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Zoobenthos in the Xhimojay Dam, State of Mexico

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Abstract: Monthly samplings were carried out during 2013 in the Xhimojay dam, Jilotepec, Estado de Mexico with the objective of determine changes in the composition and abundance of zoobenthos throughout time and its relationship with environmental conditions of their habitat. The organisms were collected performing trawls 1 m2. The samples were sieved and the obtained organisms were placed in vials for fixing. The different groups were identified to a permissible level, organisms each taxa were counted and weighed. 19 orders belonging to nine classes were identified, the insects were the group with highest richness, Order hemiptera were more abundant (29.81%) and decapods were the most ecologically important for the system (89.83%). Diversity (0.7 decits) and evenness (0.63), although on average it is low, is normal for this type of systems and presented variations during the year, mainly due to the rainy and dry seasons, registering in August the highest value (H′= 0.9117 decits and J′= 0.7751) and in February the lowest value (H′= 0.4949 decits and J′ =0.4753). Distribution, presence and abundance of zoobenthos, is changing along the year due to the biology of each of the groups, as well as variations in the volume of water in the system due to the seasonality of rainfall and dry and use of this body of water for agriculture, livestock and domestic use, therefore, the factors that most determine the distribution and abundance of the zoobenthos, were depth, pH, and transparency.

Keywords: Zoobenthos, Abundance, Richness, Composition, Distribution, Dominance, Dam

1. Introduction

Benthic animals constitute a highly diversified group and its study represents a contribution to ecological and economic aspects, as part of the food web and energy transfer (Juárez and Ibanez, 2003) since they are the main element in the food of important commercial species because they serve as a link between the food (for example microorganisms detritus, algae, vascular aquatic plants) and fish as well as other vertebrates of higher trophic levels (Merrit and Cummins, 1996). They are also one of the main sources of supply of fish species susceptible to exploitation by man, which since decades ago has been concerned with determining the type of food that eat economic and nutritional value fishes (Hurtado *et al*., 2005).

The study of benthic fauna presents important aspects of the aquatic ecology, as it is part of the food web. Also it helps the sediment degradation and provides nutrients to the environment, by the metabolic activities of movement and excretion so they can be reused by the primary producers, keeping the plant and animal production (Kajak and Hillbricht, 1972).

The distribution of these microorganisms is ubiquitous and they are normally abundant. Their presence is directly influenced by the physical and chemical water conditions. For this reason the use of macroinvertebrates as bioindicators has become a common practice in water bodies that began over 100 years ago in Europe and currently is a tool very useful and relatively low-cost (Springer, 2010a). Because of their high abundance, they are practically in all freshwater ecosystems, its size is sufficient to see them with the naked eye and collection is simple and low-cost (Chapman, 1994; Solimini*et al.,* 2006; Gamboa*et al.,* 2008). Ecological processes such as primary production, decomposition of organic matter and nutrient cycling depend on specific biotic communities constituted by many different species (Covich, 2006). When the local extinction of a species occurs, emerges an uncertainty related to the resilience of the ecological community and ecosystem processes that support nutrient cycling and productivity, which are the basis for essential ecosystem services (Covich*et al.,* 2004).

The term Zoobenthos refers to the fauna of invertebrates inhabiting the submerged substrates of the aquatic environment. In the zoobenthos macroinvertebrates and microinvertebrates are distinguished. Macroinvertebrates are relatively large size invertebrates or visible to the human eye and not less than 0.5 mm.

Comprise mainly arthropods such as insects, arachnids and crustaceans and within these dominate insects, especially their larval forms; also found oligochaetes, hirunidea and molluscs and less frequently coelenterates, bryozoans or flatworms. Macroinvertebrates are the dominant group in rivers, lakes and wetlands. The microinvertebrates group the smaller invertebrates, generally less than 1 mm and form part of these protozoa, nematodes, rotifers, cladocerans, ostracods, copepods and mites (Alba-Tercedor*et al.,* 2005; Hanson *et al.,* 2010).

Despite its importance, for the case of Mexico, there are few studies on the components of zoobenthos in different bodies of water. Because of this, the objective of this study was to determine changes over time in the composition and abundance of zoobenthos in the Xhimojay dam.

2. Material and Methods

Monthly samples from January to December 2013 were performed at the Xhimojay dam, Jilotepec municipality in the Estado de Mexico. The collection of zoobenthos was performed with a water bottom net with aluminum frame with rectangular mouth mark WaterMark 25.4 cm by 45.72 cm to 25.4 cm deep, handle 152.4 cm and an aperture of 500 µm (network approved by the United States Environmental Protection Agency for reliable sampling of benthic organisms in rivers, lakes, dams or reservoirs) (Forestry Suppliers Inc., 2005; Ramírez, 2010a). In each sampling was performed a trawl of 1.0 m2. The samples were sieved and the organisms obtained were fixed with 10% formalin, were placed in previously labeled containers (Ramírez, 2010a) and transported to the laboratory of Ecology of Fishes in the Facultad de EstudiosSuperioresIztacala, UNAM.

The different groups were identified to a permissible level with the keys of Ruttner-Kolisho (1962), Needham and Needham (1978), Merrit and Cummins (1996), Thorp and Covich (2001), Flowers and de la Rosa (2010), Gutiérrez-Fonseca (2010), Ramírez (2010b) and Springer (2010b).

The organisms of each group were counted and weighed on a digital scale Acculab VI-1 mg with a capacity of 120 g and 0.001 g accuracy; abundance was standardized in individuals/m2 and g/m2.

The value of ecological importance was determined (VEI 300%) from the relative dominance, relative density and relative frequency. The ecological diversity was estimated using the Shannon-Wiener index (H') with the logarithm base 10, evenness (J') using Pielou index (Pielou, 1975), and dominance using the inverse of evenness index obtained from the program PRIMER 6 v.6.1.6 (Brower *et al.,* 1998; Clarke and Warwick, 2001; Krebs, 2014).

The similarity between the sampled months and density of the collected groups was obtained with the program PRIMER 6 v. 6.1.6; to perform a quantitative, politetic and agglomerative hierarchical classification analysis was used the index of Euclidean distances weighted and for the construction of the phenogram was used the average ligament criteria (Brower *et al.,* 1998; Clarke and Warwick, 2001; Krebs, 2014). An analysis of indirect ordination by principal component analysis (PCA), to define the factors that determine variations in the density of zoobenthos community was applied using the program PRIMER 6 v.6.1.6 (Brower *et al.*, 1998; Clarke and Warwick, 2001; Krebs, 2014).

3. Results

The system was characterized with an average depth of 57.01 cm, with a minimum of 25.5 cm in August and a maximum of 92 cm in February, average transparency of 30.36 cm, with a minimum of 8.50 cm in June and a maximum of 62 cm in February, water temperature average of 20.86 °C, with a minimum of 17.1 °C in March and a maximum temperature of 25.53 °C in October, dissolved oxygen averaged 8.78 mg/L with minimum of 6.33 in September and a maximum concentration of 11.24 mg/L in December, an average conductivity of 144.28 mS was recorded, with a minimum of 80.83 mS in August and a maximum of 234.85 mS in May. An average pH of 9.39, with a minimum of 7.8 in March and a maximum of 13.78 in December was recorder.

The Group of zoobenthos was composed by 19 Orders: Planorbidae, Lymnaeidae, Physidae, Calanoida, Cyclopoida, Ostracoda, Cladocera, Amphipoda, Decapoda, Ephemeroptera, Odonata, Hemiptera, Coleoptera, Diptera, Hymenoptera, Hydrachnida, Hyrudinea, Oligochaeta and Anuraelonging to nine Classes and a total of 15643 organisms.

The Group of insects was dominant throughout the study, but nonetheless by biomass the decapods were the most significant (Fig. 1). However, there were monthly variations, being Hemiptera the group with the highest relative density with 43.98 ind/m2 in January and 60.18 ind/m2 in February, in July, the highest abundance was represented by Coleoptera with 25.67 ind/m2 and amphipods showed an abundance of 53.00 ind/m2 in March (Fig. 2).

During the annual cycle was presented a richness of 19 orders, with the greatest richness in October and November with 16 orders and the lowest in March with 10 orders. Of which Hymenoptera, Oligochaeta, Anura and Lymnaeidae are considered rare groups, while Physidae, Amphipoda, Decapoda, Ephemeroptera, Odonata, Hemiptera and Coleoptera were presented throughout the study (Fig. 3).

According to VEI, decapods were the group with the highest values because in March, April, May, July, August, September and November months had the highest biomass. During the months of January, February, October and December, values higher importance were obtained by Hemiptera since during all sampling obtained the greatest abundance, and specifically during these months a decrease occurred in the density of decapod (Fig. 4).

The estimated annual average diversity was 0.7 decits with evenness of 0.63, although variations were estimated during the sampling cycle, since in August, the highest value was recorded (H´= 0.9117 decits and J´= 0.7751) and in February the lowest value (H´= 0.4949 decits and J´=0.4753). The highest diversity values were recorded in the dry season when decreasing water volume. This change in the water level means a reduction in the size of habitat (Fig. 5).

The classification analysis determined a first group comprising for the months of April and May being similar because of the greater abundance of decapod throughout the sampling. A second group formed by June, July, August and September grouped by the greater abundance of Coleoptera. Finally, a third group by grouping the months of January, February, March, October, November and December as they have the greatest abundance of Hemiptera (Fig. 6).

The ordination analysis determined that the depth (main component 1 with 36.6% of explained variance) and pH (main component 2, with 25.4% of explained variance), were the most influential factors in variations of the distribution and abundance of zoobenthos community, but said importance of environmental factors change according to the behavior of the system in rainy and dry season (Fig. 7).

Three groups were obtained: January and February influenced by the depth and pH, the second composed of October, November and December only influenced by pH and the third group formed by March, April, May, June, July, August and September without influence of any of the two variables.

In Table 1 the values of the mean and standard deviation of the physicochemical parameters recorded on the Xhimojay dam during the annual cycle 2013 are presented. The system was characterized as temperate (20.86 °C), oversaturated dissolved oxygen (8.77 mg/L), with a high damping capacity (pH 9.39) and hard water (conductivity of 144.27 mS).

Were collected 3053 organism corresponding to four species and four families: Atherinopsidae represented by *Chirostoma jordani* (Woolman, 1894), Goodeidae by *Girardinichthys multiradiatus* (Meek, 1904), Poeciliidae by *Heterandria bimaculata* (Heckel, 1848) and Cyprinidae represented by *Cyprinus carpio* (Linnaeus, 1758).

The best represented species was *G. multiradiatus*with 1501 females and the species with less number of organisms was *H. bimaculata* with 121 males (Fig. 2).

The VEI demonstrated than females of *G. multiradiatus* are organisms of greatest importance with 89.7%, while males of *H. bimaculata* were those of lower VEI with 24.71% (Fig. 3).

It was estimated the value of diversity (H') and evenness (J´) of the months sampled during the study.

October was the most diverse month with a value of 0.74 and an evenness of 0.95 (Fig. 4).

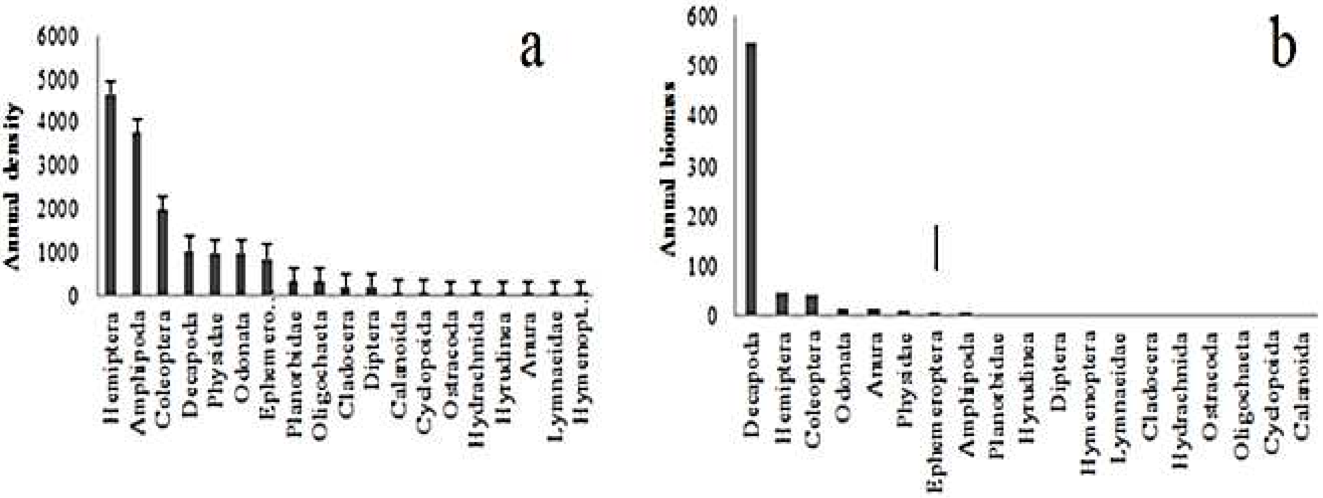

Figure 1. *Density (a) and biomass (b) annual in the Xhimojay dam.*

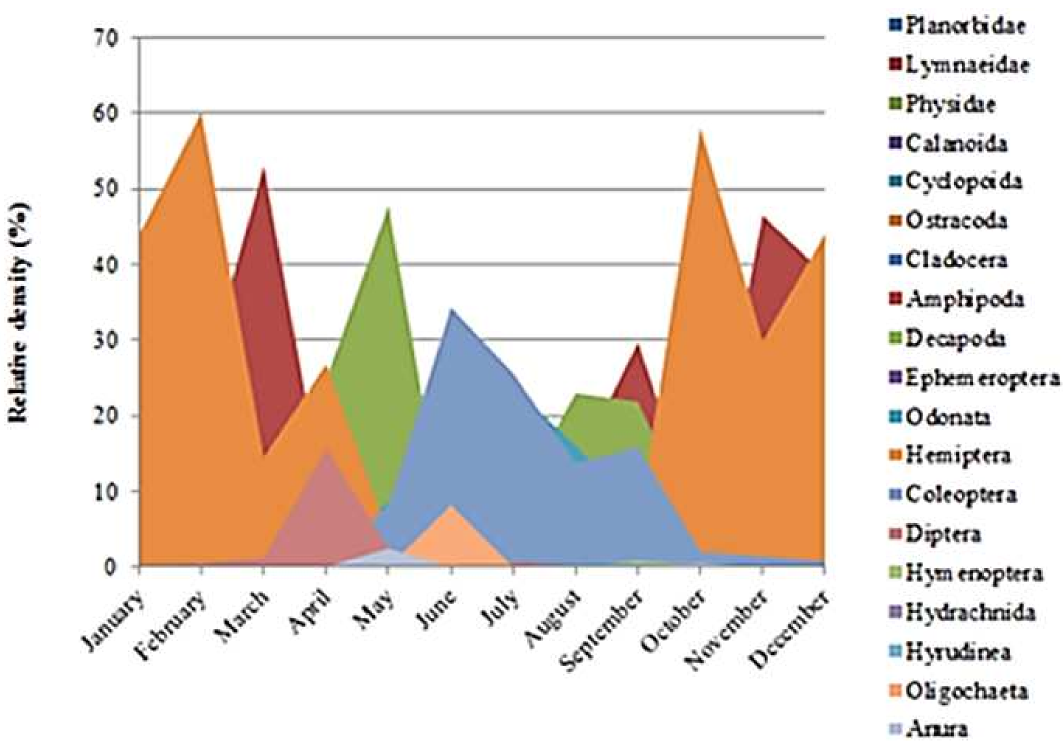

Figure 2. *Annual relative density at the Xhimojay dam.*

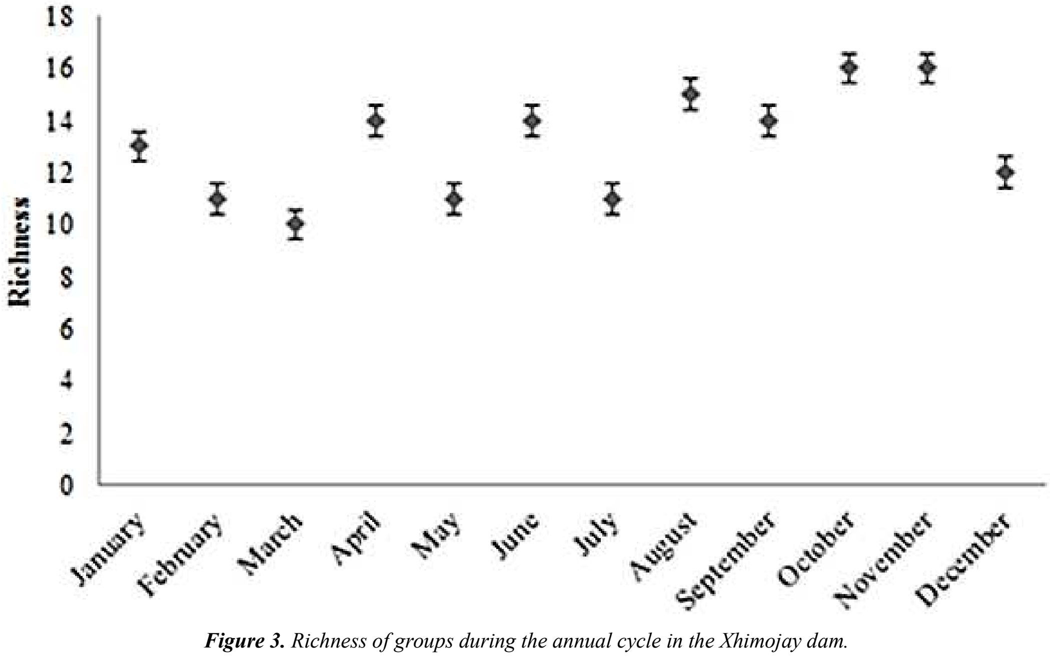

Figure 3. *Richness of groups during the annual cycle in the Xhimojay dam.*

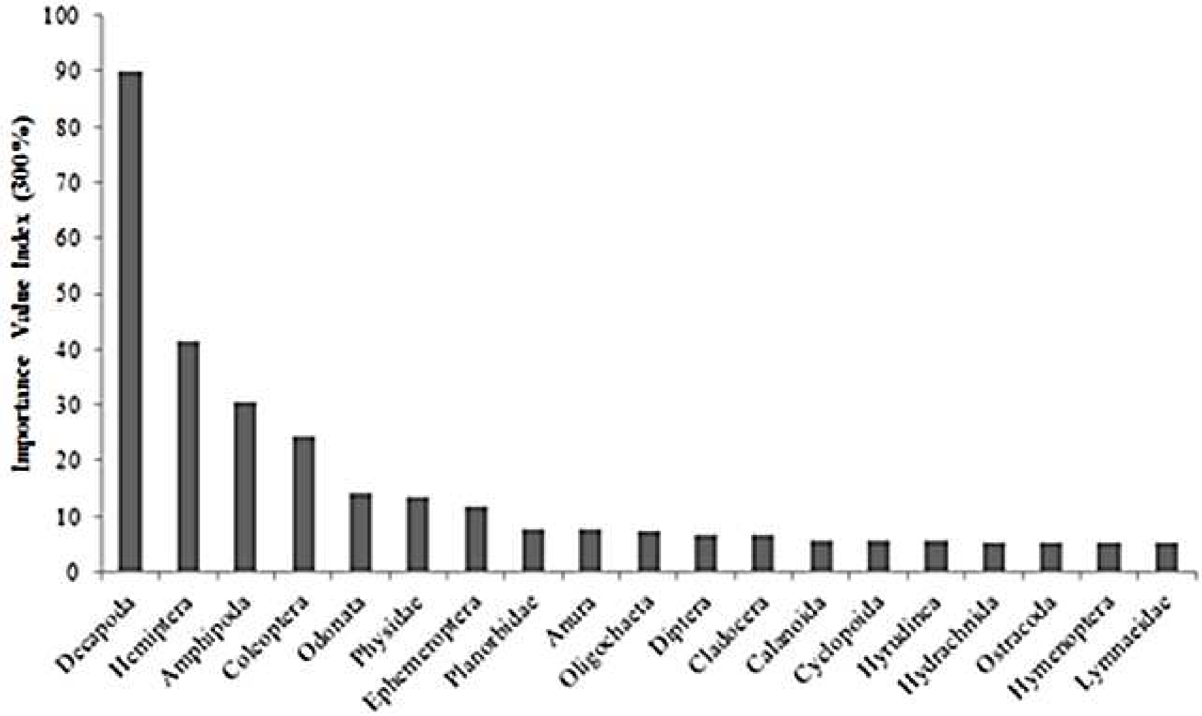

Figure 4. *Value of annual ecological importance in the Xhimojay dam.*

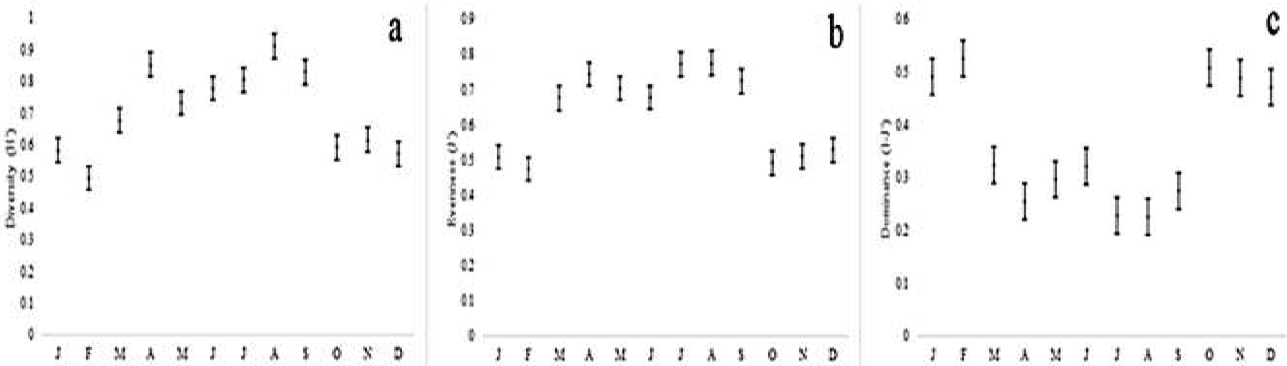

Figure 5. *Monthly variations in a) diversity (H'), b) evenness (J') and c) dominance (1-J) (standard error is presented for each parameter).*

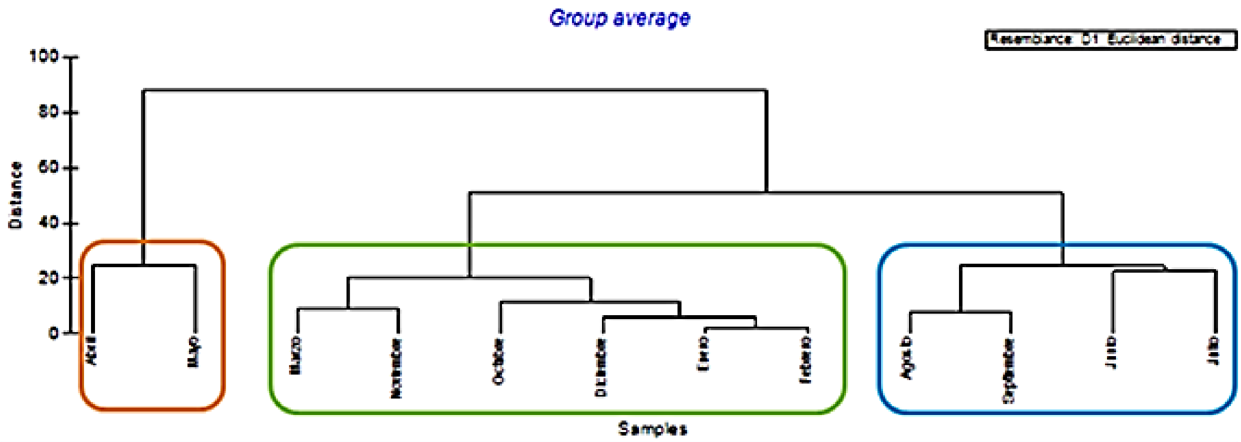

Figure 6. *Phenogram from monthly samples in Xhimojay dam according to the abundance of organisms (ind/m2) during the annual cycle.*

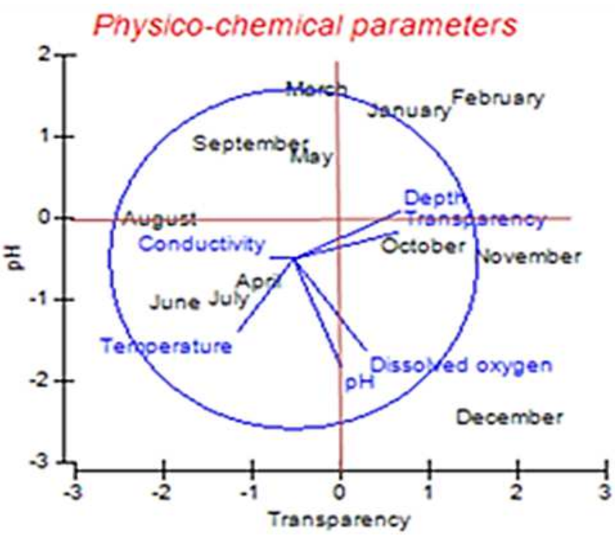

Figure 7. *Ordination diagram, where the vectors of environmental variables are represented during the annual cycle 2013 in the Xhimojay dam.*

4. Discussion

The dam showed a marked seasonal change for the majority of registered factors, common aspect in this type of water bodies in the Estado de Mexico, in where the rainy and dry periods determine their specific hydrological characteristics (Fig. 8).

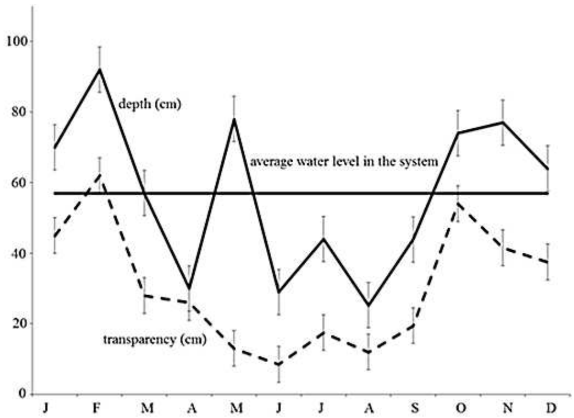

Figure 8. *Changes in the depth and transparency during the annual cycle 2013, in the Xhimojay dam.*

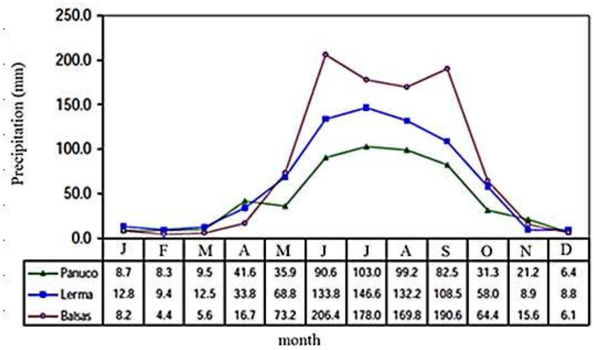

Figure 9. *Average monthly precipitation for hydrological region (Modified from INEGI, 2006).*

The depth varied in each month due to decreased water levels by the drought and water use for agriculture and domestic use, in addition to terrain stoniness. Transparency results are mainly due to planktonic organisms and organic matter in the sediment, In the case of this, also found the presence of native material (detritus) and allochthonous (cattle feces, garbage and contribution from rivers).

There are no studies providing information about the species found in the waters of many reservoirs distributed in different areas of Mexican territory, this due to many reservoirs and dams are being used for various activities such as irrigation, this derives into the loss of species in these freshwater systems which alters the stability thereof (Kinzig*et al.,* 2002). There are records of the existence of 13935 lentic water bodies in the Mexican Republic, of which the major number locates in the geoeconomic Central-Western zone that includes the states of Jalisco and Michoacan, following in importance the Central-Southern and the North zone (FAO, 2000). Within these, reservoirs and dams are essential because they serve to regulate the water supply for agriculture, hydropower generation, water supply to cities and industry (Margalef, 1983).

Benthic organisms in a body of water epicontinental are strongly affected by changes in the environment in which they are located; these can be of different types, such as weather, local geochemical changes (White and Miller, 2008), distance from the littoral zone, depth, oxygenation and water quality, predation by certain groups, sediment composition, altitude of the lake and the life history of organisms (Payne, 1986).

As in the majority of studies on aquatic macroinvertebrates, insects were found to be the most abundant and diverse group (Hanson *et al.,* 2010) and of these the hemipterous were the dominant; Contreras *et al.* (2009), reports that this is a group that is presented in shallow waters with an average of 35 cm, conditions similar to those presented during the samplings conducted for this study in which the average depth was 57 cm; In the same way these authors mention that the suitable temperature values for its development are above 10 °C, on the present study, was registered a minimum temperature of 17.1 °C, which promotes the reproductive process and therefore the increase in abundance.

The group of decapod particularly crayfish or shrimp river, was the most dominant because of its biomass and therefore the most important ecological, And its presence is an important factor in the processing of the organic matter, the transformation and flow of energy (Hobbs, 1991), as they act as predators of groups such as oligochaetes, dipteran and insect larvae in general, prey present in significant abundance in the system (Williner and Collins, 2013).

Contreras and Navarrete (1995), collected 11 zoobentónic groups in the reservoir San Miguel Arco, Estado de Mexico, belonging to the hydrologic region Lerma, that richness was considered low for the reservoir, so the richness obtained for Ximojay (19 groups) can be considered high, these differences may be due to seasonality between dry and rainy period and consequently the average rainfall in both regions, although in the region of Panuco to which the dam under study in this research belongs, it rains less (Fig. 9).

Quiroz *et al.* (1999), evaluated aspects of the abundance and distribution of major groups of benthic fauna in Lake Zempoala in the state of Morelos corresponding to the region of the Balsas, collecting a total of 10618 organisms on an annual cycle (fewer than those reported in this study), determined that the benthic abundance is related to seasonality, observed a decrease in abundance during the spring-summer period and an increase in autumn-winter, similar behavior with the temporality of abundance recorded in the Xhimojay dam despite belonging to the Panuco, since at beginning the rain season the water level increases and increases the number of individuals. The differences in the abundance of zoobentonic groups among water bodies are due to monthly average rainfall that determine variations in water level systems and thus, in environmental conditions of the habitat, and as observed in Figure 9 although the hydrologic region of Panuco the average monthly rainfall is lower, compared to Lerma or Balsas that is the highest, a higher density of organisms was collected, so the Xhimojay dam could be assumed that despite its low rainfall, has the resources necessary for the broad development of the species that inhabit it.

Hurtado *et al.* (2005), determined that the distribution and abundance are influenced by changes in the water level and the type of substrate for the stream Boyecito, in Queretaro and belonging to the hydrologic region Lerma, which agrees with that observed in the present study, wherein was seen that the depth plays an important role in the development of the group of zoobenthos.

With regard to the ecological diversity, Hurtado *et al.* (2005), estimate a maximum value of diversity of 0.99 decits for Boyecito stream, in Querétaro, that when compared with the estimate for the dam Xhimojay is higher. Likewise for a reservoir in the region of Aligarh, in which obtained a diversity annual average of 0.99 decits and a maximum of 1.07 decits during the month of August, which coincides with the present study, the same authors mentioned that this is due to the physical alterations in terms of water flow, temperature, concentration of ions and substrates since they are the main factors that determine the composition and abundance of benthic invertebrates. The benthic insect density may be high during the winter because it is influenced by the variation of the water temperature (Kabir *et al.,* 2013). This situation reflects the characteristics of annual rainfall of each hydrologic region that determines the behavior of the rainy season and dry and therefore in water levels, as was indicated above. Moreover, although during the dry period where there is less water in the system level, and it might be thought that there is a stress for the organisms, the dominance of groups as crayfish and insects decreases, causing that ecological diversity values rise statistically.

Aquatic organisms present in the bodies of water such as rivers, lakes or reservoirs may reflect the water quality (Alba-Tercedor*et al.,* 2005), on the one hand ostracods are a group that is characterized by living in shallow and temporal areas, they are organisms highly eurioic covering broad ranges of physical-chemical water as conductivity, dissolved oxygen and alkalinity. The mayflies are a group of short life cycle, prefer clean water so they are susceptible to changes in chemical concentrations of water, so they are indicators of the quality of the same (Pujante, 1997), there are records in which it is mentioned that this group is restricted to waters with relatively high concentrations of oxygen or moderate amounts of organic matter (Robback, 1974). In this sense the concentrations of dissolved oxygen registered for Xhimojay dam (avarage concentration of 8.77 mg/L), indicate that the water is supersaturated or hyperoxygenated, attributed to a high photosynthetic activity phytoplanktonic species (Gama *et al.,* 2010), which could reflect a good quality of water from the dam due to the presence of these organisms (Springer, 2010a).

The benthic organisms possess certain adaptive mechanisms through which they react to changes in its environment, either by entering to sleep states or dying; adaptive capacity of benthic animals within their physiological limits, regarding the dynamics of environmental parameters and food availability is essential for distribution, growth and productivity (Wetzel, 1981).

The importance of ecological studies in communities is based on that these can explain the distribution and abundance of organisms, for which requires an understanding of the interactions that these establish with the environment. In general, changes in the organization of the species that are forming populations, and these in turn communities, will be determinant for understand the functioning and establishment of interacting superior systems (ecosystems). Particularly, the importance of studies on freshwater zoobenthoscommunity, lies both in its position as one of the first that supports higher levels communities and its high sensitivity to changes in the environment to be considered as indicators of the quality of water bodies, in which are presented (Alba-Tercedor *et al.*, 2005). Their study also allow us to give a follow up on the evolution of particular environments where they are established.

We can concluded that a) The system was characterized as temperate (20.86 °C), dissolved oxygen supersaturated (8.77 mg/L) with a high damping capacity (pH 9.39) and hard water (conductivity of 144.27 mS), normal conditions for this type of water bodies belonging to the hydrologic region of Panuco, b) The annual species richness was in total of 19 taxa, c) The insects were the richest and variant group, Hemiptera were denser and decapods were those with biggest biomass, d) According to the seasonality of rainfall and dry, the more fluctuating groups were amphipods (March, September and November), decapod (May and August) and Coleoptera (June and July), e) Decapods were the group with the highest VEI (89.83%), f) The average annual diversity was 0.7 decits with an evenness of 0.63, with a minimum of 0.49 decits in February and evenness of 0.4753 and a maximum of 0.91 decits and evenness of 0.7751 in August. g) The fluctuations in the ecological characteristics presented of the zoobenthos group, are mainly associated with the decrease of the volume of water in the system, as well as to the intrinsic variations in the biology of each of the groups and h) The variations of the water volume of the system are related to the rainy season (precipitation) and dry (evaporation and to meet domestic and economic activities such as agriculture).

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