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Water quality and limnological features of a high altitude Andean lake, Chungará, in northern Chile

Calidad del agua y características limnológicas de un lago andino de gran altitud, Chungará, en el norte de Chile

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ABSTRACT

The water quality of lake Chungará (4,520 ma.s.l.), in the Unesco world biosphere reserve Lauca, northern Chile was investigated between October 1982 - April 1984. Additional water quality information and data over the trophic status of the lake were collected during short visits carried out in April 1980, October 1985 and Jannuary 1986. Lake Chungará can be classified as a cold-polymictic, high altitude, tropical, volcanic, and saline lake. Cations in lake Chungará ranks as: Mg^{+2} > Na^{+} > Ca^{+2} > K^{+}. The chemistry of water in lake Chungará is also dominated by: SO_4^{2-}, CO_2, HCO_{3-}, Li, and Al. Large concentrations of P-PO_4, up to 10 μM l^{-1} were measured in the lake water. Nitrate and Silica in the lake, are in moderate concentrations. The phytoplankton in Lake Chungará is dominated by Chlorophyta and Bacillariophyta. Zooplankton is dominated by calanoids and cladocerans. Fishes are present: *Trichomycterus* sp. (Trichomicteridae) and *Orestias* sp. (Cyprinodontidae). Lake Chungará is a sanctuary for an abundant migratory avifauna. The trophic status of this lake was estimated according to chlorophyll *a* concentration (1.49 μg l^{-1}) as oligomesotrophic, and according to photosynthetic activity (0.0428 g C m^{-2} h^{-1}) as meso-eutrophic. Concurrence of unique physical, chemical and biological features make lake Chungará worth of further specific intensive studies and long term monitoring.

Key words: tropical, water quality, trophic status, endorheic, saline, volcanic.

RESUMEN

La calidad del agua del lago Chungara (4.520 m.s.n.m.), ubicado en la reserva mundial de la Biosfera Lauca de Unesco, fue investigada durante el período octubre 1982 a abril 1984. Datos complementarios acerca de la calidad del agua y del estado trófico del lago fueron colectados durante visitas realizadas en abril de 1980, octubre de 1985 y enero de 1986. El lago Chungará puede ser clasificado como un cuerpo de agua tropical, de alta altitud, polimíctico frío, volcánico y salino. Los cationes en este lago presentan la siguiente secuencia de importancia: Mg^{2+} > Na^{+} > Ca^{2+} > K^{+}. La química del agua del lago Chungará está también dominada por: SO_4, CO_2, HCO_{3-}, Li, Al. En el lago se midieron altas concentraciones de P-PO_4, hasta de 10 μM/l. Las concentraciones de nitrato y sílice disueltos en el agua fueron moderadas. El fitoplancton está dominado por Chlorophyta y Bacillariophyta. El zooplancton está dominado por calanoídeos y cladóceros. Los peces están presentes, predominando: *Trichomycterus* sp (Trichomycteridae) y *Orestias* sp (Cyprinodontidae). El lago Chungará es un importante santuario para varias especies de aves migratorias. El estado trófico del lago Chungará determinado de acuerdo a la concentración de clorofila *a* corresponde a oligomesotrófico. De acuerdo a su productividad primaria corresponde a mesoeutrófico. La concurrencia de características físicas, químicas y biológicas únicas hacen del lago Chungará un sistema que merece estudios específicos intensivos y un seguimiento sostenido de largo plazo.

Palabras clave: tropical, calidad de agua, estado trófico, endorreico, salino, volcánico.

INTRODUCTION

High altitude lakes occurring over 3,500 ma.s.l. represent a challenge to limnologists. The difficulty of sampling, the variety of morphometric and hydrological characteristics, the complexity of the geological pattern of their watersheds and a wide range of chemical and biological features, make their study very arduous (Margalef 1984, Mosello 1984, Aizaki et al. 1987). Lake Chungará located at 4.520 m a.s.l. is one of the highest mountain lakes in the world. The limnology of this lake is only recently

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known. Previous investigations relate mainly to hydrology, phytoplankton and zooplankton (Klohn 1972, Dominguez 1973, Sanzana 1984, Cabrera & Montecino 1987, Andrew et al. 1989). To define the water quality, and connected features of this unique mountain lake, a one year survey was carried out.

Lake Chungará (Fig 1) is located in northern Chile (18°14' S, 69° 09' W), at the border with Bolivia. Its basin lies in the Lauca National Park, a Unesco World Biosphere Reserve. The watershed extends for about 260 km^2. Maximal depth is 34 m, seasonal fluctuations in the water level of about 0.5 m were observed. The lake basin is endorheic and water losses occur mainly through evaporation and seepage to the water table. According to Klohn (1972) the main tributary is river Chungará, with flows between 300 $l\ s^{-1}$ and 500 $l\ s^{-1}$ (the later in the rainy season), this contributes about 80 % of total water flux to the lake. Annual evaporation fluctuates around 1200 mm (Niemeyer 1964). Lake Chungará has a tectonic-volcanic origin. Volcanic activity around the lake reached its maximum in the Paleozoic, but is still present today. Andrew et al. (1989) refers to the lake as belonging to the polymictic type.

MATERIAL AND METHODS

Morphometric features were calculated from satellite images (Landsat), aerial photographs and a bathymetric chart (Villwock et al. 1985). Temperature, pH, conductivity, Secchi disk and light penetration was measured periodically. Water samples were collected, monthly, between October 1982 and April 1984 at a station located at the deepest part (34 m) of the lake (Fig 1) and concentration of dissolved oxygen (D.O.) was measured in the field. Light extinction coefficient (k) was

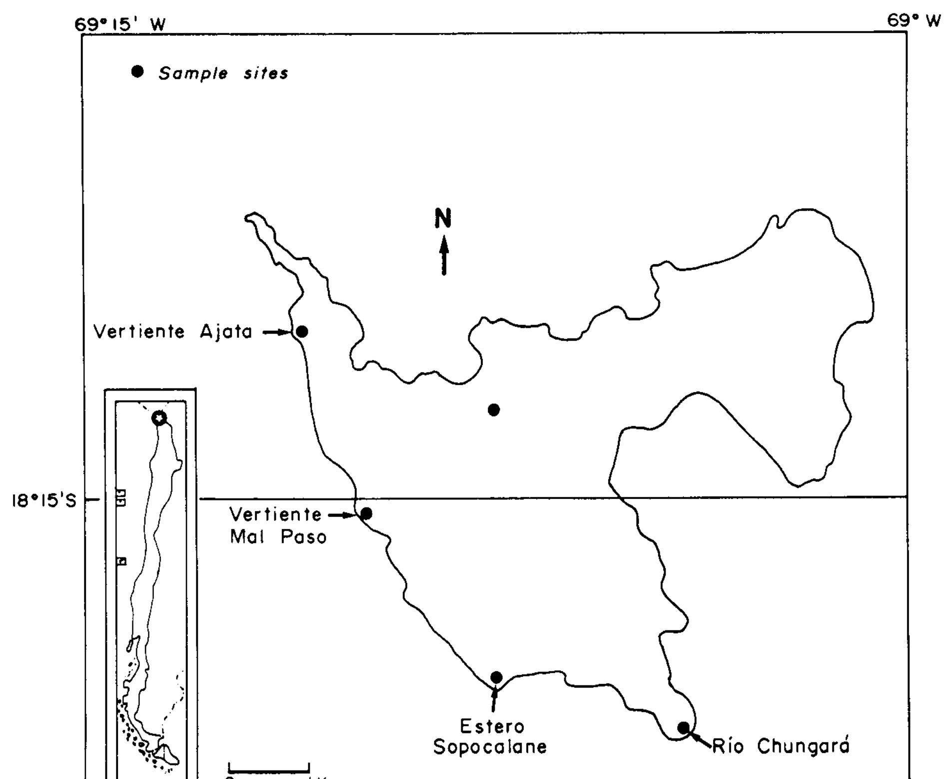

Fig. 1: Lake Chungará. Unesco Biosphere Reserve Lauca. Northern Chile 18° 14' S; 69° 09' W), and sampling stations. (•)

Lago Chungará. Reserva de la Biosfera Lauca de Unesco, Norte de Chile (18° 14' S; 69° 09' W). Estaciones de muestreo. (•)

measured by mean of a submersible Licor cosine sensor. During short visits (April 1980, October 1985 and January 1986) samples were taken at the deepest station and at incoming water-flows located along the western shore of the lake. Water samples were collected with a transparent Ruttner sampler at 0, 5, 10 and 20 m depth. Subsamples filtered through membrane filters (Millipore HAWP 0,45 µm) were analyzed for plant nutrients ($N\text{-}NO_3$, $P\text{-}PO_4$ and SiO_2) (Zahradnik 1981). Subsamples filtered through glass fiber filters (Millipore AP40) were analyzed, by atomic adsorption spectrophotometry, for: macroelements (Ca^{+2}, K^+, Na^+, Mg^{+2}, SO_4^{-2} (APHA, Standard Methods, 1975), and total inorganic carbon (CO_3^{-2} and $HCO_{3-}l^{-1}$) (Golterman et al. 1978). Subsamples poured into separate bottles were analyzed, by atomic adsorption spectrophotometry, for Lithium and Aluminium (APHA, Standard Methods 1975). Phytoplankton samples collected in the 1980 expedition were quantified in an inverted microscope, according to Utermöhl (Sournia 1978) but in $mm^2\ l^{-1}$. Taxonomical identification of species was supported through the works of Fott (1972), Patrick and Reimer (1966), Reháková (1969), Theriot et al. (1985), Tutin (1940), and Thérézien and Couté (1977). During October 1985, chlorophyll a and ^{14}C primary productivity were also measured according to Cabrera (1984) and Montecino and Cabrera (1982) respectively.

Lake Chungará was compared with other high altitude andean aquatic systems using Multivariate Statistical Analysis. Variables for each system were arranged in a matrix, and the systems ordered with a principal components multivariate analysis.

RESULTS

Physical and chemical characteristics

Morphometric parameters are shown in Table 1. Thermal conditions in lake Chungará shown in Fig 2A are typical of a tropical high mountain lake. Water temperature measured through the sampling period fluctuated between 3.0°C (July) and 13.5°C (March). The water mass cools from March until July and warms up from August until February. Secchi disk measurements in lake Chungará range between 5 m and 10 m. Light penetration measurements gave k values of 0.19 m^{-1} in April 1980 (Cabrera & Montecino 1987) and 0.295 m^{-1} in October 1985. This corresponds to a euphotic zone (z_{eu}) of 24.2 m and of 17.0 m respectively (z_{eu} = 1 % of I_0). pH values were very stable through the sampling period and fluctuated between 9.0 and 9.5 (Fig 2b). Dissolved oxygen in Lake Chungará (Fig 2c) followed a distribution pattern similar to that of temperature, with high concentrations between July and September and the lowest concentrations in January and February. The concentration of dissolved oxygen ranged from 3 to 6.3 mg l^{-1}. The values of dissolved oxygen concentrations as computed for the altitude of this lake from Mortimer (1981) nomogram, seemed almost at the saturation value (98 %). The low partial atmospheric pressure (about 450 mm Hg) at lake Chungará's altitude results in a lower saturation value (6.3 mg O_2 l^{-1} at °C). Results for abiotic features (Tab 2) showed that conductivity (standardized at 25°C) fluctuated between 1,100 and 1,600 µS cm^{-1}. Major constituents in the water showed a uniform distribution with spatial and temporal variability of conductivity. The carbonate-bicarbonate system in lake Chungará is dominated by HCO_{3-}, and the molar distribution, at a conductivity of 1,100 µS cm^{-1} (Rebsdorf 1972), of free CO_2, bicarbonate and carbonate, per thousand is: 3, 958, 39 at pH 9.0 and a water temperature of 4 °C; and 2, 949, 49 at pH 9.0 and a water temperature of 12°C respectively. Results of the plant nutrient analysis showed that silica (SiO_2) is present in low concentrations, never above 0.058

TABLE 1

Morphometric characteristics of lake Chungará

Características morfométricas del lago Chungará

Maximum Length	lm	7.78 km
Maximum breadth	bm	7.58 km
Mean breadth		2.06 km
Shore line	L	35.10 km
Area	A_0	13.25 km^2
Volume	V	0.40 km^3
Maximum depth	Z_m	34 m

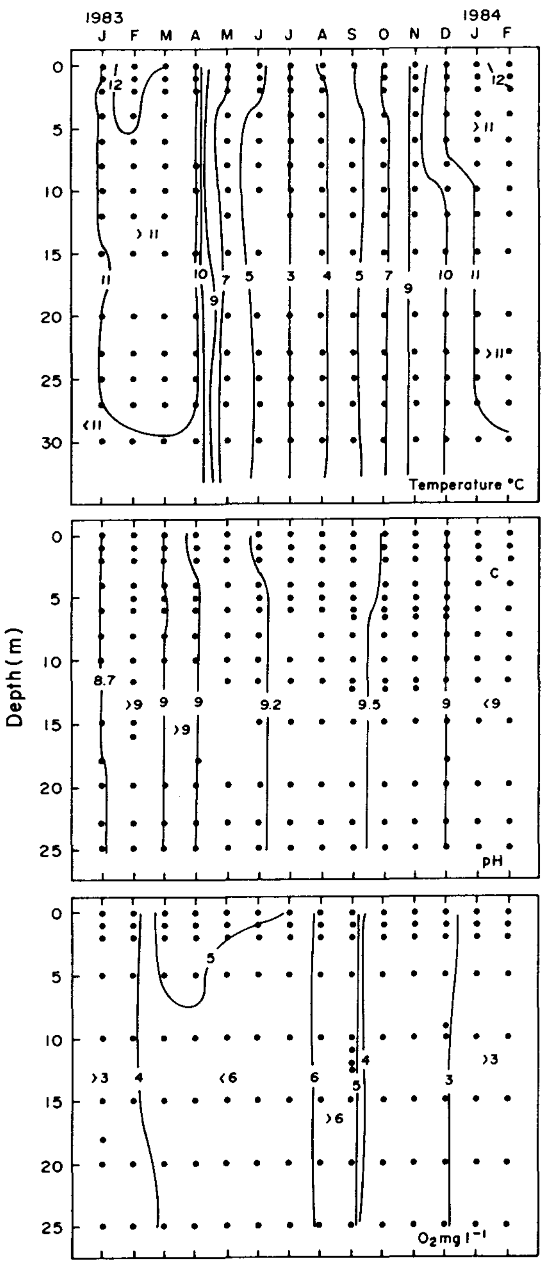

Fig. 2: Distribution of temperature (°C), pH, and oxygen (mg l^{-1}) in the deepest area of lake Chungará. Each dot corresponds to one measure.

Distribución de temperatura (°C), pH y oxígeno (mg l^{-1}) en la parte más profunda del lago Chungará. Cada punto corresponde a una medición.

mM. Mean concentration of nitrate in the water was 7.14 μM l^{-1} N-NO_3 with a range of 0.64 - 18 μM l^{-1}. Orthophosphate fluctuated in the range 6.4 -13.3 μM l^{-1} with a mean value 10.2 μm l^{-1} P-PO_4. Lithium and Aluminium showed greater temporal and spatial variability as compared to macro elements.

Biological features

Results of chlorophyll ***a*** and productivity measurements carried out in October 1985 are shown in Table 2. Pigment concentration increased from 0 m to 6 m depth reaching a maximum of 2.9 mg chl ***a*** m^{-3}. Afterwards it decreased steadily with increasing depth. Photosynthetic rate reached a maximum of 4.65 mg C m^{-3} h^{-1} at 3 m depth. With an euphotic depth of 17 m, light was not considered to be a limiting factor.

The macrophytes association distributes as a conspicuous belt along the south-western shore of the lake. *Myriophillum elatinoides, Potamogeton filifolius, Nostoc* and *Cladophora* sp were co-dominant around the year and perennial. From the microalgae, the dominant one was *Botryococcus braunni*, a colonial species *Nephroclamys subsolitaria* was codominant together with two diatoms species *Cocconeis placentula* and *Cyclotella andina* (Table 3). Zooplankton was dominated by Copepoda, especially calanoids and cladocera. The littoral benthos is rich in Turbellaria and Molluscs (*Ancylus, Pisidium* and *Taphius*; Cecilia Osorio personal communication). The ichtyc fauna of lake Chungará is mainly represented by *Trychomycterus* sp (Trychomycteridae) and *Orestias chungarensis* (Cyprinodontidae) (Vila & Pinto 1986).

The littoral of lake Chungará is inhabited by some genera of Amphibia like *Pleurodema* sp. (Leptodactylidae), *Telmatobius* sp. (Leptodactylidae) and *Bufo* sp (Bufonidae) (Veloso and Bustos, 1982). The abundant littoral aquatic vegetation is a sanctuary for an abundant avifauna, most of them migratorial birds including *Phoenicopterus chilensis, Anas speceularioides, Fulica gigantea, Larus serranus* and *Charadrius articola*, (Veloso & Bustos, 1982).

Results of physico-chemical measurements in lake Chungará and published data for other andean high altitude aquatic ecosystems, shown in Table 4, were submitted to a principal components multivariate analysis. Results are showed in Fig. 3. The analysis shows that lake Chungará is in the same group as river Colpas, river Putani and,

TABLE 2

Chlorophyll *a* (chl ***a***) and primary productivity measurements in lake Chungará (October 1985)

Clorofila *a* (chl *a*) y medidas de productividad primaria en el lago Chungará (Octubre 1985)

Depth m	Pigment concentration mg chl ***a**** m^{-3}	Photosynthetic rate mg C m^{-3} h^{-1}	Specific Photo-synthetic rate mg C (mg chl ***a***)$^{-1}$ h^{-1}
0	0.45	2.55	4.8
1	0.80	1.55	1.7
2	1.20	3.85	3.2
3	1.40	4.65	3.2
4	1.60	4.45	2.7
6	2.90	2.05	0.5
9	2.10	2.35	1.0
12	1.40	0.95	0.5
16	1.50	1.55	1.0
20	1.60	1.55	1.2

Integrated photosynthetic rate over depth (P)	42.8 mg C m^{-2} h^{-1}
Integrated pigment concentration (B) over euphotic zone (17 m)	33.7 mg chl ***a*** m^{-2}
Maximal specific photosynthetic rate	4.8 mg C (mg chl ***a***)$^{-1}$ h^{-1}
Integral assimilation number (P/B)	1.3

* corrected for phaeopigments.

TABLE 3

Phytoplankton abundance in the vertical profile of lake Chungará. April, 1980*

Abundancia de fitoplancton en un perfil vertical del lago Chungará. Abril 1980

Depth (m) / Species	0	7.5	15	20	30	Total
Botrycoccus braunni	4.20	3.60	7.32	5.16	11.34	31.6
Cocconeis placentula	3.59	3.59	3.07	4.61	6.15	21.0
Nephroclamys subsolitaria	0.21	7.29	7.86	3.25	2.36	20.9
Cyclotella andina	0.00	4.35	15.31	3.41	3.96	17.0
Schroederia setigera	1.23	1.78	2.06	0.64	0.57	6.3
Sphaerocystis sp	0.15	0.83	0.34	0.24	0.10	1.7
Oocystis marssonii	0.00	0.17	0.07	0.06	0.06	0.4
Closterium tortum	0.04	0.08	0.01	0.08	0.06	0.3
Synedra aff. *rumpens*	0.02	0.04	0.07	0.06	0.08	0.3
Unidentified Bacillariophyta	0.10	0.08	0.40	0.01	0.005	0.6
Total	9.6	21.8	26.6	17.6	24.7	

* Units are in mm^2 l^{-1} (1 mm^2 = 2.500 standars units l^{-1}).

salines of Surire. The salines of Huasco represents another group. The peruvian systems belong to another group with lake Naboba and lake Titicaca.

DISCUSSION

The physical, chemical, biological, structural and functional pattern of lake Chungará bears a general resemblance to other high altitude tropical mountain lakes in the Andes. Nevertheless, Chungará lake at the southern border of the tropical region conforms to the aquatic systems located in the southern tip of the Central Andes as characterized by Little (1984).

From data in Table 4 and the PCA resemblance analysis (Fig. 3) we suggest that the observed clusters conform to differences existing in the geological and geochemical composition, and climatic conditions between (and within) the humid Andes located north of Perú and the high plateau Central Andes range (Altiplano), stretching south from Ecuador to north of Chile and Argentina (Johnson et al. 1984, 1985).

TABLE 4

Physical and chemical features of high altitude Andean aquatic systems

Características físicas y químicas de sistemas acuáticos andinos

Features	Lake 1	Lake 2	Lake 3	Saline 4	Spring 5	Spring 6	Spring 7	Lake 8	Lake 9	Lake 10	River 11	River 12
Latitude	18:15	15:74	08:50@	18:53	18:48	20:18	20:17	14:00@	13:00@	–	17:35	17:37
Longitude	69:18	69:17	77:00	69:04	68:58	68:53	68:53	71:00	72:00	–	69:30	69:30
Altitude	4,520	3,812	4,185	4,280	4,248	3,790	3,791	3,800	3,600	4,400	4,050	4,045
Temperature °C*	8.0	11.0	9.1	–	–	–	–	11.9	13.3	10.9	–	–
pH	9.0	8.2	6.7	–	–	–	–	7.9	7.3	6.4	–	–
HCO_3 + CO_3**	6.2	2.2	0.2	3.5	2.4	3.5	3.5	2.2	1.03	–	1.4	1.6
SO_4	4.2	0.8	–	1.1	0.7	0.9	0.9	3.6	21.3	0.07	0.7	0.7
Cl^-	1.0	1.5	<.008	1.9	0.9	1.2	0.8	1.7	0.40	0.00	0.5	0.6
Na^+	1.7	3.2	0.02	2.1	1.2	3.1	2.7	1.7	1.04	0.02	0.9	1.0
K^+	0.5	0.4	0.002	0.4	0.3	0.2	0.3	0.1	0.20	0.005	0.07	0.01
Mg^{2+}	6.4	1.4	0.006	1.3	0.8	0.4	0.5	1.2	6.60	0.040	0.70	0.8
Ca^{2+}	2.6	1.6	0.060	1.2	0.8	1.2	1.1	1.4	6.10	0.050	0.50	0.6
Source***	1	2	3	4	4	4	4	3	3	5	4	4

• : 1, Chungará (Chile); 2, Titicaca (Perú-Bolivia); 3, Parrón (Perú); 4, Surire (Chile); 5, Surire 1 (Chile); 6, Huasco (Chile); 7, Huasco 1 (Chile); 8, Tungasuca (Perú); 9, Huaypo (Perú); 10 Naboba (Colombia); 11, Colpas (Chile); 12, Putani (Chile).

* : mean values for surface water temperature.

** : all ions in mM l^{-1}

*** : 1. Author's data; 2. Carmouze et al. 1981; 3. Löffler, 1960; 4. Ministry of Public Works (Chile); 5. Löffler, 1972.

@ : Latitude and Longitude are coarse approximates.

– : Unknown.

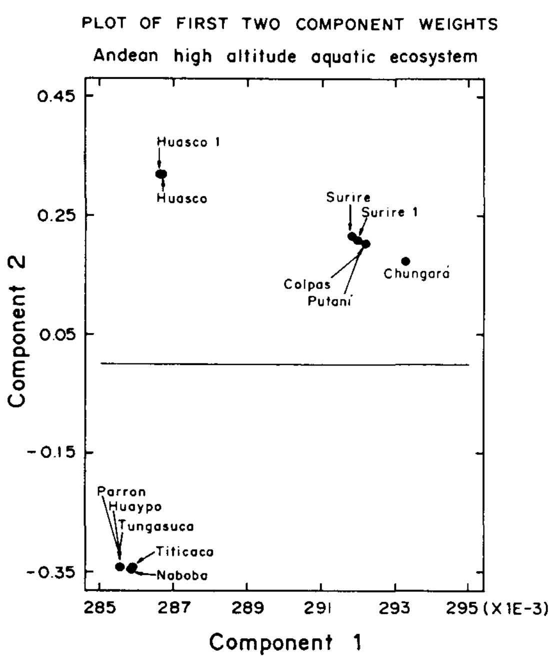

Fig. 3: Principal Components Analysis (PCA) of the data base showed in Table 4. Comparison of different high altitude Andean aquatic ecosystems.

Análisis de Componentes Principales (PCA) utilizando la base de datos del Cuadro 4. Comparación de distintos ecosistemas acuáticos andinos de alta altitud.

Heat budgets in tropical lakes are dominated by high, relatively aseasonal, solar input and evaporation output (Richerson et al. 1977). In lake Chungará the maximum irradiance occurs between September and December reaching 554.45 Ly day^{-1} in October / November, at the end of the dry season. There is a further decrease later between December and March, due to the rainy season (Cabrera & Montecino 1987). Photosynthetic available radiation measurements carried out during a cloudless day in October 1985 gave values between 2100 $\mu E\ m^{-2}\ s^{-1}$ (at 11.05 h) and 1500 $\mu E\ m^{-2}\ s^{-1}$ (at 15.30 h). In addition, a negative hydrologic balance with a mean annual precipitation of 330 mm y^{-1} and an evaporation mean value around 1200 mm y^{-1} (Niemeyer 1964), conforms to the low heat budgets of high altitude, tropical, Puna lakes (Löffler 1960, Hutchinson 1975). As a result; in lake Chungará heat has a small storage term with a mixed layer greatly affected by the short term weather changes. Moreover Löffler (1964, 1968) asserts that in tropical high mountain lakes, physical parameters are less stable than in temperate lakes. Water transparency in lake Chungará (mean Secchi disk depth = 7.5 m) allows most of the bottom area to be within the euphotic zone, this agrees with the transparency known for other tropical high altitude lakes (Löffler 1960, 1964, 1968, 1972, 1978, Margalef 1984, Mosello 1984).

In the endorheic watershed of lake Chungará, water evaporation should produce an increase in the concentration of dissolved solids.

Lake Chungará can be classified as a moderate saline lake dominated by SO_4^{2-}, Ca, Mg, Na, CO_3^{2-} + HCO_{3-}, Li, and Al, suggesting the relation of the lake water with dolomitic rocks, probably of the Oxaya formation (Klohn, 1972). The rank order of cations in lake Chungará is $Mg^{2+} > Na^+ > Ca^{+2} > K^+$, which is in contrast to the more common one: Na+ > Ca+ > Mg^{2+} > K+. This is not surprising, Löffler (1960), Hegewald and Runkel (1981) and Vareschi (1987) already stated that Puna and generally saline lakes, like lake Chungará, exhibit diverse salt concentration, salt composition, and a wide spectrum of combinations, depending on very regional conditions. For the ionic composition of the water, the geological conditions are most important. Mg^{2+} in lake Chungará is in excess (2.5:1) in respect to Ca^{2+}.

At the altitude of lake Chungará, a CO_2 pressure of 0.0002 atm is a reliable value (Hutchinson 1975). CO_2 involvement in the carbonate/bicarbonate system of Chungará should be smaller than estimated (< 0.3 %). At the high altitude of lake Chungará the partial pressure of atmospheric oxygen is reduced to 57 % of sea level values. The observed oxygen concentrations agrees with saturation values corresponding to the altitude of the lake. Similar values were measured for lake Parrón (4,185 ma.s.l.) by Löffler (1960); by Hutchinson (1937) for Yaye-tso (4,686 m.a.s.l.) and by Vincent et al. (1985) for lake Titicaca (3,800 ma.s.l.).

From a chemical point of view, dissolved reactive phosphorus concentration in aquatic ecosystems is regulated by vegetation biomass, but also by pH and some metals, mainly calcium and iron (Stumm & Morgan 1981). At high pH and calcium concentration values, most of the phosphate will precipitate as $Ca_5(PO_4)_3$ (F, Cl, OH) or apatite, thus causing low concentrations of dissolved P-PO_4. Soluble P-PO_4 in tropical high mountain lakes has been so far described as rather low (Löffler 1968, Richerson et al. 1977). Nevertheless a broad trend of increasing soluble reactive phosphate concentration with increasing salinity was found by Wood and Talling (1988) in ethiopian lakes, some of them at high altitudes. Lake Chungará, a moderate saline lake, has considerable amounts of dissolved P-PO_4 (mean concentration = 10.2 $\mu M\ l^{-1}$). Reasons for its high concentrations include the enduring alkaline pH conditions which hinder the formation of variscite ($AlPO_4.2H_2O$) and or strengite ($FePO_4.2H_2O$), although concentrations of Al (20.5 ± 0.5 $\mu g\ l^{-1}$) and Fe (102.1 ± 0.4 $\mu g\ l^{-1}$) in the lake water are considerable. Significant is the water total hardness (516.8 ± 2,3 mg $CaCO_3\ l^{-1}$) which diminishes the possibilities of apatite formation. Phosphate enrichment is probably derived from volcanic sources flowing in from springs and rivers, and possibly lake sediments (Mühlhauser, unpublished data). We suggest that phosphorus is not limiting for the vegetation in lake Chungará.

Sulphate in the lake is in excess as compared with chloride, a result of the active volcanism existing in the area.

Our results for silica measurements in lake Chungará are comparable to those reported for peruvian high altitude mountain lakes by Löffler (1960), and for lake Titicaca by Richerson et al. (1977).

Phytoplankton biomass expressed as chlorophyll *a* has been surveyed by several investigators in tropical high altitude mountain lakes. Stout (1969) reported values of 0.22-5.43 μg chl ***a*** l^{-1} in mountain lakes from New Zealand. Vincent et al. (1984) reported a mean value of 2.6 $\mu g\ l^{-1}$ for lake Titicaca. Lake Chungará with a mean value of 1.49 μg chl ***a*** l^{-1} can be classified as oligo-mesotrophic (Wetzel 1983).

Photosynthetic activity in tropical high altitude lakes has been reported to have a large range of values (Löffler 1968, Massey 1981, Carney 1984, 1987). Lake Chungará with a integrated photosynthetic rate of 0.043 g C $m^{-2}\ h^{-1}$ would correspond to a meso-eutrophic (Wetzel 1983) Puna lake. The different trophic classification according to biomass (chl *a*) or photosynthetic rate can be explained by the interaction of several factors. Because of the lake's altitude, phytoplankton should be adapted to high irradiance and low temperature, but deep mixing probably affects negativelly its growth rates and consequently its biomass concentration, which is less than half of that reported for mesotrophic lake Titicaca (Carney et al. 1987). Taking into account the low zooplankton respiration rates reported by Andrew et al. (1989) herbivory should not play an important role.

The deep euphotic zone (20 m) in lake Chungará, which is well over the mean value of 12.5 m defined for tropical lakes investigated by Lewis (1978) allows the development of conspicuous macrophytes beds. This beds should be considered in further energy flow studies.

Cosmopolitanism is common among different planktonic groups in lake Chungará. For instance many of the phytoplankton and zooplankton genera present in the lake have been described also for lake Titicaca (Richerson et al. 1977, Lazzaro 1981, Carney et al. 1987), and for laguna Mucujabi by Gessner and Hammer (1967). Löffler (1968) suggests that passive dispersal of species through the Andean range is guaranteed by migratory birds.

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