



Phytoplankton from the Peri-Pampean hills: Córdoba system

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With 2 figures

Abstract: The province of Córdoba, located in the central region of Argentina, is subdivided into two areas: a hilly area to the west and a plain to the east. The fluvio-lacustrine systems developed in these areas form both exorheic and endorheic basins. The phytoplankton dynamics of these basins is determined mainly by their physicochemical and hydrological features and the succession of dry and wet periods. In addition to these factors, there are allochthonous impacts caused by the human activities developed in the area of influence. This article describes the phytoplankton from the exorheic river systems of Tercero and Cuarto Rivers, the endorheic rivers Tegua, Chucul and Santa Catalina, and urban (Villa Dalcar and Parque Sarmiento) and natural Suco shallow lake lentic systems.

Keywords: Phytoplankton, mountainous rivers, urban shallow-lakes

Introduction

The province of Córdoba, located in the central region of Argentina, covers 165,321 km² (Fig. 1). It is subdivided into two distinct geomorphological areas: a hilly area to the west and a flat area to the east. This feature gives rise to the multiplicity of environments developed in the province: plains, hills and valleys, creating the basis of the identity of the landscape that includes part of the Humid Pampas and part of the Chaco and western plains.

The hilly formations make up part of the Sierras Pampeanas, with three types of landscapes: hilly ranges (dominant in N-S direction), high plains or “pampas”, and depressions or valleys. The southern region of the province, which covers approximately 4,000,000 ha, includes the Pampas region characterized by gentle slopes, neotectonic activity and a succession of wet and dry climatic periods (Iriondo 1989). The climate is subhumid and varies in N-SW direction in response to masses of warm humid air and trade winds from the Atlantic (Degiovanni & Blarasín 2005). These features give rise to a variety of environments shaped

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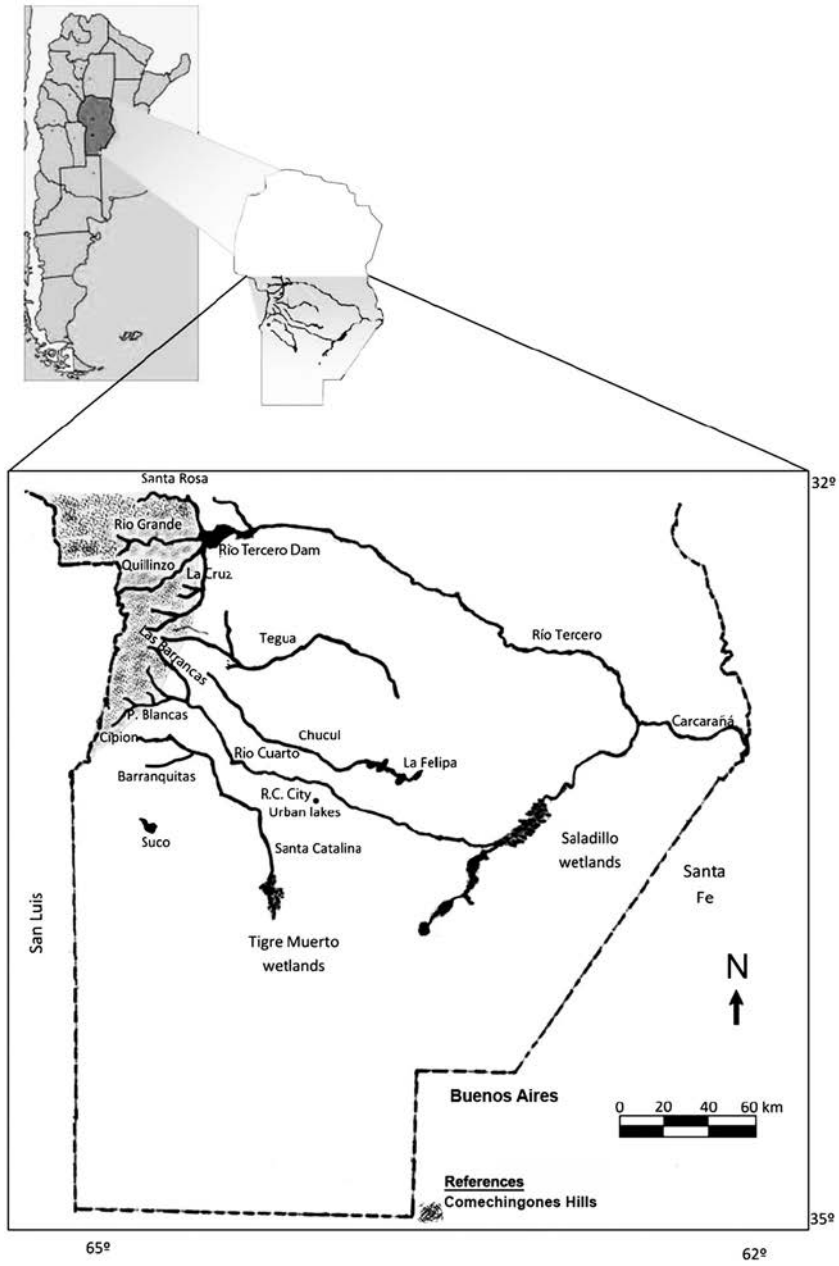


Fig. 1. Location of lotic (exorheic and endorheic) and lentic systems studied.

by processes of water and wind erosion, flooding and salinization of the land and water (Cantú & Degiovanni 1984).

We can thus distinguish a marked contrast between the hilly area and the plain. The hills run north-south, and comprise igneous and metamorphic rocks, with a steep slope to the west and a longer and less pronounced slope to the east. The plain has a strongly undulating relief at the base of the foothills and a moderate relief to the east. The key components of the landscape of this region are fluvio-lacustrine systems. The lotic systems descend in W-SE direction from their headwaters into tectonic depressions at the foothills and then spread into the plain, forming a lake system (Vazquez et al. 1979). These streams flow across urban centers and areas with agricultural and industrial activities, which produce a gradual deterioration of the quality of surface waters by organic enrichment, input of nutrients, heavy metals and pathogens, and changes caused by river channeling processes (Gomez & Licursi 2001).

Frenguelli (1923) made the first study of algal communities in the province of Córdoba and focused on the diatoms of Primero River (Suquia). In later years, several works on the phycoflora of the south of the province, and taxonomic, bioecological and floristic inventories of the region were carried out. Limnological studies of the Tercero River basin (Ctalamochita) were started in the 1980s by researchers at the Universidad Nacional de Río Cuarto (Martínez de Fabricius 1986, Martínez de Fabricius et al. 1988, Martínez de Fabricius & Corigliano 1989).

The Cuarto River basin was studied later (Chocancharava). Since most of the environmental heterogeneity of this basin is recorded along the longitudinal and altitudinal gradient, the basin was subdivided into *upper*, *middle* and *lower* basins. The first studies were on the phycoflora and later studies included hydrogeochemical and bacteriological analysis. In recent years, studies of lentic systems and fluvio-lacustrine endorheic systems have also been carried out. The former were carried out in artificial urban lakes in the city of Río Cuarto (Novoa 2004, Novoa et al. 2006) and in natural lakes (Martínez de Fabricius et al. 2010, Huber 2010, Huber et al. 2010a, 2010b). Three basins were selected from the fluvio-lacustrine systems: Chucul, Santa Catalina and Tegua (Novoa et al. 2007, Sosa 2010, Martínez de Fabricius et al. 2012).

This article describes the dynamics of phytoplankton in the aquatic systems of southern Córdoba province and its relation to ecological-landscape aspects of the different drainage basins (endorheic and exorheic).

Exorheic lotic systems

The basins of Tercero and Cuarto Rivers constitute one of the main exorheic systems of Córdoba province (Fig. 1). From their source in the hills of Comechingones until they flow into the Bañados del Saladillo, both rivers join the basin of the Carcarañá River, the main tributary of the Paraná River, thus integrating the great basin of the Río de la Plata (see Gomez, 2014).

Tercero River basin

The system of streams and tributaries of the Tercero River dam belongs to the basin which has the same name, which drains an area of approx. 3300 km². The study area is located in the headwaters of streams that are characterized by high slope, torrential regime and pluvial origin, with large floods in summer. The Quillinzo, La Cruz, Santa Rosa and Grande Rivers are part of the Tercero River basin, whose headwaters are over 1400 m a.s.l. The fluvial components of the basin have similarities in their physical-chemical values: circumneutral pH values, mean depths between 40–100 cm and maximum transparency (Martínez de Fabricius 1986, Martínez de Fabricius & Corigliano 1989). The phytoplankton of the rivers shows a specific composition (144 taxa), characteristic of low order lotic systems (Strahler 1964).

The most common species belong to the class Bacillariophyceae, mainly of the order Pennales, derive from the benthos. The reaches downstream Tercero River dam show a decrease in diatoms and an increase in Chlorophyceae and Cyanobacteria because of the influence of the dam and the change of substrate in the plain area (Martínez de Fabricius et al. 1988). The mean density value is 975 ind. ml. The most abundant species are *Melosira varians*, *Synedra ulna*, *Cocconeis placentula* var. *euglypta* and *Navicula radiosa*, several species of *Scenedesmus*, *Closterium*, *Staurastrum* and *Pediastrum*, the filamentous forms *Cladophora glomerata*, *Spirogyra* and *Stigeoclonium tenue* and the Cyanobacteria *Merismopedia punctata* and *Oscillatoria limosa* (Martínez de Fabricius 1986).

Cuarto River basin

Along its over 300 km length, the Cuarto River drains an area of 2200 km² of the phytogeographical province known as Chaco-Pampeana Plain. This river is born at the confluence of Las Barrancas and Piedras Blancas systems in the Comechingones hills and flows into the Bañados del Saladillo. This area of wetlands is a vast plain of fluvial origin, characterized by the presence of interconnected shallow lakes, marshes and swamps, which join the great Río de la Plata basin through the Saladillo River at its confluence with the Tercero River (Fig. 1).

The Cuarto River basin presents variations in its course, which are associated with the slope and geomorphological changes of the substrate, its torrential regime, its growth in summer and low flow in winter. It follows a meandering pattern of varying sinuosity and it is between cliffs of up to 12 m in height along almost its entire length. Since these changes impact directly on phytoplankton, the basin has been divided into: *upper basin* in the hilly area, *middle basin* in the floodplain area, and *lower basin* in the spread area (Martínez de Fabricius 1996).

The *upper basin* covers approximately 90000 ha fully developed in the Comechingones hills. The high drainage density, coupled with the intensity of rainfall, defines surface runoffs of torrential regime. This basin is subdivided into two sub-basins: 1) the Las Barrancas River system and 2) Piedras Blancas River system, as these are two major tributaries of the Cuarto River. The water systems that constitute the basin have discharges that do not exceed 9 m³ seg⁻¹. The water is alkaline with pH values close to 8 and the conductivity is just over 100 µS cm⁻¹, which are features characteristic of hill streams of calcic carbonated waters (Corigliano et al. 1998, Luque & Martínez de Fabricius 2000, 2002, 2003, 2005, Martínez de Fabricius et al. 2005).

The plankton in the *upper basin* is dominated by organisms from the benthos, represented by 258 taxa, of which 121 are Bacillariophyceae (Fig. 2). The class Bacillariophyceae dominated throughout the study period with an average density of 407 ind. ml⁻¹ (Luque & Martínez de Fabricius 2003).

The order Centrales presented only two species, *Cyclotella meneghiniana* and *Melosira varians*, whereas the remaining species belonged to the order Pennales; the genera with the highest number of species were *Navicula*, *Nitzschia*, *Gomphonema* and *Achnanthes*. The most abundant species were *Achnanthes biosoletiana*, *A. deflexa*, *A. delicatula*, *A. microcephala*, *Achnantheidium minutissimum*, *Amphipleura lindheimerii*, *Cocconeis placentula* var. *euglypta*, *Cocconeis placentula* var. *lineata*, *Cymbella silesiaca*, *Cymbella cymbiformis*, *Denticula kuetzingii*, *Diatoma vulgare*, *Encyonema minutum*, *Eunotia pectinalis*, *Fragilaria virescens*, *Gomphonema minutum*, *G. subclavatum*, *G. gracile*, *Melosira varians*, *Navicula cryptocephala*, *N. elginensis*, *N. perminuta*, *N. radiosa*, *N. salinarum*, *Nitzschia frustulum*, *N. dissipata*, *Planothidium lanceolatum*, *Reimeria uniseriata* and *Synedra ulna*. The environmental conditions favored the development of filamentous forms like *Cladophora glomerata* and *Oedogonium* sp., which predominated in number of species and density during the warmer months. The most abundant Chlorococcales were *Dictyosphaerium pulchellum*, *Monoraphidium* sp., *Pediastrum boryanum*, *Scenedesmus acuminatus* and *Scenedesmus ecornis*. Cyanobacteria species were recorded at low densities, being the most abundant *Lyngbya* sp. Diversity showed fluctuations throughout the sampling period, showing a maximum of 3.57. Evenness varied between 0.52 and 0.85 (Martínez de Fabricius et al. 2005). According to the saprobic value of the species present, the *upper basin* is in the range of oligo-mesosaprobe to β-mesosaprobe, with weak to moderate pollution (Schwoerbel 1975).

The *middle basin* is developed on sediments with high susceptibility to erosion; the course varies from meandering, with medium to low sinuosity, to intertwined, which is attributed to the sharp fluctuations in flow and the availability of traction load (Doffo & Degiovanni 1993). The fieldwork was carried out from the stretch of alluvial plain, characterized by a system of intertwined and anastomosed bars, to the plain area with sediments of lower grain size and lower slope. The values of the physicochemical variables in the *middle basin* differ from those recorded in the *upper basin*, in correspondence to the geomorphology of the watercourse in these sections. The pH is alkaline, with values above 8. The discharge reaches mean values of 40 m³ seg⁻¹, and the conductivity exceeded 500 μS cm⁻¹. In this section, 5 km downstream the city of Río Cuarto there is sewage discharge, with scarce purification treatment, a fact that impacts directly on the phytoplankton (Bruno et al. 2003). Phycological studies conducted in the *middle basin* of the Cuarto River identified a total of 142 taxa, being Bacillariophyceae the class with the highest number of species, followed by Chlorophyceae and Cyanobacteria (Fig. 2). The same pattern was observed with respect to abundance, with a maximum density of 216 ind. ml⁻¹ in the lower stretch of the *middle basin*. The most abundant species were *Achnantheidium minutissimum*, *Nitzschia linearis* and *Navicula perminuta*. In the section that crosses the urban area the latter species, together with *Nitzschia palea*, recorded the highest values of abundance in the area of sewage dump. The highest diversity (4.49) was recorded in this sector in summer (Bruno et al. 2003). Among Cyanobacteria, *Lyngbya martensiana* and *Anabaena variabilis* were the most abundant species in the first stretch of the *middle basin* (Martínez de Fabricius et al. 2007). Evenness indicates a more homogeneous distribution of species in summer and a heterogeneous behavior in the other seasons.

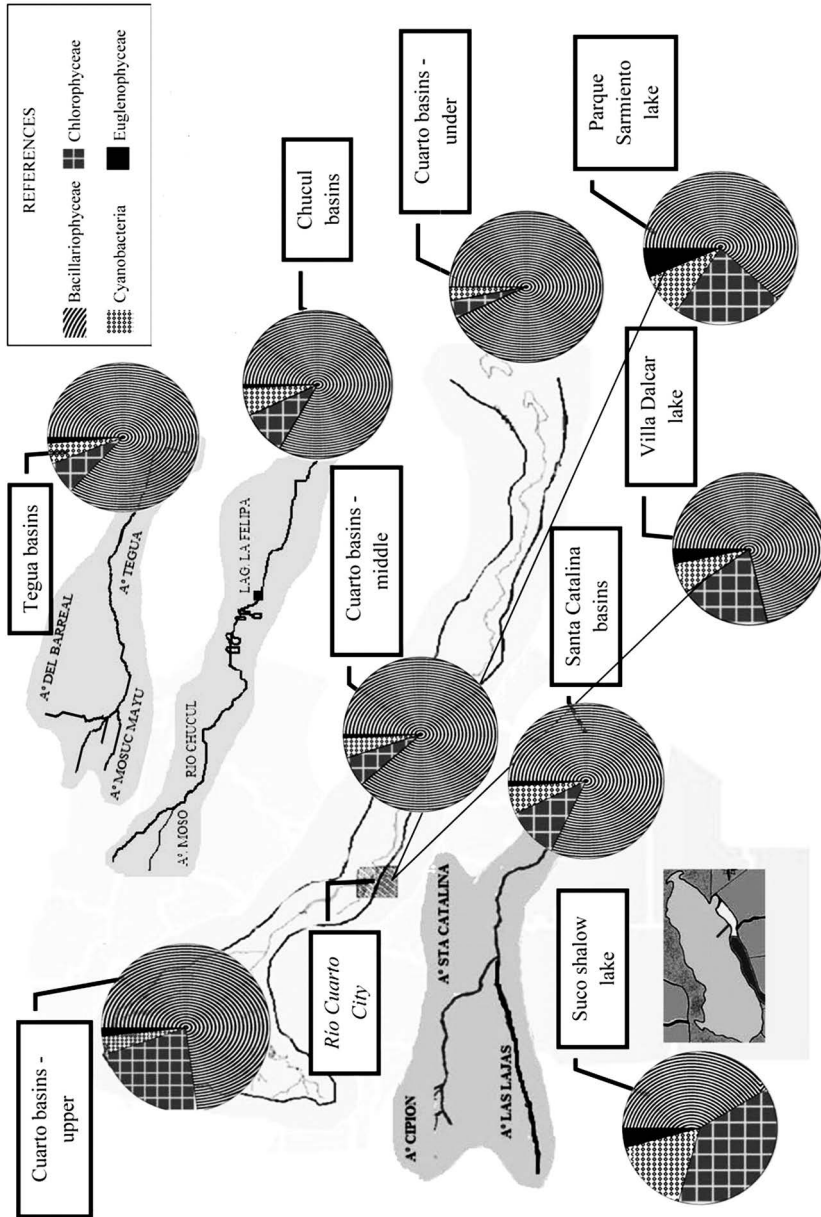


Fig. 2. Percentage Value richness of algal classes in the systems studied. *Chysophyceae* and *Dinophyceae* were not included because of their low contribution.

Taking into account the saprobic index of Pantle & Buck, the water quality in this stretch of the river showed values within the β -mesosaprobic range and moderate contamination for the upper reaches of the basin and polysaprobic and high pollution in the area of sewage dump at the lower stretch (Martínez de Fabricius et al. 2007).

In the lower basin or spread area, the river has a muddy substrate, low transparency, and increased current velocity and discharge. The sampling sites selected extended from the area of change in the river substrate, mainly clay loam, to the spread area in the lower lagoon system. In this stretch pH is higher than 8.5 and there is a downstream progressive increase in conductivity, with mean values greater than $500 \mu\text{S cm}^{-1}$ and suspended solids (Luque & Martínez de Fabricius 2010), features related to the substrate type and flow variations characteristic of this basin (Martínez de Fabricius et al. 2003). Species richness recorded (103 taxa) was the lowest compared with the other stretches of the basin. The class Bacillariophyceae dominated both qualitatively and quantitatively, and Chlorophyceae and Cyanobacteria recorded low abundance values, features that do not differ from those reported in the *upper* and *middle basin* (Fig. 2). The mineralized water conditions favored the development of species of the genus *Nitzschia*, which is the best represented. The species that contributed with the greatest percentage to total density were the epiphytes *Diatoma vulgare* and *Synedra ulna* because of their detachment of the filamentous alga *Cladophora glomerata*, while the abundance of *Melosira varians*, *Nitzschia linearis*, *N. frustulum* and *Sellaphora pupula* was associated with local pollution episodes, especially during the low flow period. Although *Nitzschia palea* is regarded as a taxon characteristic of polluted waters, it is likely that the conditions of mineral water and the silty clay substrate are the most important aspects that contributed to the presence of this species (Luque & Martínez de Fabricius 2010). The maximum diversity recorded was 4.26 in spring and maximum evenness reached 0.99 in autumn. The application of the biotic index to determine the water quality characterized the basin within the α - β -mesosaprobic range with high to moderate pollution (Luque & Martínez de Fabricius 2010).

Endorheic lotic systems

We selected three fluvio-lacustrine systems located in the south of the province: Chucul, Santa Catalina and Tegua (Fig. 1). One of the most prominent physiographic features of these three basins is their endorheic character; as a direct consequence of this, the surface water tends to accumulate in closed depressions, forming ponds that make up an important wetland system for its potential anthropic use and reservoir of the greatest biodiversity of the region (Cantú & Degiovanni 1984) (Fig. 1).

Novoa et al. (2006, 2007) carried out studies on the three basins and described their hydrological and physicochemical features. In the basin of the Chucul River, the maximum flow was $2.56 \text{ m}^3 \text{ seg}^{-1}$ in the middle stretch of the basin, with alkaline waters and conductivity exceeding $1,200 \mu\text{S cm}^{-1}$ in the spread area.

The basin of the Tegua River recorded flow values slightly higher than those of the Chucul River basin, with a maximum value of $4.90 \text{ m}^3 \text{ seg}^{-1}$ in its lower reaches. pH was higher than 7 in all cases, reaching a maximum of 9.1 and a maximum conductivity of $3,857 \mu\text{S cm}^{-1}$. In the final stretch of the Santa Catalina River basin, the flow rate increases, with values of

7.25 m³ seg⁻¹. Waters are alkaline, reaching a maximum pH of 9.1, and the conductivities higher than 2,000 µS cm⁻¹ (Novoa et al. 2008a, b, Sosa 2010).

The main course of the Chucul River descends in NW-S direction from its headwaters in the foothills area and spreads into the plain, forming a fluvio-lacustrine system. Along its path, there are dunes with NE orientation, within which lie shallow lakes, many of which are silted or silting. The most important lentic water body of these wetlands is the La Felipa shallow lake, where the Chucul River flows, and which, in 1986, was enacted Provincial Wildlife Reserve.

Floristic studies conducted by Novoa et al. (2006) recorded a total of 340 taxa, of which 284 belonged to Bacillariophyceae, 33 to Chlorophyceae, 21 to Cyanobacteria and 2 to Euglenophyceae (Fig. 2). *Nitzschia* and *Navicula* were the genera with the greatest number of species, among which the most frequent were *Navicula cryptocephala*, *N. cryptotenella*, *N. peregrina*, *N. radiosa*, *N. tripunctata*, *Nitzschia amphibia*, *N. capitellata*, *N. littoralis*, *N. microcephala*, *N. palea*, *N. recta* and *N. sigma*.

The greatest number of species was recorded in spring in the spread area, in the proximity to La Felipa Lake. *Synedra ulna* was present in all seasons and at all sampling sites. The Sorensen-Dice index revealed a high similarity in the phycoflora among seasons and sampling sites. The maximum diversity was 4.94 in autumn and spring whereas minimum diversity was 1.6 in winter. Evenness was highest in the entire stretch of the basin in summer. The saprobic index (close to 3) indicates that this basin is within the α -mesosaprobic range with highly contaminated waters (Novoa et al. 2006, 2007, 2008, Sosa 2010, Sosa et al. 2010).

The Tegua River basin is born in the geomorphological association known as eolic perihill undulating stretch, which is subjected to acute water erosion, and its waters flow in WE direction (Orozco 1998). A total of 226 taxa were recorded, of which the largest percentage belonged to Bacillariophyceae, followed in a smaller proportion by Chlorophyceae and Cyanobacteria (Fig. 2).

In agreement with that found in the other basins, *Nitzschia* and *Navicula* recorded the highest number of species. The most frequent species were *Navicula cryptocephala*, *N. peregrina*, *N. tripunctata*, *N. veneta*, *N. viridula*, *Nitzschia capitellata*, *N. constricta*, *N. linearis*, *N. microcephala*, *N. palea*, *N. recta*, *N. sigma*, *N. umbonata*, *Surirella minuta* and *S. ovalis*. However, the abundance was dominated by *Cocconeis placentula* var. *euglypta*, *Nitzschia microcephala*, *N. palea*, *N. linearis* and *Planothidium lanceolatum*. Diversity was high (> 3.5) and evenness resembled the rest of the basin (Novoa et al. 2006, 2007, 2008).

The Santa Catalina River basin, which drains the eastern slope of the Comechingones hills and runs in a NW-S direction, results from the convergence of the Barranquitas and Cipión streams. Cantú & Degiovanni (1984) described the middle region of its path through hydrohalomorphic depressions. In its final stretch, it enters a depressed area, with a SE-S slope (Degiovanni et al. 2004). Novoa et al. (2006) found 280 species throughout the basin, of which over 75% belonged to the class Bacillariophyceae (Fig. 2). As in the Tegua River basin, *Nitzschia* and *Navicula* were the genera with the greatest number of species, followed by *Gomphonema* and *Surirella*. The species with higher frequencies were *Navicula cryptocephala*, *N. cryptotenella*, *N. peregrina*, *N. tripunctata*, *Nitzschia capitellata*, *N. constricta*, *N. microcephala*, *N. palea*, *N. recta*, *N. sigma*, *Gomphonema clavatum*, *G. parvulum*, *G. truncatum*, *Surirella ovalis*, *S. splendida* and *S. striatula*. The species with the highest density in the study period was *Cocconeis placentula* var. *euglypta* (Novoa et al. 2006a, b, 2008a,

b). Maximum diversity was 4.7 and evenness was close to 1 over the entire basin during the sampling period.

Lentic Systems

The southern Córdoba Province is characterized by a large number and variety of lentic water bodies that are either natural or artificial, permanent or temporary, deep or shallow, endorheic or exorheic (Novoa 2006, Huber 2010). Here we describe the natural and artificial ones (Fig. 1).

Urban lakes

The urban lakes of the city of Río Cuarto are exposed to strong anthropogenic pressures; their turbidity levels are high due to the runoff of adjacent sediments during the rainy season.

The Parque Sarmiento Lake, located in the north of the city of Río Cuarto, is surrounded by a large number of trees which limit the penetration of sunlight. Novoa et al. (2006) analyzed its physicochemical characteristics and found mean pH of 8.5 and conductivity ranging from 300 to 400 $\mu\text{S cm}^{-1}$. The floristic analysis showed 180 taxa: 109 belong to Bacillariophyceae, 41 to Chlorophyceae, 16 to Cyanobacteria, 11 to Euglenophyceae, 2 to Dinophyceae and 1 to Chrysophyceae. Small differences were recorded in species richness among the sampling sites and over the annual cycle (Novoa 2004). Maximum total density was of 209 ind. ml^{-1} ; the most abundant species were *Aulacoseira granulata*, *Melosira varians*, *Sphaerocystis Schroeterii*, *Microcystis aeruginosa*, *Navicula gottlandica*, *Oscillatoria annae*, *O. subbrevis*, *O. limosa* and *O. tenuis*. Maximum diversity was 3.3 and evenness ranged between 0.8 and 0.3. Considering the mean value of saprobic index ($S = 3.42$), the lake may be classified as α -mesosaprobic.

The Villa Dalcar lake is located in the west of the city of Río Cuarto. Unlike Parque Sarmiento Lake, it has no light limitation, which favors greater photosynthetic activity and species richness (Novoa 2004). Determined 231 taxa, of which the best represented group was Bacillariophyceae with 162 species, 44 Chlorophyceae, 15 Cyanobacteria, 7 Euglenophyceae, 2 Dinophyceae and 1 Chrysophyceae. Algal blooms were recorded during the warmer seasons: *Aphanizomenon flos-aquae* (summer) and *Peridinium pusillum* (spring). The species that contributed most to phytoplankton density were *Aulacoseira granulata*, *Epithemia sorex*, *Synedra acus*, *S. ulna*, *Mougeotia* sp., *Merismopedia minima*, *Oscillatoria limosa*, *O. tenuis* and *O. subbrevis*. Maximum diversity and evenness were 4.6 and 0.79, respectively. Jaccard's similarity index between sites ranged between 63 and 20%. The saprobic index corresponds to the α - β -mesosaprobic range, with highly contaminated water.

Natural lakes

The Pampean lakes are the main natural component of the central region of Argentina. They were characterized by Quirós & Drago (1999) as very shallow, exceptionally deeper than 4 m, permanent, of variable salinity, naturally eutrophic and currently under environmental

stresses, which further increases their content of nutrients. In these lakes bottom sediments resuspend in the water column by wind action, causing increased turbidity by solids, organic matter and increased algal growth (Sánchez 2007, Sosnovsky & Quirós 2006).

The Suco shallow lake is located in the Chaco-Pampean domain, 60 km from the city of Río Cuarto. It has an area of 90 ha, with its major axis oriented NE-SW; its maximum depth is 4 m and its mean depth 2 m; it is endorheic, with an artificial relief channel. According to its structural and geomorphological features, it has tectonic origin and lies to the east in a slope of a fault that plays an important role in the metabolism of the lake, controlling the input of nutrients from the drainage network, as well as the distribution of dissolved gases and organisms (Sagripanti 1996). There are intensive agricultural activities in its surroundings, from which it can be inferred that the lake receives effluents of herbicides and fertilizers or other chemicals. According to the classification of Pampean lakes proposed by Izaguirre & Vincur (1994), it belongs to the “turbid Pampean lakes” due to the dominance of phytoplankton over the submerged macrophyte community (Huber 2010).

The water has an alkaline character and a high conductivity, which reaches values of $2,251 \mu\text{S cm}^{-1}$ (Huber 2010a), also characteristic of shallow Pampean lakes dominated by phytoplankton (Alvarez & Bazán 1994, Quirós et al. 2002, Bazán 2010). Huber et al. (2010a) determined a total of 199 taxa during an annual cycle; most of them correspond to Bacillariophyceae and Chlorophyceae (Fig. 2). The best represented genera were *Nitzschia*, *Scenedesmus*, *Chroococcus* and *Aphanocapsa*, with species characteristic of eutrophic systems had a seasonal pattern related with the climatic fluctuations and polymictic characteristics of the lake (Huber et al. 2010b). Phytoplankton abundance was high, with a maximum of $406,102 \text{ ind. ml}^{-1}$. Cyanobacteria dominated, with 85% of the total density, due to frequent algal blooms of *Aphanizomenon flos-aquae* (autumn) and *Planktothrix agardhii* (other seasons), accompanied by *Phormidium* sp. (autumn and winter), *Coelosphaerium minutissimum* (spring) and *Aphanizomenon flos-aquae* (summer). The Chlorophyceae species that had higher density belonged to the order Chlorococcales and Bacillariophyceae provided mainly species characteristic of eutrophic brackish shallow lakes, including *Aulacoseira granulata*, *Cyclotella meneghiniana*, *Chaetoceros muelleri*, *Aulacoseira granulata* var. *angustissima* and species of *Nitzschia*. The abundance did not show marked seasonal variations, characteristic of hypereutrophic systems with permanent blooms of Cyanophyceae, where the density is fairly constant (Padisák et al. 2004). Diversity and evenness were low, ranging from 0.53 to 0.21 and seasonally between 2.41 and 0.86, respectively, a fact expected because of the presence of blooms (Huber 2010).

Final considerations

Bacillariophyceae are dominant in the phytoplankton throughout the Río Cuarto basin; although many species have benthic or epiphytic habit, their presence in the plankton in these lotic environments is very frequent. Moreover, benthic species of the genera *Achnanthes*, *Gomphonema* and *Navicula* have been found only in the plankton. This marked proportion of picoplanktonic organisms suggests a continuous supply of benthos due to the characteristics of hydrological regime. In the Piedras Blancas River, the relatively continuous contribution of epilithon to plankton, results from the morphological and hydrological characteristics of

the river bed. A similar behavior occurred along the entire stretch of the Cuarto River, that has sandy substrate, shallow depth and torrential regime. The environmental conditions in the *upper basin*, namely high water transparency, moderate flow, shallow depth, long periods of sunshine and relatively high temperatures, favor the presence of numerous species of Chlorophyceae, especially filamentous ones such as *Cladophora glomerata*. These organisms are important substrates for epiphytic organisms such as *Cocconeis placentula* var. *lineata* and *C. placentula* var. *euglypta*; their detachment greatly contributes to phytoplankton. The fluctuations of conductivity, pH and discharge explain the variation in total species richness, diatom species richness and diversity. In the *middle basin*, in the sewage discharge area, nitrogenous compounds exceeded the minimum allowed concentrations, indicating the presence of organic debris. *Nitzschia palea*, which was the most abundant and frequent species, has been considered as a taxon tolerant to polluted waters. The physicochemical and hydrological characteristics and residence time of the water in the *lower basin* are the most important factors in the development of river plankton. The presence of *Nitzschia* species in this section is favored by the conditions of mineralized water and that of algal species of higher saprobic index is probably due to the response of the water to moderate to high contamination.

Regarding the endorheic basins, the Chucul River has the highest species richness. In all cases, Bacillariophyceae presented the highest number of species, followed by Chlorophyceae. *Nitzschia* and *Navicula* were the genera with more species in the Chucul River, followed by *Pinnularia* and *Gomphonema*; *Surirella* contributed the most in Santa Catalina and Tegua rivers. These three river systems have alkaline waters; the maximum conductivity and flow occurred in the final stretch of the Santa Catalina basin.

Among the lentic systems, in the urban lakes the species richness of Villa Dalcar lake was higher than in Parque Sarmiento lake. *Navicula* showed the highest number of species in both lakes. Abundance was higher in Villa Dalcar, in response to the development of two blooms corresponding to *Aphanizomenon flos-aquae* in summer and *Peridinium pusillum* in spring. The saprobic values calculated for these urban lakes located in the city of Río Cuarto were in the α polisaprobic range. In the natural Suco shallow lake, the algal classes with the greatest number of species recorded were Bacillariophyceae, Chlorophyceae and Cyanophyceae. The low seasonal and spatial variability of species richness found can be attributed to the polymictic characteristic of the lake. The basic structure of phytoplankton is characterized by the dominance of Cyanobacteria. Algal blooms of *Aphanizomenon flos-aquae* in autumn and *Planktothrix agardhii* in the other seasons were recorded throughout the study period. Both diversity and evenness showed low values.

Acknowledgements

We thank the Department of Science and Technology of the National University of Río Cuarto (UNRC) for the funding of research projects and scholarships, which allowed the development of our work. We also thank CONICET for granting Doctoral Research Fellowships carried out in the Laboratory of Phycology of the UNRC. We also acknowledge the help of Dr. Nora I. Maidana in taxonomic studies, MSc. Maria Elisa Luque for her work and campaigns, MSc. Daniela Lombardo for bacteriological analysis and support in the campaign of Río Cuarto. Finally, we thank Drs. Mónica Blarasin and Adriana Cabrera for the hydrogeochemical measurements.

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