Lugliè, Antonella Gesuina Laura; Sechi, Nicola (1993) *Trophic status and phytoplankton in Lake Bidighinzu.* Giornale botanico italiano, Vol. 127 (4), p. 765-785. ISSN 0017-0070.

http://eprints.uniss.it/7833/

ISSN-0017-0070

GIORNALE BOTANICO ITALIANO

FONDATO NEL 1844

PUBBLICATO DALLA SOCIETÀ BOTANICA ITALIANA
CON IL CONTRIBUTO DEL CONSIGLIO NAZIONALE DELLE RICERCHE

Vol. 127, n. 4, 1993

Giorn. Bot. Ital., 127: 765-785, 1993

Trophic status and phytoplankton in Lake Bidighinzu

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Accepted: 28 July 1993

ABSTRACT. — From March 1988 to April 1989 a survey was carried out on the phytoplankton of Lake Bidighinzu, a hypertrophic reservoir in Northern Sardinia. The purpose of this work was to assess the general limnological conditions of the reservoir after a diversion of the urban and industrial wastes. The dynamics of chlorophyll *a*, and the structure and composition of the phytoplankton density and of its biomass in the study period were determined. Moreover the found trends for trasparency, temperature, conductivity, alkalinity, pH, dissolved oxygen, reactive and total phosphorus, nitrate, nitrite, ammonium nitrogen, and reactive silica are reported. The effect of water aeration on the dynamics of the other parameters is discussed.

Key words: Aeration, Algae, Cyanophyceae, Phytoplankton, reservoir, trophic status.

INTRODUCTION

In man-made lakes the phytoplankton is normally the dominant component of the entire botanical community. The settlement of a littoral benthic component is hindered in Sardinia by ample variations in the water level. Phytoplankton is even more important in these enviroments for the consequences it may have on the utilization of water. The limitations on the potable use can become serious, if the reservoirs are affected by the eutrophic process. In Sardinia, eutrophication affects over 80% of the water from reservoirs (SECHI, 1983; 1986; 1989; SECHI & COSSU, 1979) representing the main source of water supply in the region. In the last fifteen years, these environments have been the subject of various limnological studies. From these studies a pattern has emerged that algal structuring is made up of a limited number of species, normally not more than fifty per lake. Among these species, the Cyanophyceae play a prominent role (COTTA RAMUSINO & ROSSARO, 1979; LUGLIÉ & SECHI, 1990; 1992; MURA *et al.*, 1992; SECHI, 1978; 1981; 1983; SECHI & COSSU, 1985; SECHI & LUGLIÉ, 1987; 1989; SECHI & MANCA, 1983; SECHI *et al.*, 1985). The problems encountered when these algae are conspicu-

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Work financed by the Assessorato alla Programmazione of the Regione Autonoma della Sardegna (Protocollo d'intesa Università-Regione).

ously present are the difficulty of their removal in the potabilization processes (HUTSON *et al.*, 1987; SECHI & VACCA, 1992), and the risk of producing toxins dangerous to the general population (CARMICHAEL, 1982; 1985; LOIZZO *et al.*, 1988; 1989; VOLTERRA *et al.*, 1986). The present survey was carried out on Lake Bidighinzu from March 1988 to April 1989 as part of a wide research programme on the composition, structure and biomass of phytoplankton in the reservoirs of Sardinia. In this study one of our aims was to assess the general limnological conditions of the lake.

DESCRIPTION OF THE RESERVOIR

Lake Bidighinzu (Fig. 1, Table 1) was built in 1958 in North-West Sardinia as a reservoir of potable water. Two yearly samplings taken in 1978-1979 (during vernal mixing and summer stratification) showed a highly eutrophic situation (SECHI & COSSU, 1979), which has previously described in the early years of operation (ALAMANNI *et al.*, 1971). Due to serious difficulties encountered during potabilization, the plant had to be modified (ALAMANNI *et al.*, 1968) to include a microfiltration phase for the exclusion

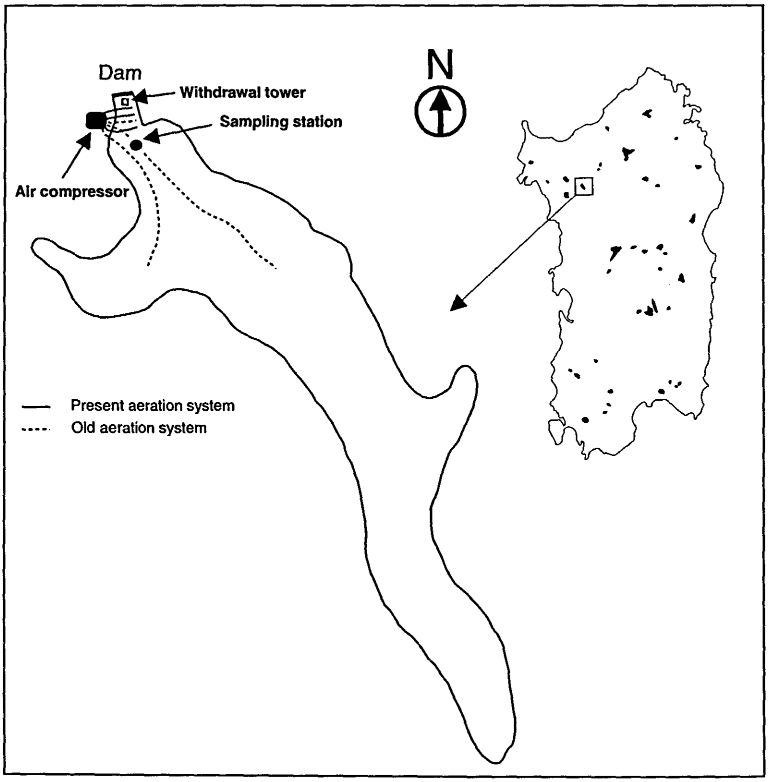

Fig. 1 — Lake Bidighinzu showing the site of the sampling station and its position in Sardinia together with all the other reservoirs.

of algae, and an aeration system had to be installed near the dam next to the water intake tower, to oxygenate the anoxic, hypolimnic waters (MESSINA, 1966). Originally this aeration system (Fig. 1) consisted of three pipelines anchored one meter from the bottom of the reservoir starting from the left shore proximal to the dam, next to two 30 CV compressors. However, the system today consists of 3 much shorter pipes, parallel and very close to the dam.

The reservoir's catchment basin extends over 52 km^2 and is characterized by sparse woodland exposed to considerable agropastural activity. Not far from the reservoir, the town of Thiesi having 3,200 inhabitants is located which contains a few cheese factories processing an average of about 30 million liters of milk per year. The input of water to the reservoir is supplemented by pumping from a neighbouring catchment basin to make up for an insufficient supply.

As assessment of the theoretical load of phosphorus (6.3 t P a^{-1}) (SECHI, 1986), which due to the difficulty encountered in quantifying the real entity of cheese production in the factories, was rather a rough estimate, has shown values far greater than permitted (0.6 t P a^{-1}) according to the O.E.C.D. (1980).

In 1987, a pipe was built to bring forward all urban and industrial wastes downstream from the reservoir. Theoretically, this should have modified the trophic state of Lake Bidighinzu significantly although, due to a high prosphorus contribution (1.5 t P a^{-1}) from various sources including livestock farming in the wild state, manuring and the soil, the reservoir should have remained eutrophic (SECHI, 1986) though much less than in the past.

METHODS

A total of eleven samplings, approximately one a month, were taken at about 0.5 km from the dam, away from the aeration system. The water was collected with a Niskin bottle at depths of 0, 1, 2.5, 5, 7.5, 10 and 20 m. The following parameters were analyzed: pH, alkalinity, conductivity, dissolved oxygen (Winkler method), nitrate nitrogen (according to RODIER, 1971), nitrite nitrogen (BENDSHNEIDER & ROBINSON, 1952), ammonium nitrogen, reactive and total phosphorus, reactive silicates (all according to STRICKLAND & PARSONS, 1968). Transparency was determined with a Secchi disk and the relative temperature at each depth measured with a thermistor. Moreover the following parameters were also assessed: chlorophyll *a* (GOLTERMAN *et al.*, 1978) by adjusting the final acidification concentration to 3×10^{-3} HCl; phytoplanktonic density (Utermöhl method) and biomass (FINDENEGG, 1974).

TABLE 1

Main morphometric characteristcs of L. Bidighinzu.

Height at maximum storage	m a.s.l.	334
Maximum nominal volume	$m^3 \times 10^6$	11
Maximum nominal area	$m^2 \times 10^6$	1,5
Mean depth	m	7,3
Maximum depth	m	30

RESULTS

A synthesis of the conditions in the reservoir is given in Table 2, which reports the average values of the parameters analyzed in the surface and deep layers. Abundance of nutrients together with a significant phytoplankton content, which is expressed by chlorophyll *a* and by the density and biomass, are clearly seen.

From a detailed analysis of the parameters it is seen that, notwithstanding the distance from the plant, aeration has far-reaching repercussions on the limnological dynamics found in the sampling station. Thermal stratification (Fig. 2a) started in April, consolidated between May and June, and was interrupted in July, when aeration started. After this, homeothermy at progressively lower temperatures was maintained till the following March. The highest temperatures (peak 26.8°C) were measured at the surface in July, while lowest (8.5°C) were measured on the water column in March '88.

Changes in the pH in most of the samplings (Fig. 2b) along the vertical profile were slight. Differences became evident during the short stratification period between May and July. For the first 2.5 meters in June and July, pH values were greater than 9 units.

TABLE 2

Annual mean values of the analyzed parameters.

Parameters		Layer	1988/89
Temperature	°C	0-5 m	16,5
		7,5-15 m	14,1
pH		0-5 m	8,25
		7,5-15 m	7,91
Oxygen	% sat.	0-5 m	91
		7,5-15 m	24
Alkalinity	meq l^{-1}	0-5 m	2,79
		7,5-15 m	2,86
Conductivity	$\mu S\ cm^{-1}$	0-5 m	552
		7,5-15 m	561
Ammonia nitrogen	mg N m^{-3}	0-5 m	231
		7,5-15 m	811
Nitrate nitrogen	mg N m^{-3}	0-5 m	333
		7,5-15 m	291
Nitrite nitrogen	mg N m^{-3}	0-5 m	16
		7,5-15 m	16
Reactive phosphorus	mg P m^{-3}	0-5 m	255
		7,5-15 m	350
Total phosphorus	mg P m^{-3}	0-5 m	357
		7,5-15 m	416
Reactive silica	mg l^{-1}	0-5 m	8,1
		7,5-15 m	8,8
Chlorophyll *a*	mg m^{-3}	0-5 m	29
		7,5-15 m	6
Total biomass	mgl^{-1}	0-5 m	5,5
		7,5-10 m	1,1
Total density	Cells x 10^6 l^{-1}	0-5 m	130
		7,5-10 m	18
Secchi disk	m		1,25

A peak value greater than 10 was observed in July in the first meter of water. In following samplings, especially from November onwards, the values were much lower, with a minimum in March (around 7.25 units). Significant differences in dissolved oxygen could be observed both in the annual cycle and in the vertical profile (Fig. 3a). Except for the months of April and December '88, the greatest difference in the average oxidative state occurred between surface and deep waters, with higher percentages at the surface than at depths greater than 7.5 m. The layer below 15 m was almost constantly anoxic, while from May through July, the first 5 m were extremely oversaturated, reaching a peak of 300% in July. Alkalinity (Fig. 3b) was mostly homogeneous over the entire water column. The highest values were observed in September and December (greater than 3.0 meql^{-1}) and the lowest for April (up to 10 m, less than 2.4 meql^{-1}). Between 15 and 20 m the concentrations were much greater than in the overlying layers only in the last two months. Conductivity showed a similar trend (Fig. 4). In this case the highest values (greater than 600 μS cm^{-1}) corresponded to the period between July and September while the lowest (around 450 μS cm^{-1}) occurred in March '88. These minimal values were probably due to an input of water with a low ion content.

Among the nitrogen compounds ammonia (Fig. 5a) had the highest concentrations. The difference between surface and bottom was always very marked. As a matter of fact, notwithstanding aeration, the ammonia content in the water at 20 m was usually greater than 1000 mg N m^{-3}. In July, before stratification was interrupted, the water mass below 7.5 m had shown very high values, with a maximum (2028 mg N m^{-3}) at 7.5 m. Nitrate nitrogen (Fig. 5b) was generally homogeneous in the column. Between May and September concentrations were significantly lower than those of the other months with minimum values between June and August (around 25 mg N m^{-3}). In March '89 there was a strong increase (a maximum of 1030 mg N m^{-3} at 1 m), that affected the layers between 0 and 10 m. This was probably due to the inflow of new volumes of water from the catchment basin, but at the next sampling the values were almost reduced by half.

Availability of reactive phosphorus (Fig. 6a) was high, with concentrations seldom lower than 200 mg P m^{-3}. The effect of phosphorus utilization by phytoplankton appeared to be marginal. Despite forced mixing of the water between May and September, values between 434 mg P m^{-3} and 636 mg P m^{-3} on average were observed in deep layers while the surface layers had between 281 and 391 mg P m^{-3}. This was probably due to a phosphorus release from the sediment. The trend of total phosphorus (Fig. 6b) tightly followed that of reactive phosphorus though May to September, when the phytoplankton was at its highest peak of development. The difference between the concentrations in surface waters (between 307 and 553 mg P m^{-3}) and those of the deep waters (between 311 and 691 mg P m^{-3}) was less evident. Reactive phosphorus always made up the most part of total phosphorus representing less than 50% only in July.

Availability of silica (Fig. 7a) was also always high. Only in May and June were the contents of the first 5 m (5.4 and 4.8 mg Si l^{-1} on average) lower than those of the other months. However, they were never low enough to suggest a limiting effect on the development of the Diatoms. The maximum homogeneous value in the column (10 mg Si l^{-1}) was observed in November.

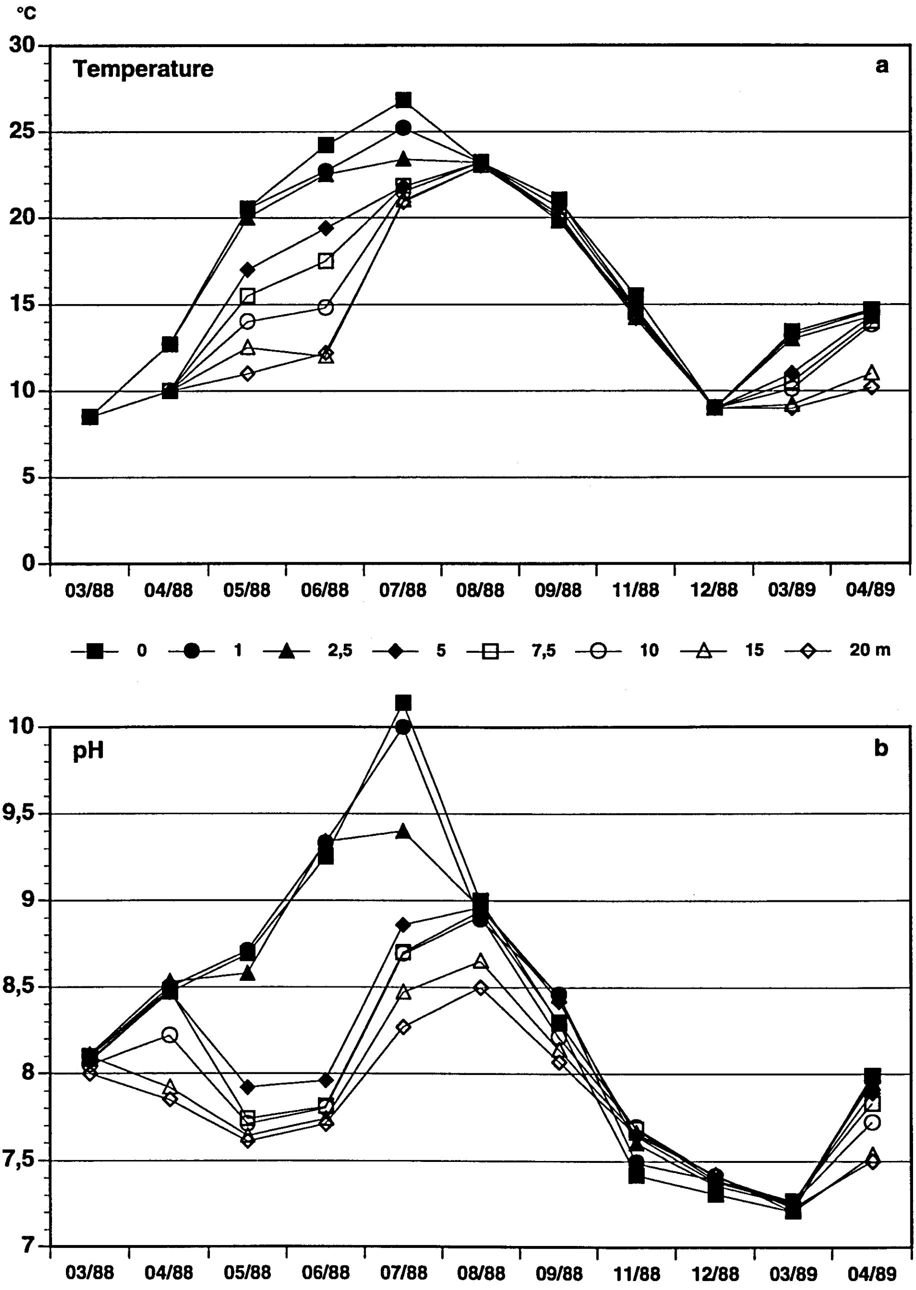

Fig. 2 — Temperature and pH values during the eleven months of the sampling.

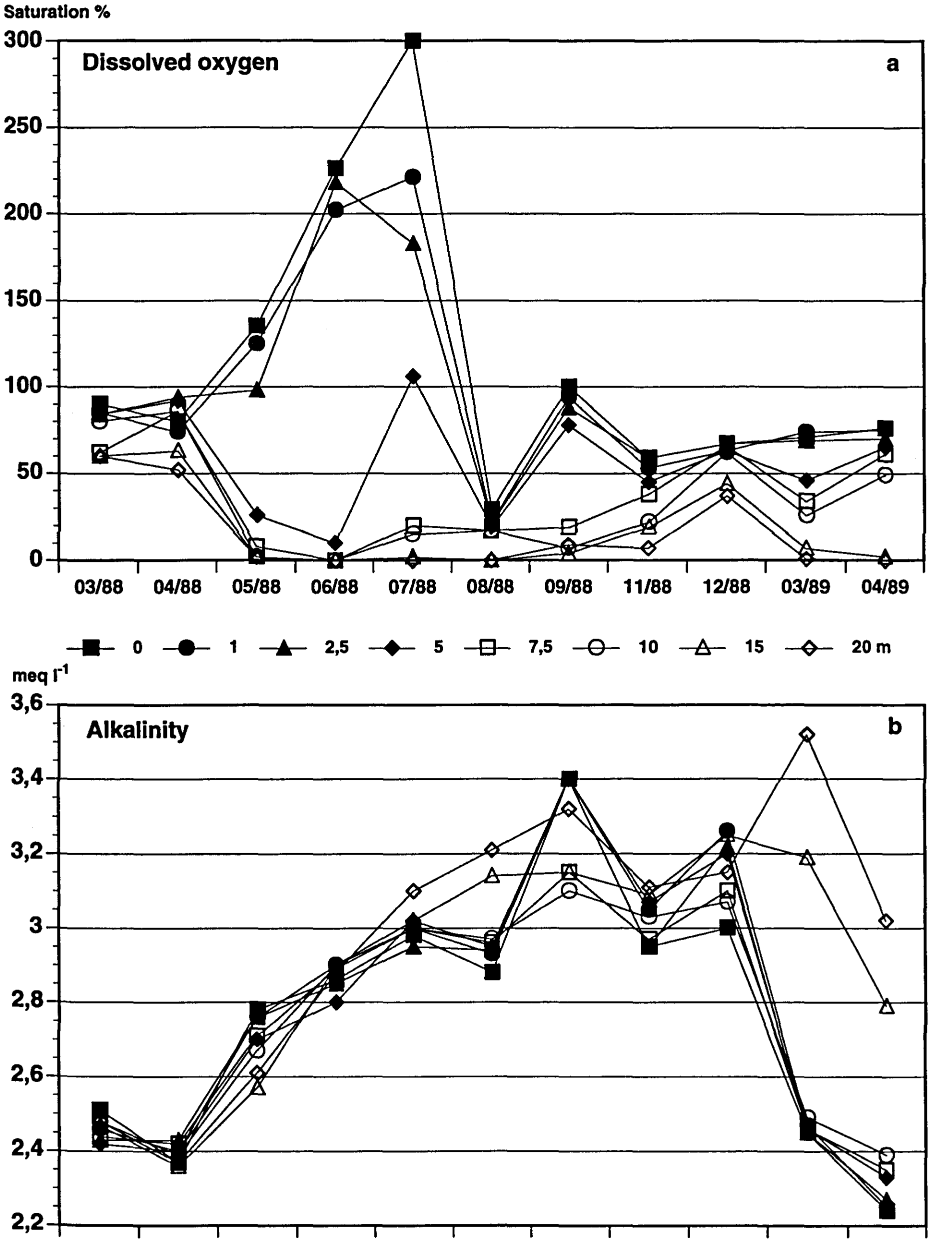

Fig. 3 — Dissolved oxygen saturation and total alkaline content values during the eleven months of the sampling.

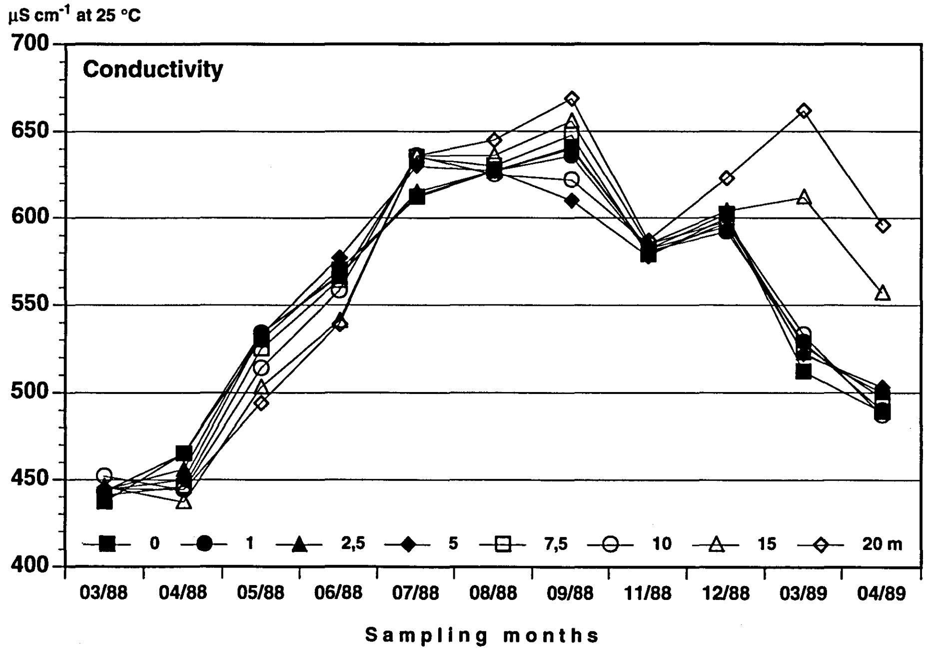

Fig. 4 — Conductivity values at 25°C during the eleven months of the sampling.

The average concentration of chlorophyll *a* for the year (Fig. 7b) in the photic zone was 32 mg m^{-3}. Along the vertical profile, values showed a sharp drop below 7.5 m with concentrations very rarely higher than 10 mg m^{-3}. In the photic zone, average values ranged from 12 to 40 mg m^{-3} in most of the sampling. They were lower in December and March '89 (less than 5 mg m^{-3}) and higher from June to July (greater than 55 mg m^{-3}). The absolute maximum peak of 159 mg m^{-3}) and higher from June to July (greater than 55 mg m^{-3}). The absolute maximum peak of 159 mg m^{-3} at 1 m was observed in July. Mean annual water transparency was low (1.25 m) with a peak in September (2.4 m) and a minimum in July (0.3 m).

The presence of phytoplankton, as total cell density and biomass (Fig. 8a, b, respectively), had annual mean values in the photic zone of 1.2×10^8 cells l^{-1} and of 5.5 mgl^{-1}, respectively. The mean biomass varied from a minimum of 0.37 cm^3 m^{-3} in March to a maximum of 15.6 mgl^{-1} m^{-3} in July. The fluctuation in density was even wider: from 9.6×10^5 cells l^{-1} in March '88 to 6.4×10^9 cells l^{-1} in July. The maximum density of 1.3×10^9 cells l^{-1} was observed in July coinciding with the chlorophyll *a* peak. As far biomass, although the highest mean value was observed in July, the highest absolute peak of 41.3 mgl^{-1} m^{-3} occurred in April '89.

About fifty different species (Table 3) make up the phytoplankton. The Cyanophyceae, the Chlorophyceae and especially the Diatomeae are the most numerously represented. Table 4 shows the annual mean values and the maximum values for density and biomass for the main species encountered.

The annual cycle in the photic zone started with a prevalence of the Diatomeae

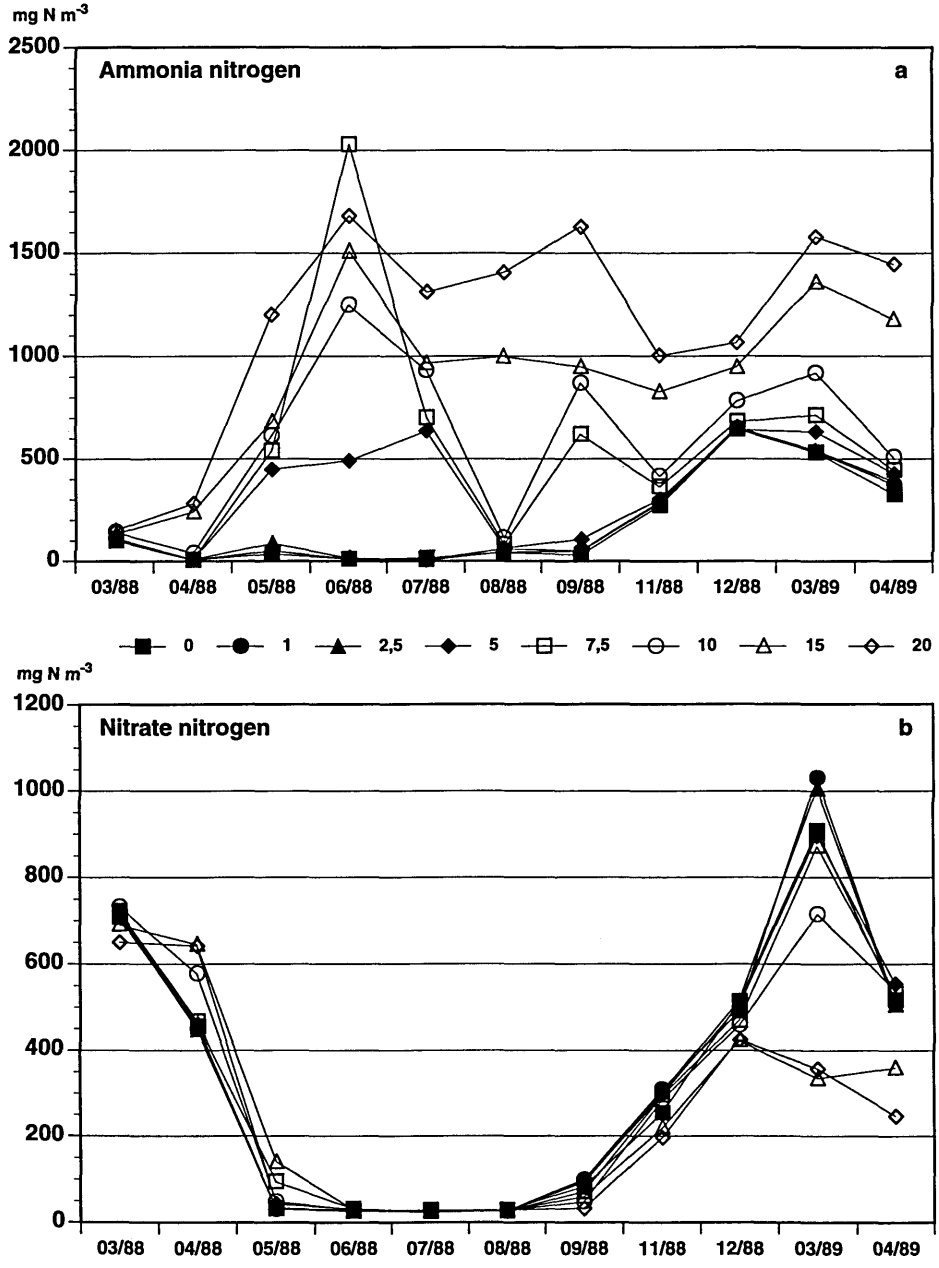

Fig. 5 — Ammonia nitrogen and nitrate nitrogen concentration values in the eleven months of the sampling.

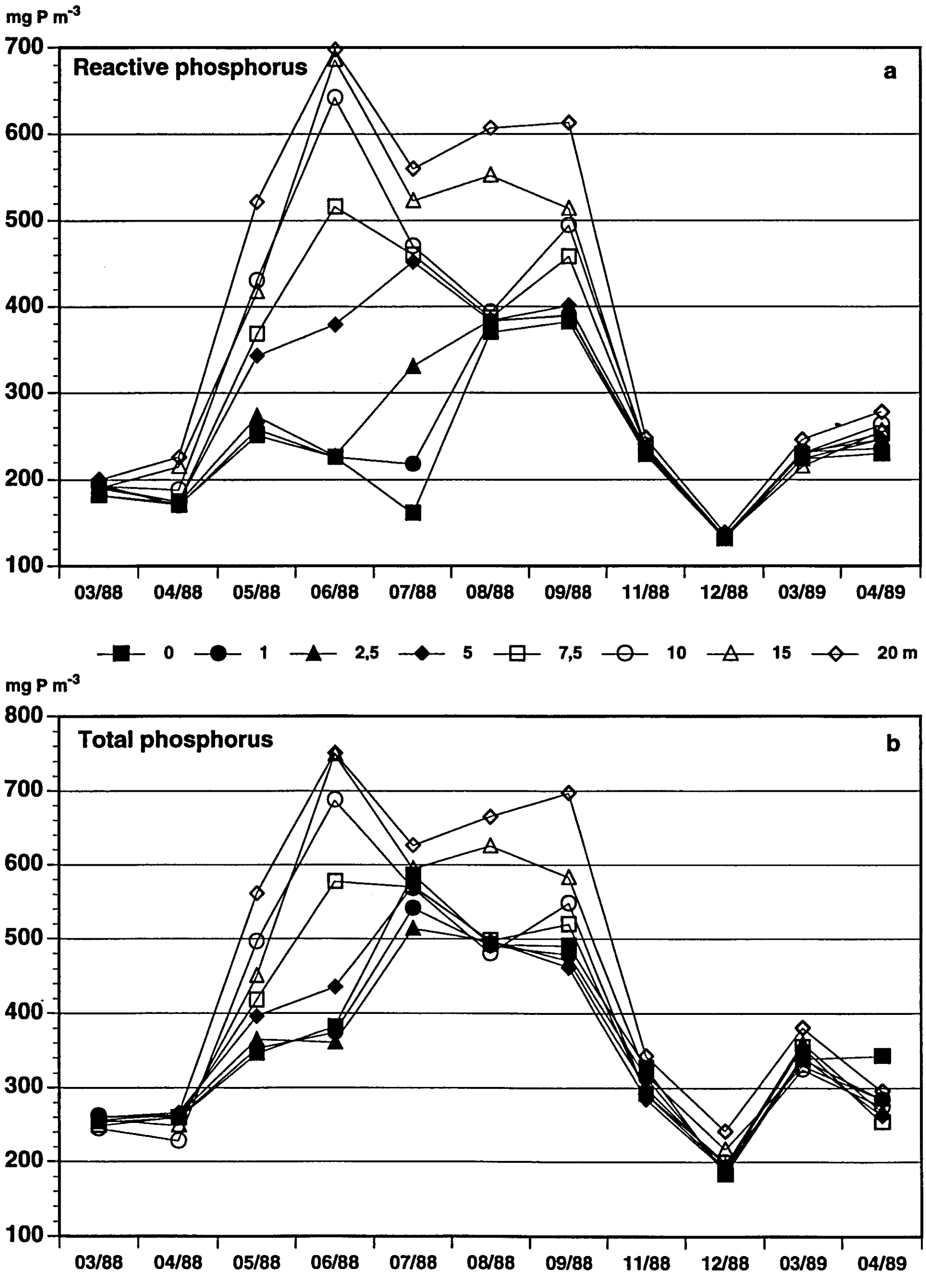

Fig. 6 — Reactive and total phosphorus concentration values in the eleven months of the sampling.

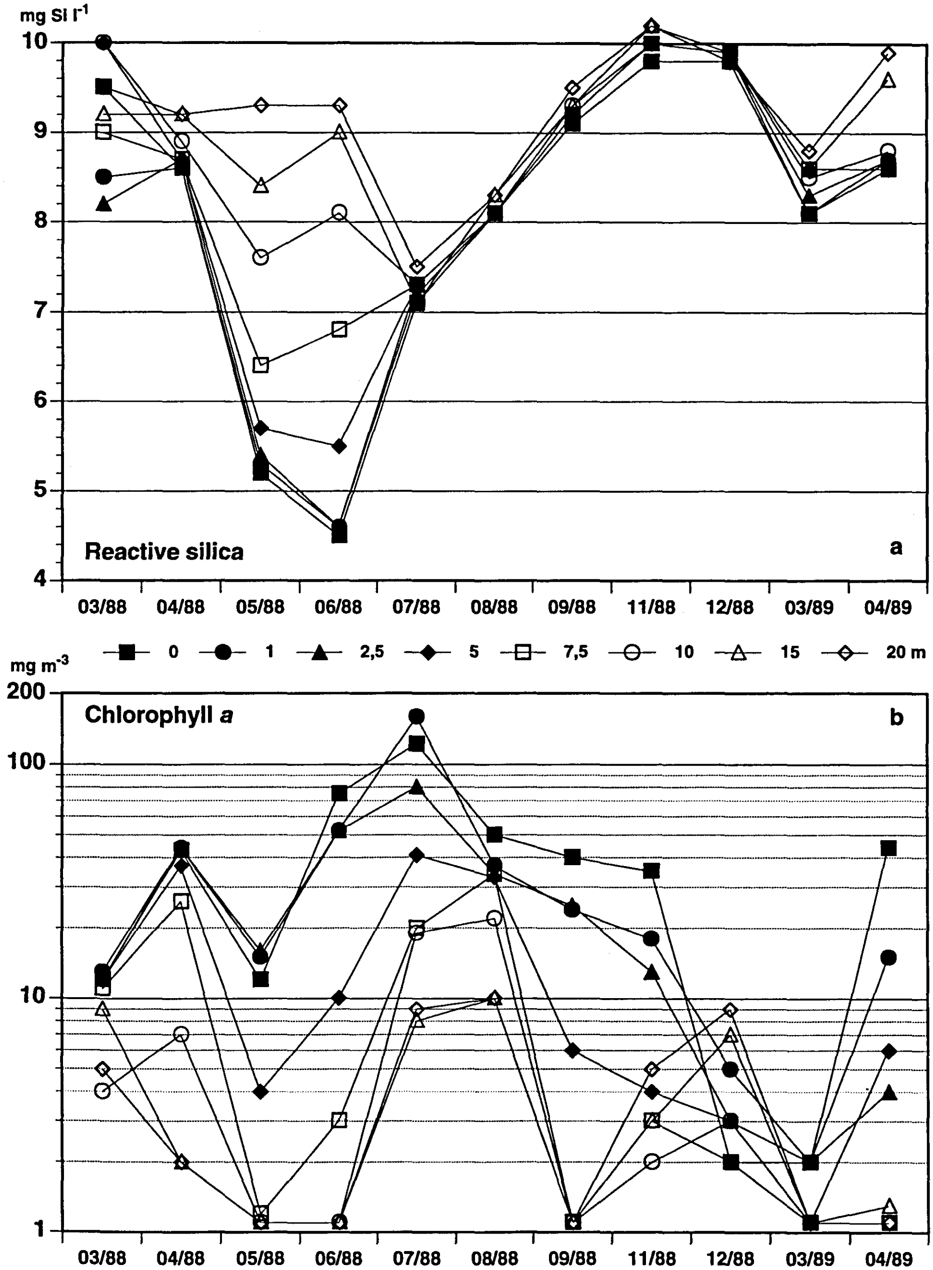

Fig. 7 — Reactive silica and chlorophyll *a* concentration values in the eleven months of the sampling.

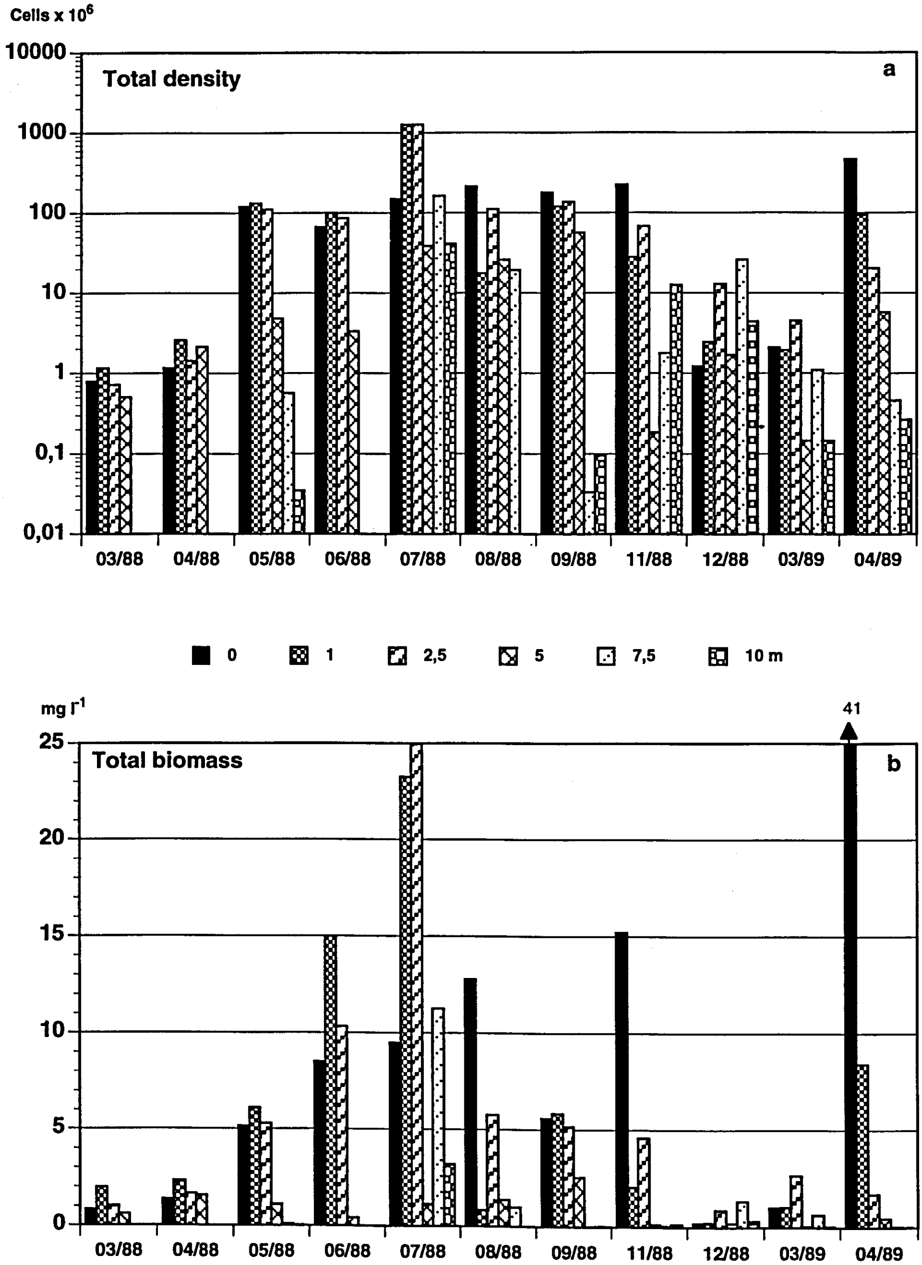

Fig. 8 — Cell density and biomass content values in the eleven months of the sampling.

TABLE 3

List of phytoplankton species observed in Lake Bidighinzu duringe the study period.

Species	Species symbol	Mean vol. (μm^3 cell.$^{-1}$)
Cyanophyceae		
Microcystis aeruginosa Kg.	Mic aer	16
Microcystis flos-aquae (Wittr.) Kirchn.	Mic fla	68
Aphanocapsa delicatissima W. et G.S. West	Aph del	—
Merismopedia Meyen sp.		
Anabaena flos-aquae (Lyngb.) Bréb.	Ana fla	50
Anabaena planctonica Brunnth.	Ana pla	267
Anabaena spiroides Kleb.	Ana spi	275
Anabaena Bory sp.		96
Aphanizomenon flos-aquae (L.) Ralfs.	Aph fla	56
Oscillatoria tenuis Ag.		—
Phormidium mucicola Naumann et Huber-Pestal.		—
Chlorophyceae		
Carteria Diesing sp.		1454
Chlamydomonas Ehrenberg sp.		—
Sphaerocystis planctonica (Kors) Bourr.	Sph pla	157
Neochloris Starr sp.	Neo sp.	3572
Ankyra judayi (G.M. Smith) Fott	Ank jud	81
Pediastrum duplex Meyen	Ped dup	461
Micractinium pusillum Fres.		34
Oocystis marssonii Lemm.	Ooc mar	357
Oocystis A. Braun sp.		650
Monoraphidium contortum (Thur.) Kom.-Legn.	Mon spp	15
Monoraphidium komarkovae Nyg.	Mon spp	39
Monoraphidium Kom.-Legn. species	Mon spp	—
Ankistrodesmus falcatus (Corda) Ralf		—
Coelastrum microporum Näg. in A. Br.	Coe mic	34
Scenedesmus quadricauda (Turp.) Bréb. sensu Chod.		—
Scenedesmus Meyen sp.		65
Conjugatophyceae		
Closterium aciculare T. West		—
Closterium gracile Bréb. ex Ralfs		—
Staurastrum gracile Ralfs		—
Euglenophyceae		
Euglena Ehrenberg sp.	Eug sp.	1883
Diatomeae		
Cyclotella meneghiniana Kg.	Cyc spp	—
Cyclotella ocellata Pantocs	Cyc spp	—
Cyclotella chaetoceras Lemm.	Cyc spp	—
Cyclotella comta (E.) Kg.	Cyc spp	—
Cyclotella Kützing sp.	Cyc spp	—
Melosira granulata (E.) Ralfs	Mel gra	—
Melosira granulata var. *angustissima* Müller		929
Melosira Agardh sp.		1402
Stephanodiscus Ehrb. sp.	Ste sp.	2752

(*continued*)

(*continued Table 3*)

Species	Species symbol	Mean vol. (μm^3 cell.$^{-1}$)
Diatomeae		
Fragilaria crotonensis Kitton		229
Fragilaria Lyngbye sp.		—
Asterionella formosa Hassall		635
Synedra ulna (Nitzsch) Ehb.		—
Achnanthes Bory sp.		—
Cocconeis placentula (Ehr.)		—
Cymbella Agardh sp.		—
Gomphonema Agardh sp.		—
Surirella Turpin sp.		—
Nitzschia Hassall sp.		—
Navicula Bory species	Nav spp	—
Cryptophyceae		
Cryptomonas Ehrenberg species	Cry sp.	—
Chroomonas acuta Utermöhl	Chr acu	41
Dinophyceae		
Peridinium Ehrenberg sp.		—

TABLE 4

Annual mean values in the photic zone and density and biomass maximum values of the main species.

Species	Density Cells × 10^6 l^{-1}		Biomass mgl^{-1}	
	mean	maximum	mean	maximum
Cyanophyceae				
M. aeruginosa	56	1235	1,0	21,0
M. flos-aquae	57	271	2,0	15,2
A. planctonica	0,6	8	0,2	2,2
A. flos-aquae	8	99	0,6	8,4
Aph. flos-aquae	9	378	0,9	36,4
Cryptophyceae				
Cryptomonas spp.	0,1	1,3	0,1	1,6
Euglenophyceae				
Euglena sp.	<0,01	0,1	0,0	0,4
Chlorophyceae				
S. planctonica	0,3	4,2	0,0	0,7
A. judayi	7	117	0,3	4,7
O. marssonii	0,4	4,3	0,1	1,2
Diatomeae				
Cyclotella spp.	0,09	0,9	0,1	0,9

(*Stephanodiscus* sp., *Cyclotella* spp., *Navicula* sp.) and of the Cryptophyceae (*Cryptomonas* spp. and *Chroomonas acuta*) in the first two samplings (Figs. 9 and 10). The total values did not exceed 2×10^6 cells l^{-1} and 2 mgl^{-1} respectively for density and biomass. A sharp increase in May brought the values up to about 8.4×10^7 cells l^{-1} and 3.9 mgl^{-1}. The rise in values was determined by the development of the Chlorophyceae, especially *Ankyra judayi*, followed by *Coelastrum microporum*, *Neochloris* sp. and *Sphaerocystis planctonica*. The Cyanophyceae made their first appearance in this sampling with a sparse presence of *Anabaena flos-aquae*. In June there was an explosion of Cyanophyceae with *Microcystis flos-aquae, Microcystis aeruginosa, Aphanocapsa delicatissima* and *Anabaena planctonica*. Total density showed a slight increase with respect to May (8.8×10^7 cells l^{-1}) while the biomass was almost three times as much (12.1 mgl^{-1}). In the same month there were again significant amounts of Chlorophyceae, with *Oocystis marssonii, Pediastrum duplex* and *S. planctonica*, and of Diatoms, with *Melosira granulata* and *Cyclotella* spp. Moreover, the Euglenophyceae made their first appearance with a significant biomass of *Euglena* sp. From July to December the composition of the phytoplankton was much poorer, consisting almost exclusively Cyanophyceae. In July, due to an intense bloom of *M. aeruginosa*, peak in total density (6.4×10^8 cells l^{-1}) and total biomass (15.6 mgl^{-1}) were reached (mean values) in the euphotic zone. At the same time, *M. flos-aquae, A. flos-aquae* and *Anabaena spiroides* were present in abundant quantities. In the subsequent months, the phytoplankton was made up of a smaller number of species: *M. flos-aquae, M. aeruginosa, A. flos-aquae* and *A. delicatissima* in August and September; *M. flos-aquae, A. delicatissima* and *S. planctonica* in November; *M. flos-aquae, Cryptomonas* spp. and *Stephanodiscus* sp. in December. Generally the amount of algae dropped progressively up to a minimum 10^6 cells l^{-1} and 0.4 mgl^{-1} in March '89. In this month the Cyanophyceae disappeared completely, while the Chlorophyceae reappeared with *S. planctonica* and the Cryptophyceae with *C. acuta*. Finally in April '89 a new peak was observed with much higher total density and biomass values (1.2×10^8 cells l^{-1}; 11.1 mgl^{-1}) than in the previous year. The composition of the phytoplankton was once more dominated by the Cyanophyceae with *M. flos-aquae* and *A. flos-aquae* as well as a remarkable bloom *Aphanizomenon flos-aquae*.

DISCUSSION AND CONCLUSIONS

The results obtained suggest a few comments both on the general limnology of Lake Bidighinzu and on its management, with particular reference to the consequences of the aeration process on the ecosystem.

The average and maximum values for chlorophyll *a*, those for the phytoplankton density and biomass, the high pH values and the dissolved oxygen saturation percentage values during the greatest algal development, have outlined a picture of high productive level, confirming the eutrophic assessments of the previous years.

Further proof from the qualitative point of view was given by the composition of the phytoplankton which, for most of the study period, was dominated by the Cyanophyceae and characterized by the presence of numerous species (*A. spiroides, A. planctonica, Aph. flos-aquae, M. aeruginosa, M. flos-aquae, P. duplex, Micractinium pusil-*

lum, Scenedesmus quadricauda, C. microporum, Fragilaria crotonensis, M. granulata, and *Closterium aciculare*) reported as being indicators of eutrophy (RAWSON, 1956; SPODNIEWSKA, 1979; HEINONEN, 1980; HÖRNSTRÖM, 1981; ROSÉN, 1981; MANTERE & HEINONEN, 1982).

Many of the species observed were irrelevant to total production, that occurred almost exclusively in a few species, mostly belonging to the Cyanophyceae (*M. aeruginosa, M. flos-aquae, A. planctonica, A. flos-aquae, Aph. flos-aquae*). Among all the species found, the maximum density value, in absolute terms, was that observed for *M. aeruginosa* while the maximum biomass value was for *Aph. flos-aquae*. The greater affirmation of *M. aeruginosa* led to very high levels of density, biomass and chlorophyll *a*. The peak of *Aph. flos-aquae* did not coincide with equally high values of chlorophyll *a*. It is probable that at the time of sampling the bloom was already collapsing and that *Aph. flos-aquae* had already lost its vitality. Though expressing lower density and biomass values than *M. aeruginosa, M. flos-aquae* was the dominating species for a longer time (from June to December, with one only exception in July).

Other algal classes were significant in terms of biomass and cell density only in the first four months and in March '89. Before the dominance of the Cyanophyceae, the classes contributing most significantly to the composition of the phytoplankton were the Cryptophyceae, with *Cryptomonas* spp., and the Chlorophyceae with an abundant growth of *A. judayi* in May and a considerably smaller growth of *O. marssonii* in June. The Diatoms showed a limited presence prevalently in spring, observed also from the trend of reactive silica, with the Centrales, mostly represented by *Cyclotella* and *Stephanodiscus*, sharply prevailing over the Pennales. Moreover, the survey cycle terminated with a situation that was totally different from the values recorded the same month the year before. It is also possible that the subsequent months may have shown a different dynamic trend.

The immediate consequences of the abundant phytoplankton were less water transparency with minimum values corresponding to a greater algal growth and the deposition of large quantities of organic material on the bottom of the reservoir. From May onwards, oxidation of this organic material together with the beginning of thermal stratification created a situation of serious oxygen deficiency in the lower portion of the water column (below 7.5 m in June) which lasted into the following months in spite of the activity of the aeration plant in July. The plant was not used continuously, but only when, due to the absence of oxygen, it would have been impossible to use the water for drinking.

For this reason artificial aeration brought about only slight variations in the oxidative state of the deeper water (which were sufficient for the water drawn for potabilization), but it significantly altered the thermal state of the reservoir causing interruption in the stratification effecting the dynamics of the other parameters.

The most evident effects were a higher temperature in the hypolimnion, higher alkalinity and a lower pH. Such symptoms have already been observed in other artificially aerated reservoirs (FAST *et al.*, 1973) which, at least for the last two parameters, simulate the natural dynamics occurring during the circulation of the water in the autumn. The major consequences, however, were due to the fact that the nutrients were regenerated on the bottom and prematurely introduced in the trophogenic layers in the summer, a highly favourable season for algal development.

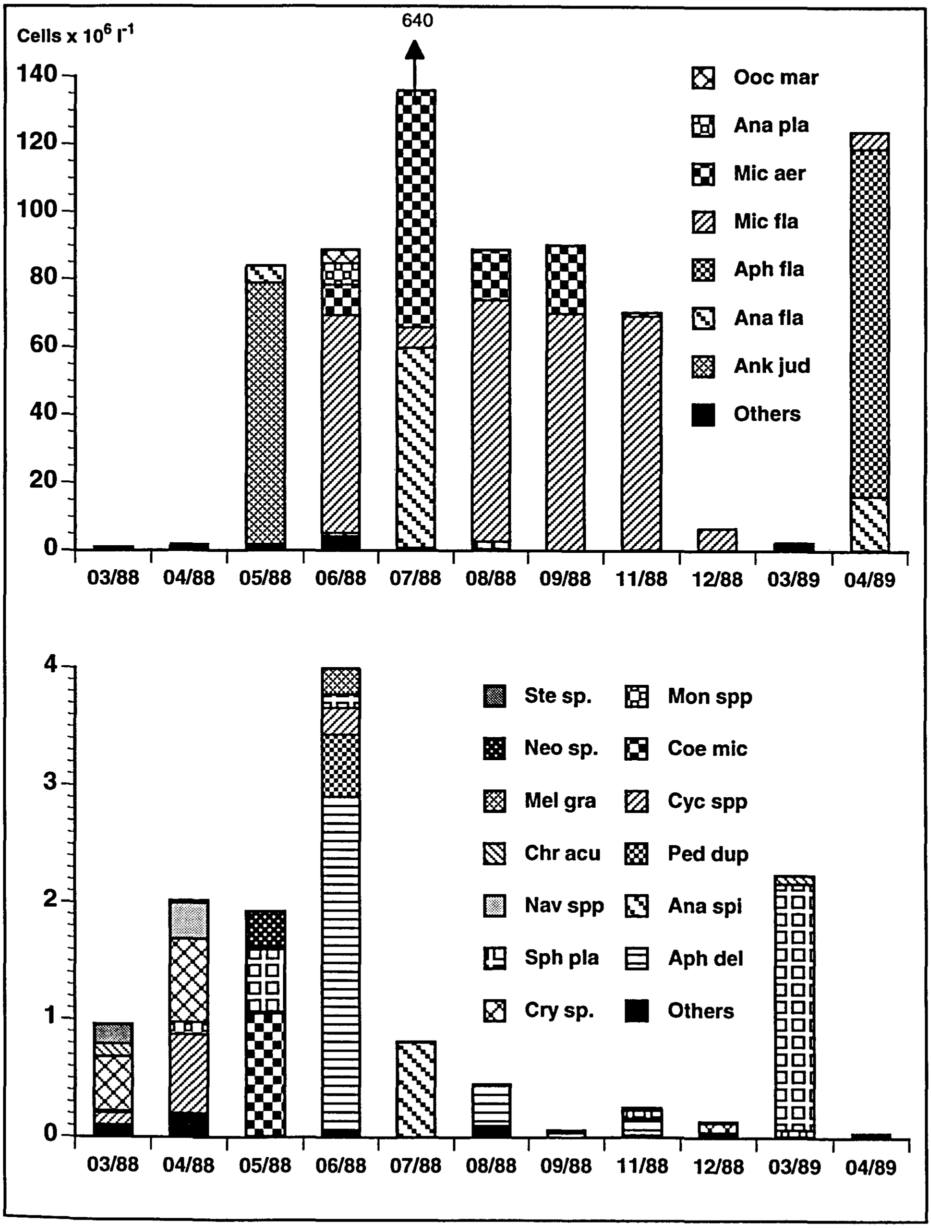

Fig. 9 — Seasonal succession of the density of the main phytoplankton species in the eleven months of the sampling.

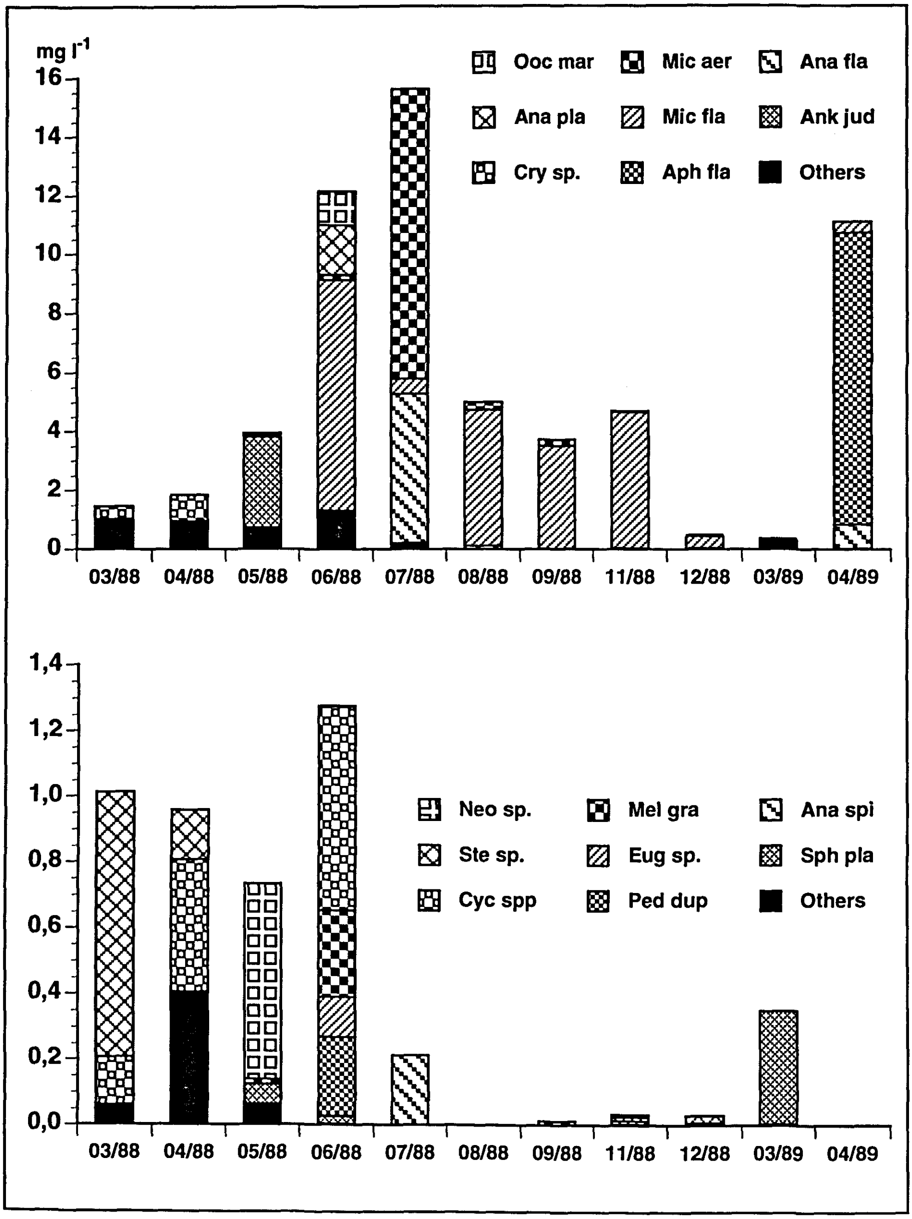

Fig. 10 — Seasonal succession of the biomass of the main phytoplankton species in the eleven months of the sampling.

Immediately after the aeration plant went into operation, we observed an increase in the amount of phytoplankton, which was due to the development of the Cyanophyceae. Opinions differ on the effect of artificial destratification on the development of this group (FAST *et al.*, 1973; HAYNES, 1975). In our case it has not been possible to confirm either. The subsequent drop in phytoplankton does not seem to be due to a lack of main nutrients, in that the continuous availability of phosphorus and nitrogen salts in the water column has ruled out the possibility that the nutrients may have had a limiting role. The concentrations found during the study period were higher than those observed in '78/'79. Moreover, from May to September, the release of phosphorus from the sediments was probably intense, since as pointed out previously, the aeration plant only operated discontinuously and it did not change the anoxic conditions of the bottom. It is evident that, due to the presence of very large quantities of this nutrient in the reactive form, with concentrations above 150 mg P m^{-3}, very high productive levels could be reached. In the study period, therefore, the check of productivity in Lake Bidighinzu depended on factors that were difficult to determine from the data available.

In spite of the diversion of domestic wastes, the trophic level of Lake Bidighinzu was so high in 1988-89 that it was difficult to determine whether the diversion was actually operating or if enough time had elapsed since the diversion to be able to observe an improvement in the trophic conditions. A comparison among a few significative parameters observed on various occasions since 1978, goes as far as to show an increase in the concentration of nutrients. This tendency, moreover, does not seem to invert its course after the diversion (Table 5).

TABLE 5

Comparison between the values of seven parameters recorded in some months beginning from 1978.

Parameter	Layer	Aug. 1978	Feb. 1979	Mar. 1985	Mar. 1988	Aug. 1988	Mar. 1989
Temperature	0-5 m	23,7	9,7	—	8,5	23,2	12,7
°C	7,5-20 m	22,8	9,7	—	8,5	23,1	9,7
$N\text{-}NH_3$	0-5 m	10	140	73	104	52	559
mg N m^{-3}	7,5-20 m	139	140	84	127	648	1141
$N\text{-}NO_3$	0-5 m	56	643	612	715	27	960
mg N m^{-3}	7,5-20 m	56	654	670	715	28	570
$P\text{-}PO_4$	0-5 m	43	120	—	187	380	228
mg P m^{-3}	7,5-20 m	80	120	—	192	485	230
P-tot	0-5 m	172	158	269	258	495	345
mg P m^{-3}	7,5-20 m	114	166	262	250	567	348
$Si\text{-}SiO_2$	0-5 m	2,2	7,7	4,8	9,1	8,1	8,3
mg Si l^{-1}	7,5-20 m	2,2	7,7	4,3	9,4	8,2	8,6
Chlorophyll *a*	0-5 m	222	9	—	12	39	2
mg m^{-3}	7,5-20 m	2	8	—	8	28	1

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