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Phytoplankton functional groups indicators of environmental conditions in floodplain rivers and lakes of the Paraná Basin

Grupos funcionais fitoplanctônicos indicadores de condições ambientais em rios e lagos de planície de inundação

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Abstract: Aim: The objective of this study was to evaluate the efficacy of phytoplankton functional groups as indicators of environmental conditions in floodplain rivers and lakes with different trophic state and connectivity degree to the Paraná River. Phytoplankton functional groups (FGs) cluster sensitive species to environmental variation and can be an alternative for environmental monitoring. **Methods:** Samples were performed quarterly from 2010 to 2013 in the Ivinhema, Paraná and Baia Rivers and in three lakes permanently connected to each river. **Results:** 419 taxa were identified, and those taxa that had values greater than 5% of the total biovolume were classified into FGs (P, C, A, B, MP, H1, W1, J, TD, L_O, and N). The lakes presented higher biovolume and were more productive than rivers, especially in the dry periods. The rivers presented light limitation and low phytoplankton development. The FG L_O was an indicator in rainy seasons. Both rivers and lakes were mostly oligotrophic. We registered FG indicators only for the lakes (A, B, C, E, L_O, P, and W1) and mesotrophic environments (A, B, C, E, J, L_O, and P). **Conclusion:** The FGs reflected the seasonal variation and the trophic state of environments in the upper Paraná River floodplain, mainly in the lentic environments. The species-environment relationship (FGs as indicators) was clearer in the lakes, probably because of the longer water retention that allows evidencing the response of the phytoplankton community to environmental factors. On the other hand, the absence of FGs as indicators in the rivers could be due to the high water flow that promotes dispersal stochasticity and masks the relationship between the environmental factors and the phytoplankton community. Thus, phytoplankton FGs proved to be a viable tool to evaluate the environmental conditions in a floodplain.

Keywords: connectivity; trophy; rainy season; dry season; hydrosedimentological regime.

Resumo: Objetivo: O objetivo deste estudo foi avaliar a eficácia do uso de grupos funcionais fitoplanctônicos como indicadores das condições ambientais em rios e lagos de planície de inundação de diferente estado trófico e grau de conectividade ao rio Paraná. Os grupos funcionais (GFs) fitoplanctônicos reúnem espécies sensíveis às mudanças ambientais e podem ser uma alternativa para o monitoramento ambiental. **Métodos:** Foram realizadas amostragens trimestrais entre 2010 a 2013 nos rios Ivinhema, Paraná e Baía, e em três lagos conectados permanentemente a cada rio. **Resultados:** Foram identificados 419 táxons. Maiores valores de biovolume fitoplanctônico foram verificados nos lagos comparado aos rios, principalmente no período seco e estiveram associados a maior disponibilidade luminosa. Foram registrados 11 GFs (P, C, A, B, MP, H1, W1, J, TD, L_O e N). O GF L_O foi indicador dos períodos de chuva. Os rios mantiveram-se oligotróficos em grande parte do período de estudo, enquanto os lagos mantiveram-se mesotróficos. Os GFs A, B, C, E, L_O, P e W1 foram indicadores dos lagos e os GFs A, B, C, E, J, L_O e P indicaram características mesotróficas. **Conclusão:** Os GFs refletiram a variação sazonal e o estado trófico dos ambientes na planície de inundação do Alto Rio Paraná, especialmente nos ambientes lênticos. A relação espécie-ambiente (GFs indicadores) foi mais evidente nos lagos devido, provavelmente, ao maior tempo de retenção da água que permite evidenciar a resposta da comunidade fitoplanctônica aos fatores ambientais. Por outro lado, a ausência de GFs como indicadores nos rios provavelmente deveu-se ao alto fluxo de água que promove estocasticidade na dispersão e mascara a relação entre os fatores ambientais e a comunidade fitoplanctônica. Assim, GFs do fitoplâncton provaram ser uma ferramenta viável para avaliar as condições ambientais em uma planície de inundação.

Palavras-chave: conectividade; trofía; período chuvoso; período seco; regime hidrossedimentológico.

1. Introduction

Periodic flooding affects the environmental and biological characteristics of floodplain systems (Neiff, 1990) because water-level fluctuation drives the exchange of organisms and nutrients among the main channel, tributaries, and lakes. Thus, flooding is an important event that drives the dynamics of materials and species in floodplains (Neiff, 1990). However, the effect of the water level variation of the main channel on their associated environments depends on the size, position and the connection degree of these environments (Junk et al., 1989).

The environments in floodplain show high connectivity and environmental homogeneity in flood periods (Thomaz et al., 2007). In dry periods, when the connectivity is lower, the floodplain shows high environmental heterogeneity. The diversity patterns of the aquatic communities response to the temporal variation of the environmental conditions of floodplains (Neiff, 1990). For instance, phytoplankton presents higher diversity in dry periods than in flooding (Devercelli, 2006, 2010; Nabout et al., 2006; Lasne et al., 2007; Loverde-Oliveira et al., 2007; Stanković et al., 2012; Bovo-Scomparin et al., 2013).

The upper Paraná River floodplain is affected by several anthropic activities, and the construction of reservoirs is one of the most important (Agostinho et al., 2004). Dams cause intense modifications in the fluvial system (Souza Filho, 2009). For example, dams operations promote daily variation on the water level (Agostinho et al., 2008; Souza Filho, 2009), cause interference in the nutrient balance and increase the downstream water transparency (Roberto et al., 2009).

Each environment associated with floodplain have different factors that influence the structure and dynamic of aquatic communities. Lakes have a high productivity-diversity ratio and an important role in the maintaining the biodiversity and system integrity (Korhonen et al., 2011; Stomp et al., 2011; Borics et al., 2012). On the other hand, highly dynamic rivers select species that are adapted to high flow and turbidity (Devercelli & O'Farrell, 2013; Fraisse et al., 2013).

Phytoplankton presents temporal patterns related to environmental changes (Huszar et al., 1998; Borges & Train, 2009), and the processes acting on this community operates on a reduced timescale. Therefore, phytoplankton is an important ecological tool to obtain short-term responses (Reynolds, 2002; Rodrigues et al., 2002).

Environmental filters give a structured to phytoplankton community through the selection of species characteristics (Padisák et al., 2003; Naselli-Flores et al., 2007; Brasil & Huszar, 2011; Zhang et al., 2015). Hence, the phytoplankton functional approach is justified to understand the key processes that drive the community assemblage. In this context, species can be grouped into groups based on the species functional features. This Functional Groups (FGs), grouped species with shared physiological, morphological and phenological characteristics, independent of phylogenetic relationships (Petchey & Gaston, 2006; Litchman et al., 2010). Based on this assumption, Reynolds et al. (2002) proposed the approach of phytoplankton FGs to cluster species sensitive to environmental changes (Padisák et al., 2009) and simplify extensive taxonomic lists. Phytoplankton FGs are sensitivity to environmental variation, hence efficient to predict environmental conditions (Kruk et al., 2002; Nabout et al., 2006; Becker et al., 2009; Bovo-Scomparin et al., 2013; Crossetti et al., 2013; Bortolini et al., 2014).

This study aimed to verify the efficacy of phytoplankton FGs as indicators of environmental conditions in floodplain and the effects of the connectivity of the environments to the main river on phytoplankton variation. Therefore, we hypothesized that (i) the phytoplankton FGs respond to the environmental conditions of each sampled site and its trophic state; (ii) the FGs indicators will be different in each hydrological periods.

2. Material and Methods

2.1. Study area

The Paraná River is the second largest river in South America (4,965 km), the tenth largest river worldwide in water discharge (9,900 m^3/s) and the fourth in drainage area (2.8 × 106 km^2) (Agostinho et al., 2008). The Ivinhema and Baia Rivers are the main tributaries of Paraná River. The Ivinhema State Park is an important area of environmental protection. Ivinhema State Park is located in the distal portion of the Ivinhema River. This study was developed in the upper Paraná River floodplain, located downstream of the Porto Primavera reservoir and upstream of the Itaipu Reservoir. This region is important for the regional biodiversity because it is the last damming-free stretch in all Brazilian territory.

We sampled the main channel of Paraná River (R1 - 22°45'S; 53°15'W), Ivinhema River (R2 - 22º47'S; 53º32'W), Baía River (R3 - 22º43'S; 53º17'W), and three lakes permanently connected to these rivers. The Garças lake (L1 - 22°43'S; 53°13'W) is connected to the Paraná river by a channel approximately 50m longer and has an extension with 3,8ha. The Guaraná lake (L2 - 22º43'S; 53º18'W) has dark watercolor, 4.2ha and is connected to the Ivinhema river by a 70m channel. The Patos lake (L3 - 23º49'S; 53º33'W) has a large extension with 113.8ha and has a short connection channel a 10m length to Baia river (Figure 1).

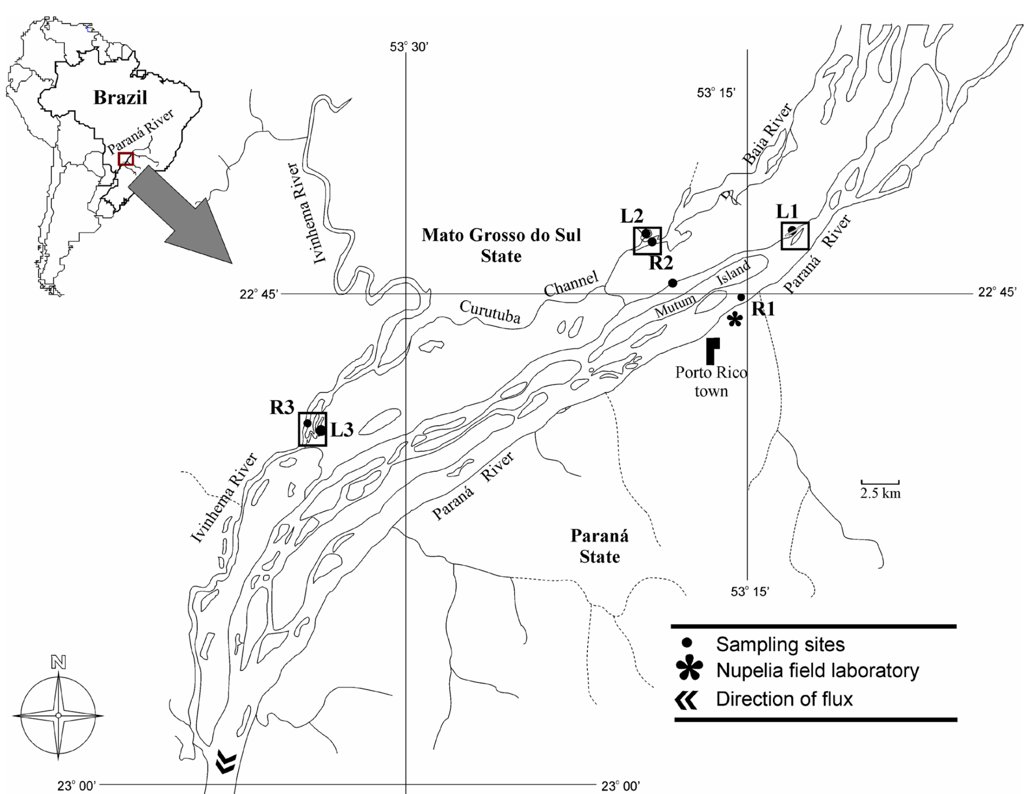

Figure 1. Map and localization of sampling sites in the upper Paraná River floodplain (R1: Paraná River; R2: Baia River; R3: Ivinhema River; L1: Garças lake; L2: Guaraná lake; L3: Patos lake).

2.2. Methodological procedures

Samples were taken quarterly to analyze the phytoplankton community and environmental variables from March 2010 to December 2013. Thus, in each one of the six environments were collected 16 samples in total (n = 96). Total phytoplankton was collected with flasks at the subsurface (20 cm depth) of the pelagic zone. The samples were preserved with 1% Lugol solution (Bicudo & Menezes, 2006).

The randomly counting were performed in transect per field using an inverted microscope (400x magnification) (Lund et al., 1958; Utermöhl, 1958). Phytoplankton biomass was estimated from the biovolume ($mm^3.L^{-1}$), by multiplying the density of each species by its respective volume. The volume of each cell was calculated by approximate individuals to geometric shapes such as cylinders, spheres, and ellipses (Hillebrand et al., 1999; Sun & Liu, 2003). Phytoplankton taxa with contribution greater than 5% to the total biovolume of each sample were classified into FGs, according to Reynolds et al. (2002) and Padisák et al. (2009).

We measured water temperature (WT, °C), pH, electrical conductivity (EC, $\mu S.cm^{-1}$) and dissolved oxygen (DO, $mg.L^{-1}$) using digital portable potentiometers. Total phosphorus (TP, $\mu m.L^{-1}$), soluble reactive phosphorus (SRP, $\mu m.L^{-1}$), nitrate (NO_3-N, $\mu m.L^{-1}$), nitrite (NO_2-N, $\mu m.L^{-1}$), inorganic soluble material (ISM, $mg.L^{-1}$) and ammonium (NH_4-N, $\mu m.L^{-1}$) were measured following Bovo-Scomparin et al. (2013). The dissolved inorganic nitrogen (DIN, $\mu m.L^{-1}$) was calculated as the sum of the NH_4-N, NO_2-N and NO_3-N concentrations. We measured the maximum depth (Z_{max}, m), and the euphotic zone (Z_{eu}, m) was calculated as 2.7 times the Secchi-disk depth (Cole, 1994). The mixing zone (Z_{mix}, m) was calculated according to the thermal profile. The Itaipu Binational (Itaipu Binacional), National Water Agency (Agência Nacional de Águas – ANA) and the Limnology, Ichthyology, and Aquaculture Research Center (Núcleo de Pesquisas em Limnologia, Ictiologia, e Aquicultura - Nupélia) provided the daily water levels (WL) of Ivinhema and Paraná Rivers. Rainy periods were considered when the water level of Paraná River was ≥ 3.5m (Souza Filho et al., 2004). For each lake, we calculated the temporal water level variation (ΔZ_{max}) as the difference between the water level registered in a sampling and the previous sampling.

2.3. Numerical analysis

Principal Component Analysis (PCA) was used to characterize spatially and temporally the environmental variation. An Indicator Value Analysis (IndVal – Dufrêne & Legendre, 1997) was applied to verify if FGs are indicators of environmental conditions. The indicator value makes possible to predict the association of a given FG with a specific habitat or particular environmental conditions. The indicator value was statistically tested using random Monte Carlo allocations. For this analysis, we used a matrix of the FGs and as environmental conditions, we included the hydrological period (dry and rainy), environment type (as river and lake) and trophic state. The trophic state was characterized according to OECD (1982), by using chlorophyll (oligotrophic: < 8 $\mu g\ L^{-1}$, mesotrophic: 8-25 $\mu g\ L^{-1}$ and eutrophic: >25 $\mu g\ L^{-1}$) and TP (oligotrophic: < 10 $\mu g\ L^{-1}$, mesotrophic: 10-35 $\mu g\ L^{-1}$ and eutrophic: 35 $\mu g\ L^{-1}$).

The PCA and IndVal analysis were performed using PC-Ord program (Mccune & Mefford, 1999). Graphs were generated using the software STATISTICA version 7.1 (Statsoft, 2005).

3. Results

3.1. Water level and depth

The upper Paraná River showed the highest water level in March 2010 and 2011, which is characterized as rainy periods, according to Souza Filho (2009). The maximum depth of lakes was influenced by the water level of the rivers (Figure 2). A similar variation occurred in the lakes associated

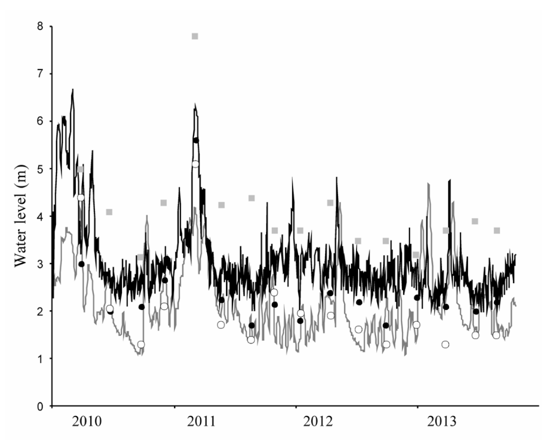

Figure 2. Paraná River (R1) and Ivinhema River (R2) daily water levels and maximum depth (Z_{max}) of the lakes (L1: Garças lake; L2: Guaraná Lake; L3: Patos lake) from March 2010 to January 2014.

with the sites R1 and R2. The highest depth was registered in the lake associated with the site R3 (Figure 3).

3.2. Limnological characterization

The two first axes of the PCA were selected by the broken stick criterion and explained 45% of the total environmental variation. Temporal and spatial gradients were observed. The rainy periods were associated with the highest water level. The site R1 was related to greater values of Z_{eu}, Z_{mix}, Z_{max}, EC, and DIN. The site R3 was associated with ISM and DO. The sites R2 and L2 were related to the highest SRP, PT, and TN concentrations (Table 1 and Figure 4). Lakes showed total mixing of the water-column in almost all the hydrological periods, and stratification occurred in some rainy periods. The lakes had mesotrophic characteristics in most of the study, and most of the samples of rivers showed oligotrophic characteristics.

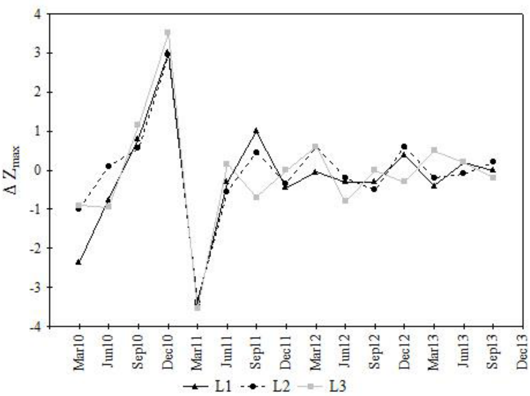

Figure 3. Temporal variation of the water level (ΔZ_{max}) of lakes in the upper Paraná River floodplain from March 2010 to December 2013. For each lake, the variation was considered as the difference between the water level registered in a sampling and the previous sampling.

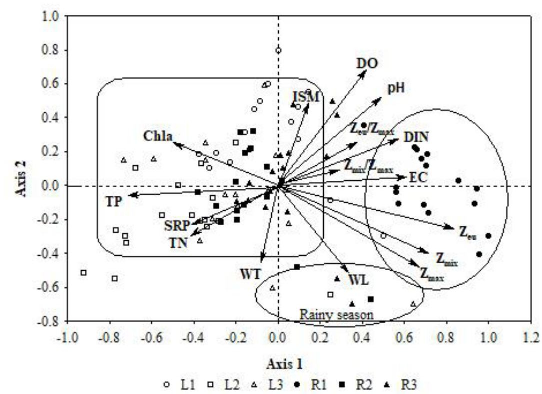

Figure 4. First two axes generated by Principal Component Analysis (PCA) on the studied environments. Water level (WL), Water temperature (WT), Soluble reactive phosphorus (SRP), Total nitrogen (TN), Dissolved inorganic nitrogen (DIN), Dissolved oxygen (DO), Electrical conductivity (EC), Chlorophyll a (Chla), Inorganic soluble material (ISM), Mixture zone (Zmix), Euphotic zone (Zeu), Depth (Zmax).

Table 1. Mean values and coefficient of variation (% - CV) of the limnological variables in the studied environments. Water temperature – WT (°C), soluble reactive phosphorus – SRP (μg.L^{-1}), total nitrogen – TN (μg.L^{-1}), dissolved inorganic nitrogen – DIN (μg.L^{-1}), dissolved oxygen – DO (mg.L^{-1}), electrical conductivity – EC (μS.cm^{-1}), inorganic soluble material – ISM (mg. L^{-1}), mixing zone – Z_{mix} (m) and euphotic zone – Z_{eu} (m).

		WT	DO	pH	EC	Z_{eu}	Z_{eu}:Z_{max}	Z_{mix}:Z_{max}	Z_{mix}	ISM	TN	DIN	TP	SRP
Lakes														
2010	Mean	25	5	7	44	2	1	1	2	1	879	50	41	6
	CV	17	48	10	32	44	29	27	43	110	34	98	34	52
2011	Mean	25	5	6	42	3	1	1	4	1	1011	51	36	10
	CV	16	40	8	30	62	21	0	55	105	35	109	44	62
2012	Mean	28	6	7	37	1	1	1	2	2	890	42	40	11
	CV	9	30	10	29	32	46	32	44	130	28	83	59	69
2013	Mean	26	5	6	43	1	1	1	2	1	894	81	50	19
	CV	17	51	13	26	35	37	23	42	93	37	150	53	81
Rivers														
2010	Mean	25	7	7	43	4	1	1	5	2	709	100	30	10
	CV	17	32	8	35	39	32	0	37	125	30	74	59	50
2011	Mean	26	6	7	44	4	1	1	5	2	791	124	30	14
	CV	17	36	6	30	44	27	0	40	113	19	76	71	50
2012	Mean	28	7	7	39	3	1	1	4	2	804	112	28	13
	CV	8	13	8	37	54	34	0	34	81	40	64	72	80
2013	Mean	26	7	7	42	3	1	1	4	2	652	119	29	18
	CV	16	19	10	43	64	35	0	39	63	17	58	53	49

3.3. Phytoplankton community

We registered the highest biovolume values in the dry periods. The biomass was high in the lakes and R2, and low in R1 and R3. Cyanobacteria dominated in the sites L3, L2, and R2; Chrysophyceans dominated in L1. In the Paraná River dinoflagellates, cryptophyceans, diatoms, and cyanobacteria showed the highest biovolume.

We classified 419 taxa into 13 FGs (Figure 5). The FGs P, B, C and A were the most representative in the lakes in the rainy periods, and the FGs A, C, H1, MP, and P were the most expressive in dry periods (Figure 5a-c). In rivers, the FGs A, L_o, M, N, P, and MP were the most representative FGs in rainy periods and the FGs A, J, H1, MP e P in dry periods (Figure 5d-f).

The main representatives of the FGs were: P, *Aulacoseira granulata* (Ehr.) Sim. var. *granulata*; FG C, *Aulacoseira ambigua* (Grun.) Sim. var. *ambigua*; FG A, *Urosolenia eriensis* (H. L. Sm.) Round & Craw. and *Acanthoceras zachariasii* (Brun) Sim.; FG B *Aulacoseira herzogii* (Lemm.) Sim.; FG E, *Dinobryon sertularia* Ehr. and *Dinobryon divergens* Imh.;

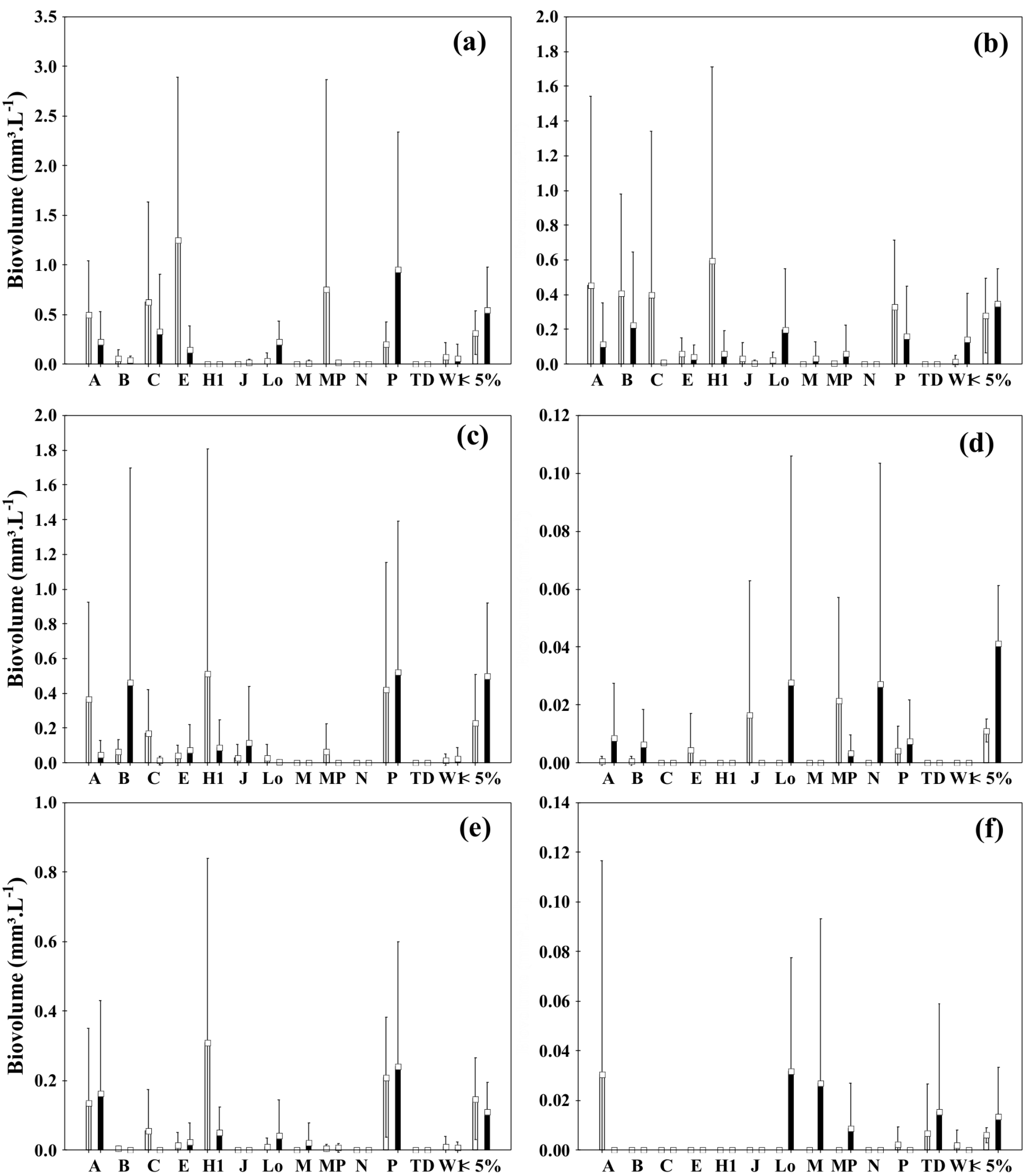

Figure 5. Biovolume of the phytoplankton FGs in the sampling sites from March 2010 to December 2013 (a = L1; b = L2; c = L3; d = R3; e = R2; f = R1. <5% - Total biovolume of taxa with less than 5%; white bar= dry; black bar= rainy).

FG MP *Nitzschia acicularis* (Kütz.) W. Smith, *Synedra goulardii* Bréb. and *Amphipleura lindheimeri* Grun.; FG H1 *Dolichospermum planctonicum* (Brunn.) Wacklin et al., *Dolichospermum solitarium* (Kleb.) Wacklin et al., and *Dolichospermum spiroides* (Kleb.) Wacklin et al.; FG W1 *Lepocinclis ovum* var. *ovum* (Ehr.) Lemm. and *Phacus* sp.; FG J *Pediastrum duplex* Mey.; FG TD *Onychonema laeve* Nordst. and *Gonatozygon aculeatum* Hast.; FG $L_{O,}$ *Peridinium* sp. and *Radiocystis fernandoi* Kom. & Kom. Legn.; and FG **N** *Cosmarium decoratum* West and G. S. West.

3.4. IndVal for FGs

We registered the FG L_O as an indicator group of rainy periods. Considering the trophic state, only the mesotrophic state presented FGs indicator (A, B, C, E, J, L_o, P). For the environment type, only the lakes exhibited FGs indicators (A, B, C, E, L_o, P, W1) (Table 2).

4. Discussion

Our results show that the phytoplankton functional groups reflect the environmental characteristics of the analyzed floodplain environments. Our findings suggest that the analyses of biovolume variation of functional groups can be a useful tool for monitoring the trophic state of floodplain lakes.

Table 2. Phytoplankton FGs indicators of hydrological periods (Rain and Dry), environment type (river and lake), and trophic state (Oligotrophic and Mesotrophic).

FGs	Rain			Dry			*p*
	A	F	IV	A	F	IV	
Lo	80	33	**27**	20	15	3	0.0136
	Mesotrophic			**Oligotrophic**			***p***
	A	F	IV	A	F	IV	
A	80	74	**60**	20	38	7	0.0002
B	81	59	**48**	19	26	5	0.0026
C	88	70	**62**	12	16	2	0.0002
E	81	52	**42**	19	17	3	0.0006
J	89	19	**17**	11	3	0	0.0136
Lo	75	41	**30**	25	17	4	0.0116
P	79	93	**73**	21	49	10	0.0002
	Lakes			**Rivers**			***p***
	A	F	IV	A	F	IV	
A	83	63	**52**	17	33	6	0.0004
B	99	58	**58**	1	13	0	0.0002
C	96	52	**50**	4	10	0	0.0002
E	97	46	**45**	3	8	0	0.0002
Lo	82	33	**27**	18	15	3	0.0112
P	85	81	**69**	15	42	6	0.0002
W1	95	25	**24**	5	6	0	0.0046

A = abundance; F = frequency; IV = indicator value.

The studied environments presented high variation in light availability and nutrient concentrations, which probably influenced the spatial distribution of phytoplankton biovolume (Oliver & Merrick, 2006; Devercelli, 2010; Istvánovics et al., 2010; Soares et al., 2012). The site R1 (Paraná River) showed the lowest phytoplankton biovolume, probably influenced by high water-flow and low nutrient concentration. As the dams built in the Paraná River have increased the transparency and decreased the nutrient concentration, studies suggest that the oligotrophic characteristics of Paraná River negatively affect the primary productivity (Zalocar de Domitrovic et al., 2007; Agostinho et al., 2008; Roberto et al., 2009; Souza Filho, 2009; Bovo-Scomparin et al., 2013).

In several periods, the lakes and the Ivinhema and Baía Rivers presented similar nutrient concentration. However, lakes showed the highest phytoplankton biovolume. Although rivers can present optimal nutrient concentrations for phytoplankton development (Jones & Elliott, 2007; Fantin-Cruz et al., 2016), they can limit the phytoplankton because of the low light availability and short water-retention time (Reynolds & Descy, 1996; Devercelli, 2010; Fraisse et al., 2013). Systems with short water-retention time (e.g., continuously flushed systems) can present high loss of phytoplankton biomass attributed to wash-out, hence difficult the establishment of planktonic organisms (Fraisse et al., 2015). In the other hand, phytoplankton biomass was favored in the studied lakes probably because of the high stability of water column and high nutrient concentration.

The FGs responded to the environmental conditions and it could be an important tool for environmental monitoring, hence we accepted the first hypothesis. The results showed that the phytoplankton biomass responds to temporal environmental variation and suggest that the predictability of the phytoplankton structure depends on the analyzed climatic period. For instance, we registered FG as indicators only for the rainy period. The higher connection among environments probably guaranteed the FG L_O to reach all the studied sites in the rainy period. On the other hand, we did not register FG indicator of the dry periods, probably because of the higher environmental heterogeneity in dry periods (Thomaz et al., 2007) that favored different organisms in each environment.

The dinoflagellates included in the FG L_O present mobility and can tolerate the nutrient losses

(Reynolds et al., 2002) caused by the water-column stratification in rainy periods (Becker et al., 2008; Mihaljević et al., 2013). In stratified environments, these organisms are good competitors (Bellinger & Sigee, 2011) because they can migrate in the water column to find resources (Rangel et al., 2009). Whereas the low FG L_O biovolume registered in periods with high water-column mixing (dry periods) could be explained by the sensitivity of these organisms to deep (e.g. reservoirs) and prolonged mixing (Reynolds et al., 2002; Padisák et al., 2009; Borics et al., 2012). We do not disregard the possibility that the high contribution of FG L_O in the rivers could be related to the influence of the upstream reservoirs in the Paraná and Paranapanema Rivers, as the dispersion of organisms from the reservoir can influence the structure in downstream (Bovo-Scomparin et al., 2013).

The same FGs indicators of the trophic state were associated with the type of environment, because of almost all rivers were categorized as oligotrophic and the lakes as mesotrophic. Only lakes (or mesotrophic environments) presented FG indicators. In fact, the FGs indicators of the trophic state that we registered were organisms mostly associated with lentic conditions. Moreover, lakes present large water-retention time that favors the establishment and development of phytoplankters and could explain why more FGs were related to lakes than to rivers (Margalef, 1978; Bortolini et al., 2014; Török et al., 2016; Moresco et al., 2017).

Some of the FGs indicators of the mesotrophic state have been originally associated with oligotrophic (FGs A and E) or eutrophic (FGs P, C, and J) environments (Reynolds et al., 2002; Padisák et al., 2009). Our results suggest that representatives of these FGs exhibit a broader trophic range than thought.

The representatives of the FGs E and W1 can present both autotrophic and heterotrophic nutrition (Alves-de-Souza et al., 2006), and their association with the lakes was probably favored by the registered high inorganic material in these environments. In the case of FG A (diatoms related to clear waters), the high biovolume registered in the lakes suggests that light did not limit the phytoplankton development in these environments (Cellamare et al., 2013). The lakes also presented high water-column mixing as suggested by the high biovolume of FGs B, C, and P (diatoms). Species belonging to these groups are good competitors in nutrient-enriched conditions and associated with well-mixing environments (Reynolds, 1998). These organisms have a siliceous wall and present a high sedimentation rate, and they are dependent on the water mixing to maintain their high biomass (Reynolds et al., 1994; Stević et al., 2013). A high water-column mixing promotes materials resuspension and guarantees the position of phytoplankters in the euphotic zone (Padisák et al., 2010). Centric diatoms (e.g., FG B - *Aulacoseira* spp.) are common in rivers and lakes of floodplain (Bovo-Scomparin & Train, 2008; Borges & Train, 2009) because these organisms are adapted to turbulence and have a life cycle related to the regime of the water-column mixing (Lund, 1965).

Although rivers and lakes presented particular physical, chemical, and biological differences, only the lakes presented FG indicators. Determine patterns of phytoplankton distribution may be difficult because microorganisms distribution is strongly influenced by dispersal stochasticity (Nabout et al., 2009). The species-environment relationship (FGs as indicators) was clearer in the lakes, probably because of the longer water retention that allows evidencing the response of the phytoplankton community to environmental factors (Rodrigues et al., 2017). In rivers, phytoplankton is especially affected by stochastic processes associated to flow and flood pulse (Thorp, 2010). In this sense, the absence of FGs as indicators in the rivers was probably due to the high water flow that promotes dispersal stochasticity and prevents to determine the relationship between the environmental conditions and the phytoplankton distribution (Rodrigues et al., 2017). Moreover, the hydrodynamics of the rivers difficult the phytoplankton establishment because of the wash-out that increases the biovolume losses (Abonyi et al., 2012; Stanković et al., 2012; Devercelli & O'Farrell, 2013; Fraisse et al., 2013). This study demonstrated that the use of phytoplankton FGs is an alternative to obtain ecological and environments responses in the floodplain since the FGs were efficient indicators of hydrological periods and the environmental conditions in lakes and rivers.

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