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Freshwater Phytoplankton from Argentina

Phytoplankton of the reservoirs of Central and North Patagonia

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With 2 figures and 5 tables

Abstract: The basins of the Limay, Neuquén, and Negro rivers comprise the greatest hydrographic system developed in its entirety in Argentina. The reservoirs constructed in this basin are distinguished by their numbers, dimensions and unitary system of management. Within the framework of environmental-monitoring programs carried out from 1977 to the present, 394 species were identified in these systems. Only 30 taxa were common to all the reservoirs. Some of the dominant taxa were: *Anabaena* spp. (toxic complex), *Ceratium hirundinella*, *Gymnodinium* sp., *Asterionella formosa*, *Aulacoseira ambigua* var. *ambigua* f. *spiralis*, *Aulacoseira pseudogranulata*, *Aulacoseira subarctica*, and *Stephanodiscus niagarae*. Chlorophyta and Chrysophyta were the algal groups with the highest species richness. The Cyanobacteria played a significant role, and so, two agendas for monitoring algal blooms were developed in the basin: (a) at one sampling station on the Limay River (near Arroyito Reservoir), (b) in the Mari Menuco reservoirs of the Neuquén River. *Anabaena* spp. (*toxic complex*) was seen to exhibit the greatest abundance between the spring, the summer, and the beginning of the autumn. Another reservoir that has been the object of limnological investigations since 1990 is the Florentino Ameghino, situated within the eastern-central region on the Chubut River. The centric diatoms – principally *Aulacoseira granulata, Stephanodiscus* sp., and *Cyclotella* sp. were the best represented in this reservoir. The phytoplankton was composed of species characteristic of mesotrophic to eutrophic lakes.

Keywords: Phytoplankton, reservoirs, Argentinean Patagonia

Introduction

The reservoirs constructed in the north of the Patagonian Plateau within the Río Negro River basin are distinguished by their numbers, dimensions, and unitary system of management. These artificial water bodies have been the object of numerous environmental studies from the time of their origin – and the phytoplankton therein is hardly an exception. Indeed, in

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1977, five years after the construction of the first and most extensive structure to date – to form the Exequiel Ramos Mexía Reservoir – known as El Chocón Dam, monitoring programs for planktonic and benthic algae were already under way. During the investigations of those years was a plethora of technical documentation generated yielding extremely valuable information on the evolution of those water bodies (Guarrera et al. 1981, 1985, 1986, 1987, 1995, Echenique et al. 1988, Guerrero et al. 1991, Mariazzi et al. 1991, Guarrera & Echenique 1992a, 1992b, 1995, Echenique & Guarrera 1994, Echenique & Guerrero 2003).

Diverse studies have been carried out over the years, both during the construction of newer, more recent reservoirs in the basin and afterward. In this chapter we have selected certain periods in which the investigations on the phytoplankton were more complete and systematized and were carried out during various consecutive yearly cycles. Accordingly, two time intervals are represented: (A) the period 1995–1999 with information on all the reservoirs existing at the present time, with the single exception of Pichi Picún Leufú, which was under construction during those years (Alcalde et al. 1996, AIC 1999), and (B) the cycle 2005–2009 for those reservoirs (or associated rivers) chosen to be part of the program Control of Algal Blooms (AIC, 1999, 2004, 2010a, 2010b). A large part of the information presented is found in the bulletins pertaining to the Autoridad Interjurisdiccional de las Cuencas de los Ríos Limay, Neuquén y Negro (Interjurisdictional Authority of the Limay, Neuquén, and Negro River Basins), a. k. a. the AIC, to which authority the authors are grateful for the permission to utilize those records.

Another reservoir that has been the object of limnological investigations is the Florentino Ameghino, situated within the eastern central region on the Chubut River. The majority of the studies on the phytoplankton on this reservoir were carried out by Sastre et al. (1991b, 1994b, 1994c). Other publications refer to the Chubut River (Ivanissevich et al. 1991, Sastre et al. 1991a, 1994a, 1996, Santinelli Cortés et al. 1992) along with publications on algal taxonomy (Otaño et al. 1994, Otaño & Santinelli 1995). Later on investigations of monitoring by consulting agencies were also conducted (Peralta 2006).

Reservoirs of the Río Negro River Basin

The basins of the Limay, Neuquén, and Negro rivers (total area, 115,800 km^2) comprise the greatest hydrographic system developed in its entirety in Argentina. The Limay and Neuquén basins, consisting in more humid zones at their sources in the Andes mountain range, cross arid plateaus to the east down to their confluence. The Río Negro River likewise runs across the arid plateaus, but with reduced downward slopes and secondary branches that contain numerous islands down to their mouth in the Argentine Atlantic. In these basins is found approximately 34% of the dammed-off area in Argentina, through structures constructed in the biogeographic province of Monte – with the sole exception of the reservoir of Alicura, it in the Subantarctic Domain. The reservoirs Alicura, Piedra del Águila, Pichi Picún Leufú, Exequiel Ramos Mexía (with the El Chocón Dam), and Arroyito are located on the Limay River and the Los Barreales and Mari Menuco reservoirs on the Neuquén (Fig. 1).

The natural hydrologic cycle of these basins – where two phases are usually well distinguished by their flow rates of ebb (low discharges at the end of summer) and surge (high discharges resulting from the winter precipitations and the spring thaws) – have been altered

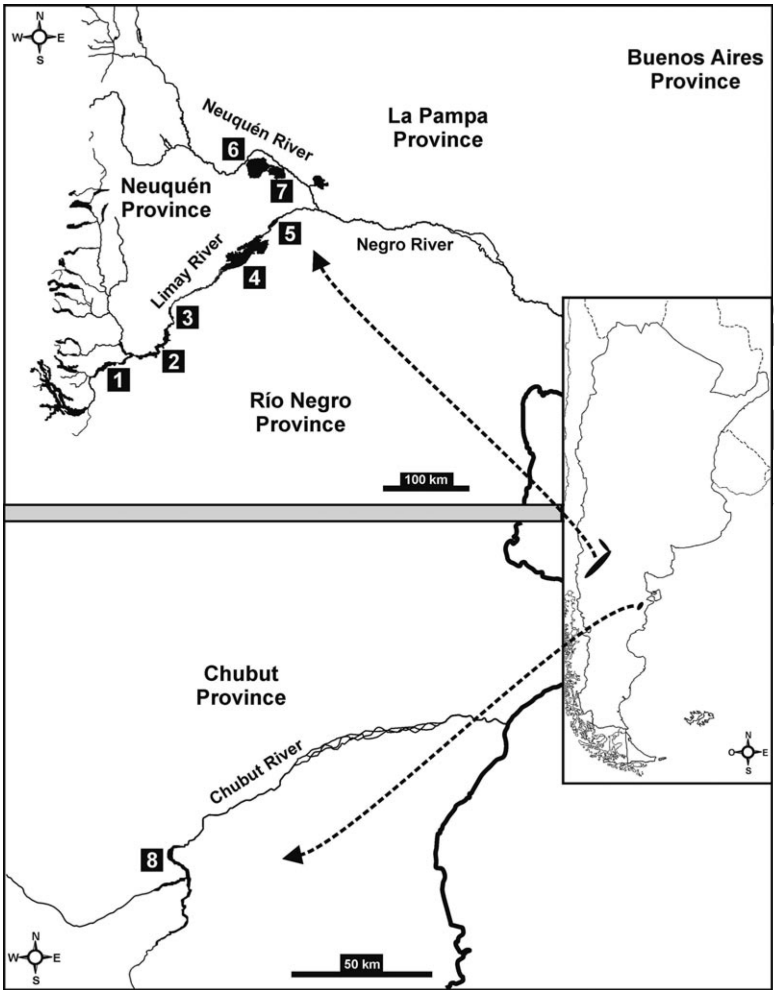

Fig. 1. Location of the Limay, Neuquén, Negro and Chubut river basins. Key to reservoirs: 1) Alicura, 2) Piedra del Águila, 3) Pichi Picún Leufú, 4) Exequiel Ramos Mexía, 5) Arroyito, 6) Los Barreales, 7) Mari Menuco, 8) Florentino Ameghino.

after the construction of the major hydroelectric projects and their corresponding reservoirs. These changes have decreased the maximal and enhanced the minimal flows with a resulting closure of the branches of the rivers, an increase in the transparency of the water, and an augmented development of the primary producers. The water can be characterized as calcium bicarbonate and with a west-to-east gradient of increasing salinity and nutrient concentrations starting from the areas within the Andes Mountains and becoming maximal at the mouth of the Río Negro River (Cifuentes et al. 1995, 1996).

From 1970 to 2000, numerous projects were under construction in the Limay and Neuquén rivers involving flow regulation and hydroelectric-power generation that gave rise to

Table 1. Years of filling and principal morphometric and water-quality parameters of the reservoirs. Key to abbreviations: ALI = Alicura, PDA = Piedra del Águila, ERM = Exequiel Ramos Mexía, ARR = Arroyito, LB = Los Barreales, MM = Mari Menuco, Z = water depth, MWLC = Maximum water-level change, PEA = potential exposure area, WRT = water-residence time, WRR = water-renewal rate, LB = length of the banks, * = approximated, TP = total phosphorus, TN = total nitrogen ** = occasional summer stratification, SP = stratification period, TS = trophic state, Su = summer, N = never, OTR = oligotrophic, MTR = mesotrophic.

	ALI	PDA	PPL	ERM	ARR	LB	MM
Morphometric parameters							
Area (km^2)	65	285	19	826	35	407	176
Volume (km^3)	3.1	12.0	0.2	20.2	0.3	28.2	13.9
Z mean (m)	48.3	40.0	11.4	23.4	8.5	69.1	78.9
Altitude (m a.s.l.)	705	592	479	381	315	422	415
MWLC (m)	13	16	2	10	5	10	3
PEA (%)	17.6	22.3	s/d	19.7	16.2	8.6	3.2
WRT (year)	0.36	0.52	0.01	0.96	0.01	2.84	1.40
WRR (year $^{-1}$)	2.8	1.9	111.9	1.0	73.4	0.3	0.7
LB (km)	183	586	74	373	50	263	98
Z max.* (m)	115	120	25	60	20	110	125
year of filling	1980	1990	2001	1972	1978	1975	1977
Water-quality parameters							
Temp. (ºC)	12.5	13.0	11.5	14.3	14.6	15.2	15.1
Cond. (mS cm^{-1})	36	50	57	86	87	214	215
pH	7.4	7.0	7.0	7.7	7.8	8.0	8.0
Transparency (m)	7.3	6.7	4.6	4.5	3.8	2.4	7.4
DO (mg L^{-1})	9.4	10.0	9.7	9.1	9.1	8.8	8.9
Chl *a* (mg L^{-1})	0.6	1.1	0.6	1.7	1.6	0.9	0.7
TP (mg L^{-1})	8	10	12	14	14	20	11
TN (mg L^{-1})	58	72	79	98	84	84	67
SP	Su	Su	N	N*	N	Su	Su
S	OTR	OTR	MTR	MTR	MTR	MTR	OTR

the aforementioned reservoirs, whose years of filling, principal morphometric parameters and water qualities are summarized in Table 1. The dams in both of these rivers were built in fundamentally different manners: whereas in the Limay a chain of five reservoirs were constructed along some 300 kilometres directly on the riverbed, in the Neuquén constructions were effected to deviate the water in order to fill up two enormous natural depressions that then became reservoirs.

The phytoplankton of the Alicura, Piedra del Aguila, E. Ramos Mexía, Arroyito, Los Barreales, and Mari Menuco reservoirs (1995–1999)

As of the year 1993 a permanent monitoring of the water quality in the reservoirs of the basin has been conducted and coordinated by the AIC. The bimonthly samplings are carried out by the hydroelectric-power companies and the analyses performed by diverse laboratories. Particularly during the period 1995–1999 samples were collected for assessment of the relative abundance of phytoplankton in open-water sampling stations within the vicinity of the dams and were analyzed in at the National University of La Plata.

Altogether 265 species were determined and the dynamics of their timing as well as their principal algal groups evaluated. The original relative-abundance data for each species (from 6 annual samplings in each reservoir over a five-year period) were converted into a numerical scale – 1, rare; 2, scarce; 3, frequent; 4, abundant; 5, very abundant; 10, dominant – with the objective of comparing the results among different years and over the four seasons of a given year.

Table 2 shows the species recorded in all the reservoirs and indicates the total number of taxa identified for each algal group and reservoir. Considering all the studied systems, Chlorophyta contributed with the highest species richness, but Chrysophyta (mainly diatoms), showed the higher number of species in most of the environments.

The Cyanobacteria have played a major role since the very beginning of the presence of the reservoirs in the Río Negro Basin. Blooms of *Dolichospermum circinale* (*Syn: Anabaena circinalis*) were reported since 1978 in the E. Ramos Mexía Reservoir just as during the filling stages and first years thereafter of the Alicura and Piedra del Águila reservoirs (see Echenique et al., this volume). After the biotic stabilization of the reservoirs occurring various years after their creation, the blooms of the *Anabaena* species have become concentrated in only certain ones (e.g., E. Ramos Mexía and Arroyito) and in general occur at the end of the spring and beginning of the summer. Of this genus, three very closely related species morphologically are responsible for these blooms – *A. circinalis, A. spiroides*, and *A. lemmermannii* – whose precipitous growth has constituted the cause of and rationale for the announcement of alerts for possible toxicity as well as for the coining of the sobriquet for the species of this genus as, collectively, "*Anabaena* spp. (toxic complex)".

Among the total species identified, 11% (30 taxa) were common to all the reservoirs. Of these latter, the following 8 species (3% of the total) were dominant at some moment within the seasonal cycle: *Anabaena* spp. (toxic complex), *Ceratium hirundinella*, *Gymnodinium* sp., *Asterionella formosa*, *Aulacoseira ambigua* var. *ambigua* f. *spiralis*, *Aulacoseira pseudogranulata*, *Aulacoseira subarctica*, and *Stephanodiscus niagarae*. Table 3 summarizes the seasonal succession of these species within the totality of the reservoirs. Any species found exclusively in a sole reservoir was never seen to become dominant in that same body of water during any season.

Table 4 shows the relative abundance of the algal groups during the seasons of the year in the different reservoirs. In the Alicura Reservoir diatom species predominate throughout the entire annual cycle, though principally in the winter and spring months (during the mixing period within the reservoir's thermal cycle) coinciding with the maximum biomass expressed

Table 2. Number of taxa corresponding to each algal group for the studied reservoirs; the total number of taxa found is indicated between brackets.

Species recorded in all the reservoirs	Total number of species per reservoir					
	ALI	PDA	ERM	ARR	LB	MM
TOTAL ALGAE (265 taxa)	113	98	130	103	110	84
CYANOPHYTA (27 taxa)	11	5	9	10	8	6
Anabaena sp. (Toxic complex)						
PYRROPHYTA (9 taxa)	5	5	6	5	6	5
Ceratium hirundinella						
Peridinium willeii						
CHLOROPHYTA (125 taxa)	49	39	49	41	40	36
Eudorina elegans						
Eutetramorus fottii						
Eutetramorus tetrasporus						
Pauschultzsia tenera						
CHRYSOPHYTA (99 taxa)	45	47	61	43	54	35
Asterionella formosa						
Aulacoseira distans						
Aulacoseira pseudogranulata						
Cyclotella meneghiniana						
Epithemia adnata						
Epithemia sorex						
Fragilaria crotonensis						
Gomphoneis herculeana						
Melosira varians						
Rhopalodia gibba						
Stephanodiscus niagarae						
Synedra ulna						
Urosolenia eriensis						
CHRYPTOPHYTA (3 taxa)	2	2	3	3	1	2
Chroomonas minuta						
EUGLENOPHYTA (2 taxa)	1	0	2	1	1	0

as chlorophyll *a* registered during that time (1.8 μg L^{-1}, winter value). The Chlorophyta are likewise present in appreciable numbers during spring and autumn, but their species do not predominate in density. In contrast, the Pyrrophyta become notable during the summer. As in Alicura, in the Piedra del Águila Reservoir immediately downstream, the diatoms represent the predominant group although other groups begin to manifest a greater relative abundance as well. The Pyrrophyta become notable here too, but in the spring and summer, while the Chlorophyta exhibit a pattern similar to that seen in former. The maximum biomass in this instance coincides with the end of the period of thermal stratification of the reservoir at the end of the summer and the beginning of the autumn (Chl *a*, 1.7 μg L^{-1}, autumn value). In the Ezequiel Ramos Mexía Reservoir, the diatoms again constitute the best represented

Table 3. Dominant phytoplankton taxa and their time of greatest abundance in each reservoir. Key to abbreviations: ALI = Alicura, PDA = Piedra del Águila, ERM = Exequiel Ramos Mexía, ARR = Arroyito, LB = Los Barreales, MM = Mari Menuco, A = autumn, W = winter, Sp = spring, Su = summer

Dominant taxa / Reservoir	ALI	PDA	ERM	ARR	LB	MM
Asterionella formosa	Sp					
Aulacoseira pseudogranulata	A-W-Sp	A-W-Sp	W-Su	end W-Sp	Sp	W
Aulacoseira subarctica		A-W				
Aulacoseira ambigua var. *ambigua* f. *spiralis*			W	A		
Stephanodiscus niagarae					W-Sp	W
Gymnodinium sp.	Su-A	Sp-Su				
Ceratium hirundinella			Sp-Su-A	W-Sp-Su-A	W-Su-A	W-Sp-Su -A
Anabaena spp. (toxic complex)		end Sp-begin Su	end Sp-Su	end Sp-begin Su		

Table 4. Seasonal phytoplankton composition of the reservoirs. The predominant groups in each period – as determined after transformation of the raw relative-abundance data expressed on a numerical scale – are indicated by shadowing. Period from 1995 through 1999. Key to abbreviations: ALI = Alicura, PDA = Piedra del Águila, ERM = Exequiel Ramos Mexía, ARR = Arroyito, LB = Los Barreales, MM = Mari Menuco,

	Chryso-phyta	Pyrro-phyta	Chloro-phyta	Cyano-bacteria	Chryso-phyta	Pyrro-phyta	Chloro-phyta	Cyano-bacteria
	Winter				**Spring**			
ALI	X				X		X	
PDA	X				X	X		
ERM	X		X		X		X	X
ARR	X		X		X			X
LB	X		X		X			
MM	X				X			
	Summer				**Autumn**			
ALI	X	X			X		X	
PDA	X	X			X		X	
ERM	X		X		X	X		
ARR	X		X		X	X		
LB	X	X	X		X	X		
MM	X	X	X			X		

algal group, though as in the Piedra del Águila other divisions become prevalent at specific moments during the annual cycle. Certain species of Pyrrophyta, for example, predominate throughout the various seasons of the year, while the Cyanobacteria exhibit their greatest relative abundance in the spring and summer. The Chlorophyta maintain a significant presence as a general group, but their species do not prevail at any moment of the year. This reservoir does not become thermally stratified, except for reduced periods of time during certain summers; thus in the spring and fall maximum peaks of chlorophyll *a* become recorded (e.g., 4.5 and 5.5 μg L^{-1}, respectively). In Arroyito Reservoir, downstream from Ramos Mexía, consecutive patterns of algal growth occur, which are similar to those observed in the latter reservoir: the alternation of the groups is the same, with the notable exception that certain species of the Pyrrophyta exhibit an elevated relative abundance throughout the entire year. The combination of great depth and a high rate of water renewal insure that this reservoir never becomes thermally stratified, and that the maximum biomasses registered (in spring and autumn) correspond to those observed in its upstream counterpart (5.3 and 3.9 μg L^{-1} of chlorophyll *a*, respectively). Here the participation of the dinoflagellates and the Cyanobacteria as the principal taxa becomes notable.

As to the reservoirs located on the Neuquén River, in Los Barreales a permanent dominance of the diatoms occurs throughout the year, but becomes more pronounced during the winter and spring months. Although the Chlorophyta and Cyanobacteria are poorly represented, certain species of the Pyrrophyta predominate during a large part of the year. The maximum values of chlorophyll *a* are recorded in autumn and winter (3.2 and 3.7 μg L^{-1}, respectively), coinciding with the end of the thermal-stratification period and the time of renewed water admixture. Among the principal species, *Ceratium hirundinella* is notable during the greater part of the year (Table 3). In Mari Menuco Reservoir, the patterns of seasonal succession of both, the dominant algal groups and the species, coincide completely with those recorded for the reservoir's upstream counterpart (Los Barreales), thus emphasizing the relative abundance of Pyrrophyta species throughout the entire yearly cycle (Tables 3 and 4). The maximum values for chlorophyll *a* likewise are found in the fall and winter – the end of thermal stratification and the beginning of admixture (1.2 and 2.2 μg L^{-1}, respectively).

Cycle 2005–2010: Case studies

As part of the program for controlling algal blooms, two agendas for monitoring were developed in the basins.

The Ramos Mexía and Arroyito reservoirs in relation to the Limay River

The blooms of *Anabaena* spp. that habitually occur in the Ramos Mexía and Arroyito reservoirs during the spring and summer months exert effects that extend downstream in the Limay and Negro rivers disrupting the water-supply systems there through the resulting high algal densities (Labollita 1989, Cifuentes et al. 1995, 1996, Alcalde et al. 1996, 1998). The inconveniences incurred in the purification process along with the deterioration in the quality and potential toxicity that high densities of Cyanobacteria could impart on the treated water have given rise to specific plans of control aimed at forewarning the providers of the service of potable water in such circumstances. Within this context, the program "Control of Algal Blooms" was initiated in 1996 and was put into permanent practice from the year 2001 on. The most recent registers, corresponding to the years 2005 through 2010 are shown below.

One of the representative locations of the phytoplankton dynamics within the E. Ramos Mexía and Arroyito reservoirs is the sampling station referred to as *Limay River in Arroyito*. As the site is situated at a very short distance (about 3 km) downstream from its namesake reservoir, the samples there serve as good indicators of the existing conditions in this final water body. In this regard, an excellent correlation has been verified between the diverse variables recorded at that site and in the Ramos Mexía Reservoir, which agreement could be a result of the high water-renovation rate of the Arroyito Reservoir at 73.4 times year^{-1}, or once every 5 days – it being located between the two sites. The periodic analyses of phytoplankton density between the years 2005 and 2010 were performed at that location on the Limay River by means of biweekly samplings from October to April, since previous studies showed that this period was representative of the environmental scenario within the two reservoirs situated upstream (Cifuentes et al. 1995, 1996, AIC 2010a).

During this 5-year period 96 species were identified that had not been present in the previous study period, totalling 199 taxa associated with the Arroyito Reservoir. The presence of more than two new species of the following genera can be considered relevant: *Anabaena*, *Pseudoanabaena*, *Phormidium* (Cyanobacteria), *Monoraphidium*, *Scenedesmus* and other Chlorococcales (Chlorophyta), *Dinobryon*, *Cyclotella*, *Cymbella*, *Diatoma*, *Fragilaria*, *Nitzschia*, and *Tabellaria* (Chrysophyta). Only 16% of the total taxa were found exclusively within the period 1995–1999.

From the analyses of density, *Anabaena* spp. (*toxic complex*) was seen to exhibit the greatest abundance between the spring and summer (except during the years 2008–2009), that peak coinciding in general with *Aulacoseira pseudogranulata*; while *Chroomonas minuta*

Table 5. Principal species at the Limay River in Arroyito sampling station and their predominance during the period from 2005 through 2010.

Period	Season	Main species
2005–2006	end of spring – beginning of summer	*Anabaena* spp. (complex) *Aulacoseira pseudogranulata*
	end of summer	*A. ambigua* var. *ambigua* fa. *spiralis*
2006–2007	end of spring – beginning of summer	*Anabaena* spp. (complex)
	middle – end of summer	*Aulacoseira pseudogranulata* *Fragilaria crotonensis* *Discostella glomerata*
	autumn	*Chroomonas minuta*
2007–2008	spring – beginning of summer	*Aulacoseira pseudogranulata*
	summer	*Anabaena* spp. (complex)
	end of summer – autumn	*Discostella glomerata*
2008–2009	spring – beginning of summer	*Aulacoseira pseudogranulata* *Discostella glomerata*
	summer – autumn	*Anabaena* spp. (complex)
2009–2010	end of spring – beginning of summer	*Anabaena* spp. (complex)
	spring – beginning of summer	*Aulacoseira pseudogranulata*
	end of summer – autumn	*Fragilaria crotonensis* *Chroomonas minuta*

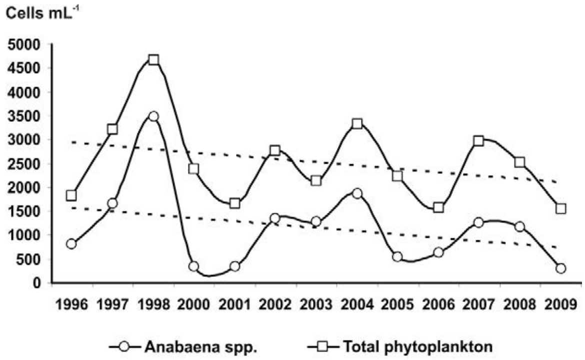

Fig. 2. Average total phytoplankton and *Anabaena* spp. (*toxic complex*) densities for the years 1996 through 2009 at the Limay River in Arroyito sampling station.

became prevalent at the end of the summer and in the autumn. Table 5 summarizes the principal species and the time of the year when they predominated.

During the years 2005–2009, the average total density and that of *Anabaena* spp. (*toxic complex*) were registered at about 2.2 10^3 and 0.8 10^3 cells. ml^{-1}, respectively. By comparison, the greatest average total phytoplankton density for a given year within that period was recorded in 2007 at almost 3 10^3 cells. ml^{-1}. If we consider as point of reference the average density values recorded from 1996 to 2009 of ~ 2.5 10^3 cells. ml^{-1} for total phytoplankton, and of ~ 1.2 10^3 cells. ml^{-1} for *Anabaena* spp., the notably lower figures cited above for the last five-year period would point to a decreasing tendency in the abundance of the phytoplankton populations in the Arroyito Reservoir (Fig. 2).

Mari Menuco Reservoir

In the two reservoirs of the Neuquén River (Los Barreales and Mari Menuco) – in contrast to what was recorded historically for the reservoirs of the Limay River – *Anabaena* spp. did not exhibit high densities and Cyanobacteria did not constitute a notable group. Despite this difference, by the end of 2008 episodes of Cyanobacteria blooms began to be detected in certain areas along the banks of the Mari Menuco that, upon persisting over time, could affect the quality of the water designated for human consumption since that reservoir had been the origin of an aqueduct that subsequently supplied wide urban areas. For that reason, during the period extending from October 2009 through April 2010, two sampling sites were placed in the reservoir aimed at bloom monitoring, applying the same methodological criteria as had been used for the Limay River (i.e., analysis of the phytoplankton densities in biweekly samples).

With respect to the previous period, 33 new species were accordingly identified, totalling 117 taxa within the entire Mari Menuco Reservoir. The new taxa were *Oscillatoria* aff. *crassa*, *Phormidium* aff. *tenue* (Cyanobacteria), *Cryptomonas* sp. (Cryptophyta), *Euglena* sp. (Euglenophyta), *Carteria* sp., *Chlamydomonas* sp., *Cosmarium* sp., *Eudorina* sp., *Monoraphidium contortum, Monoraphidium tortile, Pseudokirchneriella irregularis, Scenedesmus* *intermedius, Scenedesmus spinosus*, *Scenedesmus* sp., *Tetraedron minimum* (Chlorophyta), *Achnanthes minutissima, Anomoeoneis* sp., *Caloneis* sp., *Cocconeis placentula, Cyclostephanos patagonicus, Cyclotella ocellata, Cymbella cistula, Cymbella prostrata, Cymbella* sp., *Diatoma* aff. *vulgare, Diatoma hiemale, Diploneis* sp., *Discostella glomerata, Gomphonema parvulum, Hantzschia amphioxys, Neidium* sp., *Synedra acus, Tabellaria* sp. (Chrysophyta). Of those total species, 40% had been found only during the cycle 1995–1999, probably as a result of the brevity of the sampling time during that second period (i.e., 6 months). The Cryptophyta *Chroomonas minuta* was the best represented species during the entire interval, with maximum densities in the fall (at about 1.35 10^3 cells. ml^{-1}), but elevated concentrations of *Anabaena* spp. (*toxic complex*) were detected on certain occasions at the end of the summer and the beginning of the fall (about 7.5 and 5.7 10^3 cells. ml^{-1}, respectively). Other accompanying taxa of high densities were *Asterionella formosa*, *Cyclotella ocellata*, *Stephanodiscus* sp., *Navicula* sp., *Fragilaria crotonensis*, and *Epithemia sorex*. The average total phytoplanktonic density for the entire period was about 1.3 10^3 cells. ml^{-1}, although maxima of around 6 to 8 10^3 cells. ml^{-1} had been registered at the end of the summer and the beginning of the fall, coinciding with the *Anabaena* spp. blooms.

Florentino Ameghino Reservoir

The Florentino Ameghino Dam – located within the Province of Chubut on the Patagonian Plateau at 170 m a.s.l. (43°42'S; 67°27'W) – retains the water of both the Chico and the Chubut rivers, the latter in turn originating from the Andes snow and ice thaws (Fig. 1) . The reservoir has an area of 65 km^2, a depth of 24.6 m, and a volume 1,500 hm^3. Constructed in 1943 for the provision of hydroelectric power, the reservoir began service in 1963. The discharge is either through a valve located 20 m above its base, or at lower depths, through valves situated near the base. The reservoir is also used, when necessary, for flood retention, for irrigation, and indirectly for the provision of potable water (Sastre et al. 1994c). Along one side of the reservoir lies the village Villa Dique Florentino Ameghino.

In a study of the phytoplankton of the reservoir during the summer, Izaguirre et al. (1990) recorded species characteristic of mesotrophic to eutrophic lakes. Subsequently, Sastre et al. (1991a, 1994b, 1994c) conducted 16 samplings from the surface and other water depths between April 1990 and November 1992 at a site located near the dam and found as the most abundant group the centric diatoms – principally *Aulacoseira granulata, Stephanodiscus* sp., and *Cyclotella* sp. (Sastre et al. 1994b).

Within the two-year period from 1990 to 1992, minimum densities were registered in the winter. The maximum values were observed in the fall of 1990 (1.3 10^3 cells. ml^{-1}) and in the springs of 1990 and 1991 (0.8 10^3 cells. ml^{-1} and 2 10^3 cells. ml^{-1}, respectively). From April until August of 1990 the centric diatoms dominated, while between October and December the chlorophytes proliferated, with *Pandorina morum* attaining some 56% of the total in October and *Eudorina elegans* dominating in December. In contrast, the diatoms dominated during the entirety of 1991, with *Aulacoseira granulata* being the principal species during the bloom of December. The chlorophytes, however, then became the major group during the summer, reaching a maximum of 13 μg L^{-1} toward the end of March 1992.

The number of cells in the water column was low, rarely exceeding 2 10^3 cells. ml^{-1}. Sastre et al. (1994b, c) noted that the cell concentration in the vertical profile diminished gradually with depth, with the sole exception of the samples taken near the bottom, where, in fact, high concentrations were measured. For example, at a depth of 47 m *A. granulata* attained densities of about 20 times those at the surface in October 1991. Meanwhile, in 1992, *Stephanodiscus* sp. and *Cyclotella* sp. became 10 and 12 times more prevalent in deep layers in August and November, respectively. The authors related the abundance peaks of the first two species to their capability of remaining within the sediments in the dormant state as resistance cysts. Accordingly, their proliferation coincided with the times of lower nutrient concentration in the reservoir.

In a previous period, Sastre et al. (1991a) found blooms of *Aulacoseira granulata* during the summer months of 1986–1987 and 1987–1988 in the reservoir, and subsequently associated the high densities recorded in the lower stretch of the Chubut River with those earlier growth spurts.

Final remarks

Certain authors have suggested that the reservoirs within the Río Negro River basin should be grouped according to either of two mechanisms controlling their trophic state: (1) those reservoirs whose states are determined by both light and nutrient availability (e.g., Los Barreales in the Neuquén River) and (2) those with states regulated exclusively by the nutrient availability (e.g., the reservoirs of the River Limay and Mari Menuco of the Neuquén). The second mechanism follows a relationship in which the chlorophyll-*a* concentrations peak during the period of admixing (i.e., the winter), while the overall pattern of the trophic state with respect to this latter parameter for all the reservoirs of both rivers is, in turn, a function of the mean depth (Labollita & Pedrozo 1997). Nevertheless, the changes observed in the phytoplankton composition of the reservoirs of the Río Negro basin during different study periods (Pizzolón et al. 1997) would vary according to the changes that diverse water-quality parameters have undergone over the past 30 years (AIC 2002). As a case in point, the gradual incorporation of new water bodies into the Limay River that has led to the formation of a concatenated series of reservoirs appears to have played a key role in the loading of phosphorus into the water, which effect in combination with the system's generally positive coefficient of retention for phosphorus (Labollita et al. 1999) has caused the final links in this reservoir chain (i.e., the Ramos Mexía and Arroyito) to now receive lower inputs of phosphorus than in former years. This fact could at least partially explain the recent tendency of the phytoplankton densities to decrease in general (and species of the genus *Anabaena* in particular) along with a resulting enhancement of the water transparency in those reservoirs (AIC 2008, Labollita 2007).

The above hypothesis, however, does not apply to the reservoirs of the Neuquén River since no dams have been constructed in this basin since the '70s. In the Río Negro basin the diatoms represent the predominant algal group along with scattered brief occurrences of Cyanobacteria blooms and in particular those species of the genus *Anabaena*. The recent occurrence of Cyanobacteria blooms in the Mari Menuco Reservoir, however, has not yet been convincingly explained, though the development of tourist towns along one bank of this reservoir over recent years no doubt represents a significant additional input of nutrients that would certainly favour an increase in the phytoplankton density. The blooms that occurred in the Mari Menuco Reservoir in 2008, though not affecting the water-purification process, ought to be particularly monitored as a result of their potential influence on the uses of the water in those agricultural and urban areas served by this reservoir.

The Cyanobacteria blooms detected in the Limay River reflect the existing situation in the Exequiel Ramos Mexía and Arroyito reservoirs. Though these algae continue producing conspicuous blooms, signs indicating a decrease in their intensity and duration have been noted that would in turn contribute to an attenuation of their effects downstream and thus result in a reduction in the inconveniences to the water-purification plants located on the Limay and Negro rivers.

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