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Algal and Cyanobacterial communities in two rivers of the province of San Luis (Argentina) subjected to anthropogenic influence

Comunidades de Algas e Cianobactérias em dois rios da província de San Luis (Argentina) submetidos a influência antropogênica

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Abstract: Aim: The use of biological indicators of pollution has increased in recent years as an alternative to the monitoring of water quality. Phytoplankton community selectively respond to different anthropogenic disturbances, such as water dams and the increase of nutrients coming from city centers, which leads to the eutrophication of the aquatic environment. The objective of this work was to evaluate the composition and the structure of the algal and Cyanobacterial communities in order to prove human influences by the presence of reservoirs with some degree of eutrophication and the impact of urbanization in two rivers at the Bebedero basin in San Luis province (Argentine). **Methods:** Four sites were sampled: two of them were placed before dams and villages ($\mathbf{V_1}$) and ($\mathbf{P_1}$) and two after them ($\mathbf{V_2}$) and ($\mathbf{P_2}$). Each site was visited in every season of the year: summer, autumn, winter and spring. Qualitative and semi-quantitative phytoplankton samples were taken, and the frequency of occurrence was determined. Variations between pairs of sampling stations were analyzed through the Jaccard similarity and complementarity indices. **Results:** Ninety two taxa were identified, of which diatoms were the most frequent. The most affected station was P_2 with high abundance, less diversity and equitability, whereas the species more tolerant to the presence of organic matter were *Melosira varians*, *Navicula tripunctata*, *Oscillatoria limosa*, *Gomphonema parvulum* and *Coelastrum microporum,* and some species of euglenophytas. **Conclusion:** Therefore, the structure and composition of the algal and Cyanobacterial communities allowed us to identify sections more sensitive to human-induced alterations.

Keywords: biological quality, algal communities, urbanization effect, regulated streams.

Resumo: Objetivo: O uso de indicadores biológicos de poluição tem aumentado nos últimos anos como alternativa de monitoramento da qualidade da água. A comunidade fitoplanctônica responde seletivamente a diferentes perturbações antrópicas, como construção de barragens e aumento dos nutrientes em centros urbanos que levam à eutrofização de ambientes aquáticos. O objetivo deste trabalho foi avaliar a composição e a estrutura das comunidades de algas e cianobactérias, a fim de comprovar a influência humana através da presença de reservatórios com algum grau de eutrofização e do impacto da urbanização em dois rios na bacia do Bebedero da província de San Luis (Argentina). **Métodos:** Quatro estações de coleta foram selecionados: duas antes dos reservatórios e aldeias (V1) e (P1) e duas após os mesmos (P2) e (V2). Cada estação foi visitada quatro vezes durante um ciclo anual: verão, outono, inverno e primavera. Foram coletadas amostras quantitativas e semiquantitativas do fitoplâncton e foi determinada a frequência de ocorrência. Foram analisados o grau de semelhança entre pares de estações de coleta, utilizando o índice de similaridade de Jaccard e índice de complementaridade. **Resultados:** Foram identificados 92 táxons, sendo mais frequente as diatomáceas. P2 foi a estação mais afetada, mostrando alta abundância com menor diversidade e uniformidade. As espécies mais tolerantes à presença de matéria orgânica foram *Melosira varians*, *Navicula tripunctata*, *Oscillatoria limosa*, *Gomphonema parvulum* e *Coelastrum microporum* e algumas espécies de euglenophytas. **Conclusão:** Portanto, a estrutura e composição das comunidades de algas e cianobactérias permitiu identificar secções mais sensíveis a alterações induzidas pelo homem.

Palavras-chave: qualidade biológica, comunidades de algas, efeito da urbanização, rio regulado.

1. Introduction

The first descriptive studies of algal assemblages in different aquatic environments focused on the relationship among phytoplankton species as productivity indicators in lakes; for this reason, some indices and specific values defining productivity were established (Patrick and Reimer, 1975; Wetzel, 1981). Since phytoplankton constitute the first link in the trophic chain, their analysis of is of great interest in environmental. Additionally, their response to different environmental changes make them good water quality indicators, and they are a referent of the ecological status of the environment (Martínez de Fabricius, 2000; Pereira et al., 2000). The response of the phytoplankton community structure to different anthropogenic disturbances is a commonly used criterion to characterize water bodies (Mirande and Tracanna, 2005; Martínez de Fabricius et al., 2007). The growth of human population during the last decades, and the consequent expansion of towns and city centers, has generated solid and liquid wastes that affect water bodies, causing atrophic eutrophication (Dolbeth et al., 2003).

Changes in water quality are among the most frequent phenomena in eutrophic dams. These changes are mainly related to the high concentration of nutrients in water bodies, such as phosphorus and nitrogen (Ramírez García et al., 2007). The trophic state of a dam is directly related to the contributions they receive. Dams management is based on the stimulation of all those natural processes aimed at improving water quality while keeping the native population in balance with the environment, as well as placing a special emphasis on the combination of the physicochemical and biological factors. All of these factors determine the distribution of algal communities (Martínez de Fabricius et al., 2003, 2007).

Bacillariophyceae constitutes a group within algal communities with a rapid response to environmental changes (Rojo et al., 1994). They have are often used in studies aimed at monitoring the quality of water due to their ubiquitous distribution, high species diversity, and their siliceous frustules all enable the diatoms to function as sound environmental indicators (Reynolds, 1988, Cox, 1991).

Phytoplankton research in the province of San Luis has mainly focused on Bacillariophyceae (Maidana and Herbest, 1994; Daruich and Martínez de Fabricius, 2000, 2001, 2006; Verteramo et al., 2001; Nievas et al., 2003; Daruich et al., 2003, 2005).

The objective of this work was to evaluate the composition and the structure of the algal and Cyanobacterial communities in order to prove human influences by the presence of reservoirs with some degree of eutrophication and the impact of urbanization in two rivers at the Bebedero basin in San Luis province (Argentine).

Our hypothesis is that the structure and composition of the algal community will allow us to identify sections more sensitive to human-induced alterations.

2. Material and Methods

2.1. Study area

The Bebedero basin is located at the centre of the province of San Luis . It is an endoreic basin, formed by two sub-basins which cover an area of 5500 km^2, both of which are regulated and show different degrees of anthropogenic activity, since they run across tourist villages. The sub basin of *El Volcán* river, which is regulated by the Cruz the Piedra dam (built in 1941) supplied the water treatment plant of the city of San Luis until the decade of 1990, when it started to be eutrophicated (Silva et al., 1995; Tognelli et al., 1997). The sub-basin of the Potrero river is regulated by the Potrero de los Funes dam, which was built in 1927, and today presents eutrophication signals (Almeida et al., 2007). These rivers drain over the eastern side of the San Luis mountains. This favors the development of a relatively important hydrographic network where the main constant flow rivers are born (Ceci and Cruz Coronado, 1981). The river systems of this area have annual variations in their watercourses (river flows), with droughts and flooding directly related to the rainfall rate. Rain occurs mainly in summer, from October to March, with an annual rainfall average between 500 and 650 mm. This area corresponds to the Algarrobo district (Cabrera, 1976), and to the vegetal formation called Pastures and Mountain Forest (Anderson et al., 1970).

2.2. Field and laboratory procedures

Four sampling sites were chosen on the Bebedero basin. Two stations were placed before the location of the dam, and *El Volcan* and *Potrero de los Funes* villages: one was at *El Volcan* river (**V$_1$**), and the other at *Los Molles* river (**P$_1$**). The other two stations were placed after the dam: one at *Las Chacras* river (**P$_2$**), and another at the *Cuchi Corral* river (**V_2**) (Figure 1). Each station was visited four times along 2009 (summer, autumn, spring and winter) in order to check seasonal variations.

The hydraulic parameters of the river were recorded - width, current speed and flow. The physicochemical parameters were measured *in situ* with portable sensors: pH (accuracy ± 0.01 pH), conductivity (accuracy ± 1% μS. cm^{-1}), temperature (accuracy ± 0.5 °C) (with CONSORT C532), and dissolved O_2 (mg.L^{-1}) with CONSORT Z921.

Semi-quantitative and qualitative samples of phytoplankton were taken in each site . The collection of the samples was performed in the centre of the river. The taxonomic analyses were obtained using a mesh with an opening of 10 μm directly exposed into the water current for 20 minutes. The samples were fixed in situ with formaldehyde at 4%. The semi-quantitative samples were stored in 500ml vessels using formaldehyde at 4% for their conservation. Quantification was made using a 40x magnification optic microscope, and a fixed number of randomly chosen fields were counted. Unicellular algae, colonies and filamentous algae were considered as individual units (Alveal et al., 1995).

For species identification, the following taxonomic references were used: Desikachary (1959), Prescott (1962), Patrick and Reimer (1966), Germain (1981), Krammer and Lange-Bertalot (1986, 1988, 1991a, b), Round and Bukhtiyarova (1996) and Stoermer et al., (1999). All the species described were ordered according to Bourrely (1981,

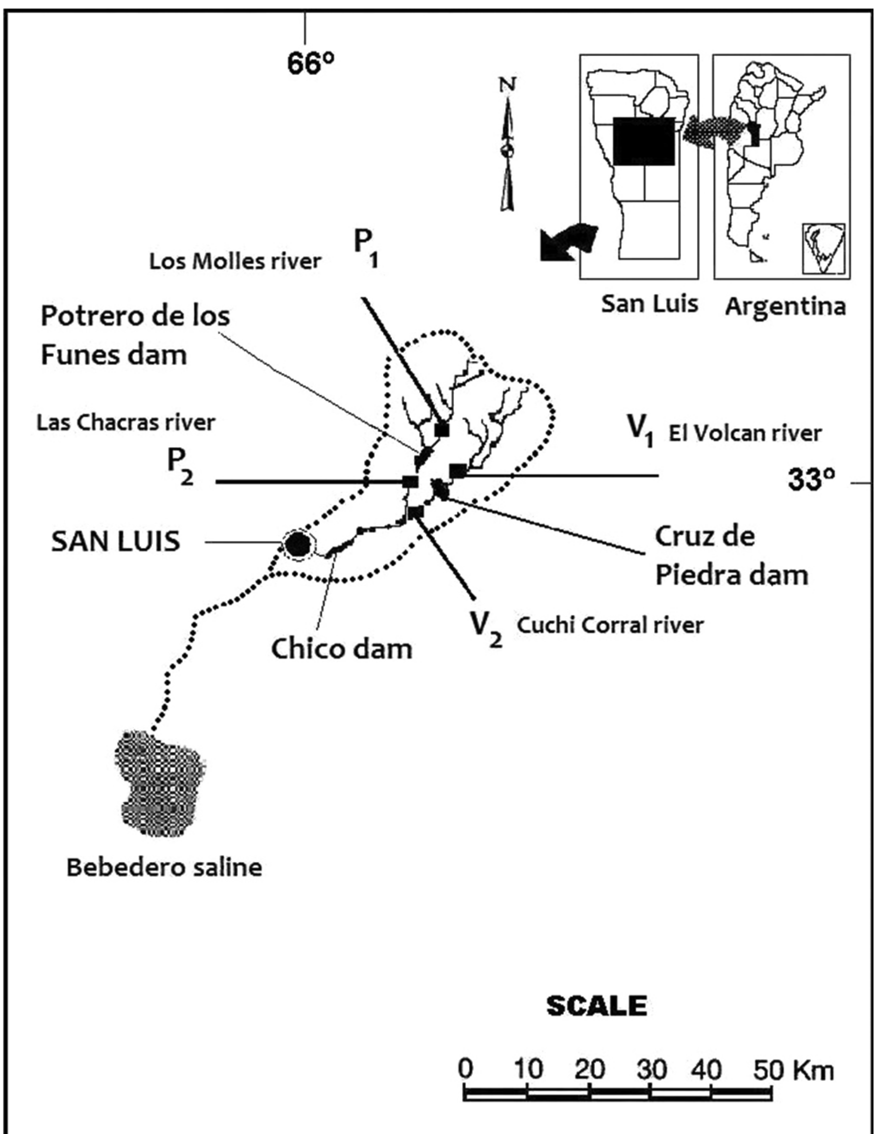

Figure 1. Location of the sampling sites in the Bebedero Basin: V_1 *El Volcán* River, V_2 *Cuchi Corral* River. P_1 *Los Mollles* River and P_2 *Las Chacras* River.

1985, 1990) for *Cyanophyceae*, *Chlorophyceae* and *Euglenophyceae,* and according to Simmonsen (1979) for *Bacillariophyceae.*

Counts were performed through transects, using the method developed by Utermöhl (1958) and adapted by Villafañe and Reid (1995). Three transects were predetermined as horizontal, and edge effects were avoided. We used a slide and a coverslip of 24 × 50 mm. A 0.3 mL aliquot of mother sample was settled in the slides, which allowed for the observation of the material with a magnification of 400×. We counted several preparations in order to obtain a constant average number of individuals (unicellular, colonies or filaments). For filamentous organisms, such as *Oscillatoria,* a unit was considered to be the equivalent to the length of a common single-celled organism, such as *Synedra*. Those species with a relative abundance of ≥1% were included in at least in one sample.

2.3. Data analysis

A table of presence-absence of species was made in order to determine the distribution of algae along the annual cycle. Following Paredes et al. (2007), taxa were considered as constant when they were recorded in more than 50 % of the samples; they were determined to be common when they were found between 10% and 50%of the samples, and they were regarded as rare when they appeared in less than 10 % of the samples. Density (org.mL^{-1}), species richness (diversity α), and Shannon-Wiener diversity index (H') were calculated in each sampling site. Jacquard's qualitative index of similarity (bits.ind^{-1}.) was used to evaluate human influences through the degree of similarity in the composition between pairs of stations. This qualitative index considers the presence-absence of taxa by means of $Ij = c / (a + b + c) \times 100$, where c is the number of species in both samples, a is the number of species in sample 1, and b is the number of species in sample 2. Values vary between 0 and 100, the closer to 1 values are, the more species are lost and the stronger is the impact produced. β ecological diversity was analyzed to differentiate the composition in each pair of sampling sites within each sub basin. To achieve this goal the complementarily index (IC) was used, which predicts when two communities are complementary (Colwell and Coddington, 1994; Moreno 2001)**.** $B=IC_{AB}= U/S$, **U** (number of unique species in any of the two sites) is calculated as: **a+b–2c.S** (the total richness for both sites combined) whose formula is **S=a+b–c**., where **a** is the number of species in the area A; **b** is the number of species in the area B, and **c** is the number of common species in the both areas. Their values can vary between 0 and 1.

Due to the fact that data do not have a normal distribution, the non-parametrical Kruskal-Wallis test was used with the physicochemical variables and the abundances of the collected samples in order to determine seasonal variations among the sampling sites. The Mann Whitney test was used to compare each pair of sampling sites.

3. Results

3.1. Hydrological and physico-chemical parameters

The average values of the hydrologic and physico-chemical variables of 4 sampling sites are presented in Table 1. Stations $\mathbf{V_2}$ and $\mathbf{P_2}$ registered

Table 1. Values (mean ± standard deviation [SD]) of the measured physical, chemical and geographic variables in the study sites of the *Bebedero* basin (San Luis). V_1 *El Volcán* River, V_2 *Cuchi Corral* River, P_1 *Los Mollles* River and P_2 *Las Chacras* River.

	V_1	V_2	P_1	P_2
Elevation (m a. s. l.)	992	799	1000	903
Stream Order	2	3	2	3
Location	33°13'53.20" S 66°12'17.43" W	33°173'40.64" S 66°15'45.27" W	33°12'34.67" S 66°13'46.72" W	33°14'32.15" S 66°14'28.66" W
Discharge ($m^3.seg^{-1}$)	0.235 ± 0.052 0.18-0.30	0.178 ±0.07 0.08-0.25	0.145 ± 0.054 0.1-0.22	0.195 ± 0.09 0.06-0.28
Velocity ($m.seg^{-1}$)	0.303 ± 0.11 0.22-0.46	0.377 ± 0.134 0.26-0.57	0.448 ± 0.32 0.22-0.9	0.272 ± 0.15 0.15-0.48
pH	8.12 ± 0.36 7.6-8.4	7.32 ± 0.22 7-7.5	8.07 ± 0.05 8-8.1	7.62 ± 0.43 7 - 8
Conductivity ($mS.cm^{-1}$)	447.3 ± 332.1 138 - 830	972.5 ± 219.9 760 - 1200	131.8 ± 31.6 110 - 177	380.8 ± 102.7 310 - 533
O_2 ($mg.l^{-1}$)	12.73 ± 2.43 9.7-14.7	7.30 ± 0.99 6.05 - 8.2	8.50 ± 2.26 6.4-11.7	6.88 ± 1.16 5.72-7.97
Water temperature (°C)	17.4 ± 2.23 15-19.5	17.3 ± 2.12 15-19.2	16.3 ± 4.93 10.5-21.4	15.18 ± 4.67 10.9-19.7

the highest values of conductivity and the lowest values for dissolved oxygen. No significant differences were observed in relation to seasonal variations using the Kruskal Wallis.

Mann-Whitney test between pairs of stations showed no significant differences.

3.2. Biological aspects

The statistical comparison derived from the Kruskal-Wallis test of abundance at each sampling site showed no significant seasonal differences ($p > 0.05$). These results were averaged for further calculations.

The phytoplankton community studied was composed of 92 species. According to its frequency, 33% (*Synedra ulna*, *Melosira varians* and *Gomphonema parvulum*) were considered as constant; 65.2 % were common species, and 31.3 % were rare ones. No percentage variation within different seasons (Table 2) was observed. The less affected reference habitats presented the richest species of algae communities, with a tendency to a higher equitabilty (Table 3).

Table 2. Distribution and relative frequency of planktonic algae and Cyanobacteria in the sampling stations of the *Bebedero* basin. **C**: constant, **c**: commons and **r**: rare. V_1 *El Volcán* River, V_2 *Cuchi Corral* River, P_1 *Los Mollles* River and P_2 *Las Chacras* River**.**

	Sampling sites				Relative	
Taxones	**V_1**	**V_2**	**P_1**	**P_2**	**frequency (%)**	
CYANOPHYCEAE (CYANOBACTERIA)						
Chroococcales						
Chroococcaceae						
Chroococcus turgidus (Kütz.) Näg.		X		X	12.5	**c**
Chroococcus sp_1	X	X		X	25	**c**
Chroococcus sp_2			X	X	18.75	**c**
Gloeocapsa sp.				X	12.5	**c**
Merismopedia glauca (Ehren.) Näg.		X			6.25	**r**
Hormogonales						
Nostocaceae						
Dolichospermum sp.		X		X	12.5	**c**
Oscillatoriaceae						
Artrospira sp.		X			12.5	**c**
Lyngbya sp.	X			X	12.5	**c**
Oscillatoria limosa Agardh	X	X	X	X	68.75	**C**
Oscillatoria tenuis Agardh	X	X	X	X	43.75	**c**
Oscillatoria sp			X	X	18.75	**c**
Oscillatoria sp_1			X	X	18.75	**c**
CHLOROPHYCEAE						
Volvocales						
Chlamydomonadaceae						
Chlamydomonas sp.				X	6.25	**r**
Chlorococcales						
Oocystaceae						
Ankistrodermus sp.				X	6.25	**r**
Oocystis sp.	X	X	X		25	**c**
Scenedesmaceae						
Coelastrum microporum Nägeli				X	6.25	**r**
Crucigenia sp.		X		X	18.75	**c**
Scenedesmus acutus Meyen		X	X		18.75	**c**
Scenedesmus acutus f. *costulatus* (Chod.) Uherk.			X		6.25	**r**
Scenedesmus sp.			X		18.75	**c**
Hydrodyctaceae						
Monactinus simplex (Meyen) Corda, Alm.				X	6.25	**r**
Stauridium tetras (Ehren.) Hegew.				X	12.5	**c**
Ulothrichales						
Ulothrichaceae						
Ulotrix sp.	X	X	X		31.25	**c**

Table 2. Continued...

Taxones	Sampling sites V_1	V_2	P_1	P_2	Relative frequency (%)	
Oedogoniales						
Oedogoniaceae						
Oedogonium sp.	X				6.25	**r**
Siphonocladales						
Cladophoraceae						
Cladophora glomerata (Linn.) Kütz.	X	X			18.75	**c**
Zygnematales						
Zygnemataceae						
Mougeotia sp.	X	X			18.75	**c**
Spirogyra sp.	X	X	X	X	43.75	**c**
Zygnema sp.	X		X		25	**c**
Desmidiaceae						
Closterium acutum Bréb. in Ralfs			X		6.25	**r**
Closterium moniliferum (Bory) Ehren.ex Ral.	X	X	X		37.50	**c**
Cosmarium botrytis Meneg. ex Ral.	X	X	X		25	**c**
Cosmarium sp_1.				X	6.25	**r**
Staurastrums sp_1.		X	X	X	25	**c**
EUGLENOPHYCEAE						
Euglenales						
Euglenaceae						
Euglena sp_1.		X		X	25	**c**
Euglena sp_2.		X			12.5	**r**
Phacus sp.			X	X	18.75	**c**
DINOPHYCEAE						
Peridiniales						
Ceratiaceae						
Ceratium hirundinella (O.F. Müll.) Bergh	X		X		25	**c**
Peridiniacea						
Peridinium sp.		X			6.25	**r**
BACILLARIOPHYCEAE						
Centrales						
Coscinodiscinae						
Thalssiosiraceae						
Cyclotella meneghiniana Kütz.	X	X		X	25	**c**
Melosiraceae						
Aulacoseira granulata (Ehren.) Sim.	X	X			12.5	**c**
Melosira varians Ag.	X	X	X	X	62.50	**c**
Pennales						
Araphidinae						
Diatomaceae						
Diatoma vulgare var. *vulg.* Bory	X	X		X	50	**c**
Fragilaria capucina Desm.	X	X	X		18.75	**c**
Fragilaria sp.		X			6.25	**r**
Synedra acus Kütz.	X	X	X	X	43.75	**c**
Synedra ulna (Nitz.) Ehr.	X	X	X	X	100	**C**
Rhaphidinae						
Achnanthaceae						
Achnanthes exigua Grunow			X		6.25	**r**
Achnanthes lanceolata (Bréb.) Grun.	X	X	X		25	**c**
Achnanthes minutissima Kütz.	X	X			25	**c**
Cocconeis placentula Ehren.	X	X	X	X	43.75	**c**
Naviculaceae						
Amphora veneta Kütz.		X			12.5	**c**
Amphora sp.		X			6.25	**r**
Craticula cuspidata (Kütz.) Mann	X				6.25	**r**
Cymbella amphicephala Nägeli		X		X	12.5	**c**
Cymbella affinis Kütz.	X	X	X		43.75	**c**

Table 2. Continued...

Taxones	V1	V2	P1	P2	Sampling sites Relative frequency (%)	
Cymbella cistula (H.& Ehren.) O. Kir.		X		X	18.75	c
Cymbella cymbiformis Agardh		X	X		18.75	c
Cymbella minuta Hilse	X		X			c
Cymbella prostrata (Berk.) Cleve		X	X	X	50	c
Denticula kuetzingii Grun.		X			6.25	r
Diploneis smithii (Brébisson) Cleve	X		X		31.25	c
Encyonema minutum (Hilse ex Rabh.)	X				6.25	r
Gomphoneis sp.	X	X	X		25	c
Gomphonema acuminatum Ehr.	X	X	X	X	43.75	c
Gomphonema gracile Ehr.			X		6.25	r
Gomphonema parvulum (Kütz.) Kütz.	X	X	X	X	62.50	C
Gyrosigma accuminatum (Kütz.) Rabh.	X	X	X		37.50	c
Navicula capitatoradiata Germ.	X		X	X	31.25	c
Navicula decussis Östrup	X		X		18.75	c
Navicula exigua Greg. ex Grun.	X				6.25	r
Navicula mutica var. tropica Husted		X			12.50	c
Navicula menisculus Schum.	X		X		12.50	c
Navicula radiosa Kütz.	X	X	X	X	50	c
Navicula tripunctata (O.F.Müll.) Bory	X	X	X	X	68.75	C
Navicula sp.	X		X		31.25	c
Neidum affine (Ehr.) Cleve			X		6.25	r
Pinnularia abaujensis (Pant.) Ross		X			12.5	c
Pinnularia divergens W. Smith				X	6.25	r
Pinnularia divergentissima (Grun.) Cl.		X			6.25	r
Pinnularia sp_2		X			6.25	r
Reimeria uniseriata Sala et al.	X		X		25	c
Epithemiaceae						
Epithemia sorex Kütz.	X	X	X		25	c
Epithemia turgida Kütz.	X		X		31.25	c
Rhopalodia gibba (Ehr.) Müller	X	X	X	X	37.50	c
Nitzschiaceae						
Nitzschia acicularis (Kütz.) W. Smith	X	X	X	X	43.75	c
Nitzschia amphibia Grun.	X	X		X	18.75	c
Nitzschia linearis (Ag.) W. Smith	X	X			12.5	c
Nitzschia palea (Kütz.) W. Smith	X	X	X		18.75	c
Surirellaceae						
Cymatopleura solea (Bréb.) W. Smith		X	X		18.75	c
Surirella angusta Kütz.		X			6.25	c
Surirella ovalis Brèb.	X	X	X		25	c

Table 3. Ecological attributes of algal and cyanobacterial communities calculated with average values obtained along the water cycle in the two studied sub-basins. Sampling sites: *El Volcán* ($\mathbf{V_1}$), *Cuchi Corral* River ($\mathbf{V_2}$), *Los Molles River* ($\mathbf{P_1}$) and *Las Chacras* River.

	V_1	V_2	P_1	P_2
α Diversity	48	58	50	39
Shannon and Wiener (H')	3.947	4.759	4.133	2.742
β Diversity (Complementarily Index)	0.51		0.75	
Jaccard's index of similarity	0.49		0.28	

3.2.1. El Volcán river sub-basin

While station $\mathbf{V_1}$ presented a richness of 48 species, in which 39 % of them were Bacillariophyceae, 58 species were found in station $\mathbf{V_2}$, with a 60% increase in Bacillariophyceae, at the expense of Chlorophyceae and Dinophyceae, and the presence

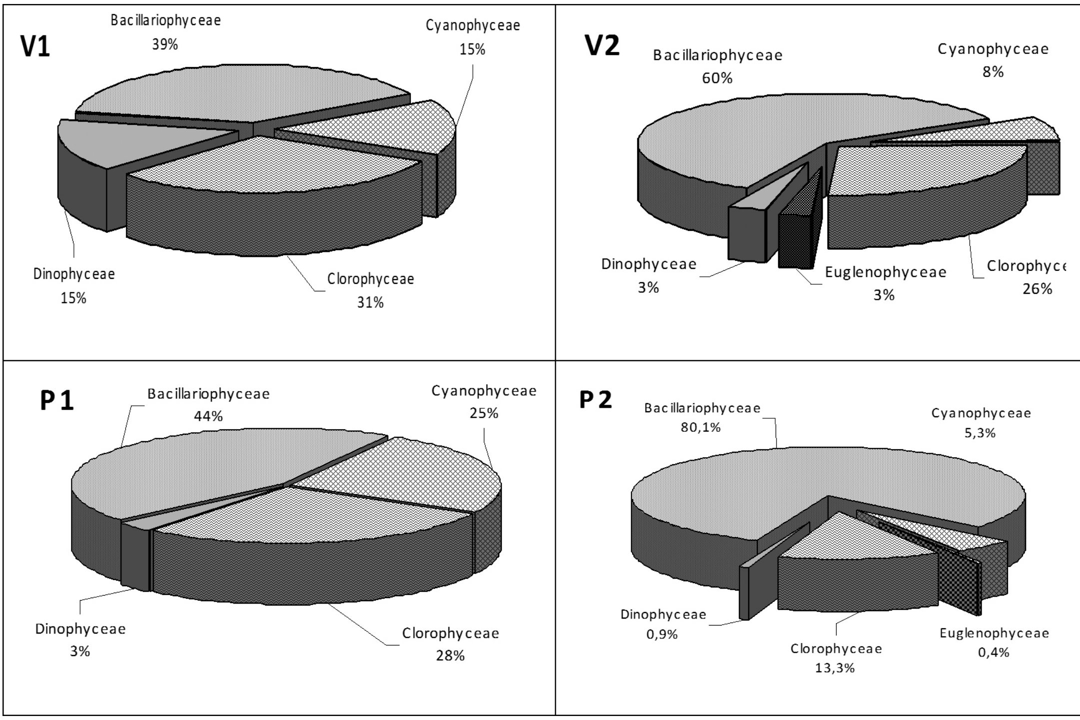

Figure 2. Relative abundance of different class of algae at the sampling sites in the *Bebedero* Basin (San Luis). V_1 *El Volcán* River, V_2 *Cuchi Corral* River, P_1 *Los Mollles* River and P_2 *Las Chacras* River.

of 3 % of Eugnophyceae (Figure 2). This increase was also reflected in the specific diversity (H') that arises from 3.95 to 4.76 bits.ind^{-1}.

An increase in the stream width and a decrease in the speed of the current were observed during the autumn sampling, which caused stagnation of water. A proliferation of dinoflagellate C*eratium hirundinella* was also observed during this season; while *Oscillatoria limosa* was observed in winter.

Station $\mathbf{V_2}$ was placed after a gravel removal site; this produced an increase in finer sediments, and turbidity. A decrease in phytoplankton abundance was observed in the station located after the dam, especially due to the decrease of *Synedra ulna*, *Gomphonema parvulum*, *Cladophora glomerata*, *Oscillatoria limosa,* and to the disappearance *of Ceratium hirundinella*.

The β diversity and the lj showed that the two stations are different in a 50-49% respectively (Table 3), while the statistical comparison showed that they are significantly different (p = 0.0008; u = 862, 0).

3.2.2.Potrero river sub-basin

In spring, the presence of ashes produced as a result of large fires in the mountains was registered in station $\mathbf{P_1}$, mainly at stream heads. $\mathbf{P_1}$ presented a richness of 50 species - 44% were Bacillariophyceace - while in the station $\mathbf{P_2}$, 39 species diminished - 80% of them were Bacillariophyceace with a remarkable decrease in the rest of species.

Euglenophyceae was registered in $\mathbf{P_2}$ at 0.4% (Figure 2), and the proliferation of Cyanophyceae - which doubles its richness in relation to the reference station - was observed. This variation also corresponds to the reduction in the value of species diversity (H'), and reveals a less equitable community in the station located after the dam

Phytoplankton abundance was higher, and there was an increase in the station located after the dam from 290 to 639 ind.mL$^{-1,}$ especially due to the increase of *Melosira varians*, *Navicula tripunctata*, and *Synedra ulna,* and to the appearance of *Coelastrum microporum*.

The diversity β and the lj showed that the two stations are different in a 75-28% respectively (Table 3), while the statistical comparison did not show important difference (p=0.766; u=938.5).

4. Discussion

The sites studied present algal communities with high diversity and low abundance. This situation is common to other streams in the area (Martínez de Fabricius et al., 2007). All the species reflected low values of frequency, with the exception of some diatoms, such as *Synedra ulna* and *Gomphonema parvulum*. These two species were found in four sampling stations, and they were pointed out as species adapted to a wide range of conditions, and highly tolerant to waters with high organic matter concentration (Salomoni et al., 2006). A better phytoplankton structure was observed in the head station that was only interrupted in station $\mathbf{P_1}$, where a great fire affected this area.

Euglenophytas form a group related to contamination with organic matter, and a qualitatively well represented group in lentic environments. They were present in the post-dam sites , and they are subjected to the anthropogenic influence, revealing that they are good indicators of water quality (Reynolds, 1997; Reynolds et al., 2002, Mirande et al., 2005).

The lowest density values were registered during summer at the *Cuchi Corral* river. This fact is related to the presence of sediments, which produce a turbidity that reduces the penetration of light - a well known factor that limits the development of phytoplankton -, thus generating an unstable environmental situation and preventing a good development. This effect has already been acknowledged in the bibliography (CARP, 1989; Bonilla and Conde, 2000). The presence of *Artrospira sp* - only local cyanophytes- would be related to the maximum tolerance to highly mineralized environments and with high conductivity. All those conditions were found in this site. This parameter is frequently measured and used as geochemical index for the control of natural waters (Espinosa et al., 1999).

Variation and reduction of phytoplankton in $\mathbf{P_1}$ could be influenced by the fires that happened in this zone in spring. According to Holopainen and Huttunen (1992), changes in water quality, such as the increase in the washing of nutrients in disturbed zones, causes changes in the algal flora. These authors found that there is a diversity of more than 63 algae taxa, and that dominant groups change. In our case, there was a remarkable decrease in the composition and abundance of phytoplankton. If these areas are not properly protected, there could be an increase of nutrients (eutrophication) that impact on the body water receptors developing different forms of aquatic vegetation (phytoplankton, periphyton, etc.) that are not characteristic of the environment (Temporetti, 2006). Bacillariophyceae, in particular species of the Pennales Order, were both qualitatively and quantitatively predominant. Central Order species, on the other hand, had little representation, except for the central diatom *Melosira varians* which predominated in $\mathbf{P_2}$, characterized as a primary colonization agent in environments with low flow conditions, accumulation of organic matter and nutrients in the water (Martínez, 2003; Seeligman et al., 2001). These results differ from the observations by Daruich (2007), but agree with those by Molloy (1992), who asserts that central diatoms are more frequent downstream. According to Álvarez-Cobelas and Rojo (1994), the increase in central populations is related to high eutrophic systems, which might be happening in $\mathbf{P_2}$.

The success of diatoms is due to high photosynthetic effectiveness, high amount of chlorophyll and low threshold of light saturation, features that give them adaptive advantages over other components of phytoplankton (Reynolds, 1988), in addition to their capacity of living in highly unstable environments and of quickly responding to environmental changes in fluvial unstable systems (Rojo et al., 1994). Transparency and stability of water column in $\mathbf{V_1}$ and $\mathbf{P_1}$, as well as the decrease of flow determined the diminution of diatoms as a result of the increase in their sinking rate and their replacement by green algae (Margalef, 1993). It is interesting to note the proliferation of *Ceratium hirundinella* in $\mathbf{V_1}$ during autumn. This dinoflagellate has been found in Argentine dams, and it extends from south to north with no particular explanation, a situation that could be related to important environmental alterations (Boltovskoy et al., 2003). The most affected station was $\mathbf{P_2}$, showing high abundance with less diversity and equitability. The most tolerant species to organic matter, such as *Melosira varians*, *Navicula tripunctata* and *Oscillatoria limosa* are predominant in autumn and winter, whereas *Coelastrum microporum* predominates in summer. According to Dolbeth et al. (2003) and Western (2001), all this suggests an evolution in the eutrophic process from an initial to an intermediate level, or what is more, from an intermediate to an advanced level of this process. Consequently, the chemical evaluation of water quality in the *Potrero* river showed deterioration signs downstream from the village, with an increase in the organic matter (Almeida et al., 2007). Although *Coelastrum microporum* was found in all types of lakes in Argentina (Mirande et al., 2009), particularly in cool lakes with important anthropogenic disturbances

(Vila and Pardo, 2003). The occurrence of this species during summer in the $\mathbf{P_2}$ reveal that it originates in dams with eutrophication signs.

5. Conclusion

The phytoplankton community was mainly composed of diatoms and chlorophytes on a smaller scale, with some downstream variations as a response to aquatic environment conditions. A remarkable change in the number and specific composition of phytoplankton was produced in the disturbed sites, and species more tolerant to cyanophytes appeared in their place. Euglenophytes – which have an affinity with organic matter coming from the dam – appeared in the post-dam station, and the diatoms such as *Melosira varians* and *Navicula tripunctata* were also present. All the species reflected low values of frequency, with the exception of some diatoms, such as *Synedra ulna* and *Gomphonema parvulum*, which are considered as species tolerant to a wide range of ecological conditions. Therefore, the structure and composition of the algal and Cyanobacterial communities allowed us to identify sections more sensitive to human-induced alterations.

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