Revista Nordestina de Zoologia
ISSN 1808-7663
Volume 9 Número 1 2015

NEMATODE COMMUNITY OF CONTINENTAL LAKES WITH DIFFERENT CONCENTRATIONS OF SALTS

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ABSTRACT

The knowledge of freshwater biodiversity is lesser than that of marine aquatic ecosystems. The nematofauna of continental aquatic environments is less known than many other water groups. Because of such knowledge gaps, this paper aims to describe the structure of the nematode fauna in three water reservoirs, thus contributing to the knowledge on biodiversity in Brazilian continental waters. Abiotic factors varied among analyzed environments. Salinity, especially, had high values, characterizing the analyzed water reservoirs as brackish water or, in the case of the Olivedos reservoir, as saline. The nematofauna was represented by *Monhystrella*, *Crocodorylaimus*, *Oncholaimus*, *Paracyatholaimus*, *Trefusia*, *Diplolaimella*, *Microlaimus*, *Pseudosteineria*, *Theristus* and *Odontophoroides*. The *Monhystrella* was relevant for the ecosystems analyzed because it is in all water reservoirs. *Trefusia*, *Pseudosteineria* and *Odonthoporoides* were recorded, although not in inland water bodies. Juveniles and non-selective deposit feeders were prevalent in the nematofauna, as with other freshwater ecosystems in the world. This research brings new and relevant data on the nematofauna of continental waters.

Keywords: Abiotic factors, *Monhystrella*, Salinity

RESUMO

O conhecimento da biodiversidade dulcícola é menor do que o de ecossistemas aquáticos marinhos. A nematofauna dos ambientes aquáticos continentais é menos conhecida do que muitos grupos aquáticos. Em virtude de tais lacunas de conhecimento, esse trabalho pretende descrever a estrutura da nematofauna de três reservatórios hídricos contribuindo para o conhecimento da biodiversidade das águas continentais brasileiras. Os fatores abióticos variaram entre os ambientes prospectados, especialmente a salinidade que teve valores altos, caracterizando a água dos açudes analisados como salobras ou, no caso do açude Olivedos, como salina. A nematofauna esteve representada por *Monhystrella, Crocodorylaimus, Oncholaimus, Paracyatholaimus, Trefusia, Diplolaimella, Microlaimus, Pseudosteineria,* *Theristus* e *Odontophoroides.* O gênero *Monhystrella* mostrou-se importante para os ecossistemas analisados por aparecer em todos os reservatórios hídricos. *Trefusia, Pseudosteineria* e *Odonthoporoides* foram registrados mesmo não sendo organismos de águas continentais. A nematofauna esteve dominada por jovens e por comedores não seletivos de depósitos assim como em outros ecossistemas aquáticos continentais do mundo. A presente pesquisa traz dados novos e relevantes para nematofauna aquática continental.

Introduction

The diversity of freshwater organisms is little known, especially regarding microorganisms and invertebrates (Rocha, 2005). In aquatic ecosystems, the benthic community differs in biomass and composition and it is maintained according to variables such as salinity, pH, dissolved oxygen, sediment type and amount of organic matter (Giere, 2009).

Arid and semiarid areas of the world have characteristics that distinguish them as very particular ecosystems. In the Brazilian Northeast, the Caatinga stands out as a semiarid region with many peculiar characteristics such as high spatio-temporal variation of rainfalls, low temperature range during the year, great potential of evapotranspiration, poor soils, shallow drainage basins from rivers and streams, and a typical deciduous vegetation called caatinga, which gives its name to the biome (Barbosa et al., 2012).

Studies on the continental reservoirs biodiversity are rare and when available, they do not address the aquatic biota because they include Meiofauna. Existing works address mainly macroscopic and terrestrial organisms. There are few studies on phytoplankton, periphyton, macrophytes, benthic macroinvertebrates and fish in the aquatic environment (Leal et al., 2003; Barbosa et al., 2012; Ramos et al., 2005).

Considering the lack of knowledge on the biodiversity of the Brazilian semiarid environments, this paper aims at describing the structure of nematofauna community of three artificial water reservoirs, contributing to the knowledge on the biodiversity of continental waters.

Materials and Methods

Study area

The study was conducted in three water reservoirs of the Brazilian Northeast semiarid, more specifically located in the Curimataú Paraibano Ocidental, a microregion of the Paraíba state (Figure 1).

Figura 1. Location of the three analyzed reservoirs in the Brazilian semiarid region (AESA Geoportal, 2015 (with modifications)

- Soledade reservoir: located in the municipality of Soledade, Paraíba state (7°4’4” S/ 36°20’47” W), at an altitude of 519 meters. It is a reservoir near the urban area with a low level of water (10.2%), which until recently was used for the city’s supply. The maximum water capacity of the reservoir is 27,058,000 m^3 (AESA, 2014).
- Olivedos reservoir: located in the municipality of Olivedos, Paraíba state, at an altitude of 575 meters (6°57’52” S and 36°14’33” W). It is a reservoir distant from the urban area. In sampling periods, it presented a low level of water of approximately 5% of its total capacity, which is 5,875,124 m^3 (AESA, 2014).
- Poleiros reservoir: Poleiros (6º43’47” S/36º05’18” W) is located in the municipality of Barra de Santa Rosa, Paraíba state, at an altitude of 484 meters. It has a total capacity of 7,933,700 m^3. At the time of the sampling, it had 15.4% of its total capacity. The water is used for city service purposes, fishing etc. (AESA, 2014).

Field Methodology

Fifteen samples were collected at three different points of the reservoir with the aid of a PVC corer with a 15.89 cm^2 internal area at 5 cm depth. Sediments for particle sizing and organic matter analysis were collected. Water was collected to measure temperature, salinity and pH. The sediment samples were fixed with formalin and taken to the Meiofauna Laboratory of UFCG (LabMeio) for analysis.

Laboratory Methodology

In the laboratory, the methodology proposed by Elmgren (1976) for meiobenthology was used. The density was calculated regarding the number of individuals per 10 cm^2. The Nematodes were submitted to diafanization (De Grisse, 1969). The slides followed the methodology proposed by Cobb (1917). For the generic identification, a pictorial key proposed by Warwick et al. (1998) and Zullinni (2010) was used. Besides the identification of the genera, the buccal cavity was examined following Wieser (1953) and the stages of the organism's development were observed. The classification follows Lorenzen (1994) and De Ley et al. (2006). The particle size analysis was carried out according to Suguio (1973) and the results processed using the Sysgran software, which allows calculating parameters such as skewness, kurtosis and grain selection, following the method of Folk & Ward (1957). To calculate the organic matter content contained in sediments, the ignition furnace method was adopted (Walkley & Black, 1934).

Data analysis

Aiming at determining spatial changes in the structure of nematode communities in the reservoirs, the abundance values, genera composition and applied univariate and multivariate analyses were necessary. Therefore, the Shannon (H') and Pielou's equitability (J') ecological diversity indexes were calculated. Multivariate analyses, such as MDS (multidimensional scaling analysis), SIMPER and ANOSIM were performed. A significance of 5% was used in all tests. The similarity index of Bray-Curtis was used to build the similarity matrix used in the analyses. The BIOENV analysis pointed the environmental parameters with best relation with the community structure. The correlation coefficient used was the Spearman's (Clarke & Gorley, 2001). All analyses were performed using the PRIMER® software (Plymouth Routine in Marine Ecology Research) version 6.

Results

Abiotic factors

The values of measured environmental factors observed in the reservoir are shown in Table 1.

Table 1- Averages of measured environmental factors in the reservoirs

Factors	Soledade-PB (Soledade)	Olivedos-PB (Olivedos)	Barra de Santa Rosa-PB (Poleiros)
Water Temperature (ºC)	23.7	25.3	24
Dissolved oxygen (mg/l)	7.66	8.9	6.8
Salinity (‰)	19	>100	4
pH	8.67	7.92	7.80
Organic matter (%)	0.94	12.19	5.42

Nematofauna community

The nematofauna was represented by ten genera that, in order of relative abundance, are *Monhystrella*, *Crocodorylaimus*, *Oncholaimus*, *Paracyatholaimus*, *Trefusia*, *Diplolaimella*, *Microlaimus*, *Pseudosteineria*, *Theristus* and *Odontophoroides*. The last six genera contributed less than 0.5% (each) to the total relative abundance. *Monhystrella* was the only genus that was present in all prospected reservoirs; others were present in only one. Analyzed separately, the reservoirs had differences regarding the main Nematode genera found (Figure 2).

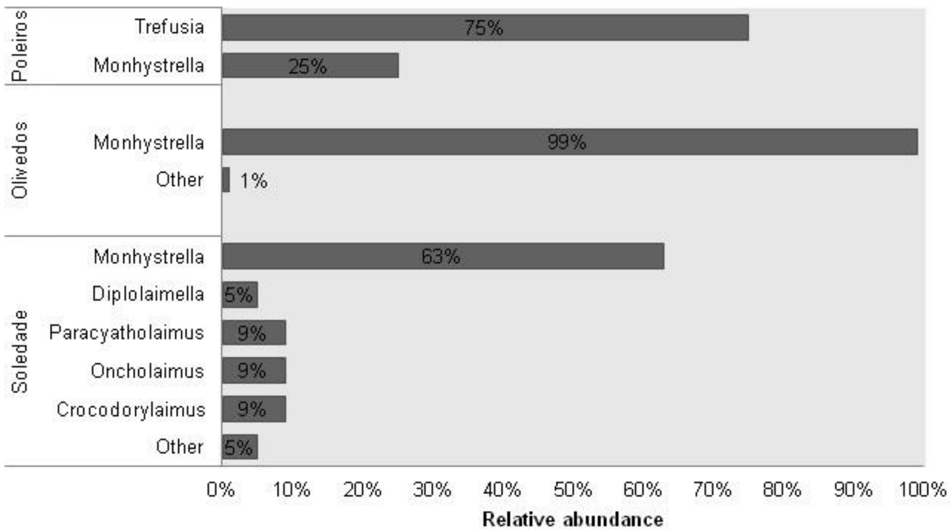

Figura 2. Relative abundance of Nematode genera in reservoirs

The Soledad reservoir had only seven genera. This was the highest number found because the Poleiros and Olivedos reservoirs had 2 and 3 genera, respectively. The neamtofauna of Olivedos reservoir is virtually monospecific since 99.3% of individuals belong to the species *Monhystrella hoogewijsi* Eyualem-Abebe & Coomans, 1996.

The nematofauna community showed significant differences among the reservoirs studied. The ANOSIM presented global R value of 0.632 at 0.1% significance. The MDS showed clusters in Olivedos and Soledade reservoirs and dispersion of representative points in the Poleiros reservoir (Figure 3). SIMPER showed that *Monhystrella* was primarily responsible for the dissimilarities among the samples analyzed.

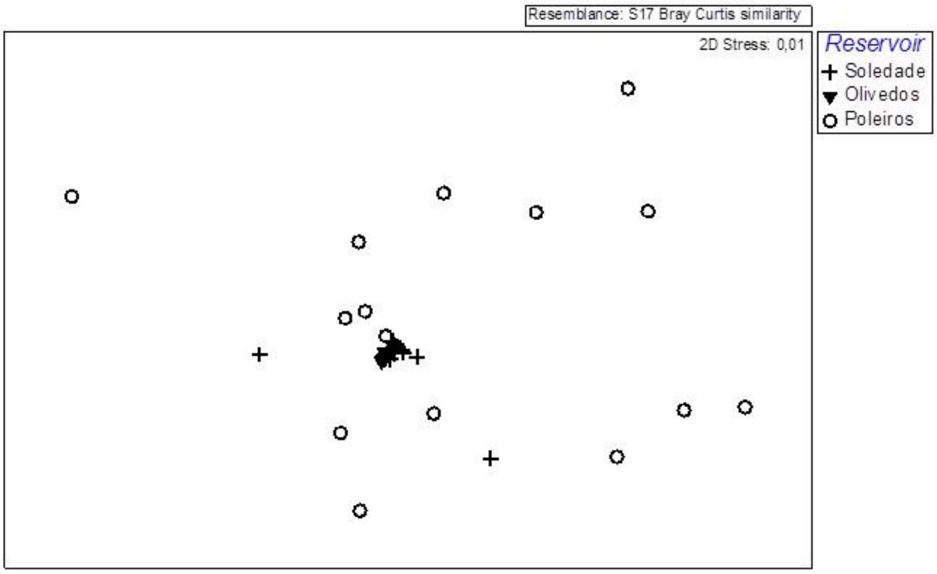

Figura 3. Multidimensional ordination analysis (MDS) of the nematofauna community in reservoirs

The Soledad reservoir had the highest diversity (H'= 0.456) and the highest equitability (J'=0.413), while Poleiros reservoir had the lowest diversity (H'= 0.042) and the Olivedos reservoir had the lowest equitability (J'=0.413) (Figure 4).

According to development stages, the nematofauna community has 93% of juveniles, 6% of females and 1% of males. It is important to note that the Poleiros reservoir, where the amount of nematodes found was lower (n=4), had no adult individuals. Among the reservoirs, this development stage percentage slightly varied (Figure 5).

The buccal cavity of nematodes found is predominantly 1B - nonselective deposit feeders. Nematodes in the Soledade reservoir have the four existing buccal cavities and this reservoir was the only one to present omnivore or predator nematodes with a 2B buccal cavity (Figure 6).

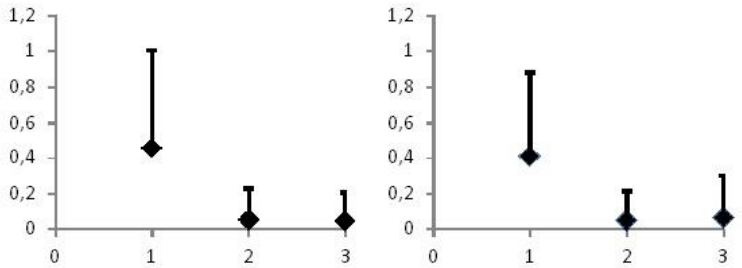

Figura 4. Diversity Index of Shannon (H'), Pielou's Equitalbility (J') and standard deviation of the reservoirs. 1: Soledade; 2: Olivedos; 3: Poleiros

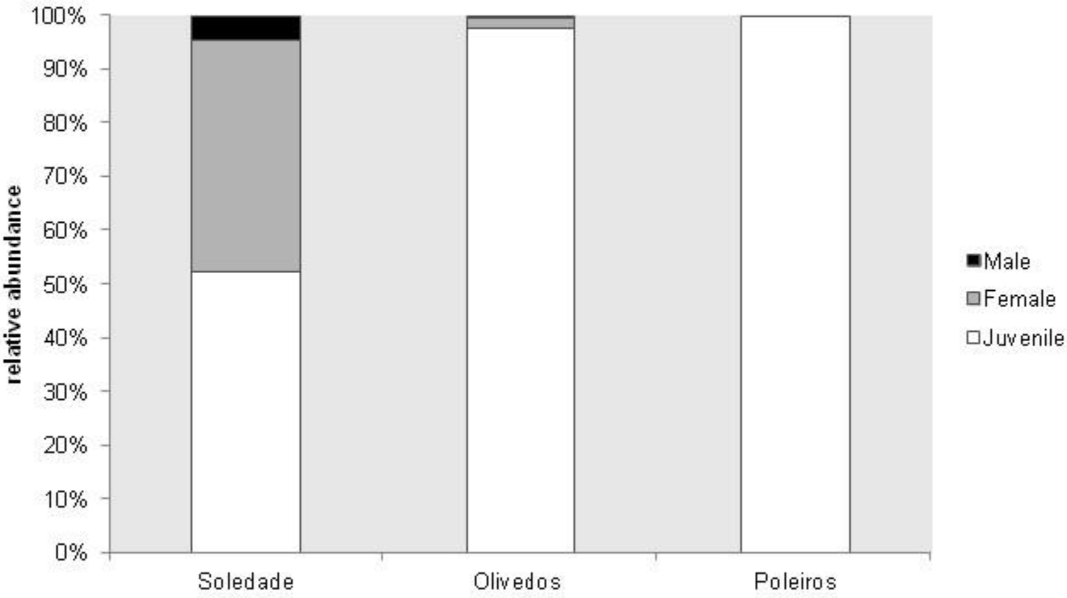

Figura 5. Development stage of the nematofauna in reservoirs

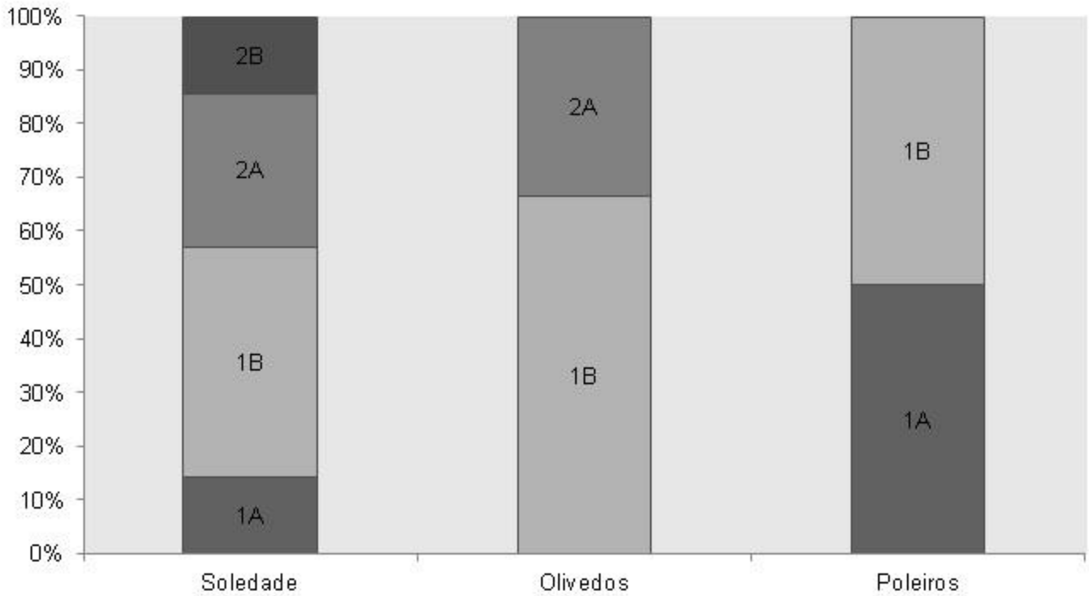

Figura 6. Proportionality of the nematodes buccal cavities types found in reservoirs. 1A= Selective deposit feeders; 1B= non-selective deposit feeders; 2A= epistrate feeders; 2B= Predators or omnivores.

Discussion

According to Barbosa et al. (2012), physical and climatic characteristics of the analyzed reservoirs are consistent with the description of aquatic ecosystems in the Brazilian semiarid region. The high level of eutrophication detected by the author when reviewing Brazilian semiarid reservoir studies can also be confirmed in this study by the high content of organic matter found. The main distinguishing feature of the analyzed reservoirs is the high salinity that allows stating, according to the Resolution of the National Environmental Council

(CONAMA, 2005), that Soledade and Poleiros reservoirs have brackish water while Olivedos reservoir has saline water.

The genera diversity found in this study was lower than that detected by Bert et al. (2007), who found 17 genera in 14 lagoons in the agricultural field. According to Traunspurger (2013), the animals of Monhysterida Order are predominant in studies on freshwater environments such as lakes and rivers mainly because they have a short life cycle. This is confirmed by the results of this study, which found that four genera belong to this order. *Monhystrella* is the primarily responsible for the dissimilarities among the samples analyzed. It belongs to the Monhysterida Order. Even being a constant genus in freshwater environments, it is always found with a low number of individuals (Andrássy, 1981), a fact that differs from this research, which found high abundance of this genus in most reservoirs.

The presence of certain genera in the reservoirs may indicate environmental conditions analyzed, evidencing the bioindicator role of phylum Nematoda. *Theristus* and *Oncholaimus* are found in rivers and lakes in arid regions of Russia (Gusakov & Gargarin, 2012) and, along with *Monhystrella*, are common in arid regions of southern Africa (Heyns, 2002). *Theristus* is commonly found in river sediments (Smythe & Hope, 2008; Heinenger et al., 2007), more particularly in sandy portions (Bongers & Van De Haar, 1990). It is considered an opportunistic genus, such as *Microlaimus*, for living in disturbed environments and presenting high maturity index (Gyedu-Ababio & Baird, 2006). *Microlaimus* and *Paracyatholaimus* are common in areas with high primary production and high amounts of oxygen (Bongers & Van De Haar, 1990). There was *Microlaimus* in the Olivedos reservoir, demonstrating that it can withstand extreme environmental variables. This highlights the opportunistic characteristic of this genus.

Crocodorylaimus is recorded in freshwater environments (Gagarin, 2011; Gagarin & Gusakov, 2013). This genus has been recorded in high relative abundance in different lakes in Switzerland (Peters & Traunspurger, 2005), and it is studied using artificial substrates in Croatia (Vidaković et al., 2011). In this study, only females were found, opposed to the work by Vidaković et al. (2011), who found higher abundance of juveniles. The authors associate the high incidence of juveniles to the beginning of the ecological succession process. The lack of those individuals at a juvenile stage in the present study may indicate a community already established, although no males or juveniles have been found.

Currently, there are 12 valid species of *Diplollaimela* (Fonseca & Decraemer, 2008), two of which are found exclusively in freshwater environments. This genus has been recorded in arid environments such as the Sahara desert, and one species was discovered by Gerlach (1957) in Brazil. In this study, this genus was registered in the Soledade reservoir, which has brackish water, a characteristic consistent with the preferred habitat of this taxon.

The genera *Trefusia*, *Pseudosteineria* and *Odontophoroides* were not present according to the main identification keys in a genus level for freshwater nematodes, thus demonstrating that they are not common in these environments (De Ley et al., 2006; Zullinni, 2010). This is an important result of our study for the Brazilian semiarid region. *Trefusia* was present in the Poleiros reservoir and it has been mentioned for Brazil by Gerlach (1957). However, this mention refers to estuaries, and this study presents the first record of it for freshwater environments. *Pseudosteineria* species are recorded for the Brazilian coast (Venekey et al., 2014), as well as species of *Odontophoroides* (Venekey et al., 2010). This research presents the first record of these genera in freshwater ecosystems.

According to Traunspurger (2013), the distribution and abundance of Nematoda in freshwater environments is strongly influenced by depth. However, there is no clear evidence relating it to other factors. The author explains that there are not enough freshwater studies to formulate hypotheses on both abundance and diversity. The highest amount of organisms found in the Olivedos reservoir compared to the others is probably due to salinity, which was the factor that most varied among other environments analyzed. Belmont et al. (2012) emphasizes that the presence of an "explosion" of monospecific populations in hypersaline lakes is common due to the absence of complex food webs and the presence of short trophic chains. These facts may explain the presence of a high number of individuals belonging to *Monhystrella hoogewijsi* in Olivedos reservoir. This dominance of *Monhystrella* has been found in other studies such as Gusakov & Gargarin (2012), where *Monhystrella parvella* accounted for 78-93% of the local fauna, and Bongers & Van de Haar (1990), where this genus proved to be quite common in the different types of sediments analyzed.

For Williams (1998), when testing in environments with different salt concentrations, as it is the case presented here, there is a tendency to involve differences in the saliniy factor. However, there are other factors affecting the community of freshwater ecosystems: the amount of dissolved oxygen, ionic composition, pH, hydrological model, geographical position, paleoclimate events, accidents, human intervention and biological interactions. According to Alcocer et al. (2001), salinity and pH are the parameters that best explain the environmental variation in temporary and/or salty lakes. In this research, the BIOENV showed that the amount of oxygen and the type of sediment affected more the lake's community with a varying salinity and exposed to seasonal drought regimes than other abiotic factors. Such differences further reinforce the idea that various environmental factors contribute to the community structure.

The dominance of juveniles followed by females is a common feature for freshwater ecosystems (Beier & Traunspurger, 2003; Michiels & Traunspurger, 2004; Schroeder et al., 2013). A high abundance of juveniles indicates a constant reproduction throughout the year (Michiels & Traunspurger, 2004), a fact that may occur in the analyzed reservoirs.

Works on temporal dynamics of taxa and trophic groups in temporary and/or saline lakes are relatively scarce (Alcocer et al., 2001). The diversity of foods in a single ecosystem has been found in works such as Traunspurger (2000) in stream ecosystems and Michiels & Traunspurger (2005) in alpine oligotrophic lakes.

Nematodes are one of the main consumers of organic matter in the reservoirs, as seen in other works (Michiels & Traunspuger, 2005; Schmid-Araya & Schmid, 2000). They may stimulate bacterial production for consumers, when playing bioturbation on sediment or when they excrete metabolic waste products that serve as food for microorganisms (Hakenkamp & Morin, 2000). One factor that may be a confirmation of this statement is the predominant type of buccal cavity in the reservoirs analyzed, especially that of nonselective deposit feeders (1B). This characteristic is highly consistent with the amount of organic matter found in analyzed environments. In many organisms in the Olivedos reservoir, it was possible to find bacterial colonies completely adhered to the body of nematodes (observed data). Others found genera that represent the other three buccal cavities discussed in the literature (Wieser, 1953), thus demonstrating the availability of different food resources in Brazilian semiarid ecosystems. Despite being from the 1950s, the classification created by Wieser is still widely used. Moens & Vincx (1997) subdivided the four buccal cavities, creating more three subdivisions. However, because it is a laboratory experiment, this classification is not used in all studies. Jensen (1987) made two changes to Wieser's scheme, which is explained by Moens & Vincx (1997) as the combining of two groups of deposit feeders (1A and 1B) forming a single group. Traunspurger (1997) accepted this group for freshwater Nematoda. Thus, it is important to emphasize that both classifications (Wieser, 1953; Moens & Vincx, 1997) are applied to marine environments and, in the absence of exclusive classifications, for freshwater environments. The classification most commonly used for natural environments was that of Wieser's used in this study (Wieser, 1953).

Conclusion

The abiotic factors salinity, dissolved oxygen and organic matter were decisive parameters for analyzing the nematofauna community structure in the reservoirs studied. It emphasizes the extreme character conditioned by high salinity to which nematodes are submitted in one of the reservoirs. It showed an almost monospecific community. The significant presence of organic matter observed in the reservoirs probably affects the expressive dominance of deposit feeders found in all environments.

The presence of *Trefusia, Pseudosteineria* and *Odontophoroides*, which are not common in continental aquatic environments, demonstrates the importance of further studies on the nematofauna of continental aquatic environments unexplored in this study and in other areas still not studied.

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