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Distribution of *Leptodiaptomus novamexicanus* (Copepoda: Calanoida) in a Mexican hyposaline lake

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Abstract: The temporal and vertical fluctuation of the planktic copepod *Leptodiaptomus novamexicanus* was surveyed in a Mexican saline crater-lake. A one year monthly sampling was made between August 1993 and July 1994. Samples were obtained at one station along the entire water column (60 m) with a Van Dorn sampler and filtered through a 55 µm mesh. Copepod densities were evaluated. Vertical profiles of temperature, dissolved oxygen, pH, specific conductivity (K_{25}), and chlorophyll a concentrations were measured. Lake Alchichica limnetic area is hyposaline (K_{25}=13000 µS cm-1 .8.5 g l^{-1}), basic (pH 8.6-9.2) and oligo-mesotrophic (0-17.7 mg m^{-3} of chlorophyll a concentration). The lake is warm monomictic and circulates during the cold season (winter-spring). *L. novamexicanus* was the only crustacean zooplankton species inhabiting the limnetic area of the lake. Copepod densities ranged between 0 and 267 org l^{-1}. A significative difference in copepod densities was observed between circulation (66.91±75.62 copepods l^{-1}, mean ± 1 s.d.) and stratification (15.83±32.43 copepods l^{-1}) period, and between the upper (0-30 m, 44.54±64.64 copepods l^{-1}) and lower strata (40-60 m, 19.77±43.88 copepods l^{-1}) of the lake. Maximum copepod densities coincided with the presence of two phytoplankton blooms: a diatom bloom in January (chlorophyll *a* 4.1-8.5 mg m^{-3}), and after wards, a cyanobacterial bloom (chlorophyll *a* 1.4-17.7 mg m^{-3}), in May. Highest values of copepod densities were found between 10-15 m depth, within the photic zone (20- 25 m) of the lake. *L. novamexicanus* population of Lake Alchichica limnetic zone might live under low interspecific competition conditions due to the absence of other crustacean zooplanktic species. Under these circumstances vertical and temporal fluctuations of this copepod population mainly depends on environmental conditions, basically on the periods of circulation-stratification of the lake that influence food availability.

Key words: zooplankton, ecology, saline lake, crater-lake, Mexico.

Osorio-Tafall (1942) described a new calanoid copepod species *(Diaptomus garciai),* found in the saline lake Alchichica, Puebla state, Mexico. Later, Wilson & Yeatman (1959) showed that *D. garciai* was a synonym of *Leptodiaptomus novamexicanus* (Herrick, 1895). According to Reid (1990) *L. novamexicanus* has a wide distribution in North America, from Canada to Mexico, but in the latter country it has been observed only in Lake Alchichica, Puebla and in Yucatan and Campeche states (Suárez-Morales *et al.* 1996). Nonetheless, several unpublished works developed in water bodies located along the Mexican Plateau, in the central portion of Mexico, have shown that *L. novamexicanus* is a widespread species in the area, mainly inhabiting reservoirs and shallow water bodies as aquacultural and temporal ponds (Rojas & Sánchez 1988, Cruz 1989, González 1991, Camacho 1996, Grimaldo 1996, Ocampo 1996). It also has been found in the high-altitude lake "El Sol" inside the crater of the Nevado de Toluca volcano (Camacho 1996). In most of these water bodies *L. novamexicanus* is commonly associated to

Mastigodiaptomus montezumae Brehm, 1955 (Dos Santos-Silva *et al.* 1996).

All the mentioned studies show *L. novamexicanus* prefers shallow freshwater bodies, with low Secchi disc values, warm temperature, slightly acidic to slightly basic pH conditions and total alkalinity and hardness fluctuating from low to medium values. Environmental conditions in Lake Alchichica markedly differs from those mentioned above and thus results highly interesting to know the relationship between *L. novamexicanus* planktonic population and the environmental fluctuations in the lake.

MATERIAL AND METHODS

There are six maars crater-lakes located in the endorheic Cuenca de Oriental, in the central portion of Mexico. The area of the basin is 4982 km^2 and the mean altitude is 2300 masl (Alcocer *et al.* 1998). Lake Alchichica (19° 24' 22" N and 97° 23' 52" W, 2345 masl) is the largest and deepest of the six lakes (Fig. 1). All the lakes are filled mainly by underground water and secondarily by rain water. Lake Alchichica has a circular form and the littoral area shows a pronounced slope. Arredondo *et al.* (1983) obtained several morphometric and bathymetric data from the lake, as follows: z_m= 64.6 m, $\bar{z}$= 38.55 m, l= 1733 m, L= 5.06 km, A_o= 1.81 km^2, V = 69.62 x 10^6 m^3. The lake region was originated a million years ago (Gasca 1981). Climate is dry temperate, with a mean annual temperature of 12.9°C and the mean annual precipitation less than 400 mm (García 1988). Evaporation is very high and causes a notorious water deficit especially in March (Arredondo *et al.* 1984). The rainy season occurred during the summer, together with the highest temperatures. In winter time, precipitation is rather low and temperature is the coldest.

There are two endemic vertebrate species inhabiting the lake: the atherinid fish *Poblana alchichica alchichica* de Buen 1945 (Alvarez 1950) and the ambystomid salamander *Ambystoma taylorii* (Taylor 1943, Brandon *et al.* 1981).

The limnetic area of Lake Alchichica is saline (8.5 g l^{-1}) and basic (pH around 9.0). Sodium chloride is the salt with the highest concentration and ionic dominance are Na>K>Mg>Ca and $Cl>SO_4>CO_3>HCO_3$ (Vilaclara *et al.* 1993).

Twelve monthly samples were made in Lake Alchichica from August 1993 to July 1994, between the 9:00 and 13:00 hours. A prospective sampling throughout the lake, showed the limnetic area to be horizontally homogeneous. Thereafter, a single sampling station was located in the central area of the lake with the maximum depth (62.6 m). Ten samples (two replicates each) were obtained along the entire water column at 0, 3, 5, 10, 15, 20, 30, 40, 50 and 60 meters. Five liters were taken at each depth using a Van Dorn water sampler (Wetzel & Likens 1979), and filtered through a 55 µm mesh. Copepods were washed and then preserved with formalin (4 %) added with bengal rose (Dussart & Defaye 1995). Each developmental stage (nauplii, copepodites, males, females, and ovigerous females) was counted separately. When possible, at least 40-50 individuals were counted in each sample to obtain a coefficient of variation between 30-50% (Cassie 1971)

At the same depths another set of 5 l samples was obtained for chlorophyll *a* measurements in the laboratory. These samples were preserved cold (4 °C) and in darkness until their analysis. In the laboratory 3 l of each sample were filtered through a 0.45 µm pore-size Millipore membrane filter. After 24 h cold (4 °C) 100% methanol extraction (Marker *et al.* 1980), absorbance was measured in a Hewlett-Packard 8450A UV/VIS spectrophotometer. Chlorophyll *a* concentration was calculated using the equation proposed by Talling & Driver (in Vollenweider 1969) without phaeophytins correction.

Vertical profiles of temperature, dissolved oxygen, conductivity (K_{25}) and pH were measured at each sample date employing a Hydrolab Datasonde 3/Surveyor 3 multiparameter water quality logging system.

RESULTS

Environmental conditions in the lake: Copepod population dynamics was related to the environmental fluctuation in the lake. Lake water temperatures ranged from 14.8 to 19.8 °C and circulation temperature was around 15 °C.

Dissolved oxygen (DO) fluctuation in the lake was associated to the thermal regime (Fig. 1). During the circulation period DO was found in concentrations > 3 mg l^{-1} in the entire water column. Gradually, DO concentration in the bottom decreased until anoxic conditions appeared (April). The anoxic layer increased in size to reach the 25 m depth in August, in agreement with the strongest thermal stratification. A sharp separation between epilimnion and hypolimnion could then be distinguished (Fig. 1). At the beginning of the cold season (September-October) the anoxic layer initiates reduction in size. In the first month of the circulation period (January) DO is present along the entire water column but in uniform a low concentration (< 4 mg l^{-1}). DO concentration in the upper layer of the lake ranged between 4 and 9 mg l^{-1}. Peak values were found associated to an April bloom of the cyanobacteria *Nodularia spumigena* Mert. ex Born. et Flah. 1888 (Fig. 1). Most common values fluctuated between 5 and 6 mg l-1 in the upper 15 m (Fig. 1).

pH in the lake mirrored the basic-alkaline conditions and ranged from 8.6 to 9.2. The highest values were recorded in April caused

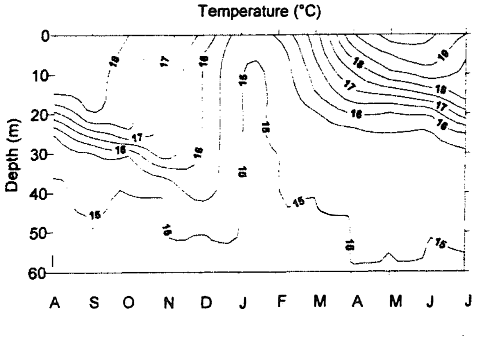

Figure 1. Depht-time diagram of isotherms (EC) in Lake Alchichica. August 1993-July 1994.

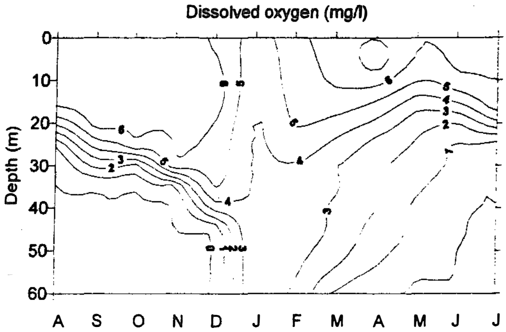

Fig. 2. Depht-time diagram of isopleths of dissolved oxygen concentrations (mg l^{-1}) in Lake Alchichica. August 1993-July 1994.

by the *N. spumigena* bloom. The lowest values were measured in October, at the end of the rainy season.

Specific conductivity (K_{25}) varied between 12 676 and 13 727 $\mu S\ cm^{-1}$. These values clearly indicated mineralized lake water. The maximum value was measured in June, the warmest month in the area.

Chlorophyll *a* concentrations in Lake Alchichica were generally low (mean column value < 5 mg m^{-3}) suggesting the prevalence of oligotrophic conditions (Margalef 1983). Higher concentrations were measured in the upper layer (0 to 20 m) corresponding to the photic zone of the lake (Fig. 3). During the thermal stratification period a chlorophyll peak was frequently observed at 30 m deep coinciding with the lowest boundary of the epilimnion.

In January, water circulation triggered a diatom bloom and allowed a better chlorophyll distribution along the water column (4.1-8.5 mg m^{-3}), thus resulting in the highest total column mean value (7.2 mg m^{-3}). In April, the presence of a *N. spumigena* bloom caused a different pattern with the maximum concentration (17.7 mg m^{-3}) located at the surface and a rapid decrease in chlorophyll values as depth increases (total column mean value 4.8 mg m^{-3}) (Fig. 4)

Distribution of *L. novamexicanus*: *L. novamexicanus* was the only zooplanktic crustacean species found in the limnetic area of

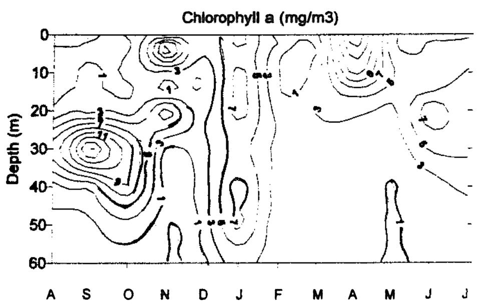

Fig. 3. Depht-time diagram of isopleths of chlorophyll *a* concentrations (mg m^{-3}) in Lake Alchichica. August 1993-July 1994.

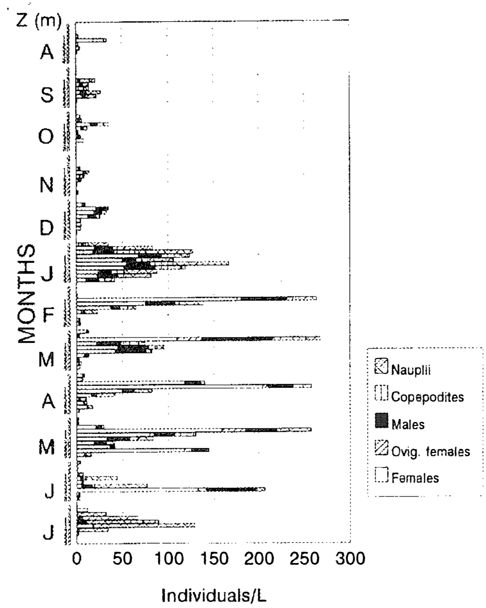

Fig. 4. Temporal and vertical fluctuation of *L. novamexicanus* in Lake Alchichica. August 1993, July, 1994.

Lake Alchichica. The copepod showed a clear vertical distribution pattern, it attains maximum densities usually between 10 and 15 m, near the lower limit (20-25 m) of the photic zone of the lake (Fig. 4). However, this pattern varied in some months. For example, in January (Fig. 4), during the circulation period, high densities of copepods were observed along the entire water column. Considering the total sampling period, there was a significant difference (two samples comparison test, $n^1=36$, $n^2=84$ unequal variances $p < 0.05$) between the copepods densities at the lower (40 to 60 m depth) and the upper (0 to 30 m) layers. Highest values (44.54±64.64 copepods l^{-1}, mean ± 1 s.d.) were found in the upper stratus and lower counts (19.77±43.88 copepods l^{-1}) were obtained at the deepest stratus. This fact is not common because samplings were performed in the morning and normally copepods stay at greater depths during the day and move to shallower depths at night (Lampert 1989). A notorious exception wasan unexpected high densities found at 40 m depth in July 1994 (Fig. 4). In this case high density were found at a depth were the dissolved oxygen was absent. It is possible that organisms caught at 40 m were dead or they could stay in a dormancy state (Dussart & Defaye 1995).

Seasonal fluctuations of the copepod population showed a pattern which was clearly related to the stratification-circulation periods of the lake. Throughout the circulation period (January-May), copepod densities (66.91±75.62 copepods l^{-1}, n=50) were higher (two samples comparison test, unequally variances, p<0.05) than those observed during the stratification period (15.83±32.43 copepods l^{-1}, n=70). High food concentration (phytoplankton) and better DO conditions can explain the copepod higher abundance during the circulation period. Copepod abundance peaks (January and April) coincided with chlorophyll *a* highest values during the early winter and spring blooms Fig. 4). Both phytoplankton blooms favored a fast increase of the copepod numbers. It is known that *Diaptomus* displays a peculiar feeding behavior. Some species in this genus can feed on filamentous algae, both cyanobacteria and diatoms, cutting small pieces of the filaments (Vanderploeg & Paffenhofer 1985, De Mott & Moxter 1991, Schaffner *et al.* 1994). In Lake Alchichica *L. novamexicanus* could exploit the cyanobacteria bloom or the associated non-filamentous algae as *Oocystis* spp., *Chroococcus* sp. and other abundant species. Afterwards, copepod grazing activity on phytoplankton could be one of the most important factors that causes the blooms disappearance.

Adult females were the most abundant copepod stage in Alchichica, thus population sex-ratio (males/females) was below one. Rojas & Sánchez (1988), Cruz (1989), González (1991) and Ocampo (1996) found the sex-ratio of *L. novamexicanus* to be around 1. According to Dussart & Defaye (1995) sex-ratio is related to the adaptavility of the population to local ecological conditions. Peculiarities of Lake Alchichica can favor females prevalence in the population. Adult males, copepodites and nauplii showed lower densities. During the stratification period, females were clearly prevalent in the planktic population, however at the beginning of the circulation period all copepod stages increased their densities. High number of ovigerous females were observed along this period and the mean egg number was 7 eggs per female.

The highest values in copepod densities were associated to the lake circulation period. Following a long stratification season with low copepod densities, when females were prevalent, in January population density increased and was dominated by nauplii. In February, one month later, nauplii seems to reach the adult stage and females are once again the most abundant stage. This situation continued until May, but in June, nauplii increased its number and in July they became dominant (Fig. 5). Males reached an abundance peak during January, a reproduction season, but later their abundance was usually lower.

DISCUSSION

Although some authors (Arredondo *et al.* 1984) considered the thermal regime of the lake as polymictic, our results clearly showed that between 1993 and 1994 Lake Alchichica was warm monomictic (Wetzel 1975) showing a circulation period during the cold and dry season (January-May), and a thermal stratification along the warm and rainy season (June to December, Fig. 2).

The stratification period of the lake had a notorious effect on the environmental conditions. For example, the low DO concentrations found during the beginning of the circulation period has been associated in tropical lakes to the oxidation of accumulated reduced substances in the hypolimnion during stratification (Estevez 1988).

The low number of zooplankton species found in Lake Alchichica is attributed to the ionic composition and hyposalinity (*sensu* Hammer *et al.* 1990, salinity: 3-20 g l^{-1}) of the water. Williams *et al.* (1990) showed that intermediate salinity values, as those found in Alchichica, have the maximum adverse effect on the number of species in a water body. Except Alchichica, studies on *L. novamexicanus* in Mexican water bodies found the species inhabitant fresh-waters, but some authors (Rojas & Sánchez 1988, Cruz 1989, González 1991, Ocampo 1996) detected a positive correlation between *L. novamexicanus* density and total alkalinity or total hardness. Combination of hyposalinity, high alkalinity and hard-waters in Lake Alchichica could represent advantageous conditions for this species.

Zooplankton diel vertical migration might be an antipredator behavior, with populations moving to a greater depth during the day to reduce risk from visual predators (Zaret & Suffern 1976). As previously mentioned, the only fish species inhabiting Lake Alchichica is the atherinid silver side *Poblana alchichica*, supposedly zooplankton feeder as most silver side species. However, the stomach contents of Alchichica silversides showed that they feed primarily on littoral benthic organisms and they consume insignificant amounts of copepods (Flores 1998). The low predation pressure by fishes could explain why copepods may stay in the photic zone of Alchichica during the day and exploit its food resources. Most mexican authors (Ocampo 1996 in January; Rojas y Sánchez 1988 in March; Cruz 1989 and González 1991 during May) have found maximum copepods densities in the season between January and May and this findings agree with the seasonal density pattern at Alchichica.

Due to the absence of other crustacean zooplankton species the *L. novamexicanus* population inhabiting Lake Alchichica limnetic zone seems to be under low interspecific competition conditions. Predation pressure is probably low, too. Under these circumstances, the vertical and temporal fluctuations of the population depends mainly on environmental conditions, basically imposed by the circulation-stratification periods of the lake that influence food availability for *L. novamexicanus*.

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RESUMEN

Se investigó la variación temporal y vertical de la densidad y composición de la población plánctica del copépodo *Leptodiaptomus novamexicanus* Herrick 1895 en un lago cráter salino en México. Se realizaron muestreos mensuales a lo largo de un año entre agosto de 1993 y julio de 1994. Las muestras se obtuvieron en una estación central en la parte más profunda del lago (62.6 m) mediante una botella Van Dorn y se filtraron a través de una malla de 55 µm de apertura. Se evaluaron las densidades de copépodos por cada estadio de desarrollo. Se midieron perfiles verticales de temperatura, oxígeno disuelto, pH, conductividad específica (K25) y clorofila *a*. La zona limnética del Lago Alchichica es hiposalina (8.5 g l^{-1}), de pH básico (8.6-9.2) y oligo-mesotrófica (concentración de clorofila *a* 0-17 mg m^{-3}). El lago es monomíctico cálido y circula durante la época fría del año (invierno-primavera). *L. novamexicanus* fue la única especie de crustáceo del zooplancton presente en la zona limnética del lago. Las densidades del organismo variaron entre 0 y 267 ind. l^{-1}. Se encontraron diferencias significativas en las densidades de copépodos entre los períodos de circulación (66.91±75.62 copépodos l^{-1}, media ± 1 d.e.) y estratificación (15.83±32.43 copépodos l^{-1}) del lago y entre la zona superficial (0-30 m, 44.54±64.64 copepodos l^{-1}) y la profunda (40-60 m, 19.77±43.88 copepodos l^{-1}). Las máximas densidades de organismos coincidieron con la presencia de dos florecimientos de fitoplancton: un florecimiento de diatomeas en el mes de enero (clorofila *a* 4.1-8.5 mg m^{-3}) y después de un florecimiento de cianobacterias (clorofila *a* 1.4-17.7 mg m^{-3}) en el mes de mayo. Verticalmente, las mayores densidades de copépodos se encontraron entre los 10-15 m de profundidad, dentro de la zona fótica del lago (20-25 m). La población de *L. novamexicanus* que vive en la zona limnética del Lago de Alchichica parece vivir en condiciones de baja competencia interespecífica debido a la ausencia de otras especies de crustáceos del zooplancton. En estas circunstancias, la fluctuación vertical y temporal de la población de copépodos depende fundamentalmente de las condiciones ambientales, principalmente de los períodos de circulación y estratificación del lago que determinan la cantidad de alimento disponible.

REFERENCES

Alcocer, J., A. Lugo, M.R. Sánchez, M. Chávez & E. Escobar. 1998. Threats to the saline lakes of Oriental basin by human activities. Verh. Int. Verein. Limnol. 26: 1383-1386.

Alvarez, J. 1950. Contribución al conocimiento de los peces de la región de los Llanos, estado de Puebla (México). An. Esc. Nac. Cienc. Biol. VI: 81-107.

Arredondo, J.L., L.E. Borrego, R. Castillo & M. Valladolid. 1983. Batimetría y morfometría de los lagos "maars" de la Cuenca de Oriental, Puebla, México. Biótica 8: 37-47.

Arredondo, J.L., O. Vera & A.O. Ortíz. 1984. Análisis de Componentes Principales y Cúmulos de datos limnológicos, en el lago de Alchichica, Puebla. Biótica 9: 23-39.

Brandon, R.A., E.J. Maruska & W.T. Rumph. 1981. A new species of neotenic *Ambystoma* (Amphibia, Caudata) endemic to Laguna Alchichica, Puebla, Mexico. Bull. Southern California Acad. Sci. 80: 112-125.

Camacho, M. 1996. Análisis de los Ordenes Calanoida y Cyclopoida (Crustacea: Copepoda) en diversos reservorios naturales y artificiales del Estado de México. Tesis de Licenciatura, Universidad Nacional Autónoma de México Campus Iztacala, Tlalnepantla, México. 76 p.

Cassie, R.M. 1971. Sampling and Statistics, p. 174-209. *In* Edmonson, W.T. & G.G. Winberg (eds.). A manual on methods for the assessment of secondary productivity in fresh waters. Blackwell, Oxford and Edinburgh.

Cruz, F. 1989. Estudio de algunos aspectos de la biología de los calanoideos del embalse Danxhó, Edo. de México. Tesis de Licenciatura, Universidad Nacional Autónoma de México. Campus Iztacala, Tlalnepantla, México. 66 p.

De Mott, W.R. & F.M. Moxter. 1991. Foraging on cyanobacteria by copepods: responses to chemical defenses and resource abundance. Ecology 72: 1820-1834.

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

Dussart, B.H. & D. Defaye. 1995. Copepoda. Introduction to the Copepoda. SPB, Amsterdam. 277 p.

Estévez, F. de A. 1988. Fundamentos de Limnología, Interciencia/FINEP. Río de Janeiro. 575 p.

Flores, E. 1998. Estudio poblacional de tres especies de *Poblana* (Pisces: Atherinopsidae) en tres lagos cráter de Puebla, México. Tesis de Maestría en Ciencias (Biología de Sistemas y Recursos Acuáticos), Facultad de Ciencias, Universidad Nacional Autónoma de México. México. 101 p.

García, E. 1988. Modificaciones al sistema de clasificación climática de Köppen. E. García, México, D.F. 217 p.

Gasca, D.A. 1981. Algunas notas de la génesis de los lagos-cráter de la Cuenca de Oriental. Puebla-Tlaxcala-Veracruz. Instituto Nacional de Antropología e Historia de México, México. 55 p.

González, M. 1991. Contribución al conocimiento biológico y ecológico de los copépodos: Calanoidea en la Presa Trinidad Fabela, Edo. de Méx. Tesis de Licenciatura, Universidad Nacional Autónoma de México Campus Iztacala, Tlalnepantla, México. 51 p.

Grimaldo, D. 1996. Copépodos (Crustacea: Calanoida, Cyclopida) en algunos cuerpos de agua temporales del Estado de México. Tesis de Licenciatura, Universidad Nacional Autónoma de México Campus Iztacala, Tlalnepantla, México. 55 p.

Hammer, T.U, J.S. Sheard & J. Kranabetter. 1990. Distribution and abundance of littoral benthic fauna in Canadian prairie saline lakes. Hydrobiologia 197: 173-192.

Lampert, W. 1989. The adaptative significance of diel vertical migration of zooplankton. Functional Ecol. 3: 21-27.

Margalef, R. 1983. Limnología. Omega, Barcelona. 1010 p.

Marker A.F.H., C.A. Crowther & R.J.M. Gunn. 1980. Methanol and acetone as solvents for estimating chlorophyll *a* and phaeopigments by spectrophotometry. Archiv. Hydrobiol. Beih. Ergebnisse Limnol. 14: 52-69.

Ocampo, L.M. 1996. Dinámica del zooplancton en un estanque temporal utilizado para el cultivo de carpa en el Edo. de México. Tesis de Licenciatura, Universidad Nacional Autónoma de México Campus Iztacala, Tlalnepantla, México. 42 p.

Osorio-Tafall, B.F. 1942. Un nuevo "Diaptomus" del México Central (Copepoda, Diaptomidae). Rev. Brasil. Biol. 2: 147-154.

Reid, J.W. 1990. Continental and coastal free-living Copepoda (Crustacea) of México, Central America and the Caribbean Region, p. 175-213. *In* D.L. Navarro y J.G. Robinson (eds.). Diversidad biológica en la Reserva de la Biósfera de Sian Ka'an, Quintana Roo, México. Centro de Investigaciones de Quintana Roo (CIQRO) y Program of Studies in Tropical Conservation, University of Florida. Chetumal.

Rojas, M. & R. Sánchez. 1988. Aportación a la biología y ecología de *Diaptomus novamexicanus* (Copepoda-Calanoidea) del Embalse La Goleta, Edo. de México. Memorias del IX Congreso Nacional de Zoología. Tabasco, México. 1: 176-182.

Schaffner, W.R., N.G. Hairston, & R.W. Howarth. 1994. Feeding rates and filament clipping by crustacean zooplankton consuming cyanobacteria. Verh. Int. Verein. Limnol. 25: 2375-2381.

Suárez-Morales, E., J.W. Reid, T.M. Illife & F. Fiers. 1996. Catálogo de los copépodos (Crustacea) continentales de la Península de Yucatán, México. Comisión

Nacional para el Conocimiento y Uso de la Biodiversidad (CONABIO) y El Colegio de la Frontera Sur, México. 296 p.

Taylor, E.H. 1943. A new ambystomid salamander adapted to brackish water. Copeia 3: 151-156.

Vanderploeg, H.A. & G.A. Paffenhofer. 1985. Modes of algal capture by the freshwater copepod *Diaptomus sicilis* and their relation to food-size selection. Limnol. Oceanogr. 30: 871-855.

Vilaclara, G., M. Chávez, A. Lugo, H. González and M.L. Gaytán. 1993. Comparative description of crater-lakes basic chemistry in Puebla state, Mexico. Verh. Int. Verein. Limnol. 25: 435-440.

Vollenweider, R. (ed.). 1969. A manual on methods for measuring primary production in aquatic environments. Blackwell, Oxford. 213 p.

Wetzel, R.G. 1975. Limnology. Saunders, Philadelphia. 743 p.

Wetzel, R.G. & G.E. Likens, 1979. Limnological Analyses. Saunders, Philadephia. 357 p.

Williams, W.D., A.J. Boulton, & R.G. Tafee. 1990. Salinity as determinant of salt lake fauna: a question of scale. Hydrobiologia 197: 257-266.

Wilson, M.S. & H.C. Yeatman. 1959. Free-living copepoda, p. 735-861. *In* Edmonson, W.T. (ed.). Fresh Water Biology. Wiley, New York.

Zaret, T.M. & J.S. Suffern. 1976. Vertical migration in zooplankton as a predator avoidance mechanism. Limnol. Oceanogr. 21: 804-813.