JCBPS; Section D; May 2018 – July 2018, Vol. 8, No. 3; 269-284, E- ISSN: 2249 –1929
[DOI: 10.24214/jcbps.D.8.3.26984.]

Journal of Chemical, Biological and Physical Sciences

An International Peer Review E-3 Journal of Sciences

Available online atwww.jcbsc.org

Section D: Environmental Sciences

CODEN (USA): JCBPAT Research Article

Variation of Endemic Copepod *Leptodiaptomus cuauhtemoci* in Zempoala Lake, Morelos, Mexico

Variación Del Copépodo Endémico *Leptodiaptomus cuauhtemoci* en el Lago Zempoala, Morelos, México

Roberto Trejo-Albarrán[1], José Guadalupe Granados-Ramírez [2], José Luis Gómez-Márquez[3] y Andrea Elizabeth Granjeno-Colín[4]

[1]Laboratorio de Hidrobiología, Centro de Investigaciones Biológicas, Universidad Autónoma del Estado de Morelos. Av. Universidad 1001, Col. Chamilpa, C. P. 62209, Cuernavaca, Morelos

[2]Laboratorio de invertebrados, Facultad de Ciencias Biológicas, UAEM.

[3]Laboratorio de Limnología, FES Zaragoza, UNAM.

[4]Laboratorio de Edafoclimatología, Centro de Investigaciones Biológicas, UAEM.

Received: 18 June 2018**; Revised:** 05 July 2018; **Accepted:** 12 July 2018

Abstract. Copepods have an ecologically important role in the freshwater ecosystem, since they constitute the secondary basic unit of organic matter production in these ecosystems and in the State of Morelos, there are few faunistic registers of this group. The aim of this study was to analyze the spatial and temporary variation of the *Leptodiaptomus cuahutemoci* and its relation with some environmental parameters. Six stations were established for biological collection: three (E-1, E-2 and E-3) in the limnetic zone with vertical collections at three depths and three more in the littoral zone (E-4, E-5 y E-6) with a superficial collection (0.30 m). Monthly samples were taken for physical and chemical water analysis at different depth levels. At the level of 0.30 m, the abundance in decreasing order was: 1 543 org/L in E-1, E-2 with 1 251 org/L, E-4 with 1 117 org/L, E-5 with 1024 org/L, E-3 with 932 org/L and 662 org/L with E-6, with larger densities in the limnetic stations compared to littoral stations (Kruskal-Wallis, H=22.5; $p<0.05$). Due to physical and chemical characteristics of water, Zempoala Lake is considered an aquatic system well oxygenated, low in conductivity aquatic system with warm waters, with a mixing period and another of water stratification. *L. cuauhtemoci* is a species whose composition, abundance and spatial distribution, respond more to biological cycles affecting the population dynamic rather than physical and chemical factors.

Key words: Abundance, endemic species, Zempoala Lake, seasonal variation, zooplankton

Resumen. Los copépodos tienen un papel ecológico importante en el ecosistema dulceacuícola, ya que constituyen la unidad básica de producción secundaria de materia orgánica en estos ecosistemas y en el estado de Morelos, se cuentan con pocos registros faunísticos de este grupo. El objetivo de este estudio fue analizar la variación espacial y temporal de *Leptodiaptomus cuahutemoci* y su relación con algunos parámetros ambientales. Se establecieron seis estaciones: tres (E-1, E-2 y E-3) en la zona limnética con recolectas verticales a tres profundidades y tres más en la zona litoral (E-4, E-5 y E-6), con recolecta de manera superficial (0.30 m). Se tomaron muestras mensuales para análisis físico y químico del agua a diferentes niveles de profundidad. A nivel de 0.30 m la abundancia en orden decreciente fue: 1 543 org/L en la E-1, la E-2 con 1 251 org/L, la E-4 con 1 117 org/L, la E-5 con 1024 org/L, la E-3 con 932 org/L y con 662 org/L la E-6, con mayores densidades observadas en las estaciones limnéticas que en las litorales (Kruskal-Wallis, H= 22.5; $p=0.000$). Por las características físicas y químicas del agua el lago Zempoala se considera como un sistema acuático bien oxigenado, baja conductividad y aguas templadas, con un periodo de mezcla y otro de estratificación. *L. cuauhtemoci* es una especie cuya composición, abundancia y distribución espacial obedece más a ciclos biológicos que afectan la dinámica poblacional y no por el efecto de los factores físicos y químicos.

Palabras clave: Abundancia, especie endémica, Lago Zempoala, variación temporal, zooplancton

INTRODUCTION

Freshwater copepods make up for relevant percentages of zooplankton from the littoral biomass. As an ecological group, it is widely distributed in plankton, benthos and littoral regions of these ecosystems, in which limnetic species are different from those located in the littoral zone. Limnetic species are generally smaller, thinner and transparent, littoral species are larger, stronger and darker. Likewise, they are found in a minor abundance in rivers, reservoirs and ponds[1,2]. Although there are four free-life copepod orders represented in continental waters, Calanoida, Cyclopoida, Harpaticoida and Gelyelloida (this last one with its own forms of karstic underground environments)[3], in the largest part of the temperate and tropical lakes, copepod fauna is not as diverse as in the sea [4 - 6].

The copepods group plays an ecologically important role in the freshwater ecosystem, since it

[DOI:10.24214/jcbps.D.8.3.26984.]

constitutes the basic unit of organic mass production in these ecosystems[7, 8]. From economic and social points of view, copepods and water fleas, constitute an excellent source of food for fishery production [9] and represent an important component in terms of hydrological condition indicators [10, 11] (masses of water, movement, pollution and eutrophication) including rotifers in this factor[12,13]. The study of its ecology contributes to information regarding the conditions of any aquatic system [8].

Freshwater copepods constitute a group with very interesting ecological characteristics; its importance is unquestionable and contrasting with the rather scarce knowledge about the group, mainly in tropical areas [2.14]. Zooplankton community composition and biomass have been studied in several tropical inland water bodies, but there is still limited information for the state of Morelos, since there is not a single copepod faunistic register, which is the case as well for many other countries [8, 15]. Therefore, the purpose of this research is to provide information about seasonal and temporary variation of *Leptodiaptomus cuahutemoci* (Osorio-Tafall, 1941), a native copepod[16]. This research will provide information regarding its abundance and density for a cycle of one year in Lake Zempoala, State of Morelos, Mexico.

MATERIALS AND METHODS

Study area description. Lake Zempoala belongs to Zempoala Lagoon National Park and is located at 65 km South of Mexico City and 30 km North of Cuernavaca City[17]. Lake Zempoala (19°03’00’’ N, 99°18’42’’ W) is the largest of four existing lakes (Zempoala, Tonatiahua, Compila and Acoyotongo), a endorheic basin located (Fig. 1) at 2800 meters above sea level [18]. It has an area of 10.56 hectares during the dry season and 12.34 hectares during the rainy season[19]. It has a maximum length of 401 to 508 m in North-Northeast direction with average width of 207.9 m. It is a permanent aquatic system with an average depth[17] of 8.0 m. It supplies water to activities located within the area and provides water for general municipal use [20]. The study area is characterized by sub-humid warm climate (C(w2’’)(w)big), with rain in the summer, an annual average temperature between 12 and 18 °C and annual average precipitation between 800 to 1000 mm[21,22].

Study sites. Monthly monitoring was performed from August 2006 to July 2007 and six stations were established (**Fig. 1).** The first three stations (E-1, E-2 and E-3) were located in the deepest limnetic zone of the aquatic system and samples were taken at three levels (0.30, 2.5 and 5.0 m). The other three stations (E-4, E-5 and E-6) were located in the littoral zone and samples collected in the surface (0.30 m). For the physical and chemical analyses, samples water was taken in the surface (0.30 m), at 2.5 and 5 m with a three liter Van-Dorn device. Transparency was determinate using a Secchi disc, environmental and water temperature, conductivity, pH, dissolved oxygen, dissolved and total solids were measured in situ using a HANNA portable waterproof pH/EC/TDS/Temperature Tester model HI 98130. Carbon dioxide, total hardness and total alkalinity, were determined according to the methods described by Boyd[23,24], APHA, AWWA and WPCE[25] and Wetzel & Likens[26]. At each station, zooplankton was collected with a three-liter Van-Dorn device. Samples were pooled and preserved in a 4% formalin solution, until its subsequent analysis in the laboratory [26]. Estimations of the zooplankton abundance were performed taking 1 mL aliquots from concentrated samples (250 mL approximately) and analyzed in a Sedwick-Rafter chamber for its subsequent observation and identification in the microscope with the help of specific taxonomic literature [3, 15,27]. The mean density used to compute abundance was obtained by the analyses of two sub-samples of 1 mL each.

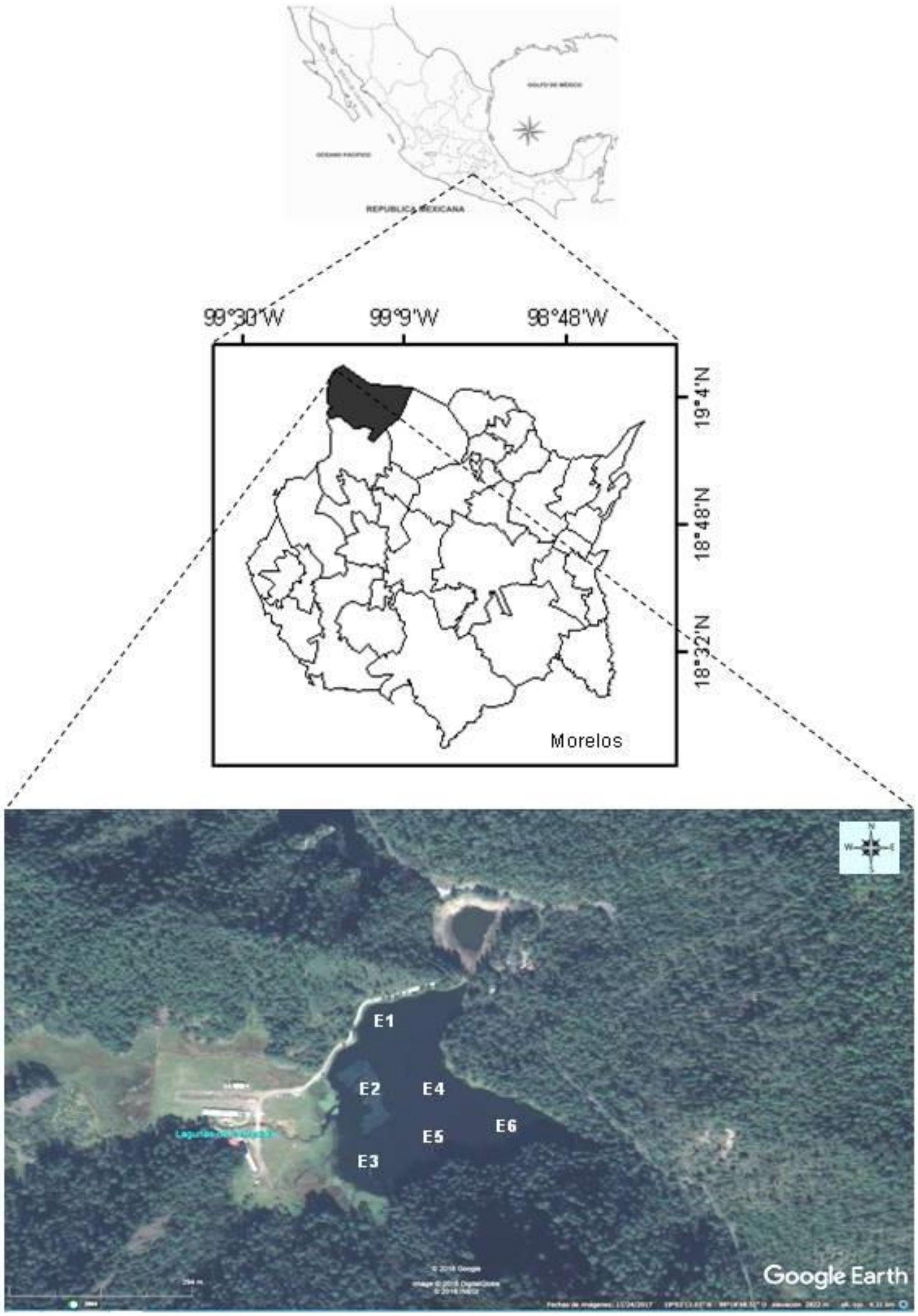

Figure 1: Geographic localization of study area

Statistical analysis. The Exploratory Data Analysis was applied[28] using the Statgraphics v. 5.0 software as to observe variables behavior as well as testing the assumption, for the application of the parametric statistics and determining whether there are any significant differences in the physical-chemical and biological variables between stations and depth levels at $p<0.05$ level of significance. Principal Component Analysis (PCA) was performed with the objective of abbreviating the total acquired parameters during the study and by doing this, determining the behavior in the systems based on the most relevant parameters [29,30]. Finally, a Spearman rank correlation coefficient was applied [31,32], using the SPSS software ver. 5.0 to establish the main relations between the species abundance and each of the physical and chemical registered variables.

RESULTS

Minimum water temperature values in the limnetic zone (11±0.1 ºC) were registered on January in all the stations and the maximum values of 22.2±0.1 ºC were registered during August in E4 **(Fig. 2a).** The dry season in the study area was meaningfully warmer than the rainy season; therefore, statistical differences between the two periods was registered (Kruskal-Wallis H=127.4; $p<0.05$).

The dissolved oxygen (**Fig. 2b)** shows the lowest values in June (E1) with 0.2 mg/L at 5.0 m and the highest value in February with 10 mg/L (E2) at 2.5 m (Kruskal-Wallis H=41.2; $p<0.05$). pH (**Fig. 2c)** shows moderate alkalinity values (8.9 units) in September, with a decrease in acidity (pH=6.1) during the dry season and at the start of the rainy season, due to the geological origin of rocks and soil in the lake location (Kruskal-Wallis H=124.3; $p<0.05$).

The lowest conductivity value was registered in September (14.5 µS/cm) and the highest value (17.2 µS/cm) was obtained in March 2007 (**Fig. 2d).** Statistical analysis shows statistical differences between seasons (Kruskal-Wallis H=131.6; $p<0.05$).

For carbon dioxide concentrations differences were observed between months (Kruskal-Wallis H= 89.8; $p<0.05$) and absence of this gas was registered in February, mainly in littoral zone stations which present the lowest depth (**Fig. 2e);** in June, this same phenomenon comes up in all water columns due to water column mixing being a process favored by wind action, which correspond to high values of dissolved oxygen, likewise, the highest values of carbon dioxide were obtained before water column stratification, after June.

Secchi disc transparency values ranged between 1.7 m (November) in E4 and 4.1 m (September) in all stations, which suggests that the lake has a few particles in suspension which will decrease light penetration in the water column (Kruskal-Wallis H=9.05; p=0.616), mainly in the trophogenic layer.

Due to total hardness values (**Fig. 2f),** Lake Zempoala is characterized as a soft water aquatic ecosystem (34 mg/L $CaCO_3$ average); nonetheless, it registered statistical differences among the different months of the year (Kruskal-Wallis H=70.61; $p<0.05$) and tends to decrease towards the end of the study.

[DOI:10.24214/jcbps.D.8.3.26984.]

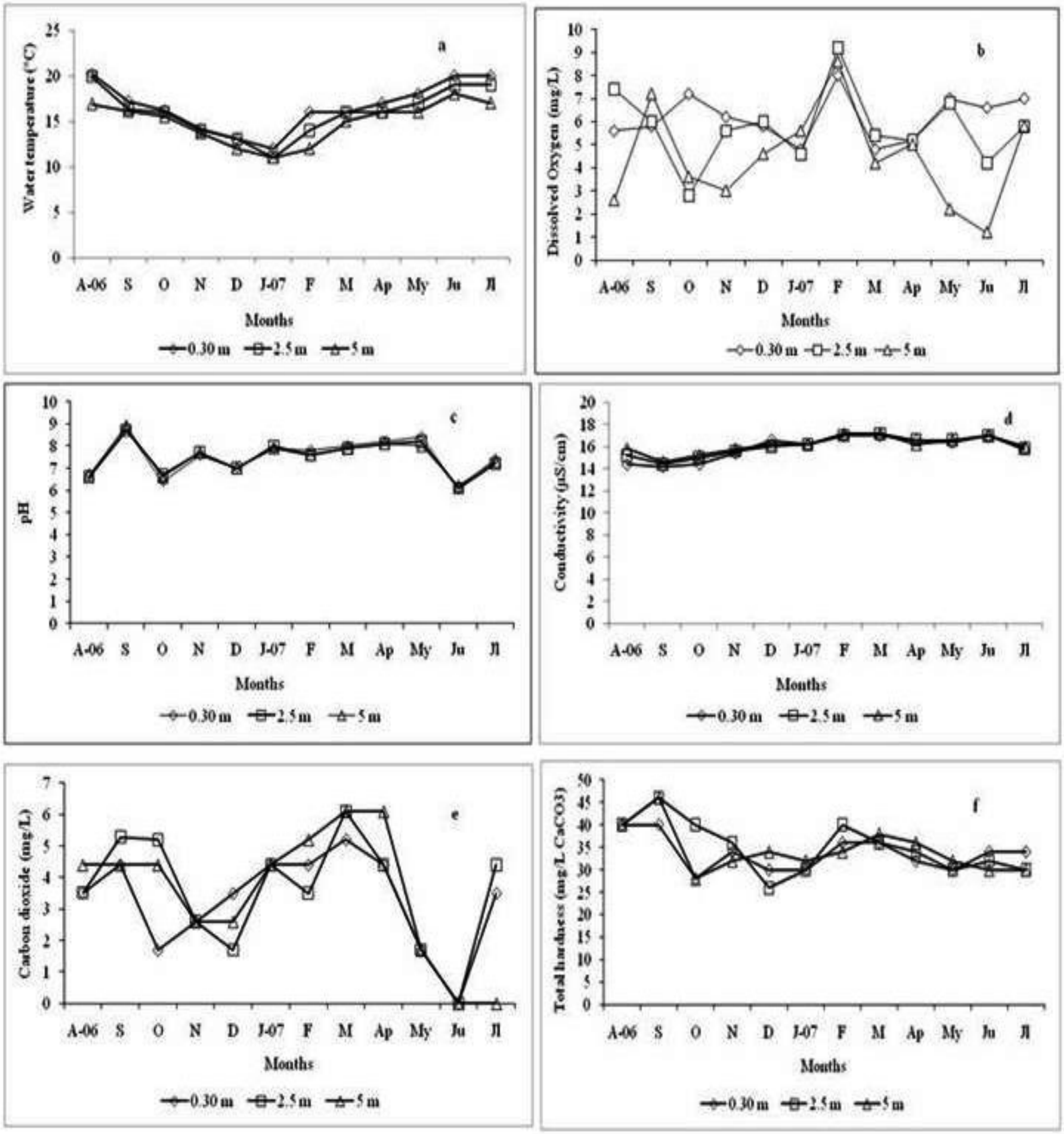

Figure 2: Seasonal variation of water temperature (a), dissolved oxygen (b), pH (c), conductivity (d), carbon dioxide (e) and, total hardness (f) of Lake Zempoala

In regards to the abundance of *Leptodiaptomus cuauhtemoci*, differences were registered in all sampling stations (Kruskal-Wallis H = 22.55; p<0.05), vertically as well as horizontally. In the surface level of 0.30 m, the greatest abundance value was registered in E-1 with 1543 org/L, followed by E-2 with 1251 org/L, E-4 with 1117 org/L, E-5 with 1024 org/L, E-3 with 932 org/L and finally E-6 with 662 org/L. In most stations in the superficial zone, this species was found frequently and constantly (Kruskal-Wallis H=10.91; p=0.053), which can be considered as an important species for the zooplankton community. In this same stratum (0.30 m), a higher abundance was observed during September in E-5 with 538 org/L, followed by E-3 with 377 org/L in January and finally E-1 with 360 org/L in April; the minimum abundance value was registered in November and June with 3 and 8 org/L respectively **(Fig. 3a).**

For a depth of 2.5 m, the total registered abundances for three sampling stations were of 111 org/L, 77 org/L and 50 org/L in E-1, E-2 and E-3, respectively (Kruskal-Wallis H=0.677; p>0.05); seasonally the highest values in E2 were registered with 26 org/L in November; while the minimum values were 1 org/L in all the sampled stations for this depth (**Fig. 3b).**

At a depth of 5 meters, the lowest abundances and frequencies were quantified during the sampling period, although there were no statistical differences at this level (Kruskal-Wallis H=4.86; p>0.05) with a maximum registration in E-3 with 8 org/L in August and May; in E-2 the same abundance was also observed but in July (**Fig. 3c),** the statistical analysis showed significant differences of the zooplankton abundance between stations (Kruskal-Wallis H=22.5; p<0.05) (Fig. 4), but not among different sampling months in the limnetic zone (Kruskal-Wallis H=7.42; p > 0.05) and in the littoral zone (Kruskal-Wallis H=13.87; p>0.05).

The abundance of *L. cuauhtemoci* was more prevalent during the rainy season between the months of April to August, while their population decreased during the dry season, between November and March.

The spatial distribution of *L. cuauhtemoci* (**Fig. 4),** in terms of abundance and frequency values of this organism, a trend was found in the littoral zone of the lake (U de Mann-Whitney U=2936.5; p<0.05); however, it can be observed that for E-5 during September, E-3 in January and E-1 in April, the largest concentration of these organisms was registered (**Fig. 5a, 5b**), while in water column of the three stations in the limnetic zone, which was quantified frequently between the surface level (0.30 m) and the 2.5 m depth, with high abundances to be located in the surface **(Fig. 3a).** Therefore it was considered to be a species which prefers to be located in the trophogenic zone.

As for the PCA diagram, the purpose of the analysis was to obtain a small number of linear combinations of 11 variables which account for most of the variability in the data. Multivariate analysis using PCA showed four components had been extracted and together they accounted for 74.7% of the variability in the original data. In **Fig. 6**, it is observed that zooplankton abundance is directly related to carbon dioxide, pH, total hardness, total alkalinity and water temperature, which affects abundance mainly during the dry warm season and at the beginning of the rainy season. The coldest months are located in the bottom to the right, with the water column mixing of the ecosystem emerging in January and in this case, such factors have an influence over the chemical conditions in the water, which is linked to the depth of lake.

Spearman rank correlation coefficient was applied among zooplankton abundance and environmental variables. Zooplankton abundance is only directly associated to Secchi disk transparency (Spearman = 0.699; p<0.05), water temperature (Spearman = 0.238; p<0.05) and dissolved oxygen (Spearman = 0.190; p = 0.015); although the level of association of these last two variables was low.

[DOI:10.24214/jcbps.D.8.3.26984.]

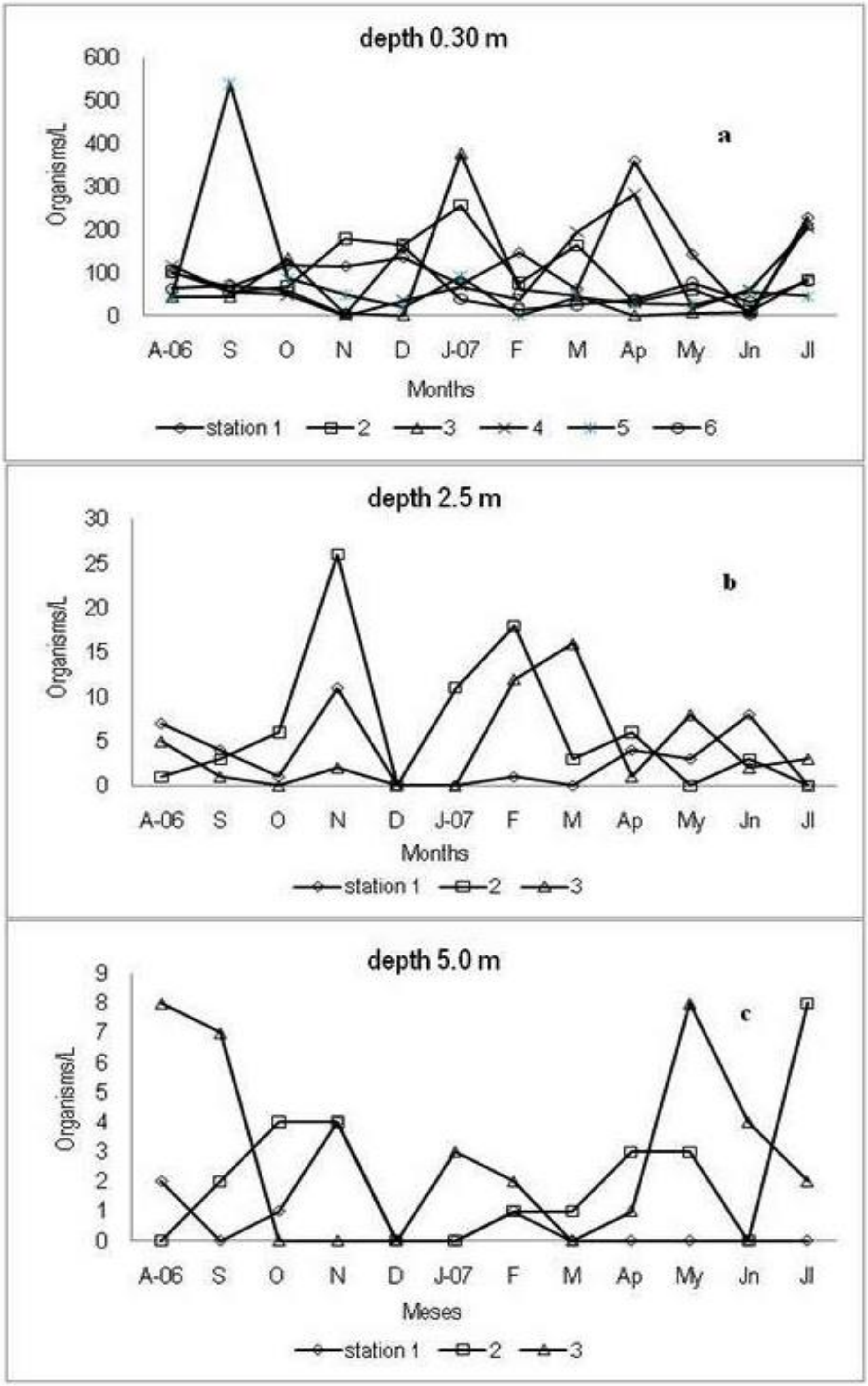

Figure 3: Abundance of *L. cuauhtemoci* at 0.30 m (a), 2.5 m (b) and 5.0 m (c) depths in six sampling stations in Lake Zempoala

[DOI:10.24214/jcbps.D.8.3.26984.]

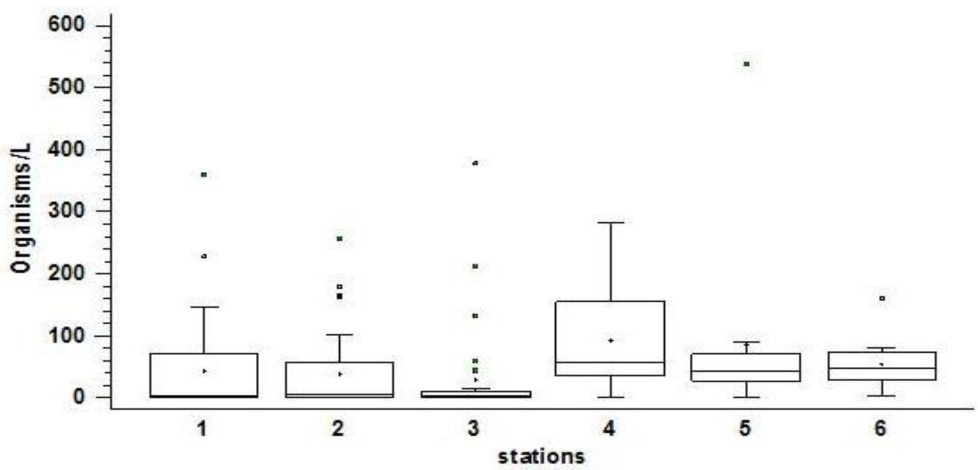

Figure 4: Spatial variation of L. *cuauhtemoci* abundance in Lake Zempoala

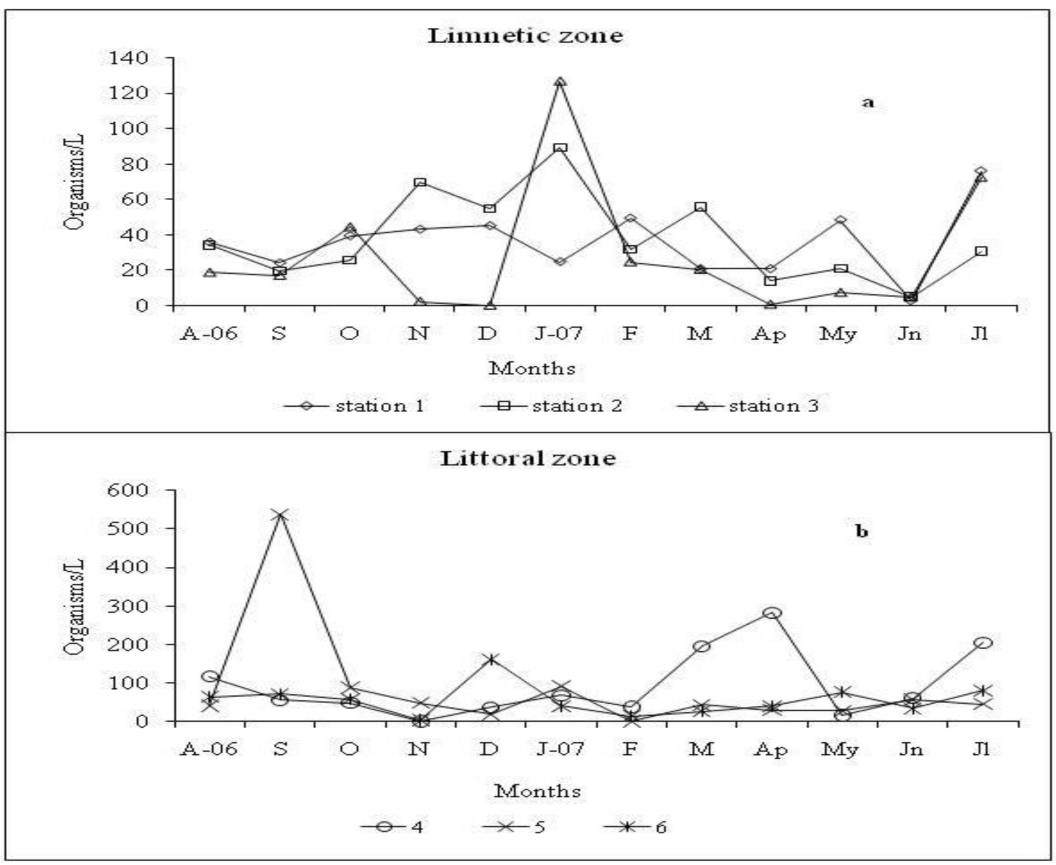

Figure 5: Temporal variation of *L. cuauhtemoci* abundance in limnetic zone (a) and littoral zone (b) registered in Lake Zempoala

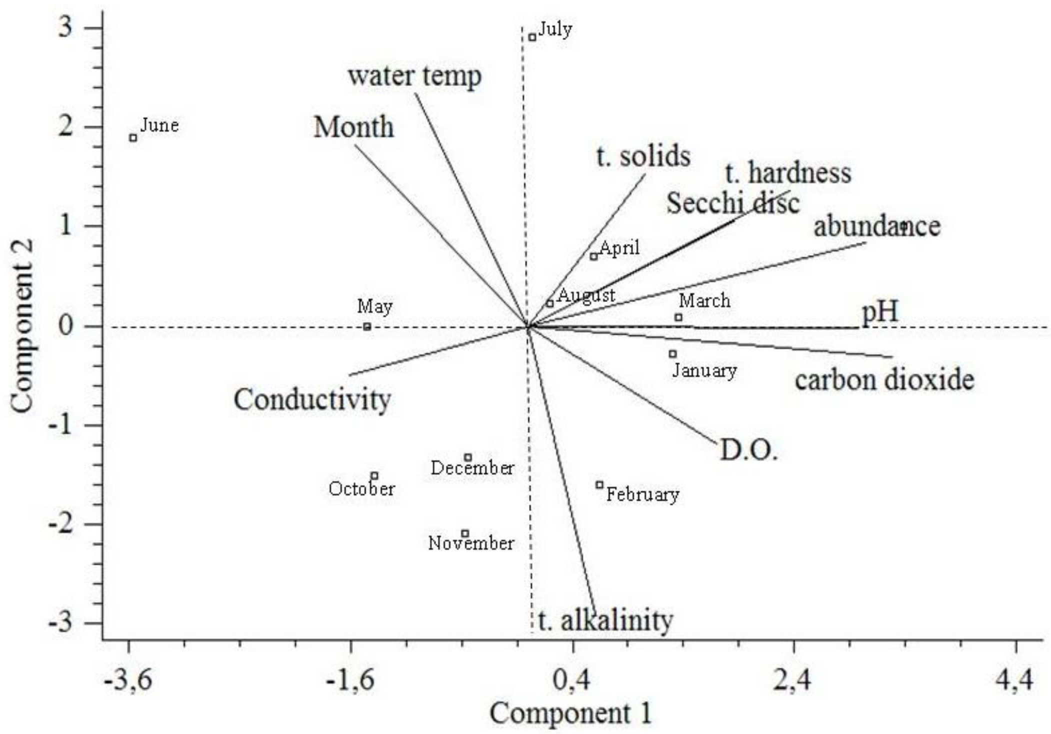

Figure 6: Principal Component Analysis among environmental factors, time and abundance of *L. cuauhtemoci*

DISCUSSION

Natural (lakes) and artificial (reservoirs) aquatic systems are considered favorable environments for the development of zooplankton communities, which can be established in relatively short periods of time after the creation of a reservoir. There are several factors which usually contribute to the establishment of zooplankton communities in a reservoir, including water quality, nutrients, phytoplankton availability, hydrologic characteristics of reservoirs and reservoir ageing [33].

Calanaid copepods show a wide distribution in America[34] and Diaptomidae are exclusively confined to freshwater, they are widely distributed in the U.S.A. and central Mexico [35,36] with a high grade of endemism; such situation is more pronounced in tropical zones than in temperate zones and, tropical and temperate climate species are not usually found together [5]. It was recorded that the abundance and spatial distribution of *Leptodiaptomus cuauhtemoci* were highest during the rainy season, when there is an input of organic matter to the system and the depth and volume increased. [37]Chapman and Kramer (1991) point out that the onset of the rainy season indicates a radical change in the physical and chemical characteristics of the aquatic system. Therefore, the input of allochthonous organic material during the rainy season decreases conductivity, pH, alkalinity and total dissolved solids but, increases biochemical oxygen demand.

Leptodiaptomus cuahutemoci, is an endemic species of the State of Morelos which was first described by Osorio-Tafall (1941; cited in: Suárez-Morales *et al*.,[15]), redescribed and validated by Suárez-Morales *et al*.[15], who mentions that *L. cuahutemoci* is a species different from *L. siciloides*, since they differ in several characteristics shown by males and females, characteristics that distinguish both species, and that the genus *Leptodiaptomus* is of Nearctic affinity, including different species which probably radiated southwards and reached central Mexico[36,38]. For Zempoala Lake, high values of abundance and frequency were recorded, but this is a species that tends to remain on the surface level (euphotic zone) of the aquatic ecosystem.

Brandorff[39] mentions that genus *Leptodiaptomus* is largely spread in North America and Elías-Gutiérrez *et al.*[38] cited that *Leptodiaptomus* is a clearly temperate origin species which radiated southwards, having Central America as its limit. Other species are spread just in cold-temperate regions but some others like *L. siciloides* y *L. novamexicanus* supposedly have a wide latitudinal distribution rank that includes the U.S. and Canada and they reach Neotropical region [38].

Suárez-Morales *et al.*[15] and Suárez-Morales *et al*.[36] point out that *L. cuauhtemoci* has a large distributional rank, including different states of Central Mexico (Aguascalientes, State of México and Morelos) and currently Central-Western Canada as well. Elías-Gutiérrez [40] confirms the presence of this species which has been previously registered for the State of Morelos. It was expected that the distribution rank of this species includes Northern Mexico and The United States. It is also suggested that some of the North American registers of *L. siciloides* can belong to *L cuauhtemoci* [15].

Granados-Ramírez & Suárez-Morales[41] mentioned that ancestral members of *Leptodiaptomus* could have been expanded from the Neartic region (there are at least 12 registered species in Northern Canada and U.S.) and the Neotropical region where it radiated. Silva-Briano & Suárez-Morales[42] performed a second registry of *L. dodnosi* after its original description regarding specimens collected in Jalisco, while Elías-Gutiérrez *et al.*[43] consider this species as endemic and restricted to this location.

Leptodiaptomus cuauhtemoci was reported by Arroyo-Bustos *et al.*[44] working with three aquatic system planktonic crustaceans, which were composed by 7 copepod species, reporting three species of the genus *Leptodiaptomus* (*L. novamexicanus*, *L. dodsoni* y *L. cuautemoci*), the last one was just found in the reservoir Tepuxtepec, Méx., and is associated to eutrophic waters which are also rich in minerals. For Lake Zempoala, García[45] and García-Rodríguez & Tavera[46] pointed out that there are minor fluctuations in chlorophyll concentrations which are mainly dominated by diatoms, emphasizing among them *Asterionella formosa* and *Fragilaria crotonensis,* followed by species of cyanobacteria, particularly *Anabaena* cf. *portoricensis* in the autumn. The aquatic system is characterized as a eutrophic environment. However, Granados-Ramírez *et al.*[47] mentioned that Lake Zampoala is an environment that can be characterized as in a mesotrophic state, based on the Carlson trophic state index [48].

Regarding data shown in this study, the aquatic system can be considered as a warm monomictic lake. García[49], García-Rodríguez & Tavera[46] and Mondragón[50] characterized Lake Zempoala as a warm monomictic body of water due to the fact that two periods were observed, a stratification period in July and a mixing period in January, in which the lowest temperatures and the highest *L cuauhtemoci* abundance were registered, such values match with those reported in this study. Under these conditions *L. cuauhtemoci* is a species that is linked to a highly trophic state as it is shown in this ecosystem, possibly due to the small depth registered (up to a maximum of 8 meters) which provokes a relevant population dynamic.

Thermocline is an ecological barrier which provokes stagnation in plankton populations, resulting in slow movement of the organisms. Likewise, the concentration of dissolved oxygen sets another limit for zooplankton; however, there are other species which spend their life moving to the bottom and to the surface[7,51,], as it occurs in Lake Zempoala in which *L. cuauhtemoci* is present in all the water column, but diminishes its abundances depending on depth due to the low concentrations of dissolved oxygen in the aphotic zone, by the thermal stratification effect. On the other hand, *L. cuauhtemoci* is an organism that preferred a horizontal distribution in the lake Zempoala, since it moved to the littoral zone and its movement was supported by the air streams that are shown throughout the aquatic system.

Several species of *Leptodiaptomus* have been identified in different ecosystems such as *L. novamexicanus* in hyposaline lakes of Mexico, the population living in the limnetic zone of the Lake Alchichica with an alkaline pH (8.6-9.2) and in oligo-mesotrophic waters (chlorophyll concentration at 0.17 mgm^{-3}), seems to live under conditions of low interspecific competition due to the absence of other zooplankton crustacean species under these circumstances.

Lugo *et al* [52] cited that vertical and temporary fluctuation of the copepod population depends mainly on environmental conditions, mainly during mixing and stratification periods of the lake, which determines the quantity of available food. In the temperate regions, the most influential factors in vertical migration of organisms are temperature water and lightening period, while in tropical latitudes the dry and rain season play an important role[53, 54]. However, when a variation in temperature comes up, a better distribution for the species is registered.

Sampaio *et al.*[55] mentioned that factors such as temperature water, salinity, conductivity, reservoir size, trophic and succession state can greatly influence the composition of zooplankton species; besides, either the quality or availability of food, competition and predation in natural environments act simultaneously and, can also modify the zooplankton community in different ways.

Despite the advance in the inventory of known species for Central Mexico, these works represent a small fraction of systems in the region, where the higher part of freshwater in the country is concentrated. This study covers a first stage in the gap regarding the composition of zooplankton and the behavior of the physical and chemical factors that affect spatial and temporary distribution of plankton organisms.

In Mexico, as well as in other countries in the Neotropical region, many of the environments are being threatened by human activity due to changes in freshwater systems related to pollution, and to the introduction of alien species.

This is a very important aspect for the management and conservation of water quality, an overwhelming problem in all the aquatic system throughout the country. Moreover, the prevention of ecological deterioration, it would turn out into a more productive body of water, zooplankton rich and with better fishing.

ACKNOWLEDGEMENTS

We thank everyone who kindly assisted in several parts of the work processing and providing values of environmental variables. This work was supported by the Autonomous University of Morelos State.

REFERENCES

1. G.A.Humes, How many copepods? In: Ferrari, F.D. & B.P. Bradley. (eds). Ecology and morphology of copepods. Hidrobiology, 1994, 292/293: 1-7.
2. J.Thorp & P. Covich, Ecology and classification of North American Freshwater invertebrates. Academic Press, Estados Unidos de America, 2001.
3. M.E. Elías-Gutiérrez, M. A. Suárez-Morales, M. Gutiérrez-Aguirre, J.G. Silva-Briano, Granados-Ramírez & T. Garfías-Espejo, Cladócera y Copépoda de las Aguas Continentales de México. Comisión Nacional para la Biodiversidad y Escuela Nacional de Estudios Profesionales Iztacala, Universidad Nacional Autónoma de México, México, 2008, 322.
4. R. Margalef, Limnología. Omega, S.A. Barcelona, 1983, 1001.
5. E. Suárez, J. Reid, M. Iliffe & F. Fiers, Catálogo de los copépodos (Crustacea) continentales de la Península de Yucatán, México. Comisión Nacional para el Conocimiento y uso de la Biodiversidad. El Colegio de la Frontera Sur. México, 1996, 296.
6. V.L.S. Almeida, Ê.W. Dantas, M. Melo-Júnior, M.C. Bittencourt-Oliveira & A.N. Moura, Zooplanktonic community of six reservoirs in northeast Brazil. Braz. J. Biol., 2009, 69(1): 57-65.
7. I.A. González, El Plancton de las aguas continentales. Secretaría General de la Organización de los Estados Americanos, Programa Regional del Desarrollo Científico y Tecnológico, Washington, D.C.1988, 130.
8. W. Sousa, J.L. Attayde, E. Da S. Rocha & E.M. Eskinazi-Sant'a, The response of zooplankton assemblages to variations in the water quality of four man-made lakes in semi-arid northeastern Brazil. J. Plankton Res., 2008,30 (6): 699–708.
9. J. Luna-Figueroa, T. Vargas-Zavala & J. Figueroa-Torres, Alimentos vivos como alternativa a nauplios de *Artemia franciscana* en la dieta de alevines y juveniles de *Cichlasoma istlanum*. Mesoamericana, 2010, 14 (1): 45-54.
10. R.S. Stemberg & J.M. Lazorchak, Zooplankton assemblage's responses to disturbance gradients. Can. J. Fish. Aquat. Sci., 1994, 51: 2435–2447.
11. R.M. Pinto-Coelho, J.F. Bezerra-Neto & C.A. Jr. Morais, Effects of eutrophication on size and biomass of crustacean zooplankton in a tropical reservoir. Braz. J. Biol., 2005, 65, 325–338.
12. V. Sládecek, Rotifers as indicators of water quality. Hydrobiologia, 1983, 100: 169-201.
13. N. Korovchinsky & N.N. Smirnov, Introduction to the "Cladocera" (Ctenopoda, Anomopoda, Onychopoda and Haplopoda).Supplemented for America. Study Material, Escuela Nacional de Estudios Profesionales Iztacala, Universidad Nacional Autónoma de México, México, 1998,143.
14. C. Brusca & J. Brusca, Invertebrados. 2ª Ed. McGraw-Hill, Interamericana. España, 2005, 1005.
15. E. Suárez-Morales, M. Silva-Briano & M. Elías-Gutiérrez, Redescription and taxonomic validity of *Leptodiaptomus cuauhtemoci* (Osorio-Tafall, 1941) (Copepoda, Calanoida), with notes on its known distribution. J. Limnol., 2000, 59(1): 5-14.

16. Suárez-Morales *et al.*, *Diaptomus cuauhtemoci* nov. sp. de la mesa central de México (Copepoda, Diaptomidae). *Ciencia*, 1941, 2: 296-298.

17. J.R. Bonilla-Barbosa, & R.A. Novelo, Manual de identificación de plantas acuáticas del Parque Nacional de las Lagunas de Zempoala, México. Instituto de Biología, Universidad Nacional Autónoma de México, México, 1995, 168.

18. INEGI, Anuario Estadístico del Estado de Morelos. Instituto Nacional de Estadística, 2000.

19. B.J. Bonilla, Flora y vegetación acuática vascular de las Lagunas de Zempoala, Morelos, México. Tesis de Maestría. Facultad de Ciencias. Universidad Nacional Autónoma de México, México, 1992, 134.

20. S. Santillán-Alarcón, V.D. Sorani, J.R. Bonilla-Barbosa, J. Luna-Figueroa & H. Colín,. Escenario geográfico. Capitulo 1. In: Bonilla-Barbosa, J.R., V.M. Mora, J. Luna-Figueroa, H. Colín & S. Santillán-Alarcón. (eds). Biodiversidad, conservación y manejo en el Corredor Biológico Chichinautzin. Condiciones actuales y perspectivas. Universidad Autónoma del Estado de Morelos y Consejo de Ciencia y Tecnología del Estado de Morelos, México, 2010, 315.

21. E. García, Modificaciones al sistema de clasificación de Köppen (para adaptarlo a las condiciones de la República Mexicana). México, Distrito Federal, 1988, 71.

22. S.M. Taboada, A.E. Granjeno-Colín & G.R. Oliver, Normales climatológicas (Temperatura y Precipitación) del Estado de Morelos. Facultad de Ciencias Biológicas. Universidad Autónoma del Estado de Morelos. Cuernavaca, Morelos, 2009, 258.

23. C.E. Boyd, Water quality in warmwater fish ponds. Auburn, University, Alabama, USA, 1979, 354.

24. C.E. Boyd, Water quality in warm water fish ponds. Auburn University. 2nd edition. Cramfmaster Printers, Inc.1981, 359.

25. APHA, AWWA, WPCF, Standard Methods for the Examination of Water Wastewater. 18 ed. American Public Health Association, Washington. USA, 1992, 1108.

26. R.G. Wetzel & G.E. Likens, Limnological analyses. Third edition. Springer, New York, 2000, 429.

27. M. Silva-Briano & E. Suárez-Morales, The copepoda calanoida (Crustacea) of Aguascalientes state, México. Scientiae Naturae 1998, 1: 37-68.

28. U.I.H. Salgado, El análisis Exploratorio de Datos Biológicos. Fundamentos y Aplicaciones. Marc Ediciones y Universidad Nacional Autónoma de México, México, 1992, 243.

29. L.E. Pla, Análisis multivariado: Método de componentes principales. Serie de matemáticas. Monografía No. 27. Secretaría General de los Estados Americanos. Programa de Desarrollo Científico y Tecnológico. Washington, E.E.U.U.1996, 94.

30. E.J. Dallas, Métodos multivariados aplicados al análisis de datos. Internacional Thompson, México, 2000, 566.

31. R. Sokal & F.J. Rohlf, Introducción a la bioestadística. Ed. Reverté. Barcelona, España, 1980, 362.

32. C.P.Reyes, Bioestadística aplicada. Ed. Trillas. México, 1982, 216.

33. K.M. Mustapha, Zooplankton assemblage of Oyun Reservoir, Offa, Nigeria. Rev. Biol. Trop., 2009, 57(4): 1027-1047.
34. E. Suárez-Morales & W. Reid, An update list on the free living freshwater copepods (Crustacea) of Mexico. Southwestern Naturalist, 1998, 43: 256-265.
35. E. Suárez-Morales &, M. Elías-Gutiérrez., Estado actual del conocimiento de Copépodos de aguas continentales de México. Planctología Mexicana, 2003, 8: 157-170.
36. E. Suárez-Morales, J. W. Reid & M. Elías-Gutiérrez, Diversity and distributional patterns of neotropical freshwater Copepods (Calanoida: Diaptomidae). Internat. Rev. Hydrobiol, 2005. 90(1): 71-83.
37. L.J. Chapman & D. L. Kramer, Limnological observations of an intermittent tropical dry forest stream. *Hydrobiology,* 1991, 226: 153-166.
38. M. Elías-Gutiérrez, E. Suárez-Morales & B. Romano-Márquez, A new species of *Leptodiaptomus* (Copepoda, Diaptomidae) from Northwestern Mexico with comments on the distribution of the genus. J. Plankton Res., 1999b, 21: 603-614.
39. G. Brandorff, Distribution of some Calanoida (Crustacea: Copepoda) from the Yucatán Peninsula, Belize and Guatemala. Rev. Biol. Trop., 2012, 60 (1): 182-202.
40. M. Elías-Gutiérrez, Estudio comparativo del zooplancton en dos regiones de México. El Colegio de la Frontera Sur, Informe final SNIBCONABIO proyecto No. AS019 México, Distrito Federal, 2006, 47.
41. J. Granados-Ramírez & E. Suárez-Morales, A new Light *Heperodiaptomus* (Copepoda, Calanoida, Diaptomidae) from Mexico with comments on the distribution of genus. J. Plankton Res., 2003, 25(11): 1383-1395.
42. M. Silva-Briano & E. Suárez-Morales. Illustrated record of the freshwater copepod *Leptodiaptomus dodsoni* (Calanoida, Diaptomidae) from central Mexico with comments on the distribution of the genus. Biota Neotropica, 2010, 10(2): 409-414.
43. M. Elías-Gutiérrez, E. Suárez-Morales & M. Silva-Briano. The freshwater cladocera (Orders Ctenopoda & Anomopoda) of México, with comments on selected taxa. Crustaceana, 1999, 72: 171-186.
44. G.A.M. Arroyo-Bustos, E. López-López & D. Voltolina, Planktonic crustacean assemblages of three reservoirs from the Mexican central plateau: relationships with biotic and abiotic factors. Hidrobiológica, 2008, 18(1): 75-83.
45. R.J. García, Distribución espacio tiempo del fitoplancton del lago Zempoala, Morelos México, durante un ciclo anual. Tesis de Maestría. Facultad de Ciencias. Universidad Nacional Autónoma de México. México, 2004, 36.
46. J. García-Rodríguez. & R. Tavera, Phytoplankton composition and biomass in a shallow monomictic tropical lake. Hydrobiologia, 2002, 467: 91–98.
47. J.G. Granados-Ramírez, J.L. Gómez-Márquez, B. Peña-Mendoza & M. Martínez-Alaníz., Inventario de cuerpos de agua del estado de Morelos. AGT Editor, S.A. y Universidad Autónoma del Estado de

Morelos, México, 2014, 369.

48. R.E. Carlson, A trophic state index for lakes. Limnol. Oceanogr., 1977, 22: 361-369.

49. R.J. García, Distribución espacio tiempo del fitoplancton del lago Zempoala, Morelos México, durante un ciclo anual. Tesis de Maestría. Facultad de Ciencias. Universidad Nacional Autónoma de México. México, 2004, 36.

50. E.O. Mondragón, Variación horizontal y vertical de la temperatura, oxígeno disuelto y bióxido de carbono en dos lagos del Parque Nacional Lagunas de Zempoala, Morelos, México. Tesis de Licenciatura. Facultad de Ciencia Biológicas, Universidad Autónoma del Estado de Morelos Cuernavaca, Morelos, México, 2007, 59.

51. S.C. Contreras, Contribución al conocimiento de las especies de copépodos, cyclopoides y algunos aspectos de su biología y ecología, de la presa "La Goleta", estado de México. Tesis de Licenciatura, Facultad de Ciencias. Universidad Nacional Autónoma de México, México, 1993, 79 pp.

52. A. Lugo, M.E. González, M.R. Sánchez & J. Alcocer, Distribution of *Leptodiaptomus novamexicanus* (Copepoda: Calanoida) in a Mexican hyposaline lake. Rev. Biol. Trop., 1999, 47(1): 141-148.

53. W.J. O'Brien, C. Buchanan & J.F. Haney, Artic zooplankton community structure: exceptions to some general rules. Artic, 1979, 32(3): 237-247.

54. J. Urabe, Relative importance of temporal and spatial heterogeneity in the zooplankton community of an artificial reservoir. Hydrobiologia, 1989, 184: 1-6.

55. E.V. Sampaio, O. Rocha, T. Matsumura-Tundisi & J.G. Tundisi. Composition and abundance of zooplankton in the limnetic zone of seven reservoirs of the Paranapanema River, Brazil. Brazil Journal Biology, 2002, 62(3): 525-545.

Corresponding author: Dr. José Luis Gómez Márquez,

Laboratorio de Limnología, FES Zaragoza, UNAM

Online publication Date: 12.07.2018