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Effects of intensive fish-farming and domestic wastewater on the periphytic algal community in a tropical coastal lagoon (Juara, Brazil)

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ABSTRACT. This study aimed at evaluating the effects of the intensive fish-farming and the domestic wastewater on the structure of the phycoperiphyton community. Three experimental supports containing artificial substrate were assembled in two sampling sites: IF – region with intensive fish-farming and DW – near the domestic wastewater discharge. Samplings were carried out after the 21st, 26th and 31st day of colonization. The abiotic variables evaluated were: transparency, electrical conductivity, pH, turbidity, total suspended solids, alkalinity, dissolved oxygen, water temperature and nutrients. Phycoperiphyton was examined with regard to density, richness, abundance, dominance, diversity and eveness. Nutrients (total nitrogen, nitrate, ammonia nitrogen, orthophosphate and silicate) were different among the sampling sites. Although the total density, richness, diversity and evenness of phycoperiphyton were not affected by the different impacts, the density by class had differences between the sampling sites, with Bacillariophyceae presenting higher density at IF and Cyanophyceae and Coscinodiscophyceae at DW. Four taxa have been associated with the impact by domestic wastewater, and four, to the intensive fish-farming. The density by class of phycoperiphyton was the best attribute to evaluate the effects of human activity.

Keywords: Bacillariophyceae, late successional stage, nutrients, phycoperiphyton, artificial substrate.

Efeitos da piscicultura intensiva e de efluentes domésticos na comunidade de algas perifíticas em uma lagoa costeira tropical (Juara, Brasil)

RESUMO. A presente pesquisa visou avaliar o efeito da piscicultura intensiva e de esgoto doméstico na estrutura da comunidade ficoperifítica. Foram implantados três suportes experimentais contendo substratos artificiais em duas estações amostrais da lagoa Juara: IF - região de piscicultura intensiva e DW - próxima ao lançamento de efluentes domésticos. As coletas foram realizadas após 21, 26 e 31 dias de colonização. As variáveis abióticas avaliadas foram transparência, condutividade elétrica, pH, turbidez, sólidos totais em suspensão, alcalinidade, oxigênio dissolvido, temperatura da água e nutrientes. As algas perifíticas foram analisadas pelos atributos: densidade, riqueza, abundância, dominância, diversidade e equitabilidade. As concentrações de nutrientes (nitrogênio total, nitrato, nitrogênio amoniacal, ortofosfato e silicato) diferiram entre as duas estações amostrais. Apesar da densidade total, riqueza, diversidade e equitabilidade não diferirem em relação às estações amostrais, a densidade por classes apresentou diferenças com Bacillariophyceae, tendo maior densidade em IF e Cyanophyceae e Coscinodiscophyceae em DW. Quatro táxons estiveram relacionados com o impacto por efluente doméstico e quatro com a piscicultura intensiva. A densidade por classes do ficoperifíton mostrou ser o melhor atributo quando se deseja avaliar o efeito das atividades antrópicas.

Palavras-chave: Bacillariophyceae, estágio sucessional tardio, nutrientes, ficoperifíton, substrato artificial.

Introduction

Periphyton community is controlled by several factors, such as: temperature (MURAKAMI; RODRIGUES, 2009), light and nutrients (HILL; FANTA, 2008). In recent centuries, the growing urbanization and agricultural practices have increased the input of nutrients in shallow lakes worldwide, causing changes in the biological structure and dynamics of these environments (JEPPESEN et al., 2005), due to the eutrophication process, which may derail the multiple uses of the water bodies due to the unpleasant taste and odor, the potential presence of toxins and anoxia (MOLICA; AZEVEDO, 2009). Fish farming and the discharge of domestic wastewater stand out among the activities that contribute with the allochthonous input of nutrients into the water bodies. Approximately 47% of the entire world supply of fisheries derive from fish farming, with a great increase in the production per capita of 0.7 kg in 1970 to 7.8 kg in 2008 (KASSAM et al., 2011).The collection and treatment of domestic sewage are insufficient in many countries, as in Brazil, where only 55.2% of the municipalities have sewerage system throughout the sewage collection network, but not all collected is treated (IBGE, 2010).

Studies involving changes in the community structure before environmental gradient or different human impacts have been frequently neglected (BLANCO et al., 2008) and the evaluation of these dynamics may reveal environmental changes or conditions of water quality suitable for the development of problems (PORTER et al., 2008). Studies concerning the influence of human impacts on the structure of periphytic communities are necessary, mainly in tropical regions.

This study aimed at evaluating the fish-farming and the domestic wastewater influence on the structure of periphytic community, during the latter stages of colonization. The hypothesis tested was that the developing of periphyton, mainly Chlorophyceae and Cyanophyceae, is enhanced in the region where the domestic wastewater is discharged rather than in the intensive fish-farming region.

Material and methods

Study area

The Juara Lagoon is located in the basin of the Jacaraipe River (220 km² of area), in the municipality of Serra, State of Espírito Santo, Brazil, and covers an area of 2.9 km² (PMS, 2010 – Figure 1). The climate is tropical hot and humid, with annual mean temperature of 24°C, ranging from 18°C to 34°C, with a unimodal rainfall regime, and annual range from 900 to 1.200 mm (PMS, 2010). The rainy period is from October to January, while the dry period is well-defined from July to August (SIAG, 2010).

Two sampling sites were established: 1) in the area of intensive fish-farming (IF), at 40° 14' 15'' W and 20° 06' 17'' S, and near the mouth of Laranjeiras Stream, and 2) the primary means for transporting domestic wastewater into the lagoon (DW), at 40° 12' 43'' W and 20° 07' 40'' S (Figure 1a, b and c). The distance between the sampling sites was about 3.7 km.

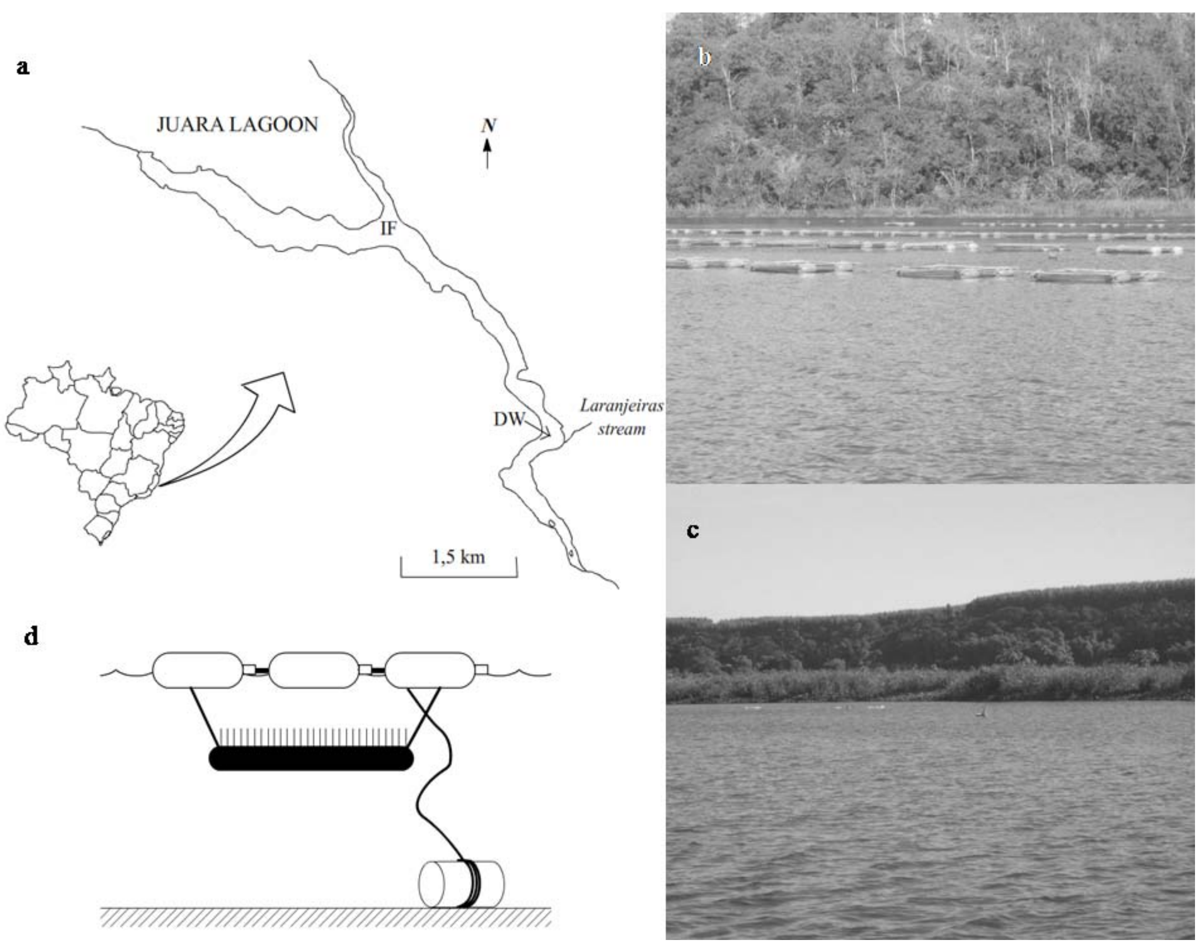

Figure 1. Location of Juara lagoon, State of Espirito Santo, Brazil (a), sampling stations IF (intensive fish-farming) (b) and DW (domestic wastewater) (c), and experimental structure (d).

Its main tributaries are the streams Juara, Cavada, Doutor Robson, Castelo, Cachoeira do Putiri, Independência, Roncador, São Domingos, Laranjeiras and Quibebe. The lagoon is connected with the sea through the Jacaraipe river, with 4.5 km length. The surrounding vegetation consists of riparian vegetation and plantations of *Eucaliptus* sp. (PMS, 2010).

The lagoon is used for multiple purposes such as recreation, fishing, artisanal fishing, and since 2000 has been developed intensive fish-farming (net cages) for the tilapia culture (*Oreochromis* sp.). The number of cages varies over time and in the month of collection (December 2009) there were 90 net cages in the lagoon. The streams that flow into the lagoon bring a load of nutrients from the urbanized regions and agricultural areas, and the Laranjeiras stream that drains near the Fishermen Association, is the main carrier of high organic load (fresh domestic sewage).

Methods

Three structures were attached to the sediment in each sampling site, on 18th December, 2009, and equipped with floats to maintain the substrate under the water surface (0.2 m). Each experimental structure was made up of circular rubber supports and built to hold 50 glass slides, artificial substrate for the algal colonization (Figure 1d).

The abiotic and biotic samplings were carried out after the 21st, 26th, and 31st day of colonization by periphytic algae, from the implantation of the experimental structures. This is the period considered as representative of the mature stage of succession (POMPÊO; MOSCHINI-CARLOS, 2003).

The substrates were collected at random, stored in refrigerated moist chambers, and the periphytic material was removed through scraping and water jets. In each sampling, 10 substrates (glass slides) were taken and scraped into a single integrative sample with known volume (providing a volume/area ratio), from which aliquots with known volume were taken for biological analyses.

At each sampling site were determined in the field: climatic, morphometric and limnological variables; the variables assessed during the experiment were: daily mean air temperature and daily accumulated precipitation (SIAG, 2010); depth (water depth gauge, Speedtech), wind speed (anemometer, Instrutherm AD-250), water transparency (Secchi disk), electrical conductivity, water temperature and dissolved oxygen (YSI 85 probe), pH (portable digital potentiometer Alfakit AT 300). In the laboratory were determined: turbidity (turbidimeter Alfakit Plus V1.25), total suspended solids (APHA, 2005), total alkalinity (CARMOUZE, 1994), total nitrogen and total phosphorus (VALDERRAMA, 1981), nitrate (MACKERETH et al., 1978), nitrite and silicate (GOLTERMAN et al., 1978), ammonia nitrogen (KOROLEFF, 1976), and orthophosphate (STRICKLAND; PARSONS, 1960).

The samples for quantitative analysis of periphytic algae were fixed in 5% acetic lugol solution and analyzed under inverted microscope Nikon Eclipse TS 100 (400x), according to Utermöhl (1958), and the sedimentation time according to Lund et al. (1958). The count limit was given when dominant taxa achieved 100 individuals. The samples for qualitative analysis were fixed with 4% formalin and analyzed under optical microscope Olympus CX 41. The algae were sketched, photographed and identified using specialized literature.

The dominant species were those whose occurrence exceeded 50% of the total number of individuals of the sample and the abundant species were those whose occurrence was higher than the mean of the total number of individuals of the sample (LOBO; LEIGHTON, 1986). The diversity index of Shannon and Weanner (1963) and the eveness, according to Pielou (1975, apud LEGENDRE; LEGENDRE, 1983) were also calculated. The descriptive species were those whose density represented at least 5% of the total density.

The data were analyzed using exploratory univariate analysis, through mean, minimum, maximum, standard error, and coefficient of variation. In order to test the possible differences between mean values for the limnological variables of the sampling stations, it was applied a one-way ANOVA ($\alpha = 0.05$), and the Kruskal-Wallis test was used for mean values of biotic variables. The relationships between densities by class and abiotic variables were given by the Pearson's correlation ($p < 0.05$). All these analyses were run with the software STATISTICA 7.0 (STATSOFT, 2004). The Principal Component Analysis (PCA), performed with a correlation matrix, was used to evaluate spatially the relationship between sampling sites and abundant algae (LOBO; LEIGHTON, 1986). The software PC-ORD 4.0 (McCUNE; MEFFORD, 1999) was used to execute the PCA.

Results

The experimental period was characterized by high air temperatures (mean temperature of 27.6°C, minimum of 23.8° and maximum of 29.7°C) and low rainfall (total accumulated rainfall of 70.0 mm, with maximum accumulated rainfall of 26.2 mm). The mean depth of the sampling sites ($n = 9$) was 2.1 m for IF and 1.2 m for DW.

Higher values of silicate were found in IF and higher values of electrical conductivity, turbidity, total nitrogen, nitrate and ammonia nitrogen in DW. The Table 1 lists the descriptive analysis for the limnological variables and the ANOVA results.

The Kruskal-Wallis test evidenced a higher density of Bacillariophyceae in IF, mainly on the 26th and 31th

day of colonization, and higher density of Coscinodiscophyceae (26th and 31th day) and Cyanophyceae (31th day) in DW. Other classes showed no difference, as well as total richness, diversity and eveness between both sites, and among days of colonization (Table 2).

The total density was similar between sites, and among days of colonization. Bacillariophyceae and Cyanophyceae were the most representative classes in IF and Cyanophyceae and Coscinodiscophyceae in DW (Figure 2).

Table 1. Exploratory univariate analysis (mean, standard deviation and coefficient of variation) and ANOVA ($p < 0.05$) for the limnological variables, considering the two sampling sites (IF and DW).

Variable	Code	IF	DW	ANOVA
Transparency (m)	Tra	0.6 ± 0.01; 6.9%	0.4 ± 0.01; 7.6%	F = 14.78; p = 0.001
Electrical conductivity (μS cm^{-1})	CoE	141.7 ± 2.0; 4.2%	188.2 ± 2.4; 3.8%	F = 222.75; p = 0.000
Hydrogenionic potential	pH	7.3 ± 0.1; 2.4%	7.3 ± 0.02; 1.0%	F = 1.60; p = 0.224
Turbidity (NTU)	Tur	7.3 ± 0.2; 8.9%	10.4 ± 0.4; 10.6%	F = 52.65; p = 0.000
Total suspended solids (mg L^{-1})	TSS	10.0 ± 0.6; 16.8%	14.4 ± 1.0; 21.4%	F = 13.987; 0.001
Total alkalinity (mEq L^{-1})	Alc	0.4 ± 0.01; 8.4%	0.6 ± 0.02; 10.2%	F = 57.91; p = 0.000
Dissolved oxygen (mg L^{-1})	OxD	6.4 ± 0.2; 10.1%	6.8 ± 0.1; 4.6%	F = 2.90; p = 0.108
Water temperature (°C)	Tag	31.4-32.5 (31.8 ± 0.1; 1.3%)	30.3-32.0 (30.8 ± 0.2; 1.9%)	F = 15.52; p = 0.001
Total nitrogen (μg L^{-1})	Nto	255.9-631.4 (399.5 ± 34.9; 26.1%)	466.5-1242.9 (873.5 ± 97.7; 33.5%)	F = 20.88; p = 0.000
Nitrate (μg L^{-1})	Nta	1.0-31.3 (15.1 ± 3.8; 75.4%)	9.5-44.1 (28.2 ± 4.4; 47.3%)	F = 4.96; p = 0.041
Nitrite (μg L^{-1})	Nti	5.9-20.9 (14.0 ± 1.9; 40.1%)	5.9-30.4 (15.1 ± 2.8; 55.7%)	F = 0.12; p = 0.738
Ammonia nitrogen (μg L^{-1})	Nam	29.7-98.0 (53.7 ± 7.2; 40.1%)	36.4-855.9 (471.3 ± 115.3; 73.4%)	F = 13.06; p = 0.002
Total phosphorus (μg L^{-1})	Pto	10.6-43.7 (30.4 ± 4.2; 41.8%)	20.0-84.6 (44.0 ± 6.5; 44.2%)	F = 3.07; p = 0.099
Orthophosphate (μg L^{-1})	Por	9.0-13.8 (10.7 ± 0.5; 13.6%)	11.4-21.7 (16.3 ± 1.1; 21.0)	F = 20.63; p = 0.000
Silicate (mg L^{-1})	Sil	4.1-5.3 (4.7 ± 0.1; 7.2%)	2.1-3.0 (2.5 ± 0.1; 15.9%)	F = 174.68; p = 0.000

Table 2. Mean, standard error, and Kruskal-Wallis test of the biotic variables for the sites and days of succession.

Variable	IF21	IF26	IF31	DW21	DW26	DW31
Coscinodiscophyceae (10^{-3}ind cm^{-2})	86.547c (12.112)	73.193d (25.520)	75.353c (4.385)	111.490b (30.683)	167.512a (19.207)	164.297a (56.112)
Bacillariophyceae (10^{-3}ind cm^{-2})	214.352a (45.497)	224.542a (35.137)	128.992b (38.927)	53.682e (18.067)	93.959c (25.412)	76.185d (37.852)
Chlorophyceae (10^{-3}ind cm^{-2})	40.189a (5.899)	42.896a (9.338)	41.575a (8.818)	41.105a (9.161)	49.869a (17.113)	77.025a (46.257)
Cyanophyceae (10^{-3}ind cm^{-2})	117.236d (36.846)	136.256c (28.501)	94.313e (3.116)	216.590b (63.542)	232.359b (42.088)	280.381a (69.729)
Oedogoniophyceae (10^{-3}ind cm^{-2})	1.252a (1.391)	2.564a (1.318)	2.848a (1.640)	1.911a (2.435)	1.551a (1.777)	1.008a (1.746)
Zygnemaphyceae (10^{-3}ind cm^{-2})	5.269a (3.434)	2.206a (1.317)	5.643a (6.909)	1.080a (1.871)	0.388a (0.671)	0.924a (0.810)
Xanthophyceae (10^{-3}ind cm^{-2})	0.000a (0.000)	0.458a (0.794)	0.252a (0.436)	0.000a (0.000)	1.304a (1.380)	0.504a (0.873)
Euglenophyceae (10^{-3}ind cm^{-2})	0.229a (0.397)	0.000a (0.000)	0.000a (0.000)	0.388a (0.671)	0.388a (0.671)	0.000a (0.000)
Total richness (individuals)	33a (8)	36a (3)	32a (5)	29a (6)	32a (4)	32a (5)
Diversity (bits ind^{-1})	3.48a (0.12)	3.52a (0.12)	3.62a (0.17)	3.53a (0.30)	3.74a (0.25)	3.58a (0.23)
Eveness	0.51a (0.13)	0.46a (0.06)	0.56a (0.05)	0.58a (0.09)	0.62a (0.08)	0.55a (0.03)

Same letters indicate similar results between each variable, for the Kruskal-Wallis test.

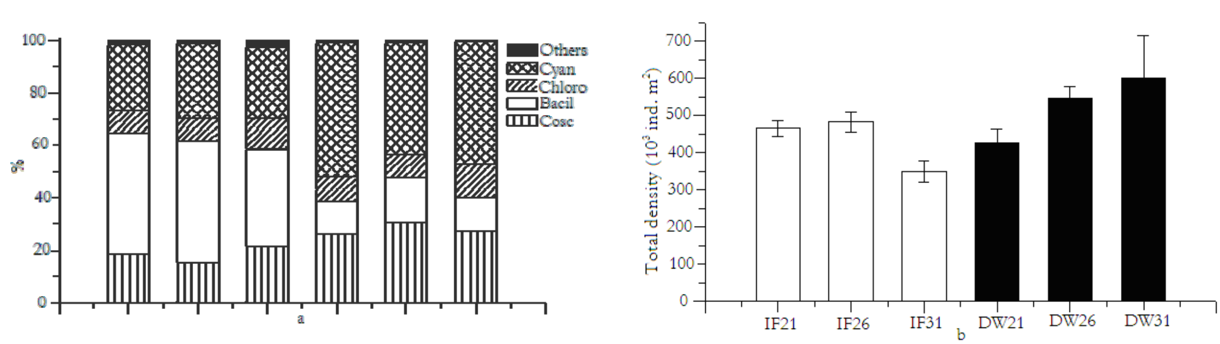

Figure 2. Representativeness of the algal classes in the density (A) and total density (B) for the periphytic algae in the sampling sites and successional days. Cosc = Coscinodiscophyceae; Bacil = Bacillariophyceae; Chlor = Chlorophyceae; Cyan = Cyanophyceae; Others = Oedogoniophyceae, Zygnemaphyceae and Xanthophyceae.

Table 3. Pearson's correlation between abiotic variables and densities of algal classes. Cosc = Coscinodiscophyceae; Bacil = Bacillariophyceae; Chlor = Chlorophyceae; Cyan = Cyanophyceae; Oedo = Oedogoniophyceae; Zygn = Zygnemaphyceae; Xant = Xanthophyceae and Eugl = Euglenophyceae. ⋆ are significant ($p < 0.05$).

	Tra	CoE	pH	Tur	STS	Nto	Nta	Nti	Nam	Pto	Por	Sil
Cosc	-0.42	0.68⋆	-0.18	0.57⋆	0.59⋆	0.29	0.23	0.09	0.29	0.57⋆	0.41	-0.80⋆
Bacil	0.64⋆	-0.84⋆	0.46	-0.67⋆	-0.52⋆	-0.70⋆	-0.38	-0.00	-0.58⋆	-0.23	-0.74⋆	0.78⋆
Chlor	-0.04	0.22	-0.05	0.16	0.13	-0.09	-0.13	-0.18	-0.13	0.15	0.15	-0.40
Cyan	-0.54⋆	0.73⋆	-0.15	0.68⋆	0.44	0.45	0.28	0.07	0.37	0.32	0.60⋆	-0.80⋆
Oedo	0.26	-0.16	-0.30	-0.09	-0.11	0.00	-0.25	0.18	-0.03	-0.08	-0.04	0.19
Zygn	0.33	-0.50⋆	0.20	-0.51⋆	-0.56⋆	-0.39	-0.30	-0.03	-0.33	-0.20	-0.30	0.47⋆
Xant	-0.11	0.24	-0.31	0.29	0.41	-0.07	0.00	0.59⋆	0.05	0.60⋆	0.07	-0.35
Eugl	0.00	0.27	-0.08	0.30	0.20	0.53⋆	0.32	-0.00	0.41	0.23	0.28	-0.14

Codes for abiotic variables are listed in the Table 1.

Classes Coscinodiscophyceae, Bacillariophyceae, Cyanophyceae and Zygnemaphyceae have been more correlated with abiotic variables (Table 3). Abiotic variables with higher correlation with densities of the algal classes were electrical conductivity, turbidity, total suspended solid and silicate, considering three or more significant correlations.

No dominant species was found in the samplings. Twenty abundant species were recorded (Table 4), whereby five were common to both sampling sites (*Aulacoseira* sp.1, *Cyclotella* sp., *Fragilaria* sp., *Sphaerocystis planctonica* (Korshikov) Bourrelly and *Synechocystis* sp.), seven were abundant only at TR (*Achnanthidium minutissimum* (Kützing) Czarnecki, *Aphanocapsa hosaltica* (Lemmermann) Cronberg and Komárek, *Aulacoseira* sp.2, *Gomphonema gracile* Ehrenberg, *Gomphonema lagenula* Kützing, *Gomphonema parvulum* (Kützing) Kützing and *Leptolyngbya angustissima* (West and West) Anagnostidis & Komárek, and eight were abundant only at ED (*Aulacoseira* sp.3, *Aulacoseira* sp.4., *Eunotia* sp., *Gomphonema* sp., *Leibleinia epiphytica* (Hieronymus) Compére, *Leptolyngbya faveolarum* (Rabenhorst and Gomont) Anagnostidis and Komárek, *Phormidium tergestium* (Kützing) Anagnostidis and Komárek and *Stigeoclonium* sp.).

Table 4. Abundant taxa, presence/absence at the sampling sites, codes, and Pearson's correlation with the axes of the principal component analysis.

Taxon	IF	DW	Code	Axis1	Axis2
Achnanthidium minutissimum	X		Achn	-0.803⋆	0.152
Aphanocapsa hosaltica	X		Apha	-0.355	-0.128
Aulacoseira sp1.	X	X	Aul1	0.833	0.354
Aulacoseira sp2.	X		Aul2	-0.222	-0.033
Aulacoseira sp3.		X	Aul3	0.371	-0.628⋆
Aulacoseira sp4.		X	Aul4	0.507	0.769⋆
Cyclotella sp.	X	X	Cycl	0.023	-0.649⋆
Eunotia sp.		X	Euno	0.579	-0.495
Fragilaria sp.	X	X	Frag	0.592	0.535
Gomphonema gracile	X		Ggra	-0.683⋆	0.114
Gomphonema lagenula	X		Glag	-0.281	0.050
Gomphonema parvulum	X		Gpar	-0.645⋆	0.117
Gomphonema sp.		X	Gomp	0.694⋆	0.258
Leibleinia epiphytica		X	Leib	0.896⋆	-0.076
Leptolyngbya angustissima	X		Lang	-0.660⋆	0.105
Leptolyngbya faveolarum		X	Lfav	0.206	-0.593
Phormidium tergestium		X	Phor	0.333	-0.267
Sphaerocystis planctonica	X	X	Spha	-0.413	0.608⋆
Stigeoclonium sp.		X	Stig	0.546	0.243
Synechocystis sp.	X	X	Syne	0.712⋆	0.300

⋆: Pearson's correlation > 0.6 with the PCA axes.

The descriptive taxa and the percentage of representativeness of the sampling sites and colonization days are presented in the Table 5. The sampling site IF had six descriptive species: *Aulacoseira* sp.1, *S. planctonica*, *G. gracile*, *Synechocystis* sp., *A. minutissimum* and *G. parvulum*. All these species were descriptive in all evaluated days, except *G. parvulum* which was not representative on the 31st day of succession. The site DW presented six descriptive species: *Aulacoseira* sp.1, *Cyclotella* sp., *A. hosaltica*, *Synechocystis* sp., *L. epiphytica* and *Eunotia* sp. In the site TR, 50% of the descriptive species belongs to the class Bacillariophyceae, and in the site DW, 50% of the descriptive species, to the class Cyanophyceae.

Table 5. Percentage of representation of descriptive taxa in sampling sites (IF and DW) and colonization days.

	IF21	IF26	IF31	DW21	DW26	DW31
Aulacoseira sp.1	14.1	9.7	15.0	20.3	18.9	20.9
Sphaerocystis planctonica	5.7	5.3	6.6			
Cyclotella sp.					6.5	
Gomphonema gracile	15.9	10.0	5.2			
Aphanocapsa hosaltica				5.7		
Synechocystis sp.	15.6	18.4	16.4	25.8	26.1	28.6
Achnanthidium minutissimum	15.3	18.9	24.2			
Gomphonema parvulum	7.5	16.8				
Leibleinia epiphytica				11.6	7.1	8.3
Eunotia sp.					5.8	

The PCA summarized along the first two axes 50.1% of total variability (Figure 3). The axis 1 (34.9%) has separated the two sampling sites, with IF being negatively correlated with this axis and with higher correlation with the abundant taxa *Achnanthidium minutissimum*, *Gomphonema parvulum*, *Gomphonema gracile* and *Leptolyngbya angustissima*. The site DW was positively correlated with the axis 1, and presented correlation with the taxa *Aulacoseira* sp.1, *Gomphonema* sp., *Leibleinia epiphytica* and *Synechocystis* sp. The results of the Pearson's correlation between the abundant taxa and the PCA axes are presented in the Table 4.

Discussion

Limnological variables indicated eutrophic conditions (nitrogen species) in both sampling sites, particularly in DW, due to higher values of total nitrogen, ammonia nitrogen, and electrical conductivity, as evidenced by the ANOVA. This result may be explained by the contribution of Laranjeiras Stream that flows into the lagoon a few meters from the sampling site, and represents the main carrier of fresh domestic sewage for the environment. As evidenced by Santos et al. (2008), these limnological variables (nitrogen species and electrical conductivity) are good indicators of the environmental quality for water bodies which receive this type of effluent. Regions with intensive rearing of fish in net cages tend to release the leftovers and metabolites directly into the water, which may result in increased trophic status of the environment (ALVES; BACCARIN, 2005), likewise in the IF site presently studied, mainly for nitrogenous nutrients.

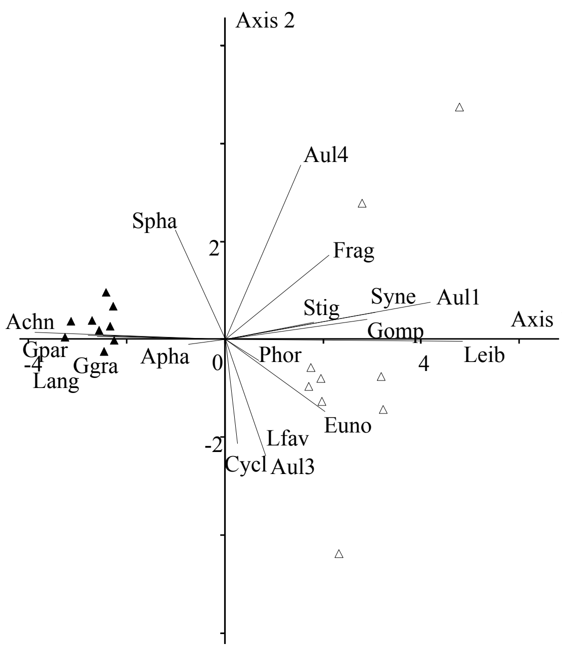

Figure 3. PCA biplot of density of the abundant algae in the sampling sites IF (▲) and DW (△). The codes of the abundant algae are presented in Table 5.

No difference was detected between sampling sites and colonization days, with regards to the total density of phycoperiphyton, which was probably because both sampling sites showed evidence of eutrophication and the community would already be in the mature stage of the succession process. The literature states that during this period there are small oscillations in density values caused by higher stability in the populations (KRALJ et al., 2006). Blanco et al. (2008) and DeNicola et al. (2006) by studying the periphyton community in mesocosm and in three Irish lakes, respectively, under nutrient enrichment, also observed no difference among treatments for total density. DeNicola et al. (2006) verified that the difference of nutrients in the water column among the studied lakes was more related to the taxonomic composition than to the abundance. Ferragut and Bicudo (2009) developed an experiment of enrichment with phosphorus and did not observe any difference for total density among treatments, with mature community (30^{th} day of colonization). Nevertheless, in relation to the numerical representation of the algal classes, these authors found a remarkable difference among treatments, as observed in the present study.

The only class which presented higher density at IF was Bacillariophyceae. In the present study, the highest values of silicate may have determined the predominance of this class, and the increase in the phosphorus concentration at DW may have acted synergistically with other factors to reduce the density of Bacillariophyceae in this site, as presented in the Table 3, with a high positive correlation with silicate and a high negative correlation with orthophosphate. Among the descriptive species, half of the species belongs to this class and were ordinated by the PCA, close to the samplings of this site, aside from being exclusively descriptive of IF.

In general, *Achnanthidium minutissimum* is indicator of good water quality, frequently nutrient-poor. The species has wide tolerance to several environmental factors, and is found with high densities in environments with low concentration of nutrients and ionic content (PONADER; POTAPOVA, 2007). The species *Gomphonema gracile* has a wide distribution, being found in environments ranging from oligotrophic to eutrophic (NDIRITU; GICHUKI, 2006; POTAPOVA; CHARLES, 2007), and in the present study *G. gracile* was descriptive for the region with net cages, with eutrophic characteristics. As for *Gomphonema parvulum,* the species can be found in environments ranging from moderately polluted (LOBO et al., 1995) to highly polluted environments (SALOMONI et al., 2006; SZCZEPOCKA, 2005), being common in environments with high nitrate concentrations (NDIRITU; GICHUKI, 2006), supporting the fact that this species was descriptive for the periphyton community at IF.

The class Coscinodiscophyceae, of higher density at DW, presented more significant correlations with abiotic variables (electrical conductivity, turbidity, STS, total phosphorous and silicate), in which *Aulacoseira* sp.1 was the major representative species of this class, present in all colonization days in both sites. This result probably pointed out that although correlated with the site DW, by the PCA, the taxon is adapted to environments with high trophic level.

The class Cyanophyceae, of higher densities at DW, had significant positive correlations with electrical conductivity, turbidity, and orthophosphate. Blanco et al. (2008) on studies with different nutrient levels, also noticed positive correlations between Cyanophyceae with electrical conductivity, nitrate, ammonia and total phosphorus. The same authors also observed that increased concentrations of nutrients stimulated an abundance of Cyanophyceae, particularly filamentous such as *Leptolynbya* sp., as well as in the present study. DeNicola et al. (2006) observed that the increase of phosphorus was associated with the abundance of filamentous cyanobacteria.

Leibleinia epiphytica best described the periphyton community at DW, by being descriptive in all evaluated days of succession, exclusive of this sampling site, and ordinated by the PCA. Despite the lack of knowledge about the ecology of this species, the characteristics of Cyanophyceae provided some advantages for eutrophic environments, such as the adaptability to low light, and better use of dissolved phosphorus (CHORUS; BARTRAM, 1999), as well as forms of nitrogen, since these were higher values in DW.

Conclusion

The present study enabled to conclude that the sampling sites presented eutrophic conditions, with differences in the intensity of impact caused by intensive fish-farming and domestic wastewater discharge, changing the composition and abundance of periphytic community. The community for the region influenced by the fish-farming was dominated by Bacillariophyceae, while the region that received the stream water with domestic sewage was dominated by Cyanophyceae and Coscinodiscophyceae. Our results partially confirm the initial hypothesis, since the total density and the class Chlorophyceae did not differ between the sampling stations. This area of effluent discharge can be a potential situation which may occur in the region with intensive fish farming, in view of the increased demand for production, and consequently the increase of nutrients input. This difference in the periphytic community evidences its sensitivity to environmental changes caused by the input of nutrients from different sources and the importance of using its attributes for environmental monitoring and the management of water sources.

References

ALVES, R. C. P.; BACCARIN, A. E. Efeito da produção de peixes em tanques-rede sobre a sedimentação de materiais em suspensão e de nutrientes no córrego da Arribada (UHE Nova Avanhandava, baixo Rio Tiete, SP). In: NOGUEIRA, M. G.; HENRY, R.; JORCIN, A. (Ed.). **Ecologia de reservatórios**: impactos potenciais, ações de manejo e sistemas em cascata. São Carlos: Rima, 2005. p. 329-348.

APHA-American Public Health Association. **Standart methods for the examination of water and wastewater**. 21st ed. Washington, D.C.: American Publication Health Association; American Water Works Association and Water Pollution Control Federation, 2005.

BLANCO, S.; ROMO, S.; FERNANDEZ-ALAEZAND, M.; BÉCARES, E. Response of epiphytic algae to nutrient loading and fish density in a shallow lake: a mesocosm experiment. **Hydrobiologia**, v. 600, n. 1, p. 65-76, 2008.

CARMOUZE, J. **O metabolismo dos ecossistemas aquáticos**: fundamentos teóricos, métodos de estudo e análises químicas. São Paulo: Edgard Blücher, 1994.

CHORUS I.; BARTRAM J. **Toxic cyanobacteria in water**: a guide to their public health consequences, monitoring and management. London: E and FN Spon, 1999.

DENICOLA, D. M.; EYTO, E.; WEMAERE, A.; IRVINE, K. Periphyton responses to nutrient addition in 3 lakes of different benthic productivity. **Journal of the North America Benthological Society**, v. 25, n. 3, p. 616-613, 2006.

FERRAGUT, C.; BICUDO, D. C. Efeitos de diferentes níveis de enriquecimento por fósforo sobre a estrutura da comunidade perifítica em represa oligotrófica tropical (São Paulo, Brasil). **Revista Brasileira de Botânica**, v. 32, n. 3, p. 569-583, 2009.

GOLTERMAN, H. L.; CLYMO, R. S.; OHNSTAD, M. A. M. **Methods for chemical analysis of freshwater**. Oxford: Blackwell Scientific Publications, 1978.

HILL, W. R.; FANTA, S. E. Phosphorus and light colimit periphyton growth at subsaturating irradiances. **Freshwater Biology**, v. 53, n. 2, p. 215-225, 2008.

IBGE-Instituto Brasileiro de Geografia e Estatística. **Pesquisa Nacional de Saneamento Básico, 2008**. Available from: <http://www.ibge.gov.br>. Access on: Nov. 22, 2010.

JEPPESEN, E.; SONDERGAARD, M.; MAZZEO, N.; MEERHOFF, M.; BRANCO, C. C.; HUSZAR, V.; SCASSO, F. Lake restoration and biomanipulation in temperate lakes: relevance for subtropical and tropical lakes. In: REDDY, M. V. (Ed.). **Restoration and management of tropical eutrophic lakes**. Oxford: Oxford and IBH Publishing, 2005. p. 341-359.

KASSAM, L.; BUBASINGHE, R.; PHILLIPS, M. **Aquaculture farmer organizations and cluster management**: concepts and experiences. Available from: <http://www.fao.org/docrep/014/i2275e/i2275e.pdf>. Access on: Nov. 22, 2011.

KOROLEFF, F. Determination of nutrients. In: GRASSHOFF, K. (Ed.). **Methods of sea water analysis**. New York: Verlag Chemie, 1976. p. 117-181.

KRALJ, K.; PLENKÓVIC-MORAJ, A.; GLIGORA, M.; PRIMC-HABDIJA, B.; SIPOS, L. Strutucture of periphytic community on artificial substrata: influence of depth, slide orientation and colonization time in karstic Lake Visovacko, Croatia. **Hydrobiologia**, v. 560, n. 1, p. 249-258, 2006.

LEGENDRE, L.; LEGENDRE, P. **Numerical ecology**. Oxford: Elsevier Science Publish, 1983.

LOBO, E. A.; KATOH, K.; ARUGA, Y. Response of epilithic diatom assemblages to water pollution in rivers in the Tokyo Metropolitan area, Japan. **Freshwater Biology**, v. 34, n. 1, p. 191-204, 1995.

LOBO, E.; LEIGHTON, G. Estruturas comunitarias de lãs fitocenozes plakctonicas de los sistemas de desembocaduras y esteros de rios de la zona central de Chile. **Revista de Biologia Marina**, v. 22, n. 1, p. 1-29, 1986.

LUND, J. W. G.; KIPLIND, C.; LECREN, E. D. The inverted microscope method of estimating algal number and the statistical basis of estimating by counting. **Hydrobiologia**, v. 11, n. 2, p. 143-170, 1958.

MACKERETH, F. J. H.; HERON, J.; TALLING, J. F. **Water analysis**: some revised methods for limnologists. Kendall: Titus Wilson and Son, 1978.

McCUNE, B.; MEFFORD, M. J. **PC-ord. Multivariate analysis of ecological data, version 4.0**. Oregon: MjM Software Design, 1999.

MOLICA, R.; AZEVEDO, S. Ecofisiologia de cianobactérias produtoras de cianotoxinas. **Oecologia Brasiliensia**, v. 13, n. 2, p. 229-246, 2009.

MURAKAMI, E. A.; RODRIGUES, L. Resposta das algas perifíticas às alterações de temperatura e ao enriquecimento artificial de nutrientes em curto período de tempo. **Acta Scientiarum. Biological Sciences**, v. 31, n. 2, p. 273-284, 2009.

NDIRITU, G. G.; GICHUKI, N. N. Distribution of epilithic diatoms in response to environmental conditions in an urban tropical stream, Central Kenya. **Biodiversity and Conservation**, v. 15, n. 10, p. 3267-3293, 2006.

PMS-Prefeitura Municipal da Serra. Available from: <http://www.serra.es.gov.br>. Access on: Sept. 21, 2010.

POMPÊO, M. L. M.; MOSCHINI-CARLOS, V. **Macrófitas aquáticas e perifíton**: aspectos ecológicos e metodológicos. São Carlos: Rima, 2003.

PONADER, K. C.; POTAPOVA, M. G. Diatoms from the genus *Achnanthidium* in flowing waters of the Appalachian Mountains (North America): ecology, distribution and taxonomic notes. **Limnologica**, v. 37, n. 3, p. 227-241, 2007.

PORTER, S. D.; MUELLER, D. K.; SPAHR, N. E.; MUNN, M. D. Efficacy of algal metrics for assessing nutrient and organic enrichment in flowing waters. **Freshwater Biology**, v. 53, n. 5, p. 1036-1054, 2008.

POTAPOVA, M.; CHARLES, D. F. Diatom metrics for monitoring eutrophication in rivers of the United States. **Ecological Indicators**, v. 7, n. 1, p. 48-70, 2007.

SALOMONI, S. E.; ROCHA, O.; CALLEGARO, V. L.; LOBO, E. A. Epilithic diatoms as indicators of water quality in the Gravataí river, Rio Grande do Sul, Brazil. **Hydrobiologia**, v. 559, n. 1, p. 233-246, 2006.

SANTOS, I. R.; COSTA, R. C.; FREITAS, U.; FILLMANN, G. Influence of effluents from a wastewater treatment plant on nutrient distribution in a coastal creek from southern Brazil. **Brazilian Archives of Biology and Technology**, v. 51, n. 2, p. 153-174, 2008.

SHANNON, C. E.; WEANNER, W. **The matematical theory of communication**. Urbana: University Illinois Press, 1963.

SIAG-Serviço de Informações Agrometereológicas. **Incaper (Instituto capixaba de pesquisa, assistência técnica e extensão rural)**. Available from: <http://www.incaper.es.gov.br>. Access on: Apr. 13, 2010.

STATSOFT, INC. **Statistica** (Data Analysis Software System), version 7. Tulsa, 2004.

STRICKLAND, J. D. H.; PARSONS, T. R. **A Manual of sea water analysis**. Canada: Fisheries Research Board, 1960.

SZCZEPOCKA, E. Water quality assessment using diatoms in the Bzurariver. **Oceanological and Hydrobiological Studies**, v. 34, n. 4, p. 67-79, 2005.

UTERMÖHL, H. Zur vervollkommung der quantitativen phytoplankton: methodik. **Mitteilungen Internationale Vereinigung für Theoretische und Angewandte Limnologie**, v. 9, p. 1-38, 1958.

VALDERRAMA, J. C. The simultaneous analysis of total nitrogen and phosphorus in natural waters. **Marine Chemistry**, v. 10, n. 2, p. 109-122, 1981.

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