretch of Caatinga with historic

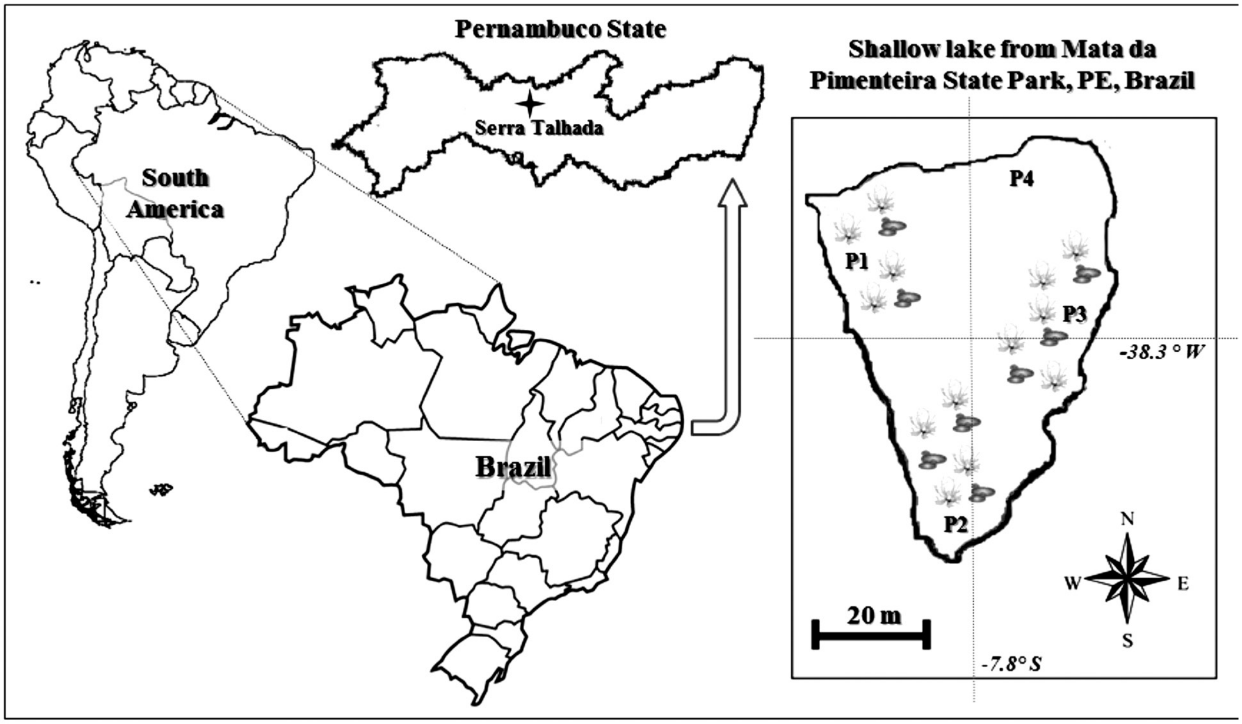


**Figure 1.** Location of a temporary shallow pond in the Mata da Pimenteira State Park (Serra Talhada, Caatinga of Pernambuco), with the distribution scheme of the sampling points with the presence (P1, P2 and P3) and without vegetation (P4).

conservation of at least 20 years, which was officially categorized as a State Park-type Conservation Unit in January 2012.

The landscape of the Mata da Pimenteira State Park presents a rich diversity of vegetation, in addition to other temporary shallow lagoons and creeks. The studied pond consists of a small and shallow water body, with depth not exceeding two meters (the depth showed a continuous decline during the study, reducing to about 0,1 meters in the last month of sampling), having a flooded area of approximately 2,900 $m^2$ with its native riparian vegetation preserved. Moreover, it presents a wide variety of aquatic macrophytes, including floating and fixed submerged, amphibious and emerging ones, such as: *Nymphaea pulchella* D.C., *Chara martiana* Wallman, *Echinodorus palaefolius* (Nees & Mart.) J.F. Macbr., *Croton argeuteus* L., *Tarenaya spinosa* (Jacq.) Raf. and *Eclipta prostrata* (L.) L. (Cordeiro *et al.*, in press). The seasons in the semiarid region are variable between the years (Crispin *et al.*, 2006), but generally the rainy season is registered between December and April, while the dry season is observed during May to November.

*Limnological variables*

The monthly mean values for rainfall in the region of the Mata da Pimenteira State Park were obtained from the website of the Agronomic Institute of Pernambuco (IPA). Data on the limnological variables of the studied pond (water temperature, pH, dissolved oxygen, conductivity, total solids, turbidity and salinity) were measured from a multiparameter probe, Horiba U-52 model. The measurements of these variables were started in October 2011.

*Procedures for sampling and analysis of biological material*

The cladoceran samples were taken in the dry (June, July and October 2011, and May and August 2012) and in the rainy (December 2011, and January and March 2012) seasons, in four fixed sampling points in the littoral area of the pond, three with and one without the presence of macrophytes. Due to logistical problems, the sampling in June 2011 was only qualitative. A lot of macrophytes in almost any littoral region of the lake enabled the collection of planktonic fauna at a single sampling point. At each point, approximately

100 L of water at the subsurface were sampled, with the aid of a graduated container, filtered in plankton net with 45 µm mesh size and fixed with 4% neutral formalin (Harris *et al.*, 2000). However, this method apparently only allows sampling of cladocerans inhabiting the water between the macrophytes, making unfeasible the sampling of some individuals that were adhered to plants. Considering this fact, the number of individuals of the truly phytophilous species is, therefore, likely to be underestimated.

In the laboratory, the organisms were observed under optical microscope and stereomicroscope with identification performed from the usual dissection methods for microcrustaceans and specialized bibliography (Smirnov, 1996; Elmoor-Loureiro, 1997). For each sample, the quantification was carried out through three 2-mL replicates into Sedgwick-Rafter-type chambers, prepared specifically for this volume, in concentrated samples at 50 mL (May 2012) to 300 mL (August 2012). The samples with a low number of organisms were counted in full.

Data were initially treated regarding the species richness, relative abundance (%), frequency of occurrence (%), density of individuals (ind. $L^{-1}$), diversity index of Shannon-Wiener (H’) based on the $\log_2$ (Shannon, 1948) and the evenness calculated according to Pielou (1977). Furthermore, fluctuation index (Guisande-González *et al.*, 2006) was applied, using data on number density for the most common and abundant species, and data of environmental variables were also used for obtaining the index of environmental fluctuation, using the equation:

$$D = \sum_{i=1}^{s} p_i \log_2 \frac{p_i}{p_{im}}$$

where *s* is the number of variables, *Pi* is the relative proportion of the variable *i* at specific time and *Pim* is the reference state, which is calculated as the average figure for the relative proportions of the variable *i* during the study period. Thus, comparing the two indexes is possible to observe in which period the environmental variables were most associated with the cladocerans’ dynamic. The differences in all biological and environmental variables between the littoral areas with and without macrophytes, and between the seasons (dry and rainy) were assessed using the non-parametric Mann-Whitney test (U). The Pearson correlation matrix was used in order to highlight the possible relationships among environmental variables (water temperature, pH, dissolved oxygen, oxygen saturation, conductivity, total solids, turbidity and salinity, and their fluctuation index). The outliers were analyzed in this last case. On the other hand, the Spearman correlation test was also used in order to emphasize the possible relationships among biological (richness, density, fluctuation index for the major species, diversity and evenness) and the environmental variables. Variables that showed significant correlations ($p < 0.05$) were selected to explain the community structure of cladocerans. For statistical analyses, the statistical package Bioestat 5.3 was used.

## Results

### *Limnological variables*

During the whole study, the historical rainy season in the region showed greater precipitation than the dry season (Mann-Whitney; $p < 0.05$). In July 2011, and May and August 2012, the period was dry (< 15 mm; Fig. 2A); in January and March 2012 the period was rainy, but the rainfalls (< 50 mm) were not sufficient to permit that a large quantity of water remained in the pond. As a consequence of this, the water depth decreased during whole period (Fig. 2B). In July 2011 the pond was almost completely flooded, even in the dry season. However, the pond did not show limnological differences between the dry and rainy seasons (Mann-Whitney; $p > 0.05$). Also, no significant differences in these variables were detected between the sampling areas, with and without macrophytes (Mann-Whitney; $p > 0.05$).

The water temperature was always high, especially in the rainy season, being higher for data measured among macrophytes. The

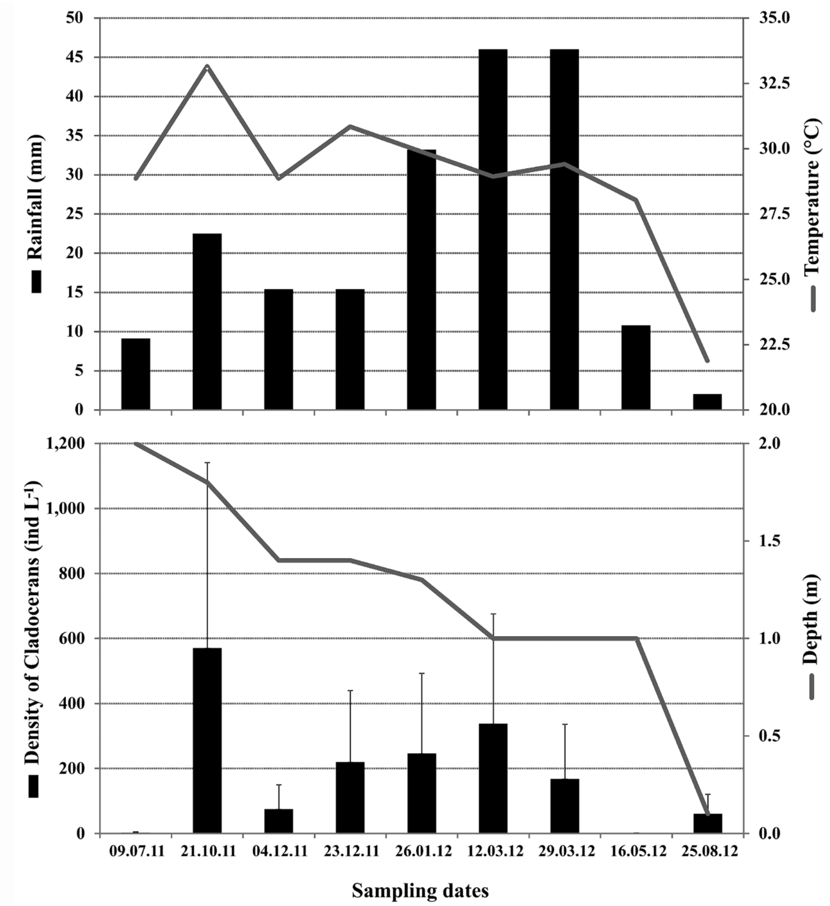


**Figure 2.** Monthly variation of the (A) mean water temperature (°C) and rainfall (mm), and (B) density (mean ± standard deviation; ind. $L^{-1}$) of cladocerans and water depth of a shallow temporary pond in the Mata da Pimenteira State Park (Caatinga of Pernambuco). Sampling dates format: dd.mm.yy.

only exception was observed during the dry season in August 2012 (20.9 °C) (Fig. 2A). The water was predominantly well oxygenated (4.1 to 13.9 mg $L^{-1}$), with a pH from slightly acidic to alkaline (5.3 to 9.6) and low electrical conductivity (0.2-0.5 mS $cm^{-1}$). Regarding the other limnological variables, oxygen saturation was higher in January 2012 (rainy season) for both collection points with vegetation (184%) and without vegetation points (168%). The highest values for turbidity and salinity were also recorded in January 2012 (379.67 NTU and 0.05, respectively) when the rainfall was above 30 mm (rainy season), and in August 2012 (958 NTU and 0.02 respectively), and the water stock was low (dry season) and rather trampled by large-size vertebrates (Tab. 1).

*Cladoceran community*

Twenty-two cladoceran species were recorded, distributed among the families Sididae (2), Moinidae (1), Daphniidae (3), Ilyocryptidae (1), Macrothricidae (2) and Chydoridae (13), the latter accounting for almost 60% of total. Among the species identified, two are new records for the state of Pernambuco: *Chydorus* cf. *brevilabris* Frey, 1980 and *Macrothrix superaculeata* (Smirnov, 1992) (Tab. 2).

The values of species richness were slightly higher in almost every month at the sampling points with vegetation, ranging from three to 15 species; the total richness of non-planktonic cladocerans (16 species) was higher than that of the planktonic ones (four species). Higher values of richness were recorded for the cladoceran community when precipitation was less than 30 mm in the region (Tables 2, 3), with a reduction in the number of taxa when precipitation was greater than 30 mm, especially for members of the Chydoridae family (Table 2).

Only one species was exclusive to the rainy season: *Diaphanosoma brevireme* Sars, 1900, while seven other species occurred

**Table 1.** Amplitude (minimum-maximum), monthly mean and standard deviation (SD) of limnological variables in a temporary shallow pond in the Mata da Pimenteira State Park (Caatinga of Pernambuco), considering the sampling areas with and without vegetation.

| Study point / Variable | With vegetation | | | Without vegetation | | |
|---|---|---|---|---|---|---|
| | Amplitude | Mean | SD | Amplitude | Mean | SD |
| Water temperature (°C) | 20.9-35.2 | 29.3 | 3.4 | 22.4-29.6 | 27.8 | 2.4 |
| pH | 5.3-9.6 | 7.9 | 1.2 | 6.4-8.2 | 7.2 | 0.6 |
| Conductivity (mS $cm^{-1}$) | 0.2-0.5 | 0.3 | 0.1 | 0.2-0.3 | 0.2 | 0.06 |
| Turbidity (NTU) | 6.1-958 | 119 | 228 | 9.5-312 | 67.4 | 120 |
| Dissolved oxygen (mg $L^{-1}$) | 4.6-13.9 | 9.3 | 2.9 | 4.1-12.8 | 8.8 | 3.2 |
| Oxygen saturation (%) | 61.2-184 | 122.4 | 41.1 | 52.9-168 | 113.7 | 41.5 |
| Total solids (g $L^{-1}$) | 0.09-0.31 | 0.20 | 0.15 | 0.1-0.18 | 0.10 | 0.04 |
| Salinity | 0.01-0.02 | 0.00 | 0.004 | 0.01-0.05 | 0.00 | 0.01 |

**Table 2.** Inventory and distribution of the cladocerans considering their occurrence depending on rainfall and those from areas with and without vegetation in a temporary shallow pond in the Mata da Pimenteira State Park (Caatinga of Pernambuco). F.O.: frequency of occurrence.

| **Species** | **Precipitation** | | | | **Occurrence** | |
|---|---|---|---|---|---|---|
| | **< 15 mm** | **15.1 – 30 mm** | **> 30 mm** | **F.O. (%)** | **With vegetation** | **Without vegetation** |
| **SIDIDAE** | | | | | | |
| *Diaphanosoma brevireme* Sars, 1901 | | | x | 8.1 | x | x |
| *Diaphanosoma spinulosum* Herbst, 1966 | x | x | x | 59.5 | x | x |
| **MOINIDAE** | | | | | | |
| *Moina micrura* Kurz, 1873 | x | | x | 13.5 | x | x |
| **DAPHNIIDAE** | | | | | | |
| *Ceriodaphnia cornuta* Sars, 1885 | x | x | x | 67.6 | x | x |
| *Simocephalus acutirostris* King, 1852 | x | x | x | 35.1 | x | x |
| *Simocephalus mixtus* (Müller, 1776) | x | x | x | 21.5 | x | x |
| **ILYOCRYPTIDAE** | | | | | | |
| *Ilyocryptus spinifer* Herrick, 1881 | x | x | x | 27.0 | x | x |
| **MACROTHRICIDAE** | | | | | | |
| *Macrothrix elegans* Sars, 1900 | x | x | x | 97.3 | x | x |
| *Macrothrix superaculeata* (Smirnov, 1982) | x | x | x | 10.8 | x | x |
| **CHYDORIDAE** | | | | | | |
| **CHYDORINAE** | | | | | | |
| *Chydorus* cf. *brevilabris* Frey, 1980 | x | | | 2.7 | x | |
| *Chydorus nitidulus* (Sars, 1901) | x | x | | 5.4 | x | |
| *Chydorus pubescens* Sars, 1900 | x | | | 16.2 | x | x |
| *Alona dentifera* (Sars, 1901) | | x | | 2.7 | | x |
| *Ephemeroporus hybridus* (Daday, 1905) | x | x | | 51.3 | x | x |
| *Chydorus* cf. *sphaericus* (Müller, 1776) | | x | | 8.1 | x | |
| **ALONINAE** | | | | | | |
| *Alona glabra* Guerne & Richard, 1892 | | x | | 8.1 | x | x |
| *Alona guttata* Sars, 1861 | x | | | 2.7 | x | |
| *Coronatella poppei* (Richard, 1896) | x | x | | 21.6 | x | x |
| *Anthalona verrucosa* (Sars, 1901) | x | x | | 10.8 | x | x |
| *Karualona muelleri* (Richard, 1897) | x | x | x | 29.7 | x | x |
| *Leydigia ipojucae* Brehm, 1938 | | x | | 5.4 | x | |
| *Oxyurella longicaudis* (Birge, 1910) | x | x | x | 29.7 | x | x |
| **Richness** | 17 | 17 | 11 | | 21 | 17 |

exclusively during the dry season: *Chydorus* cf. *brevilabris, Alona dentifera* (Sars, 1901), *Alona guttata* Sars, 1862, *Leydigia ipojucae* Brehm, 1938, *Alona glabra* Guerne & Richard, 1892, *Chydorus nitidulus* (Sars, 1901) and *Chydorus pubescens* Sars, 1900.

Four species had frequency of occurrence exceeding 50%. The non-planktonic species *Macrothrix elegans* Sars, 1901 had the highest frequency of occurrence, followed by planktonic species *Ceriodaphnia cornuta* Sars, 1886 and *Diaphanosoma spinulosum* Sars, 1901 and the non-planktonic *Ephemeroporus hybridus* (Daday, 1905). The others had frequencies lower than 36% (Table 2).

The mean density of cladocerans was 186.7 ± 273.6 ind. $L^{-1}$, with the lowest values recorded in some months of both dry and rainy seasons (Fig. 2b). As a consequence of this, during the whole study, the cladoceran density was not different between the seasons (Mann-Whitney; $p > 0.05$). However, the two lower values were registered during the dry season. Besides, due to the large variability of density data, no significant differences were detected between the two sampling areas, with and without macrophytes (Mann-Whitney; $p > 0.05$).

The most abundant species were *Macrothrix elegans* Sars, 1900, *Diaphanosoma spinulosum* Herbst, 1966 and *Ephemeroporus hybridus* (Daday, 1905). *Macrothrix elegans* occurred in virtually every month and had its highest density in rainy season (January 2012; 227.0 ± 215.7 ind. $L^{-1}$), just as *Diaphanosoma spinulosum* (late March 2012; 148.9 ± 208.1 ind. $L^{-1}$). On the other hand, *Ephemeroporus hybridus* showed the highest density in dry season (October 2011; 486.0 ± 601.2 ind. $L^{-1}$). To this last species, the peak coincided with the highest values of water temperature (> 33 °C), whereas no other species showed a population peak in the month of lower water temperature (August 2012). In a month of the rainy season (early March 2012), the lowest pH (5.9) was recorded, and this time it coincided with the occurrence of population peaks of *Ceriodaphnia cornuta* Sars, 1886 (151.1 ± 13.3 ind. $L^{-1}$), *Moina micrura* Kurz, 1873 (39.5 ± 47.3 ind. $L^{-1}$) and *Diaphanosoma brevireme* Sars, 1900 (221.1 ind. $L^{-1}$).

Both cladoceran diversity and evenness data were not different between the seasons and between the sampling areas with and without vegetation (Mann-Whitney test, $p > 0.05$). The Shannon-Wiener diversity index showed values ranging from very low (between 0 and 1 bit. $ind^{-1}$) to medium (between 2 and 3 bits. $ind^{-1}$), varying between 0.00 and 2.11 bits. $ind^{-1}$, both for the point without vegetation. Higher values of diversity were recorded for the cladoceran community when precipitation was less than 30 mm in the region. The lowest values for diversity were recorded in the dry season (May 2012), with only three species: *Macrothrix superaculeata* (Smirnov, 1992), *Diaphanosoma spinulosum* Herbst, 1966 and *Coronatella poppei* (Richard, 1896). In this same month, the evenness recorded their minimum value (0.00) for the area without vegetation. The maximum evenness value was 0.971 (rainy season), registered also for the area without vegetation. Other three values higher than 0.8 were registered during the dry season (Tab. 3).

*Cladoceran community, environmental variables and scores of fluctuation index*

The density and richness of cladocerans were positively correlated with water temperature (Spearman, $r = 0.50$ and $p < 0.01$ and $r = 0.43$ and $p < 0.05$, respectively). The other parameters of the cladoceran community did not show significant correlation with the any variables (Spearman, $p > 0.05$). The density of *Macrothrix elegans* was correlated with dissolved oxygen (Spearman, $r = 0.39$ and $p < 0.05$) and *Ceriodaphnia cornuta* abundance showed a negative correlation with pH (Spearman, $r = -0.36$ and $p < 0.05$).

The fluctuation index for the most frequent and abundant species (*Ceriodaphnia cornuta, Diaphanosoma spinulosum, Ilyocryptus spinifer, Karualona muelleri, Simocephalus acutirostris,* and *Macrothrix elegans*) showed no significant correlation with any limnological

**Table 3.** Temporal variation in richness, diversity and evenness of cladocerans from areas with and without vegetation in a temporary shallow pond in the Mata da Pimenteira State Park (Caatinga of Pernambuco).

| Month | Richness | | Diversity (H'; bits. ind$^{-1}$) | | Evenness (J') | |
|---|---|---|---|---|---|---|
| | With vegetation | Without vegetation | With vegetation | Without vegetation | With vegetation | Without vegetation |
| June 2011 | 12 | - | 1.963 | - | 0.686 | - |
| July 2011 | 9 | 3 | 1.969 | 1.371 | 0.816 | 0.865 |
| October 2011 | 15 | 10 | 1.238 | 1.874 | 0.427 | 0.564 |
| Early December 2011 | 6 | 7 | 1.212 | 2.106 | 0.639 | 0.750 |
| Late December 2011 | 6 | 2 | 1.006 | 0.971 | 0.626 | 0.971 |
| January 2012 | 9 | 4 | 1.345 | 0.750 | 0.515 | 0.375 |
| Early March 2012 | 8 | 4 | 1.532 | 1.423 | 0.620 | 0.711 |
| Late March 2012 | 5 | 4 | 1.135 | 0.671 | 0.722 | 0.336 |
| May 2012 | 3 | 1 | 0.681 | 0.000 | 0.553 | 0.000 |
| August 2012 | 5 | 5 | 1.543 | 1.581 | 0.854 | 0.681 |

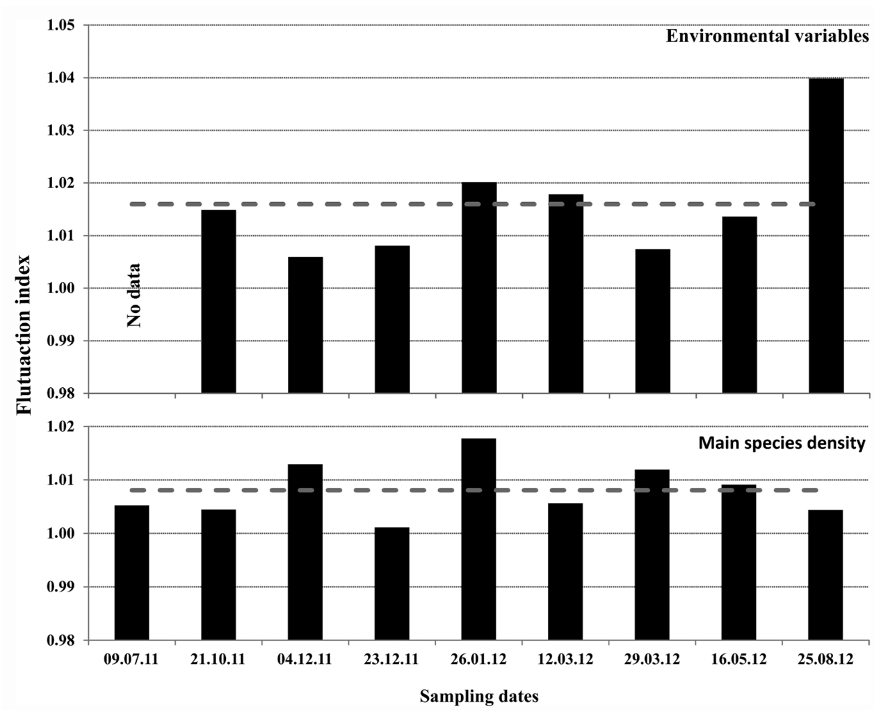


**Figure 3**. Monthly variation of the fluctuation indexes of environmental variables and the density of the main species (most abundant and frequent species) of cladocerans from a temporary shallow pond in the Mata da Pimenteira State Park (Caatinga of Pernambuco). Sampling dates format: dd.mm.yy.

variable, but varied markedly during the study period, with greater instability during two extreme periods: when drought was most severe in spring (August and early December 2011) or when rainfall was high (late March 2012), being more stable in those months with intermediate rainfall (Fig. 3). However, during the whole study, this fluctuation index was not different between the seasons (Mann-Whitney; $p > 0.05$).

In the same way, the fluctuation index of environmental variables did not show differences between the seasons (Mann-Whitney; $p > 0.05$), not varying much over the study period, except for the months when the pond almost dried out (December 2011 and August 2012) (Fig. 3). However, this index showed a negative correlation with temperature (Pearson, $r = -0.75$ and $p < 0.05$) and a positive correlation with turbidity (Pearson, $r = 0.74$ and $p < 0.05$).

## Discussion

The temporary shallow pond of Mata da Pimenteira State Park showed great variability in the structure of cladoceran populations and major environmental variables. This variability, however, was not associated to the seasons, even the precipitation has showed differences between dry and rainy seasons. According to Maltchik (1990), the lagoons of the semiarid region are characterized by low and irregular rainfall amounts with 1 to 11 months of drought, and this irregularity is observed between the areas and the years in semiarid region (Crispim *et al.*, 2006). This may explain the instability in the fluctuation index of species and environmental variables during the driest months or those with greater precipitation, which ends up promoting significant changes in the environment. According to Vieira *et al.* (2009), changes in environmental characteristics resulting from irregular rainfall are determining factors in the dynamics of zooplankton communities from semiarid region.

The knowledge of the fauna of limnic cladocerans in Brazil is still limited (Elmoor-Loureiro, 2000), so it is important to carry out studies on the diversity of these organisms in the different types of water bodies to increase knowledge of this key-community to the dynamics of freshwater ecosystems. Accordingly, this study stands out by representing one of the first monthly surveys on the diversity of planktonic and non-planktonic cladocerans in temporary environments of Caatinga provinces. In a recent update of the list of cladocerans to Pernambuco, the occurrence of 51 taxa was verified (Soares and Elmoor-Loureiro, 2011). Thus, the two new occurrences in Pernambuco (*Chydorus* cf. *brevilabris* and *Macrothrix superaculeata*) increase to 53 the total number of species known in the State.

According to Maltchik (2000), the semiarid lakes are considered true biodiversity hotspots and perhaps therefore the richness of cladocerans in the Pimenteira temporary pond can be considered high when compared with other studies performed in artificial lentic environments (Crispim and Watanabe, 2001; Melo Júnior *et al.,* 2007; Almeida *et al.,* 2009). In the Neotropical region, Aranguren-Riaño *et al.* (2011) analyzed 15 large lentic ecosystems and recorded a total of 19 cladoceran species, leading the authors to conclude that this richness was related to the large catchment area of the springs. In contrast, 22 species were inventoried for a single shallow and small pond, the object of this study, which sustains a great number of macrophytes when compared with the large lakes studied by Aranguren-Riaño *et al.* (2011). However, the occurrence of typical planktonic species, such as *Ceriodaphnia cornuta* and *Diaphanosoma brevireme,* in the littoral zone of the Pimenteira pond, confirming the plasticity of these species in living areas with and without vegetation, as stated by Elmoor-Loureiro (2007a), show that bio- and ecological features of these species need to be more explored in future studies.

The high richness observed in Mata da Pimenteira pond is also highlighted in comparison with the results observed in other temporary ponds. Crispim and Freitas (2005) recorded ten cladoceran species in a temporary pond in a semi-arid region of Paraíba state (Northeastern Brazil). In a temporary pond in La Pampa province, Argentina, Vignatti *et al.* (2012) reported 16 zooplankton taxa, but only three of them were cladoceran species. Only five cladoceran species was observed in a temporary pond in Northeastern Spain (Boix *et al.*, 2001). Waterkeyn *et al.* (2008), studying 30 temporary ponds in Southern France, recorded 17 cladoceran species, the majority belonging to the Chydoridae family.

The dominance of the Chydoridae family was also reported by other researchers (Elmoor-Loureiro, 2007b; Elmoor-Loureiro and Mendonça-Galvão, 2008; Maia-Barbosa *et al.*, 2008; Sousa and Elmoor-Loureiro, 2008; Castilho-Noll *et al.*, 2010; Soares and Elmoor-Loureiro, 2011) (Table 4). This fact may be related to the peculiar characteristics of organisms in this family that have a thicker shell, spines and appendages specialized in grasping substrates, allowing greater mobility and success in the littoral lake areas. Even with

**Table 4.** List of some water bodies in the Caatinga, Atlantic Forest, Cerrado and Amazon regions, already studied regarding the cladocerans with highest representativeness of the families Chydoridae and/or Bosminidae (*). Coordinates: Geographic coordinates; States of Pernambuco (PE), Ceará (CE), Minas Gerais (MG), Goiás (GO) and Amazonas (AM).

| Location/State | Coordinates | Mesh (μm) | Richness | Authority |
|---|---|---|---|---|
| Apipucos Dam – PE | 8°1'16.6" S; 34°55'59" W | 80/100 | 15 | Soares and Elmoor-Loureiro, 2011 |
| Dois Irmãos Dam – PE | 8°00'51" S; 34°56'47.7" W | 80/100 | 18 | Soares and Elmoor-Loureiro, 2011 |
| Tank in the Casa Forte Square – PE | 8°2'4.3" S; 34°55'10.6" W | 80/100 | 2 | Soares and Elmoor-Loureiro, 2011 |
| Tanks of the Oceanography Laboratory- UFPE – PE | 8°9' S; 34°54' W | 80/100 | 3 | Soares and Elmoor -Loureiro, 2011 |
| Piedade beach flooded – PE | 8°9' S; 34°54' W | 80/100 | 4 | Soares and Elmoor-Loureiro, 2011 |
| Lagoon of Sítio do Pica-pau Amarelo Club – PE | 7°56' S; 34°52' W | 80/100 | 3 | Soares and Elmoor-Loureiro, 2011 |
| Engenho Camaçari Lagoon – PE | 8°19' S; 35°14' W | 80/100 | 7 | Soares and Elmoor-Loureiro, 2011 |
| *Shallow temporary pond in the State Park Mata da Pimenteira – PE* | *7°53'48.96"S; 38°18'14.30"W* | 45 | 22 | *Present study* |
| Capivaras Lagoon – GO | 18°16.24' S; 52°50.52' W | 80 | 12 | Sousa and Elmoor-Loureiro, 2008 |
| Vereda – GO | 18°16'10.9" S; 52°45'17.9" W | 80 | 11 | Sousa and Elmoor-Loureiro, 2008 |
| Formoso river – GO | 18°15'42.9" S; 52°53'23.2" W | 80 | 4 | Sousa and Elmoor-Loureiro, 2008 |
| Buriti Torto Stream – GO | 18°14.27' S; 52°53.10' W | 80 | 6 | Sousa and Elmoor-Loureiro, 2008 |
| High Headland of Formoso River – GO | 18°15.59' S; 53°01.96' W | 80 | 6 | Sousa and Elmoor-Loureiro, 2008 |
| Dom Helvécio lake – MG | 19°45' S; 42°35' W | 68 | 32 | Maia-Barbosa *et al.*, 2008 |
| Tupé Lake (large) – AM* | 03°02'35.4"S; 60°15'17.5"W | 55 | 19 | Ghidini and Santos-Silva, 2011 |
| Precabura Lagoon – CE | 3°48'39"S; 38°26'41"W | 80 | 1 | Sousa and Elmoor-Loureiro, 2009 |
| Banana Lagoon – CE | 3°37'28"S; 38°45'22"W | 80 | 5 | Sousa and Elmoor-Loureiro, 2009 |
| Marginal pond to Banana Lagoon – CE | 3°37'28"S; 38°45'22"W | 80 | 13 | Sousa and Elmoor-Loureiro, 2009 |
| Cahuípe Stream – CE | 3°39'37"S; 38°48'14"W | 80 | 13 | Sousa and Elmoor-Loureiro, 2009 |
| Lagamar do Cahuípe – CE | 3°36'17"S; 38°46'50"W | 80 | 10 | Sousa and Elmoor-Loureiro, 2009 |
| Guaribas Stream - CE | 3°33'19"S; 38°52'27"W | 80 | 10 | Sousa and Elmoor-Loureiro, 2009 |
| Lagoon at Pecém – CE | 3°33'22"S; 38°49'26"W | 80 | 2 | Sousa and Elmoor-Loureiro, 2009 |
| Swamp at Ypioca Farm – CE | 3°34'39"S; 38°52'31"W | 80 | 10 | Sousa and Elmoor-Loureiro, 2009 |

differing climatic conditions, the proximity regarding richness and dominance of the same family may indicate a possible similarity between these ecosystems listed in Table 4 – most of them being shallow and rich in macrophyte banks. A contrasting and large lake in the Amazon region (Ghidini and Santos-Silva, 2011), on the other hand, was the furthest from this pattern because there was dominance of Bosminidae, a typical planktonic family, in terms of number of species – in this case, the great amount of limnetic area in this ecosystem explain this dominance. Furthermore, the net mesh size used in sampling seems to affect the number of species. The number of species was considerably higher when smaller mesh size was used, as seen in Mata da Pimenteira pond (Caatinga region), Tupé lake (Amazon region) and Dom Helvécio lake (Mata Atlântica region) (Table 4). However, species richness values are known to be very sensitive to sampling effort and this fact should be considered. Besides the more reduced net mesh size, those three studies had higher sampling efforts when compared to the other studies.

On the other hand, the representatives of the Chydoridae family virtually disappeared in the months of highest rainfall (> 30 mm), especially when considering the subfamily Chydorinae. A reduction in the number of taxa in the subfamily Aloninae was also recorded, with only the non-planktonic species *Karualona muelleri* and *Oxyurella longicaudis* being recorded. These months coincided with noticeable reductions in macrophyte banks, with prevalence only of aggregates of the algae *Chara martiana* Wallman. Whereas rainfall is scarce in semiarid regions, its sporadic occurrence in greater volume (> 30 mm) in the Caatinga could act on reducing the macrophyte banks, as already observed for other temporary ponds in the Caatinga (Pedro *et al.,* 2006). According to these authors, the richness of aquatic macrophyte communities is lower in temporary ponds during flood events, and this fact could explain the reduction in Chydoridae species in the Mata da Pimenteira pond, a typically dominant family in terms of species richness in several Brazilian shallow ponds with predominance of macrophytes (Table 4). Moreover, taking into account the visual predominance of *Chara martiana* in Mata da Pimenteira pond, and considering that cladoceran composition varies with macrophyte size (Lauridsen *et al*., 1996), the slender folioles of this alga would not be sufficient to maintain Chydoridae populations during the periods when the pond is flooded.

On the other hand, reduced water volume causes instability of aquatic populations and influences diversity of Cladocera (Panarelli *et al*., 2010). This may be in agreement with the theory proposed by Naselli-Flores *et al.* (2003), who suggest a tendency of non-equilibrium of the steady-state conditions in the phytoplanktonic community when one or more environmental factors are at the extreme of the range in which organisms can grow and when the change is either too abrupt or too complete and exceeds the homeostatic plateau of the assemblage. Thus, the variation in water volume was accompanied by significant fluctuation in abundance of macrophytes (Cordeiro *et al*., in press) in the pond studied, which may have promoted changes in composition and structure of populations of cladocerans (mainly the phytophilous ones), probably by interfering with their stability.

In fact, the hydroregime, namely the duration, frequency and predictability of the aquatic phase, is a key feature of temporary habitats in structuring the aquatic community (Vanschoenwinkel *et al*., 2009). However, the water temperature probably also had an influence on cladocerans. This was the only variable that correlated significantly with the richness and density of these microcrustaceans. A similar result was also observed by Shurin *et al*. (2010), studying 53 lakes in the temperate zones of North America and Europe, where they found that the chemical variations in ponds tend to exclude zooplankton species, while temperature variability promotes greater richness. Despite being within the semiarid region, the shallow pond of Mata da Pimenteira showed a marked variation in water temperature (20.9 to 35.2 °C).

Even without showing significant differences regarding the sampling points, diversity data should be discussed because it was expected that the greatest diversity would be recorded at sampling points in the presence of vegetation. According to Sakuma *et al.* (2002), vegetation areas in the littoral region of lakes have rich biodiversity. This is because aquatic macrophytes provide a habitat and refuge for many organisms in addition to providing greater environmental heterogeneity (Nogueira *et al*., 2003). However, the maximum diversity was observed at the sampling point without vegetation in early December 2011, with the caveat that most species recorded that day were not typical of the plankton. Almeida *et al*. (2006), studying rotifers in Tapacurá reservoir (Pernambuco), also found significant participation of non-planktonic taxa in the vegetation-free zone, and the authors related this fact to wind action (which brings up individuals from the bottom), precipitation (which carries various organisms from the margin) and floating macrophytes (moved by wind action and may influence biological communities across the surface of the water column, being an efficient mean of transportation for organisms related to them).

Among all these factors, the wind could be a possible explanation to the greater diversity found for the collection point without vegetation, since the Mata da Pimenteira pond showed no occurrence of floating macrophytes (Cordeiro *et al.,* in press) and/or heavy rainfall in the region for some days prior to the samplings. Moreover, predation of cladocerans may also have been an important factor. For that same pond, França and Severi (in press) reported five fish species [*Characidium fasciatum* Reinhardt, 1866; *Astyanax lacustris* (Lütken, 1875); *Serrapinnus heterodon* (Eigenmann, 1915); *Serrapinnus piaba* (Lütken, 1875) and *Hoplias malabaricus* (Bloch, 1794)], which especially in the juvenile stage inhabit the macrophyte banks, feeding on microcrustaceans (Agostinho *et al.,* 2003). However, these two factors (wind and predators) need to be tested in the future to confirm these hypotheses.

The results indicate that although the ecosystem studied here displays intense variations in temperature, water depth and rainfall during the annual cycle and is fed only on rainwater, this temporary shallow pond in the Caatinga houses a rich biodiversity of cladocerans, mainly the non-planktonic ones, and high seasonal variation in the density and structure of their populations, which reinforces the importance of their preservation. The causes and trophic consequences occasioned by reducing the number of taxa of Chydoridae in periods of high rainfall in the Caatinga should be further investigated experimentally.

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