ON THE ZOOPLANKTON COMMUNITY OF A MEXICAN EUTROPHIC RESERVOIR, A SEASONAL SURVEY

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ABSTRACT

The seasonal fluctuation in the zooplankton community of the J.A. Alzate Dam (México), an eutrophic reservoir, was studied during a year cycle (1986 - 1987). A total of twenty one species, belonging to Rotifera, Copepoda and Cladocera, were observed. These three groups showed seasonal density and distribution fluctuations. Zooplankton community was widely dominated by cladocerans, constituting more than 90 % of the total annual catch. The dominant species throughout the year was the cladoceran *Moina macrocopa*, with densities between 15,000 and 800,000 ind m^{-3}, and peaks in summer and autumn. The highest densities of cladocerans and rotifers occurred in autumn, when maximum temperatures took place. Some rotifers also show predation-related seasonal changes. The horizontal distribution of zooplankton in the surveyed area seemed to be related with known distributional patterns. It is suggested that the structure of the local zooplankton community is strongly influenced by the dam depletion and filling seasonal rythms.
KEY WORDS: Freshwater zooplankton, eutrophic reservoirs, space-time distribution.

RESUMEN

Se estudian las variaciones estacionales del zooplancton de la Presa J. A. Alzate, un cuerpo de agua eutrófico, durante un ciclo anual (1986-1987). Se observó un total de veintiún especies pertenecientes a tres grupos: Rotifera, Cladocera y Copépoda. Estos mostraron variaciones estacionales en cuanto a su distribución y densidad. La comunidad zooplanctónica se encuentra dominada por cladóceros, que constituyeron más del 90% de la captura media total durante el ciclo estudiado. La especie dominante fue *Moina macrocopa*, un cladócero que se presentó con densidades entre 15,000 y 800,000 ind m^{-3}, con picos de abundancia en el verano y el otoño. Las mayores densidades de rotíferos y cladóceros se observaron en el otoño, cuando se presentaron las más altas temperaturas. Algunos rotíferos mostraron variaciones estacionales relacionadas con la depredación. La distribución horizontal del zooplancton responde a patrones conocidos. La estructura de la comunidad zooplanctónica local se ve fuertemente afectada por los ritmos estacionales de vaciado y llenado de la presa.
PALABRAS CLAVE: Zooplancton dulceacuícola, presas eutróficas, distribución espacio-temporal.

INTRODUCTION

Freshwater ecosystems have been studied under several aspects, and maybe one of the least attended refer to the zooplankton community composition, structure and/or dynamics. Zooplankton surveys in limnological systems can produce valuable information about the trophic stage and general productivity processes of lakes and reservoirs (Anderson *et al.*, 1978; Barica, 1978; Balvay, 1985), they provide ways of predicting and increasing the productivity of a freshwater system.

Studies on Mexican freshwater planktonic fauna are still very limited since most limnological works have been restricted to only general hydrobiological aspects. The lack of limnological studies is more relevant when the high number of lakes and reservoirs existing in Mexico (Arredondo & Aguilar, 1987; Arredondo & Flores, 1992) is taken into account. Some works on different zooplankton aspects in Mexican localities are by: Ahlstrom (1932), Brehm (1932, 1943), Rioja (1940), Comita (1950), Osorio-Tafall (1942), Téllez and Motte (1980) and Suárez *et al.* (1986). Most of them are limited to systematic lists of species with a relatively scarce analysis of the community structure. Very few efforts have been made to analyze the seasonal fluctuations of zooplankton communities, specially in reservoirs, which differ from natural lakes, where zooplankton is certainly better known (Kerfoot, 1980).

In this paper we study the abundance, composition and seasonal fluctuations of the zooplankton community of the Antonio Alzate Dam, a Mexican reservoir with strong eutrophic conditions and a very high primary production, during a year cycle. The influence of seasonal changes of the hydrological conditions on the local zooplankton community is also studied.

STUDY AREA

The Antonio Alzate Dam is a recent (1962) man-made reservoir located on the central portion of the Toluca valley, central Mexico. It is located between the 99°54.0' and 99°41.3 'W, and between the 19°32.4'-19°34.0' N, and belongs to the Temoaya Municipality, in the state of Mexico (Fig. 1). It has a total capacity of *ca.* 52 millions of cubic meters. The reservoir is integrated to the hydrologic system called "Alto Lerma" and constitutes —as most modern reservoirs (Marzolf, 1990)—, the main final collector of urban and industrial residues generated from adjacent industrial areas. The Lerma-Santiago system has been described as one of the most contaminated hydrologic basin in central Mexico (SARH, 1976). Mainly because of this situation, the surveyed reservoir show extreme eutrophic features, receiving large quantities of suspended organic matter (Vázquez *et al.*, 1986a). Primary productivity increases rapidly and continuously enhancing a general high productivity in other trophic levels, as has been previously observed for other eutrophic systems (Brylinsky & Mann, 1973). Derivated from these phenomena, in the Alzate Dam large volumes of cladocerans are produced and fished, constituting a local economic activity (Vázquez *et al.*, 1986b).

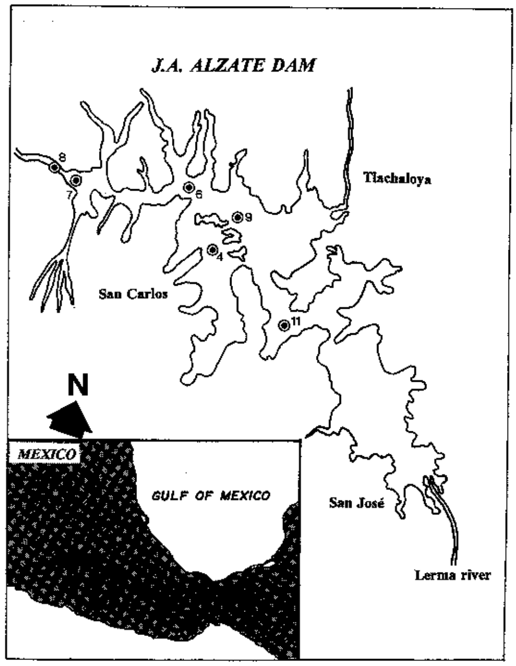

Figure 1. Zooplankton sampling stations in the A. Alzate Dam, México.

The mean depth of this hydrologic basin is *ca.* 5.5 m, with values ranging from 2.5 to 13.0 m. The reservoir is monomictic, with mixing during late spring and early summer, when the dam is depleted. An unstable stratification also occurs during mid-summer (Vázquez *et al.*, 1987). Because of the high concentrations of suspended matter, with maximum values of 250 mg l^{-1}, and a mean of 78 mg l^{-1}, turbidity also increases, specially in late spring (122 mg l^{-1}), when the dam depletion takes place. The massive nutrient entrance, and the consequent increase of primary production in spring (mean annual chlorophyll: 204.9 mg m^{-3}; spring: 524.7 mg m^{-3}; summer: 70.7 mg m^{-3}; autumn: 57 mg m^{-3}; winter: 156 mg m^{-3}) promotes high oxydation and sedimentation rates. Surface oxygen concentrations show a minimum during summer (0.65 mg l^{-1}) and a maximum in winter (2.2 mg l^{-1}); during summer and autumn the hipolimnion becomes anoxic. Values of pH range from 7.7 to 8.1, with highest mean values during autumn (7.92) and lowest during winter (7.5). The strong fluctuation of the dam level breaks the relation high mixing: high oxygenation. Mean annual temperature of the surface water is of 18.3°C, with a maximum in summer (25°C), and a minimum during winter (11°C).

MATERIAL AND METHODS

Zooplankton samples were collected at seasonal intervals during August, 1986 (summer), November, 1986 (autumn), February, 1987 (winter) and April, 1987 (spring), completing a seasonal year cycle. Six sampling stations were selected (Fig. 1), and zooplankton was collected in each site at three different levels of the water column (surface, mid-water and bottom) towing a Clarke-Bumpus net (0.140 mm-size mesh), equipped with a flowmeter to estimate the volumes of water filtered by the net.

Samples were fixed and preserved in a 10% formalin solution; crustacean zooplankton was then transferred to a 70% ethanol solution. The entire sample was analyzed, but for quantitative estimations, the use of 10% aliquots was necessary in most cases. Temperature, turbidity, oxygen concentrations, and chlorophylls were measured at all sampling sites (Table 1). Copepods, rotifers and cladocerans were counted and identified using a compound and dissection microscopes. Numerical data of abundance were analyzed using a clustering index to find affinities among sampling stations and species during the different seasons.

RESULTS

From the taxonomic analysis of the three main zooplanktonic groups found (Rotifera, Cladocera and Copepoda) in the surveyed area, a total of twenty-one species was determined (Table 2). Total zooplankton densities during the different surveyed periods showed strong variations and were distributed as follows: 41.36% of the total annual zooplankton catch occurred during the autumn period; 26.45% in summer, 20.67 % in winter, and 11.52% during the spring period.

Numerically, cladocerans were widely dominant during the four seasons, representing more than 80% of the total annual mean zooplankton density; they were followed by rotifers (18.9%) and copepods (0.4%) (Table 3).

During each different season, the comparative group percentages showed some fluctuations. In the spring period, cladocerans represented 93.39% of the zooplankton catch. During summer this value increased to 98.37%, decreasing into the autumn (66.14%) and peaking again in winter (80%). Rotifers showed low percentages during the spring and summer periods (3.77 and 1.45%, respectively), which increased in the autumn (33.8%) and decreased in winter (19.9%). Copepods showed a maximum of 2.84% in spring, and a minimum (0.1%) in autumn. The relative annual and seasonal mean densities of the species here reported is presented in table 2.

The most abundant zooplankton species throughout the year was the cladoceran *Moina macrocopa*, with peak densities (over 800,000 ind. m^{-3}) in summer and autumn, followed by *Daphnia similis* with peaks in spring and winter, and by *D. pulex* which only peaked during spring. The most abundant rotifer was *Ascomorpha* sp, with an annual mean density of 98, 698 ind m^{-3}, and a peak in autumn; other abundant

Table 1. Physical and chemical factors measured in the Alzate Dam during the surveyed period.

Station	pH				Temperature (°C)				Oxygen concentration (mg l^{-1})				Conductivity (microohms)			
	Sp	Sm	F	W	Sp	Sm	F	W	Sp	Sm	F	W	Sp	Sm	F	W
4S	7.50	7.60	7.70	7.90	25	17	11	15	2.8	3.3	4.4	4.7	280	240	424	840
4F	8.00	7.90	7.67	7.90	23.5	18	11	14	0.2	0.7	3.5	4.1	350	286	430	700
6S	7.60	7.80	7.58	7.70	18.5	18	13	15	0.8	0.3	3.4	0.5	400	270	476	840
6F	7.60	8.00	7.70	7.90	18.5	14	14	15	0.2	0.7	2.0	0.2	270	280	512	960
7S	7.70	7.90	7.76	7.80	21	23	14	14.5	0.5	0.4	2.5	0.5	400	300	400	920
7F	7.60	8.10	7.73	7.90	20	17	15	13.5	0.4	0.1	1.0	0.1	420	270	500	960
8S	7.70	8.20	7.61	7.70	18.5	18	12	14	---	---	---	---	400	306	476	980
8F	7.50	8.10	7.73	8.10	19	18	14	14	0.4	0.1	1.5	0.4	400	290	370	680
9S	7.80	7.90	7.60	7.80	22	23	12	16	0.6	1.8	4.7	0.6	370	296	440	970
9F	7.80	8.00	6.66	7.90	19	18	13	15	0.5	0.7	0.5	0.3	370	320	536	980
11S	7.50	7.90	7.64	7.30	18.5	20	13	21	0.2	0.2	0.3	0.9	350	304	504	940
11F	---	7.70	7.88	7.40	---	20	13	19	---	0.2	0.0	0.9	---	344	520	1100

Sp= Spring
Sm= Summer
F= Fall
W= Winter

rotifers were the large predator *Asplanchna priodonta* (28,000 ind • m^{-3}) and *Brachionus calyciflorus* (7,510 ind • m^{-3}).

Among the Copepoda, the cyclopoid *Acanthoyclops vernalis* was the most abundant copepod in the surveyed area, occurring with an annual mean density of 2,555 ind m^{-3}, and a spring peak. The other relevant copepod was *Macrocyclops albidus* (295 ind • m^{-3}), which occurred during the four seasons.

During summer, 86.5% of the total zooplankton catch was distributed in the central portion of the surveyed area, in stations 6 (9.54%), 4 (39.86%) and 9 (37.10%). In stations located near the exit channel of the dam (stations 7 and 8), almost 37% of the zooplankton occurred, while station 11 was the poorest during this period (0.5%).

In the autumn, almost 80% of the total zooplankton occurred in the central portion of the dam, and station 4 showed the highest relative zooplankton abundance (55.1%), followed by stations. 9 (13.42%) and 6 (10.52%). Stations 7 and 8, near the exit channel, showed a relative abundance of 15.45 % and 0.1%, respectively, while station 11 showed 5.43%.

During winter, distribution of zooplankton relative abundance was similar to that described for summer and autumn, with highest values in the central portion of the dam (81.8%) (stations 6: 31.3 %; 4: 30.9 %; 9: 19,6%). Stations 7 and 8 represented 10.1 % and 3.97%, respectively, and station 11 showed again the lowest value (4.07%). The distribution pattern of relative abundances described for winter, autumn and summer changed in spring. In station 4, more than 92% of the total zooplankton was collected, followed by station 8 (3.7%). The other four localities showed low values (2.0%).

Cluster analysis (Bray-Curtis Index) of species densities in each sampling station

Table 2. Zooplankton composition, seasonal density (%) fluctuations, and mean annual densities observed at the Alzate Dam (Mexico).

	Spring	Summer	Fall	Winter	Annual (%)
COPEPODA					
Mastigodiaptomus montezumae ?		•			0.0013
M. albuquerquensis (Herrick)		•			0.0015
Paracyclops fimbriatus (Rehberg)	•				0.0033
Eucyclops agilis (Koch)		•			0.0094
Macrocyclops albidus (Jurine)	•	•	•	•	0.0380
Mesocyclops leuckarti (Claus)		•			0.0084
Acanthocyclops vernalis (Fischer)	•				0.3300
Microcyclops bicolor (Sars)				•	0.0040
ROTIFERA					
Polyarthra trigla (Ehr.)			•		0.0004
Tetramastix opoliensis Zach.	•		•	●	0.8600
Asplanchna priodonta Gosse			•	⚫	3.6400
Filinia terminalis Ehr.		●			0.2600
Ascomorpha sp. Perty	•	•	⬤	•	12.840
Brachionus calyciflorus Pallas	•		•		0.9800
B. quadridentatus Hermann	●				0.3400
CLADOCERA					
Moina macrocopa (Straus)	●	⬤	⬤	⚫	56.7600
Daphnia longispina (O.F. Müller)	⬤			⬤	19.8400
Daphnia pulex (Leydig)	⬤				3.2500
Simocephalus serrulatus (Koch)	•		•	•	0.6500
Ceriodaphnia reticulata (Jurine)	•			•	0.2100
Macrothrix sp. Jurine			•		0.0360

LEGEND

0.001-5% •

5.1–15% ●

16%–28% ⚫

29%---- ⬤

Table 3. Mean densities (ind. m^{-3}) and seasonal relative abundance of Copepoda, Rotifera and Cladocera in the Alzate Dam during the surveyed period

Season/Group	Copepoda	%	Rotifera	%	Cladocera	%	Total	%
Spring	10,1082	2.8	13,334	3.8	331,000	93.4	354,415	11.5
Summer	1,384	0.1	11,800	1.4	800,000	98.4	813,184	26.4
Autumn	564	0.04	429,915	33.8	841,000	66.1	1217,479	1.4
Winter	237	0.04	126,800	19.9	508,500	80.0	635,537	20.7

produced dendrograms separating groups of localities in each season. Three groups were defined during summer, two during autumn, three in winter, and two again in spring (Fig. 2).

Most zooplankters were bathymetrically distributed in surface layers, but we found no consistent tendencies occurred in a particular level for any species.

DISCUSSION

Inland copepods in Mexico are represented mainly by members of the Order Cyclopoida; however, the Order Calanoida (Family Diaptomidae, several genera) is commonly present in freshwater plankton collections. In the studied area, cyclopoid copepods were most abundant and species-rich. Most of them have been previously collected in adjacent areas. *Paracyclops fimbriatus* (Fischer), *Macrocyclops albidus* (Jurine) and *Microcyclops bicolor* (Sars) have been collected from Michoacán, S.L.P., and Distrito Federal; *Eucyclops agilis* (Koch) is known from Distrito Federal, S.L.P. and the states of Mexico and Hidalgo; *Acanthocyclops vernalis* (Fischer) from Michoacán and S.L.P. (Reid, 1990). *Mesocyclops americanus* (Dussart), refered by some authors as *M. leuckarti* (Claus) (Reid, 1990), has probably not been reported previously in central Mexico. Diaptomid calanoid copepods occurred in the Alzate Dam with only two species, one is *Mastigodiaptomus albuquerquensis*, reported from Distrito Federal, Guanajuato, Michoacán, S.L.P., Puebla and Veracruz (Reid, 1990; Suárez *et al.*, 1986), and the other, is probably *M. montezumae*, known from S.L.P., but the report cannot be confirmed.

All the species of Rotifera observed in the surveyed area have been previously reported from the Lerma-Santiago hydrologic system (Osorio-Tafall, 1942; Suárez *et al.*, 1991). Some of the cladoceran reports should be reviewed.

Regarding the results on the hydrologic conditions and its relation with the zooplankton community fluctuations throughout the year, maximum zooplankton densities during the autumn coincide with the maximum water level of the dam, with the lowest turbidity —a condition which may enable cladocerans to increase grazing rates (Aruda, 1980; Vázquez *et al.*, 1987)—, with low chlorophyll values, and with medium oxygen concentrations. Contrastingly, lowest zooplankton densities (spring period) were related to maximum turbidity —which is often sufficient to limit the photosynthetic activity of planktic algae (Marzolf & Osborne, 1972)—, to decreased grazing rates by herbivorous zooplankters (Lampert, 1977; Arruda *et al.*, 1983), and to the minimum level of water in the reservoir.

Although the knowledge on the horizontal distribution of zooplankton in lakes and reservoirs is still very limited, some general patterns have been proposed (Marzolf, 1990). One of them (Taylor, 1971) describes the distribution of crustacean zooplankton densities (Cladocera and Copepoda) as a curve with its maximum level more or less half the way between the river inflow area and the outflow channel, and is related to

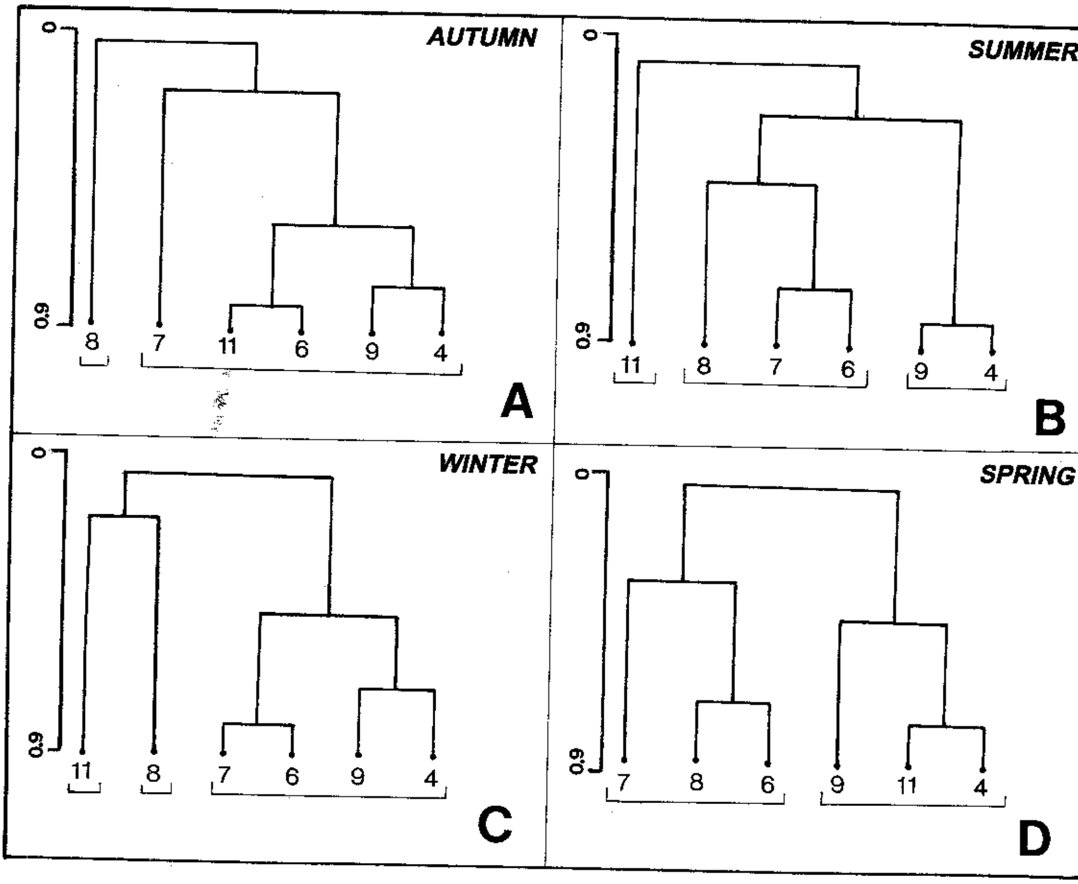

Figure 2. Clustering (Bray-Curtis Index) of stations from zooplankton species density and distribution during: A) autumn, B) summer, C) winter, and D) spring.

the spatial and time process of the resources entering the reservoir from the river as they are metabolized by the microflora and ingested by the zooplankton. The same general pattern can partially explain the behavior of the zooplankton community distribution in the Alzate Dam, where the central portion of the surveyed area consistently showed the highest zooplankton abundances throughout the year; stations near the inflow and outflow areas were not so dense. Another factor which could also favour the same horizontal distribution tendency observed in the Alzate Dam —specially for crustacean zooplankton— is the "avoidance of shore" effect, in which zooplankton tends to distribute in central areas, away from the shore. This effect has been previously described in lakes and reservoirs by several authors (Ringelberg, 1964; Siebeck, 1968; Daan & Ringelberg, 1969).

Several works have outlined the regulatory role of cladoceran populations over chlorophyll and phosphate concentrations (Anderson *et al.*, 1978; Marzolf, 1990). At the present it is still difficult to determine whether local chlorophyll concentration decline in spring into the summer is due to grazing of the large populations of filter-feeding zooplankters during the winter period, or to the anoxic conditions associated to the dam depletion in the surveyed area. It remains clear that eutrophication processes produce successive changes on the local community structure throughout the year, and are thus related to the hydrologic dynamics and hydraulic regime of the reservoir.

Protozoans may represent a link between microheterotrophic production and invertebrate predators (Vasconcelos, 1990). This group was not sampled; however, the high grazing rates of the abundant herbivorous zooplankters on phytoplankton in the surveyed area (Vázquez *et al.*, 1987) would diminish the local relevance of the protozoan role as a trophic link.

Vertical migration of zooplankton in reservoirs has not been sufficiently studied; in the Alzate Dam, results on the vertical distribution of zooplankton suggest that a moderate migration takes place in the water column, specially in Copepoda. However, in most cases, highest densities of Cladocera and Rotifera were recorded in surface samples. This behavior is mainly related to the vertical distribution of phytoplankton and to the turbidity (Anderson *et al.*, 1978).

According to Edmonson (1946, 1965), King (1967) and Wetzel (1975), temperature constitutes a key factor in determining reproductive rates in rotifers, stating that temperatures between 15 and 20°C are optimal for planktonic rotifer reproduction. In the surveyed area, our results support this statement. Rotifers peaked during autumn, when temperature ranged from 15 to 23°C. High temperatures may also result in an immediate increase of the rate of cladoceran population growth and thus in their abundance (MacArthur & Baillie, 1929; Hall, 1964). In the surveyed area, cladocerans showed their maximum densities during autumn, when the highest temperatures occurred.

Asplanchna priodonta is a large carnivorous rotifer, feeding on *Brachionus* or *Ascomorpha*-type rotifers (Hutchinson, 1967; Gilbert, 1967; Wetzel, 1975), and causing successional changes in both prey and predator populations (Gilbert & Waage, 1967; Suárez *et al.*, 1986). In the surveyed area this relation is evident between autumn and winter; during autumn, *A. priodonta* occurred with medium densities along with *B. calyciflorus* and *Ascomorpha*'s high densities. In winter, the abundance of the predator *Asplanchna* increased five times thus *Brachionus* dissapeared, and eventually *Ascomorpha* populations declined. A similar succession pattern is described in a tropical mexican lake by Suárez *et al.* (1986). Vasconcelos (1990) observed no evident impact of the densities of *A. priodonta* on the populations of other rotifers in the Azibo reservoir at Portugal. This may be due to the fact that the diversity and availability of potential preys at Azibo reservoir (Vasconcelos, 1990) is noticeably higher than the one found at the Alzate Dam, where only a reduced number of rotifer species become available preys for *A. priodonta*. Predation can play a relevant role as a population controlling mechanism, but there are several other factors which must also be evaluated (Hall, 1982; Marzolf, 1990).

Regarding the cladoceran populations, the dynamics observed at the reservoir studied seems contrasting to a natural eutrophic lake. Hall (1964) described a typically high cladoceran peak during spring and a lower one during autumn, and in the Alzate reservoir cladocerans showed an inverse seasonal peak pattern, which could be related to the depletion effects discussed earlier. The effect of depletion is evident from the results of the cluster analysis, in which seasonal variations on the arrangement and structure of the zooplanktic community in the area are probably related to the hydraulic regime. During summer, when the water of the reservoir is up to a medium level, zooplankton at the middle portion is homogeneous; it differs from the community near the outflow, not unstable now and forming a separate group of stations (station 6 to 8); the only atypical locality is st. 11, with a zooplankton structure probably modified by the intense inflow.

The maximum level of the dam occurrs during autumn; by this time, zooplankton homogeneity increased; most stations are grouped together —with a stable zooplankton structure—, and only station 8, near the outflow channel remains atypical. In winter, the water level is still high; the station grouping suggest a stable zooplankton community which is homogeneous in all the central portion (stations 4,6,7,9). Stations 8 —in the outflow channel— and 11 —inflow zone— showed differences. In spring, when the dam is depleted, the scenario is drastically modified, the stability of the zooplankton community is broken and the effect of depletion reach the middle portions of the system (station 6 to 8); the other three stations (4, 9, 11) showed zooplankton structural differences and were grouped together. As a whole, the local zooplankton community seemed to be strongly influenced by the hydraulic regime of the reservoir, with an unstable zooplankton structure at the unstable inflow/outflow areas. During stable periods the local zooplankton community tends to homogeneity.

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