

## Water quality in the lower section of the Chubut River, Patagonia, Argentina

A. V. Sastre, N. H. Santinelli, S. H. Otaño and M. E. Ivanissevich

### Introduction

The Chubut River arises in the Andes, flows across the Patagonian plain from west to east, and discharges into the Atlantic Ocean. Its lower section (200 km long, approximately) is regulated by the Florentino Ameghino Dam (43°42' S and 67°2' W). Its water is used mainly for the supply of potable water to the most important cities in the area (~200,000 inhabitants) and for irrigation via a net of canals situated in the lower valley of the Chubut River (17,000 ha).

In its upper half (~100 km) it flows through an uninhabited area; from the dam it flows by a tourist village, Florentino Ameghino, with only a few inhabitants. The river then flows through open, shepp-raising lands. In this part of the river there are four plants for the extraction and washing of kaolin. In its last half, it flows through the most populated area; there are four large riverside cities as well as farms where the most important activity is agriculture (7,000 ha, approximately). Farmers grow potatoes, alfalfa and apples and raise cows and pigs. In this area, the river receives effluents from a factory producing algal products (agar and carragennans), from a wool-washing and spinning plant, and from an industrial dry-cleaning plant.

The mean velocity of flow is ~0.87 m/sec in the first 150 km, and 0.58 m/sec in the last 50 km up to its discharge into the Atlantic Ocean.

The aim of this study was to estimate the quality of the water in the lower part of the Chubut River by means of physical, chemical and biological (phytoplankton) indicators.

### Material and methods

Between 1989 and 1992, on 13 occasions, the lower part of the Chubut River was sampled in 11 selected stations, from Florentino Ameghino Dam to Rawson city (Fig. 1). Stations 1 and 2 were widely spaced; the other stations were closer in the most populated area with important industrial and agricultural activities.

Methods used for taking and processing samples of phytoplankton were described in (SASTRE et al. 1994 a, b). Temperature and conductivity were measured in situ. Turbidity, pH, alkalinity, total hardness,

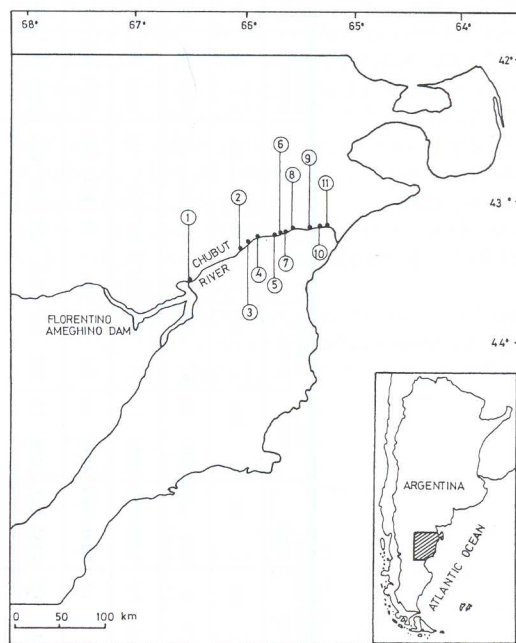


Fig. 1. Geographic localization of Chubut river showing the position of sampling station.

calcium, magnesium, sulfate, chloride, phosphate, silicate, nitrate, nitrite, ammonium and DO were determined by APHA (1985) in the Centralized Chemical Service of CENPAT (CONICET) and in the Water Treatment Plant Laboratory of Puerto Madryn.

An ANOVA was carried out for each parameter to determine its behaviour along the longitudinal axis of the river. PCA was used as a tool for statistical analysis of data, assuming that the species data were quantitative abundance values, to explain the abundance values of several species according to a particular environmental variable (JONGMAN et al. 1995).

### Results and discussion

Table 1 shows the mean values and standard deviations of physical and chemical parameters at

Table 1. Physical and chemical parameters.

|            | NO <sub>3</sub> <sup>-</sup><br>(mg/l) |       | NO <sub>2</sub> <sup>-</sup><br>(mg/l) |     | NH <sub>4</sub> <sup>+</sup><br>(mg/l) |      | Ca <sup>++</sup><br>(mg/l) |     | Mg <sup>++</sup><br>(mg/l) |     | SiO <sub>2</sub> <sup>-</sup><br>(mg/l) |     | PO <sub>4</sub> <sup>-</sup><br>(mg/l) |       | D.O.<br>(mg/l) |     | Turbidity<br>(N.T.U) |      | T<br>(°C) |     | pH        |      | Conduct<br>(µS/cm) |      | Alkalinity<br>(mg/l) |      | T.hardness<br>(mg/l) |     | Cl <sup>-</sup><br>(mg/l) |     | SO <sub>4</sub> <sup>-</sup><br>(mg/l) |      |
|------------|----------------------------------------|-------|----------------------------------------|-----|----------------------------------------|------|----------------------------|-----|----------------------------|-----|-----------------------------------------|-----|----------------------------------------|-------|----------------|-----|----------------------|------|-----------|-----|-----------|------|--------------------|------|----------------------|------|----------------------|-----|---------------------------|-----|----------------------------------------|------|
|            | $\bar{x}$                              | SD    | $\bar{x}$                              | SD  | $\bar{x}$                              | SD   | $\bar{x}$                  | SD  | $\bar{x}$                  | SD  | $\bar{x}$                               | SD  | $\bar{x}$                              | SD    | $\bar{x}$      | SD  | $\bar{x}$            | SD   | $\bar{x}$ | SD  | $\bar{x}$ | SD   | $\bar{x}$          | SD   | $\bar{x}$            | SD   | $\bar{x}$            | SD  | $\bar{x}$                 | SD  | $\bar{x}$                              | SD   |
| STATION 1  | 0.015                                  | 0.011 | 1.16                                   | 0.2 | 0.04                                   | 0.03 | 20.8                       | 1.8 | 4.4                        | 0.7 | 12.8                                    | 3   | 0.081                                  | 0.004 | 10.06          | 1.2 | 19.7                 | 19.4 | 11.2      | 3.4 | 8.01      | 0.2  | 125.4              | 24   | 89.3                 | 9.6  | 69.9                 | 6.5 | 7.4                       | 2.5 | 20.5                                   | 23   |
| STATION 2  | 0.007                                  | 0.005 | 0.85                                   | 0.4 | 0.1                                    | 0.15 | 22.1                       | 1.1 | 4.6                        | 0.6 | 12.5                                    | 2.8 | 0.036                                  | 0.002 | 10.82          | 1   | 26                   | 25.5 | 12.2      | 5.2 | 8.17      | 0.26 | 132.2              | 27.7 | 91                   | 10.4 | 78.5                 | 4   | 8.7                       | 3.4 | 21.8                                   | 17.4 |
| STATION 3  | 0.007                                  | 0.005 | 0.84                                   | 0.4 | 0.06                                   | 0.04 | 23.1                       | 3.1 | 4.3                        | 1.2 | 11                                      | 3.7 | 0.026                                  | 0.009 | 10.83          | 1.3 | 22.9                 | 19   | 13        | 5.8 | 8.11      | 0.23 | 139                | 38.6 | 95                   | 13.7 | 75.4                 | 4.8 | 10.2                      | 5.2 | 23.8                                   | 22.5 |
| STATION 4  | 0.006                                  | 0.004 | 0.9                                    | 0.5 | 0.06                                   | 0.06 | 21.5                       | 3.8 | 5.8                        | 2.6 | 9.3                                     | 2.8 | 0.116                                  | 0.21  | 10.43          | 1.1 | 23.6                 | 21.4 | 13.4      | 5.5 | 8.14      | 0.22 | 152.6              | 36   | 96.3                 | 11.5 | 78.2                 | 7.5 | 13.6                      | 6   | 23.7                                   | 21.1 |
| STATION 5  | 0.007                                  | 0.006 | 1.2                                    | 0.3 | 0.16                                   | 0.2  | 23.1                       | 4.4 | 6.7                        | 2.6 | 8.9                                     | 2.9 | 0.065                                  | 0.02  | 10.01          | 1.2 | 33.1                 | 33   | 12.6      | 5.5 | 8.07      | 0.2  | 197.8              | 48.2 | 103.3                | 10.8 | 86.7                 | 8   | 23.8                      | 9   | 30.4                                   | 17.5 |
| STATION 6  | 0.006                                  | 0.005 | 1.02                                   | 0.6 | 0.13                                   | 0.2  | 23.6                       | 5.3 | 6.7                        | 2.7 | 9.5                                     | 3.2 | 0.044                                  | 0.01  | 10.35          | 1.3 | 32.5                 | 34.1 | 13        | 5.8 | 8.06      | 0.16 | 198.3              | 42   | 104.5                | 10.3 | 85.7                 | 6.1 | 24.4                      | 8.2 | 30.7                                   | 18   |
| STATION 7  | 0.007                                  | 0.004 | 0.9                                    | 0.2 | 0.1                                    | 0.09 | 23.8                       | 5.7 | 6.4                        | 3.2 | 8.4                                     | 3   | 0.058                                  | 0.01  | 10.01          | 1.3 | 33.4                 | 39.6 | 13.2      | 6.3 | 8.01      | 0.15 | 193.1              | 42.4 | 104.1                | 10.4 | 86.8                 | 4.9 | 23.5                      | 8.2 | 29.1                                   | 17.7 |
| STATION 8  | 0.007                                  | 0.006 | 1.3                                    | 0.4 | 0.1                                    | 0.16 | 26.1                       | 3.1 | 6.1                        | 1   | 8.6                                     | 3.4 | 0.065                                  | 0.01  | 10.02          | 1.3 | 33.3                 | 31.3 | 13.3      | 6   | 8.03      | 0.26 | 222.2              | 52.5 | 103.7                | 10.5 | 90.2                 | 11  | 32                        | 12  | 32.2                                   | 19   |
| STATION 9  | 0.006                                  | 0.003 | 0.8                                    | 0.2 | 0.13                                   | 0.15 | 23.8                       | 5.7 | 7.1                        | 2.6 | 7.9                                     | 3.9 | 0.036                                  | 0.01  | 10.4           | 1.4 | 33.3                 | 40.5 | 12.9      | 5.7 | 8.04      | 0.2  | 226.4              | 51   | 104.3                | 10.1 | 86.7                 | 7.7 | 39.8                      | 18  | 32.8                                   | 20   |
| STATION 10 | 0.007                                  | 0.006 | 1.2                                    | 0.6 | 0.08                                   | 0.07 | 24.2                       | 3   | 6.7                        | 1.4 | 7.8                                     | 3.5 | 0.024                                  | 0.01  | 10.22          | 1.5 | 35.2                 | 43.2 | 13.2      | 6   | 7.97      | 0.3  | 231                | 55.2 | 103.7                | 11   | 88                   | 9   | 35.2                      | 14  | 32.5                                   | 19   |
| STATION 11 | 0.006                                  | 0.004 | 1.1                                    | 0.5 | 0.09                                   | 0.07 | 24                         | 5.5 | 7.5                        | 2.1 | 8.3                                     | 4.3 | 0.082                                  | 0.06  | 10.22          | 1.3 | 34.6                 | 48.1 | 12.9      | 6.2 | 8.03      | 0.18 | 236.8              | 55.1 | 105.3                | 9.8  | 90.5                 | 8.4 | 34.6                      | 11  | 33.3                                   | 16.8 |

each sampling station. Correlations showed that with high temperatures and low flow dissolved oxygen decreased and the concentration of ammonium and silicates increased. An increase of nitrates was noted together with high values of DO. The values of nitrates and phosphates were generally lower, with high water temperatures; this can be explained by phytoplankton uptake.

ANOVA gave different results according to the parameters analysed: pH, ammonium, DO, nitrate and phosphate showed no significant differences along the river. However, in the irrigation season, stations 7 and 8 (which lie above and below the discharge of one of the most important collector canals) show differences in the concentration of total inorganic nitrogen and phosphorus as phosphate ( $258.30 \mu\text{g} \cdot \text{L}^{-1}$  and  $301 \mu\text{g} \cdot \text{L}^{-1}$ ;  $15.50 \mu\text{g} \cdot \text{L}^{-1}$  and  $21.03 \mu\text{g} \cdot \text{L}^{-1}$ ). The variability of these values suggests that the external contributions of compounds that produce such variation are important for example the contributions from the system of drainage collector canals. This system collects water from cultivated soils, so collecting an im-

portant amount of nutrients used as fertilizers. This process is favoured by clay soils, abundant in the valley, which absorb little irrigation water, and so draining drainage towards the river.

The other parameters showed significant differences ( $p < 0.01$ ). Sulfates and magnesium showed a similar behaviour and homogeneous distribution from station 1 to 4. They then increased downstream. The same pattern occurred with the silicates, but they decreased downstream. This is explained by the presence of kaolin activities along the upper part of the river. Chlorides, total hardness, conductivity and turbidity showed three patterns. The first, between stations 1 and 4, had low values; the second, from station 5 to 7, and the third one with higher values, from station 8 to station 11. Alkalinity showed four different patterns: stations 1 and 2, station 3, station 4 and the section between stations 5 and 11. Nitrites in the station nearest the dam had different patterns from the rest of the river.

For phytoplankton density, station 1 to 7 separate from the lower ones, where however station 10 stands apart from stations 8, 9 and 11.

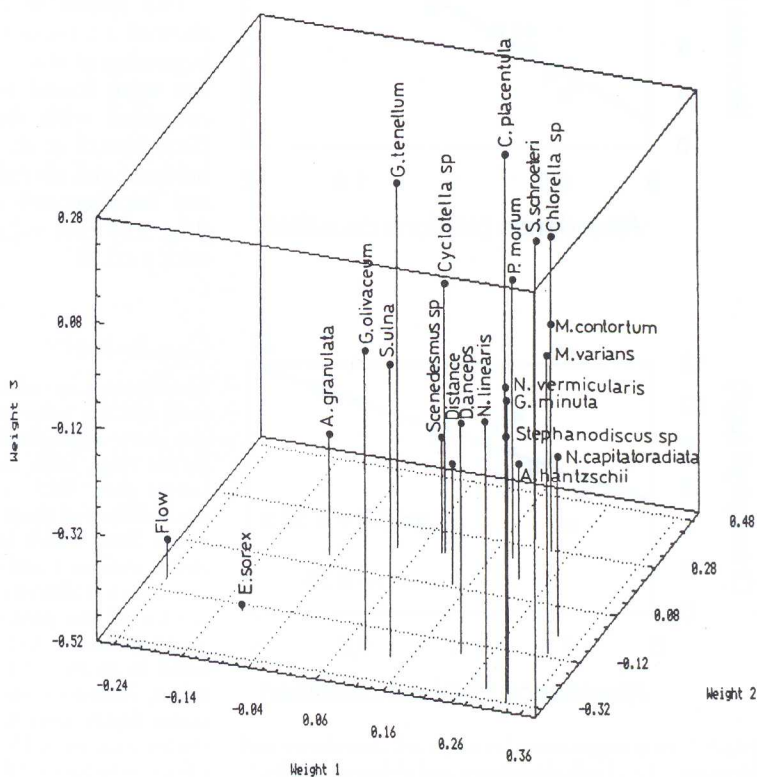


Fig. 2. PCA-ordination diagram of phytoplankton species, flow and distance of Chubut river.

PCA involved phytoplankton species, river flow and the distance measured from the dam (Fig. 2). The first component loads the 18.36 % from the total variation and is explained by river flow. This is situated in the negative part, whereas in the positive part there is a group of diatoms that show their preference for low flow conditions. *Melosira varians*, *Navicula capitatoradiata*, *Nitzschia vermicularis*, *N. linearis*, *Diatoma anceps* and *Gomphonema minuta* are species which were found in the autumn and spring of 1990. In this period, the river showed the lowest volume of water during the study period. *M. varians* is a polysaprobe species mentioned in the literature as an indicator of pollution by organic matter and eutrophic environments. LOEZ & SALIVIAN (1990) found this species in the Reconquista River, a highly polluted river in Argentina. The

other species appear under similar conditions in this river.

The second component, which loads 15.78 % of the variation, is explained by a group of green algae. This indicates that there is a change in the structure of the community. Within the plankton succession in this river, the presence of green algae such as *Monoraphidium contortum*, *Pandorina morum* and *Sphaerocystis schroeteri* is restrained to its middle and lower sections, especially during spring and summer.

The third component accounts for 8.45 % of the variation and is characterized by the presence of *Aulacoseira granulata*, *Stephanodiscus* spp., *Actinastrum hantzschii* and *Ephitemia sorex*. These species are positively correlated with distance. *A. granulata* produces summer blooms and causes blockade of the sand filters for the water supplies to riverine cities (SASTRE et al. 1994 a, b). Both *A. granulata* and *Stephanodiscus* spp. are indicators of eutrophic environments (MARGALEF 1983, REYNOLDS 1984). This shows a gradient of anthropogenic influence along the river. Both associations of diatom species and individual species are good indicators of water quality (PATRICK 1973).

The spatial distribution of phytoplankton showed a tendency to increase in cell number beginning at stations 4 and 5. The highest values were found in the lower stations which coincided with the presence of bigger cities (SANTINELLI et al. in press). Linear regression between cell abundance and biomass (Fig. 3 a) and between cell abundance and chlorophyll (Fig. 3 b) gave values of  $r = 0.96$  and  $r = 0.79$ , with  $p < 0.05$ .

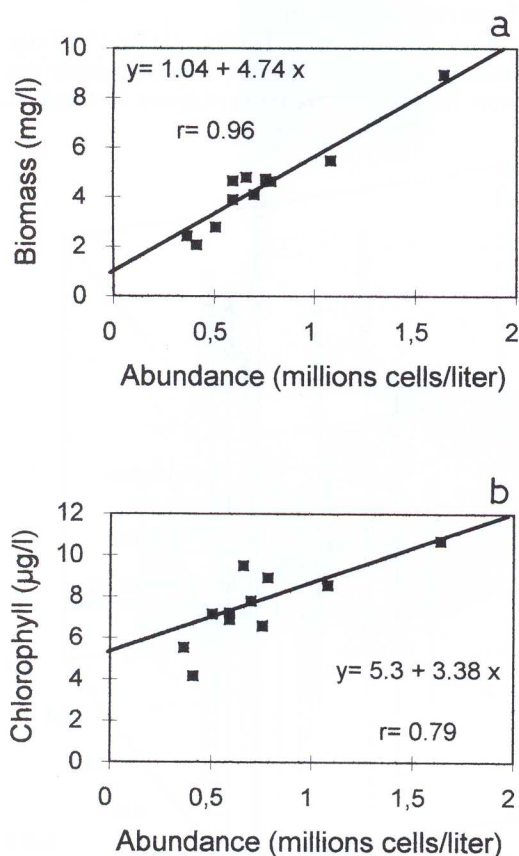


Fig. 3. Linear regressions between cell abundance and biomass (a) and cell abundance and chlorophyll (b).

## Conclusions

The increase in most physical and chemical parameters and the presence of some phytoplankton species show a longitudinal gradient of eutrophication in the river, with maximum eutrophication in the lowest part. With a few exceptions, the variables studied showed three distinct sections in the river.

The first, which is homogeneous, is situated between stations 1 and 4 (first 120 km), and runs in an area which is almost uninhabited. It presents low values for all the parameters. The middle section, between stations 5 and 8 (50 km approximately), is situated in an area of high anthropogenic impact with urban, industrial and farming effluents. Values increase significantly here. The third section, which includes stations 9, 10 and 11 (last 20 km), and where values increase slightly, shows stabilization with high

values of variables. This process is favoured because the lower part of the Chubut River shows a significant decrease in the mean velocity of flow, with a consequent increase in the residence time of phytoplankton and an enrichment in nutrients.

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## Authors' address:

A. V. SASTRE, N. H. SANTINELLI, S. H. OTAÑO and M. E. IVANISSEVICH, Facultad de Ciencias Naturales, Universidad Nacional de la Patagonia, Belgrano 504, 2° Piso, 9100, Trelew, Chubut, Argentina.

