CHAPTER 8

Phytoplankton from urban and suburban polluted rivers

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Abstract

The rivers and streams of the suburban area of Buenos Aires City are strongly affected by punctual discharges of industrial and domestic waste-waters as well as by diffuse pollution due to agricultural activities. Water quality in these systems is highly deteriorated thus influencing the structure and dynamics of phytoplankton. The response of the assemblages occurring in each water course depends upon the sensibility and tolerance of algal populations to the different types of pollutants and the local hydrological conditions. In this chapter, the phytoplankton from several lowland water courses of the Buenos Aires Province is compared on behalf of the information produced by field surveys and *in situ* and laboratory experimental studies. Spatial and temporal changes in phytoplankton composition is analysed for the largest rivers and streams, which present stretches with different levels of pollution. A synthesis of the data is presented taking into account the phytoplankton species and assemblages tolerant of pollution.

Key words: pollution, rivers, phytoplankton assemblages

River pollution

Organisms are seen as fundamental sensors that respond to the stress affecting the system in which they live (Loeb & Spacie, 1994). Any stress, physical, chemical or biological, imposed on aquatic systems manifests its impact on the organisms living within that ecosystem through their health, which is affected when its capacity to absorb stress is exceeded. This concept proposes that the environmental health of aquatic ecosystems can be assessed by biological monitoring using organisms as diagnostic tools (Dokulil, 2003). Understanding the responses of river phytoplankton to changes in physical and/or chemical parameters is valuable for detecting pollution and predicting how anthropogenic influences may affect flowing water systems (Peterson & Stevenson, 1989). The environmental factors most frequently indicated as regulators of the distribution and abundance of plankton in fluvial systems comprise hydrological (current velocity, flow, water residence time), physical (temperature, light environment) chemical (nutrient and ion concentrations) or biotic features (grazing, competition) (Reynolds, 1988). Regional differences in the geology, hydrology as well as in human activity in the drainage basins can affect some of these factors and consequently the composition of algal assemblages.

Pampean rivers and streams of urban and suburban areas are affected by point source contamination, caused by sewage residues and industrial effluents and by diffuse contamination mainly due to farming and animal husbandry activities (Sala et al., 1998; Gómez & Rodrigues Capítulo, 2001). Moreover, since 1870 many watercourses in Buenos Aires were modified by rectifications and tubings. Pollution in these watercourses comes from a diversified industrial activity, mainly metallurgy and the activities related to leather, textile and food manufacture. Other frequent problems in these basins are consequence of processes linked to human occupation in inundation valleys, with areas of habitat degradation associated to the environmental problem of flooding and garbage dumps (Herrero & Fernández, 2008). The periodical dredging and profiling carried out in the pampean plain to increase the flow of watercourses to the Rio de la Plata or to the sea, as a management tool for flood prevention, introduced additional disturbances. These works usually lacked proper technical advice and adequate planning and therefore led to habitat destruction. Likewise, destruction of margins affected hydrophytes and riverside vegetation, and on several occasions worsened the water quality, thus affecting the ecosystem productivity (Bauer, 2009; Licursi & Gómez, 2009).

The basins most affected by pollution correspond to the Matanza-Riachuelo, Reconquista and Luján rivers, all influenced by the industrial and domestic activities of Buenos Aires City, and to small streams that flow directly into the Rio de la Plata (Figs.1, 2, 3 and 5).

In this chapter we summarize the phytoplankton studies conducted in these watercourses, identifying those phytoplankton species and assemblages tolerant to pollution.

Matanza Riachuelo Basin

General features

The Matanza Riachuelo basin (35° 06' S – 58º49' W and 34° 38' S - 58º 21' W), with a surface of 2,240 km^2 and a length of 70 km (Fig 1) is considered one of the most polluted systems of Argentina. The main course of the river and its tributaries present well defined basins and the drainage system is clearly developed in relation to other zones of Buenos Aires Province. Its depth varies from 0.3 to 0.6 m at the headwaters and 7 m at the river mouth; the minimum mean flow is ca. 6.20 m^3s^{-1}, while maximum flow may exceed 1,000 m^3s^{-1}. The hydraulic regime of the river is affected by both, astronomical and meteorological tides that alter its flow along an important length, but most noticeable in its inferior section. In the lower basin, channelization and rectification works were performed to prevent flooding. Approximately 30% of the total surface of the basin is for urban use, 22% for farming and 42% for pasture (Acumar, 2008). The deterioration of the water quality of the main course and of most of its tributaries responds to a high polluting load from household and industrial sewage waters that widely exceed the diluting and self-depuration capacity. Agricultural processes have also caused strong changes in the terrestrial ecosystems within the basin; such is the case of animal husbandry that causes strong alterations due to overgrazing and trampling.

The industrial activity is mainly concentrated in the middle and lower basin and it includes the refrigerating, feeding, metallurgic, textile, tannery, chemical, galvanoplasty, pharmaceutical and petrochemical sectors. The basin gathers approximately 3.5 million inhabitants and includes one of the most populated metropolitan areas of Argentina. The presence of garbage dumps in the open and of human settlements in the river margins provide further environmental problems within this basin. According to a recent diagnosis performed by the ACUMAR (2008), the tributaries in rural areas that are not affected by urbanization (located in the upper basin) have a dissolved oxygen content between 7 and 9 mg L^{-1} and biological oxygen demand (BOD_5) values of up to 3 mg L^{-1}. In the tributaries affected by urbanization, the degree of pollution is moderate with oxygen contents between 4 and 8 mg L^{-1} and BOD_5 between 3 and 5 mg L^{-1}; in the middle and lower basin these values are below 7 mg L^{-1} or widely exceed 20 mg L^{-1}, respectively. This situation becomes critical with low flows, as great part of the basin reaches anoxia conditions (Fig. 1a). Nutrient mean concentrations for the basin fluctuate from 2,7 to 9,9 mg L^{-1} of ammonium and from 1,8 to 2,7 mg L^{-1} of phosphorous. As regards toxic contaminants, chrome, copper, lead and cadmium concentrations exceed from 2 to 10 times the guide levels of water quality for protection of aquatic life in superficial freshwater according to Law 24051 of Dangerous Residues (ACUMAR, 2008).

Phytoplankton

The characteristics and distribution of the phytoplankton in the Matanza-Riachuelo basin are associated with the deterioration of water quality. According to the studies by Conforti et al. (1995) carried out from 1986 to 1987 at 4 sampling sites located from headwaters to the lower basin of the river, 281 taxa were identified, 48.7% corresponded to euglenophytes, 25.3% to diatoms, 14.9% to chlorophytes, 10.7% to cyanobacteria and the rest to dinoflagellates. Distinct group of species related with different levels of water quality were identified. The sites with low BOD_5 and phosphorous concentrations and high dissolved oxygen content were characterised by *Aulacoseira granulata, Gyrosigma spencerii, Achnanthes lanceolata, Navicula cincta, Oscillatoria tenuis, Spirogyra* sp., *Coelastrum microporum* and *Monoraphidium contortum*. As water deteriorated due to increasing organic matter and nutrients concentrations, species composition revealed assemblages richer in euglenophytes namely *Phacus curvicauda, P. unguis, P. triqueter, Lepocinclis playfairiana, Euglena klebsii* and *E. splendens,* frequently accompanied by the cyanobacteria *Myxosarcina burmensis, Oscillatoria amphibia* and the diatoms *Fragilaria construens var. subsalina, Pinnularia microstaurum, Cyclotella meneghiniana, Navicula cuspidata,* and *N. pygmaea*.

In the worst water quality conditions, *Euglena acus, E. gracilis, Lepocinclis salina, Phacus longicauda, Ph. longicauda var. insecta, Ph. telli, Ph. tortus, Nitzschia palea* and *Pinnularia biceps* had a common occurrence. It is interesting that some years later, Conforti (1998) found that many of the euglenophyte taxa registered in the river were morphotypes of single species produced in response to organic enrichment.

The phytoplanktonic abundances reported by Conforti et al. (1995) and Magdaleno et al. (2001) indicate the eutrophic character of the basin with values of 10^3 and 10^4 ind. mL^{-1} for the upper and lower basin respectively. Chlorophyll *a* fluctuated from 0.33 to 84 $\mu g\ L^{-1}$ in the upper basin and from 0.3 to 17 $\mu g\ L^{-1}$ in the lower basin, but were surpassed in recent years according to results obtained in 2008 (unpublished data) (Fig. 1b). These results emphasize the eutrophication of the Matanza-Riachuelo Basin and agree with the increasing intensity of land use and inefficient control of water quality.

Phytoplankton response to water toxicity was assessed by Magdaleno et al. (2001) through an algal growth inhibition test with *Selenastrum capricornutum* in five sampling sites along the river. They observed 40% of inhibition at four sites and 87% at the site located in the lower basin. Moreover, they indicated the existence of antagonic effects between some heavy metals, the presence of particles and complexing agents, such as organic matter and high concentrations of Ca^{++}, which would contribute to a lesser water toxicity effect on this alga in most of the analysed sites.

Reconquista River

General features

The Reconquista River Basin (34°41'S, 59°24'W) has a surface of 1,670 km^2 and is densely populated (approximately 3 million inhabitants). The river discharge ranges from 70,000 to 1,700,000 $m^3 day^{-1}$ and receives along its 82 km length the output of 80 small tributaries, among which the Morón stream delivers extremely high concentrations of sewage and industrial wastes. There are some 10,000 industries settled on the margins of the Reconquista River discharging in its waters their untreated effluents and using large quantities of water in processing, cooling and cleaning.

Salibián (2006) summarized the research work done by his group over 15 years at five sites along the river from a rural area (S1) to a much polluted industrial zone (S5) near to its mouth (Fig. 2). He asserted that there is a progressive but sustained alteration of the water quality downstream, especially after the confluence of the Morón Stream, and that the deterioration has increased with time. A progressive downstream decrease of dissolved oxygen from 7-8 mg L^{-1} at S1 to 0-0.3 mg L^{-1} at S5 characterized this river over the study period. Conversely, BOD_5 increased towards the mouth (maximum 49.3 ± 7.5 mg L^{-1}) in coincidence with enhancements of chemical oxygen demand (COD) that was consistently higher (maximum at S4 194.6 ± 25.7 mg L^{-1}). Thus, the resulting COD/BOD ratios between 11 at headwaters and 4 at the lower section suggested the presence of important amounts of non-biodegradable organic matter. Domestic sewage indicators and municipal wastes such as chlorides, dissolved nutrients and phenols increased abruptly after the input of the Morón Stream, achieving values well above the maximum guide levels (GLs) established by Argentine law for protection of freshwater life. Total heavy metals concentrations always largely exceeded GLs (zinc 700, cadmium 7900, chrome 300 µg L^{-1}), and organochlorine insecticide levels exceeded these limits from 40 to 400 fold. In a similar way, the river water showed an alarming degree of bacterial pollution. Some years later, Arreghini (2008) evidenced a further deterioration of the water quality in the middle and lower stretches with almost persistent anoxia, high phosphorus, carbon, nitrogen (mainly as ammonium) and dissolved chloride, which were directly related to waste water and domestic discharges. The worst conditions once again appeared downstream the confluence with the Morón Stream due to the high heavy metal concentrations.

Phytoplankton

In the river surveys performed (Loez & Salibián, 1990; Castañé et al., 1998), 160 phytoplankton taxa were registered. Algal density generally ranged between 1.6 x 10^3 and 25.6 10^3 ind ml^{-1}, though values up to 13 x 10^8 ind ml^{-1} were achieved when blooms occurred. Phytoplankton abundance generally increased along the river up to S2 (1984-1985) and even up to S4 (1993-1996), it then decreased downstream near to its mouth (S5) (Fig. 2) in a similar way to species richness. The increasing trend was explained as a response to the augmentation of nutrients, whereas the decline in the vicinity of the downstream section is attributed to stress caused by elevated hardness and heavy metals concentrations. Chlorophyll *a* concentrations were relatively low (mean 4 μg l^{-1}) for the 1985-1987 period, though a peak of 35 μg l^{-1} was detected in coincidence with a great summer development of *Aulacoseira granulata* var. *angustissima* at the onset of the 1985 summer; during the 1993-1996 survey, chlorophyll *a* mean increased to 30 μg l^{-1}. Bacillariophyta constituted the bulk of the river´s phytoplankton density (40-98%) and Chlorophyta subdominated (10-45%). Other groups presented more relevance in definite stretches: Euglenophyta increased near to the mouth (S5) and Cyanobacteria at S2. Loez & Topalián (1999) asserted that the differences in composition between the upstream and downstream stretches corresponded to the significant differences in physical and chemical parameters. In particular, the density of all algal classes was significatively related with dissolved oxygen concentration (Loez & Salibián, 1990). Several species presented a regular temporal and spatial occurrence in this polluted river (Table 1).

The negative influence of high concentrations of heavy metals on phytoplankton was proved by the responses of natural river phytoplankton communities to different zinc concentrations assayed in the laboratory. These bioassays (Loez et al., 1995) evidenced a decrease in species diversity, richness and equitability and the thriving of few zinc-tolerant species (Table 1). Loez & Salibián (1990) showed concordance of laboratory and field results, as they registered an augmentation of Chlorophyta in the 1987 summer with highest Zn concentrations in the river water, which were explained by the high tolerance of Chlorella vulgaris in the bioassays performed.

Luján River

General features

The Luján River flows over 128 km draining an area of 3,300 km^2 in the North West of Buenos Aires Province (34°15’S 59°37’W), joins the Paraná River Delta and discharges to the Río de la Plata Estuary (Fig. 3). The river is divided in three stretches: an upper reach of 47 km, the middle reach of 30 km and the lower reach of 60 km. The hydrological regime is defined by rainfall and underground seepage in the middle and upper reaches, whereas in its lower reach it is influenced by the discharge fluctuations in the Paraná River, the tidal regime of the Río de la Plata and strong southeastern winds (sudestadas). The annual average discharge is 5.4 m^3s^{-1} in the middle reach, while in the lower reach it varies between 18 and 204 m^3s^{-1} upstream and downstream the Gobernador Arias Channel (Delta region), respectively. In the upper and mid reaches, the Luján River flows over flatlands rich in organic matter, with intense agriculture and livestock activity. Several cities are located on the riverside: Suipacha, Mercedes Luján and Pilar. In its lower reaches it flows over lowlands, and is characterized by a widening floodplain. The lower inferior reach receives the highest concentration of a wide range of industrial activities and urban wastewaters with practically no treatment through tributaries of increasing discharge (Escobar, Garín, Claro, Reconquista via the Relief Channel).

Feijoó et al. (1999) found that most of the watershed streams inflowing to the main course of the Luján River had high nutrient concentrations and evidenced a pollution gradient that increased downstream. In particular for the Lower Basin, Lombardo et al. (2010) asserted that the river´s longitudinal spatial variations evidenced major discontinuities due to the riverine and deltaic water influenced zones, area from where water quality amelioration was evident. Nevertheless, the influence of anthropogenic activities occurred, mostly in relation to the input from the above mentioned polluted watercourses flowing through urban and industrial areas, as the dissolved heavy metals concentrations (Cr, Cu, Cd, Pb, Zn) were frequently above freshwater GLs for aquatic life.

Phytoplankton

The phytoplankton studies carried out along the Luján River in different stretches over the past two decades cover almost its entire length, thus allowing to assembly a longitudinal picture of the structure and dynamics of this community. Fig. 3 integrates the sampling sites of the different studies performed in this river.

del Giorgio et al. (1991) analysed the upper and middle reaches (from headwaters-S1, Mercedes-S2, Luján-S3, down to Pilar-S4) (Fig. 3) and recorded 167 taxa within a seasonal succession characterised by dominance of Bacillariophyta with a brief summer Chlorophyta phase. The community dynamism was attenuated at the more polluted sites, concomitant with an increased predominance of a broad-tolerance algal assemblage, co-dominated by *Cyclotella meneghiniana* and *Nitzschia umbonata*. Changes in the phytoplankton structure and dynamics involved alterations in the distribution and relative proportions of the algae, rather than modifications in the basic species composition. Several species presented a constant occurrence along the river: *Crucigeniella neglecta, Dictyosphaerium pulchellum, Didymocystis bicellularis, Eudorina elegans, Monoraphidium arcuatum, M. komarkovae, M. minutum, M. pusillum, Oocystis novae-semliae, Pediastrum tetras,* *Scenedesmus quadricauda, Amphiprora alata, Cyclotella meneghiniana, Gomphonema parvulum, G. subclavatum, Navicula cuspidata, Nitzschia denticula, N. sigma, N. umbonata, Pinnularia viridis, Pleurosira laevis* and *Ulnaria ulna.* The alteration of phytoplankton was only partially reflected in a slight decrease in species diversity at the more polluted sites. The recorded inter-annual differences were related to a change in the pattern of discharge, mainly decreasing diatom density in more wet/rainy periods. Phytoplankton density ranged from less than 1,000 ind ml^{-1} to 46,000 ind ml^{-1} at Luján during summer time. As a response to increasing nutrient enrichment, algal density generally increased from headwaters to the city of Luján, where the river expands and current velocity decreases producing a more favourable habitat for algal multiplication. Despite the highest nutrient concentrations were recorded at S4 (500-700 µg L^{-1} TP, > 15,000 µg L^{-1} TN), abundances tended to decline probably due to enhanced current velocity in combination with increased organic wastes (BOD_5 2-24 mg L^{-1}) and heavy metals releases in this area densely occupied by industrial settlements. The upper section showed very weak phytoplankton density relationships with the remaining downriver sites, as there was a marked abundance increase from this unpolluted site to S2 where high levels of nutrients supplied by natural runoff were supplemented by domestic and industrial effluents. Chlorophyta dominated in spring comprising more than 50% of total phytoplankton and reached up to 70% during summer. Bacillariophyta increased in autumn and winter attaining up to 90%. Cyanobacteria rarely grew to significant concentrations, except for strong ephemeral pulses during periods of extremely low flow in summer, when *Merismopedia minima* and *M. tenuissima* attained densities of over 10,000 ind ml^{-1}. Euglenophyta presented density maxima in spring and autumn (*Phacus* sp.) and their relative importance increased downriver near the cities of Luján and Pilar, comprising up to 30% of total phytoplankton.

Recently, Platarotti (2010) made an intensive study in the middle reach of the Luján River (Fig. 3) and found that the accelerated urbanization and industrialization had a severe impact on the water quality in the Pilar zone. Despite total phytoplankton structure remained quite similar to that described by del Giorgio et al. (1991) some 20 years before, there were some differences that indicated a deterioration. Abundance attained higher values, up to 10^3 ind ml^{-1} downriver the city and industrial parks of Pilar. The alternation between Bacillariophyta in cold seasons and Chlorophyta in warm seasons was not so evident: diatoms, once again dominated (*Cyclotella meneghiniana*), and comprised more than 50% of the community in winter and Chlorophyta prevailed until summer, but in this survey Cyanobacteria occurred from July to December with higher and more even proportions.

O'Farrell et al. (2002) assessed the water quality in the Lower Luján River (Fig. 3) by using phytoplankton and algal bioassays and described three distinct sections. The first reach (S5), was not affected by the Paraná River and presented the lowest current velocity and discharge, low dissolved oxygen concentrations, extremely high nutrient (N mainly as ammonia exceeded the GLs of 1.37 mg L^{-1}) and heavy metal concentrations, thus appearing similar to the most polluted stretches of the middle reach. Likewise, chlorophyll *a* values were very high with a mean concentration of 316.2 µg L^{-1}. Diatoms dominated due to abundant populations of *Cyclotella meneghiniana*, *Nitzschia palea* and *N. umbonata*. Chlorophyta subdominated (small Chlorococcales, especially *Chlorella vulgaris*), whereas Cyanobacteria and Euglenophyta (represented by species of *Euglena*, *Lepocinclis* and *Phacus*) never exceeded 10% of total phytoplankton. When the Luján River changes its direction flowing parallel to the River Paraná, it receives waters from small tributaries that connect both courses enhancing discharge and consequently, diluted concentrations of nutrient and other ions, as well as low phytoplankton density were observed. In this section, transparency decreased by the input of suspended solids and light resulted the control factor for phytoplankton abundance ($r=0.93$, $p<0.05$). Notwithstanding, phosphorus also promoted abundant Chlorophyceae ($r=0.75$, $p<0.05$) as shown by the peak of small Chlorococcales at S7 under high phosphate and chloride concentrations, probably associated to the upriver discharge of the Escobar Stream (Fig. 3) that receives waste waters from urban and industrial areas. The poor water quality still prevailing in this stretch was evidenced by the growth inhibition of *Selenastrum capricornutum* cultures exposed to river water indicating, either acute toxicity or alguicidal and alguistatic effects. Further downriver, there is a change in hydrological conditions after the confluence of the Arias Channel (Fig. 3) that increases one order of magnitude the discharge of the River Luján and determines an even higher suspended matter load, which limited the abundance of Chlorophyta ($r=-0.62$, $p<0.05$), Euglenophyta ($r=-0.73$, $p<0.05$) and Cryptophyta ($r=-0.59$, $p<0.05$). Total phytoplankton density decreased progressively and *Aulacoseira granulata*, well adapted to light intensities and favoured by the increasing depth that promotes its entrainment in the turbulent field, prevailed in this last section. This scenario has been also described in detail by Echazú (2004). The bioassays performed in this section reflected an improvement in water quality as alguistatic rather than alguicidal effects were observed. Nevertheless, the impact of highly polluted tributaries flowing through inland industrial parks and cities was reflected in occasional changes in the phytoplankton structure, such as increased phytoplankton density and species diversity loss (Fig. 4). Diversity shifts in the lower reach reflected not only the negative influence of the inflowing waters from upriver reaches (S5) and polluted tributaries (Reconquista waters incoming via the Relief Channel, between S9 and S10), but also the species inputs from the Paraná and deltaic systems, as seen by the highest values in the confluence with the Arias Channel (between S7 and S8, Paraná waters) (Fig. 4). In particular, Maidana et al. (2005) described how a hydraulic practice implemented as a flood alleviation measure resulted in a severe ecological degradation of the Relief Channel with the consequent pollution diffusion downstream the Luján River. In this case study, the authors clearly depicted how the altered conditions at the Relief Channel affected the structure and composition of the diatom assemblage in the Luján River downstream the confluence of the two courses.

Streams

General features

Several fourth or inferior-order streams, in urban and suburban areas receive a concentration of pollutants that exceed their capacity of self-purification. Given their low flow rates, the streams have limited transport capacity. The low current velocity, the absence of riparian trees, and the high concentrations of nutrients characteristic of pampean streams favor the development of dense macrophyte communities of broad diversity (Rodrigues Capítulo et al. 2010). The deterioration of water quality in the headwater of these streams is mainly due, to agricultural and cattle-rearing activities, and downstream to wastewater from households and industrial effluents (Tangorra et al., 1998; Gómez & Rodrigues Capítulo, 2001; Bauer et al., 2002a; Bauer, 2009).

Phytoplankton

In streams with current velocities below 0.4 s^{-1}, and particularly in those segments with higher nutrient concentrations, phytoplankton density exceeded 10^4 cells ml^{-1}. Chlorophyll *a* was variable and ranged between 10 and 400 mg l^{-1}

between sites of low and high anthropic impact, respectively (Rodrigues Capítulo et al., 2010). Bauer (2009) recognized that poor water quality, mainly related to urban and industrial uses, produced an increase of the relative abundance of non-loricated Euglenophyta and Chlorophyta and a decrease in diversity. Among the species frequently associated to the deterioration of the water quality, the filamentous Cyanobacteria *Jaaginema subtilissimum*, *Phormidium chalybeum* and *Oscillatoria tenuis*, the Chlorococcales *Golenkinia radiata* and *Dictyosphaerium pulchellum* and the pennate diatoms *Gomphonema parvulum*, *Nitzschia palea*, *N. umbonata* and *Pinnularia gibba* were found. These species were related to water qualities with BOD_5 >20 mg L^{-1}. Other species such as, *Crucigeniella rectangularis*, *Dictyosphaerium pulchellum, D. subsolitarium, Monoraphidium arcuatum, M. griffithii, Lepocinclis salina,, Strombomonas scabra* and *Nitzschia gracilis* appeared frequently with phosphate concentrations > 1 mg L^{-1}, whereas *C. rectangularis, D. pulchellum, M. arcuatum, M. griffithii, Euglena acus, L. salina,* and *S. scabra* were better represented in water qualities with ammonium > 1 mg L^{-1}.

A clear response of phytoplankton to pollution and hydraulic discontinuity was observed in these small watercourses; such is the case registered in the

Rodriguez Stream by Bauer et al. (2002b) (Fig. 5). The headwaters of this stream are affected by horticulture and extensive cattle husbandry, whereas the downstream stretch receives the effluent from a meat packing industry and its hydraulic characteristics are modified by a small artificial pool, after flows through an urban area. The main structural descriptors of phytoplankton were modified by the increase of nutrients and organic matter. As water quality decreased, phytoplankton concentration increased, particularly unicellular non-motile chlorophytes ($p<0.001$). On the other hand, loricated euglenophytes, total phytoplankton diversity and evenness ($p<0.05$) decreased; the increase of phosphorous concentrations stimulated the development of small chlorococcaleans ($p<0.001$) such as *Golenkinia radiata* and *Dictyosphaerium subsolitarium*. The values of the saprobic index reflected this impoverishment of water quality reaching values related to alpha-mesosaprobic states. The effect of the hydraulic discontinuity generated by the artificial pool was immediately reflected downstream due to the wide predominance of planktonic species (99%) decreasing gradually as the water residence time diminished and water velocity increased (0.32 m s^{-1} upstream – 0.72 m s^{-1} downstream).

The effects caused by dredging were also analysed in this stream. The main consequences in the water course were the disturbances in the stream bed, by removal and destabilization of the substrate, which generated chemical changes and decreased light penetration in the water column. Suspended solids, soluble reactive phosphorus and dissolved inorganic nitrogen were significantly higher in post-dredging periods (Licursi & Gómez, 2009). Phytoplankton total density, relative abundance of loricated euglenophytes, number of species and concentration of phaeophytin also showed significant changes (Fig. 6) (Bauer, 2009). A detailed analysis on the euglenophyte assemblage, during the pre and post-dredging period allowed identifying 89 species. The modifications in the habitat during the post-dredging period led to a loss in the diversity of this group. In general, the naked species, especially *Lepocinclis acus, L. oxyuris and Phacus tortus*, were favoured after the dredging. The species richness of *Trachelomonas* diminished strongly, and only the species with small, dark brown coloured and less ornamented lorica were found in the altered habitats. On the contrary, *Strombomonas* increased its diversity, specially those taxa belonging to the "scabra group" which presented high amounts of particles adhering on its surface (Conforti et al., 2009). These examples highlight the remarkable changes which can take place in these small streams when exposed to factors of anthropic stress, being the phytoplankton an appropriate alternative for the evaluation of the water quality.

Final remarks

The characteristic phytoplankton structure and dynamics described by Reynolds & Descy (1996) for lowland rivers appear somehow distorted in these polluted courses, or at least at certain reaches, as the alternating dominance of small centric diatoms and chlorococcaleans was biased depending on the level of deterioration of water quality. Moreover, other groups such as Euglenophyta or Cyanobacteria prevailed in the most polluted river stretches. Likewise, the characteristic pattern of increasing phytoplankton density generally observed towards river mouths, was not always registered as the deterioration of water quality increased downstream in most of these suburban watercourses. The impact of discharges on phytoplankton could be clearly depicted in cases where deterioration was very high by the identification of tolerant species or algal assemblages that characterise different degrees of pollution. However, if the worsening of water quality was either progressive or slight, complex structural alterations preceded considerable compositional changes. A decrease of both species diversity and richness under the stress caused by demise in water quality mainly applied in cases of severe pollution.

The bioassays performed with different natural populations or communities from these polluted lowland rivers, revealed tolerance or sensitivity patterns that were reflected in the characteristic assemblages found in the longitudinal dimension of each system.

Finally, the modifications generated by the present climatic change must be added to the present state of deterioration of the watercourses flowing through urban areas of the pampean plain. The future climate-change scenarios proposed for the pampean area predict an increment in rainfall that will strongly affect the biological communities. Higher rainfall can increase erosion and generate flooding, thereby enhancing the transport of sediments, nutrients, and contaminants so as to affect the degree of water mineralization. Changes in water discharge and turbidity would affect the residence time and the light penetration of the water column. These factors will no doubt introduce changes in the structure and functioning of the plankton producers which will be reflected on the dynamics of the aquatic ecosystems. This new situation will require more investigations focused in the knowledge of the dynamics of phytoplankton in urbanized rivers, thus favouring the interpretation of the functioning of these watercourses under these new scenarios of environmental stress.

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Table 1: Species with constant occurrence during 1985-1987 and 1993-1996 in the River Reconquista (from Loez & Topalián 1996). Observations from field and bioassays with natural communities are here presented.

	1985-87	1993-96	Field observation	Bioassays
Merismopedia punctata			summer bloom	
Microcystis aeruginosa	x	x	summer bloom	
Phormidium chlorinum	x	x		
Choricystis chodatii			summer bloom	
Coelastrum microporum	x			
Dictyosphaerium ehrenbergianum	x			
Eudorina elegans	x			
Monoraphidium arcuatum	x	x		
Pandorina morum	x			
Pediastrum boryanum	x			
Pediastrum duplex	x			
Scenedesmus acuminatus	x			
Scenedesmus quadricauda	x			
Chlorella vulgaris		x	summer blooms	Zn tolerant
Crucigenia crucifera		x		
Euglena acus	x	x		
Euglena oxyuris	x			
Lepocinclis salina	x			
Phacus tortus	x			
Phacus undulatus	x			
Srombomonas verrucosa	x			
Aulacoseira granulata var. granulata	x			
Aulacoseira granulata var. angustissima		x	late spring bloom	
Cyclotella meneghiniana		x	winter bloom	
Gomphonema parvulum				Zn tolerant
Melosira varians	x			
Nitzschia palea	x	x		Zn tolerant
Nitzschia sigma	x			
Synedra acus				Zn tolerant
Synedra ulna var. amphirhynchus	x			Zn tolerant

Figure Captions

Fig. 1: Matanza-Riachuelo basin: a) distribution of dissolved oxygen concentrations, highlighting the anoxia conditions in the middle and low sectors of the Matanza-Riachuelo basin, adapted from ACUMAR (2008) and b) average chlorophyll *a* distribution in the Matanza-Riachuelo basin during 2008.

Fig. 2: Geographical localization of sampling sites in the Reconquista River Basin: S1 Cascallares, S2 Gorriti, S3 Paso del Rey, S4 Parque San Martín, S5 Bancalari, adapted from Loez et al. (1993).

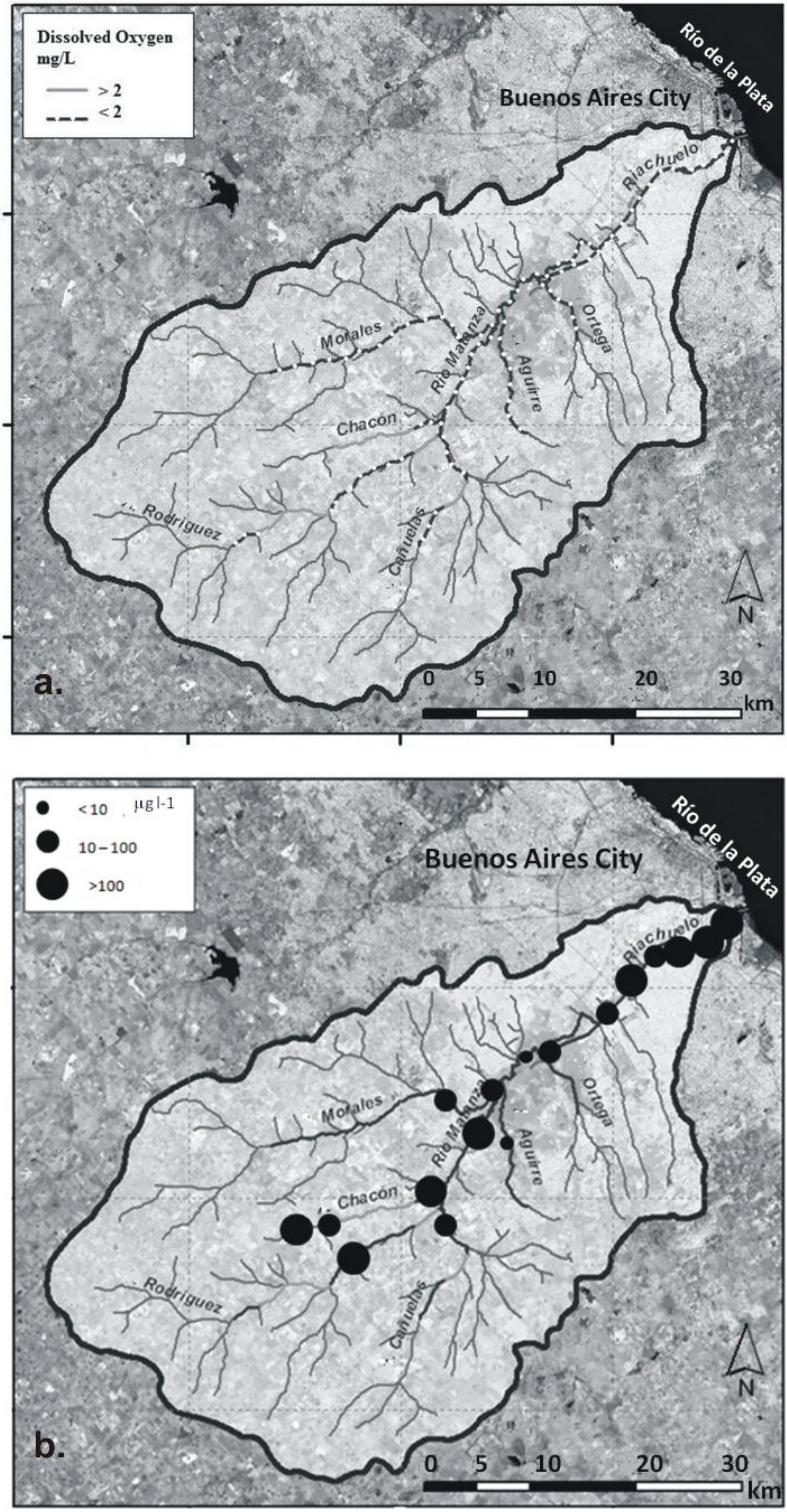
Fig. 3: Map of the Luján River Basin indicating the sampling sites analysed by del Giorgio et al. (1991) in the upper and middle reaches (S1, S2, S3, down to S4), Platarotti (2010) at S4 and O'Farrell et al. (2002) in the Lower Luján River (S5 to S10).

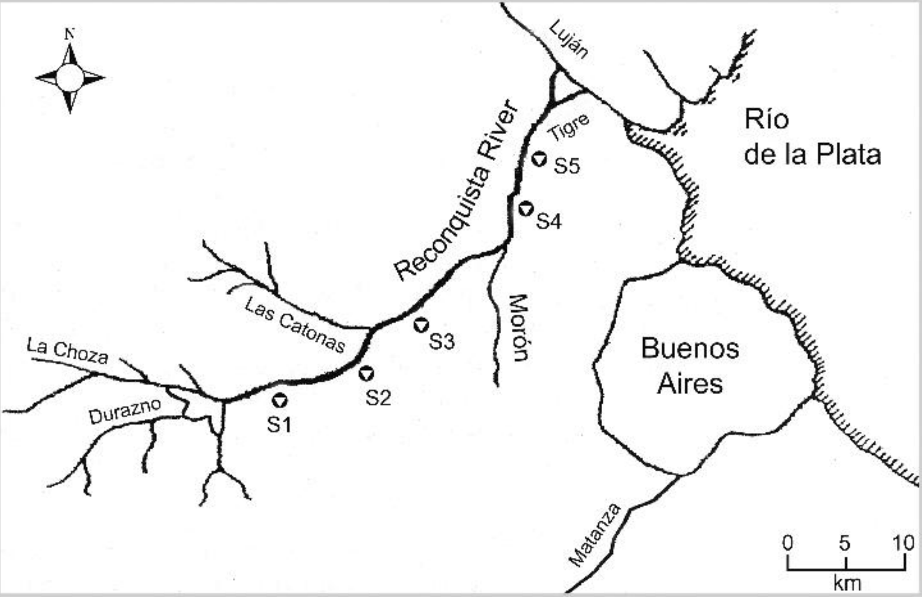
Fig. 4. Seasonal diversity changes in the lower reach of the Luján River.

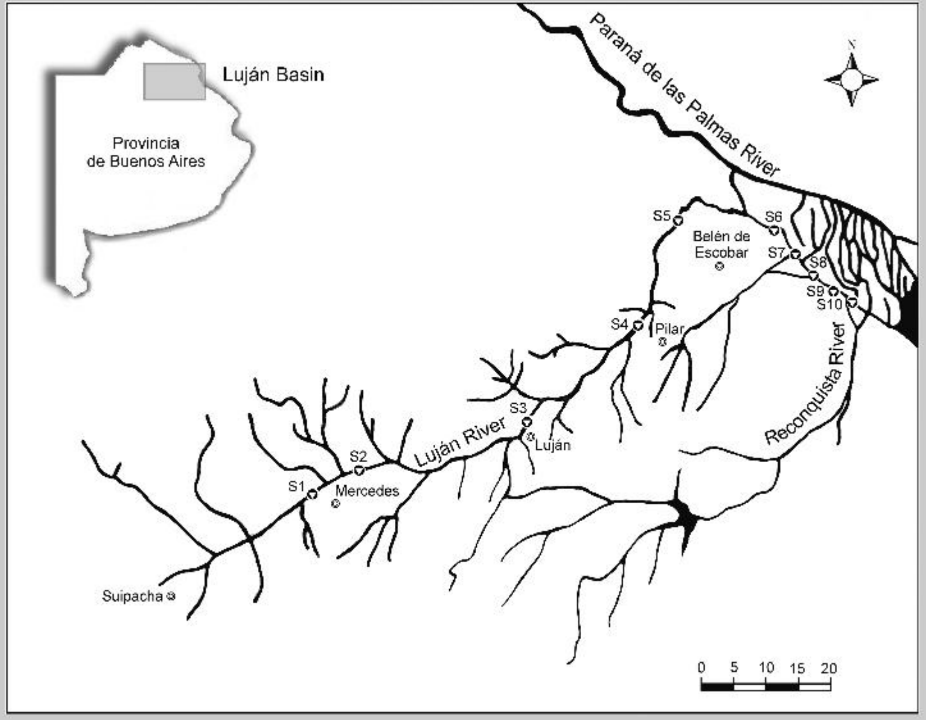
Fig. 5. Rodriguez Stream, sampling sites and details of the pool connected to the stream.

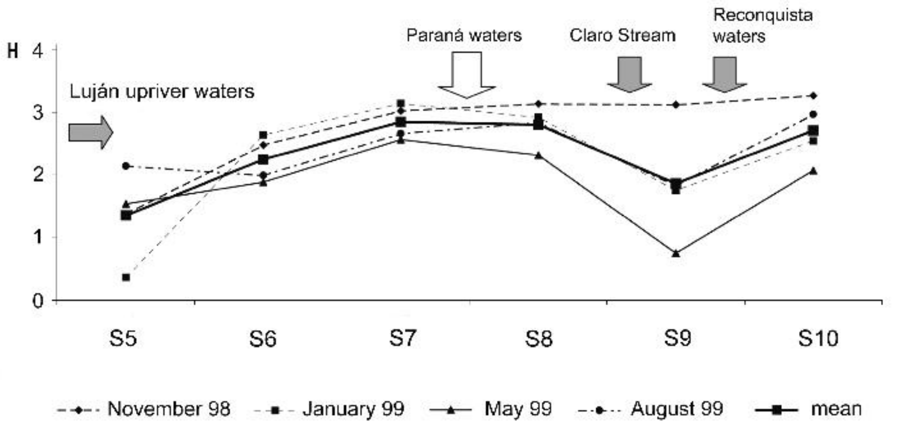
Fig. 6. Significant changes observed in phytoplankton during pre and post-dredging periods in the Rodriguez Stream. The arrows indicate the start of the

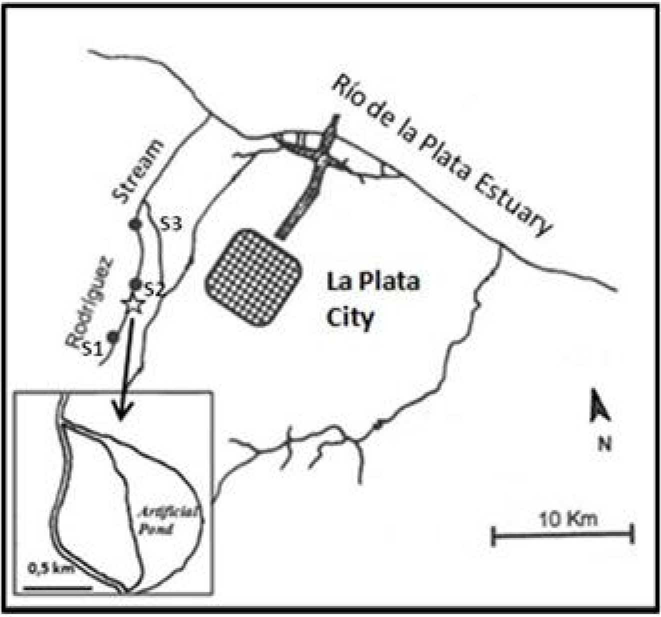
dredging works in sites 1 and 2. During the study site 3 wasn’t dredged, but it received an important quantity of suspended solids during the last 3 weeks.

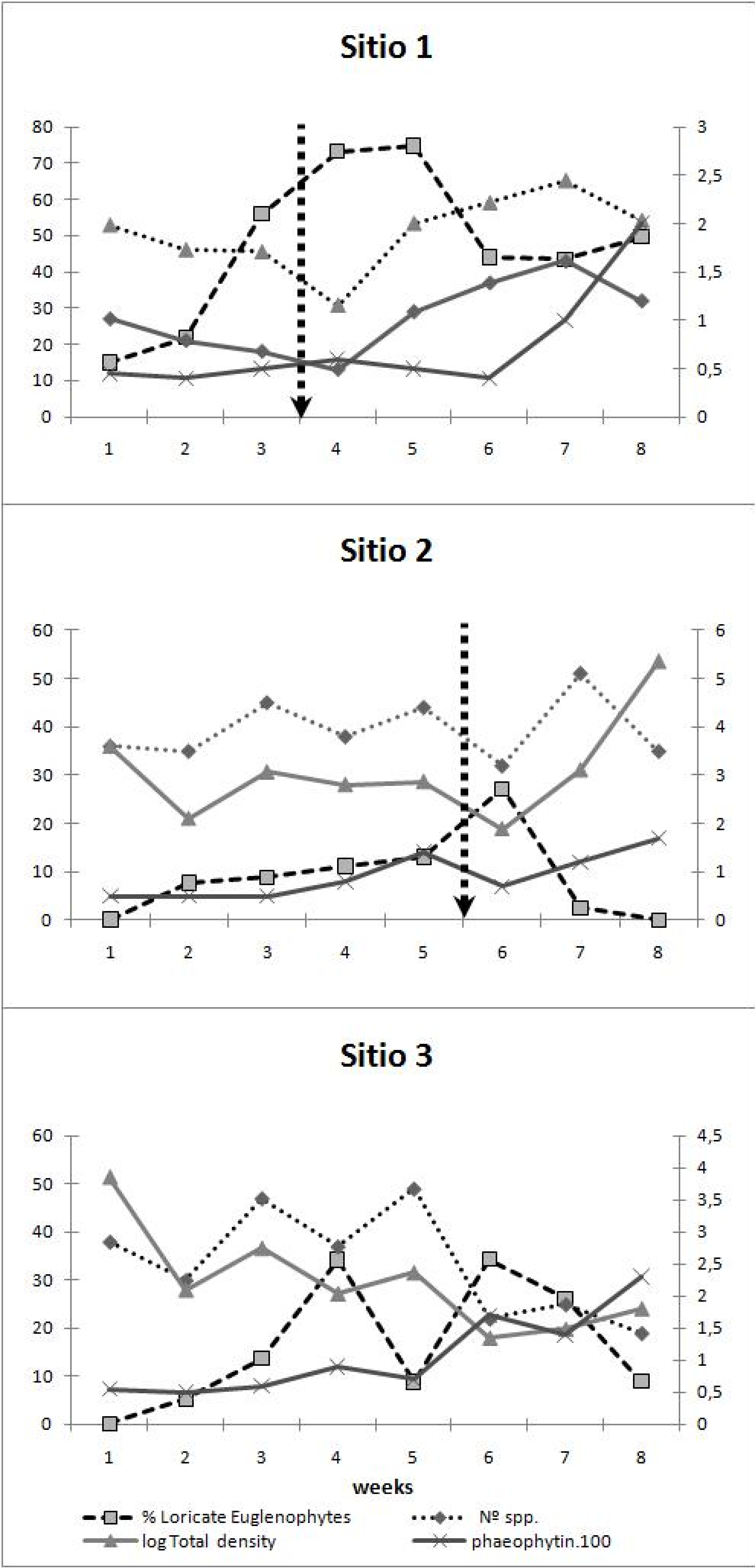

Dissolved Oxygen
mg/L
> 2
< 2
Río de la Plata
Buenos Aires City
Riachuelo
Morales
Río Matanza
Aguirre
Ortega
Chacón
Rodriguez
Cañuelas
N
a.
0 5 10 20 30
km
< 10 μg l-1
10 – 100
>100
Río de la Plata
Buenos Aires City
Riachuelo
Morales
Río Matanza
Aguirre
Ortega
Chacón
Rodriguez
Cañuelas
N
b.
0 5 10 20 30
km


N
Luján
Río
de la Plata
Tigre
S5
Reconquista River
S4
Las Catonas
Morón
S3
La Choza
S2
Buenos
Aires
Durazno
S1
Matanza
0
5
10
km


Luján Basin
Provincia de Buenos Aires
Paraná de las Palmas River
S5
S6
Belén de Escobar
S7
S8
S9
S10
S4
Pilar
Reconquista River
S3
Luján River
Luján
S2
S1
Mercedes
Suipacha
0 5 10 15 20


H
4
3
2
1
0
Luján upriver waters
Paraná waters
Claro Stream
Reconquista waters
S5
S6
S7
S8
S9
S10
November 98
January 99
May 99
August 99
mean


Río de la Plata Estuary
Rodriguez Stream
S3
S2
S1
La Plata City
Artificial Pond
0,5 km
N
10 Km


Sitio 1
80
70
60
50
40
30
20
10
0
3
2,5
2
1,5
1
0,5
0
1
2
3
4
5
6
7
8
Sitio 2
60
50
40
30
20
10
0
6
5
4
3
2
1
0
1
2
3
4
5
6
7
8
Sitio 3
60
50
40
30
20
10
0
4,5
4
3,5
3
2,5
2
1,5
1
0,5
0
1
2
3
4
5
6
7
8
weeks
% Loricate Euglenophytes
Nº spp.
log Total density
phaeophytin.100