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RESULTS OF A LIMNOLOGICAL STUDY IN A RESERVOIR PREVIOUS TO THE FUNCTIONING OF A NUCLEAR POWER PLANT (EMBALSE DEL RIO III, ARGENTINA)

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ABSTRACT

Mariazzi, A.A.; M.C. Romero; V.H. Conzonno and A.J. Mariñelarena. 1989. Results of a limnological study in a reservoir previous to the functioning of a nuclear power plant (Embalse del Río III, Argentina). *Rev. Asoc. Cienc. Nat. Litoral 20* **(1 y 2)**: 57 – 68

The Embalse del Río III, a multipurpose reservoir located in Córdoba Province, Argentina, was studied from 1977 to 1981 with the aim of knowing its structure and dynamics previous to the use of its waters for cooling purposes in a nuclear power plant. Physicochemical characteristics, primary production, chlorophyll *a*, seston, bacterial heterotrophic activity and other variables were analized, evaluating the space and time distribution, and inter-relationships. Evaluation of these parameters give us enough information to conclude that this reservoir is highly eutrophic.

RESUMEN

Mariazzi, A.A.; M.C. Romero; V.H. Conzonno y A.J. Mariñelarena. 1989. Resultados de un estudio limnológico en un embalse previo al funcionamiento de una central nuclear (Embalse del Río III, Argentina). *Rev. Asoc. Cienc. Nat. Litoral 20* **(1 y 2)**: 57 – 68

El Embalse del Río III, embalse multipropósito situado en la Provincia de Córdoba, Argentina, fue estudiado desde 1977 a 1981 con la finalidad de conocer su estructura y dinámica, previamente a la utilización de sus aguas como fuente de enfriamiento en una central nuclear. Este ecosistema está ubicado en la categoría de "cálido monomíctico" con un período de mezcla vertical en otoño–primavera y uno de estratificación estival. Durante el verano el oxígeno disuelto descendió a valores muy bajos en los estratos profundos. Las variaciones de la transparencia y del seston tuvieron relación con los cambios en el nivel del lago. La producción primaria y la clorofila *a* mostraron variaciones similares, con incrementos en el período de primavera–verano. Las mayores tasas de producción primaria se observaron entre 0,5 y 1 metro de profundidad, algo por encima de los picos de clorofila *a*. El potencial bacteriano heterotrófico evidenció un aumento en el verano con relación al invierno de un 98 %, en concordancia con el número y actividad fotosintética algal, la cual aportó elevadas concentraciones de materia orgánica. La información obtenida a través de las distintas variables consideradas nos permite concluir que el embalse es elevadamente eutrófico. Los efectos derivados del uso de sus aguas como fuente refrigerante en la central nuclear podrían acelerar el deterioro del sistema y deberán ser cuidadosamente evaluados.

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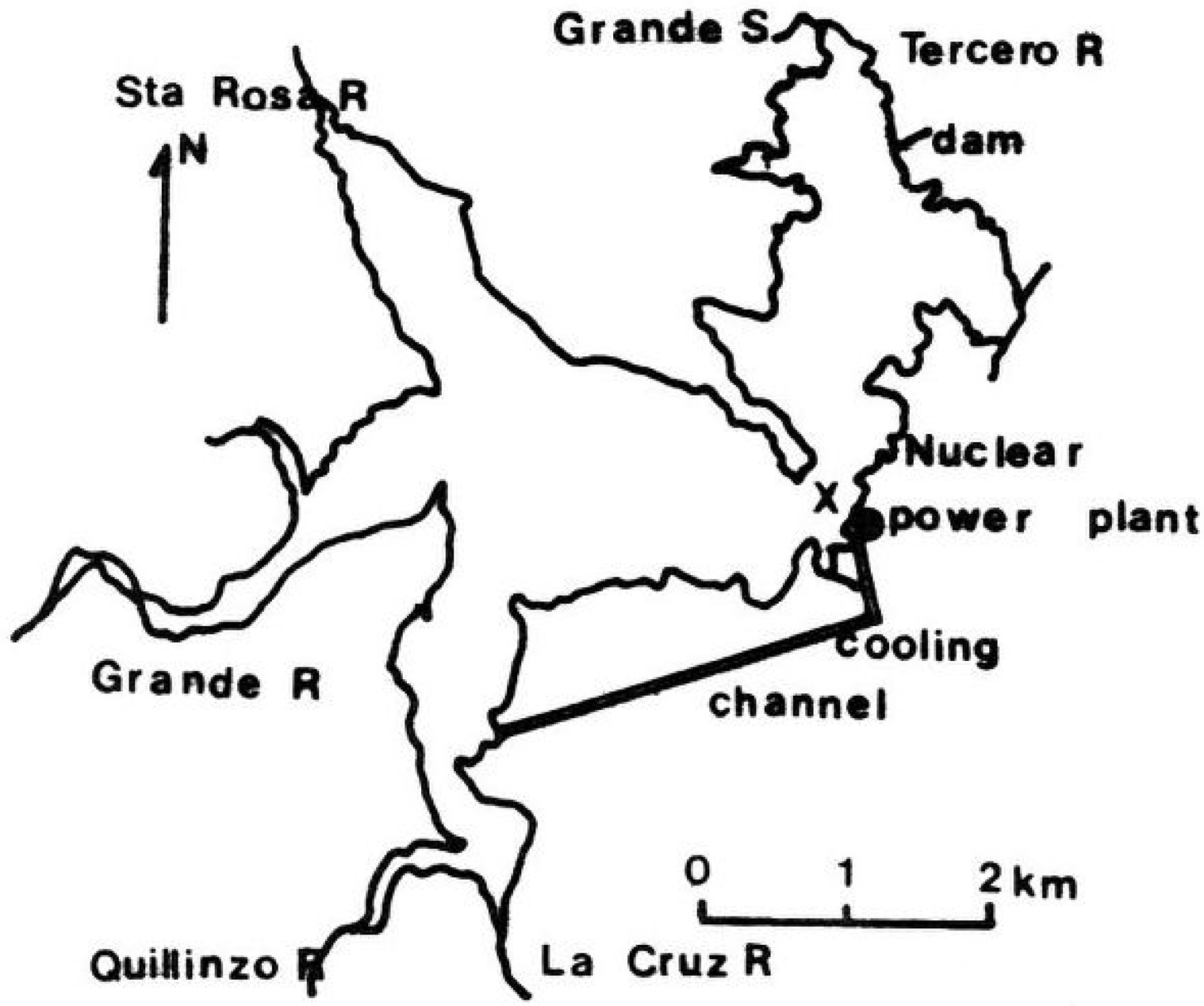

Figure 1. Map of the Embalse del Río III with (x): sampling station; Nuclear power plant and cooling channel.

Table 1

Some morphometric and physical characteristics of the Embalse del Río III.

Latitude	32° 11′ S
Longitude	64° 23′ W
Altitude	529.4 m.o.s.l.
Area	45.3 km^2
Mean depth	12.2 m
Maximun depth	46.5 m
Volume of water	560 x 10^6 m^3
Shoreline length	95.4 km
Catchment area	3250 km^2
Water residence time	0.44 y

INTRODUCTION

In this study we describe some limnological aspects of the Embalse del Río III, a multipurpose reservoir located in Córdoba Province, Argentina. It was built in 1936 for hydroelectric supply. It is sorrounded by several villages that use its waters for drinking, irrigation, fishing, and recreation. During summer the population increase due to tourism.

During 1977 the National Atomic Comission required this investigation previous to the use of the waterbody for cooling purposes in a nuclear power plant. The survey took place from 1977 to 1981. In 1983 the nuclear plant located between the two basins of the reservoir started to function, pumping 120,000 cubic meters per hour of lake water, producing a maximum change of temperature of 7°C between the inlet and the outlet, after which waters goes through a 5 km artificial channel before returning to the reservoir.

The aim of the study was to obtain basic information concerning physical and chemical characteristics, primary production, chlorophyll *a* and other variables. This research has allow us to describe the actual trophic status of the reservoir and discuss possible changes in it caused by the installment of the nuclear power plant.

General features of the reservoir

Some morphometric, physical and chemical characteristics of the Embalse del río III (Fig. 1) are given in Tables 1 and 2. The climate of the area is temperate subtropical, air temperature range between 8 and 40° C with a mean of 16.5° C. The rainy period is in spring–summer (more than 200 mm per month, September–March) and the annual mean rains obtained between 1951–1958 and 1972–1981 were 743 mm.

Chemical characteristics of the water indicate that is alkaline, hypohaline and soft, with preeminence of bicarbonate and calcium among the anions and cations respectively.

MATERIALS AND METHODS

Water samples were collected from surface, 1, 2.5, 5, 7.5, 10, 15 and 20 meters depth with a plexiglass van Dorn sampler at a central station of the reservoir (Fig. 1), close to the nuclear plant inlet. From July 1977 to January 1980 samples were taken every other month and monthly from March 1980 to November 1981. Methods used are indicated in Table 3.

RESULTS AND DISCUSSION

Thermal regime

According to Boltovskoy y Foggetta (1985) the Embalse del Río III is in the category of "warm monomictic" of Hutchinson and Löffler (1956). The thermal behaviour in the different years considered in this study show a turnover period from autumn to spring and a period of summer stratification. We choose a time–depth diagram of isotherms from April 1980 to March 1981 as a representative example of

the whole period studied (Fig. 2). During summer stratification, temperature ranged between 23 to 28° C in the epilimnion and between 19 to 22° C in the hypolimnion. During summer 1978 and 1980 differences of temperature between surface and bottom reached 6–7° C but in 1979 this difference was only of 2° C. Minimun temperature during turnover period was 9° C.

Dissolved oxygen

A strong relationship was found between vertical distribution of dissolved oxygen and water temperature (Fig. 3). During vertical mixing oxygen was distributed quite uniformly from surface to bottom. At the beginning of spring the oxygen content at deeper layers decreased rapidly and a marked vertical stratification was stablished in early summer, resulting in oxygen values less than 1 mg l^{-1}.

Seasonal changes in water level

Reservoir water level changed with a similar pattern in the different years and was related to the rainy and dry seasons. Since autumn water level decreases gradually till late spring and then the waterbody is refilled reaching maximum level in summer. Maximum variation was observed in 1977 reaching 12 meters, in the other years variation range between 5 and 8 meters (Fig. 7c).

Table 2

Chemical characteristics of the Embalse del Río III

	$\bar{X}$	C.V. (%)
pH	8.19	5.0
Total dissolved solids, mg.l^{-1}	128.6	19.6
Carbonate, mg CO_3^{2-}. l^{-1}	1.3	205.7
Bicarbonate, mg CO_3H^-,l^{-1}	83.3	19.2
Chloride, mg Cl^-.l^{-1}	1,6	73,6
Sulphate, mg SO_4^{2-}.l^{-1}	10.0	95.5
Sodium, mg Na^+.l^{-1}	10.3	28,7
Potassium, mg K^+.l^{-1}	2.5	14.1
Calcium, mg Ca^{2+}.l^{-1}	17.7	21.8
Magnesium, mg Mg^{2+}.l^{-1}	4.8	29.4

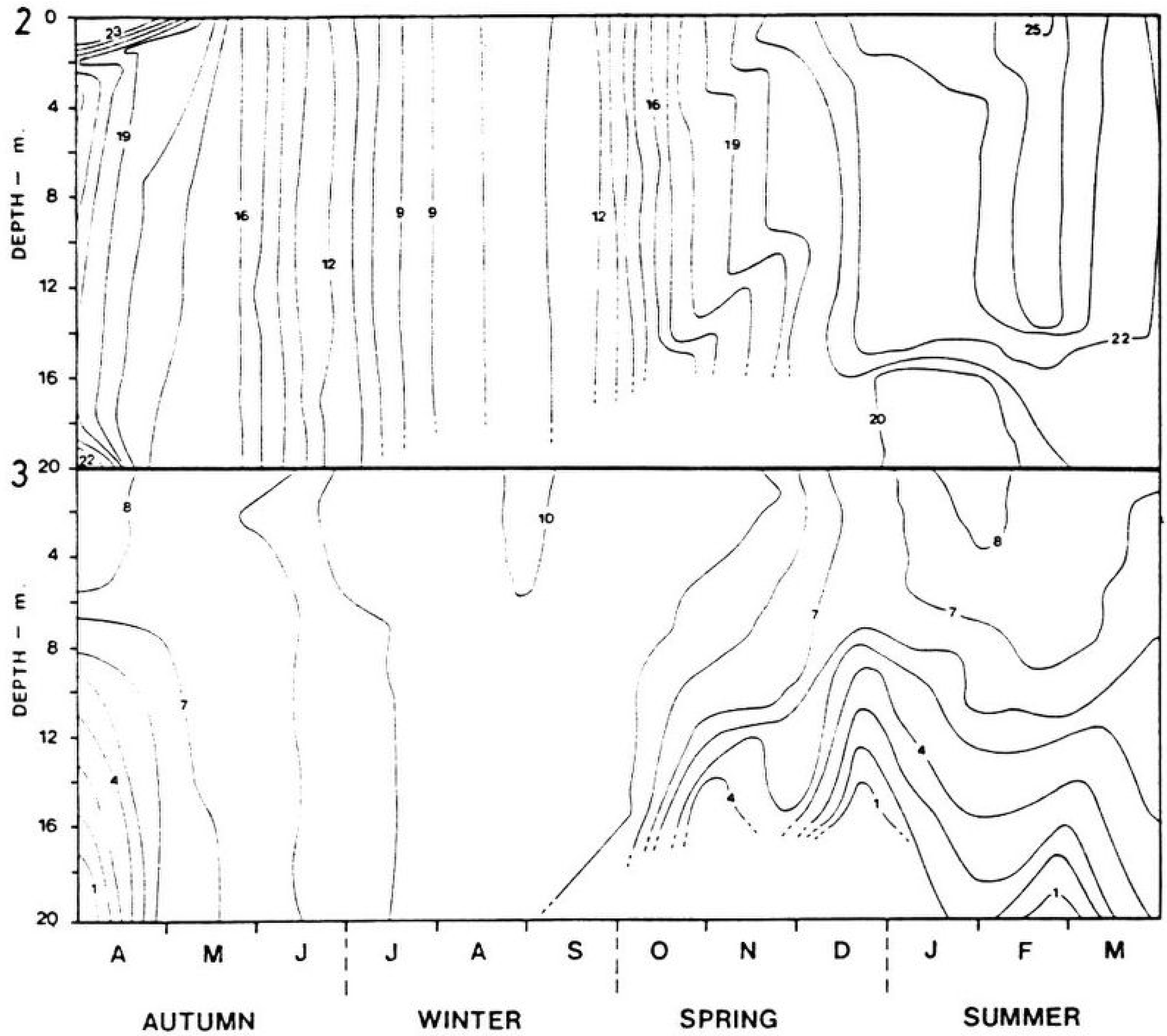

Figure 2. Isotherms

Figure 3. Spatial–time distribution of dissolved oxygen (mg $O_2.l^{-1}$).

Table 3

Methods used

Variable	Method	Reference
Temperature	thermistor	– – –
dissolved oxygen	Winkler	A P H A (1971)
transparency	Secchi disk	– – –
seston	gravimetry	Strickland & Parsons (1968)
POC	oxidation by dichromate	Strickland & Parsons (1968)
primary production	oxygen, light-dark bottle	Vollenweider (1969)
total phosphorus	digestion by persulphate, ascorbic	A P H A (1971)
total inorganic	sum of nitrite + nitrate + ammonia	A P H A (1971)
kinetic parameters	^{14}C-glucose uptake	Wright & Hobbie (1966)
chlorophyll *a*	acetone extraction	Lorenzen (1967)

Transparency

Secchi disk values fluctuated between 0.25 and 3.00 meters (mean: 1.80 m). A good relation is found between transparency and changes in the reservoir water levels suggesting that Secchi values were partially controlled by physical factors (dilution effect during filling period) while low transparency periods coincided with blooms of Cyanophyta and Chlorophyaceae (Fig. 4a).

Seasonal variation of seston and particulate organic carbon (POC)

Mean values of seston in the euphotic zone fluctuated between 3 and 28 milligram per liter. Maximum values were found in early spring or summer, except during 1980 that was observed during winter months. As was excepted, Secchi disk reading showed an inverse relationship with seston. Mariazzi *et al.* (1981) in a previous study found similar results between these two variables and chlorophyll *a* concentrations. Particulate organic carbon (POC) represented 19 °/o of the seston. Our results agree with those found by Nakanishi *et al.* (1985) with respect to the relationship between POC and chlorophyll *a* + phaeopigments; particulated organic carbon followed chlorophyll *a* variations with a Pearson correlation coefficient of r= 0.83 (Fig. 4b).

Chlorophyll *a*, primary production and dominant algae

Chlorophyll *a* in the euphotic zone ranged between 0.9 and 179 mg m^{-2} (Fig. 4). Higher values were observed in summer periods although during winter months the values were still high in the last year. Maximum concentrations in the euphotic zone

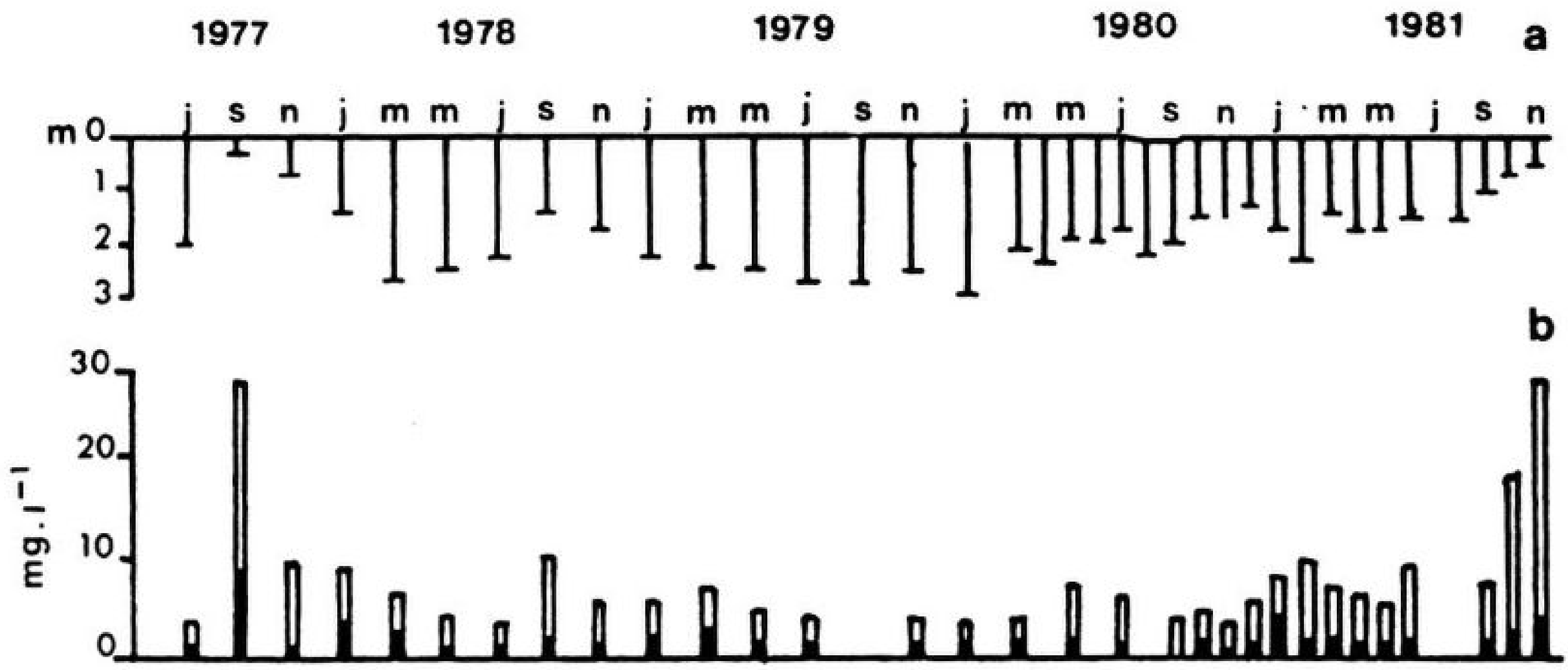

Figure 4. Seasonal variation of: (a) Secchi disk values (m); (b) seston (bars; mg l^{-1}) and particulate organic carbon (dark bars; mg l^{-1}).

varied in the range of 1.2 and 36.4 mg m^{-3} (Fig. 5) with an exceptional value of 104 mg m^{-3} during September 1977, coinciding with an *Anabaena spiroides* bloom. Dominant algae in the studied period were: *Anabaena spiroides, Peridinium gatunense, Closterium aciculare, Sphaerocystis schroeteri, Actinocyclus normanii* and *Melosira granulata* (Boltovskoy, A., personal communication).

Primary production showed a pattern similar to chlorophyll, with an increase in summer months. In 1978 and 1979 maximum rates occurred in January (10.9 and 10.8 g O_2 m^{-2} d^{-1}) and in 1980, 1981 at the end of summer, with lower values (5.2 and 6.8 g O_2 m^{-2} d^{-1}). Mean daily primary production rate of each studied year were: 5.3; 5.2; 3.0 and 2.3 g O_2 m^{-2} d^{-1} showing a remarkable decrease along the studied period. Minimum values were observed during winter and the lower one was 0.3 g O_2 m^{-2} d^{-1}. Maximum values of primary production were always found between 0.5 and 1 meter depth, just above chlorophyll *a* peaks that mostly were at 2.5 meters depth (Fig. 6). Primary production values of this study are similar to that obtained in other eutrophic lakes (Le Cren & Lowe–McDonell, 1980).

Phosphorus and nitrogen

Seasonal variations of total phosphorus nearly followed chlorophyll and primary production fluctuations. Total phosphorus had a mean of 49 µg P l^{-1} ranging from 16 to 144, µg P l^{-4} (Fig. 7a). According to Forsber & Ryding (1980) these values are typical of eutrophic lakes.

Total inorganic nitrogen presented a mean value of 210 µg l^{-1} and a range of 59 to 525 µg N l^{-1}, varing as total phosphorus, in a similar way than chlorophyll *a* and primary production. (Fig. 7b).

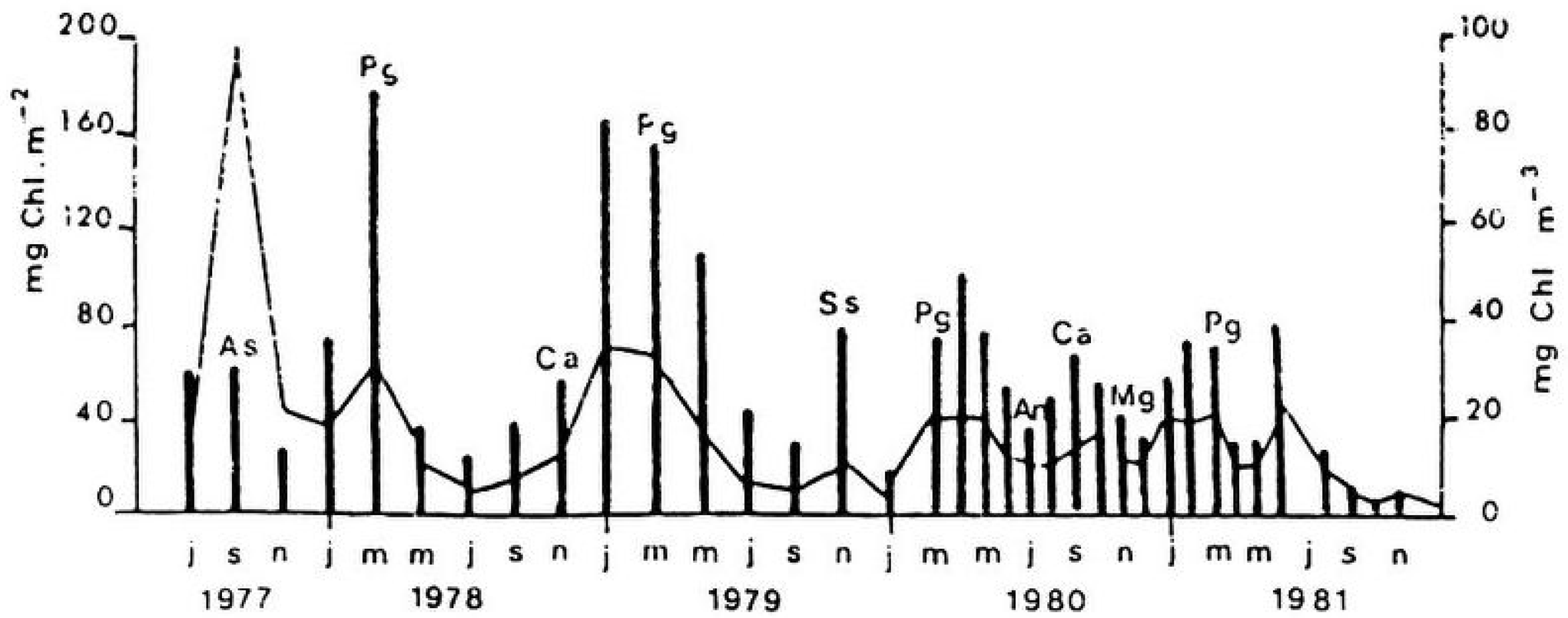

Figure 5. Seasonal variation of chlorophyll *a* in the euphotic zone (bars; mg Chl. m^{-2} and line, maximum values; mg Chl.m^{-3}). Dominant algae: As *(Anabaena spiroides);* Pg *(Peridinium gatunense);* Ca *(Closterium aciculare);* Ss *(Sphaerocystis schroeteri);* An *(Actinocyclus normanii)* and Mg *(Melosira granulata).*

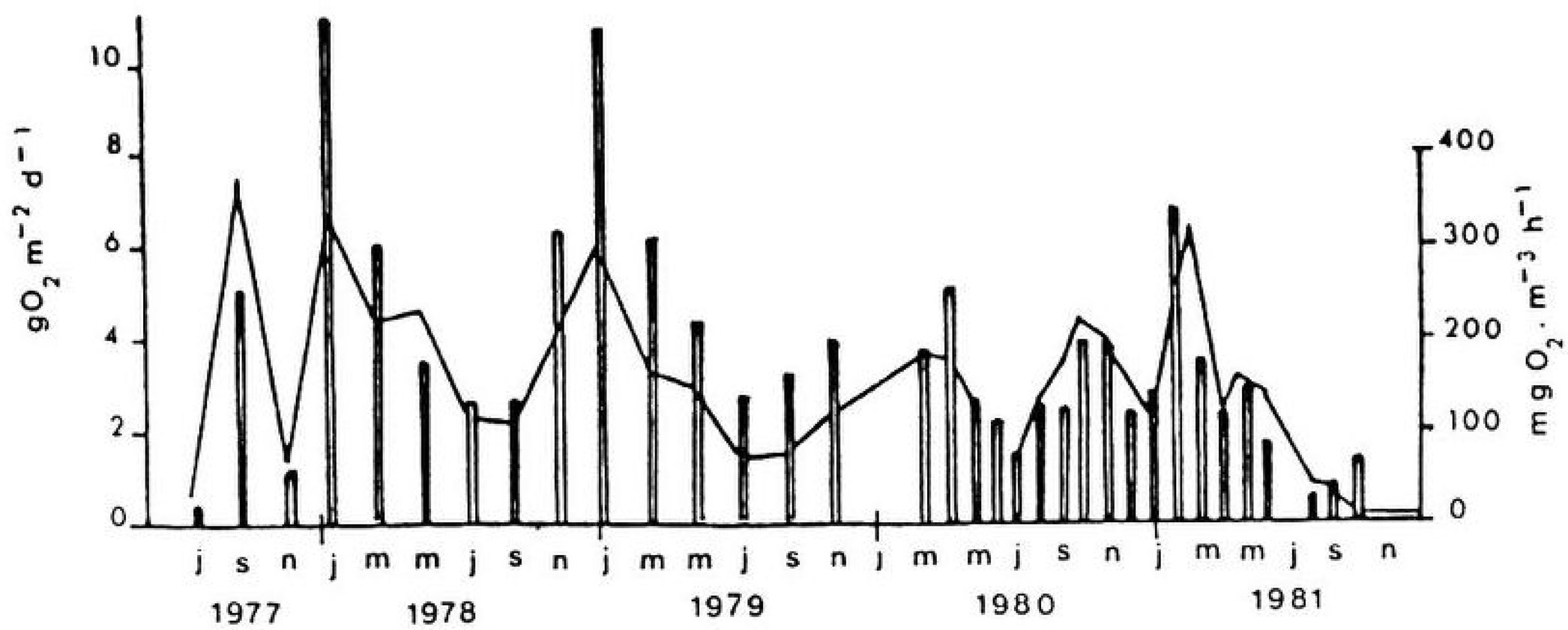

Figure 6. Seasonal variation of gross primary production (bars; g O_2 m^{-2} d^{-1} and line, maximum values; mg O_2 $m^{-3}h^{-1}$)

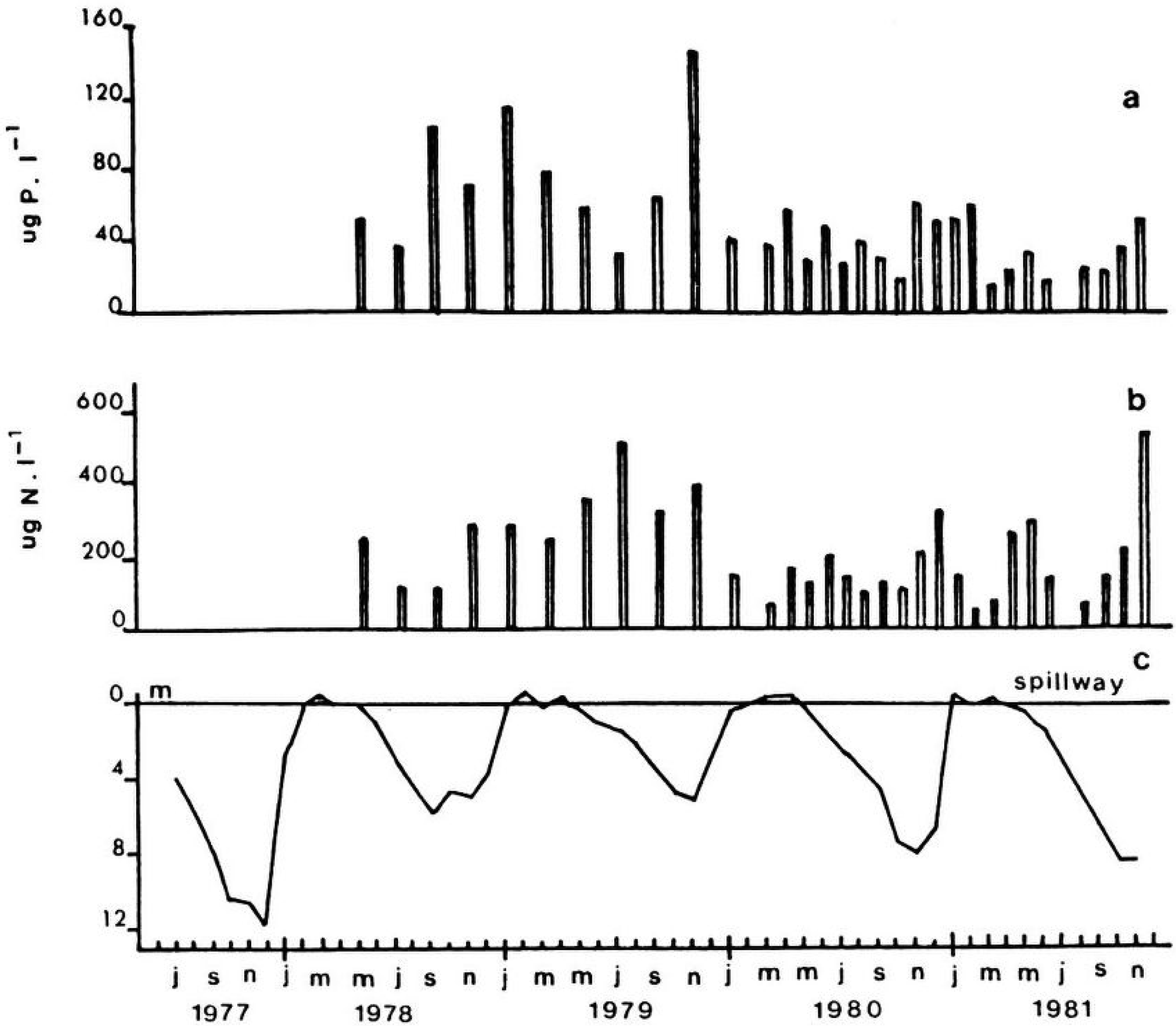

Figure 7. Seasonal variation of: (a) total phosphorus (µg P l^{-1}); (b) total inorganic nitrogen (µg N l^{-1}); (c) reservoir water level (m).

Kinetic parameters

Maximum theoretical rate of uptake (Vmax of 14_C–glucose) showed marked seasonal changes (Fig. 8) with similar pattern to that of chlorophyll *a* and primary production. Heterotrophic potential was maximum during summer with 2.08 µg glucose l^{-1} h^{-1}, in coincidence with a *Peridinium gatunense* bloom. Minimum value (0.04 µg glucose l^{-1} h^{-1}) was observed in winter. This increase of 98 °/o of Vmax during summer in relation to winter was probably due to dinoflagellate bloom which aported high amounts of organic matter. The active transport constant and the natural sustrate concentration (K_t + S_n) fluctuated between 24.5 and 1.1 µg l^{-1} in the euphotic zone,

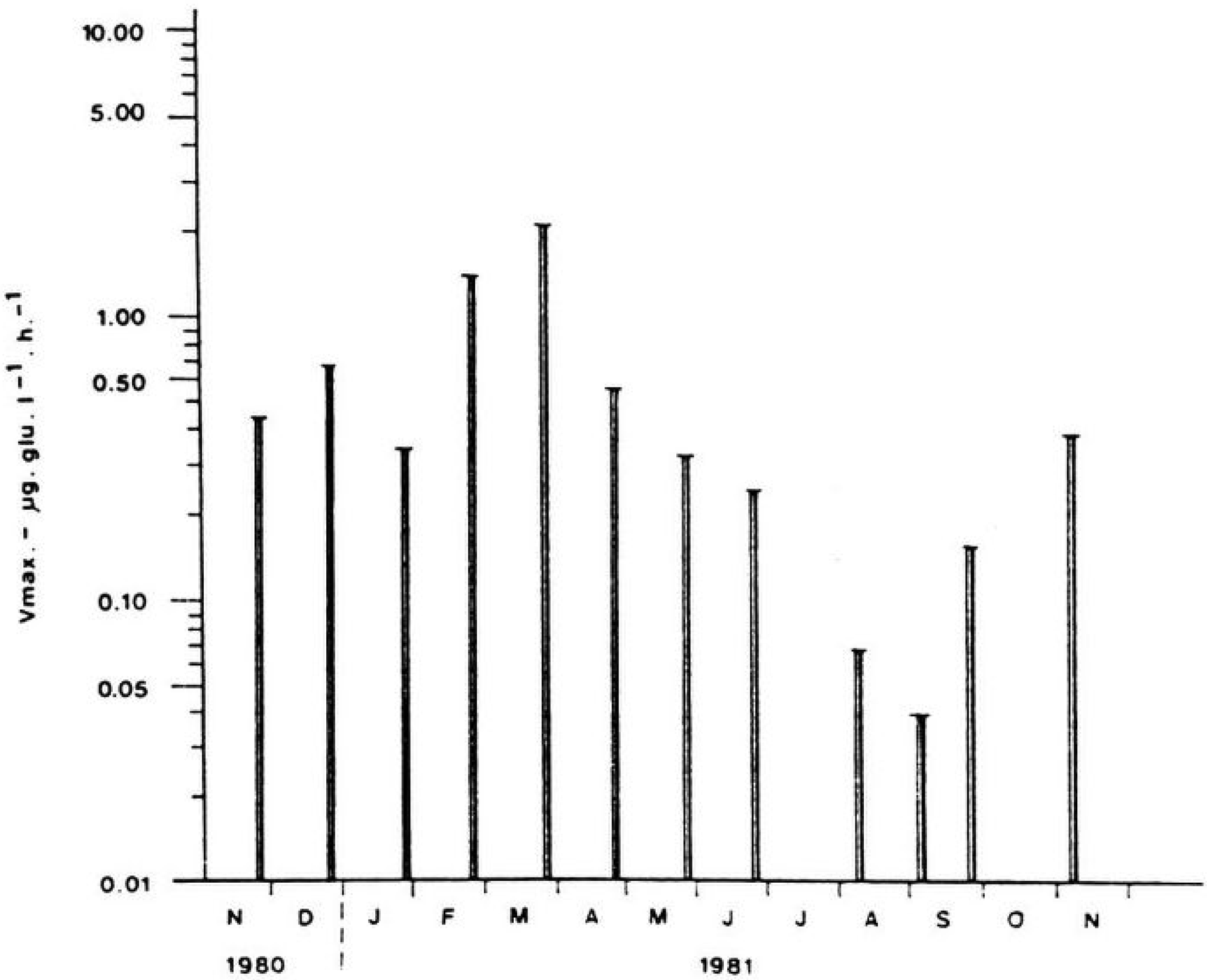

Figure 8. Heterotrophic bacterial activity, Vmax (µg glucose l^{-1} h^{-1}).

with a mean value of 10.4 µg l^{-1}. While this variables has a clear seasonal variation, T_t, the turnover time, had a marked decrease of 99.1 °/o during spring—summer respect to winter, related to the availability of organic matter. Berman *et al.* (1979) and Overbeck (1975) found similar kinetic parameters in the eutrophic lakes Kinneret and PluBsee.

The features observed in Embalse del Río III, like low transparency, high chlorophyll concentrations, the occurrence of periodical algal blooms, high primary production and total phosphorus values, oxygen depletion in deeper layers during stratification periods, as well as relevant values of bacterial heterotrophic potential, give us enough information to conclude that this ecosystem has actually a high degree of eutrophication, in accordance with what is referred in the literature (Carlson, 1977; Forsberg & Ryding, *op. cit.;* Le Cren & Lowe—McDonell, *op. cit.;* Margalef *et. al.,* 1976; Mariazzi y Romero, 1983 and Overbeck, *op. cit.*

With the functioning of the nuclear power plant changes should occur in the reservoir conditions. The plant pumps the water from a reservoir area where maximum depth is 15 meters, taking it near the bottom. The water is chlorinated previously entering to the cooling circuit. So, this effect as well as the thermal and mechanical ones could damage planktonic organisms with the consequences of an increase of the dead organic matter reaching the reservoir. This material, during stratification periods will partially settle down and through heterotrophic bacterial activity, a higher oxygen depletion would take place with release of nutrients like phosphates and ammonia. These nutrients

could be carried to the surface of the reservoir because of the cooling process yet mentioned, since the water is taken from the bottom layers. The water of the plant effluent reaches the reservoir generally with higher temperature. It is difficult to state that this fact may promote changes in the thermal pattern of the lake, but considering that the discharge take place near the confluence of Quillinzo and La Cruz rivers, these tributaries and the short residence time would help to minimize the thermal effect.

It is probable that the hydrology of the lake will change because of water requirements for the nuclear power plant. Then, water level variations will be reduced by the management of the hydroelectric plant effluent and by other dams recently placed upstreams, with the consequence of an increasing water volume during the dry season. This fact could favour the development of rooted plants and smaller flooded area may partially prevent the evolution of nitrogen and phosphorus species. Also the reduction of the hydroelectricity generation involve a lower withdrawal of hypolimnetic water through the plant effluent which, during oxygen depletion, implies a diminish of the elimination of nutrients.

Finally, much more hydrological, chemical and biological data, specially in reference to nutrients load and circulation, and the oxygen budget, are needed in order to evaluate with accuracy the influence of the functioning of the nuclear power plant over the reservoir. Predictions on this subject are difficult to do due to the changing pattern of the rainy season during the last years. Nevertheless, as a general conclusion of this analysis, a monitoring programme which include these factors and water fluxes through the system will permit a better understanding and some predictions about changes taking place in the water body.

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