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Abundance and first record of benthic macroinvertebrates in Lake Metztitlan, Hidalgo, Mexico

Abundancia y primer registro de macroinvertebrados bentónicos en el lago de Metztitlán, Hidalgo, México

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ABSTRACT

Lake Metztitlan is an endorreic lake with changes in its water levels which is now confined to approximately 650 ha. These changes are a consequence of anthropogenic factors such as the use valley's soils for intensive agriculture. Therefore, in this study it was considered relevant to know the macrobenthos of this lake due to the importance of the use of benthic organisms as indicators to characterize an aquatic system. This is the first registration for Metztitlan lake. Samples were taken bimonthly with a Van Veen dredge and a mud sifted with a light of mesh of 1∅. Three hundred and sixty two organisms were identified and placed into two phyla (Annelida and Arthropoda), from the most to the least abundant, the following benthic organisms were present: *Lumbriculus variegatus, Cypris* sp., *Chironomus* sp., *Tanypus* sp., *Helobdella elongata* and *Procladius (Holotanipus)*. An increase in the abundance and number of species were observed in May and July, time in which the minimum levels of water and maximum levels of temperature occurred. The family Chironomidae was the most represented with 50% of the genus. We could say that the low abundance of Chironomids in this reservoir may be a response to the use of insecticides on the adjacent crops as well as to the predation caused by the fishes that occur in this lake (tilapia and carp species).

Key words: Metztitlan, Hidalgo, Mexico, macroinvertebrates, freshwater, macrobenthos, benthos, insects, arthrophoda, annelida.

RESUMEN

El lago de Metztitlán es endorreico y ha sufrido importantes cambios en su espejo de agua debido a que su cuenca ha sido utilizada para cultivos agrícolas intensivos. A la fecha se encuentra confinado a unas 650 ha aproximadamente. Como consecuencia del constante acarreo de materiales aportados por los cambios en los flujos de agua se consideró relevante conocer el macrobentos del lago, dada la importancia de los organismos bentónicos como indicadores de las características de los sistemas acuáticos, siendo éste estudio el primer registro para el lago de Metztitlán. Se tomó bimensualmente una muestra de sedimento con una draga Van Veen en tres estaciones de colecta. El sedimento de tipo arcilloso fue tamizado con una luz de malla de 1∅. Fueron identificados 362 organismos de los phyla Annelida y Arthropoda. En orden de mayor a menor abundancia se presentaron: *Lumbriculus variegatus, Cypris* sp., *Chironomus* sp., *Tanypus* sp., *Helobdella elongata* y *Procladius (Holotanypus)*. Se observó un aumento en la abundancia y número de especies en los muestreos de mayo y julio, época en la que se presentaron los niveles mínimos de volumen y mayores valores de temperatura. La familia Chironomidae fue la mejor representada con el 50% de los géneros. Se discute la baja abundancia de quironómidos en el embalse y se consideran como posibles causas para explicarla: el uso de insecticidas en los cultivos adyacentes y la depredación causada por tilapias, y carpas presentes en el lago.

Palabras clave: Metztitlán, Hidalgo, México, macroinvertebrados, dulceacuícolas, macrobentos, bentos, insectos, artrópodos, anélidos.

INTRODUCTION

Among the characteristics of benthic organisms is that of playing the part of indicators, as they remain on the bottom. They may be used as indicators of a system through the bioaccumulation of pollutants or through their response to alterations in the environment with respect to their presence/absence (Hawkes, 1979).

According to Margalef (1986) there are four main factors that affect the distribution of macroinvertebrates in freshwater environments: oxygen which is essential for the metabolism of aerobic aquatic organisms, dissolved and particulate organic matter of which there is much more in freshwater systems than in the sea, and surface tension which decreases in areas affected by civilization of the result of domestic and industrial runoff, particularly of detergents and insecticides of which the intensive use causes an increased eutrophy in the water.

It has been recorded that freshwater environments that are being damaged or polluted by an enrichment of organic matter, have many species that are represented by few individuals as well as a progressive increase in indicator species or species that were previously absent (Hellawell, 1986; Forbes and Forbes, 1994; Harper, 1992). Both the presence and the abundance of oligochaetes and chironomids have been used by several authors as indicators of pollution, by organic matter in the first case (Wright, 1955; Carr and Hiltunen, 1965; Howmiller and Beeton, 1971) and by pesticides in the second (Aston, 1973; Brinkhurst, 1966; Liperovskaya, 1970).

The best studied macroinvertebrates of the freshwater environments of Mexico are, at present, the mollusks, with papers on taxonomical and commercial aspects (Olivera and Polaco, 1991; Pérez-Rodríguez, 1994). The ecological and commercial aspects of macroinvertebrates have been studied by Pérez Rodríguez *et al*. (1989), Ortiz (1981) and Orozco-Hernández et al. (1993).

Considering the importance of benthic studies, the macrobenthos of Lake Metztitlan in Hidalgo was studied as part of a greater project that covers the limnological-fishery dynamics of the lake. This study also provides the first data on the infaunal macrobenthos of the lake, and contributes to the small amount of knowledge there is on the macroinvertebrates of the freshwater environments of Mexico.

STUDY AREA

Lake Metztitlan is located in the center of the state of Hidalgo, 88 Km away from the capital of the state at 20º40’ N and 98º53’ W, and at 1329 m above sea level (Fig. 1). The predominant climate in the area is temperate semi-dry with an average annual temperature of 20.2ºC an average annual rainfall of 437.1 mm, and with September, June, and July as the most rainy months (Ibáñez and García, 1999).

A particularity of this lake is that its surface area changes from year to year as a result of the expansion of the agricultural area that has encroached on the lake’s area.

Natural processes and anthropogeneic factors such as the natural silting up of the basins and the construction of an outflow tube (drainpipe) play a great part in regulating the water level in the lake (S.R.H., 1974), as a result of which the average surface of the lake has been reduced to approximately 650 ha. The drainpipe directly benefits the agricultural activities keeping the level of the lake below 10.74 m depth. During the last two decades, the lake has dried up twice in 1988 and 1998, during the last of which the basin of the lake remained dry for four months. During the rainy seasons, the surrounding agricultural areas flood and materials are carried into the lake. The sediment is clayey with more than 15% of total organic matter, which indicates that the bottom is saturated with organic substances that constantly demand the presence of oxygen (Ibáñez *et al*., 2002).

The temperature of the water varies between 16ºC in January and February, the coldest months and 26ºC during the summer (Ibáñez et al., 2002). The most important fishery in the lake is tilapia, followed with respect to catch volumes by carp, both sustained by constant stocking.

MATERIAL AND METHODS

Sampling took place bimonthly from January to November of 2000 at three sampling stations. This study presents the results of the 2000 cycle however; spaced-out sampling took place in years before and after this cycle. A sample of approximately 12 L of sediment was obtained twice with a 6 L van Veen graf sampler that covers an area of 0.0529 m^2. The sediment waster sieved through a 1∅ (0.5 mm) mesh size, and the organisms collected from the sieve were fixed and then identified using taxonomic keys. Organisms belonging to the classes Oligochaeta, Hirudinoidea and Ostracoda were identified with the keys of Edmodson (1959) and Pennak (1978, 1989), and those of the class Insecta were identified with the keys of Pennak (1978), Pinder (1983) and Merritt and Cummins (1996).

RESULTS AND DISCUSSION

Organisms collected represented the phyla Annelida and Arthropoda and the classes: Oligochaeta, Hirudinoidea, Insecta and Ostracoda (Table 1). Species recorded in order of

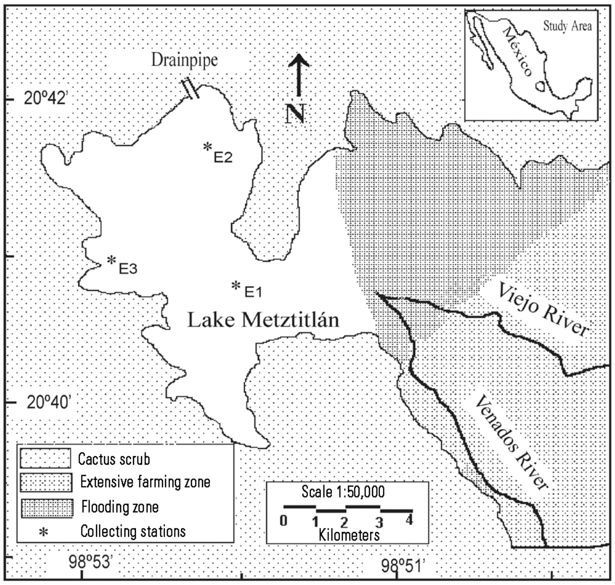

Figure 1. Study area of monitoring stations.

abundance were: *Lumbriculus variegatus, Cypris* sp, *Chironomus* sp, *Tanypus* sp, *Helobdella elongata* and *Procladius (Holotanypus)*. On the spatial scale the greatest abundance and richness of genera were recorder at station 3, probably due to this area being the deepest and remaining under water for the longest time during the drought (with a minimum depth of 10 to 20 cm). This station presented the greatest amount of organic matter that remained from the food used for the culture of tilapia in floating cages.

Although the abundance of the greater part of the organisms was low, an increase was recorded for May and July, mainly due to the higher abundance values of *Lumbriculus variegatus* and *Cypris* sp. The number of species also increased between May and July (Fig. 2). This might be related to the fact that the lake had its lowest volume and highest temperature during the spring and early summer (Ibáñez *et al.*, 2002). The greatest rainfall in the area occurs during September, together with runoff of materials from the cultivation areas adjacent to the lake (mainly pesticides). It is important to note that the species that were missing in September were those of the three genera of the family Chironomidae.

The presence of *Cypris* sp, *Chironomus* sp, *Tanypus* sp, and *Procladius [Holotanypus]*, is explained by the fact that they are carrion eaters as Pennak (1989), Pinder (1983) and Merritt and Cummins (1996) have recorded. *Lumbriculus variegatus* and *Helobdella elongata*, are detritivores (Edmonson, 1959; Pennak, 1978), Barnes and Edwards (1996) have mentioned that *Helobdella elongata* is also an hematophage species that may be a parasite of vertebrates and invertebrates. Hellawell (1986) has also recorded the genus Helobdella in eutrophic and moderately polluted habitats.

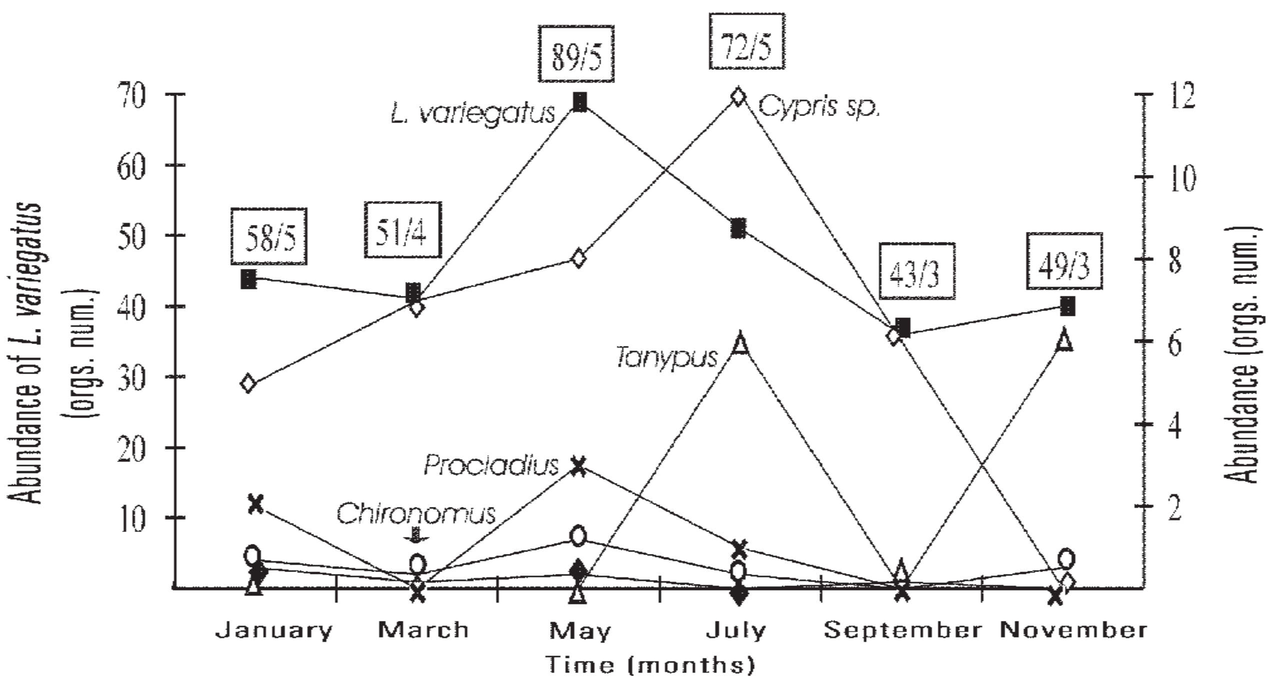

Figure 2. Temporal abundance of macroinvertebrates of Lake Metztitlan. Left scale is for *Lumbriculus variegatus*. Rigth scale all the others. In the square in the numerator is indicated the abundance; in the denominator is indicated the number of species.

Ibáñez *et al*. (2002) have recorded concentrations greater than 15% of total organic matter in the sediments of the lake. Together with these high concentrations of organic matter, values of dissolved oxygen in the water column varied between 3 mg/L at the bottom and 7 mg/L at the surface. The low concentration of dissolved oxygen at the bottom of the lake presents a barrier to the establishment of communities of organisms that don't have a mechanism that allows them to tolerate concentrations of 3 mg/L and lower of dissolved oxygen (Pennak, 1978).

Harper (1986) and Heines (1993) have mentioned that some benthic invertebrates use different mechanisms to deal with adverse environmental conditions for example, *Lumbriculus variegatus* and *Chironomus*, have hemoglobin as a physiological adaptation that favors a greater absorption and transportation of oxygen (Pennak, 1978). This characteristic is present in organisms in environments with little oxygen. The class Insecta (*Chironomus, Tanypus* and *Procladius [Holotanipus]*), also presents other morphological adaptations such as anal an ventral gills that according to Pennak (1978), serve to enhance the absorption of the dissolved oxygen that is found on top of the water-sediment interphase.

The low abundance of organisms is a notable feature in this lake, as the total density recorded was 70 org/m^2 whereas in others environments the density might vary from 350 to 95,000 org/m^2 (Table 2). In general, the greater percentage of the density of the organisms is reported by the oligochaetes, which are used in freshwater environments as indicators of organic pollution (Wright, 1995; Carr and Hiltunen, 1965; Howmiller and Beeton, 1971; Slepukhina, 1984). In this study, the greatest abundance corresponded mainly to *Lumbriculus variegatus*. However, its abundance is not as great as would reflect the high concentrations of organic matter in the lake (15% of total organic matter), and although the bottom oxygen does not present high values (minimum 3 mg/L) they are not low enough to cause such an overall low density. Which could be the causes of the low density of macroinvertebrates in the lake? It is not difficult to correlate the runoff of pesticides and organochlorated insecticides, from the regime of intensive cultivation adjacent to the lake (Fig. 1), of which the use is reported by the Health Secretariat (2000), with the low abundance in the macrobenthos.

Conditions in this lake change markedly, as in 1998 it remained practically dry for four to five months. It slowly filled up from September of the same year on, and allowed the re-establishment of macroinvertebrates with short life cycles and type "r" reproductive strategies (Krebs, 1985). This entails a rapid population growth in a short period of time after the

Table 1. Total abundance of organisms at collect sampling stations.

Organism	Sampling stations			Total abundance	Percentage
	1	2	3	of organisms	abundance (%)
Phylum ANNELIDA					
Class OLIGOCHAETA					
Family Lumbriculidae					
Lumbriculus variegatus (Müller)	96	66	119	281	77.7
Class Hirudinoidea					
Family Glossiphoniidae					
Helobdella elongata (Castle)	6	0	1	7	1.9
Phylum ARTHROPODA					
Class INSECTA					
Family Chironomidae					
Chironomus (Meigen)	7	1	10	18	4.9
Tanypus (Meigen)	1	3	8	12	3.4
Procladius (Holotanypus) (Skuse)	0	3	3	6	1.6
Class OSTRACODA					
Family Cyprinae					
Cypris sp.	6	26	6	38	10.5
Total abundance by station	116	99	147	362	100

Table 2. Macroinvertebrates density from different dams.

Author	Dams/Location	Density (org/ m^2)
Ökland (1964)	Borrevan/ Noruega	790-1,668
Saavedra (1982)	Pátzcuaro/ Mexico	350-2,070
Kasprzak (1984)	Zbechy, Polonia	768.6
Slepukhina (1984)	Ladoga, Europa	4,000-22,000
Montoya y Soriano (1995)	Alchichica/ Mexico +	38,247 *
Montoya y Soriano (1995)	Atexcac/ Mexico +	34,240 *
Montoya y Soriano (1995)	La Preciosa/ Mexico	26,975 *
Montoya y Soriano (1995)	Aljojuca/ Mexico	18,747 *
Montoya y Soriano (1995)	Tecuitlalpa/ Mexico +	7,390 *
Alcocer *et al*. (1997)	Totolcingo/ Mexico +	12,000-95,000
Mangeaud y Brewer (1997)	Suquia/ Argentina +	5,471.15
Oseguera (1997)	Tecuitlalpa/ Mexico +	84,552
Present estudy	Metztitlan/ Mexico	70

+ Saline dams. * Density due to oligochaetes species.

flooding of the basin and with it a progressive increase in the density of organisms. When comparing with the samples collected in the Spring three years after the flooding (Table 3), the maximum density was observed in May of 2000, with an increase in organisms of approximately 300% with respect to the previous year and 2002. So the time it took for the lake to fill up is not the reason for the low abundance, only the number of species increase, in accordance with Margalef (1986) who mentioned that the benthic community attains its composition after approximately a year and does not change substantially after that. In this case, only the genus *Chaoborus* (Table 3) was added to the species list after the sampling of April 2002 when the same technique was used. This genus present aereal sacs for gaseous interchange as an adaptation to low concentrations of dissolved oxygen (Borror *et al*., 1992).

The taxonomic group with the greatest number of genera was the family Chironomidae (with 50% of the genera). This coincides with the finding of Armitage *et al*. (1995) who indicated that the taxonomic group that is best represented in lakes is that of the family Chironomidae, with approximately 50% of the genera of the macrobenthos.

Among the probable reasons that cause a low abundance of chironomids in the Metztitlan lake, are the insecticides and predation. Insecticides such as malathion, fenthion, deltamethrin, permethrin and diazinon, used in agriculture to control plagues are carried by the rains into the lake. According to Mason (1994) these are used to control the abundance of chironomids and it is recorded that they are used in the cultivation fields adjacent to Lake Metztitlan (Comision Nacional del Agua, 2000). It is important to note that chironomids were absent during September, the month with the greatest rainfall and runoff of materials into the lake. Additionally, according to Mann (1957) and Elliot (1973) many invertebrates including leeches prey on the larvae and pupae of chironomids. Within the sediment of Lake Metztitlan, *Helobdella elongata* might feed on the larvae of the family Chironomidae. Armitage *et al*. (1995) mentioned that there are several fish that feed on chironomid larvae, including the carp and the tilapia, which constitute the main fisheries on this lake (Ibáñez and García, 1999). It is known that *Cyprinus carpio* has been introduced to control the populations of mosquitoes in the United States of America (Armitage *et al*., 1995).

Tudoroncea *et al*. (1988) have mentioned that chironomids larvae represent an important source of food for the juvenile stages of the tilapia *Oreochromis niloticus*, with lengths of 25–30 mm.

The clayey type of sediment, the percentage of total organic matter, the concentration of dissolved oxygen and the temperature, are characteristics that allowed the establishment of the community of macroinvertebrates that was found. The low abundance of chironomids is possibly being affected by the use of insecticides in the adjacent agricultural lands, together with predation by fish such as tilapia and carp.

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Table 3. Macroinvertebrates total abundance in the spring of 1999, 2000 and 2002.

	May (99)	May (00)	April (02)
Phylum ANNELIDA			
Lumbriculus variegatus (Müller)	10	69	12
Helobdella elongata (Castle)	2	2	0
Phylum ARTHROPODA			
Chironomus (Meigen)	6	7	1
Tanypus (Meigen)	0	0	3
Procladius (Holotanypus) (Skuse)	1	3	2
Chaoborus sp.	0	0	2
Cypris sp.	4	8	4
Total	23	89	24

quitoes, José Alejandro Gamboa Contreras for his help in the identification of the macrobenthic organisms, José Luis García Calderón suggestions and comments on the manuscript, Irene Barriga Sosa for her encouragement and review of the abstract, Roberto Torres-Orozco Bermeo for providing very useful bibliography, and finally the fisherman of the San Cristóbal cooperative for their help in the field.

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