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Periphytic diatoms as bioindicators in a tropical stream: from urban to rural environments

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ABSTRACT. Urbanization and agriculture alter expressively the physical and chemical variables of lotic habitats, especially streams, causing negative effects to the biota of these environments. This study aimed to (i) evaluate the spatial and seasonal variations in the structure of periphytic diatom assemblage in a stream under urban influence in its headwaters, and rural influence, in the rest of its course, and (ii) select diatom species as bioindicators of urban and rural stretches. Three sampling sites were set along the stream according to its longitudinal gradient. The structure of the periphytic diatom assemblage presented differences in spatial scale, differing substantially between the urban and rural habitats. There was a higher influence of nutrients (orthophosphate (PO_4) and total nitrogen (TN)) on the distribution of the assemblage. Therefore, the use of the assemblage of periphytic diatoms as environmental bioindicator indicated spatial differences along the riverine areas, from the agriculture environment to the urbanized environment.

Keywords: Bacillariophyta, water quality, urban-rural gradient, urbanization, community ecology.

Diatomáceas perifíticas como bioindicadores em um córrego tropical: do ambiente urbano para o rural

RESUMO. A urbanização e a agricultura modificam expressivamente as variáveis físicas e químicas de habitats lóticos, principalmente em córregos, provocando efeitos negativos na biota destes ambientes. O objetivo deste estudo foi avaliar as variações espaciais e sazonais (estiagem e chuva) na estrutura da assembleia de diatomáceas perifíticas, de acordo com o gradiente urbano-rural em um córrego, apontar os principais fatores controladores desta assembleia, bem como selecionar as espécies de diatomáceas bioindicadoras dos trechos urbanos e rurais. Foram estabelecidos três pontos de coleta - cabeceira, intermediário e foz, obedecendo a um gradiente longitudinal. A estrutura da assembleia de diatomáceas perifíticas apresentou diferenças em escala espacial, diferindo substancialmente entre as zonas urbanas e rurais. Houve maior influência dos nutrientes (ortofosfato (PO_4) e nitrogênio total (TN)) sobre a distribuição desta assembleia. Portanto, utilizando a assembleia de diatomáceas perifíticas como bioindicador ambiental foi possível comprovar as diferenças espaciais ao longo das áreas ribeirinhas, desde ambiente agrícola até ambiente urbanizado.

Palavras-chave: Bacillariophyta, qualidade de água, gradiente urbano-rural, urbanização, ecologia de comunidades.

Introduction

Lotic environments are among the systems that suffer most the impact of human activities (BONA et al., 2008). According to Vannote et al. (1980) and Mulholland (1996), sections of headwater streams represent greater interaction with the landscape and therefore are predominantly accumulators, processors and transporters of material from the terrestrial environment.

With the intense population growth, the urbanization process is accelerated (MEYER et al., 2005) as well as the agricultural practices. This raises concerns about the physical and chemical characteristics of rivers and streams (ALLAN; CASTILLO, 2007), negatively affecting the biota of these ecosystems (JÜTTNER et al., 2003).The current rate of destruction, alteration and fragmentation of natural habitats resulting from increasing impacts of human activities has led to an alarming loss of global biodiversity. Owing to this, an important objective of ecological studies is to understand spatial and seasonal changes in size and distribution of populations, as well as the mechanisms and processes behind these changes.

Benthic algae show high turnover rates and opportunistic life-history strategies that have enabled them to successfully exploit stream habitats; many are harsh and polluted environments (BIGGS, 1996). In many countries, the monitoring of aquatic environments using biological communities is applied routinely (GROWNS, 1999; FORE; GRAFE, 2002), in which mainly the diatoms are being used in monitoring of rivers (KELLY et al., 1998; JÜTTNER et al., 2003; DELA-CRUZ et al., 2006). Their utilization as indicators is advantageous, since the diatoms have peculiar attributes, as for instance: they are found throughout the river, have a short life cycle, responding quickly to environmental changes, are commonly related to specific environmental conditions in different geographic regions (GROWNS, 1999; STEVENSON; PAN, 1999; LOBO et al., 2002; SOININEN, 2002), presenting responses in spatial and seasonal scales, according to the climate, land use, and water chemistry (STEVENSON; PAN, 1999).

Although several indices had been developed to evaluate the water quality by means of diatoms (DESCY; COSTE, 1991; VAN DAM et al., 1994; KELLY; WHITTON, 1995; STEVENSON; PAN, 1999), few studies have been done to evaluate the responses from diatoms over drainage basins influenced by urbanization and by agricultural practices (LOBO et al., 1996; GÓMEZ; LICURSI, 2001; JÜTTNER et al., 2003; MORESCO; RODRIGUES, 2014), especially in tropical regions.

Therefore, this study evaluated the spatial and seasonal variations in the composition and structure of the periphytic diatom assemblage, according to the urban-rural gradient, relating them to physical and chemical variables, and selected diatom species as bioindicators of urban and rural stretches, in the Guaiapó Stream, Pirapó River basin. Thus, it is expected that the different environmental characteristics found along the stream have influence on the composition and structure of the periphytic diatom assemblage over a seasonal period.

Material and methods

Study area

The Pirapó River basin is in the Northwestern region of Paraná State, in the physiographic region called Third Plateau (latitudes 22º30' and 23º30' South, and longitudes 51º15' and 52º15' West), with a drainage area of approximately 5,076 km^2. The predominant climate in the region is subtropical, with abundant rainfall in summer (months: October, November, December, January, February and March), and dry winter (April, May, June, July, August and September) (MAACK, 2012), with annual mean temperatures higher than 20ºC. The municipality of Maringá is within the boundaries of the basins of Pirapó and Ivaí rivers, with sources of several streams in the urban area, including the Guaiapó Stream, of low order, located in the Pirapó River basin (Figure 1).

The source of this stream is within the urban area, with residential and industrial occupation. This stretch presents steep banks and riparian vegetation, with low incidence of light (Figure 1). The headwaters receive storm sewers, domestic sewer and superficial runoff. The middle stretch is located on the border between the urban and rural areas, presenting steep banks and scarce riparian vegetation, with high incidence of light. In turn, the mouth is situated in the rural area with crop rotation (corn, soybean and wheat), without arboreal riparian vegetation, and with intense incidence of light. The middle and mouth stretches are subjected to the discharge of agricultural and domestic effluents.

Abiotic variables

Samplings for determination of abiotic variables were conducted simultaneously to the samplings of biotic variables. Data relative to physical and chemical water conditions, like pH (Digimed DM2), electrical conductivity (Digimed DM3, μS cm^{-1}), dissolved oxygen (O_2) and water temperature (YSI 55 12 FT^{-1}, mL L^{-1} and ºC, respectively), flow velocity (Flo-Mate 2000 – Marsh McBirdey, m s^{-1}) were measured in the field with portable analytical equipments. For the analysis of concentrations of total nitrogen (TN), orthophosphate (PO_4), and biochemical oxygen demand (BOD_5), water samples were collected and analyzed by the laboratories of Sanitation and Agrochemistry of the State University of Maringá, following the methodology used by CETESB (Technology and Environmental Sanitation Company of São Paulo), L5.120 - biochemical oxygen demand, dilution and incubation method (20°C, 5 days) (CETESB, 1991). Total nitrogen and orthophosphate were determined according to Silva and Oliveira (2001).

Three sampling sites were established along the longitudinal gradient of the Guaiapó Stream (headwaters, middle and mouth). For analytical purposes, the sampling sites were grouped into urban (headwater) and rural (middle and mouth) sites. The samplings were performed every two months, from August 2007 to June 2008, which were grouped into dry (April, June, August) and rainy season (October, December, February).

For the qualitative and quantitative analyses of periphytic diatoms, at each sampling site, the samples were taken in replica. Each sample consisted of three pebbles (composite sample). This substrate was chosen for being the most abundant and present throughout the stream.

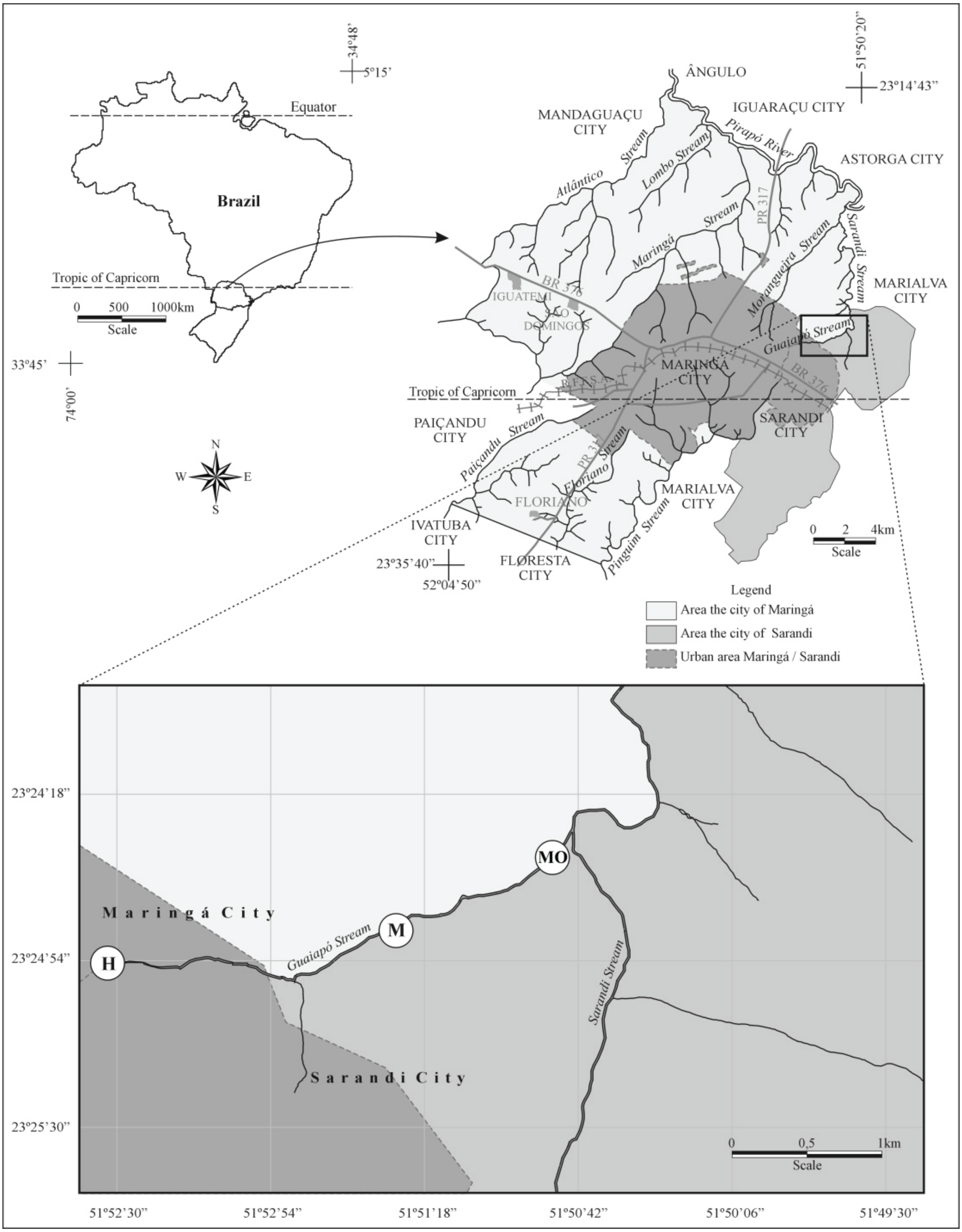

Figure 1. Location of the Guaiapó Stream in the municipality of Maringá, Paraná State, sampled from August 2007 to June 2008. H = headwaters, M = middle, MO = mouth. Dark gray: urban area; Light gray: rural area.

The side opposite to the flow direction was scraped with the aid of brush and blade, and the material was fixed with formalin solution. We also measured the area of the scraped surface, using a caliper. The material was oxidized with potassium permanganate and hydrochloric acid (MOREIRA-

FILHO; VALENTE-MOREIRA, 1981). Permanent mounts were made using Hyrax resin. The slides were deposited in the Herbarium of the State University of Maringá (HUEM 16544 -16561).

Identification and counting of diatom species were performed in an optical microscope Olympus CX31. The individuals were identified and counted to a minimum of 600 valves were recorded, as recommended by Kobayasi and Mayama (1982), added up to an efficiency of counting of 90%, determined according to Pappas and Stormer (1996). The concentration of cells cm^{-2} was estimated by multiplying the number of valves of each taxon by the conversion factor, according to Hermany et al. (2006).The classification system followed that proposed by Round et al. (1990).

Data analysis

To determine significant differences from the expected proportion in the density of diatoms in each sampling sites and periods, the chi-square test ($\chi 2$) at a significance level of 5% was applied. In order to summarize the composition and structure of the periphytic algae assemblage, it was applied a Nonmetric Multidimensional Scaling (NMDS) (KRUSKAL, 1964a, b). Sorensen distances were calculated and the general procedure of the NMDS was followed according to McCune and Grace (2002). A hundred permutations were performed and the stability criterion used was the standard deviation (≤ 0.005, stress above 100 iterations). This analysis was carried out with the matrix of abundance data (square root transformed to remove the effect of high values) in different sampling sites and periods grouped.

To test significant differences in the composition and structure of the periphytic algae assemblage, summarized by the NMDS, a two-way mixed model PERMANOVA (maximum permutations = 9999) was used to test each data set, with sampling site (urban and rural) and period (dry and rainy season) provided as factors. For this analysis, data were log transformed.

For the determination of indicator species (IndVal), the procedures used was those recommended by Dufrêne and Legendre (1997), the input data were the abundance and frequency of occurrence of species in each group, calculating indicator values for each species (McCUNE; GRACE, 2002). The species were considered as indicators when presented the results of Monte Carlo Test with $p < 0.05$ (based on 1,000 permutations).

Abiotic variables were summarized by a Principal Component Analysis (PCA). To determine which principal components should be retained for interpretation, the Broken-Stick criterion was used. According to this, only the axes with eigenvalues higher than those generated by random should be interpreted (McCUNE; GRACE, 2002). Abiotic data, except pH, were log transformed for PCA.

The association of multivariate analysis (abiotic variables and composition and structure of the periphytic diatom assemblage) was examined by means of the Procrustes analysis (PERES-NETO; JACKSON, 2001). In this analysis, the two matrices are compared using an algorithm that minimizes the sum of squared residuals between the matrices (ROHLF; SLICE, 1990). The resulting value of m^2 is the best fit, as it describes the degree of association between the matrices.

NMDS, PERMANOVA, IndVal and PCA were run using the software PC-Ord® 5.0 (McCUNE; MEFFORD, 2006). The Procrustes statistics was calculated by means of the software PROTEST® (JACKSON, 1995). The level of statistical significance adopted was $p < 0.05$.

Results

Abiotic analysis

Principal components analysis summarized the matrix of abiotic variables. Two axes were retained for interpretation (Figure 2; cumulative explained variance = 55.06; Table 1). The axis 1 (%variance: 33.84%) only distinguished the sampling sites. Flow velocity and pH, positively correlated with the axis 1 (Table 1; Figure 2), showed higher values in rural sites. On the other hand, orthophosphate (PO_4), negatively correlated with the axis 1 (Table 1; Figure 2), showed higher values in urban sites. These variables were responsible for the separation of the sampling sites. In the axis 2 (%variance: 21.22%), there was the differentiation of the sampling sites. Electric conductivity, positively correlated with axis 2 (Table 1; Figure 2), showed higher values in rural sites. In turn, total nitrogen, negatively correlated with the axis 2 (Table 1; Figure 2), showed higher values in urban sites.

Periphytic diatom assemblage

In this study, we identified 96 species belonging to 35 genera. Seventy-one specific taxa occurred in the headwaters, 72 in the middle stretch, and 53 in the mouth. Forty-three species were common to the three stretches. Considering the species exclusive to each stretch, we recorded 19, 16 and 4, for the headwaters, middle and mouth stretches, respectively.

Table 1. Results of principal component analysis (PCA) and summary of abiotic variables (mean ± standard deviation) measured in the Guaiapó Stream, municipality of Maringá, Paraná State, sampled from August 2007 to June 2008. Sampling sites were grouped into urban (headwater) and rural (middle and mouth) sites and periods were grouped into dry (April, June, August) and rainy seasons (October, December, February). It is presented, for each axis, the eigenvalues, the percent of variance explained and the broken-stick eigenvalues. For each variable, it is listed the eigenvector (loading or correlation). T = water temperature, pH = hydrogenic potential, Cond. = electrical conductivity, O_2 = dissolved oxygen, PO_4 = orthophosphate, TN = total nitrogen, BOD_5 = biochemical oxygen demand, Flow = flow velocity.

			Sampling sites		Periods	
	Axis 1	Axis 2	Urban	Rural	Dry	Rainy
Eigenvalue	2.71	1.70				
Broken-Stick	2.72	1.72				
Explained Variance (%)	33.84	21.22				
Accumulated Variance (%)	33.84	55.06				
T (°C)	-0.27	0.05	22.90 ± 0.91	22.58 ± 1.64	22.11 ± 1.13	23.38 ± 1.20
pH	0.53	0.04	7.00 ± 0.50	7.55 ± 0.37	7.43 ± 0.53	7.11 ± 0.46
Cond (μ.S cm^{-1})	0.23	0.56	128.70 ± 4.82	177.23 ± 16.07	157.03 ± 28.46	148.89 ± 26.83
O_2 (mg L^{-1})	0.31	-0.29	8.62 ± 0.56	8.78 ± 0.68	8.49 ± 0.81	8.91 ± 0.19
PO_4 (mg L^{-1})	-0.34	-0.30	1.08 ± 0.07	1.04 ± 0.05	1.04 ± 0.05	1.07 ± 0.08
TN (mg L^{-1})	0.32	-0.51	6.75 ± 1.47	5.99 ± 3.63	7.78 ± 3.26	4.96 ± 0.82
BOD_5 (mg L^{-1})	-0.25	0.43	1.95 ± 0.75	1.88 ± 0.88	1.63 ± 0.58	2.19 ± 0.91
Flow (m s^{-1})	0.47	0.26	1.17 ± 0.03	1.30 ± 0.10	1.23 ± 0.11	1.24 ± 0.09

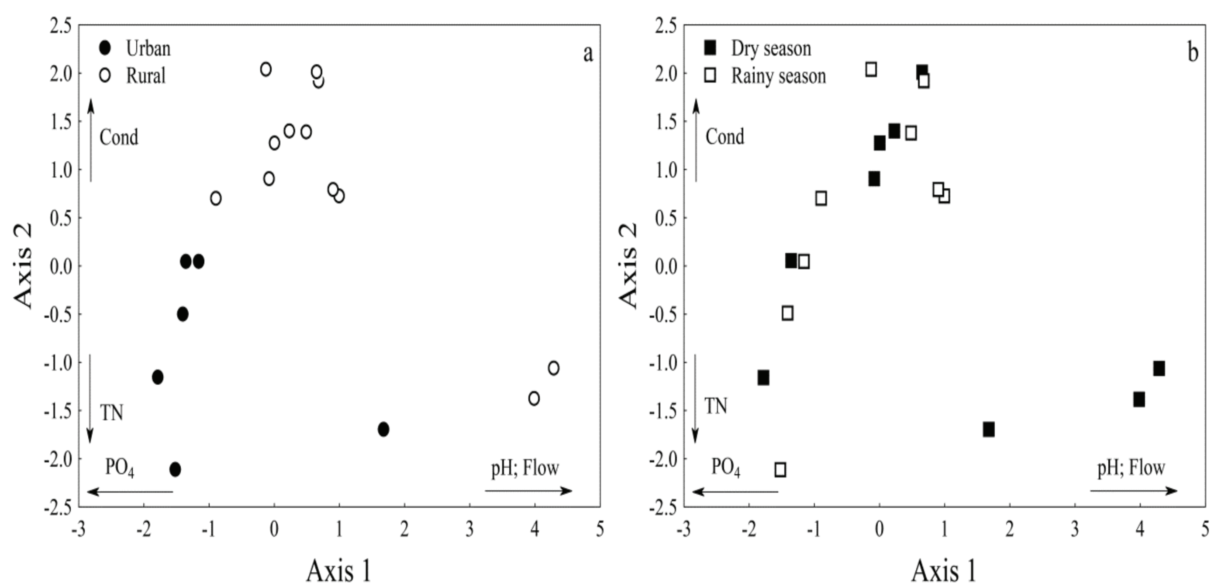

Figure 2. Scatter plot of scores of the PCA applied to the abiotic variables measured in the Guaiapó Stream, municipality of Maringá, Paraná State, sampled from August 2007 to June 2008. a) sites (urban and rural) and b) periods (dry and rainy season).PO_4 = orthophosphate (mg L^{-1}), pH = hydrogenic potential, Flow = flow velocity (m s^{-1}), TN = total nitrogen (mg L^{-1}), Cond = electrical conductivity.

Analyzing the distribution of genera, *Navicula* had the highest number of taxa, followed by *Nitzschia* and *Pinnularia*. The genera *Diadesmis*, *Diploneis* and *Neidium* occurred only in the urban area. The genera *Adlafia*, *Caloneis* and *Kobayasiella* occurred only in the rural region.

Considering the total density, higher mean values were observed in rural stretches (Chi-square test χ^2 = 59.64, $p < 0.05$, Figure 3a), in the dry period (Chi-square test χ^2 = 4.88, $p < 0.05$, Figure 3b).

The structure of the periphytic diatom assemblage, summarized by a NMDS, showed a separation only between sites studied (Figure 4a). After 47 iterations, the stability criterion was achieved with a final stress of 9.19 (Monte Carlo test, $p < 0.01$), and two axes were retained for interpretation. The variance represented by each axis, based on the distance between the r^2 on the ordination space and distances in the original space was 0.32 for the axis 1; and 0.60 for the axis 2, adding up a total of 0.92.

By plotting the axis 1 and 2 (Figure 4a), the spatial scale was identified as the main pattern for the structure of the periphytic diatom assemblage. The urban sites were set apart from the rural sites.

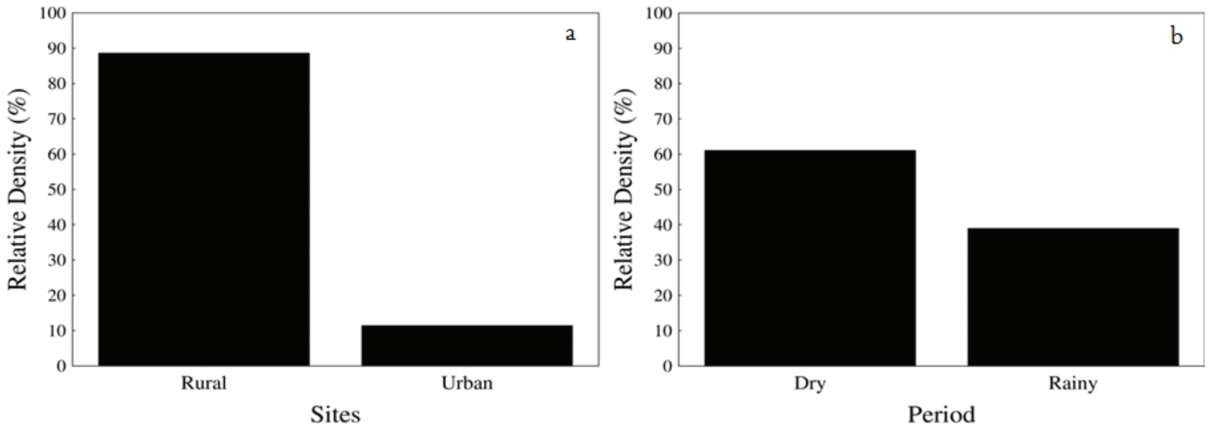

Figure 3. Density of diatoms found in the Guaiapó Stream, municipality of Maringá, Paraná State, sampled from August 2007 to June 2008. a) sampling sites; b) periods.

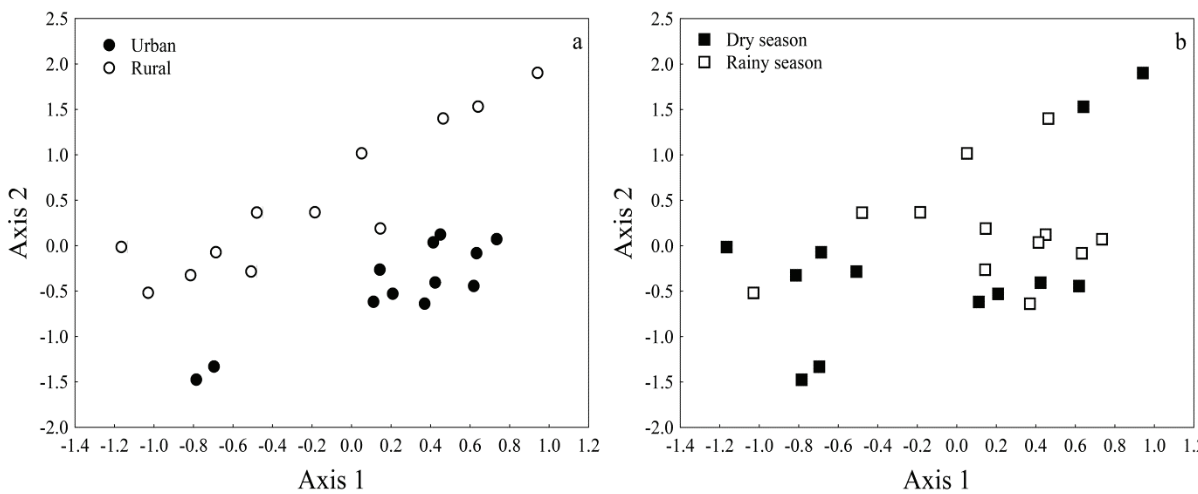

Figure 4. Nonmetric multidimensional scaling (NMDS) ordination of periphytic diatom assemblage in the sampling sites (a; urban and rural) and periods (b; dry and rainy season) of the Guaiapó Stream, municipality of Maringá, Paraná State, sampled from August 2007 to June 2008.

Regarding time, no pattern was found for composition and structure (Figure 4b). PERMANOVA detected significant differences between sites for the composition and structure of the periphytic diatom assemblage ($p < 0.05$; Table 2).

Table 2. Results of PERMANOVA main test for periphytic diatom assemblage in the sites (urban and rural) and periods (dry and rainy season) of the Guaiapó Stream, municipality of Maringá, Paraná State, sampled from August 2007 to June 2008.

Source	df	SS	MS	Pseudo-F	P(perm)
Sites	1	801286	801286	4.17	0.02
Periods	1	153547	153547	0.80	0.43
Sites x Periods	1	191246	191246	0.99	0.38
Residual	20	3841105	192055		
Total	23	4987184			

The result of the Indicator Species Analysis (IndVal) evidenced 23 species of periphytic diatoms, whose abundances and frequencies were significantly associated with some of the studied regions ($p < 0.05$; Table 3). Eleven species were indicators of urban areas and 12 of rural areas (Table 3).

Relationship between biotic and abiotic variables

A Procrustes test (matrices correlation) was run to investigate the relationship between abiotic variables and the assemblage of periphytic diatoms. In this test, the two first PCA axes were compared with the two first ordination axes of the NMDS, which summarized the structure of the periphytic diatom assemblage.

The value adjusted for the sampling sites and periods distribution was $m^2 = 0.52$ and $p < 0.01$, corroborating the influence of abiotic variables (Table 1), mainly on the spatial distribution of the assemblage of periphytic diatoms of the Guaiapó Stream, once significant temporal changes have not been verified.

Table 3. Summary of the indicator species analysis (IndVal) showing the relative abundance (RA), relative frequency (RF) and indicator value (IV) for the periphytic diatom species in the sites (U = urban and R = rural) of the Guaiapó Stream, municipality of Maringá, Paraná State, sampled from August 2007 to June 2008. Bold values indicates significant indicator results ($p < 0.05$, Monte Carlo permutation test).

	RA		RF		IV	
	U	R	U	R	U	R
Achnanthes exigua Grun.	76	24	100	50	76	12
Achnanthes rupestoides Hohn	99	1	75	8	74	0
Amphora copulata (Kütz.) Schoe. & Archib.	87	13	67	17	58	2
Aulacoseira sp.	93	7	67	8	62	1
Cyclotella pseudostelligera Hust.	89	11	58	17	52	2
Eunotia sp.	96	4	42	8	40	0
Navicula lohmannii Lange-Bert. & Rumrich	100	0	50	0	50	0
Nupela praecipua (Reich.) Reich.	99	1	100	17	99	0
Nupela sp.	96	4	83	42	80	2
Placoneis constans var. *symmetrica* (Hust.) Kobay.	90	10	92	25	83	2
Placoneis porifera var. *opportuna* (Hust.) Lange-Bert.	100	0	42	0	42	0
Amphora montana Krass.	4	96	83	92	3	88
Cocconeis placentula var. *euglypta* (Ehr.) Cleve	0	100	8	75	0	75
Cyclotella meneghiniana Kütz.	2	98	50	92	1	90
Cymbella kolbei Hustedt.	0	100	0	75	0	75
Gomphonema lagenula Kütz.	9	91	100	100	9	92
Mayamaea atomus (Kütz.) Lange-Bert.	2	98	50	92	1	90
Geissleria aikenensis (Patr.) Torg. & Oliv.	1	99	75	100	1	99
Navicula erifuga Lange-Bert.	1	99	33	92	0	91
Navicula schroeteri Meister	11	89	75	100	9	89
Navicula viridula var. *rostellata* (Kutz.) Cleve	17	83	50	83	9	69
Nitzschia frustulum (Kütz.) Grunow	13	87	17	58	2	51
Nitzschia palea (Kütz.) Smith	4	96	100	100	4	96

Discussion

Our findings pointed out that the assemblage of periphytic diatoms of the Guaiapó stream presented only spatial heterogeneity. As the geology of the microbasin herein studied is the same for the three sampling sites, it is supposed that the land use has influenced the abiotic variables of the stream, which generated similar responses from the assemblage of periphytic diatoms. In the absence of human influence, the nutrient concentration in the water of a certain stream is determined by geology, atmospheric deposition and vegetation (BIGGS, 1996). Also, variations in biotic and abiotic characteristics take place naturally along the longitudinal axis of a river (VANNOTE et al., 1980).

Periphytic diatoms are affected by anthropogenic or natural factors (PAN et al., 1996; RIMET; BOUCHEZ, 2012). In the Guaiapó Stream, the assemblage structure in the urban area was distinct from that found in rural area (middle stretch and mouth). The urban area presented the higher values of PO_4 and TN. Aquatic environments in urban centers exhibit increased concentration of nutrients, especially nitrogen, caused by poor sewage treatment and illegal discharge of effluents into these environments (PAUL; MEYER, 2008). Nitrogen and phosphorus are considered the main limiting nutrients for algal growth. Under increased concentrations of nitrogen and phosphorus, McCormick et al. (1996) registered the replacement of diatoms typical of oligotrophic environments with species indicators of eutrophication. In the Guaiapó Stream, even though the higher values of nitrogen found in the urban sites, the values of this nutrient were also high in the rural stretches. High concentrations of TN in these regions can be associated with the use of fertilizers in adjacent areas. In agreement with Lavoie et al. (2004) and Smucker and Vis (2011), the intensive agriculture is responsible for increased concentrations of nutrients in streams and also for chemical and physical changes in these environments.

High conductivity values are also considered one of the main effects of agriculture activity on streams (LELAND et al., 2001). The influence of this variable on periphytic diatoms has been previously reported in other studies (SONNEMAN et al., 2001; WALKER; PAN, 2006). Another factor that should be taken into account is the increase in flow velocity observed in downstream regions, favoring species with effective mechanisms of attachment to the substrate, like those with prostrate habit or attached to the substrate by mucilage tubes (STEVENSON, 1996; HERMANY et al., 2006). The presence of riparian vegetation was also important for the differentiation between urban and rural zones. Hill (1996) highlights the effect of light on the architecture of the periphytic algal assemblage, which influences its composition and growth, but the individual light requirements of periphytic algal species are barely known. Furthermore, the limitation of light is negative to the development of diatoms.

In this study, most indicator taxa of the urban region have a widespread distribution, but previous studies associated their occurrence with specific environments. *Achnanthes exigua* Grunow, for example, tolerates high nitrogen concentrations, being found in oligo- to eutrophic environments (LOBO et al., 2002; 2004a). *Achnanthes rupestoides* Hohn was also referred by Van Dam et al. (1994) as a species typical of meso-eutrophic waters. However, according to Hermany et al. (2006), this species has preference for eutrophic environments under strong human impact. *Cyclotella pseudoestelligera* Hustedt and *Amphora copulata* (Kutzing) Schoeman & Archibald also are taxa typical of environments with high nitrogen concentrations and eutrophic environments (VAN DAM et al., 1994).

According to the scarce literature on the ecology of *Nupela*, species belonging to this genus have been recorded in environments with moderate to high concentrations of TN (POTAPOVA et al., 2003), or in rivers severely polluted by organic matter (RUMRICH et al., 2000). In the Guaiapó Stream, *Nupela praecipua* (Reichardt) Reichardt and *Nupela* sp. were indicators of the urban region, containing higher concentrations of nitrogen and phosphorus. Similarly, ecological information concerning the species of *Placoneis* is lacking. Cox (2003) asserted that species belonging to this genus are mainly found in mesotrophic waters. Nevertheless, Taylor et al. (2007) registered species of this genus in mesotrophic to eutrophic environments. With regard to *Navicula lohmannii* Lange-Bert. & Rumrich there are no ecological data in the literature. In this research, *N. lohmannii* was indicator of the urban environment, that is, this species tolerates high concentrations of nitrogen and phosphorus.

Among the 12 species indicators of the rural region, the most cited in the literature are *Cyclotella meneghiniana* Kutzing and *Cocconeis placentula* var. *euglypta* (Ehrenberg) Grunow. They are typical of eutrophic environments, requiring high concentrations of nitrogen periodically (VAN DAM et al., 1994). In lotic systems from Southern Brazil, *Cyclotella meneghiniana* had already been registered as indicator of intermediate levels of eutrophication (LOBO et al., 2004c) and tolerant to heavily impacted environments (LOBO et al., 2004a). In addition to the preference for eutrophic environments, *Cocconeis placentula* and *Cymbella kolbei* Hustedt should get advantages from the growth form, strongly attached to the substrate, being resistant to higher flow velocity, verified in rural areas in this study. Soininen (2004) registered high abundance of *Cocconeis placentula* in environments with high current flow. Also, this species has been associated with agricultural areas (JÜTTNER et al., 2003; LAVOIE et al., 2004). *Amphora montana* Krasske and *Nitzschia palea* (Kütz.) Smith also indicated eutrophic to hypereutrophic environments (VAN DAM et al., 1994; LOBO et al., 2002; DELGADO et al., 2012). On the species *Navicula erifuga* Lange-Bert., *Navicula schroeteri* Meister, *Navicula viridula* var. *rostellata* (Kutz.) Cleve and *Nitzschia frustulum* (Kütz.) Grunow, little ecological information is available, although, according to Van Dam et al. (1994), these taxa are characteristic of eutrophic environments. Nevertheless, in the Guaiapó Stream, this species was indicator of rural stretches, in which were recorded higher pH, flow and conductivity. Furthermore, *Mayamaea atomus* (Kütz.) Lange-Bert., which is indicator of the rural section, has been reported in strongly polluted environments (LOBO et al., 2002). On the other hand, *Geissleria aikenensis* (Patr.) Torg. & Oliv. is characteristic of environments with low mineral and organic content as well as high oxygen levels (HERMANY et al., 2006), and has low tolerance to eutrophication (LOBO et al., 2004b). We did not find ecological data on *Gomphonema lagenula* Kütz. In the Guaiapó Stream, this taxon was indicator of rural stretches, where lower phosphorus and nitrogen concentrations were verified, as well higher pH, flow and conductivity.

Conclusion

The structure of the periphytic diatom assemblage demonstrated the spatial gradient of the stream, reinforcing its role as an excellent environmental indicator. Eleven species characterized the urban sites, where it was found greater values of nitrogen and phosphorus. In rural environments, where the species were strongly influenced by nutrient concentrations, was observed preference for the registered values of pH and conductivity.

Our results evidenced changes in composition and abundance of periphytic diatoms, probably caused by limnological variations along the stream gradient. There are indicator species in each stretch of the stream, which can be used to assess the water quality.

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