HUMAN IMPACT ON SOME LIMNOLOGICAL CHARACTERISTICS OF THE GASTONA RIVER (TUCUMÁN, ARGENTINA)

MIRANDE, V.[1], ROMERO, N.[2], BARRIONUEVO, M.A.[3], MEONI, G.S. B.[3], NAVARRO, M.G.[3], APELLA, M.C.[4,5], TRACANNA, B.C.[1,5]

Fundación Miguel Lillo e Instituto de Limnología del Noroeste Argentino (Facultad de Ciencias Naturales e Instituto Miguel Lillo de la Universidad Nacional de Tucumán), Miguel Lillo 205 [1]; Obras Sanitarias Tucumán, Avenida Sarmiento 991 [2]; Laboratorio de Control Ambiental, SIPROSA, pasaje Dorrego 1080 [3]; Centro de Investigaciones y Transferencia en Química Aplicada (Fac. Cs. Nat. e I.M.L. de la UNT) [4]; Consejo Nacional de Investigaciones Científicas y Técnicas [5]. San Miguel de Tucumán (4000), Tucumán, Argentina. E-mail: ilinoa@csnat.unt.edu.ar

RESUMO: Impacto antrópico sobre algumas características limnológicas do rio Gastona (Tucumán, Argentina). O objetivo deste trabalho foi avaliar o impacto antrópico ocasionado por efluentes de esgôtos e pela atividade de um engenho açucareiro nas características limnológicas do rio Gastona (Tucumán, Argentina) ao longo de um gradiente longitudinal. Foram selecionados três pontos de coleta e analisados, de março a novembro de 1998, os seguintes parâmetros físico-químicos (turbidez, oxigênio dissolvido, compostos nitrogenados e fosfatos) e biológicos (demanda bioquímica de oxigênio (DBO), colimetria e fitoplâncton).Os resultados obtidos evidenciaram um aumento em San Carlos, ponto mais perto da perturbação, para depois decrescer devido à depuração própria do rio. Observou-se, também, uma forte diferença nos meses de safra (junho-outubro) com altos teores de coliformes, (até 9 log UFC/100 mL), da DBO, fosfatos, amônia e nitritos, e valores mínimos de nitratos e oxigênio dissolvido. O fitoplâncton tendeu a diminuir corrente abaixo, acentuando-se a diminuição do número de indivíduos em aproximadamente 50 %, de julho a outubro. As diatomáceas foram dominantes, destacando-se as penadas sobre as cêntricas, sendo as espécies *Cymbella affinis* Kützing, *C. amphicephala* Naegeli, *C. helvetica* Kützing, *Fragilaria ulna* (Nitzsch) Lange-Bertalot, *Melosira varians* Agardh, *Navicula exigua* (Gregory) Grunow, *N. goeppertiana* (Bleisch) H. L. Smith e *Nitzschia palea* (Kützing) W. Smith as mais freqüentes e abundantes. Os outros grupos encontrados foram as cyanofíceas, clorofíceas e euglenofíceas. A presença deste último destacou-se, principalmente, a partir de junho, nos dois pontos de maior contaminação.

Também são reportados os resultados da análise de agrupamento para variáveis bióticas e abióticas durante o período de estudo, que confirmaram as diferenças espaciais e temporais entre os pontos de amostragem.

Palavras-chave: Impacto antrópico, parâmetros físico-químicos, parâmetros biológicos, fitoplâncton, ambiente lótico.

ABSTRACT: Human impact on some limnological characteristics of the Gastona River (Tucumán, Argentina). The aim of this paper was to evaluate the human impact caused by sewage and by the sugarcane industry in the limnological characteristics of the Gastona River (Tucumán, Argentina) along a longitudinal gradient, from March to November 1998. Three sampling sites were selected and physico-chemical parameters (turbidity, dissolved oxygen, nitrogen compounds and phosphates) as well as biological parameters (biochemical oxygen demand (BOD_5), colimetry and phytoplankton) were analysed. The results obtained showed an increase in the pollution in San Carlos, the site nearest to the disturbance, and then a decrease downstream due to the river self-recovery as regards its water quality. A marked difference in the sugarcane campaign period (June-October) was observed with high amounts of coliforms (up to 9 log UFC/100 mL), BOD_5, phosphates, ammonium and nitrites, and minimum amounts of nitrates and dissolved oxygen. The phytoplankton became lower downstream, the number of individuals getting scarcer by approximately 50 % from July to October. Diatoms were the most abundant group, the pennate diatoms prevailing over the centric ones. *Cymbella affinis* Kützing, *C. amphicephala* Naegeli, *C. helvetica* Kützing, *Fragilaria ulna* (Nitzsch) Lange-Bertalot, *Melosira varians* Agardh, *Navicula exigua* (Gregory) Grunow, *N. goeppertiana* (Bleisch) H. L. Smith and *Nitzschia palea* (Kützing) W. Smith were the most often found species. Other groups such as Cyanophyta, Chlorophyta and Euglenophyta were found, the latter becoming more frequent from June in the two sites exhibiting the largest pollution. The results of the cluster analysis of biotic and non-biotic variables in relation with the sampling period under consideration were reported, which corroborated the spatial and temporal differences among the sampling sites.

Key-words: Human impact, physico-chemical parameters, biological parameters, phytoplankton, lotic environment.

INTRODUCTION

The Gastona River is a part of the mid basin of the Salí river and is one of the four tributaries from the Rio Hondo dam, the others being the Salí, the Medina and the Marapa rivers. The Gastona rises in the Sierras del Aconquija through the union of the Solco and the

Conventillo rivers; then, it joins the Chirimayo river at the city of Concepción and continues its course southeastwards through a plain until it reaches the Rio Hondo dam. The prevailing climate according to Köppen (Torres Bruchmann, 1978) is temperate, moderately rainy with mild dry winters; towards the east the climate becomes steppelike with xerophylous vegetation and precipitation that decrease from 2,000 to 600 mm a year from west to east. On the whole, the area has a partly loessic slimy-sandy soil fit for agriculture (Aceñolaza *et al*, 1984). One of the Gastona river drawbacks is its salinization, which increases towards the dam, partly because of the rain-washed soluble salts present in sedimentites of the cretaceous-eotertiary covering on areas with a gentle slope and, consequently, with an insufficient natural drainage (Consejo Federal de Inversiones, 1980). The waste waters from a sugarcane factory together with the sewage from the city of Concepción (Chicligasta Department) are drained into the Gastona throughout its course, making this river, together with the Salí, the most highly polluted ones in Tucumán during the sugarcane campaign period, with dissolved oxygen values of 0 mg L^{-1} (Romero *et al*, 1994).

The aim of this paper was to evaluate, through the study of physico-chemical and biological parameters (bacteria and phytoplankton), the effect of human impact on the Gastona River.

MATERIALS AND METHODS

Three sampling sites along the course of the Gastona were chosen for our study: 1) El Molino dam, 2) San Carlos and 3) Chicligasta (Fig.1), located 16 km upstream, and 7 km and 33 km downstream of the waste water discharge, respectively. Monthly samplings were carried out from March to November 1998, in order to cover the sugarcane campaign period (June-October). Turbidity (Turb), biochemical oxygen demand (BOD_5), dissolved oxygen (DO), nutrients (ammonium, nitrites, nitrates and phosphates), bacteria (total coliforms (TC) and faecal coliforms (FC) and phytoplankton amounts were determined according to APHA (1992) and Rodier (1989). Phytoplankton, was counted using the Utermöhl's (1958) sedimentation technique under an inverted microscope. Primary taxonomic sources used were Simonsen (1979) for diatoms; Geitler (1932), Komárek and Anagnostidis (1986, 1989) and Anagnostidis and Komárek (1988) for blue-green algae; and Bourrelly (1972, 1985) for other groups.

The statistical analysis of the data was carried out following the clustering method, using a cosine similitude coefficient, through the UPGM mean link of the NTSYS-pc program, by means of the log transformed data of the physico-chemical variables, bacterial concentration and quantity of the algal groups in relation to the period considered in this study.

RESULTS

Turbidity (Fig. 2 A) showed an important increase in the June-October period in the three sampling sites. In August, a marked difference was observed between San Carlos and El Molino, with values of 200 and 68 NTU, respectively.

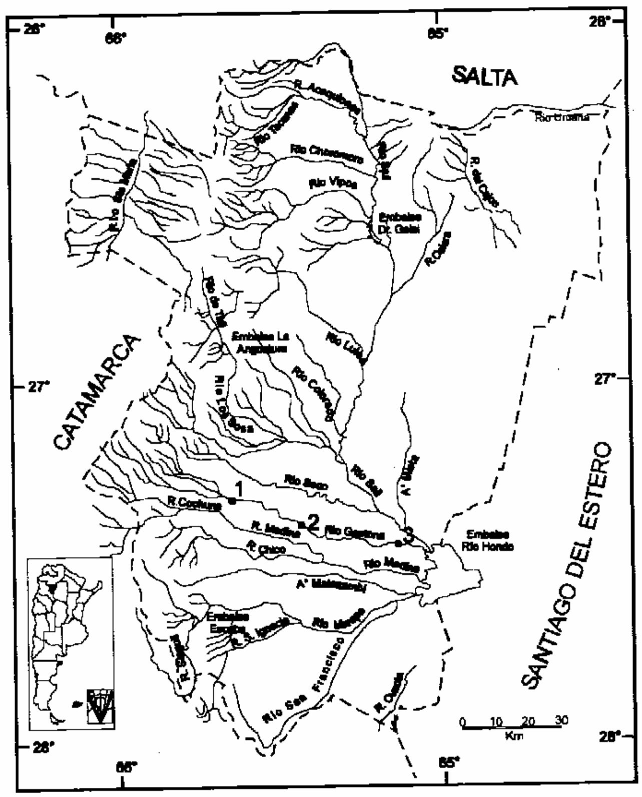

Fig. 1. Location of the sampling sites. 1.- El Molino dam; 2.- San Carlos; 3.- Chicligasta

Dissolved oxygen (DO) (Fig. 2 B) remained above 8 mg L^{-1} at El Molino dam, while in the other two sites, up to June, it fluctuated from 6.7 to 9.9 mg L^{-1}, dropping to 0 mg L^{-1} from August to October in Chicligasta and in August in San Carlos.

The biochemical oxygen demand (BOD_5) (Fig. 2 B) never reached values higher than 4 mg L^{-1} in El Molino dam. The difference between the values obtained here and those of the disturbed sites increased between July and October, maximum values being observed in August with 365 mg L^{-1} in San Carlos and 330 mg L^{-1} in Chicligasta.

Nitrate amounts tended to decrease along the course of the Gastona (Fig. 2 C). Highest values for the three sites occurred in March, with 16, 19 and 9.9 mg L^{-1} for the three sites, respectively. Lowest values were observed from May to October, 0 mg L^{-1} being found during July, August and September in San Carlos and Chicligasta.

As to the remaining nutrients (nitrites, ammonium and phosphate) (Fig. 2 D-F), an increase occurred downstream. In the more highly polluted sites, as a whole, the lowest concentrations were found from March to June and the highest from July to October, ammonium and phosphates being prevalent, with values of up to 4.9 and 14.8 mg L^{-1}, respectively. In El Molino dam, these three parameters remained more stable during the 9 months under study (March-November).

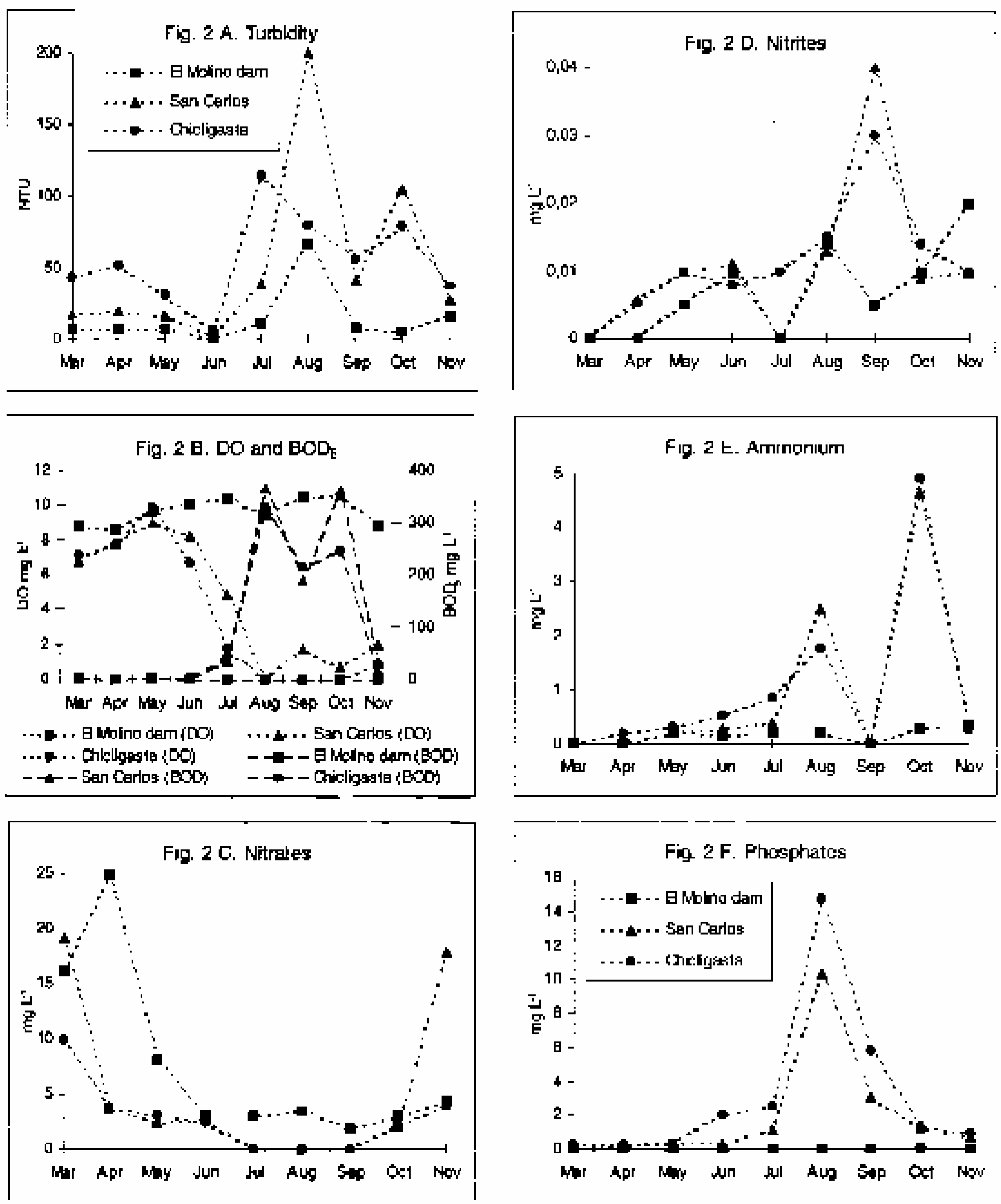

Fig. 2. Variation of physico-chemical and biological parameters in the Gastona River

Total and faecal coliform bacteria (Fig 3 A-B) showed the same behaviour throughout the period under study, increasing in April and August in the three sites. An important amount of bacteria was determined in the disturbed sites with respect to El Molino dam. In this site, total bacterial counts remained between 1-4 log UFC/100 mL with the exception of August, when they climbed up to 5 UFC/100 mL. In San Carlos, they ranged from 3 to 7 UFC/100 mL except in April and November, when they went up to 9 UFC/100 mL. In Chicligasta, they ranged between 3 and 6 UFC/100 mL, while in April, August and September they were above 7 UFC/100 mL. Faecal bacteria showed a behaviour similar to that of total ones in all three sites, but with lower values.

The amount of phytoplankton (fig. 3 C-E) became lower downstream, the decrease of individuals being 50 % or higher between July and October. Except in March and November, phytoplankton in sites 1 and 2 increased towards August (El Molino dam) and June (San Carlos) and then decreased, while in site 3 no important variations were observed. The amount

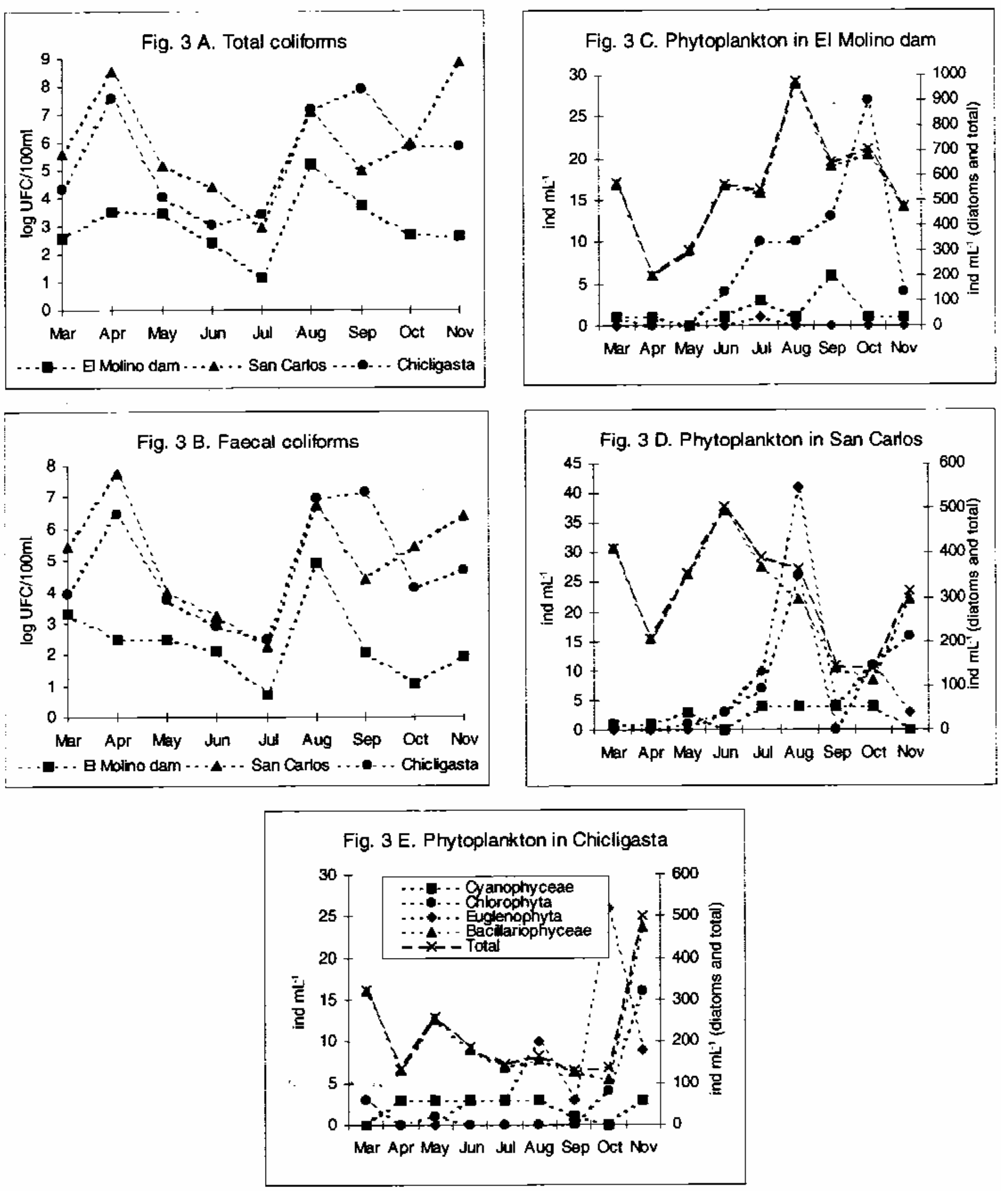

Fig. 3: Variation of biological parameters in the Gastona River

of individuals found increased from 203 (April) to 976 ind mL^{-1} (August) in El Molino dam, from 141 (October) to 503 ind mL^{-1} (June) in San Carlos, and from 131 (September) to 502 ind mL^{-1} (November) in Chicligasta. Bacillariophyceae was the most abundant group, the pennate diatoms prevailing over the centric ones, the abundant and most often found species being *Cymbella affinis* Kützing, *C. amphicephala* Naegeli, *C. helvetica* Kützing, *Fragilaria ulna* (Nitzsch) Lange-Bertalot, *Melosira varians* Agardh, *Navicula exigua* (Gregory) Grunow, *N. goeppertiana* (Bleisch) H. L. Smith and *Nitzschia palea* (Kützing) W. Smith. Cyanophyta, Chlorophyta and Euglenophyta were also observed. The last group, found mainly in San Carlos and Chicligasta from June onwards, exhibited species belonging to the genera *Euglena, Lepocinclis* and *Trachelomonas.*

The results of the cluster analysis of the sampling sites throughout the period under consideration at a level of similarity of 0.91, resulted in two groups, A and B (Fig. 4). As a whole, the former was made up of the samples from El Molino dam, which were similar as regards their low bacterial counts (3 log UFC/100 mL) and the amount of dissolved oxygen (>7 mg L^{-1}). Group A was subdivided into A_1 and A_2 on the basis of nitrates and density of diatoms. The first subgroup had higher amount of nitrates (8 - 25 mg L^{-1}, except Chicligasta - June) than A_2 (2 - 4 mg L^{-1}). On the other hand, subgroup A_1 had lower density of diatoms (180 - 201 ind mL^{-1}, except El Molino dam - March) than A_2 (474 - 680 ind mL^{-1}).

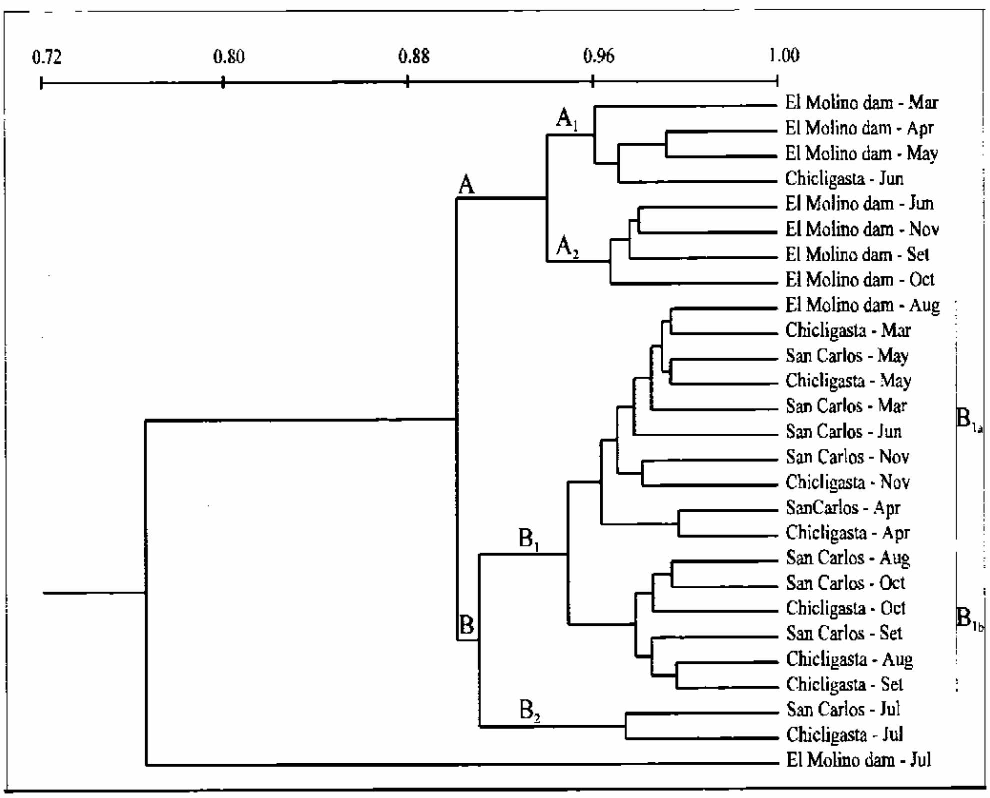

Fig. 4. Dendrogram of the cluster analysis of the sampling sites

Group B was composed mainly by the samples from San Carlos and Chicligasta and two subgroups (B_1 and B_2) were determined on the basis of biochemical oxygen demand, ammonium, phosphates and density of euglenids. B_1 was again subdivided into B_{1a} and B_{1b}, the latter comprising those samples that had been affected by the sugarcane activity, with BOD_5 values between 190 - 365 mg L^{-1} whereas the former never reached values higher than 29 mg L^{-1}. Subgroup B_2 was not included in B_1 since it showed BOD_5 values that were intermediate between B_{1a} and B_{1b} groups.

DISCUSSION

The impact caused by human activity on the Gastona River was evident, both spatially and temporally, and became more important on certain months, especially in August, coincidentally with the period of lowest rainfall and of sugarcane activity. In the first case, that is, along the course of the river, the decrease in the water quality appeared as an increase in turbidity, BOD_5, phosphates and ammonium together with a decrease in DO and nitrates, all of which in turn led to an increase in bacteria in San Carlos and Chicligasta. Phytoplankton, with the exception of Euglenophyta, decreased downstream despite the high phosphate coming from rain-washed soils (fertilizers and animal wastes) of the drainage area and of the city sewage. Euglenophyta was favoured by the high amounts of organic matter and of ammonia nitrogen, this being the only way in which nitrogen can be utilised by most species in this group (Angeli, 1979). The phytoplankton comprised a large number of tychoplanktonic species from periphyton, benthos and other communities. Different authors involve the sediments with survival of fluvial algal communities, even of primarily benthic organisms, and they observed that a large element of a river plankton, as of shallow lakes, was tychoplanktonic (Izaguirre & Vinocur, 1994; Billen *et al.*, 1994; Reynolds *et al.*, 1994). Diatoms were the most abundant group, prevailing the pennate diatoms over the centric ones. This situation was reported to other rivers from Argentina (Gagliori, 1992; Luque *et al.*, 1997; Martínez de Fabricius, 1986; Martínez de Fabricius *et al.*, 1988; Martínez de Fabricius & Corigliano, 1989).

Allocthonous contributions of organic matter favor water life by increasing the density of algae with heterotrophic behavior such as *Nitzschia* spp. and *Navicula* spp. and of deposit collecting and filtering organisms (Corigliano, 1989). *Cymbella affinis, C. amphicephala, C. helvetica, Fragilaria ulna, Melosira varians, Navicula exigua, N. goeppertiana* and *Nitzschia palea* were the most often found species. De Wolf (1982) described *Cymbella affinis, Melosira varians* and *Nitzschia palea* as eutrophic species and *Fragilaria ulna* as a meso-eutrophic species. Based on Lange Bertalot (1979) criteria, the species most tolerant to different concentrations of organic matter were *Fragilaria ulna, Navicula goeppertiana, Nitzschia palea.*

In the second case, that is, throughout time, sugarcane activity increased the differences between the sites under study, although a certain amount of the river self-depuration in water quality occurred in November. The beginning of the rainy period together with the end of the sugarcane campaign caused the dilution of certain contaminants, a decrease being observed in

BOD_5, turbidity, phosphate and ammonium. Besides, the increase in nitrates and DO resulted in an increase in phytoplankton in the disturbed sites, especially in Chicligasta. In El Molino dam, an undisturbed site, this increase in phytoplankton was related to the availability of nitrates and oxygen and with the decrease of the flow toward August and to the increase of the turbulence in this month due to atypical rains, which allowed better conditions for planktonic algae to remain in suspension. Several rivers studies (Schiaffino, 1977; Anselmi de Manavella & García de Emiliani, 1995; Luque *et al.*, 1997) described temporal variations in phytoplankton density and composition and showed its relation with water level fluctuation. García de Emiliani (1997) observed that river water regime had a high influence on river phytoplankton in a small side-arm of the Paraná River (Correntoso) and a close inverse relationship was found between water level and total biomass (dilution).

This paper would demostrate the important supply of organic matter (up to 365 mg L^{-1} in BOD_5) provided by a sugarcane plant which, together with sewage, result in undesirable conditions during the period of lowest rainfall thus producing noticeable differences, both spatial and temporal (campaign-noncampaign period) between the sites. Moreover, the cluster analysis carried out confirmed the differences between the various environments.

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