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Crustacean plankton of a high altitude tropical lake: Laguna de Chingaza, Colombia

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Introduction

High mountain lakes of the tropical America are mostly located in the "páramo" region, the typical humid zone above the andean forests of Ecuador, Colombia, Venezuela and in Costa Rica. Limnological observations on those lakes have been carried out in Ecuador (LÖFFLER 1963, STEINITZ-KANNAN et al. 1980, COLINVAUX & KANNAN 1983, MILLER et al. 1984), Colombia (LÖFFLER 1972, GAVIRIA 1984, 1988, 1989, 1991), Venezuela (GESSNER & HAMMER 1967, LEWIS & WEIBEZAHN 1971) and Costa Rica (LÖFFLER op. cit.). The crustacean plankton systematics of those lakes is relatively complete in comparison to that of the warm tropical lakes of the region.

Studies on crustacean plankton ecology like seasonality, developments related to rainfall and temperature, vertical and horizontal distribution of species, density, biomass and production studies have not been done in this region. Some more information exists on zooplankton ecology of lowland lakes of the tropical America (BRANDORFF 1977, ROBERTSON 1980, ZARET 1980, DEEVEY jr., DEEVEY & BRENNER 1980, MATSUMURA-TUNDISI & TUNDISI 1976, ZAGO 1976). On the tropical mountain region of Africa and Asia, no quantitative work on zooplankton crustaceans exists. The only mountain lakes that have been studied are Lake Begnas and Lake Rupa in Nepal (SWAR & FERNANDO 1980) but they are subtropical.

Lakes on the "páramo" are mostly oligotrophic with a polymictic type of circulation. Crustacean plankton is mostly composed of a few species, and they are limited to one or two copepods (one calanoid, one cyclopoid) and one or two cladocerans. On those lakes inhabited by centropagids, no diaptomids are present (GAVIRIA 1988). When cyclopoid species are present they are represented by *Metacyclops leptopus totensis* REID, MOLINA & FUKUSHIMA. The genera of cladocerans to be found in the plankton are *Ceriodaphnia*, *Daphnia* and/or *Bosmina*.

Due to its size, location and importance as a drinking water supply (city of Santa Fé de Bogotá), Laguna de Chingaza is an ideal lake for developing long term limnological research activities.

Description of the lake

Laguna de Chingaza (A = 88 ha, Zm = 24 m) is situated in the "páramo" region of the Cordillera Oriental of the Colombian Andes at 3250 m of altitude (Fig. 1).. The National Park "Chingaza" has its name derived from this lake.

The "páramo" of Chingaza (mean relative humidity, 84 %; air temperature, −8 to 23 °C; wind velocity, 2 to 6 m · s^{-1}) has a unimodal type of precipitation regime with a mean annual value of 1812 mm (EAAB 1989). Highest rainy period is between May and July and the dry season is from the end of December to end of February. During the period studied highest precipitation occurred in May 1990 (Fig. 2).

The annual water temperature ranged between 9 and 17 °C, it is weakly stratified with temperature gradients ranging from 1–4.5 °C. Partial mixing is often but during rainy periods when the temperature is low, complete turnover of the water body is observed. This is influenced by the high imput of low temperature water (7–8 °C) of the Río Frío.

The lake water chemistry is as follows: conductivity, 35 µS · cm^{-1} (20 °C); alkalinity, 0.34 meq · l^{-1}; total hardness, 0.34 mg · l^{-1} as $CaCO_3$; dissolved oxygen, 7.4 mg · l^{-1} (at 107 % saturation value); pH, 6.9; total nitrogen 683 µg · l^{-1} and primary productivity between 12–45 mg C · m^{-2} · d^{-1} (May and November 1990 respectively). For a greater part of the year, the atmosphere is cloudy (total duration of sunshine in 1988 amounted to 863 hours), Secchi disk transparency varies between 3.5–9.0 m.

Materials and methods

Samples of zooplankton were collected monthly between April 1990 and March 1991 (in August 1990 no samples were taken) at a central station on the lake (Fig. 1), by vertical hauls with a plankton-net of 64 µm meshsize from 12 m depth to the surface. Volumetric samples (5 l SCHINDLER sampler) were taken in 6 diurnal cycles (samples mostly at 4 hours intervals) in March, May, June, September, November of 1990 and February 1991. After collection samples were concentrated by filtering them through a 50 µm nylon strainer and preserved with 5 % formalin. Samples taken with the net were divided in two portions using a FOLSOM subsampler, one for biomass (WETZEL & LINKENS 1979) and the second for density analyses. Monthly population densi-

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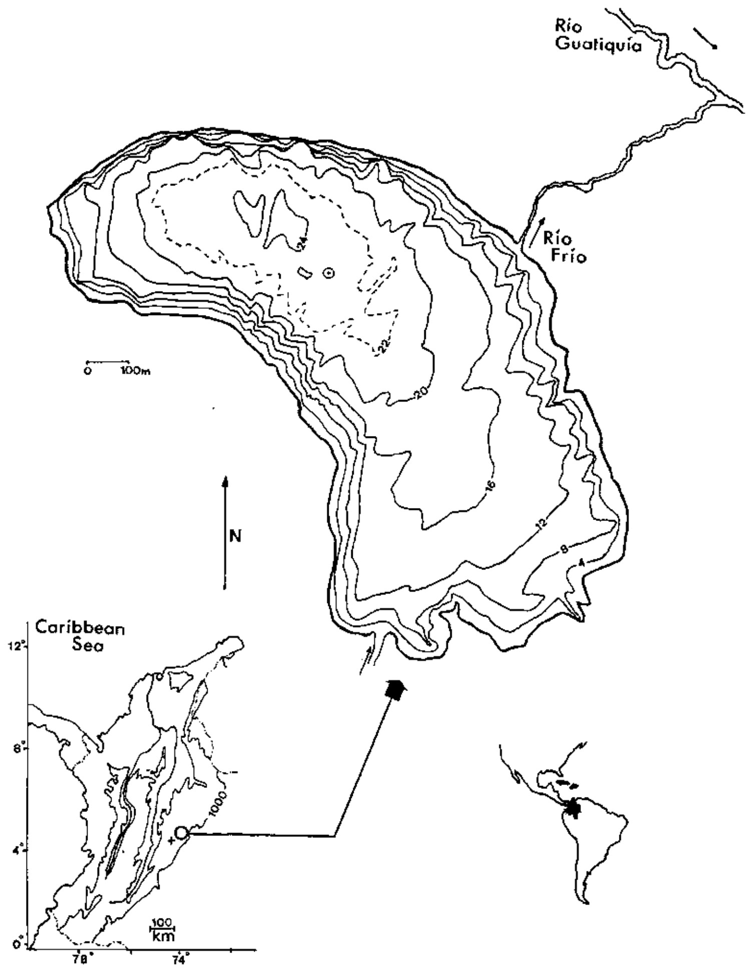

Fig. 1. Map showing the location and bathymetry of Laguna de Chingaza. Sampling station (⊙) and the location of the city of Santa Fé de Bogotá (+) are indicated.

ties were calculated from 5 subsample counts taken with an one ml HENSEN-Stempelpipett from a known and homogenized volume. SCHINDLER samples were entirely counted.

Results and discussion

Composition

The crustacean zooplankton of Laguna de Chingaza is constituted by a calanoid species *Colombodiaptomus brandorffi* GAVIRIA 1989 and two daphnids *Ceriodaphnia dubia* RICHARD 1894 and *Daphnia leavis* BIRGE 1878.

Density and biomass

Population densities were: *C. brandorffi* 3100 to 28000 ind · m^{-3}, *C. dubia* 450 to 6600 ind · m^{-3} and *D. laevis* 97 to 2200 ind · m^{-3} (Fig. 2). The fluctuation pattern of the total zooplankton density is strongly influenced by the copepod changes in density while this species dominates the zooplankton. The highest value is reached in September as it occurred with *C. brandorffi*. Peaks on April 1990 and March 1991 are also influenced by the strong development during these months of *C. dubia* and *D. laevis* respectively.

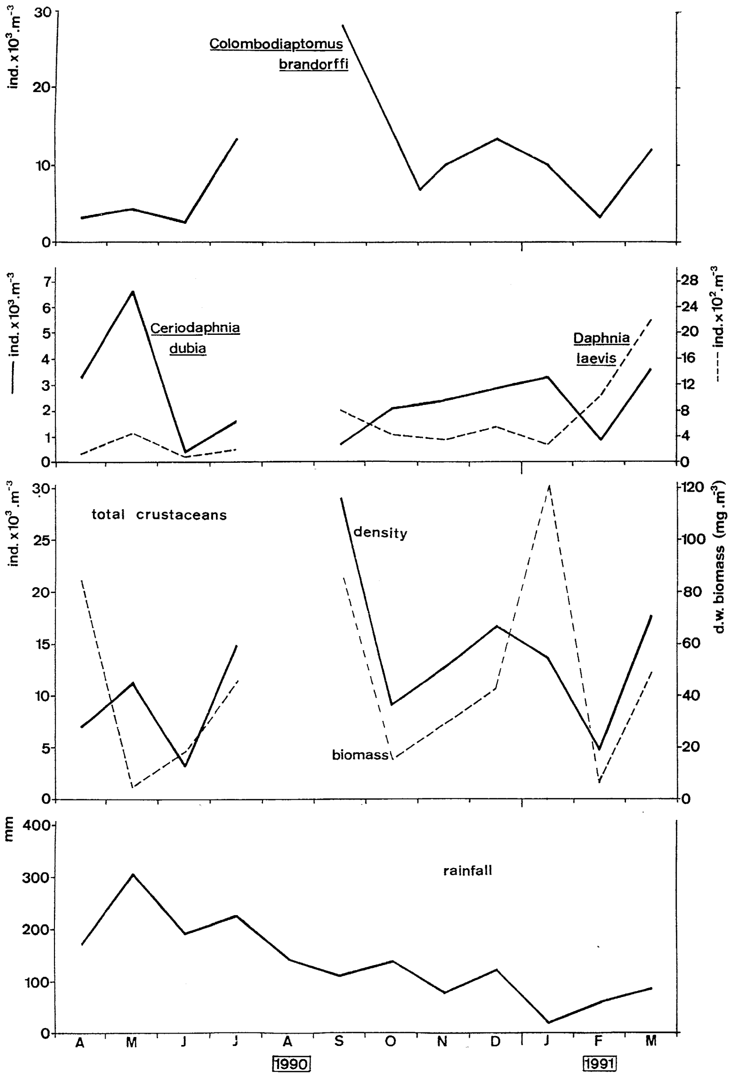

Fig. 2. Density and biomass fluctuation of the crustacean plankton, and monthly rainfall in Laguna de Chingaza. No data area available for August 1990.

Total biomass varies between 7 and 120 mg · m^{-3}. Biomass figures showed three peaks occurring along the year: the high value in April corresponds to a period when the population of *C. brandorffi* is mainly represented by adults (Fig. 3). They are most probably the major contributors to the biomass. In September the high value in biomass corresponds to that of the total density of copepods. The highest biomass value was found in the dry period (January). It can be explained by the fact that the density of copepodit stages reached in this period. *C. dubia*, *D. laevis* and adult copepods numbers were found to be appreciable.

Species development

Calanoid population seems to be benefit from the nutrient input during the rainy season. Fig. 3 indicates that at the early rainy season most of the population of *C. brandorffi* is represented by adults. Females carring eggs (egg numbers range between one and two) appear at this time and are present

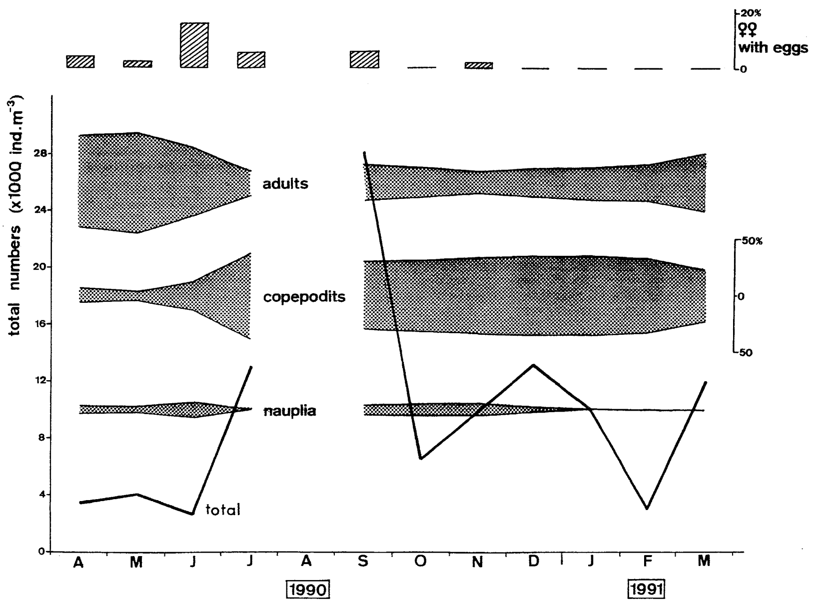

Fig. 3. Density and development of *Colombodiaptomus brandorffi* in Laguna de Chingaza. No data area available for August 1990.

during the whole rainy season. The highest number of females carring eggs occur in June. Nauplia are present during greater part of the year but are absent during the dry season. Copepodit stages show only low density in the first two months of the rainy season. This trend on development suggest that a cycle is completed during one year.

Size class distribution analyses have not been done for populations of cladocerans inhabiting this lake. Three to four peaks of density (Fig. 2) in both species indicate that they could have the same number of generations in a year. Experimental studies in laboratory are also necessary for studing their life cycles. Egg numbers were counted for *C. dubia* (one to two eggs) and for *D. laevis* (one to three). No males have been noted on the Chingaza populations.

Vertical migration

Vertical distribution of the adult population of *C. brandorffi* was observed during a diurnal cycle in six different occasions along the year (Fig. 4). Plankton samples were taken up to 15 m depth in March 1990 but just a few animals were observed below 10 m layer. Thus, subsequent sampling programm included samples only of the upper 10 m.

Classical pattern of migration of planktonic crustacean (Cushing 1951) with four periods of movements seems to be followed by *C. brandorffi:* 1) a midnight sinking was observed clearly in March, Juni, September and November 1990; 2) a dawn rise was observed in all months studied (except in November); 3) a descent to day depth is to be seen in the sampling dates from September 1990 to February 1991 and 4) an ascent from day depth at dusk occurred in all occasions studied (Fig. 4).

The week stratification developed during part of the year in Laguna de Chingaza seems to have not influence on the migration behaviour of copepods inhabiting the lake. Food distribution as well as low energy consumption at cold water layers could be the main cause of migration patterns. Predator avoidance is not the reason or explaining vertical migration, as few invertebrate predators (Hydracarina) exists in free waters. Salmonids inhabiting this lake (rainbow trout *Oncorhynchus mykiss* and brown trout *Salmo trutta*) do not feed on the crustaceans described here (EAAB 1991).

Conclusions

The crustacean community of the plankton of Laguna de Chingaza has a low diversity. *C. brandorffi* dominates

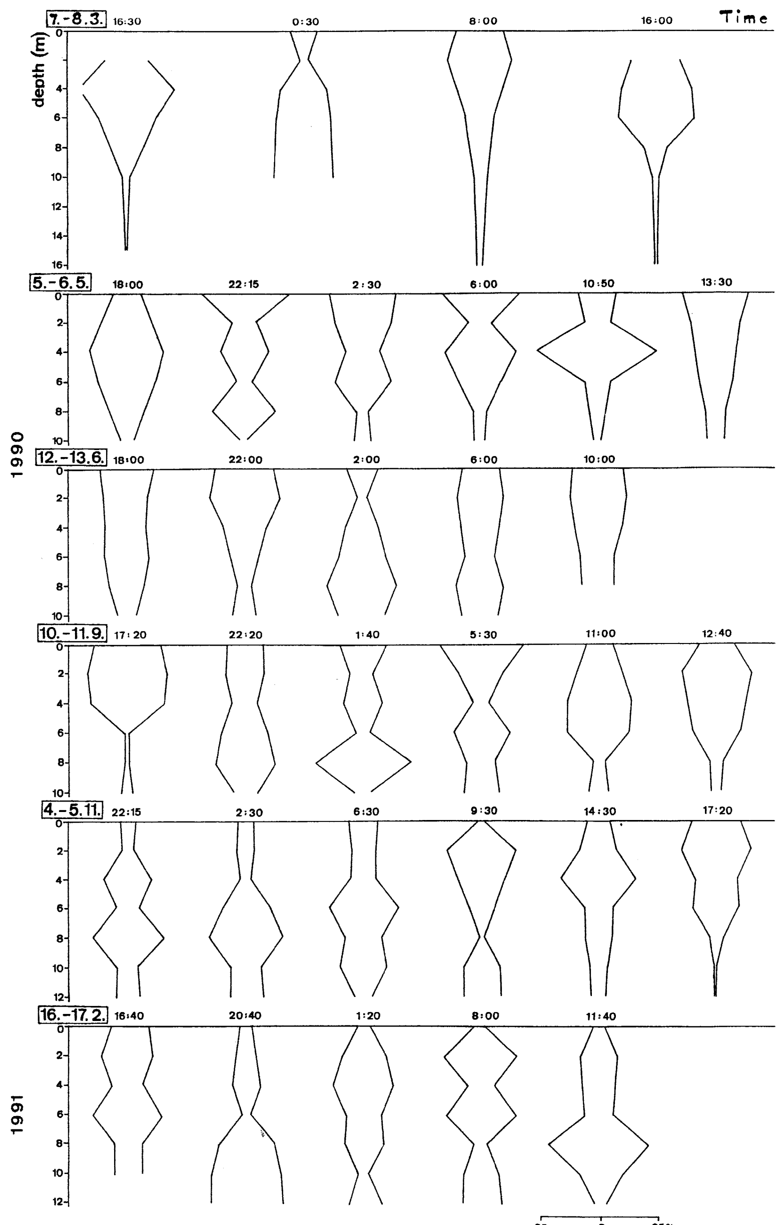

Fig. 4. Diel vertical migration patterns for *C. brandorffi* (adults) during 6 different dates in Laguna de Chingaza.

the zooplankton followed by *C. dubia. D. laevis* is always present, nevertheless in low numbers. While the population densities of the copepod species has its highest development in September, *C. dubia* has it a short time after the begin of the rainy season and *D. laevis* during the dry period.

The diaptomid species seems to have a generation in the year, both cladocerans three to four. Reproduction period of the copepod species take place during the rainy season.

The typical pattern of vertical migration appears to be the rule in Laguna de Chingaza with 3 active movements at dawn, midday and dusk, and a passive movement at midnight.

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