Seasonal Variation of the Mountain Phytoplankton in the Arid Mendoza Basin, Westcentral Argentina

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ABSTRACT

We analyzed the seasonal composition of phytoplankton from the Mendoza River and its tributaries from the High Cordillera to the plain in centralwest Argentina. A total of 72 algae species were identified; among them, 36 species were diatoms, 17 chlorophytes, 15 cyanophytes, three euglenophytes and one pyrrophyte. A marked seasonality was observed. Diatoms were dominant in all seasons at most of the sampling sites, with abundance peaks in autumn and winter. Cyanophytes were found throughout the year but with highest numbers in summer and spring. Chlorophytes were well represented throughout the year except in winter. The pyrrophytes were represented by *Peridinium gatunensis*, which was recorded exclusively in the spring along with the chlorophyte *Staurastrum sebaldii* at most of the sampling sites. Euglenophytes were found only in the lower basin and with maximum richness and density in autumn. Most of the diatoms were benthic. *Nitzschia palea*, *Euglena proxima* and *E. oxyurus* were limited to certain sectors of the river that receive sewage discharge. The remainder of the river is generally free from significant anthropogenic impact.

INTRODUCTION

The Mendoza River in centralwest Argentina is formed by tributaries that are fed largely from snowmelt and from the glaciers of the Cordillera de Los Andes. Annual spring and summer precipitation is insignificant (approximately 250 mm). In spite of the arid climate, the Mendoza River basin comprises rich and diverse environments, but its freshwater ecosystems have been poorly studied. Limnological studies are limited to the ichthyological record of Peñafort (1993) in the basin of the Mendoza River; to a characterization of the summer phytoplankton of the Grande, Atuel, Salado Rivers and of the Llancanelo pond by Peralta and Claps (2001); and to a study of the daily phytoplankton variation in the Mendoza River at the High Cordillera by Fuentes et al. (2000).

The topography of the region and the wide annual, seasonal and daily temperature fluctuations produce significant variations in the velocities and discharges of the area rivers. These conditions undoubtedly determine changes in the annual structures and dynamics of the aquatic communities (Allan 1993). We would expect marked seasonal differences in the succession of communities as well as variations along the longitudinal gradient from the high elevations to the plain (Vannote et al. 1980).

Since the construction of a major dam on the Mendoza River is currently in progress – a project which will likely effect significant changes in the system, the collection of baseline information is of some urgency . Thus, the goals of our work were to analyze the composition and dynamics of the phytoplankton from the Mendoza River and its tributaries from the High Cordillera to the plain, to determine similarities and differences of the phytoplankton community in the different basin sections, and to appraise the influence of certain hydrological, physical and chemical characteristics.

STUDY AREA

The basin of the Mendoza River is located north of Mendoza province (32° 51' S, 69° 46' W) and comprises 18,484 km^2. The river headwaters are in the Andes, in a cordilleran area between Aconcagua (6,962 m asl) in the north and Tupungato in the south. The river runs for 300 km until it reaches the Guanacache wetlands in the northern part of the province at 600 m asl (Fig. 1).

Figure 1. Map showing locations of 12 sampling stations in Mendoza River basin (1 Horcones River, 2) Cuevas River at Penitentes, 3) Tupungato River, 4) Vacas River, 5) Mendoza River upstream of Uspallata, 6) Mendoza River downstream of Uspallata, 7) Mendoza River at Evarsa, 8) Mendoza River at Potrerillos, 9) Mendoza River upstream of Cacheuta, 10) Mendoza River downstream of Cacheuta, 11) Mendoza River at Cipolleti, and 12) Mendoza River at Lavalle).

MATERIALS AND METHODS

The samples were taken once each season in 1999 (February, May, August, November) at 12 sampling stations with different topographic characteristics (Fig. 1): 1) Horcones River, 2) Cuevas River at Penitentes, 3) Tupungato River, 4) Vacas River, 5) Mendoza River upstream of Uspallata, 6) Mendoza River downstream of Uspallata, 7) Mendoza River at Evarsa, 8) Mendoza River at Potrerillos, 9) Mendoza River upstream of Cacheuta, 10) Mendoza River downstream of Cacheuta, 11) Mendoza River at Cipolleti, and 12) Mendoza River at Lavalle.

To facilitate the interpretation of results and the later characterization of the basin, sites 1, 2, 3 and 4 are considered as belonging to the high basin; 5, 6 and 7 are the high middle basin, 8, 9 and 10 are the low middle basin; and 11 and 12 are the low basin.

The following physical and chemical parameters were recorded: water temperature, conductivity, pH, transparency (Secchi disc), and flow velocity. Duplicate phytoplankton samples were obtained with a container of known capacity by filtering either 40 or 100 l (according to the sediment amount transported by the river) with a 30 μm mesh net. The samples were fixed with 10% Lugol's iodine. The counts were done with an inverted microscope and known volume cameras. The results are given as number of cells ml-1. The Shannon and Weaver index (Legendre and Legendre 1983) was applied to calculate diversity.

RESULTS

The waters of the Mendoza River had neutral to alkaline pH with the highest value (9.2) recorded in the lower basin sector (Lavalle) in spring; the lowest pH (7.4) was at the Tupungato River in summer (Table 1). The sampling station at Lavalle had the highest temperature of the entire river, with 11 °C in winter and 25.9 °C in spring. The headwater sampling stations had the lowest temperatures with minimum values in autumn. During winter, the temperature rose slightly, with a minimum value of 3.7 °C and a maximum of 7.5 °C.

The minimum water transparency was recorded in summer and spring and was caused by high concentrations of suspended solids, while during autumn and winter the river bed could be seen, with the exception of Lavalle in the lower basin (Table 1). The highest conductivity values were recorded during autumn and winter with average values of 1,432 $\mu S\ cm^{-1}$ in the higher basin, 1,098 $\mu S\ cm^{-1}$ in the middle basin, and 1,000 $\mu S\ cm^{-1}$ in the lower basin. In spring and summer, conductivity went down to 1,059 $\mu S\ cm^{-1}$ in the higher basin, to 737 $\mu S\ cm^{-1}$ in the middle basin, and to 813 $\mu S\ cm^{-1}$ in the lower basin. The highest values of conductivity were in the Cuevas River and Tupungato River. Flow velocities varied considerably with elevation and season.

All total 72 algae species were identified, of which 36 species were diatoms, 17 chlorophytes, 3 euglenophytes, 15 cyanophytes, and one a pyrrophyte (Table 2). The lowest number of species occurred in summer. The sites of the middle basin (5 and 6) had the highest diversity during summer, while the lower basin (12) had high diversity in spring (Fig. 2). Vacas River, in spite of its high species richness, had one of the lowest diversity values (0.54) but the highest density (2,853 cells ml^{-1}) with a predominance of cyanophytes (*Oscillatoria formosa, Lyngbya martesiana*) and chlorophytes (*Ulothrix tenerrima*) (Fig. 3d).

The highest species richness was in autumn with maxima in both basin extremes and the central site of the middle basin (2, 12 and 6 respectively). The highest diversity values were also observed in the same sites, together with site 10 with an average H' of 1.27 (Fig. 2). Likewise autumn yielded the highest phytoplanktonic density at sites 12 (12,640 cells ml^{-1}), 9 (2,470 cells ml^{-1}), and 3 (4,052 cells ml^{-1}) (Fig. 3). At Lavalle, the maximum was due to the abundance of *Euglena proxima* and *E. oxyuris var. charcowiensis* and the diatom *Nitzschia palea*. Also, the high abundance of the diatom *Fragillaria virescens* was the determinant for the high recorded at site 3, while *Lyngbya limnetica* effected the high in the middle basin.

In winter, the phytoplankton showed low numbers of species with an average of seven in the middle and high basins. Sites 9, 10 and 12 were those with greater richness and specific diversity (Fig. 2). In regards to the phytoplanktonic density, the highest was recorded at the Lavalle sites (3,483 cells ml^{-1}) with high frequency of *F. virescens* and *E. proxima* at site 5 (1,068 cells ml^{-1}) and *F. virescens* and *Cymbella*

Table 1. Some physical and chemical characteristics of sampling stations of Mendoza River basin during the study period

Sampling sites	Conductivity (µS cm^{-1})				Temperature (°C)			
	Summer	Spring	Autumn	Winter	Summer	Spring	Autumn	Winter
Horcones River	1293	1123	no data	no data	6.8	6.8	no data	no data
Cuevas River	1608	1625	2110	1923	12.9	7.8	4.7	3.7
Tupungato River	no data	800	1064	1154	no data	2.9	1.9	3.7
Vacas River	543	521	616	620	14.2	4.9	5.6	5.4
upstream Uspallata	786	778	1237	1100	14.5	5.3	4.3	5.2
downstream Uspallata	760	765	1059	1060	16.8	6.5	5.9	6.8
Evarsa	704	710	1054	1098	15.7	8.4	5.2	7.3
Potrerillos	698	700	1043	1120	18.1	8.3	5.9	8
upstream Cacheuta	no data	582	975	953	no data	12.3	6.7	7.3
downstream Cacheuta	no data	569	943	930	no data	12.9	6.8	7.5
Cipolletti	787	800	941	928	18.3	20	10.8	11.7
Lavalle	840	887	1393	1200	23.1	25.9	16.8	11.2

Sampling sites	pH				Velocity (m sec^{-1})			
	Summer	Spring	Autumn	Winter	Summer	Spring	Autumn	Winter
Horcones River	8.4	8.6	no data	no data	2.04	1.42	no data	no data
Cuevas River	8.3	8.6	8	8.4	2.5	2	1.4	1.25
Tupungato River	no data	8.5	7.8	8.5	no data	1.42	1.25	0.83
Vacas River	8.5	8.6	8.2	8.5	1.8	2	1.25	0.66
upstream Uspallata	8.6	8.3	7.9	8.5	1.25	0.71	1.25	1.11
downstream Uspallata	8.5	8.6	7.9	8.5	0.99	0.5	0.83	1.42
Evarsa	8.6	8.8	7.9	8.5	2.5	0.71	1.7	1.11
Potrerillos	8.4	8.8	8	8.8	1.25	1.25	1.33	1
upstream Cacheuta	no data	8.9	8.2	8.5	no data	1.4	0.52	0.9
downstream Cacheuta	no data	8.9	8.2	8.5	no data	1	0.7	1.11
Cipolletti	8.9	8.7	8.6	8.9	0	0	0	0
Lavalle	8.8	9.2	8	8.6	1	0.17	6.8	0.19

Sampling sites	Transparency (m)			
	Summer	Autumn	Winter	Spring
Horcones River	0.05	no data	no data	0.05
Cuevas River	0.05	0.25	0.5	0.1
Tupungato River	no data	0.5	0.5	0.07
Vacas River	0.05	0.3	0.4	0.15
upstream Uspallata	0.05	0.4	0.4	0.1
downstream Uspallata	0.05	0.4	0.4	0.1
Evarsa	0.05	0.4	0.4	0.05
Potrerillos	0.05	0.5	0.4	0.08
upstream Cacheuta	no data	0.1	0.15	0.05
downstream Cacheuta	no data	0.1	0.2	0.05
Cipolletti	0.05	0.5	0.5	0.05
Lavalle	0.05	0.85	0.1	0.05

tumida being the most abundant (Fig. 3). A marked rise in the species number was observed in three of the High Cordillera rivers - Horcones, Cuevas and Tupungato, as well as at sites 6 and 7 of the middle basin. Nevertheless, the highest diversity values were recorded at sites 10 and 12 (1.69 and 2.19 respectively). The greatest abundance was recorded at site 12 (1,759 cells ml^{-1}) with *E. proxima* and *Oscillatoria princeps* highly frequent. Sites 10 (935 cells ml^{-1}) and 7 (635 cells ml^{-1}) were the next most abundant upstream with high frequencies of *C. tumida* and *F. virescens* at both sites, and *O. formosa* and *Zygnema* sp. at the first station.

Several phytoplankton components showed a marked seasonal preference. *Oscillatoria formosa, C. tumida, Diatoma vulgare, F. virescens* and *Fragilaria ulna* were found on all samplings occasions. *Crinalium endophyticum, Spirulina spteni, Schizothrix* sp., *Stigeoclonium* sp., *Microspora abreviatta, Ulothrix tenerrina, Cyclotella*

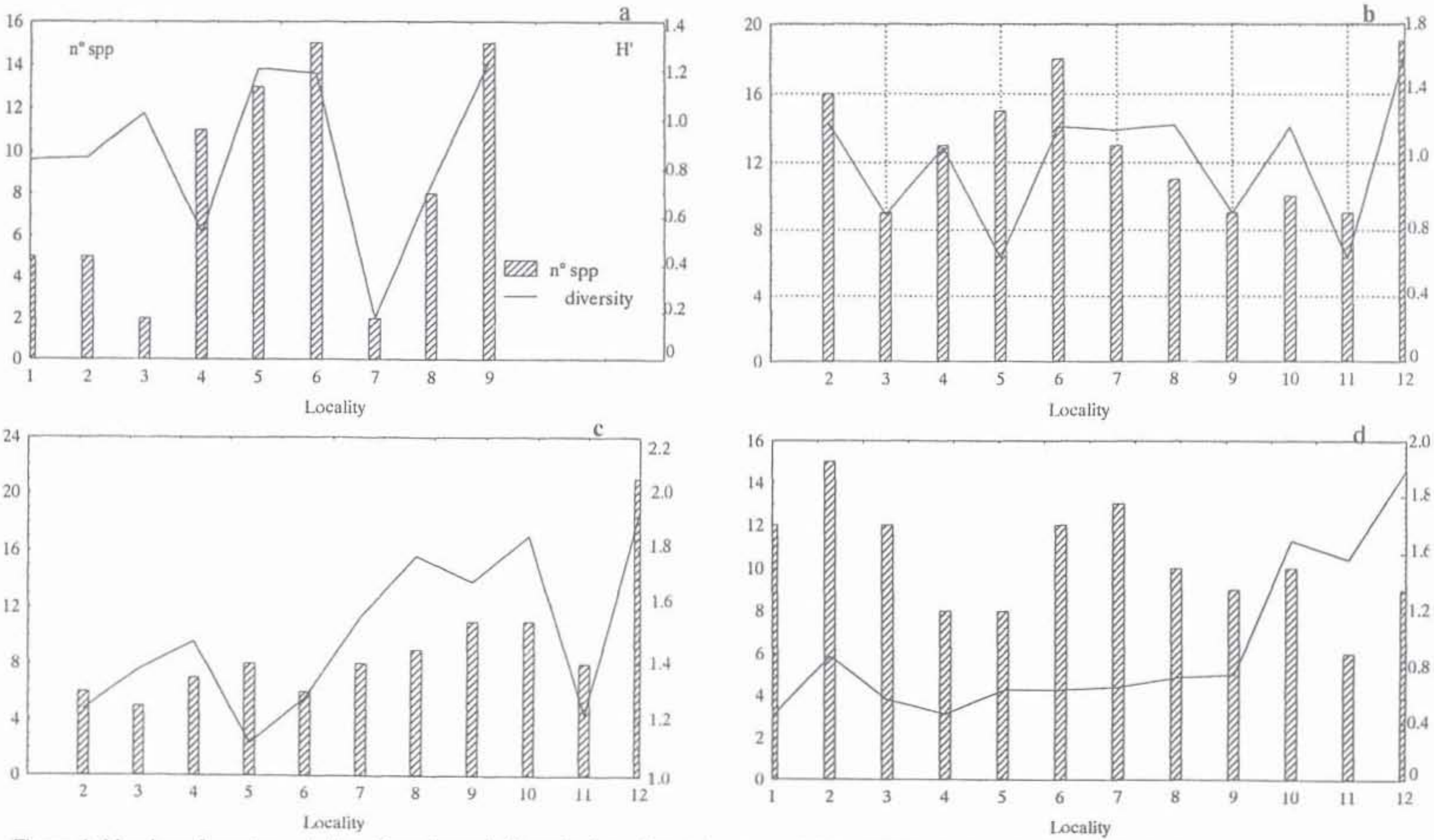

Figure 2. Number of species and diversity values of phytoplankton for each season during 1999 in the Mendoza River basin (a: summer, b: autumn, c: winter, d: spring).

Table 2. Seasonal presence of phytoplankton species in Mendoza River basin (S: Summer, A: Autumn, W: Winter, Sp: Spring)

Species	1	2	3	4	5	6	7	8	9	10	11	12
Anabaena ambigua Rao										W	S	W
Crinalium endophyticum Crow						S					S	
Lyngbya limnetica Lemm.	Sp	S	Sp	S	SA	S	SSp	S	A		S	Sp
L.martensiana Menegh.		ASp		S	SA	A		ASp	ASp	A		Sp
Merismopedia sp				A								
Oscillatoria articulata Gardner		AW				SA	A		W	W		A
O. formosa Bory	S	SAWSp	A	SA	SA	W	Sp	SSp	Sp	A	SSp	W
O. irrigua Kûtz.			Sp									
O. princeps Vaucher	Sp											Sp
O. tenuis Agardh		Sp	Sp	Sp		A	Sp	A	Sp	Sp		A
Pleurocapsa sp.		A			A	A						
Schizothrix sp.						S					S	
Spirulina platensis (Nordst.) Geitl.					S							
Spirulina sp		Sp				Sp		A				
Euglena oxyurus var.charkowiensis (Swir.)Chu												AW
E. proxima Dang.												AWSp
Phacus pseudonordstedtii Pochm.												A
Cladophora sp	S	A				SA		SSp		Sp		
Cosmarium sp						S						A
Hormidium flaccidum (Kûtz.) Braun	Sp				S							
Microspora abreviatta (Rab.)Lag.	S											
Microspora crassior (Hansgirg) Hazen		ASp			Sp		Sp	Sp	Sp	Sp		
M. quadratta Hazen	Sp	ASp		ASp	SA							
M. tumidula Hazen	Sp			Sp	A							Sp
M.willeana Lag.						A		A				
M. witthrockii (Wille) Lag.					A		A			Sp		
Oedogonium sp		Sp	Sp	S	S	SA	A	S				
Scenedesmus opoliensis P. Richter												AW
Spirogyra varians (Hass.) Kûtz.		Sp		SA		A				Sp	S	
Staurastrum sebaldi Reinsch	Sp	Sp		Sp	Sp	Sp						Sp
Stigeoclonium sp.				S								
Ulothrix tenerrima Kûtz.				S	S							
U. variabilis Kûtz.		S								W		
Zygnema sp.					A	A						
Tribonema sp.									Sp			
Peridinium gatunense Westl	Sp	Sp		Sp	Sp	Sp	Sp	Sp				Sp
Achnanthes inflata Kûtz.												W
Achnanthes sp			A	A		A	A		W	A	SA	W
A. minutissima Kûtz.			W	W		W		W			W	WSp
Anomoneis sp.												AW
Amphora ovalis Kûtz.	A	A	A	A	A	SA	AW	AW	AW	AW	A	W
A. pediculus Kûtz.				W	W	W	W	W	W	W		
Aulacoseira granulata (Ehr.) Simonsen	Sp	Sp				A						
Bacillaria paxillifer (Muller) Hendey					V	V						
Cyclotella meneghiniana Kûtz.				S							S	
Cymatopleura solea (de Brebisson) Smith							Sp	S				
Cymbella cistula (Hemprich) Grun.			Sp									W
C. tumida (de Brébisson) Van Heurck	AWSp	SAWSp	AWSp	SAWSp	SAWSp	SAWSp	AWSp	SAWSp	AWSp	AWSp	AWSp	AWSp
C. ventricosa Kûtz.					Sp	Sp	Sp					
Diatoma vulgare Bory			Sp		S	SA	AWSp	SAWSp	AWSp	Asp	SAWSp	AW
Diploneis sp.		A										
Entomoneis alata (Kûtz.)												W
Eunotia lunaris (Ehr.) Grun.			A	A		A	ASp		AW	A		
Eutonia sp						SA	A				A	
Fragilaria capucina Demazières		Sp	Sp									
F. virescens Ralfs	SAWSp	SAWSp	AWSp	SAW	SAWSp	SAWSp	AWSp	AWSp	AWSp	AWSp	AWSp	AWSp
F. ulna (Nietzsche) Ehr.	SAWSp	SAWSp	SAWSp	SAWSp	SAWSp	SAWSp	SAWSp	SAWSp	AWSp	AWSp	SAWSp	AWSp
G. capitatum Ehr.	AW	AW	AW	AW	AWSp	AWSp	AWSp	AWSp	AW	AW	AW	AW
G. truncatum Ehr.		A										
Gyrosigma acuminatum Ehr.			Sp									AW
Melosira varians Agardh					A	A	A	AW		W	SA	
Navicula cryptocephala Kûtz.						Sp						A
Nitzschia linearis W. Smith												A
N. palea (Kûtz.) W. Smith												AW
N. sigmoidea (Ehr.) W. Smith						S				Sp		A
Pinnularia sp.		A									W	
Rhopalodia gibba (Ehr.) Muller				A								
Surirella ovata Kûtz.			A									W
Synedra actinastroides Kûtz.						Sp						
S. minuscula Grun.		AW		AW	AW		W		W	W	W	W

meneghiniana, and *Bacillaria paxillifer* were recorded only during summer. The diatoms *Achnanthes inflata, Amphiprora alata*, and *Amphora pediculus* were found in winter. *Merismopedia* sp., *Pleurocapsa* sp., *Phacus pseudonordstedlt, Microspora willeana, Zygnema* sp., *Diploneis* sp., *Gomphonema truncatum*, and *Nitzschia linearis* were autumn species, while *Oscillatoria irrigua, O. princeps, Staurastrum sebaldiii, Tribonema* sp.. *Peridinium gatunensis, Cymbella ventricosa, Gomphonema acuminatum*, and *Synedra actinastroides* were recorded only in spring (Table 2).

Diatoms were the dominant group on all of the sampling occasions at most of the sites, with abundance peaks in autumn and winter (Fig. 4). Cyanophytes were found throughout the year with numerical abundance mostly in summer and spring. Chlorophytes were better represented in summer, autumn and spring and barely present in winter. The pyrrophytes were represented by the species *P. gatunensis* that was recorded in spring exclusively along with the chlorophyte *S. sebaldii* at most of the sampling sites. Euglenophytes were found only at site 12 (lower basin of the Mendoza River) with maximum specific richness and numeric density in autumn.

Of the diatoms found in the basin, 69% belong to a benthic habitat; the remaining species were planktonic. The chlorophytes constituted 70% planktonic species. The euglenophytes and pyrrophytes were all planktonic forms.

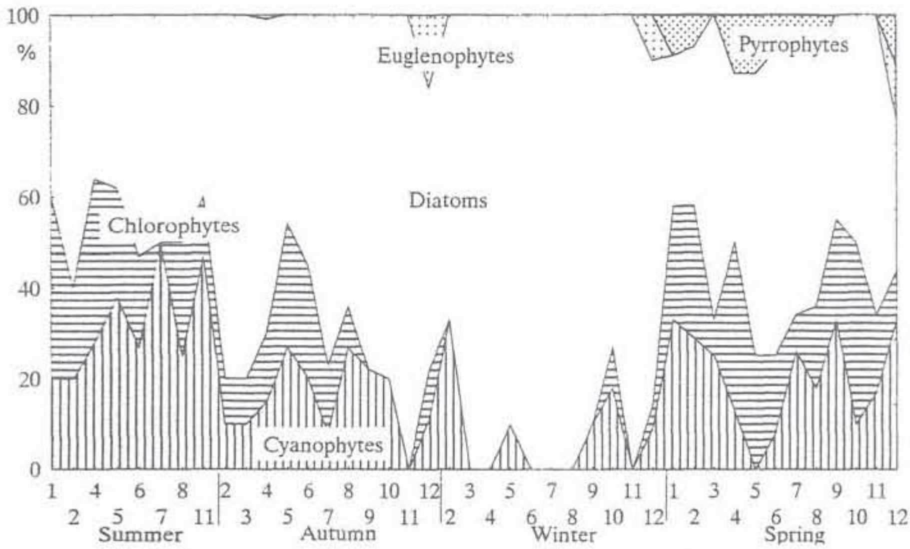

Figure 3. Seasonal density of phytoplankton recorded in the Mendoza River basin during 1999.

DISCUSSION

Significant seasonal flow variation due to snowmelt and the fusion of cordilleran glaciers causes essential differences of certain physical and chemical parameters, such as conductivity, temperature, transparency and flow speed. The values recorded during autumn and winter were of higher conductivity, lower temperatures, greater transparency and lower velocity than those found in summer and spring. The phytoplankton community showed seasonal differences as many species were found in only one climatic season, which is in agreement with thermal variations and with differences in the water transparency and the flow volume (Whitton 1975).

A marked spatial and temporal variation was observed. In spring and autumn, the community was different within different basin sectors. Summer and winter did not show marked spatial variation throughout the basin. The phytoplankton community showed similarities in composition and abundance in the middle basin sector in spring and autumn, respectively.

The phytoplankton showed structural and abundance changes in the longitudinal gradient, being more complex and numerous in the lower middle basin and during spring and autumn. This characteristic would be linked to a decrease of the flow speed and to the increase of the order number of the main watercourse (Molloy 1992). This enrichment is not exaggerated as this basin does not have lentic environments that could function as inocula (Reynolds 1995)

The phytoplankton of Mendoza River and its tributaries was formed by typical species, as well as by algae belonging to other communities. A large number of the algae recorded are characteristic of benthic communities and typical of poor environments (Biggs 1996). The low number of species coincides with the results obtained by Kawecka (1980) in non-polluted glacial creeks. The diatom supremacy, either in the number of species or as density, is linked to their ability to survive in unstable environments (Rojo et al. 1994) and in those with low temperatures (Kawecka 1980). Most of the diatoms are ticoplanktonic and prefer alkaline pH (Lowe 1974). These algae are incorporated to the free water by the washing action exercised by current in the epilithic community (Hynes 1970, Cox 1990).

The chlorophytes and cyanophytes were best represented during summer and spring. Among the first ones were the predominant the filamentous forms (*Microspora abreviatta, M. quadratta, M. withrokii, Oedogonium* sp., *Spirogyra* sp., *Ulothrix tenerrima, U. variabilis, Zygnema* sp.), which are common in pristine environments (Deniseger et al. 1986).

Phytoplankton found at Lavalle was totally different from that found in the

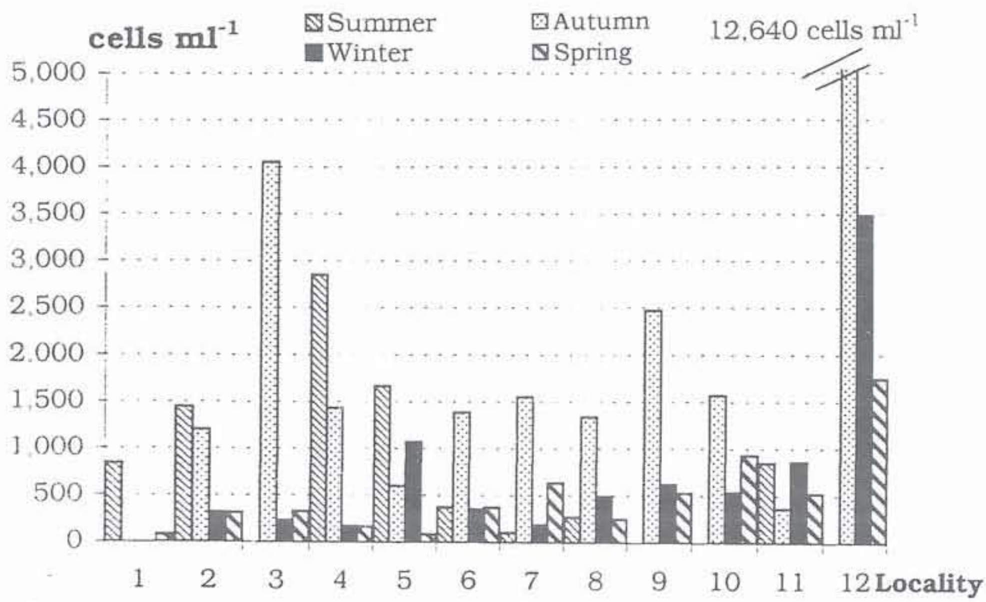

Figure 4. Seasonal distribution of phytoplankton groups present in Mendoza River basin during 1999

rest of the basin due to the more lentic character of this sector (Ward 1992). Biologically, the basin does not show signs of eutrophication as there have not been species detected that would indicate this condition – species such as *Cocconeis placentula* (Cox 1990). The presence of *N. palea*, *E. proxima* and *E. oxyurus* is limited to certain river sectors that are impacted by sewage discharge; this shows a degree of incipient organic pollution (Rakowska 1990).

Acknowledgements

We thank to A.M. Zavattieri, M. Morales, A. Peralta, Gendarmería Nacional (Rescue Group), Dirección de Recursos Naturales de la Provincia (Forester staff), for help in the field work. We also thank to M. E. Soler for English assistance.

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Received: 30 October 2000 Accepted: 13 April 2001