Hidrobiológica 2008, 18 (1): 75-83

Planktonic crustacean assemblages of three reservoirs from the Mexican Central Plateau: relationships with biotic and abiotic factors

Crustáceos planctónicos de tres embalses de la Mesa Central Mexicana: relaciones con factores bióticos y abióticos

Gloria Ana María Arroyo Bustos[1],
Eugenia López López[1*]
and Domenico Voltolina[2]

[1]Laboratorio de Ictiología y Limnología, Departamento de Zoología,
Escuela Nacional de Ciencias Biológicas. IPN
[2]Centro de investigaciones Biológicas del Noroeste Laboratorio de Estudios
Ambientales UAS-CIBNOR, PO Box 1132, Mazatlán, Sinaloa, México
*Corresponding author: Eugenia López-López email: elopezl@encb.ipn.mx

Arroyo Bustos G. A. M., E. López López and D. Voltolina. 2008. Planktonic crustacean assemblages of three reservoirs from the Mexican Central Plateau: relationships with biotic and abiotic factors. *Hidrobiológica 18* (1): 75-83.

ABSTRACT

The reservoirs Trinidad Fabela (TF), Ignacio Ramírez (IR) and Tepuxtepec (T) are located along an altitude gradient in the upper Lerma Basin of the Mexican Central Plateau. Between July 1993 and June 1994, the planktonic crustacean assemblages of these systems were dominated by seven cladoceran species and five copepod species. Specific richness ranged from 13 species in TF to 16 species in T, out of a total 20 species. Nine species were common to all three systems, while the rest were absent from at least one reservoir. Canonic correspondence analysis showed that the structure and seasonal variation of these assemblages are regulated by factors directly related (transparency and dissolved oxygen) or inversely related (turbidity, temperature, mineralization and eutrophication) to the altitude at which the reservoirs are located. TF had the lowest levels of mineralization and the lowest specific richness, as well as the highest plankton diversity and mean density, while T had the highest mineralization and highest specific richness, but showed the lowest density. Crustacean mean size was smaller in T than in TF, possibly due to predation by fish in the former system and the presence of fish predators (waterfowl) in the latter, as well as the impact of the different hydrological regime and release schedules of the reservoirs.

Keywords: zooplankton, seasonal variation, eutrophication, Mexican Central Plateau, altitude gradient.

RESUMEN

Se estudiaron los embalses Trinidad Fabela (TF), Ignacio Ramírez (IR) y Tepuxtepec (T) que se localizan en un gradiente de altitud en la subcuenca del Alto Lerma en la Mesa Central de México. La asociación de crustáceos planctónicos estuvo dominada por siete especies de cladóceros y cinco copépodos y la riqueza específica varió entre 13 y 16 especies con un total de 20 especies; nueve de éstas resultaron comunes a todos los embalses y las otras no se encontraron en al menos uno de ellos. El análisis de correspondencias canónicas mostró que la estructura y la variación estacional de las asociaciones de crustáceos planctónicos están regulados por factores que están directamente (transparencia y oxígeno disuelto) o inversamente (turbiedad, temperatura, grado de mineralización y de eutrofización) relacionados a la altitud de los tres embalses. TF fue el embalse con el menor grado de mineralización y la menor riqueza específica y con la mayor diversidad y densidad de plancton. T tuvo la mayor mineralización y riqueza específica, pero la menor densidad. Los crustáceos de T presentaron tallas medias menores que los de TF, posiblemente como un efecto de depredación de la ictiofauna en T y de la presencia de aves acuáticas piscívoras en TF, además del diferente régimen hidrológico de los embalses.

Palabras clave: zooplancton, variación estacional, eutrofización, Mesa Central Mexicana, gradiente altitudinal.

INTRODUCTION

In freshwater reservoirs, the structure and population dynamics of zooplankton assemblages may be affected by seasonal variations of several abiotic and biotic factors (Wolfinbarger, 1999) as well as by changes in water level and water quality as a result of different human activities (Kratz *et al.*, 1997; Naselli-Flores & Barone, 2000; Marchetto *et al.*, 2004).

Although Mexico has more than 4,500 man-made reservoirs (Comisión Nacional del Agua, 2002), only a limited number of studies (Flores & Martínez, 1993; Ramírez-García *et al.*, 2002; Ramírez-Olvera *et al.*, 2004) have focused on the zooplankton assemblages of these systems. The aim of this paper is to increase current knowledge on the relationships between abiotic and biotic factors and the structure of planktonic crustacean assemblages in the reservoirs Trinidad Fabela (TF), Ignacio Ramírez (IR) and Tepuxtepec (T). These reservoirs are located at elevations of 2, 674; 2,579 and 2,356 m above sea level in the upper Rio Lerma basin (Mexican Central Plateau), a region characterized by industrial parks, high deforestation due to clearing for agricultural purposes, and considerable erosion (Cotler-Avalos *et al.*, 2007). The climate is warm and wet from May to October, and cool and dry from November to April.

MATERIALS AND METHODS

Study Area

The contour and location of the three reservoirs is shown in Fig. 1. TF is an avian sanctuary with an abundant waterfowl population, and is used for irrigation and recreation purposes. It has the smallest surface area of all three reservoirs (1.4 km^2), a maximum depth of 10 m, and a water volume of 10 x 10^6 m^3 at its fullest. IR is used mainly for irrigation. It has a surface area of 2.3 km^2 and is similar to TF in terms of maximum depth and water storage capacity. T has the largest surface area of all three reservoirs (17.5 km^2). Its maximum depth and storage capacity are 22 m and 585 x 10^6 m^3. T is used mainly for power generation and supports an important silverside (*Chirostoma* spp.) fishery (Diario Oficial de la Federación, 2004).

Samples were obtained monthly from July 1993 to June 1994 by surface tows at a single station located near the dam of each reservoir, using a 60 µm mesh size Wisconsin plankton net equipped with a General Oceanic flowmeter. Samples were preserved with 4% neutral formalin.

The taxonomic determination of cladocerans and copepods was made according to Edmonson (1959) and Thorp and Covich (1991), and with the help of literature on specific Mexican zooplankton taxa (Dos Santos-Silva *et al.*, 1996; Dodson & Silva-Briano, 1996; Hebert & Finston, 1996; Silva-Briano & Suárez-Morales, 1998; Elías-Gutiérrez *et al.*, 1999; Reid & Suárez-Morales, 1999; Suárez-Morales *et al.*, 2000). Abundance of each species was determined by analysis of 5 1-mL subsamples in a Sedgwick-Rafter chamber. The mean size of each taxon was estimated based on length measurements of 10 specimens from each sample.

Water temperature, conductivity, and dissolved oxygen were recorded *in situ* using an YSI 85 portable multimeter, and a standard Secchi disk was used to measure transparency. $N\text{-}NO_2^-$, $N\text{-}NO_3^-$, $N\text{-}NH_4^+$, SO_4^{2-}, total dissolved P and Fe, turbidity, suspended solids, and color were quantified with a Hach DR/2000 field spectrophotometer. Water hardness ($CaCO_3$ mg/L) was obtained by titration with EDTA. Mean monthly rainfall was provided by meteorological stations at each reservoir.

Shannon-Wiener diversity index (*H*) and the importance index (*IIi*) of each species (Brower & Zar, 1977) were used to examine the structure of the planktonic crustacean assemblages, according to the following equations:

$$H = -\sum p_i \ln p_i \qquad \text{and} \qquad II_i = A_i\% + B_i\%$$

where:

p_i = proportion of species *i*, relative to the total number of species

A_i% = Abundance of species *i* (as a percentage of the total sample)

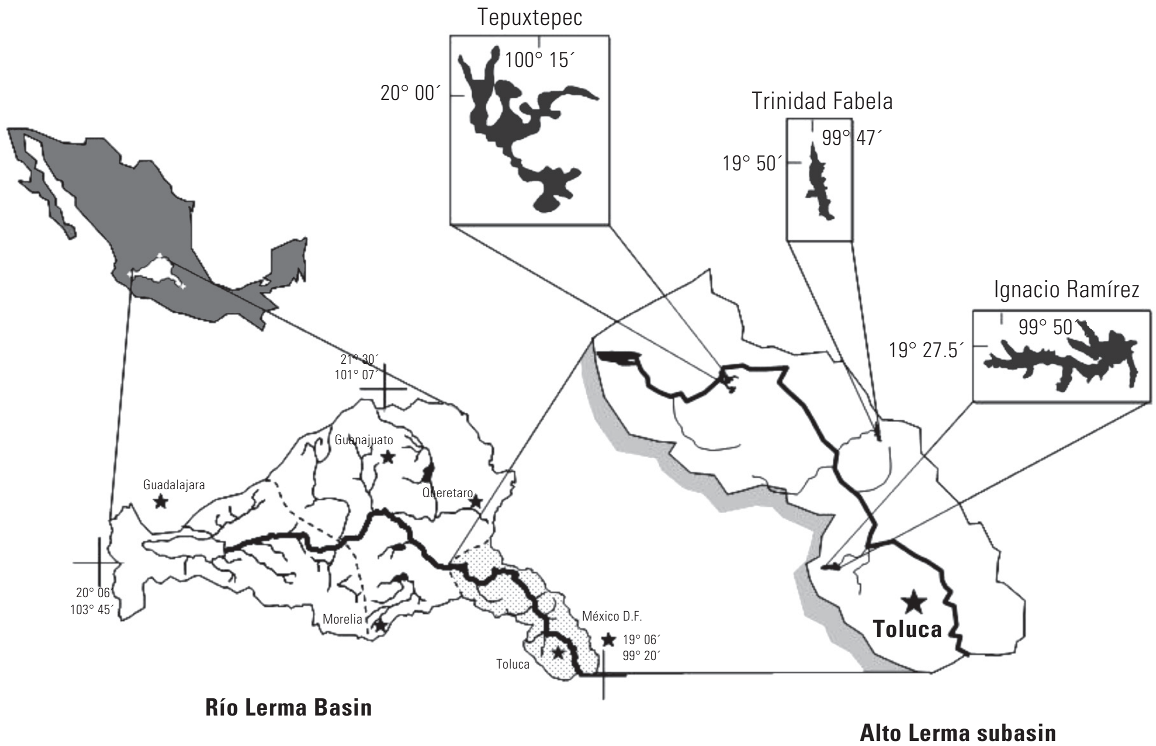

Fig. 1. Geographic location of the reservoirs Trinidad Fabela, Ignacio Ramírez and Tepuxtepec.

B_i% = Frequency of occurrence of species *i* (as a percentage of the total sample)

Each species was also ranked as dominant, constant, occasional or rare using Olmstead-Tuckey diagrams, which consider the abundance and frequency of occurrence of each species (Sokal & Rohlf, 1981). Similarities between monthly samples and stations were established with the index of Euclidean distances for environmental factors, while relationships between species and environmental factors were determined by canonic correspondence analysis (CCA). In both cases, calculations were performed after log transformation of the original data and using the statistical package MVSP 3.13 M (Kovach Computing Services, Anglesey, Wales).

RESULTS AND DISCUSSION

The seasonal trends of the physical and chemical data show that the summer rainy period is characterized by higher temperature, turbidity and suspended solids, but lower dissolved oxygen and transparency. Mean conductivity was lowest in TF, which also showed low N and P. Conductivity and P levels were highest in T. IR showed the highest total N levels during the wet season and the lowest during the dry season, while little seasonal variation in this nutrient was seen in TF or T (Table 1), indicating that the highest and lowest values of mineralization and eutrophication found in T and TF were not seasonally driven.

Ramírez-Olvera *et al.* (2004) found that the landscape position and elevation of different Mexican reservoirs is correlated with their water characteristics. This is consistent with our results: TF, in the upper part of the basin, receives low loads of surface runoff and suspended solids, which explains the higher transparency and lower mineralization of its waters. On the opposite side of the spectrum, T is located in the lower part of the basin and its main source of water is the Rio Lerma, which carries a high load of suspended material (Sedeño-Díaz & López-López, 2007) helping to increase water turbidity and mineralization.

A total of 20 species (13 cladocerans and seven copepods) were found in this study, their respective authorities are included in Table 2. Specific richness ranged from 13 species in TF to 16 in T. Nine species (six cladocerans and three copepods) are common to all three reservoirs. Three cladocerans and one copepod are found in TF and IR but not in T. Two cladocerans are shared by IR and T but are absent from TF, and two cladocerans and three copepods are present only in T (Table 2). The high number of species shared by IR with both TF and T, is related to the intermediate characteristics and location of the former reservoir.

Mean density was highest in TF (1,339 ind/L) and lowest in T (292 ind/L). This parameter showed greater variability in IR and

Table 1. Mean values and standard deviations of the environmental variables in the reservoirs Trinidad Fabela (TF), Ignacio Ramírez (IR) and Tepuxtepec (T) for the wet and dry season.

	TF		IR		T	
Variable	Wet	Dry	Wet	Dry	Wet	Dry
Rainfall (mm)	121.33 (48.14)	16.97 (6.25)	95.83 (36.03)	11.78 (7.05)	141.53 (57.21)	18.85 (14.54)
Water temperature (°C)	18.08 (0.80)	15.25 (1.47)	19.63 (2.06)	17.33 (2.04)	21.13 (1.31)	18.00 (2.92)
Dissolved O_2 (mg/L)	6.70 (0.25)	7.32 (0.64)	4.13 (0.54)	7.17 (1.51)	5.00 (0.76)	7.17 (0.57)
Conductivity (µS/cm)	121.67 (26.80)	123.33 (19.24)	175.50 (58.12)	160.00 (28.56)	276.75 (90.90)	241.67 (49.72)
$N\text{-}NO_3^-$ (mg/L)	1.20 (0.85)	1.22 (1.40)	1.58 (0.38)	0.83 (0.45)	1.26 (0.98)	1.53 (1.09)
$N\text{-}NO_2^-$ (mg/L)	0.01 (0.01)	0.00 (0.00)	0.05 (0.06)	0.01 (0.01)	0.01 (0.00)	0.01 (0.01)
$N\text{-}NH_4^+$ (mg/L)	0.49 (0.44)	0.64 (0.35)	2.12 (1.12)	0.74 (0.26)	0.95 (0.29)	0.99 (0.54)
Total P (mg/L)	0.16 (0.23)	0.19 (0.30)	0.11 (0.15)	0.33 (0.34)	0.50 (0.21)	0.49 (0.35)
Total Fe (mg/L)	1.20 (0.26)	0.94 (0.37)	1.69 (0.38)	1.49 (0.68)	0.95 (0.17)	1.00 (0.60)
Ca (mg/L)	36.50 (3.08)	35.75 (3.57)	35.25 (5.68)	42.92 (6.25)	54.00 (2.45)	51.17 (8.75)
Turbidity (UFT)	122.00 (22.34)	85.67 (12.79)	295.00 (57.45)	95.83 (17.44)	109.38 (33.26)	117.50 (20.70)
Suspended solids (mg/L)	32.17 (36.07)	16.00 (22.51)	60.75 (60.57)	5.83 (9.17)	13.50 (12.61)	2.67 (4.55)
Transparency (m)	0.19 (0.08)	0.27 (0.05)	0.12 (0.04)	0.22 (0.06)	0.19 (0.01)	0.20 (0.07)

T, where coefficients of variation above 100% were obtained, compared to 42% in TF. Mean diversity was similar in IR and T, but showed greater variability in T (Table 2).

Uku and Mavuti (1994) found a direct correlation between conductivity and degree of eutrophication, on the one hand, and the specific richness and abundance of zooplankton communities on the other. This is consistent with the low specific richness and low conductivity found in TF as well as the high number of species in T (which also showed the highest mean conductivity and P levels) although in the present study abundance trends are inversely correlated with the degree of mineralization of the reservoirs.

Mean importance index and the results of ranking using the Olmstead-Tuckey diagrams show that the assemblages were dominated by six cladocerans in TF, and four in IR and T. The highest ranking species in all reservoirs was the small cladoceran *Bosmina longirostris,* followed by *Diaphanosoma birgei* in TF and *Daphnia ambigua* in IR and T. The cumulative contribution of these cladocerans to the importance index was >60% (Table 2). With regard to copepods, three species were dominant in TF and IR, and four in T. The highest ranking species was *Mastigodiaptomus montezumae* in TF, followed by *Leptodiaptomus novamexicanus* in IR and *L. cuauhtemoci* in T (Table 2). The contribution of these species to the importance index was <20% (Table 2).

Several differences were observed in the mean size of species collected in at least two reservoirs. There was a general tendency for specimens from T to be shorter in length, while in most cases those from IR and TF were significantly longer (Table 3).

The most evident difference among the planktonic crustacean assemblages of all three reservoirs occurred with respect to mean densities. Although T may be considered the most

Table 2. Specific richness, mean density and diversity (± standard deviation), index of importance (II) and ranking according to Olmstead Tuckey (OT) of the planktonic crustaceans of the reservoirs Trinidad Fabela (TF), Ignacio Ramirez (IR) and Tepuxtepec (T) (A = absent; R = rare; O = occasional; C = constant and D = dominant).

	TF	IR	T
Specific richness	13	15	16
Mean density (org/L)	1,339 ± 531	733 ± 778	292 ± 295
Mean diversity index	0.825 ± 0.074	0.738 ± 0.074	0.741 ± 0.163
SPECIES	**II OT**	**II OT**	**II OT**
Daphnia parvula Fordyce	8.57 R	4.70 R	a
Daphnia prolata Hebert *et* Finston	7.87 R	11.33 D	2.37 R
Daphnia laevis Birge	6.41 r	9.22 c	A
Daphnia galeata mendotae Sars	12.31 D	16.28 O	11.05 D
Daphnia ambigua Scourfield	16.11 D	32.21 D	27.16 D
Ceriodaphnia quadrangula O.F.Müller	16.02 d	2.39 R	4.02 R
Ceriodaphnia acanthina L. S. Ross	16.43 d	5.42 r	A
Ceriodaphnia lacustris Birge	a	3.62 R	6.93 O
Moina micrura Kurz	a	3.38 r	2.13 r
Scapholeberis sp.	a	a	5.18 R
Alona intermedia G.O. Sars	a	a	2.13 R
Diaphanosoma birgei Korinek	20.19 D	27.19 D	11.98 D
Bosmina longirostris Müller	41.59 D	38.88 D	63.20 D
Copepoda			
Mastigodiaptomus montezumae Brehm	19.84 D	11.52 D	13.14 D
Mastigodiaptomus albuquerquensis Herrick	a	a	6.59 R
Leptodiaptomus novamexicanus Herrick	18.28 d	21.70 d	A
Leptodiaptomus dodsoni Elías-Gutiérrez	a	a	4.57 R
Leptodiaptomus cuauhtemoci Osorio-Tafall	A	A	14.31 d
Acanthocyclops vernalis Fischer	14.86 D	4.50 R	14.01 D
Mesocyclops sp.	1.52 R	7.27 D	11.19 D

eutrophic of the three, it also had the lowest mean density. All three water bodies are inhabited by several silverside species (*Chirostoma* spp.; Soto-Galera *et al*., 1999) that are selective zooplankton feeders (Navarrete *et al*., 1995). These species are particularly abundant in T, where they support one of the most important fisheries in central Mexico (Diario Oficial de la Federación, 2004). Fernando (1994) found that predation by planktivorous fish was correlated with low densities and small zooplankton sizes, while Primicerio and Klemetsen (1999) confirmed that selective predation by planktivorous fish affects the species composition and size structure of zooplankton communities. Thus, the abundant populations of *Chirostoma* spp. in T would appear to limit planktonic crustacean abundances and mean sizes in this reservoir while, in agreement with results obtained by Wahlström *et al*. (2000), the presence of ichthyophagous species, such as the abundant waterfowl in TF, would explain the higher zooplankton abundance and larger mean sizes in the latter.

According to Naselli-Flores (2000), the variability of plankton abundance and composition in man-made water bodies is largely dependent on the particular hydrological regime of these systems, since their water level is subject to change depending on local water demand. In the present case, water levels in TF and IR fluctuate in response to seasonal demand for irrigation, while T is used year-round to power generation for surrounding communities. Thus, water demand in the latter reservoir is constant, and its hydraulic residence time is low. These occurrences, as well as the biotic impact of predation by fish, may further explain the low densities and small specimen size of planktonic crustacean species in this reservoir.

Table 3. Mean size (mm) and (±) standard deviation of the cladoceran and copepod species collected in at least two of the reservoirs Trinidad Fabela (TF), Ignacio Ramirez (IR) and Tepuxtepec (T). Equal or common letters indicate lack of significant difference (one way ANOVA or Student's ⊠ test, $\alpha = 0.05$) a ≤ ab ≤ b and a < b.

SPECIES	TF	IR	T
Cladocera			
Daphnia parvula	0.80 ± 0.01 a	0.93 ± 0.03 b	
Daphnia prolata	1.46 ± 0.0 3 a	1.55 ± 0.01 b	1.42 ± 0.03 a
Daphnia laevis	1.56 ± 0.02 a	1.59 ± 0.02 a	
Daphnia galeata mendotae	1.06 ± 0.05 ab	1.17 ± 0.02 b	0.94 ± 0.04 a
Daphnia ambigua	0.91 ± 0.01 b	0.86 ± 0.07 ab	0.81 ± 0.02 a
Ceriodaphnia quadrangula	0.67 ± 0.01 ab	0.74 ± 0.01 b	0.63 ± 0.02 a
Diaphanosoma birgei	0.88 ± 0.01 b	0.95 ± 0.02 c	0.77 ± 0.03 a
Bosmina longirostris	0.43 ± 0.01 a	0.46 ± 0.02 b	0.41 ± 0.02 a
Copepoda			
Mastigodiaptomus montezumae	1.58 ± 0.02 a	1.56 ± 0.02 a	1.52 ± 0.13 a
Leptodiaptomus novamexicanus	1.25 ± 0.01 a	1.29 ± 0.06 b	
Acanthocyclops vernalis	0.93 ± 0.04 ab	0.98 ± 0.03 b	0.88 ± 0.04 a
Mesocyclops sp.		1.33 ± 0.03 b	1.05 ± 0.03 a

The highest values for Shannon-Wiener diversity index (*H*) were obtained in TF, while in IR and T they were lower but of similar range in both reservoirs (Table 2). Cardoso and da Motta Marques (2004) found that high turbulence negatively affects the diversity of zooplankton communities. Eckert and Waltz (1998) report that species with long life cycles tend to dominate in waters where turbulence is low due to infrequent mixing, but are replaced by others with faster population growth in response to increased frequency of vertical mixing.

In the present case, the water column in T is in constant movement since the reservoir is used for power generation. This may explain the low diversity of its zooplankton assemblage, while the high diversity in the other systems may be related to the different water retention and release schedule in these reservoirs, which is dependent on seasonal demand.

Cluster analysis generated a dendrogram of Euclidean distances, which separated four groups of environmental conditions. Group I comprises the warm, rainy months (June to October) of all three reservoirs. Groups II and III are composed of the cool, dry months, with colder months (January and February) in Group III and somewhat temperate but still dry conditions in Group II. Between these two groups is the data for the month of August in IR, which showed exceptionally high turbidity, suspended solids and ammonia levels, due to high precipitation during the period. Finally, Group IV is formed by two points corresponding to the warm, dry months of April and July in T, during which the highest levels of conductivity, nitrate and transparency were recorded (Arroyo-Bustos, 2005) (Fig. 2).

The CCA biplot shows a gradient along axis 1 related to the altitude and trophic status of the three reservoirs. IR, located at an intermediate elevation and with intermediate characteristics, is at the center of this gradient and separates the lowest and highest altitude reservoirs, T and TF, with both of which it shares some species. T, with warmer, more mineralized and nutrient-rich waters also showed the lowest diversity, while the most diverse assemblage was found in the less eutrophic waters of TF. Based on this, the cladocerans *Bosmina longirostris*, *Moina micrura* and *Scapholeberis* sp. and the copepods *Mastigodiaptomus albuquerquensis* and *Leptodiaptomus cuauhtemoci* are associated with the eutrophic, mineral-rich waters of T, and the small calanoid *L. novamexicanus* with the less mineralized waters of TF (Fig. 3). This seems to agree with the correlation between calanoid presence and water column stability found by Badosa *et al*. (2006). It is not the case of the higher turbulence of T reservoir, where the dominant planktonic crustaceans were small species like *Bosmina longirostris*, which is also considered a good indicator of eutrophic conditions (Gasiorowski & Szeroczynska, 2004), confirming that the structure of zooplankton communities in the upper part of the Rio Lerma basin is the result of the impact of physical and chemical factors (mineralization and hydrological regime) as well as biotic factors (predation).

ACKNOWLEDGEMENTS

This study was financed by grants from IPN-CGPI and SEMARNAT-CONACYT for the research projects: "Estudio de

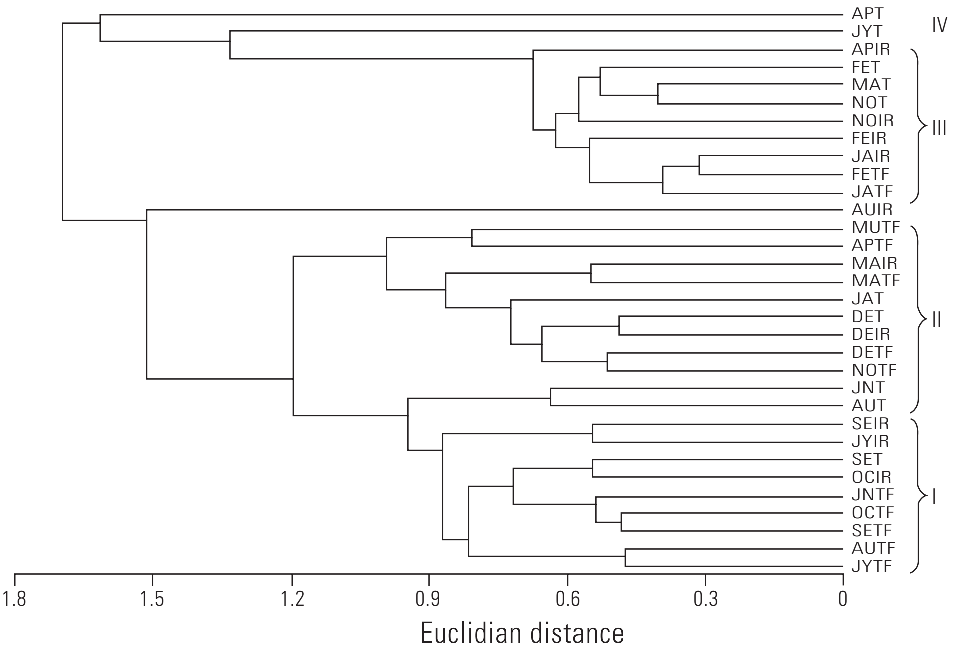

Fig. 2. Indices of euclidian distances among monthly environmental characteristics of the reservoirs Trinidad Fabela (TF), Ignacio Ramírez (IR) and Tepuxtepec (T).

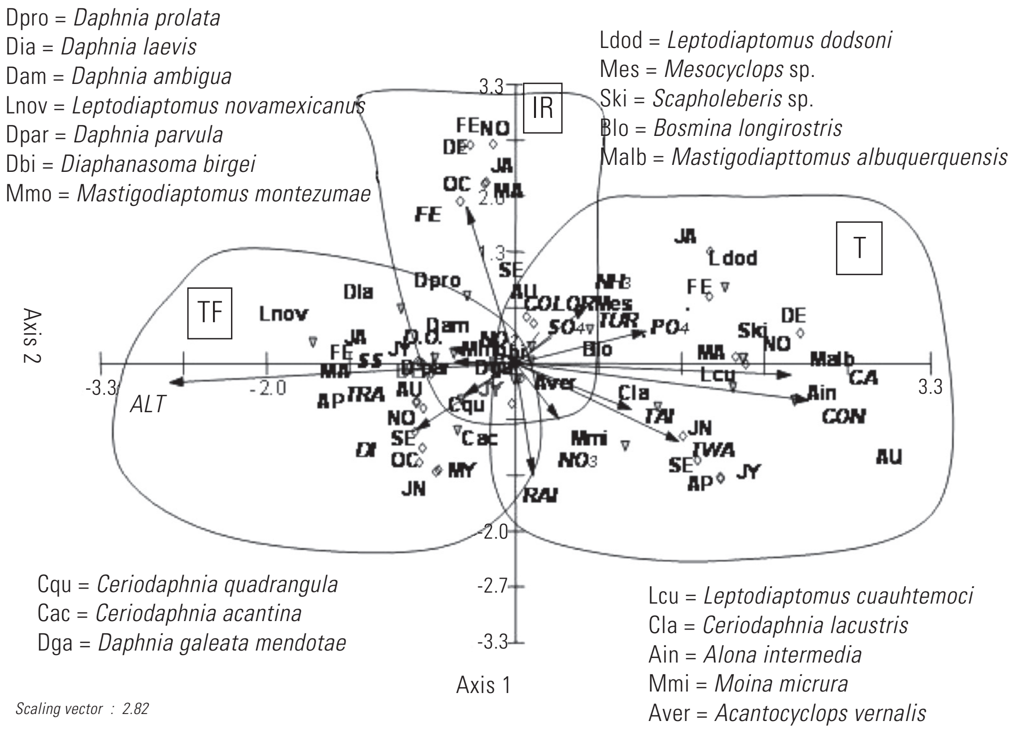

Fig. 3. Biplot of the canonic correspondence analysis between environmental factors and plankton crustacean species of the reservoirs Trinidad Fabela (TF), Ignacio Ramírez (IR) and Tepuxtepec (T). JA, FE, MA, AP, MY, JN, JY, AU, SE, OC, NO, DE: January to December. ALT: altitude; CA: calcium; COLOR: colour; CON: conductivity; DI: diversity index; D.O.: dissolved oxygen; FE: iron; NH_3, NO_2, NO_3: ammonia, nitrite, nitrate; PO_4: total phosphorus; RAI: rainfall; SO_4: sulphate; SS: suspended solids; TAI, TWA: air and water temperature; TRA: transparency; TUR: turbidity

las comunidades zooplanctónicas de los embalses de la cuenca del Río Lerma" and "Diagnóstico del estado trófico y calidad de agua en embalses de la cuenca del Río Lerma, generación de un modelo regional". E. Soto-Galera, J.A. Serna and P. Maya helped with sampling.

REFERENCES

Arroyo-Bustos, G. A. M. 2005. *Análisis comparativo de la comunidad de los crustáceos de los embalses: Trinidad Fabela, Tepuxtepec e Ignacio Ramírez, del Alto Lerma, México*. M.S. Thesis. Instituto Politécnico Nacional, Escuela Nacional de Ciencias Biológicas, México. D.F. 79 p.

Badosa, A., D. Boix, S. Brucet, R. López-Flores & X. D. Quintana. 2005. Nutrients and zooplankton composition and dynamics in relation to the hydrological pattern in a confined Mediterranean salt marsh (NE Iberian Peninsula). *Estuarine, Coastal and Shelf Science* 66: 513-522.

Brower, J. E. & J. H. Zar. 1977. *Field and laboratory methods for general ecology*. Wm. C. Brown Co. Publishers, Dubuque, Iowa. 194 p.

Cardoso, S. & D. da Motta Marques. 2004. Structure of the zooplankton community in a subtropical shallow lake (Itapeva Lake – South of Brazil) and its relationship to hydrodynamic aspects. *Hydrobiologia* 518: 123-134.

Comisión Nacional del Agua. 2002. *Compendio básico del agua en México*. Comisión Nacional del Agua, México, D.F. 96 p.

Cotler-Avalos, H., A. Garrído-Pérez & C. Enríquez-Guadarrama. 2007. Degradación de Suelos. *In*: Cotler-Avalos, H., M. Mazari-Hiriart & J. de Anda-Sánchez (Eds.). *Atlas de la cuenca Lerma-Chapala. Construyendo una visión conjunta*. SEMARNAT, INE, UNAM, IE. pp. 122-123

Diario Oficial de la Federación (DOF). 2004. Carta nacional pesquera. México, D. F. 15 de marzo de 2004. Sección 3: 6-7.

Dodson, S. I. & M. Silva-Briano. 1996. Crustacean zooplankton species richness and association in reservoir and ponds of Aguascalientes State, Mexico. *Hydrobiologia* 325: 163-172.

Dos Santos-Silva, E. N., M. Elías-Gutiérrez & M. Silva-Briano. 1996. Redescription and distribution of *Mastigodiaptomus montezumae* (Copepoda, Calanoidea, Diaptomidae) in Mexico. *Hydrobiologia* 328: 207-213.

Eckert, B. & N. Walz. 1998. Zooplankton succession and thermal stratification in the polymictic shallow Müggelsee (Berlin, Germany): a case for the intermediate disturbance hypothesis? *Hydrobiologia* 387/388: 199-206.

Edmonson, W. T. 1959. *Freshwater biology*. John Wiley, New York. 1248 p.

Elías-Gutérrez, M., J. Ciros-Pérez, E. Suárez-Morales & B. Silva-Briano. 1999. The freshwater Cladocera (orders Ctenopoda and Anomopoda) of Mexico, with comments on selected taxa. *Crustaceana* 72: 171-186.

Fernando, C. H. 1994. Zooplankton, fish and fisheries in tropical freshwaters. *Hydrobiologia* 272: 105-123.

Flores, F. J. & J. Martínez. 1993. Comparative limnology of three reservoirs on the mexican altiplano (a transition zone), Aguascalientes, Mexico. *Tropical Freshwater Biology* 3: 319-329.

Gasiorowski, M. & K. Szeroczynska. 2004. Abrupt changes in *Bosmina* (Cladocera, Crustacea) assemblages during the history of the Ostrowite Lake (northern Poland). *Hydrobiologia* 526: 137–144.

Hebert, P. D. & T. L. Finston.1996. A taxonomic reevaluation of North American *Daphnia* (Crustacea: Cladocera) II. New species in the *Daphnia pulex* group from the South-Central United States and Mexico. *Canadian Journal of Zoology* 74: 632-653.

Kratz, T. K, K. E. Webster, C. J. Bowser, J. J. Magnuson & B. J. Benson. 1997. The influence of landscape position on lakes in northern Wisconsin. *Freshwater Biology* 37: 209-217.

Marchetto, A., R. Mosello, M. Rogora, M. Manca, A. Boggero, G. Morabito, S. Musáis, G. A. Tartari, A. M. Nocentini, A. Pugnetti, R. Bettinetti, P. Panzani, M. Armiraglio, P. Cammarano & A. Lami. 2004. The chemical and biological response of two remote mountain lakes in the Southern Central Alps (Italy) to twenty years of changing physical and chemical climate. *Journal of Limnology* 63: 77-89.

Navarrete, N. A., R. Sánchez & M. L. Rojas. 1995. Selección del zooplancton por el charal *Chirostoma jordani* (Atheriniformes: Atherinidae). *Revista de Biología Tropical* 1: 757-761.

Naselli-Flores, L. 2000. Phytoplankton assemblages in twenty-one Sicilian reservoirs: relationship between species composition and environmental factors. *Hydrobiologia* 424: 1-11.

Naselli-Flores, L. & R. Barone. 2000. Phytoplankton dynamics and structure: a comparative analysis in natural and man-made water bodies of different trophic state. *Hydrobiologia* 438: 65-74.

Primicerio, R. & A. Klemetsen. 1999. Zooplankton seasonal dynamics in the neighbouring lakes Takvatn and Lombola (Northern Norway). *Hydrobiologia* 411:19-29.

Ramírez-García, P., S. Nandini, S. S. S. Sarma, E. Robles-Valderrama, I. Cuesta & M. D. Hurtado. 2002. Seasonal variations of zooplankton abundance in freshwater reservoir Valle de Bravo (Mexico). *Hydrobiologia* 467: 99-108.

Ramírez-Olvera, M. A., M. Díaz-Argüero & E. López-López. 2004. Planktonic crustacean assemblages in a system of three reservoirs in the Mexican central plateau: seasonal and spatial patterns. *Journal of Freshwater Ecology* 19: 25-34.

Reid, J. W. & E. Suárez-Morales. 1999. A new, neotropical species of *Acanthocyclops* (Copepoda: Cyclopoida: Cyclopoidae). *Beaufortia* 5: 37-45.

Sedeño-Díaz, J. E. & E. López-López. 2007. Water quality in the Rio Lerma, Mexico: an overview of the last quarter of the twentieth century. *Water Resources Management* 21: 1797–1812.

Silva-Briano, M. & E. Suárez-Morales. 1998. The copepoda Calanoida (Crustacea) of Aguascalientes State, Mexico. *Scientia Naturae* 1: 37-68.

Sokal, R. R. & F. J. Rohlf. 1981. *Biometry*. W. F. Freeman. New York. 887 p.

Soto-Galera, E., E. Díaz-Pardo, E. López-López & J. Lyons. 1999. Fishes as indicators of environmental quality in the Rio Lerma basin, Mexico. *Journal of Aquatic Ecosystems Health Management* 1: 267-276.

Suárez-Morales, E., M. Silva-Briano & M. Elías-Gutiérrez. 2000. Redescription and taxonomic validity of *Leptodiaptomus cuauhtemoci* (Osorio-Tafall, 1941) (Copepoda, Calanoida), with notes on its known distribution. *Journal of Limnology* 59: 5-14.

Thorp, J. H. & A. P. Covich. 1991. *Ecology and classification of North American freshwater invertebrates*. Academic Press. New York. 911 p.

Uku, J. & K. M. Mavuti. 1994. Comparative limnology, species diversity and biomass relationship of zooplankton and phytoplankton in five freshwater lakes in Kenya. *Hydrobiologia* 272: 251-258.

Wahlström, E., A. L. Persson, A. S. Diehl & A. P. Byström. 2000. Size-dependent foraging efficiency, cannibalism and zooplankton community structure. *Oecologia* 123: 138-148.

Wolfinbarger, W. 1999. Influences of biotic and abiotic factors on seasonal succession of zooplankton in Hugo Reservoir, Oklahoma, U.S.A. *Hydrobiologia* 400: 13-31.

Recibido: 23 de febrero de 2007

Aceptado: 5 de noviembre de 2007