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Vertical distribution of benthic macrofauna in a Costa Rican crater lake

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Abstract: The benthic macrofauna was sampled in the lake of an ancient volcano (Cerro Chato, Alajuela, Costa Rica) at a depth of 3-4 m. Twenty cores (17cm^2 x 10 cm) were sectioned in two 5 cm parts, preserved in formaldehyde solution and stained with Rose Bengal. Organisms retained in a 500 micron mesh sieve were considered as macrofauna. A total of 13 species (96 individuals) belonging to seven taxonomic groups was found. Diversity is low (H'=1.51) compared to that of other aquatic systems. The dominant groups were Chironomids (Diptera) and Oligochaetes (Oligochaeta), which comprised 76% and 16.6% of the total respectively. The latter ocurred mainly (75% of the individuals) in the deeper part of the sediment. At 3 m, five cores will contain 6±1 species; a greater number of cores will only add less abundant species.

Key words: Macrofauna, Tropical limnology, benthos, Costa Rica, crater lake.

Throughout history, volcanic lakes have held a mystical and frightening fascination to mankind. The bodies of water that occupy ancient, extinct craters are peculiar aquatic environments due to the isolation of their waters, fed only by rain (Löeffler 1972, Rice 1983). Consequently, these are systems in which the flow of nutrients, elements, organic material and organisms is primarily dependent on the contributions provided by wind and rain (Margalef 1983, Payne 1986), as well as on the animals that frequent them (Pennak 1978).

The dynamics of the animal community that inhabits the bottom of such a lake correspond with a dependence on the physical-chemical properties of the lake (Arocena 1991). The function of that community within the ecosystem is extremely important because of its role in the recycling of materials and its position within the energy cycle (Margalef 1983, Añón 1991).

This article presents a description of the benthic community of Cerro Chato as well as its vertical distribution within the sediment and is the first work done in Costa Rica on the benthic macrofauna of volcanic lakes.

MATERIAL AND METHODS

Study site: Cerro Chato, (1140 m.a.s.l.) (Fig. 1) is a truncated volcanic cone located between the Guanacaste and Central Mountain Ranges (Alvarado 1989). With the Arenal Volcano and the Chatito and Espina domes, it constitutes the Arenal-Chato volcanic system (Borgia *et al.* 1988). Cerro Chato is located within the premontane wet forest life zone (Holdridge 1979). Its slopes and summits are covered by lower montane rain forest (Gómez 1987), with hot, humid climate and a short dry season (Herrera 1987). The lake was formed after the last period

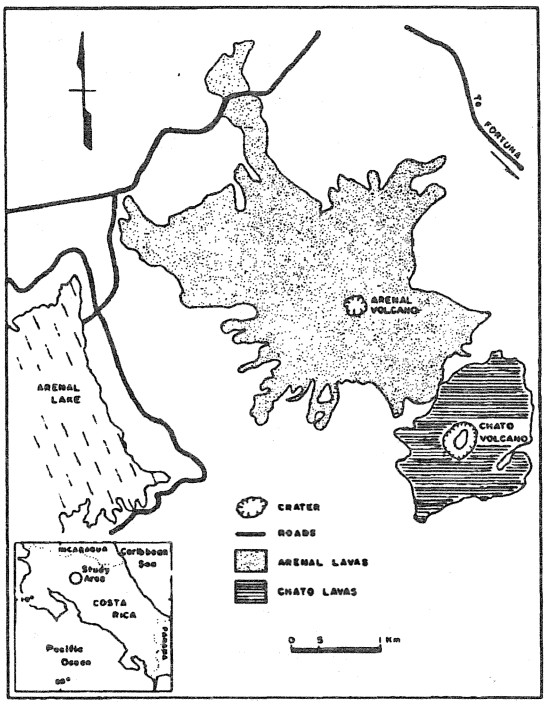

Fig. 1. Lake on Cerro Chato (Volcano) and its position within the Arenal-Chato complex. Modified according to Borgia *et al.* (1988) and Alvarado (1989).

of eruptive activity, approximately 3 550 years ago (Borgia *et al.* 1988), when the peak was destroyed and the current crater was formed. The lake has a maximum depth of 18.8 m; the pH, dissolved oxygen and temperature vary significantly with depth, hour of day and season (Umaña and Jiménez, in prep.).

Sampling: Twenty samples were taken from the benthos on two occasions (8-IV-92 & 2-V-92). The collection, done by skin diving, was made at a depth of 3 m and a distance of 3 m from the lake's southeast shore using a corer extractor made of plexiglass (area of core = 17.5 cm^2). The corer was driven into the sediment to a depth of 10 cm and at random within a 2 m^2 quadrat. The core was sliced *in situ* into two sections of 5 cm each. The samples were preserved with 10% formalin stained with Rose Bengal. The sediment was washed in a five hundred-micrometer sieve. Material retained on the sieve was considered macrofauna (Gray 1981). Organisms were separated manually under a dissecting microscope (30X). The organisms were mounted in glass slides following the methods described by Pennak (1978) and Merritt & Cummins (1984). Whenever possible, specimens were identified to species level using Pennak 1978, Merritt & Cummins 1984 and Roldán 1988, and were then deposited at the Museum of Zoology, University of Costa Rica. Mineral content of the samples was studied according to their crystallographic structure, color and texture using a magnifying glass.

RESULTS

Thirteen species of seven taxa were identified. Diversity was relatively low (H'=1.51), and the average number of individuals per sample was 4.7±3.6. Chironomids (midge larvae) are the most abundant organisms, representing 76% of the 96 individuals collected in the 20 samples (Table 1). The vast majority of the larvae are of the genus *Procladius* (Tanypodinae: Procladiini). The rest probably belong to the genera *Zavrelimyia* (Tanypodinae: Pentaneurini), *Chironomus* (Chironominae: Chironomini) and an unidentified genus (Chironominae:

TABLE 1

Vertical distribution and abundance of macrofauna in the benthos of the lake on Cerro Chato. Number of individuals per taxon by depth interval in sediment and the approximate percentage fraction with respect total number of individuals collected. For Chironomidae and oligochaeta, the percentage according to vertical distribution in the sample is indicated*

	Number of individuals by depth			
Taxon	0-5 cm	5-10 cm	Total	%
Chironomidae	58(79.4%)	15(20.6%)	73	76.0
Oligochaeta	4(25.0%)	12(75.0%)	16	16.7
Odonata	3	0	3	3.1
Crustacea	2	0	2	2.1
Acari	1	0	1	1.0
Collembola	1	0	1	1.0

* The sediment at the depth studied contained an average of 62.65% organic matter; the elements N, Fe and P were found in average concentrations (g/Kg) of 14.37, 7.37 and 0.77 respectively (Jiménez & Springer, in prep.).

Tanytarsini). The second most abundant group Oligochaeta (Annelida) with 16.6%, classified in four morphospecies. *Dasythemis* sp. (Odonata: Libellulidae) represent 3.1% of the total sample. Other organisms, such as a watermite (Arachnida: Acarina), a springtail (Collembola: Entomobryidae), fragments of a crab (Crustacea: Decapoda) and the copepod *Paracyclops* sp. - a genus never before reported for Costa Rica (Umaña, in prep.)- together comprise 4.1% of the total.

Six of the seven taxa exhibited greater abundance (or all) of individuals in the upper 5 cm of sediment (Chi-square, $p<.05$, Table 1). The chironomids in general exhibited a significantly greater abundance in the upper stratum ($p<.001$). Only *Procladius* sp. and *Chironomus* sp. had a small percentage of individuals in the lower half (20.7% and 33.3% of the total of each genus respectively). The oligochaetes were the exception, with most individuals (75%) located preferentially ($p<.05$) in the deeper 5 cm. The chironomids and oligochaetes exhibited a grouped distribution within the area (Dispersion Coeficient>1, $p<.001$).

A species per area curve was graphed (Elliot 1971, Gray 1981) (Fig. 2). An average of 6±1 species were present in five samples, while increasing the number of samples by 2, 3 and 4 times raised the average number of species to

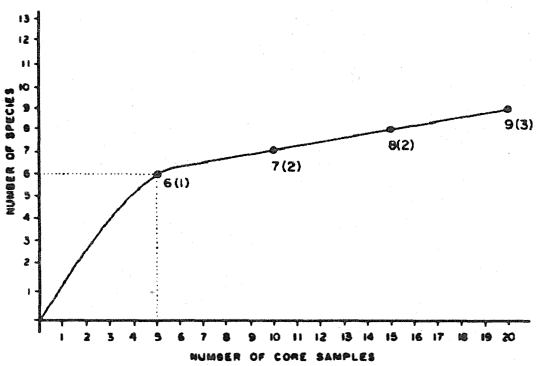

Fig. 2. Accumulative number of macrofauna and number of cores processed from the lake on Cerro Chato. Average number of species in 5, 10, 15 and 20 cores indicated. Standard deviation in parentheses.

9±3 (Fig. 2), this means a gain of just 3 species with a sampling effort four times the original.

In all samples small fragments of eruptive minerals such as plagioclases and andesites were found. Their structure, color, abundance and position in samples suggest a recent origin and a constant rate of deposition.

A large quantity of chironomids and trichopteran shelters were present in all samples.

DISCUSSION

The lake on Cerro Chato exhibits a low benthic diversity for the depth sampled comparing with river systems (Charpentier & Tabash 1988, Goitia & Maldonado 1991), with chironomids and annelids being the numerically dominant groups. Diversity is also low in similar volcanic lakes, such as in Botos Lake on Poás Volcano (H'=1.24, Jiménez, unpublished data). This characteristic, together with short trophic chains (Margalef 1983), can be a consequence of such factors as an equilibrium between introduction and extinction of species in the lake, uniform environmental conditions, the geografic isolation of the lake and dependence on the external contribution of nutrients from the wind and runoff and their diffusion in the watershed (Pennak 1978, Margalef 1983, Payne 1986). For this reason, a quantity of five cores of 175 cc. will be representative of the benthonic community at a depth of 3 m and the present study is a good representation of it.

Chironomids are insects whose aquatic larval stage can in some cases comprise up to 90% of their life cycle (F. Reiss in Hulbert & Villalobos-Figueroa 1982), lasting from a few weeks to several years (W. Coffman in Merritt & Cummins 1984). Chironomid larvae and pupae are thus an important benthonic component since they move a large amount of sediment as a result of their detriphagous alimentary habits (Margalef 1983). The penetration of the larvae in the sediment is limited to a few centimeters, which could indicate that the concentration of dissolved oxygen is greater at that level, or probably that the availability of food (sedimental phytoplankton, copepod feces, mites and other living prey) decreases in the deeper levels of the sediments. The latter is confirmed by the distribution of *Procladius* sp., which is a fairly active predator, judging by the stomach contents of the larvae. The absence of advanced larval stages from the samples is notable, and is perhaps due to the fact that the fraction of the population sampled was in an early stage of its life cycle. This situation could be different at

other times of year, at different depths (Jiménez & Springer, in prep.), or where the population dynamics differs to the degree that there are shorter generation cycles (Añón 1991). For this reason long term studies that establish community patterns and cycles are important (Umaña & Paaby 1991).

Oligochaetes are considered to be responsible for much of the stratification and chemical changes experienced by benthonic sediment (Margalef 1983) given the volume of the material that the group moves from deeper strata to more superficial ones. This activity, together with the decomposition of plant material in the sediment by fungi and bacteria (Padgett 1976, Stout 1980), causes nutrients to circulate and become accessible for other trophic levels. In this study the oligochaetes exhibited a greater penetration of the sediment than other groups; which could indicate a preference for organic material in the deeper layers of the sediment, or simply a strategy for avoiding predation.

It is possible that the observed distribution of the organisms is a response to the presence of an anaerobic stratum in the sediment (De la Cruz & Vargas 1987), since the oligochaetes exhibit a greater tolerance for low concentrations of oxygen thanks to the presence of hemoglobin (Barnes 1989) or to the forced circulation of water in their tunnels, tubes or shelters (Margalef 1983).

The other organisms found in the benthos are normally found in lake environments, as is true of chironomids and oligochaetes (see revision in Hulbert & Villalobos-Figueroa 1982, Margalef 1983, Merritt & Cummins 1984).

The presence of plagioclases and andesites in the sediment is a factor that should be considered. The positions of both volcanoes (Fig. 1), combined with northwest winds, result in material expelled by the strongest eruptions of Arenal Volcano being transported to the southwest and southeast, toward the massif of Cerro Chato. It is thus possible that Arenal Volcano is acting on the chemical composition of the lake, and perhaps influencing the benthonic communities (Jiménez & Springer, in prep.).

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RESUMEN

Se estudió la macrofauna bentónica del sedimento lacustre de la laguna de un antiguo volcán (Cerro Chato, Alajuela, Costa Rica) a 3-4 m de profundidad. Veinte núcleos (17.5 cm^2x 10 cm) fueron divididos en dos partes de 5 cm y preservados en formalina diluida y teñida con Rosado Bengala. Se consideró macrofauna a los organismos retenidos en un pascón de 500 micras. Se obtuvo un total de trece especies (96 individuos) pertenecientes a siete taxones diferentes. La diversidad es baja (H'=1.51) comparada con otros lagos. Los grupos dominantes fueron los quironómidos (Diptera) seguidos por los oligoquetos (Oligochaeta), que representaron 76% y 16.6% del total respectivamente. Estos últimos presentaron una preferencia (75% de los individuos) a localizarse en los estratos más profundos de la muestra. A 3 m, cinco núcleos contendrán un promedio de 6±1 especies; un número mayor de muestras incluirá especies raras y poco abundantes. Este es el primer trabajo que se realiza en Costa Rica sobre las comunidades bentónicas de lagunas volcánicas.

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