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Morphometric and basic limnological data of Laguna Grande de Chirripó, Costa Rica

by

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Abstract: Morphometric data together with some selected physical, chemical and biological features of the Laguna Grande de Chirripó, a small high mountain lake of glacial origin located in the Cordillera de Talamanca of Costa Rica, are discussed. The lake has a water temperature oscillating around 10 C, a very low concentration of dissolved solids and a gross primary productivity of 0.15 g C $m^{-2}d^{-1}$. The maximum productivity value recorded was found at a depth of 5 m. Levels above this are probably subjected to strong light inhibition.

Very few limnological investigations on the lakes of Costa Rica have been conducted to date, mainly because in the past many were simply inaccessible and even now it is still very difficult to reach some of them with the necessary equipment.

A group of small lakes which could be visited in the past only with great difficulties are the lakes of glacial origin in the highest parts of the Cordillera de Talamanca. A detailed account of the historic ascensions of the mountains in this region is given by Kohkemper (1968). In a tropical country such as Costa Rica, where the water temperature of the lowland lakes normally oscillates around 28 C, these high mountain lakes provide an interesting situation for limnological work.

In March 1979 a good opportunity to study the lakes of the Chirripó was provided by the US Army. The pilots of several helicopters, training in the Talamanca region, took us together with our equipment (boat, tent, etc.) to the Valle de los Lagos of the Chirripó. This allowed us to stay several days in the close vicinity of our study object.

Localization: The Laguna Grande is located in the Valle de los Lagos of the Chirripó which forms the highest peak (3819 m) of the Cordillera de Talamanca in Costa Rica. The lake itself is 3520 m above sea level. Its geographical position is 9° 21' N and 83° 29' W. In the same valley lie two smaller lakes at altitudes of 3480 m and 3440 m respectively. The valley, which contains the lakes, is U-shaped, its

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opening facing roughly to the west. Valley and lakes were formed by glacial activities. According to Weyl (1956 a, b), the last glaciation in this region (Wisconsin) extended into the Holocene and ended about 50,000 years ago. Lakes within these depressions are referred to as cirque lakes (Wetzel, 1975). As shown by Bergoeing (1978) many similar valleys and small lakes are situated in close vicinity in the same area. Our study area consists of the largest of the cirque lakes in the Chirripó region and probably also in the whole Talamanca range.

The tributaries which the Laguna Grande receives are small and of periodic nature. The same holds true for the outlet which flows into the next lake and from there to the third one. Hence, these lakes form a chain of cirque lakes, whose common outlet is the Rio Chirripó del Pacífico.

The Laguna Grande was studied during the dry season. At this time the lake did not receive any visible superficial water supply and also the outlet had fallen dry. Judging from the color of the rocks on shore, the lake level might be about 40 cm higher during the wet season than at the time of the study. As shown in Fig. 1, the dry season is of short duration. The precipitation values in this figure were obtained from Villa Mills, at an altitude of 3000 m and about 40 Km north-west from the Chirripó hence the data give only a rough indication. Direct data from Chirripó are not available.

The Chirripó consists mainly of volcanites and plutonic material (Weyl, 1957). In 1976 an extensive fire destroyed most of the Páramo vegetation around the lakes. In 1979 the vegetation had not yet recovered and the marks of the fire were still visible. A comprehensive report about the Páramo vegetation of the Talamanca is given by Weber (1958).

MATERIAL AND METHODS

Morphometric Survey: The depth recordings were done by hand with a weighted disc about 25 cm in diameter and a marked line. The positions of the recordings were determined as follows: a buoy fixed tightly on a heavy stone was anchored in the center of the lake. From the buoy a line marked at 10 m intervals was connected to conspicuous parts of the shore line. After having determined the depths along the line, its position was changed. Thus, we obtained depth recordings located like the radii of a circle. To get additional recordings near the shore, the line was also connected between various points of the shore like the chords of a circle. The positions of the line were later determined by aerial photography from the helicopter. Altogether 225 depth recordings were performed.

The depth contours were drawn by a computer. The three-dimensional graphic of the lake basin is also based on a modified computer drawing. The morphometric parameters were calculated using the equations given by Wetzel (1975).

Chemical and Biological Data: The temperature of the air was taken with a laboratory thermometer. A reversible thermometer was used to determine the temperature at various depths of the lake. Conductance and pH were measured with battery-operated meters. Alkalinity was obtained by titration with sulfuric acid and methyl orange as indicator. The oxygen determinations were performed by the Winkler method. Titrations were done by means of a micro-burette in the oxygen bottles (100 ml nominal volume) themselves.

Samples for phytoplankton studies were taken at various depths and preserved with formalin. Net plankton was obtained in vertical hauls. Sediment was

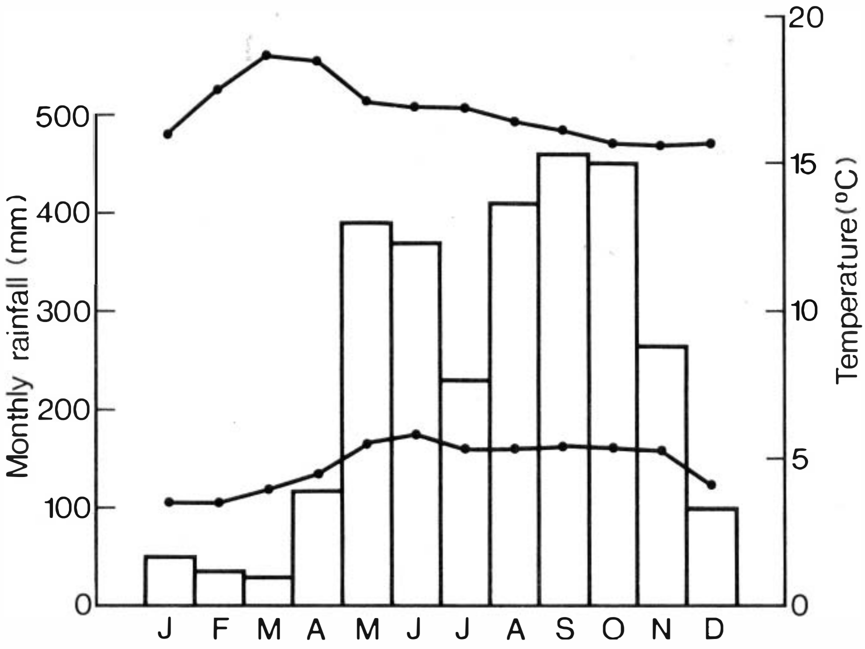

Fig. 1. Monthly rainfall and mean high and low temperatures at Villa Mills.

taken with a small grab or by scuba diving. Primary production and planktonic community respiration was measured using the oxygen difference method. Samples were taken and incubated at 0,1, 3, 5 and 8 m depths from sunrise to sunset (about 6:00 - 18:00).

RESULTS AND DISCUSSION

Fig. 2 shows a detailed bathymetric map of the Laguna Grande. The long-axis of the lake is oriented in an east-west direction. The map reveals that its central part almost forms a circle, on the eastern and western sides of which two shallow parts are attached. The greatest depth (22 m) is located roughly in the center of the lake. Especially the northern shore increases rapidly in depth.

The major morphometric parameters of the Laguna Grande are as follows:

Maximum length	378 m
Maximum width	238 m
Shore line	1190 m
Area	5.43 ha
Volume	445,700m^3
Maximum depth	22 m
Mean depth	8.2 m

The data given are valid for the dry season. During the wet season, when the water level is 40 cm higher, the water volume increases about 5%, so that the maximum volume would be 468,000m^3

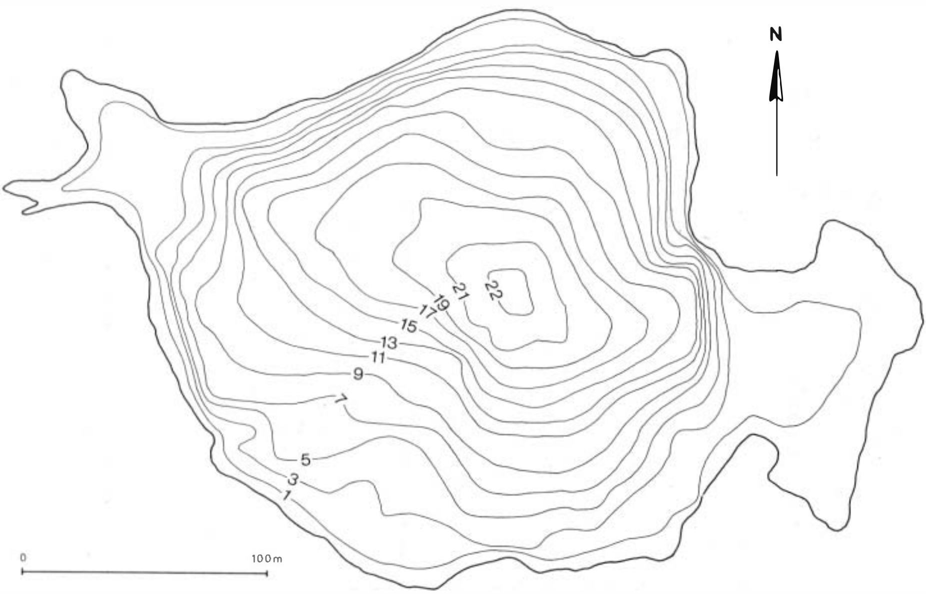

Fig. 2. Bathymetric map of the Laguna Grande de Chirripó. Depth contours in metres.

Fig. 3 and Fig. 4 present the lake basin in a three-dimensional manner. In Fig. 3 the lake is shown looking towards the west. The projection angle is 17^{o}. This is the angle at which a viewer sitting on the highest point of the Chirripó would see the lake. The three-dimensional figure clearly shows the crater-like form of the basin. In Fig. 4 the lake can be seen under a projection angle of 23^{o} looking towards the south. This is the angle looking from the mountain ridge located in the north of the Laguna Grande. The figure shows the deep central lake body and the shallow parts located on its eastern and western sides.

During the study period the air temperature at 1 m above ground varied between 14.2 C, which was the maximum value observed (16 III 1979 at 15 hrs.), and 2 C. The last value was encountered on 18 III 1979 at 6 hrs. The temperature on the ground fell below the freezing point. A thin ice layer was observed on a narrow edge of the shore. Kohkemper (1968) reports that the lowest temperature measured on the Chirripó was -8 C. The diurnal variation of the air temperature is shown in Fig.5. The temperature was measured on a cloudless day. As usual during the total study period strong winds began to blow at noon.

The water temperature showed a very small diurnal variation. The highest surface temperature was 11 C at 15 hrs. During the night the temperature fell to 10 C in the whole water column down to 17 m, the greatest depth at which temperature was measured (Fig. 5). Temperature values at different seasons are not available except those given by Löffler (1972). He reports a surface temperature of 10.7 C taken on 28 VIII 1966 at 9:45 hrs. In spite of the lack of further data it seems probable that seasonal variations of water temperature are almost nonexistent. Thus, the total range of variation will be abaout 1 C.

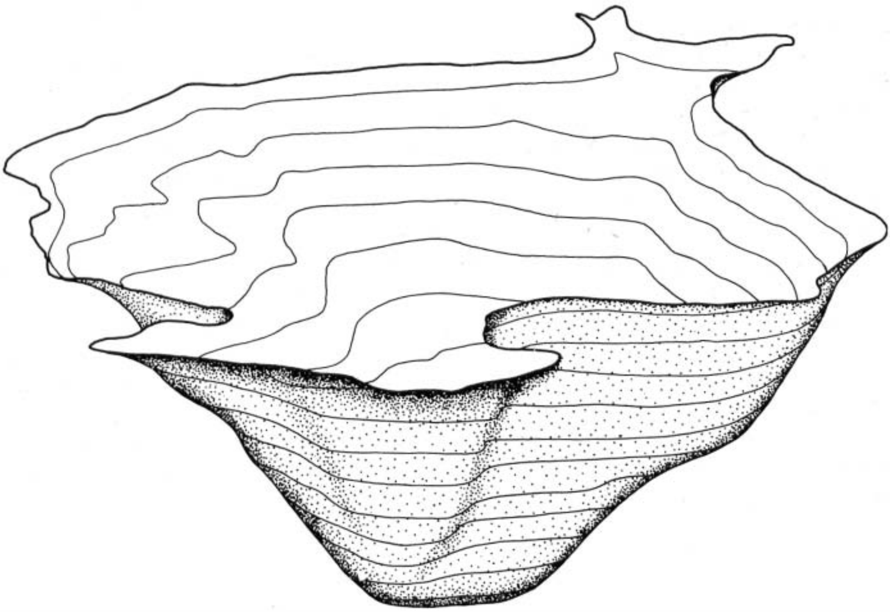

Fig. 3. Three-dimensional perspective view of the Laguna Grande de Chirripó from the East. Projection angle 17°. Vertical exageration 10 times.

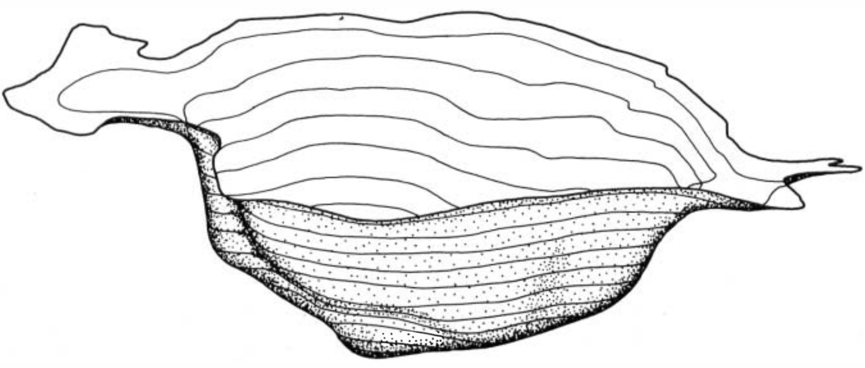

Fig. 4. Three-dimensional perspective view of the Laguna Grande de Chirripó from the North. Projection angle 23° Vertical exageration 10 times.

The temperature profile shows a weak stratification only during the day, since the uniform water temperature in the mornings indicates a complete circulation at night due to convection currents and mixing by winds. The mixing process is facilitated by the small density differences of the water at these relatively low temperatures. Obviously the lake belongs to the polymictic type (Hutchinson &

Löffler, 1956). In the Laguna Mucubaji, a small Venezuelan lake of similar altitude, however, a relatively stable stratification was found (Gessner & Hammer, 1967; Lewis & Weibezahn, 1976).

The few chemical parameters measured do not exhibit vertical differences. The conductance is only 14 μ mhos and the alkalinity 0.15 m eq/l. These values are nearly the same as those given by Löffler (1972). They indicate low concentrations of dissolved substances, which reflects the type of parent material in the small watershed of the lake. Rain falling in this area will reach the lake basin very rapidly without having been in long contact with the low soluble volcanites and plutonic material. The pH measured at several depths of the water column was near the neutral point (pH 7.1). The oxygen concentration varied between 7.2 and 7.3 mg/l (Table 1). Taking into account temperature and altitude, the lake water is almost exactly 100% saturated with oxygen. This is not surprising in view of the frequent circulations. The small increase of concentration found from noon to evening between 3 m and 8 m depth is due to photosynthetic processes. No 0_2 measurements below 8 m water depth were made so it is impossible to say whether the oxygen decrease found in deeper layers of the Laguna Mucubaji (Gessner & Hammer, 1967; Lewis & Weibezahn, 1976) also exists in the Laguna Grande. This, however, seems improbable considering the circulation patterns of the latter lake.

TABLE I

Fluctuation of dissolved oxygen in relation to depth and time of day. Measurements performed on 18 March, 1979.

Depth (m)	O_2 (mg/1) 6 hrs.	12 hrs.	18 hrs.
0	7.21	7.22	7.21
1	7.21	7.23	7.22
3	2.22	7.24	7.25
5	7.22	7.25	7.26
8	7.22	7.25	7.28

Measurements of the primary production of the Laguna Grande were done on 17 March. The net production per day was 0.095 g C m^{-2}, the gross production was 0.155 g C m^{-2} and the community respiration in the water column down to 8 m was 0.129 g C m^{-2}. The production values are slightly underestimated because the depth of the productive layer exceeded 8 m, which was the greatest depth,where the measurements were performed. The depth of maximum photosynthetic activity was 5 m (Fig. 6). This relatively deep lying maximum indicates strong light inhibition of photosynthesis. The compensation depth probably lies at about 10 m.

We may compare the productivity of the Laguna Grande with that of the Laguna Mucubaji. Lewis & Weibezahn (1976) measured the primary productivity in the latter lake using the C^{14}-technique, which is considered to be close to net production. The comparison reveals that the productivity of the Laguna Mucubaji (168 mg C $m^{-2}d^{-1}$) is almost twice as high as that of the Laguna Grande (95 mg C $m^{-2}d^{-1}$).

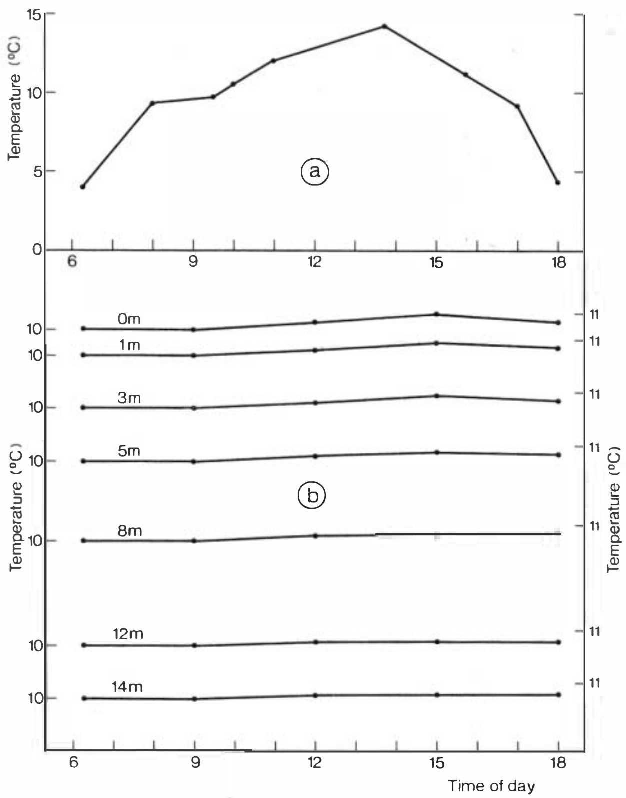

Fig. 5. a) Air temperature at 1 m above ground on 17 March 1979.
b) Water temperature at different water depths on 17 March 1979.

The sediment near the shore is almost purely inorganic. Sand, small stones and larger rocks predominate. At sheltered sites a thin layer of charcoal, which stems from the great fire in the surroundings (1976) was observed on the sediment. In the central parts of the lake the sediment is covered by a thick layer (ca. 1 m) of a soft material, which mainly consists of charcoal, plant residues, exuviae of planktonic crustaceans and fecal pellets.

The littoral vegetation of the Laguna Grande is poorly developed. In the shallow parts of the lake very few *Isoetes tryoniana* L.D. Gómez as identified by Jorge Gómez L. were found. The benthic fauna consists of amphipods and larvae of chironomids and other aquatic insects. Also a small species of an unidentified bivalve was found. The zooplankton contains fairly high numbers of a pink coloured copepod. *Peridinium* sp. seems to be the most numerous species of the phytoplankton. This coincides with the observations of Fetzmann-Kusel (1970), who found *Peridinium willei* and *Botrycoccus braunii* as the predominant phytoplankton species in the lake.

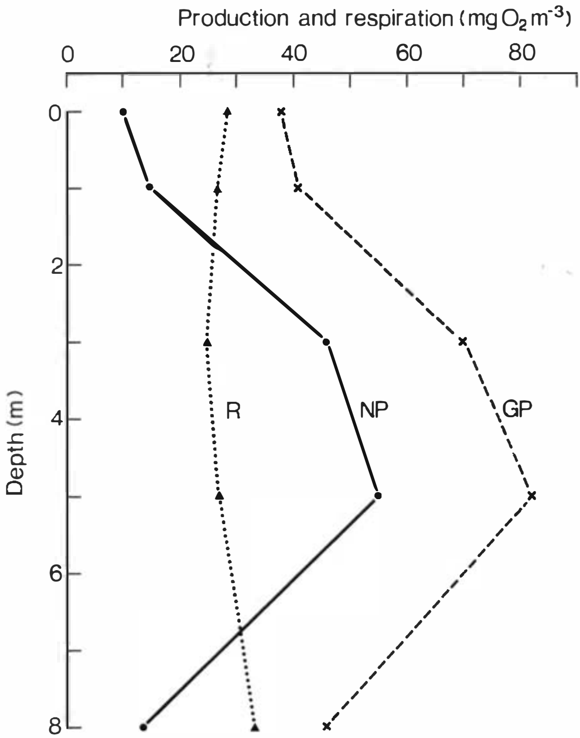

Fig. 6. Primary production and plankton community respiration on 17 March 1979. Incubation period from 6 hrs to 18 hrs. NP=net production, GP=gross production, R = respiration.

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RESUMEN

Durante el mes de marzo de 1979 se realizó un estudio de la Laguna Grande en el Cerro Chirripó de Costa Rica, con el fin de obtener algunos datos básicos de tipo morfométrico y limnológico. Esta laguna es de origen glaciar y se encuentra a 3520 m de altura en el Valle de las Lagunas. Junto con otras 2 pequeñas lagunas situadas a 3480 m y 3440 m de altura respectivamente, las tres están conectadas en serie con un desagüe común que forma el Río Chirripó del Pacífico.

Los datos morfométricos de la Laguna Grande se obtuvieron mediante fotografías aéreas y más de 200 sondeos de profundidad, como sigue:

Area de la superficie:	5,43 ha,
Volumen de agua:	445 100 m^3,
Profundidad máxima:	22 m,
Profundidad media:	8,20 m,
Perímetro:	1190 m.

Estos datos son válidos para el período seco. Durante la época lluviosa el nivel de agua está 40 cm más alto, lo que causa un aumento del volumen hasta 468,000 m^3. Los afluentes superficiales en forma de pequeñas quebradas son temporarios, lo mismo que el desagüe hacia la laguna siguiente. El sedimento cerca de la orilla consiste de arena y piedras. No tiene material orgánico en cantidad notable si no se toma en cuenta el material carbonizado proveniente de la vegetación de los alrededores, que durante el gran incendio de 1976 fue arrastrado a la laguna. A profundidades mayores se encuentra sobre el fondo mineral una gruesa capa (cerca de 1 m) de un sedimento orgánico aeróbico de muy poca consistencia.

El agua de la laguna tiene la particularidad de tener una bajísima concentración de sales disueltas, debido a las formaciones geológicas circundantes, que contienen sobre todo piedras cristalinas.

La conductividad eléctrica del agua es de solo 14 μmhos. En cualquier profundidad el agua tiene un pH de alrededor de 7.1 y alcalinidad total de 0.15 m eq l^{-1}.

Durante el período de observación la temperatura del aire a un metro sobre el suelo varió entre 2.0 y 14.2 C durante el día. La variación de la temperatura del agua en el centro de la laguna era de solo 1 C. A las 6 a.m. se midió una temperatura de 10.0 C en toda la columna del agua. A las 3 p.m. la temperatura del agua superficial subió a 11.0 C. Debido a los fuertes vientos reinantes y al enfriamiento nocturno es poco probable que se llegue a producir jamás una estratificación estable de la laguna por más de algunos días.

La concentración de oxígeno es de 100% de saturación en toda la columna del agua. La liberación de 0_2 debido a la producción primaria y el consumo de 0_2 debido a la respiración son notables, pero carecen de importancia para el presupuesto de oxígeno de la laguna, si se los compara con los procesos puramente físicos.

La vegetación bentónica es escasa y consiste solo de algunas cepas aisladas de *Isoetes tryoniana* L.D. Gómez. En el fitoplancton se encontraron sobre todo dinoflagelados. El zooplancton contenía copépodos en bastante cantidad. En el zoobentos se encontraron anfípodos, larvas de chironómidos y de otros insectos acuáticos y una especie pequeña de bivalvos. La producción primaria bruta el día de observación fue de 0.15 g C $m^{-2}d^{-1}$, por lo tanto de la misma magnitud que en otras lagunas alpinas de gran altura, es decir, de muy baja producción.

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