Rev. Biol. Trop., 44(2): 673-678, 1996

Depth related distribution of benthic macrofauna in a Costa Rican crater lake

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(Rec. 30-III-1995. Rev. 29-V-1995. Acep. 2-VI-1995)

Abstract: On two different opportunities the distribution and diversity of the benthic macrofauna was studied at different depths in the Laguna del Cerro Chato crater lake, Alajuela, Costa Rica. For both surveys, the deep samples had significantly lower species diversity and evenness than the shallow samples. There was a drop in species diversity and evenness at 6 m, followed by an increase at 9 m. This pattern is associated with fluctuations in the lake's thermocline. Chironomids were the most abundant organism in both surveys and the genus *Chironomus* dominated at all depths. Analysis of the elements Ca, Cu, S, N, Fe, P and percentage of organic matter in the bottom sediments did not show a clear bathymetrical distribution. However, at a depth of 9 m the increase in both N content and percentage of organic matter could be related to the increase in abundance of organisms.

Key words: Volcanic lake, benthos, macrofauna, aquatic insects, chironomids, Costa Rica.

The bottom sediment in a fresh water lake is a highly dynamic system where several groups of organisms coexist. For the majority of those lakes where the benthic communities have been studied, insects and particularly their larval stages are a very important component of the benthos community in terms of biomass and energy transference (Pennak 1978, Merrit & Cummings 1984).

The abundance of insects and other organisms in the benthos varies according to many factors (acting alone or in combination) such as the distance from the littoral zone, depth, oxygenation and water quality, predation by certain groups, sediment composition, altitute of the lake and the organisms' life history (Margalef 1983, Payne 1986).

For this paper, we studied the abundance and diversity of the benthic macrofauna at the Cerro Chato crater lake with regard to the lake's bathymetry and sediment composition.

MATERIAL AND METHODS

The bottom sediment samples from Cerro Chato crater lake -detailed description of the lake in Jiménez & Springer (1994) and Umaña & Jiménez (1995)-, were obtained along two radial transects oriented NE on the crater basin (Fig. 1). On both surveys (28-XI-92, 24-IV-93) the bottom was sampled with an Ekman Dredge sampler every 3 m depth, from one to 18 m (the lake's maximum depth). Samples (one dredge per depth) were preserved in 10% formalin and proccessed according to Jiménez & Springer (1994); the organisms and minerals bigger than 500 microns were manually sorted.

Analysis of elements and percentage of organic matter (OM) in the sediments were done only for the second survey samples. Bottom samples were stored cold and later dehydrated at 60°C for 72 hr. From each one, three and five grams were utilized for the elements and organic

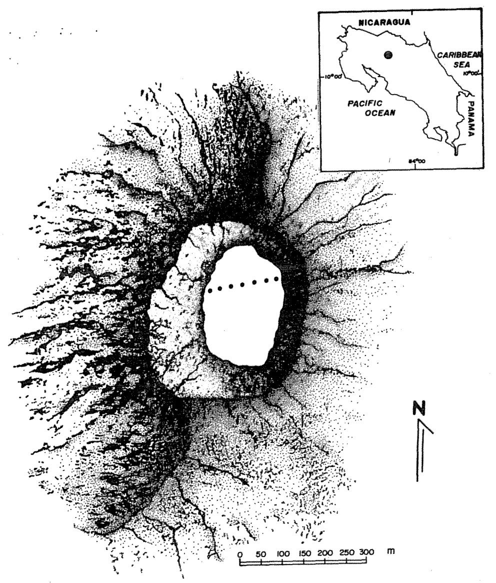

Fig. 1. Transects orientation at the Cerro Chato crater lake. Dots indicate the aproximate sampling position.

matter determinations respectively, with a total of three replicates per sample. The biologically important elements such as Ca, P, Fe, S and N (total), were analysed following the wet digestion technique described by Briceño & Pacheco (1984): the sample is inmersed in a nitropercloric solution and elements are determined by an atomic absortion spectrophotometer. Percentage of OM was measured according to the ignition method (Mook & Hoskin 1982): a known quantity of sediment is calcinized in a high temperature oven (Muffle), during eight hours at 500°C, and the OM content is determined by weight difference.

RESULTS

A total of 15 morpho-species belonging to ten taxonomic groups were identified from both surveys. In almost all depths, chironomids (Chironomidae:Diptera) were the dominant group comprising 81.9 and 63.0 % of the total individuals (Fig. 2). As a group they were not randomly distributed along the bathymetrical transect (Chi-square, $p<0.001$), and 70.3 % of their population was located between three and 15 m during the first survey (Fig. 2a) and 67.2% at less than 3 m on the second date (Fig. 2b). The Oligochaeta (Annelida), comprising

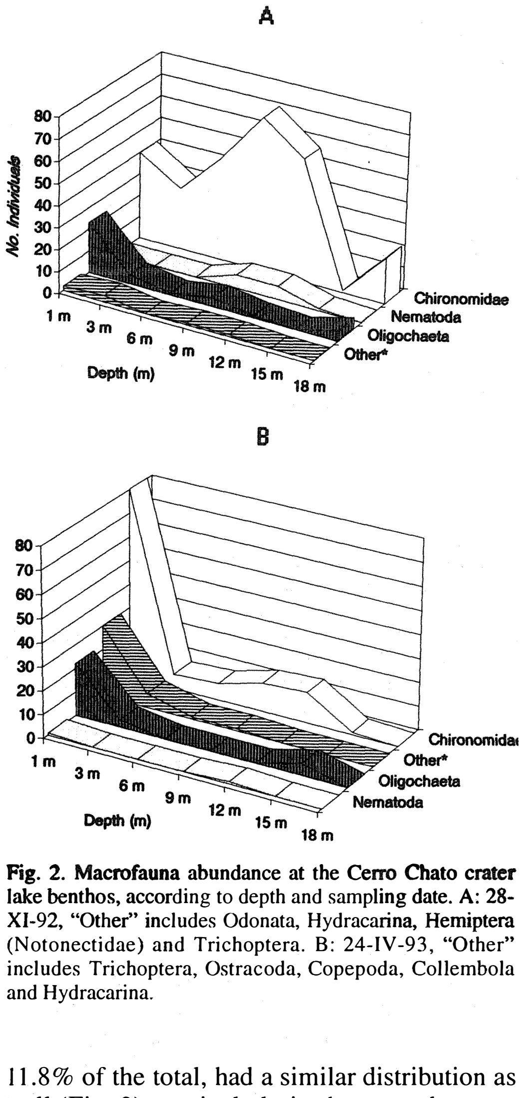

Fig. 2. Macrofauna abundance at the Cerro Chato crater lake benthos, according to depth and sampling date. A: 28-XI-92, "Other" includes Odonata, Hydracarina, Hemiptera (Notonectidae) and Trichoptera. B: 24-IV-93, "Other" includes Trichoptera, Ostracoda, Copepoda, Collembola and Hydracarina.

11.8% of the total, had a similar distribution as well (Fig. 2), particularly in the second survey when they were distributed in shallower and deeper depths (Fig. 2b). The Nematoda, 2.18% of the total, were more abundant during the first survey than in the second and they tended to be localized between nine and 15 m (Fig. 2).

In order to compare both surveys, and because some organisms were scarce in the samples, they were gathered under one single category ("Other" in Fig. 2). It is important to notice the shallow distribution (< 3 m) of *Libellula* sp. (Odonata: Libellulidae) and *Lestes* sp. (Odonata: Lestidae), the notonectids (*Notonecta* sp.), the caddisflies *Phylloicus* sp. and *Leptocerus* sp., ostracods (Ostracoda) and copepods (*Paracyclops* sp.). The springtails

(Collembola: Entomobryidae) and watermites (Arachnida: Acarina) were restricted to the 3-12 m depth range.

The different genera of chironomids showed an interesting distribution (Fig. 3). *Chironomus* sp. (Chironomini) was present at all depths except 18 m during the second survey, and became dominant below the 6 m for both samplings (Fig. 3). An unidentified genus of the tribe Tanytarsini along with *Procladius* sp. (Tanypodinae) were found between one and 12 m in the first survey (Fig. 3a), while the depth range changed in the second (Fig. 3b). The occurence of *c.f. Zavrelimya* sp. (Pentaneurini) was restricted to between one and three meters on both sampling dates (Fig. 3).

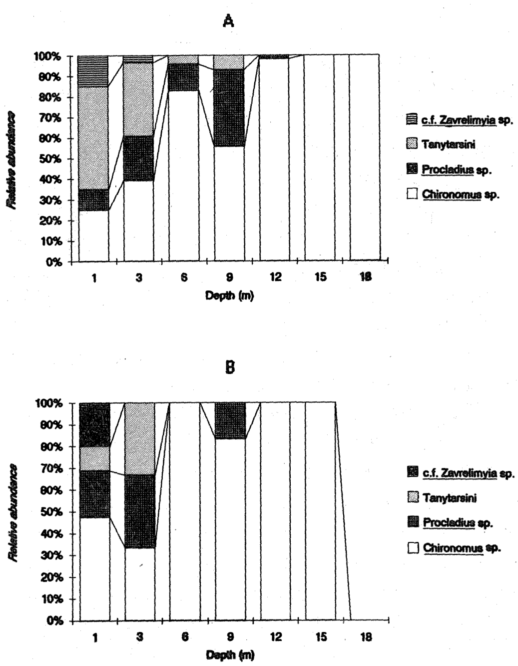

Fig. 3. Chironomids' relative abundance according to depth at the Cerro Chato crater lake benthos. A: 28-XI-92. B: 24-IV-93, note the absence of chironoids at 18 m depth.

The species diversity index (Shannon, H') and evennes (J') presented the same trends for both surveys (Fig. 4): the higher values were between 1-3 m; after that they dropped at 6 m, rose at 9 m and finnally dropped again at the maximum sampled depths. (Fig. 4). For shallow depths (<6 m),

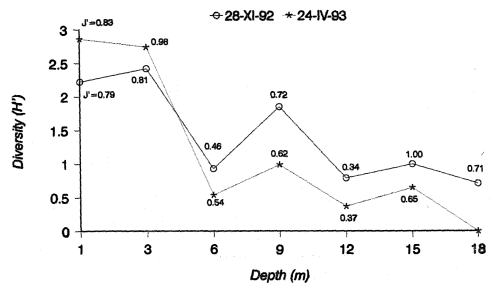

Fig. 4.Distribution according depth and survey date of species diversity (H') and evennes (J') of the benthic macrofauna at the Cerro Chato crater lake. Arrows indicate the possible thermocline's fluctuations.

the second survey had higher H' and J' than the previous one; at six meters the situation reversed and remained like that for the deep samples (Fig. 4).

Element abundance in the bottom sediments were not significantly correlated with depth for Ca and S (Pearson r=0.5698 and -0.4258 respectively, Fig. 5) and only S varied significantly with depth (ANOVA p<0.01). The other element concentrations did have a significant correlation with depth: there is a mild increase in Fe (r=0.6491) and P

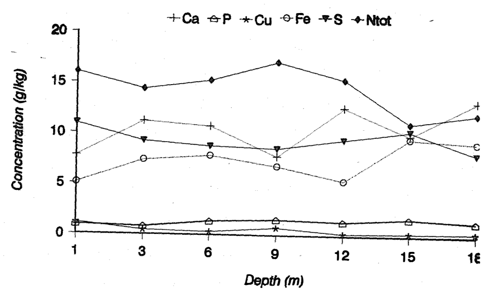

Fig. 5. Abundance of the elements Ca, P, Cu, Fe, N and S according to depth at the Cerro Chato crater lake bottom sediments.

(r=0.7548), a decrease in Cu (r=-0.6377) and total N (r=-0.6498) but only P, Cu and N (total) varied significantly between depths (p<0.01).

The percentage of OM is correlated with depth (r=-0.6427) and varied along the transect (0.1>p>0.01, Fig. 6). It is consistent with the drop at the 6 m sampling point and the peak afterwards, at 9 m.

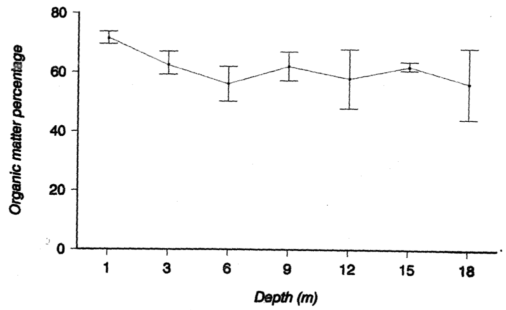

Fig. 6. Organic matter percentage of the bottom **sediments** at the Cerro Chato crater lake.

DISCUSSION

Our results confirmed previous observations made elsewhere about the lake's benthic macrofauna as regards to the heterogenety of their spatial distribution. Variations in species diversity and abundance are very common at different sections and depths of the lake (Oliver 1971, López 1988). Generally, the spatial heterogeneity is related to the physical environment and the flux of energy (Margalef 1984) in the basin. For example, fluctuations in the thermocline and mixing layer were considered unrelated to the lake's biotic component. It is now thought that the action of macropredators on the phytoplankton is sufficient to modify and change the position of the metalimnion (Mazunder *et al.* 1990). That change in the metalimnion and periodic fluctuations of the thermocline, do have a direct effect on the benthic communities, producing organisms mortalities and displacements towards less fluctuating sections of the lake (Barton 1981).

At the Cerro Chato crater lake, thermocline fluctuations have been observed at a depth between five and eight meters (Umaña & Jiménez 1995) suggesting the formation of internal seiches. The thermocline's fluctuation and depth range coincides with the decrease in species diversity and evenness (six meters depth, Fig. 4). Those oscillations produce changes in temperature and other physical-chemical parameters affecting organisms in several manners. Umaña y Jiménez (1995) suggest the intrusion of a more dense and highly oxigenated runoff water into the lake, localized at six meters depth. It is possible that this layer of water is producing high levels of siltation, altering the environment at the bottom level, thus forcing the organism mobilization. The trend for both surveys was a reduction in organisms at the six meters depth, with the exception of the chironomids. The drop at six meters depth in both the species diversity and evennness is due to the chironomids increase and thus dominance in the sediments. The latter could be related with larval mobility from deep waters to the shallow, thus getting ready for the emergence (Añón 1991) -a process that last from one week to several months (Olivier 1971)- and may explain why the abundance was duplicated in the shallow depths at the following sampling.

Chironomus has a high tolerance to anoxic conditions, allowing them to dominate at deep benthos. In the littoral zone, the competition with several other groups less tolerant to the lack of oxygen, prevents their dominance over the other chironomids. The chironomids in general, are one of the best studied organisms in limnological research (Margalef 1984) because of their abundance and position in benthic food chains (Olivier 1971, Saether 1975). Our results indicate their numerical dominance in the crater lake benthos, although at depths less than 0.3 meters, Trichoptera is the dominant group in the littoral zone (Springer in prep.).

The differential production of organic detritus in the littoral zone, is a factor that contributes to the spatial distribution of benthic organisms. The channelization of matter falling into the lake is a function of many processes such as wind patterns at the reservoir, basin steepness, water currents and internal waves, rupture of thermocline and bottom topography (Barton 1981, Mann 1988, Kerr 1991). Acting alone or in combination, they distribute the entering material far from the source. Because the majority of the benthic lentic macrofauna are detritivorous (Pennak 1978), they tend to be localized where there is high "quality" detritus, and for this reason, variations in the sediments' chemical components and organic matter, promote the patchiness in organism distributions. Even so, the variations observed in some biologically important elements, couldn't explain satisfactorialy the differences in organism abundances according to their distribution on the lake's bottom.

For example, the elements P and Fe precipitate in the presence of oxygen and tend to accumulate in the bottom sediments. That's not the case for N which in the anoxic layer is reduced to NH_4 which remains in solution, and where oxygen is abundant it is found as NO_3. That could explain the scarcity of N in the deep sediments. It is of interest that N abundance at nine meters depth coincides with an increase in both organism diversity and abundance. The detritus feeders' capacity and efficiency in transforming plant matter into more assimilable compounds is proportional to the N concentration in the sediments (Mann 1988). Thus, the observed increase of the quantity and "quality" of organic matter at nine meters, will be responsible for a higher abundance of organisms that are detritivorous. Therefore it is neccesary to further explore the possible relations between the thermocline oscillations and the sediment composition and distribution.

ACKNOWLEDGEMENTS

We thank A. Berghammer and G. Umaña for help during the sample collections; the administration of the Arenal Observatory Lodge for the use of their installations; F. Bolaños for facilitating his diversity analysis software; A. Avarado at the Centro de Investigaciones Agronómicas, Universidad de Costa Rica for the elements analysis; J.A. Vargas for the use of the CIMAR laboratories; O. Achí for the figures; J. Cortés and R. Rodríguez revised early drafts. The study was financed by the authors.

RESUMEN

Se estudió en dos ocasiones la distribución y la diversidad de la macrofauna bentónica en la Laguna del Cerro Chato, Alajuela, Costa Rica. Para ambos muestreos, la diversidad y equitatividad de las especies en las muestras profundas fue significantemente menor que en las someras y hubo una disminución bien marcada a los 6 m de profundidad. Las fluctuaciones de la termoclina pueden ser las responsables de esta distribución. Los quironómidos dominaron numéricamente ambos muestreos y *Chironomus* se distribuyó en todo el gradiente batimétrico. La abundancia de los elementos Ca, Cu, S, N, Fe, P y el porcentaje de materia orgánica en los sedimentos, no mostró una marcada distribución por profundidades, aunque un ligero aumento a 9 m podría estar relacionado con una mayor abundancia de organismos detritivoros.

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