VERTICAL AND HORIZONTAL DISTRIBUTION OF THE ZOOPLANKTON IN LAKE VALENCIA

Infante, A.G.

Escuela de Biología
Universidad Central de Venezuela
Apartado 47106, Los Chaguaramos
Caracas 1041, Venezuela

RESUMO: distribuições vertical e horizontal do zooplâncton no Lago Valencia. As distribuições vertical e horizontal do zooplâncton no lago Valencia são analisadas considerando possíveis influências antropogênicas na bacia. A distribuição vertical depende da concentração de oxigênio dissolvido. Rotíferos são mais afetados pela baixa concentração de oxigênio do que cladóceros e copépodos. A abundância de copépodos adultos e copepoditos está correlacionada com a profundidade. Náuplio e a maioria dos rotíferos estão distribuídos uniformemente. As densidades populacionais de *Moina micrura* são maiores na zona litorânea. Áreas influenciadas pela poluição orgânica têm as mais altas densidades zooplanctônicas, porém, dejetos industriais têm um efeito depressivo. A contribuição dos copépodos para a biomassa e abundância total é maior em ambas as estações, chuvosa e seca. A biomassa de rotíferos e de protozoários aumenta durante o período chuvoso.

ABSTRACT: Vertical and horizontal distribution of the zooplankton in Lake Valencia. *Vertical and horizontal distribution of the zooplankton in Lake Valencia is analyzed considering possible influence of anthropogenic activities on the lake basin. Vertical distribution depends on dissolved oxygen concentrations. Rotifers are more affected by low oxygen concentrations than cladocerans and copepods. Abundance of adult copepods and copepodids is significantly correlated to depth. Nauplii and most rotifers are evenly distributed. Population densities of Moina micrura are higher in the littoral. Zones under the influence of organic pollution have the highest zooplankton densities, but inflow of industrial wastes has a depressing effect. Copepods contribution to total abundance and biomass is highest for both climatic periods (rainy and dry season). Rotifer and protozoan biomass increase during the wet period.*

INTRODUCTION

Large dimensions, high values of shore line development index and inflow of polluted rivers determine the evolution of distinct environmental conditions within lakes. Zooplankton distribution and abundance are influenced by these conditions. There are additional determining factor (biotic and abiotic) such as wind intensity and direction, vertical gradients of light, temperature and oxygen, currents, predator abundance, food availability, reproduction, and mobility.

Lake Valencia, 10° 10'N latitude and 67° 45'W longitude is the largest natural freshwater lake in Venezuela. It is constantly fertilized by addition of sewage from domestic, industrial and agriculture activities of about two million people. Lewis & Weibezahn (1983) report an average of 3.31g m^{-2} y^{-1} of total phosphorus loading, in 1979-1981. They maintain that considering its area (350km²) and its mean depth (18m), Lake Valencia is one of the most heavily organic loaded large lakes on the world. Three affluents out of fifteen tributaries are permanent and contribute the largest part of the organic load and industrial pollution. They are River Guey, Caño Central and River Guigue. At the inflow sites of these rivers, different physical and chemical properties of the water develop. One may expect qualitative and quantitative changes of the zooplankton community in response to this influence.

Lake Valencia is warm monomictic. The mixing period extends from December to March (dry season). The lake remains stratified the rest of the year and anoxia develops below 15-20 meters depth. Vertical currents at the beginning of the deep mixing period transport reduced toxic substances (hydrogen sulfide, ammonium, etc) from the hypolimnion to the upper water layers and large mortalities of fish and zooplankton occur (Infante et al, 1979). Throughout the mixing period oxygen concentration is 1 to 5mg ℓ^{-1} at 30m depth (12 to 45% saturation). This accounts for enlarged habitable space in the water column.

Cyanophyta permanently dominates the phytoplankton biomass (90% and over) whereas diatoms, chrysophytes and chlorophytes rarely account for more than 5% of the total biomass of primary producers. *Microcystis aeruginosa*, *Synechocystis aquatilis*, and *Anabaenopsis raciborskii* are the dominant species. There are about 50 species in the zooplankton. Copepods (*Thermocyclops decipiens* and *Notodiaptomus deeveyorus*) are the most relevant in abundance and biomass. Rotifers are widely represented through *Brachionus* species and *Keratella americana* (Infante, 1982). They are also abundant, but their contribution to total zooplankton biomass is lower. Cladocerans are currently represented by *Moina micrura* and *Ceriodaphnia cornuta*. However, they are never very abundant in the lake being even absent for long periods, when concentrations of filamentous Cyanophyta increase (Infante & Riehl, 1984).

Distribution of zooplankton – horizontal and vertical – in Lake Valencia is analyzed in this study. Possible influence of polluted tributaries and of some physical factors on abundance and distribution are considered.

MATERIAL AND METHODS

Quantitative samples for vertical distribution were obtained pumping 40 liters of lake water (duplicates of 20 liters each) from the following strata: 25-20, 20-15, 15-10, 10-8, 8-6, 6-4, 4-2 and 2-0 meters depth. A peristaltic pump was connected to a metered hose having a wide funnel at the end. This funnel was kept in vertical position by a ballast and it was slowly displaced through the water layer during pumping. The 20 liters water were then filtered through a 50 micron plankton net and the zooplankton was collected by carefully washing the net to a final sample volume of 20ml. Formaldehide solution was added to the concentrate to preserve the animals. Duplicate countings of all zooplanktonic individuals contained in Sedgwick-Rafter chambers were carried out (1ml each time).

Horizontal distribution of the zooplankton was determined by means of two sampling programs. The first one included 8 stations (A-H) along the maximum length axis (West-East). They were sampled in four occasions including the rainy and the dry seasons. Duplicate 40-liter samples of 5-meter strata were pumped from 50cm above the bottom to the surface of the lake. The second program included vertical hauls with a plankton net (50 micron mesh size) by 2-meter strata from 50cm above the bottom to the lake surface at 23 points distributed over the lake. Sampling frequency was not regular, but covered one full year.

Sampling was carried out at approximately the same day time (10:00 - 12:00) to avoid that daily vertical migrations of the zooplankton may have influenced the results.

RESULTS AND DISCUSSION

Vertical distribution

The maximum depth inhabited by zooplankton in Lake Valencia depends upon dissolved oxygen content. During the mixing period (January, February and March) with averages of 5.0, 6.6 and 6.0mg ℓ^{-1} dissolved oxygen respectively at 25 meters depth, all groups (copepods, cladocerans and rotifers) were homogeneously distributed from the surface to the bottom (fig. 1). In April, when stratification started, there was a reduction on population densities below 15 meters depth. Nevertheless, this redution was not proportional for all groups. Rotifers response to decreasing oxygen concentrations was the most pronounced, followed by cladocerans. Copepods seem to be more tolerant and responded slower. By 0.4mg ℓ^{-1} oxygen concentration a few copepods and cladocerans were still able to live at 25 meters depth, but rotifers displacement upwards was noticeable. Movement of all groups upwards continued in May-June. The bulk of rotifers occupied the upper 15m layer, whereas copepods showed a deeper position (20-25m) where the oxygen concentration was 0.3mg ℓ^{-1}. A deeper distribution for all groups was observed in August, when density currents related to heavy rains probably contributed to enhance dissolved oxygen concentrations (up to 2.5mg ℓ^{-1} at 25m). Until December, the same picture of high rotifer densities above 3mg ℓ^{-1} oxygen and high copepod densities at much lower concentrations (0.5mg ℓ^{-1}) was noticed. There was a progressive reduction in cladoceran populations during the second half of that year, probably related to the increase in filamentous algae concentrations (Infante & Riehl, 1984).

The close relationship between vertical distribution of rotifers and oxygen concentrations is well known (Miracle, 1977; Ruttner-Kolisko, 1975). The majority of rotifer forms have their maximum in the epilimnion, whereas some other prefer the hypolimnion (cold stenotherm species in temperate lakes). When those belonging to the second group become dominant, the usual distribution (epilimnetic maxima) is altered. There is little information concerning the oxygen demand of rotifers at high temperatures. From the distribution observed in Lake Valencia, it is possible to assume that rotifers have high oxygen requirement. On the other extreme, copepods may tolerate very low oxygen concentrations, at least during the day hours, since they effect wide vertical migrations allowing them to inhabit well oxygenated strata during the night.

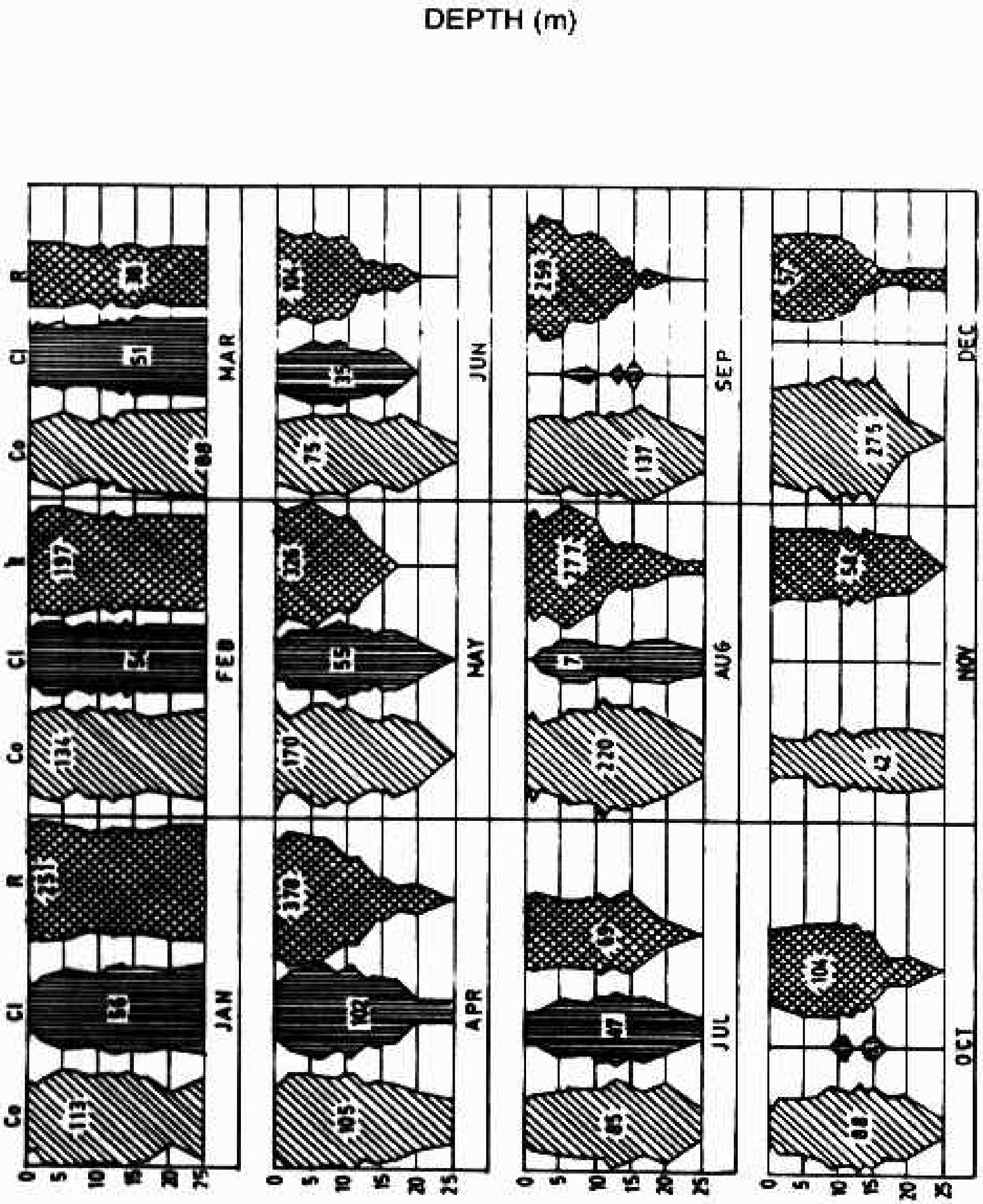

Figura 1 – Monthly vertical distribution of copepods, cladocerans and rotifers in Lake Valencia. Numbers inside the figures indicate maximum values.

Horizontal distribution

Distribution of the most relevant zooplankton species on a cross section of the lake along a depth gradient (5 to 35m) is given in fig. 2 and fig. 3. Correlation coefficients between abundance (ind. m^{-2}) and depth (m) are indicated for each species or developmental stage. Abundance of adult *Notodiaptomus deeveyorus* and *Thermocyclops decipiens* is significantly correlated to depth ($r = 0.8903$, α 0.05 and $r = 0.9499$, α 0.01, respectively). For copepodids of both species, a significant correlation ($r = 0.7193$, α 0.05) was also found. It means, that adult and copepodids have a pelagic distribution in Lake Valencia, whereas nauplii, which showed a non significant correlation coefficient, are homogeneously distributed throughout the pelagic and the littoral zone. Population densities of *Moina micrura* were higher at the littoral, in spite of a non significant negative correlation coefficient ($r = -0.6756$, α 0.05). This may have to do with a preference for the littoral zone determined by a lower predator pressure in this part of the lake, since the main planktivorous fish in Lake Valencia, *Xenomelaniris venezuelae* (Ortaz, 1985), and the main predator on cladocerans *Chaoborus* are both pelagic.

From the three common rotifers (*Brachionus calyciflorus*, *Keratella americana and Anuraeopsis navicula*) only *K. americana* is truly pelagic as indicated by a significant abundance-depth correlation coefficient ($r = 0.7692$, α 0.05). *Brachionus* showed a homogeneous distribution along the transect. However, it may locally develop high population densities (up to 1189 ind ℓ^{-1}) at the incoming zone of organic polluted rivers, where abundant detritus and bacteria provide optimal nutritional conditions (Infante, 1980).

Anthropogenic activities in Lake Valencia are so intense and uncontrolled (fig. 4), that they may be largely determining the distribution patterns of the aquatic biota. Average zooplankton abundance for the dry and the rainy season and the percentage of copepods, cladocerans, rotifers and protozoans (15 to 0m depth) at 21 stations of Lake Valencia are presented in fig. 5. Coastal localities without immediate pollution influence favour zooplankton development. The highest yearly average population density (503 ind ℓ^{-1}) corresponds to the inflow of Tapatapa River (E3), which may be considered relatively clean. At E23 zooplankton concentration averaged 421 ind ℓ^{-1}. This southeast corner of the lake is far from human settlements. Other zooplankton rich zones are located at the southwest (E17 and E15) and they are probably more influenced by River Guigue (heavy organic pollution) than by Caño Central, providing industrial and organic pollution from Valencia city. The central and deepest part of the lake is the poorest in zooplankton, with densities consistently below 100 ind ℓ^{-1}. The relative importance of rotifers and protozoans enhances where organic pollution is more intense (E3, E4, E15, E17). Cladocerans develop better where detritus particles are more abundant and far from industrial pollution (E17, E20, E23). Copepods seem to be also affected by industrial pollution as suggested by lower percentages of abundance close to industrial pollution zones (E2, E3, E4).

At the northeast coast and the west coast of the lake, inflow of domestic and industrial wastes provided by River Guey and Caño Central, and the intense development of agriculture and poultry affect the physical and chemical features of the water. It is more turbid, chlorophyll a content is relatively low and photosynthetic activity as well, whereas zooplankton is more abundant. There is a wide area extending from the northwest coast to the southcentral coast where zooplankton is less abundant, primary production is higher and a thick layer of *Microcystis* and other bluegreen algae cover extense areas of the water surface. There is a distinct zone

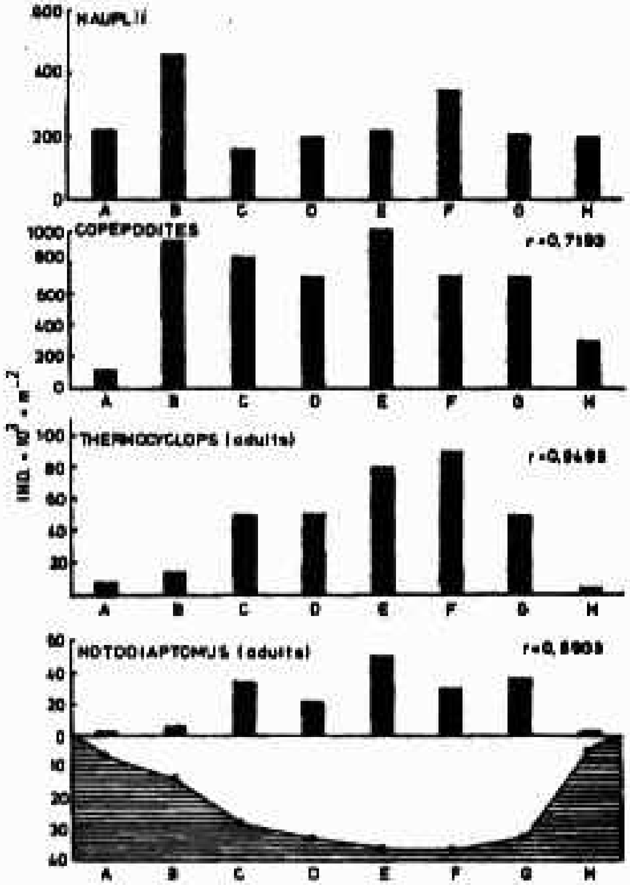

Figura 2 - Distribution of *Notodiaptomus deeveyorus* and *Thermocyclops decipiens* (adults, copepodids and nauplii) on a cross section (east-west) of the lake along a depth gradient.

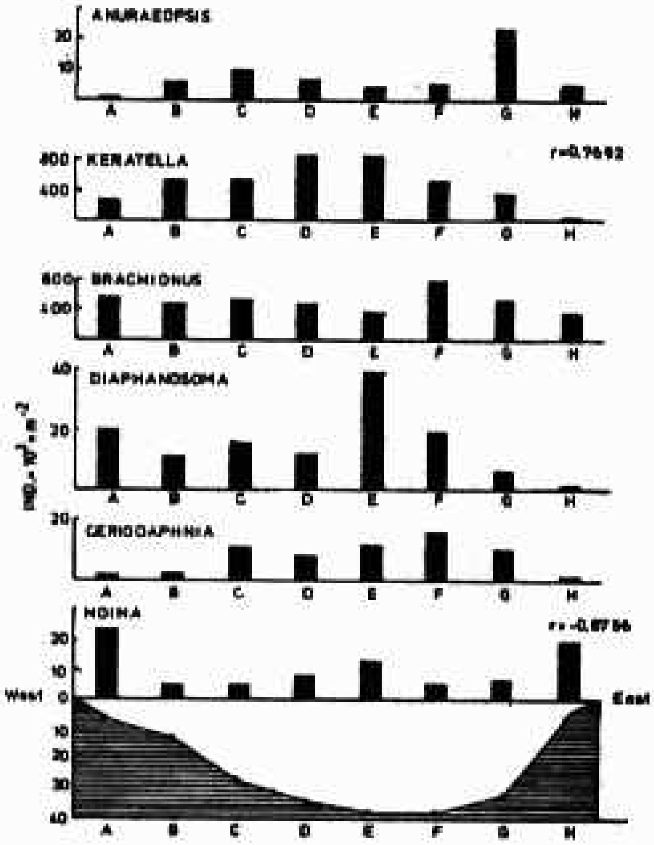

Figura 3 - Distribution of *Moina micrura, Ceriodaphnia cornuta, Diaphanosoma brachyurum, Brachionus calyciflorus, Keratella americana* and *Anuraeopsis navicula*, on a cross section (east-west) of the lake, along a depth gradient.

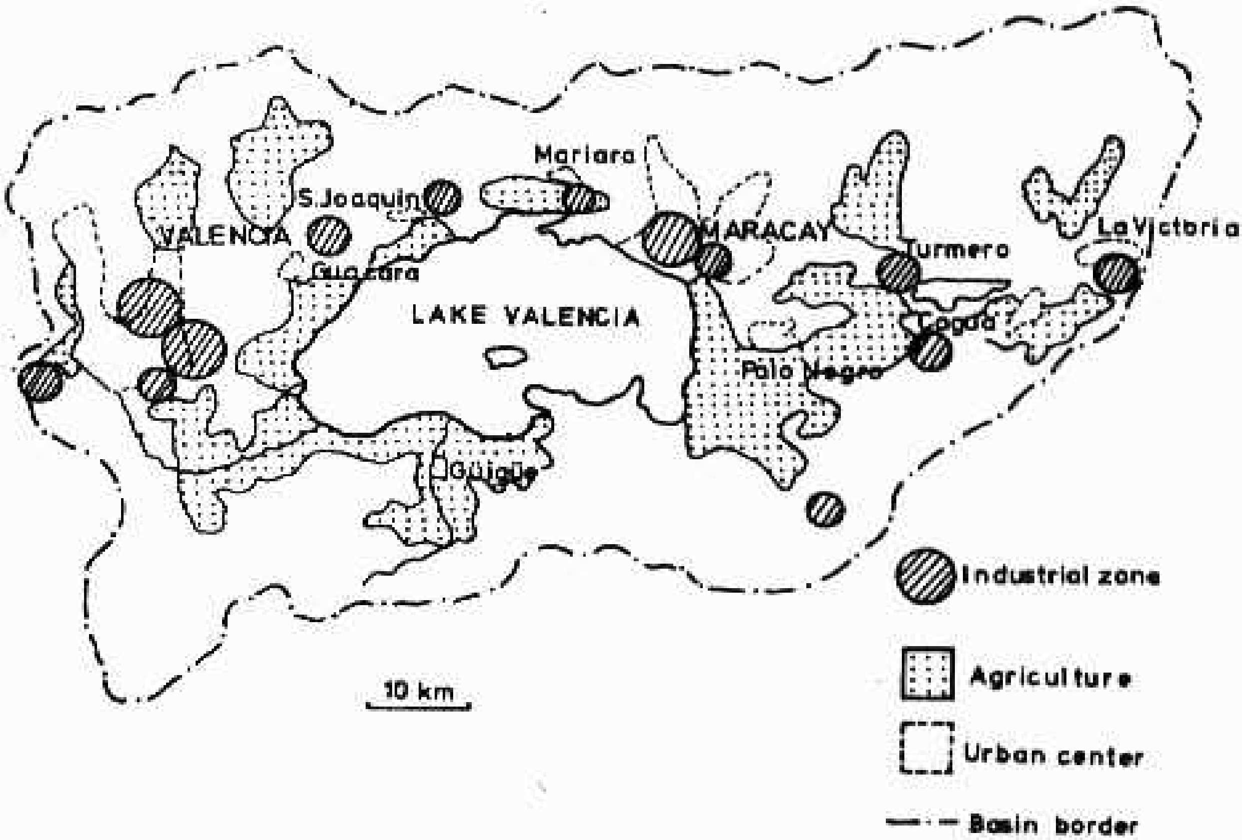

Figura 4 – Map of Lake Valencia basin with location of urban, agriculture and industrial zones.

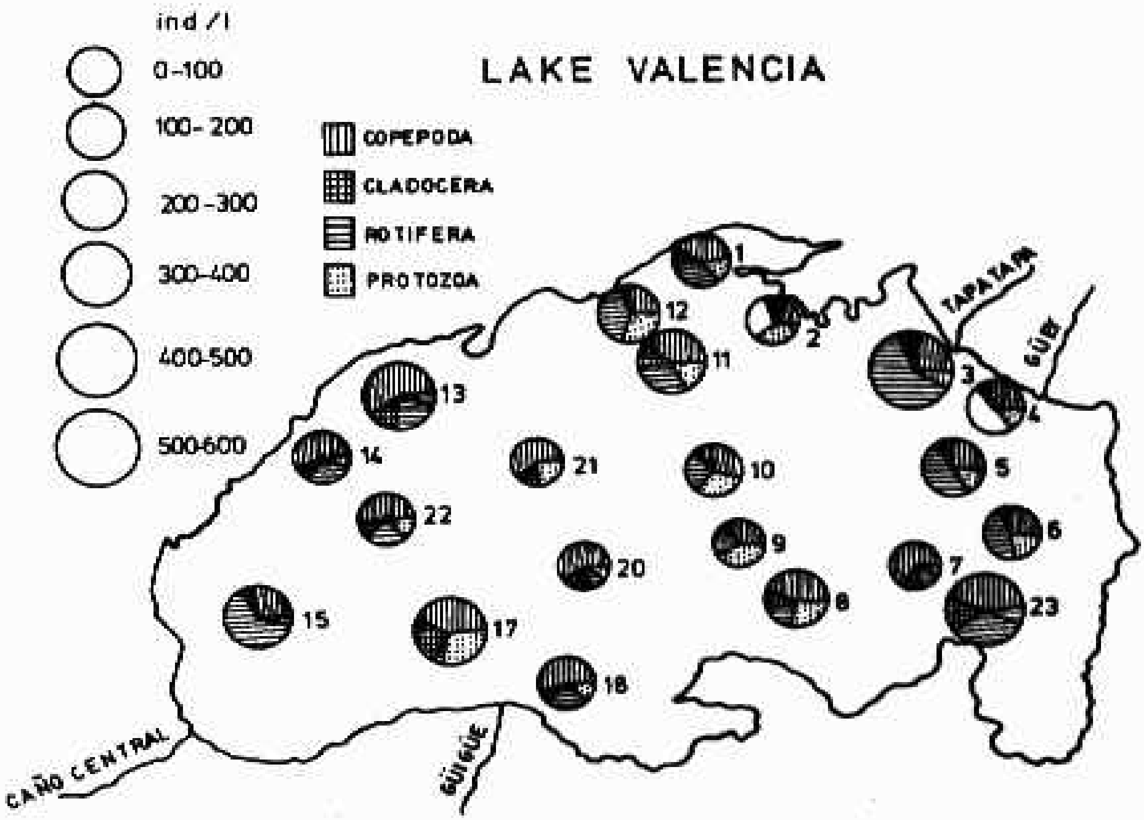

Figura 5 – Zooplankton abundance and percentages of abundance of the main zooplankton groups at 21 statios of Lake Valencia.

defined by Riber Guigue, with a very high primary production (up to 24.4g C m^{-2} d^{-1}) and also a high zooplankton biomass.

Relative abundance and biomass of zooplankton as averages from 23 stations for the rainy season (8 sampling dates) and the dry season (12 sampling dates) are presented in fig. 6. Copepods contribution is highest in numbers and biomass for both climatic periods, although their relative importance enhances during the dry season when good quality food (diatoms and cryptophytes) is more abundant. Rotifers, on the other side, have more food available during the rainy season (organic particles and bacteria) and their abundance increases. Protozoans, mainly represented by a sessile ciliate (*Vaginicola sp.*) that attaches to *Microcystis* colonies and to *Anabaenopsis* filaments, is more abundant than rotifers when blooms of these Cyanophyta occur (rainy season). Although its biomass is quite low, the actual increasing tendency of protozoan development in Lake Valencia may stress the tendency towards heterotrophic conditions. Cladocerans development is restricted in Lake Valencia. Development of dense populations of filamentous bluegreen algae and intense predation may be mentioned as limiting factors.

In conclusion, the spatial distribution pattern of the zooplankton in Lake Valencia reveals characteristics that could be associated to the effect of anthropogenic activities on the lake basin. However, experimental work (biossays) should be carried out to better quantify and identify these effects. A detailed knowledge of the water currents should be obtained for a better understanding of contaminants dispersion and its consequences.

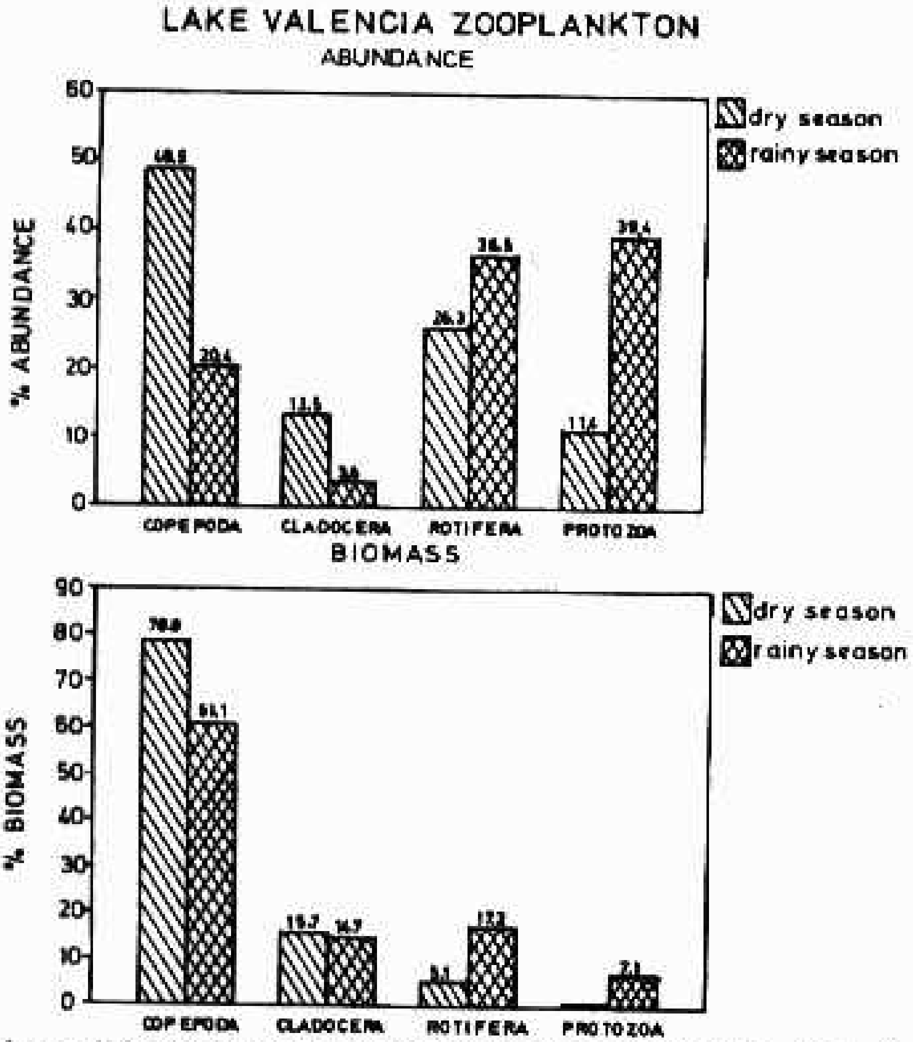

Figura 6 – Relative abundance and biomass of zooplankton in Lake Valencia, averages from 23 stations for the rainy (8 sampling dates) and the dry period (12 samplimg dates).

ACKNOWLEDGEMENTS

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