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Two practical approaches to monitoring the zooplanktonic community at Lago Grande do Curuai, Pará, Brazil

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ABSTRACT

The use of substitute groups in biomonitoring programs has been proposed to minimize the high financial costs and time for samples processing. The objectives of this study were to evaluate the correlation between (i) the spatial distribution among the major zooplankton groups (cladocerans, copepods, rotifers, and testaceans protozoa), (ii) the data of density and presence/ absence of species, and (iii) the data of species, genera, and families from samples collected in the Lago Grande do Curuai, Pará, Brazil. A total of 55 sample of the zooplanktonic community was collected, with 28 samples obtained in March and 27 in September, 2013. The agreement between the different sets of data was assessed using Mantel and Procrustes tests. Our results indicated high correlations between genus level and species level and high correlations between presence/absence of species and abundance, regardless of the seasonal period. These results suggest that zooplankton community could be incorporated in a long-term monitoring program at relatively low financial and time costs.

KEYWORDS: Biomonitoring, Cladoceran, Copepod, Rotifer, Testate amoebae.

Duas abordagens práticas para o monitoramento da comunidade zooplanctônica no Lago Grande do Curuai, Pará, Brasil

RESUMO

O uso de grupos substitutos em programas de biomonitoramento tem sido proposto para minimizar os altos custos financeiros e tempo para processamento das amostras. Os objetivos deste estudo foram avaliar a correlação entre (i) a distribuição espacial nos principais grupos zooplanctônicos (cladóceros, copépodes, protozoários testáceos e rotíferos), (ii) os dados de densidade e presença/ausência de espécies, e (iii) os dados de espécies, gêneros e famílias a partir de amostras coletadas no Lago Grande do Curai, Pará, Brasil. Um total de 55 amostras da comunidade zooplanctônica foi coletada, sendo 28 em março e 27 em setembro de 2013. A concordância entre os diferentes conjuntos de dados foi avaliada por meio dos testes de Mantel e Procrustes. Nossos resultados indicam alta correlação entre nível de gênero e espécies e entre a presença/ausência de espécies e abundância, independentemente do período sazonal. Estes resultados sugerem que a comunidade zooplanctônica pode ser incorporada em programas de monitoramento a longo prazo com custos financeiros e de tempo relativamente menores.

PALAVRAS-CHAVE: Biomonitoramento, Cladóceros, Copépodes, Rotíferos, Amebas Testáceas.

INTRODUCTION

With the rising problems that range from occupation to exploitation of terrestrial and aquatic ecosystems, the need to identify human impacts, seek mitigation alternatives, and finally, implement environmental monitoring programs in the affected areas which are emerging (Siqueira and Roque 2010). Different approaches which evaluate the physical, chemical and biologically the environment have been applied in monitoring programs (Monteiro et al. 2008). For example, biomonitoring has become increasingly important because it is capable of generating information about environmental and biological qualities in the short, medium, and long term (Buss *et al.* 2003).

Complementary to physical and chemical approach, biomonitoring is able to assess environmental conditions through morphological changes of organisms, variations in density, species richness and changes in community composition (Goulart and Callisto 2003). Therefore, environmental monitoring programs that integrate physicochemical to biological information are more complete than those restricted to just physicochemical monitoring (Buss *et al.* 2003). Physiochemical monitoring is useful for tracking the origin and intensity of changes in the environment (for example, waste discharge, deforestation, eutrophication, etc.), but it is unable to precisely identify how these changes impact biological communities (Buss *et al.* 2008).

A wide variety of organisms are used for biomonitoring (Resh 2008), such as fish (Dellinger *et al.* 2014), zooplankton (Lodi *et al.* 2011), benthic macro-invertebrates (Trigal *et al.* 2014), and plants (Szczyglowska *et al.* 2014); however, the integration of various organic groups and identification of each at the lowest possible taxonomic level (in most cases, the specific level) can be impracticable both financially and in relation to the time available for the study (Carneiro *et al.* 2010; Padial *et al.* 2012).

Some possible alternatives have been proposed to minimize these problems, such as the use of substitute groups (Lopes *et al.* 2011; Vieira *et al.* 2014), species lists based on occurrence data as an alternative to abundance data of individuals (Carneiro *et al.* 2010), and identification of organisms in less specific taxonomic scales (Carneiro *et al.* 2013).

The objectives of this study were to evaluate the correlation between (i) the spatial distribution among the major zooplankton groups (cladocerans, copepods, rotifers, and testaceans protozoa), (ii) the data of density and presence/absence of species, and (iii) the data of species, genera, and families.

MATERIALS AND METHODS

Study Area

The study was performed on the floodplain of Lago Grande de Curuai, Pará, Brazil (Figure 1). Being located on the right margin of the low course of the Amazon River between 56.10º and 55.00º W, 2.3º and 1.9º S from upstream to downstream. The area is composed of several interconnected lakes and is connected to the Amazon River through several channels. Along the year, the water level variation in the floodplain is mono-modal following the Amazon River flood pulse. The amplitude of the variations between the low and high water stages is approximately 6 m for typical hydrological cycles (Amorim *et al.* 2009). Consequently, the open water area varies along the year ranging from approximately 600 km² at a minimum water level equal to 3 m to 2,500 km² at a maximum water level equal to 11.5 m (Bonnet *et al.* 2008).

The cycles of high and low water are temporally well defined (Figure 2), with the first phase (high water peak) corresponding to the months ranging from May to July and the second phase (low water peak) occurring between October and December.

Collection and identification

A total of 55 sampling units were selected in the Lago Grande do Curuai, with 28 samples obtained in March (flooding period, points 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27 and 29) and 27, in September (flushing period, points 1, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29 and 30), 2013 (Figure 1). The sample units 2, 3 and 4 were gathered only in March and sample units 28 and 30 only in September. A sample of the zooplanktonic community was collected in each sampling unit through a plankton net with a mesh size of 68 µm using 300 liters of filtered water per sample. The samples were preserved in 4% formaldehyde (Steedman 1976).

Identification and density calculations were obtained and samples were concentrated to 75 mL, of which 7.5 mL was subsampled with Hensen-Stempel pipette and counted in a Sedgewick-Rafter chamber (Pyser SGI's of 50mm long x 20mm wide and 1mm deep). Subsequently, a qualitative analysis was conducted by using new sub samples until no new taxa were found (Bottrell *et al.* 1976). Densities were expressed as individuals m^{-3}.

Data analysis

All data were transformed into a logarithmic scale (x+1) and sorted into species, genera, families, and zooplankton groups (cladocerans, copepods, rotifers and testaceans protozoa) prior to statistical analysis.

The agreement between the different sets of data was assessed using Mantel and Procrustes tests (Legendre and Legendre 2012). The Mantel test calculates the correlation between two distance matrices, and the Procrustes computes the minimum spatial distance between the scores of the sampling units after an ordination technique (in this case,

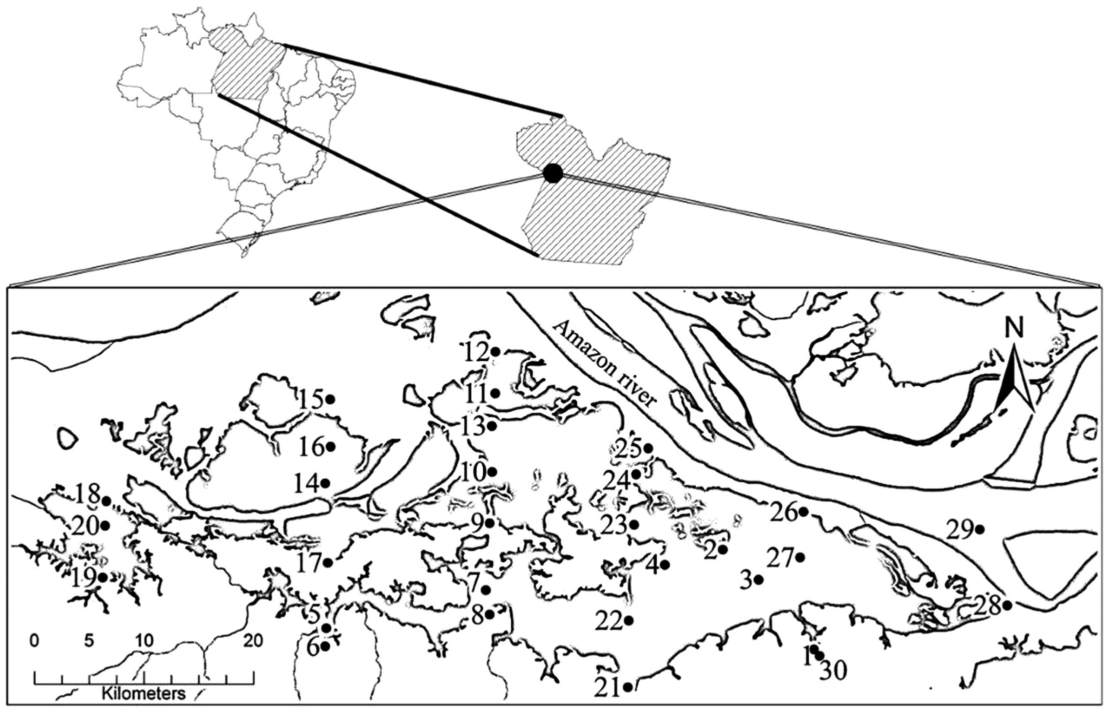

Figure 1. Map of the region and the location of Lago Grande do Curuai. The points indicate the location of sampling units.

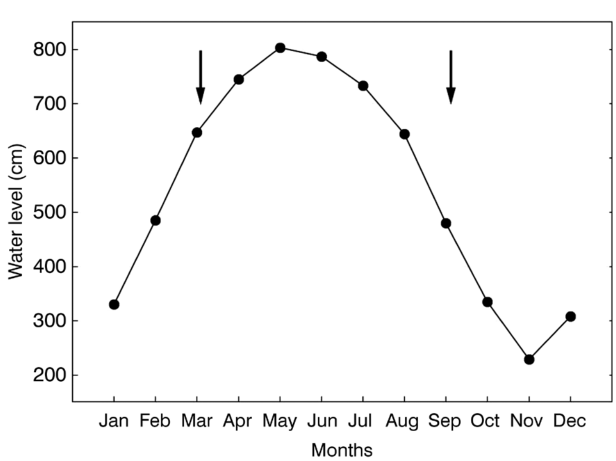

Figure 2. Water level of the Amazon River at the Óbidos gauge in 2013. Arrows indicate the sampling periods.

Principal Coordinates Analysis - PCoA). In both analyses, the strength of correlation was measured using the *r* value (*r* Mantel: ranges from -1 to +1, *r* Procrustes: ranges from 0 to +1), and randomization tests (with 9,999 randomizations) were applied to quantify the statistical significance of *r* values. Distance matrices were analyzed using the Bray-Curtis distance compared to density data matrices and the Jaccard index for the presence or absence of species (Legendre and Legendre 2012).

All the analyses were performed using the *vegan* package of R statistical software (R Development Core Team 2013).

RESULTS

A total of 166 species were sampled, including 28 cladocerans, 22 copepods, 83 rotifers, and 33 testaceans protozoa. The total abundance was 5,780,804 individuals, with 503,939 cladocerans, 3,097,837 copepods, 1,830,649 rotifers, and 348,378 testaceans protozoa. In both periods (flooding and flushing), rotifers were dominant in species richness and copepods were dominant in abundance of individuals.

The two analyses (Mantel and Procrustes) showed similar results (Tables 1 and 2). Regardless of the sampling period, there were significant correlations between cladocerans and copepods and between cladocerans and rotifers (Table 1). The results also indicated that there was no consistent pattern between rotifers and testaceans (flooding period) or between cladocerans and testaceans (flushing period) (Table 1). However, regardless of the significance of the value of correlations found, the values were low. On average, for the significant values, the strength of agreement indicated by the Mantel test was 0.32 and 0.61 by Procrustes.

Table 1. Spatial correlation among zooplankton groups of Lago Grande do Curuai based on Mantel and Procrustes tests. *r* = Mantel and Procrustes correlations, *P* = Statistical significance. Significant *r* values (< 0.05) are in bold.

Periods	Groups	Mantel		Procrustes	
		r	P	r	P
Flooding (March)	Cladoceran x Copepod	**0.50**	0.001	**0.63**	0.001
	Cladoceran x Rotifer	**0.28**	0.001	**0.65**	0.001
	Cladoceran x Testacean	0.16	0.114	**0.61**	0.014
	Copepod x Rotifer	**0.30**	0.001	**0.63**	0.001
	Copepod x Testacean	0.17	0.120	**0.59**	0.033
	Rotifer x Testacean	0.12	0.099	0.62	0.130
Flushing (September)	Cladoceran x Copepod	**0.42**	0.003	**0.56**	0.005
	Cladoceran x Rotifer	**0.42**	0.001	**0.63**	0.001
	Cladoceran x Testacean	0.13	0.083	0.54	0.055
	Copepod x Rotifer	**0.22**	0.043	0.55	0.058
	Copepod x Testacean	**0.21**	0.019	**0.55**	0.015
	Rotifer x Testacean	**0.24**	0.003	**0.63**	0.001

In the assessed periods, both tests showed significant correlation coefficients between study variables (Table 2). According to evaluations of numerical substitution, the Mantel test had an average of 0.86 and the Procrustes had an average of 0.91. Similarly, both tests had higher averages in the evaluations of taxonomic substitution (Table 2).

DISCUSSION

The results of both the Mantel and Procrustes tests demonstrated that the use of substitute groups in the zooplanktonic community is not recommended in this area of study. Although some groups have shown significant relationships, these were less than 0.7 (Heino 2010), which makes unwise to use this approach. In this sense, our results are similar to those found in other studies (Lopes *et al*. 2011; Padial *et al*. 2012; Vieira *et al*. 2014) and indicated that all zooplankton groups should be included in environmental monitoring programs, whereas only one group is not enough to understand the ecological dynamics of the community in the study area.

Similarly, the use of data at the family level instead of using them at the species level also showed significant values, but on the average the *r* values remained below

Table 2. Correlation coefficients between study variables (Dens = density, PA = presence/absence of species) and taxonomic (Sp = species, Gn = genera, Fa = family) of Lago Grande do Curuai zooplanktonic groups, based on Mantel and Procrustes tests. *r* = Mantel and Procrustes correlations, *P* = Statistical significance. Significant *r* values (< 0.05) are in bold.

Analyses	Periods	Groups	Dens x PA		Sp X Gn		Sp X Fa	
			r	P	r	P	r	P
Mantel Test	Flooding (March)	Cladoceran	**0.85**	0.001	**0.81**	0.001	**0.83**	0.001
		Copepod	**0.85**	0.001	**0.94**	0.001	**0.68**	0.001
		Rotifer	**0.80**	0.001	**0.73**	0.001	**0.62**	0.001
		Testacean	**0.87**	0.001	**0.64**	0.001	**0.53**	0.001
	Flushing (September)	Cladoceran	**0.86**	0.001	**0.73**	0.001	**0.68**	0.001
		Copepod	**0.83**	0.001	**0.88**	0.001	**0.58**	0.001
		Rotifer	**0.90**	0.001	**0.69**	0.001	**0.52**	0.001
		Testacean	**0.92**	0.001	**0.87**	0.001	**0.83**	0.001
Procrustes Test	Flooding (March)	Cladoceran	**0.90**	0.001	**0.82**	0.001	**0.80**	0.001
		Copepod	**0.91**	0.001	**0.93**	0.001	**0.68**	0.001
		Rotifer	**0.92**	0.001	**0.87**	0.001	**0.81**	0.001
		Testacean	**0.91**	0.001	**0.72**	0.001	**0.68**	0.001
	Flushing (September)	Cladoceran	**0.89**	0.001	**0.80**	0.001	**0.72**	0.001
		Copepod	**0.85**	0.001	**0.88**	0.001	**0.69**	0.001
		Rotifer	**0.95**	0.001	**0.85**	0.001	**0.79**	0.001
		Testacean	**0.95**	0.001	**0.91**	0.001	**0.89**	0.001

0.7, preventing the use of family level in substitution to species level (Heino 2010). The only exception was for the cladocerans, where the correlation values surrounded the acceptable limit in both seasons. On the other hand, the use of information identifying zooplankton to the genus level rather than to the species level can be a viable alternative for all groups, irrespective of the seasonal period. This alternative was also suggested by others (Sanchez-Moyano *et al*. 2006; Carneiro *et al*. 2010; Carneiro *et al*. 2013), as being an alternative that requires less training time of taxonomists. Finally, in contrast to other studies (Bessa *et al*. 2011; Lopes *et al*. 2011), the results of the numerical substitution also showed a high and significant values, suggesting that the use of information of the presence or absence of species, rather than the abundance of individuals, would save time, with the advantage of understanding the species richness analysis in the region.

The use of information at the species level is of great relevance in many studies, but in some cases, especially in monitoring programs, it is advisable to alleviate the sampling processing in order to maintain compatible financial and time costs, even if it involves loss of little ecological information (Machado *et al.* 2015). Our results show that although the influence of the flood pulse on environmental and biological characteristics in Amazonian floodplains (Junk *et al*. 1989; Thomaz *et al*. 2007; Junk *et al*. 2012), the concordances among groups and numerical and taxonomic substitutions observed in a seasonal period were similar to those found in the other season. Thus, our results indicated the possibility of using information at the genus level instead of the species and the presence/absence of species rather than the abundance in studies of zooplankton communities at Lago Grande do Curuai, regardless of the seasonal period.

CONCLUSIONS

Two approaches can be used at the Lago Grande do Curuai for biological monitoring purposes. Firstly, we have shown that it is possible to use genus instead of species to survey the zooplankton community. This replacement in biological surveys saves time and permits to employ less qualified taxonomists. Second, we have shown that it is possible to use the information about species presence/absence instead of abundance, which makes it possible for biomonitoring with limited resources. Thus, the information provided is at the species level but the abundance of species is not required. Choosing between these two solutions is dependent on the purpose of the biomonitoring program. Finally we also found that substitution between zooplankton groups is not recommended for this study site and that all groups need to be identified.

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