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Seasonal variations in zooplankton abundances in the Iturbide reservoir (Isidro Fabela, State of Mexico, Mexico)

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Abstract

This study was undertaken to quantify the seasonal variations of zooplankton (rotifers, cladocerans and copepods) and selected physico-chemical variables (temperature, pH, conductivity, Secchi disc transparency, dissolved oxygen, ammonia, nitrate and phosphate concentrations) in the Iturbide dam. Monthly zooplankton samples (50 l filtered through 50 µm mesh, in duplicates from each of the 4 stations) were collected from February 2008 to January 2009. Simultaneously physico-chemical variables were measured. The zooplankton samples were fixed in 4% formalin in the field. In general, the temperature ranged from 9 to 16°C, rarely exceeding 20°C. Secchi transparency was nearly 100% since the reservoir was shallow (<2 m) even during the rainy seasons. Dissolved oxygen was generally high, 13-18 mg l^{-1}. Nitrate levels (10 to 170 µg l^{-1}) were low while phosphates were relatively high (9 to 35 µg l^{-1}). The Iturbide reservoir was dominated by rotifer species. We encountered in all, 55 taxa of rotifers, 9 cladocerans and 2 copepods. The rotifer families Trichocercidae and Notommatidae had the highest number of species (7 each) followed by Colurellidae and Lecanidae (6 and 5 species, respectively). *Trichocerca elongata*, *Ascomorpha ovalis*, *K. americana*, *K. cochlearis, Lepadella patella* and *Pompholyx sulcata* were the dominant rotifers during the study period. On an annual average, rotifer density ranged between 50-200 ind. l^{-1}. Among crustaceans *Chydorus brevilabris* and *Macrothrix triserialis* were most abundant. The maximal density of these cladocerans was about 50 ind. l^{-1}. Copepods were much lower in numbers (<20 ind. l^{-1}). In general the density of zooplankton was higher during summer months (April to July) than during winter. Shannon-Wiener diversity index varied from 1.0 to 4.3 depending on the site and the sampling period. Based on the data of Secchi transparency and nutrient concentrations, the Iturbide reservoir appeared to be mesotrophic.

Key words

Rotifera, Cladocera, Copepoda, Limnology, High altitude reservoir

Introduction

Mexico has a large number of freshwater bodies. There are about 70 lakes with an area ranging from 1000 to 10,000 hectares) and about 14, 000 reservoirs of 10 hectares area or less (De la Lanza and García, 2002). In spite of such a large number of waterbodies, plankton studies in Mexico generally focus on large lakes (Chapala, Pátzcuaro, Cuitzeo, Zirahuén: Rico-Martínez and Silva-Briano, 1993; Sarma and Elías-Gutierrez, 1999), deep reservoirs (Valle de Bravo: Nandini *et al.*, 2008), shallow lakes (Xochimilco, Cuatro Ciénegas: Nandini *et al.*, 2005; Walsh *et al.*,

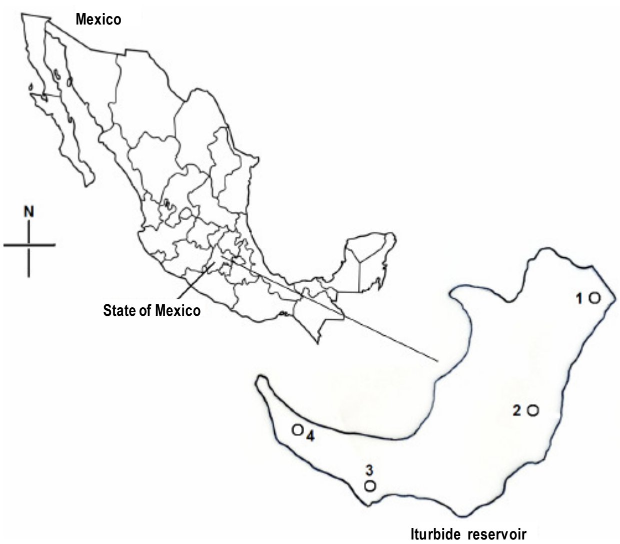

Fig. 1: Iturbide reservoir with sampling stations

2008), and other waterbodies of cultural or touristic importance (Crater Lakes such as Axalapascos and el Sol Lake: Alcocer and Hammer, 1998; Dimas-Flores *et al*., 2008).

Among the multi-cellular zooplankton, rotifers, cladocerans and copepods are the most abundant in freshwater ecosystems. However, studies from certain shallow waterbodies in central Mexico (*e.g.*, Xochimilco) have shown greater numerical dominance of rotifers over cladocerans and copepods (Nandini *et al*., 2005). This is also the situation in a few other high altitude reservoirs in the State of Mexico. For example, studies from Valle de Bravo indicated that the system is dominated by rotifers mainly of the genera *Keratella* and *Polyarthra*. Cladocerans are relatively few and copepods too are numerically less important in this reservoir (Nandini *et al*., 2008; Jiménez-Contreras *et al*., 2009).

Among rotifers, the genus *Brachionus* is pantropical and is widely distributed in Mexico. However, in high altitude waterbodies in Central Mexico the distribution of *Brachionus* is highly variable; it is only sporadically present in Valle de Bravo (Ramírez-García *et al*., 2002) but in Lake Huetzalin, Xochimilco it is the dominant component of the zooplankton community (Enríquez-García *et al.,* 2009). Therefore, in order to understand the factors that govern the distribution and abundance of several zooplankton taxa in high altitude reservoirs, it becomes imperative to conduct plankton sampling through different seasons.

Study area: The State of Mexico (Mexico) has many high altitude (> 2000 m above sea level) reservoirs. Iturbide reservoir (Las Canoitas township, municipality of Isidro Fabela, northwest of the State of Mexico, 19° 31'45.9" N and 99° 27' 55.6" W) (Fig. 1) situated at an altitude of 3,310 m above sea level, with a temperate sub-humid climate. The average annual temperature is 12°C with a maximum rarely exceeding 25°C. The water level of the reservoir is strongly influenced by rainfall. The reservoir has a maximum depth of 5 m. This reservoir is mainly used for agricultural and recreational purposes.

Compared to large reservoirs of the State of Mexico such as Valle de Bravo (Ramírez-García *et al*., 2002), which are of aquacultural importance, Itubirde reservoir is much smaller (a few hectares) and has not received much attention from limnologists in Mexico. An initial sampling showed high diversity of rotifers but relatively few crustaceans. This prompted us to sample the zooplankton through different seasons in order to assess the density and diversity of zooplankton.

Material and Methods

Zooplankton sampling was conducted monthly over an annual cycle (February 2008 to January 2009) in Iturbide Dam. There were four sampling stations representing the different sites of the reservoir (Fig. 1). Zooplankton (surface) sampling was done by filtering reservoir water (50 l in duplicates) through a plankton net with a mesh size of 50 µm. The samples were fixed using 10% formalin. For taxonomic determination of some soft-bodied rotifers, it was necessary to collect live samples and in such cases we separately collected live zooplankton. At the time of plankton collections, we also measured the following physico-chemical variables of the reservoir water: temperature, pH, conductivity (using Thermo Orion model 118), dissolved oxygen (using Winkler´s method) and transparency (using Secchi disk). Selected nutrients (nitrate and ammonia using YSI 9000 series) and phosphates using stannous chloride method (APHA, 1992)) were also estimated.

Zooplankton taxa were identified, as far as possible, to species level using standard literature (rotifers: mainly Koste, 1978; cladocerans: Smirnov, 1974, 1992; Korovchisnsky, 1993 and copepods Dumont and Negrea , 2002). We also used other pertinent literature available nationally (Elías-Gutierrez *et al.,* 2008). Species identifications were done using Stereomicroscope and light microscope (Nikon) at different magnifications (10X to 1000X). For rotifers, where needed, we separated trophi using 10% sodium hypochlorite solution. For zooplankton quantification, we counted three aliquots samples of one ml each of the concentrated sample using an inverted microscope. Cladocerans too were identified to species level and quantified. In the case of the copepods, we separately counted naupliar, copepodite stages and the adults. Naupliar and juveniles could not be identified to species level, only adult copepods were then identified. Species diversity was calculated using Shannon-Wiener diversity index (Krebs, 1993). The following formula was used to calculate diversity index:

$$H' = -\sum_{i=1}^{s}(pi)(log_2 pi)$$

Where, H' = species diversity index, Pi = proportion of total sample belonging to the species "i" with i = 1,2 ... S, where S is the total number of species present in the sample. The differences in the abundances of zooplankton among different seasons were quantified using ANOVA. We performed Pearson correlation analysis between

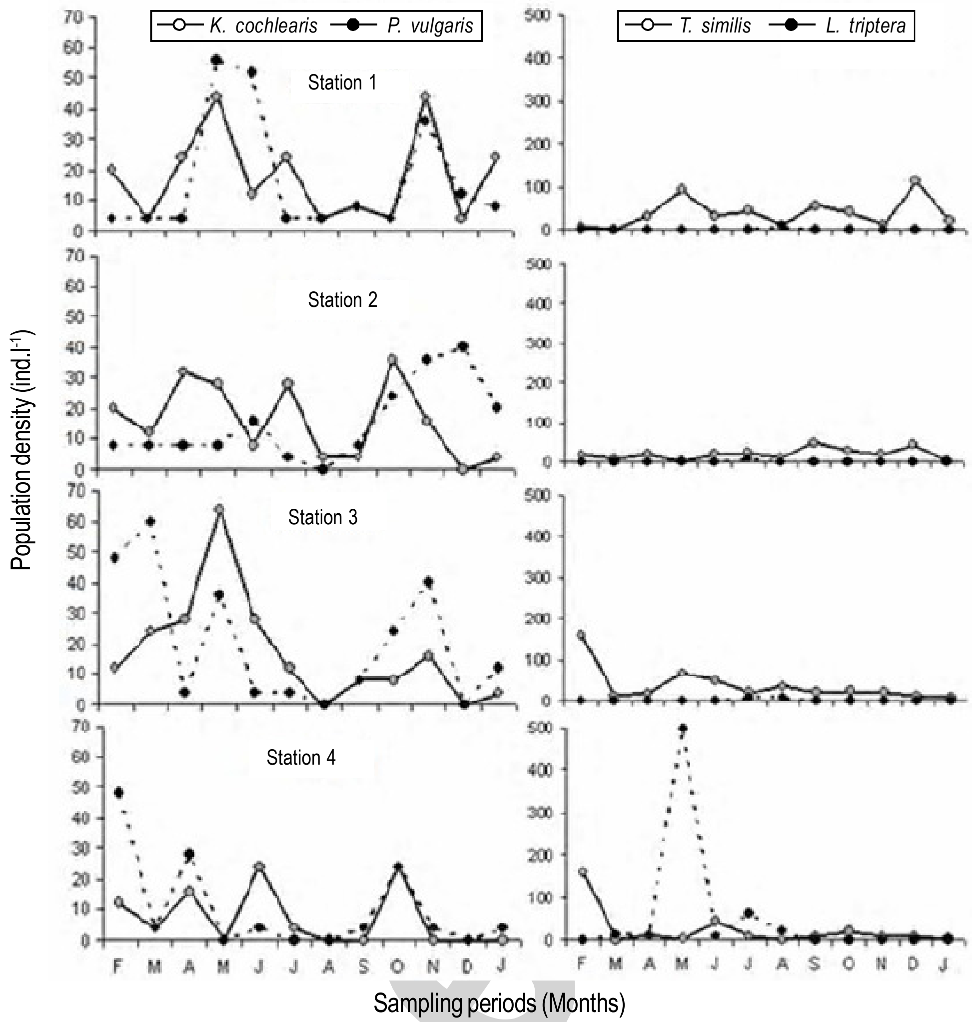

Fig. 2: Seasonal variations in the abundances (ind. l^{-1}) of four dominant rotifer species (*Keratella cochlearis*, *Polyarthra vulgaris*, *Trichocerca similis* and *Lepadella triptera*) from the different sampling stations of the Iturbide reservoir during Feb. 2008 and Jan. 2009

physicochemical variables and the species abundances (Statistical program SPSS version 13.0)

Results and Discussion

Selected data on the physico-chemical variables of the Iturbide reservoir are presented in Table 1. In general the temperature ranged from 9 to 16°C and rarely exceeded 20°C. Secchi transparency was nearly full since the reservoir was shallow (<2 m) even during the rainy seasons. Dissolved oxygen was generally high, 13-18 mg l^{-1}. Nitrate levels (10 to 170 µg l^{-1}) were low while phosphates were moderate (9 to 35 µg l^{-1}).

The Iturbide reservoir was dominated by rotifer species. We encountered, in all, 55 taxa of rotifers, 9 cladocerans and 2 copepods (Table 2). The rotifer families Trichocercidae and Notommatidae had the highest number of species (7 each) followed by Colurellidae and Lecanidae (6 and 5 species, respectively). *Trichocerca elongata*, *Ascomorpha ovalis*, *Keratella americana*, *K. cochlearis, Lepadella patella* and *Pompholyx sulcata* were the dominant rotifers during the study period. On an annual average, the density of the most abundant rotifers was about 50-200 ind. l^{-1} (Fig. 2). Among crustaceans *Chydorus* and *Macrothrix* were more abundant. The maximal abundances of these cladocerans were about 50 ind. l^{-1}. Copepods were much lower in abundance (<20 ind. l^{-1}) (Fig. 3). Information on the frequency and abundance distribution of the zooplankton species from Iturbide reservoir showed that many species were rare (Fig. 4). Data on the monthly zooplankton abundances in different collection sites are presented in Table 3. In general the density of zooplankton was higher during summer months (April to July) than during winter. Among the sites, zooplankton was higher at sites 3 and 4. High zooplankton abundances (>1300 ind. l^{-1}) were observed during May at site 4 while the lowest (<20 ind. l^{-1}) were during Aug. at sites 1 and 2.

Shannon-Wiener diversity index varied from 1 to 4.3 depending on the site and the sampling period. In general, species diversity was higher (3.0) at site 2 while lower values (2.5 to 2.8)

Table - 2: List of Zooplankton species encountered during the study period from the Iturbide dam

Rotifera

Family Brachionide
Keratella cochlearis (Gosse, 1851)
K. americana Carlin, 1943
K. lenzi (Hauer, 1953)
K. tropica (Apstein, 1907)
Kellicottia bostoniensis (Rousselet, 1908)

Family Colurellidae
Lepadella patella (O.F. Müller, 1773)
L. ovalis (O.F. Müller, 1786)
L. triptera (Ehrenberg, 1830)
L. rhomboides (Gosse, 1886)
Colurella obtusa (Gosse, 1886)
C. adriatica (Ehrenberg, 1831)

Family Lecanidae
Lecane hamata (Stokes, 1896)
L. lunaris (Ehrenberg, 1862)
L. closterocerca (Schmarda, 1859)
L. ohioensis (Herrick, 1885)
L. unguitata (Fadeev, 1925)

Familia Trichocercidae
Trichocerca similis (Wierzejski, 1893)
T. bidens (Lucks, 1912)
T. vernalis Hauer, 1936
T. longiseta (Schrank, 1802)
T. elongata (Gosse, 1851)
T. cylindrica (Imhof, 1891)
T. tigris (O.F. Müller, 1786)

Family Dicranophoridae
Dicranophorus grandis (Ehrenberg, 1832)

Family Flosculariidae
Ptygura sp.

Family Filiniidae
Filinia longiseta (Ehrenberg, 1834)

Family Collothecidae
Collotheca sp.

Family Euchlanidae
Euchlanis dilatata Ehrenberg, 1832
Euchlanis deflexa (Gosse, 1851)

Family Mytilinidae
Mytilina mucronata (Müller, 1773)
M. bisulcata (Lucks,1912)
Lophocharis salpina (Ehrenberg, 1834)

Family Trichotriidae
Trichotria tetractis (Ehrenberg, 1830)
Macrochaetus subquadratus (Perty, 1850)

Family Proalidae
Proales fallaciosa Wulfert, 1937

Family Notommatidae
Cephalodella gibba (Ehrenberg, 1838)
Cephalodella hoodi (Gosse, 1886)
C. catellina (Müller, 1786)
C. physalis Myers, 1924
Notommata cyrtopus (Gosse, 1886)
N. glyphura Wulfert,1935
Monommata arndti Remane, 1933

Family Gastropodidae
Ascomorpha ovalis (Bergendal, 1892)
A. ecaudis (Perty, 1850)
Gastropus hyptopus (Ehrenberg, 1838)

Family Synchaetidae
Polyarthra vulgaris Carlin, 1943
P. dolichoptera Idelson, 1925

Family Asplanchnidae
Asplanchna brightwelli (Gosse, 1850)
A. sieboldi (Leydig, 1854)
A. girodi (De Guerne,1888)

Family Testudinellidae
Pompholyx sulcata Hudson, 1885
Testudinella parva (Ternetz, 1892)
T. patina (Hermann, 1783)

Family Conochillidae
Conochilus natans (Seligo, 1900)
C. coenobasis (Skorikov, 1914)

Cladocera

Family Daphniidae
Daphnia laevis Birge, 1879
Ceriodaphnia dubia Richard, 1894
Simocephalus vetulus (O.F. Müller)

Family Bosminidae
Eubosmina coregoni (Baird, 1850)
Family Ilyocryptidae
Ilyocryptus spinifer Herrick, 1882

Family Chydoridae Stebbing, 1902
Chydorus brevilabris Frey, 1980
Eurycercus sp.*Camptocercus rectirostris* Schoedler, 1862

Family Macrothricidae
Macrothrix triserialis Brady, 1886

Copepoda
Orden **Calanoidea**

Orden **Cyclopoida**
Acanthocyclops americanus (Marsh, 1893)
Tropocyclops prasinus Kiefer, 1938

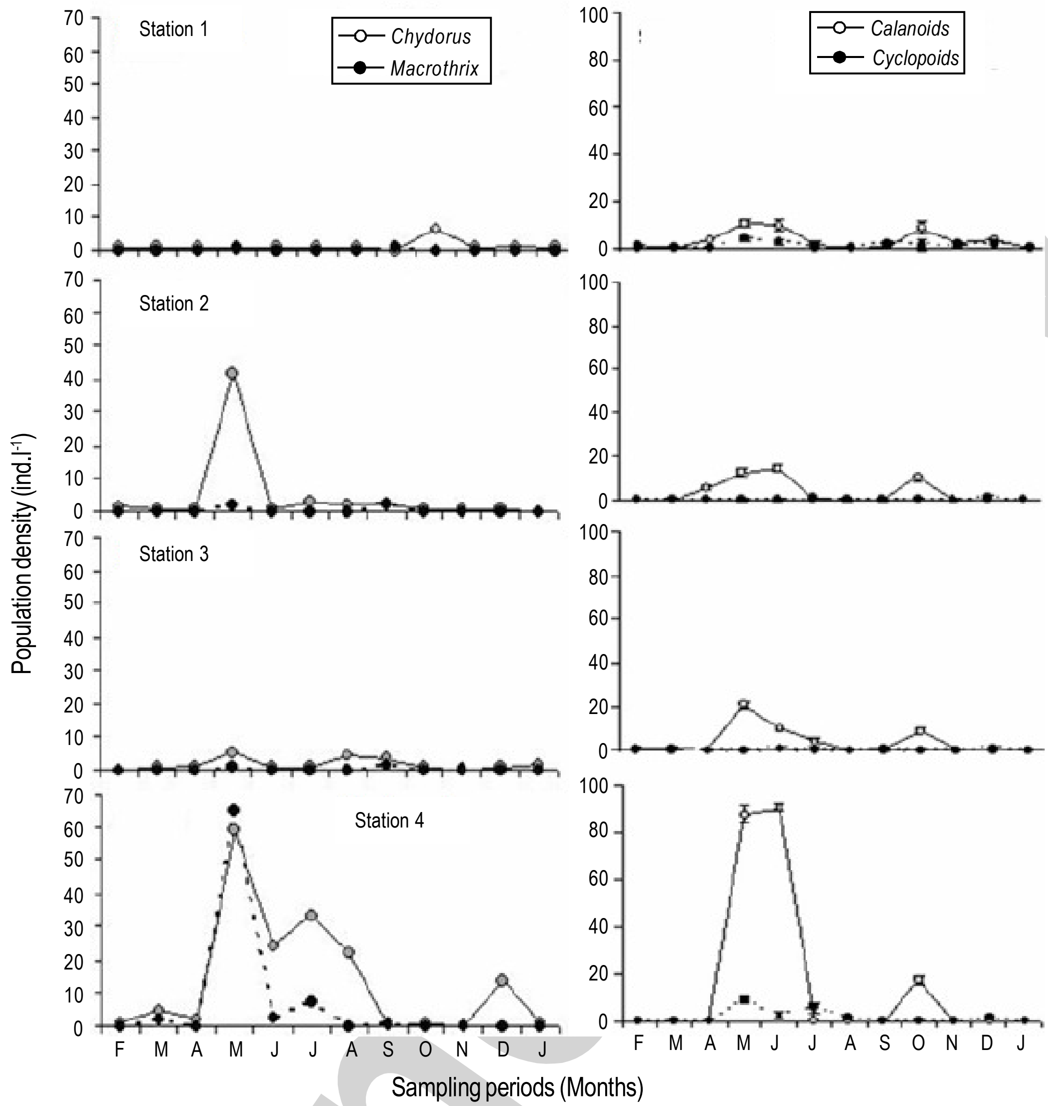

Fig. 3: Seasonal variations in the abundances (ind. l^{-1}) of dominant crustacean taxa (*Chydorus brevilabris*, *Macrothrix triserialis*, Calanoids and Cyclopoids) from the different sampling stations of the Iturbide reservoir during Feb. 2008 and Jan. 2009

were recorded from the rest of the sampling sites (Fig. 4). Results of the Pearson correlation analysis between physicochemical variables and the zooplankton abundances showed only temperature and phosphate levels were positively and significantly correlated with zooplankton densities ($p<0.05$). The rest of the variables had no significant impact on zooplankton densities ($p>0.05$).

Mexican high altitude freshwater bodies show strong variations not only through seasons but also with reference to the density and diversity of zooplankton. The range of physico-chemical variables recorded from Iturbide reservoir are similar to those recorded in the Central Mexican lakes and reservoirs of comparable altitude with nutrient levels on the lower side in the present waterbody. For example, in Valle de Bravo, a drinking water reservoir of the State of Mexico (altitude 1830 m a.s.l.), Nandini *et al.* (2008) have reported temperature in the range of 18-24°C, pH 7.3-9.3, dissolved oxygen 2-8 mg l^{-1}, phosphates 1.9 to 198 $\mu g\ l^{-1}$ and nitrates 1.4 - 311 $\mu g\ l^{-1}$. Similarly, in Lake Xochimilco, a shallow freshwater lake with a complex system of canals with an altitude of 2,250 m a.s.l. Nandini *et al.* (2005) have documented the ranges of temp. 14-22°C, dissolved oxygen 1.4-15.0 mg l^{-1}, phosphates 1900-3500 $\mu g\ l^{-1}$ and nitrates as 3000-7800 $\mu g\ l^{-1}$. Except for DO which was relatively higher in the present waterbody, rest of the measured variables was within range known from different waterbodies of this region.

Except for inland saline lakes (Lugo-Vázquez, 2000), many freshwater lakes, ponds and reservoirs of Mexico are generally rich in zooplankton species. Sarma and Elías-Gutiérrez (2000) have reported as many as 65 rotifer species from a single collection from a high altitude waterbody (2411 m.a.s.l.) in Central Mexico. The impoverishment of planktonic cladoceran species in large and

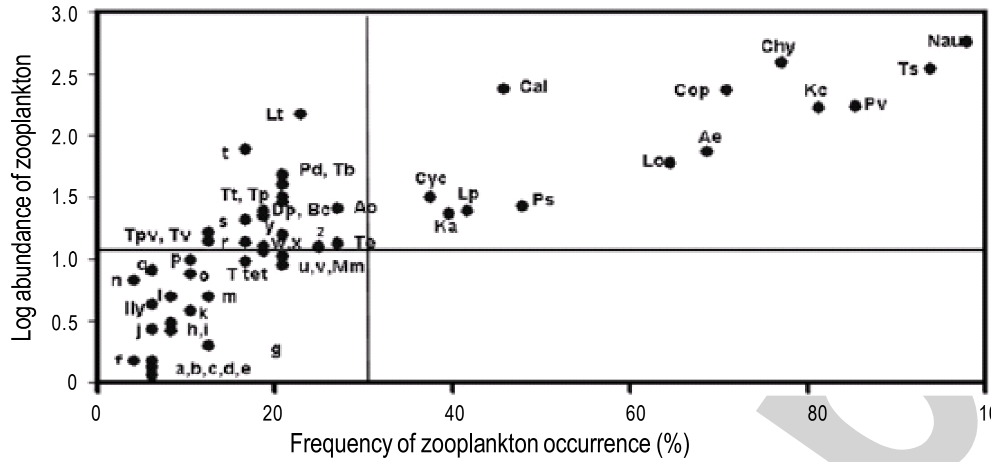

Fig. 4: Frequency and abundance distribution of zopplankton from the Iturbide dam. **Rare** *L. unguitata* (a); *T. cavia* (b); *A. brightwelli* (c); *K. bostonienses* (d); *N. cyrtopus* (e); *C. physalis* (f); *L. hamata* (g); *C. obtusa* (h); *L. ohionensis* (i); *C. natans* (j); *E. dilatata* (k); *T. longiseta* (l); *Ilyocryptus spinifer* (Ily); *C. catellina* (m); *Eurycercus* sp. (n); *T. patina* (o); *L. rhomboides* (p); *Simocephalus vetulus (*q); *G. hyptopus* (u); *Ptygura* sp. (v); *T. tetractis* (T tet); *M. mucronata* (Mm). **Temporal** *L. closterocerca* (r); *C. dubia* (s); *Macrothrix triserialis.* (t); *T. cylindrica* (w); *C. gibba* (x); *C. rectirostris* (y); *K. lenzi* (z); *T. parva* (Tpv); *T. vernalis* (Tv); *Daphnia laevis* (Dp); *T. porcelus* (Tp); *T. tigris* (Tt); *L. triptera* (Lt); *P. dolicoptera* (Pd); *T. bidens* (Tb); **Dominant** *T. elongata* (Te); *A. ovalis* (Ao); *K. americana* (Ka); *L. patella* (Lp); Cyclopoids (Cyc); *Pompholyx sulcata* (Ps); Calanoids (Cal); *L. ovalis* (Lo); *A. ecaudis* (Ae); Copepodites (Cop); *K. cochlearis* (Kc); *Chydorus brevilabris* (Chy); *P. vulgaris* (Pv); *T. similis* (Ts); Nauplii (Nau)

permanent reservoirs of Mexico is remarkable. Only fewer than 10 planktonic species of cladoceran have been reported from such waterbodies. This is similar to the observations in this study where only a few planktonic cladocerans were present in Iturbide reservoir in spite of year-long sampling effort. The density and diversity of planktonic copepods in the Mexican freshwater reservoirs is highly variable (Suarez-Morales and Reid, 2003). Majority (about 50%) of freshwater copepods reported from Mexico belong to cyclopoids and only a few species occur together due to diet overlap (competition) and predation by fish (Elías-Gutiérrez *et al*., 2001). For example, Enríquez-García *et al*. (2009) have reported only 2 species of cyclopoids from Xochimilco lake. In the present study too we found only a few species.

The Shannon-Wiener species diversity index from Iturbide reservoir generally remained below 3.0. In fact, only few freshwater ecosystems of comparable altitudes in Mexico the index values have >3 (Enríquez-Garíca *et al*., 2009). An index of higher than 5.0 is rare in literature (May, 1975). Jiménez-Contreras *et al*. (2009) have reported Shannon-Wiener diversity index of 1.8 as the highest in Valle de Bravo reservoir. Thus the diversity index from this study was within the range reported for different freshwater bodies of Mexico at comparable altitude and in fact it was higher than expected.

Many factors, including fish predation have strong influence on the abundance dynamics of crustacean zooplankton (Dodson and Frey, 2001; Fernando, 1994). Fish predation in most Mexican waterbodies is the most influencing factor controlling the abundance of cladocerans and copepods as has been documented in Valle de Bravo reservoir and Xochimilco lake (Ramírez-García *et al*., 2002; Enriquez-Garcia *et al*., 2009). In the present study, although we did not quantify the fish density, our observations during sampling indeed

Table - 3: Data on the monthly abundances (ind. l^{-1}) of zooplankton collected from Iturbide reservoir during Feb. 2008 to Jan. 2009

Month	Site 1	Site 2	Site 3	Site 4	Mean/month
Feb	84	81	382	264	203
Mar	43	52	156	84	84
Apr	117	84	78	101	95
May	244	293	229	1392	540
Jun	120	91	129	370	177
Jul	127	113	68	223	133
Aug	9	13	48	121	48
Sep	37	69	60	13	45
Oct	71	100	73	275	130
Nov	92	73	149	27	85
Dec	125	55	16	53	62
Jan	157	29	25	13	56

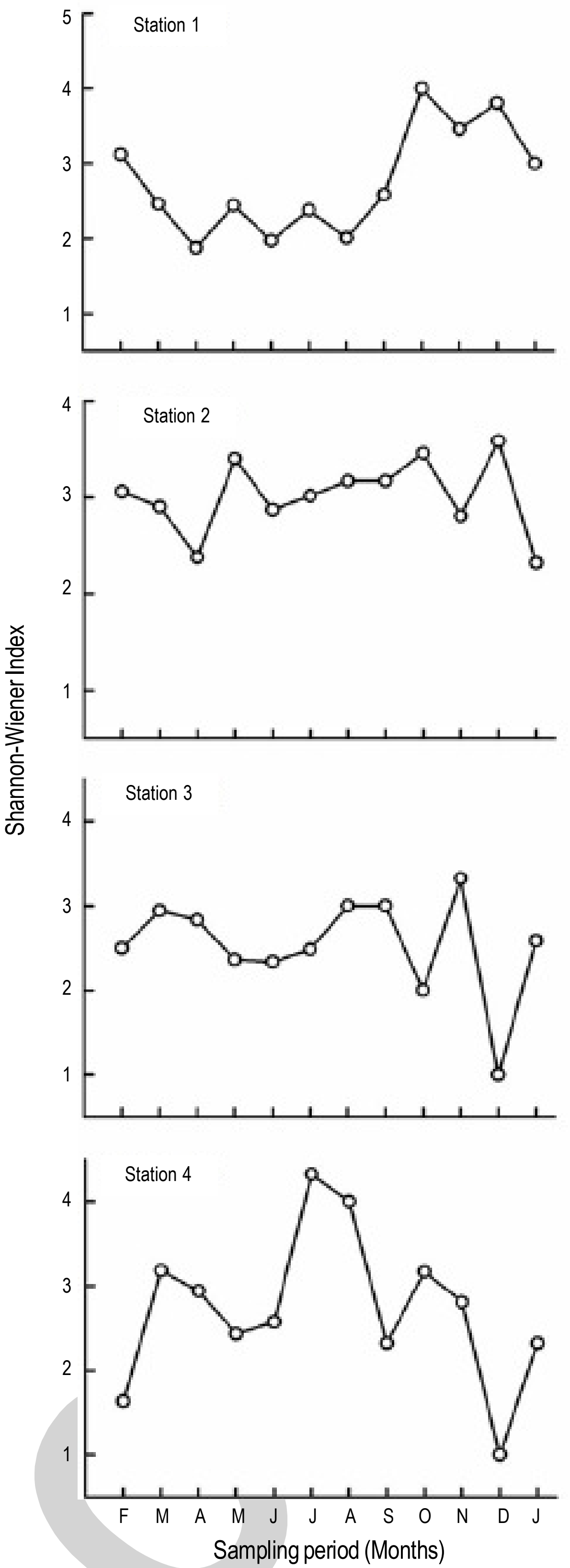

Fig. 5: Shannon-Wiener index values of zooplankton from turbide reservoir through different months and at four sampling stations

revealed the presence of planktivorous fishes, mainly trouts. Though different planktivorous fish do feed on rotifers, their impact on rotifer community is generally limited to larval stages (first 2 to 3 weeks following hatching). Beyond the larval stages, most fishes feed on cladocerans and copepods since rotifers are no longer energetically profitable (Gerking, 1994). Thus in Iturbide reservoir fish including trouts have a strong influence in controlling the abundances of planktonic crustaceans. Cladocerans and rotifers feed on similar algal types and thus there exists natural competition between these two groups (Gilbert, 1988). Since cladocerans are generally larger than rotifers, they consume higher quantities of algal food and are thus competitively superior to rotifers (Hurtado-Bocanegra *et al*., 2002). In addition, mechanical damage to the rotifer eggs during filtration process by the cladoceran has also been reported (Gilbert, 1988). When fish selectively feed on crustaceans, the competitive outcome between rotifers and cladocerans shifts in favour of rotifers and hence they proliferate. This has been interpreted as the possible reason for the high abundances of rotifers in many freshwater bodies in Mexico such as Valle de Bravo reservoir and Xochimilco lake (Ramírez-García *et al*., 2002; Enriquez-García *et al*., 2009). In the Iturbide reservoir too, fish populations probably adversely affect the crustaceans and thereby rotifers have the opportunity to graze on the available resources for reaching high densities.

The near absence of *Brachionus* in the Iturbide reservoir is striking. Since brachionid rotifers are pantropical (Koste, 1978) and since this waterbody has temperature range on the lower side, this genus is poorly represented. However, this is probably not the only explanation for the absence of *Brachionus* in Iturbide reservoir; many brachionid rotifers have been reported from Xochimilco lake with a comparable temperature regimes (Garza-Mouriño *et al.,* 2005). Both Valle de Bravo reservoir and Iturbide reservoir have few brachionid rotifers. Thus suggests that factors other than temperature (such as food type and concentration) may have some role in influencing the presence of *Brachionus* (Wallace *et al*., 2006). In our study we did not quantify the phytoplankton density. Our Secchi transparency data indicates that the Iturbide reservoir is mesotrophic (Wetzel, 2001). It has been documented that brachionids are generally rare in reservoirs while the dominat rotifer genera, as observed in our study too, are generally *Keratella* and *Polyarthra* (Devetter, 1998).

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