Basic limnology of 30 continental waterbodies of the Transmexican Volcanic Belt across climatic and environmental gradients

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ABSTRACT

Thirty waterbodies on the Transmexican Volcanic Belt were studied using standardized methods, covering an altitudinal gradient from 737 to 4283 masl and different climatic types. Waterbodies of tree different origins were included: tectonic (4), volcanic (11 craters or maars and 7 volcanic dams) and reservoirs (8). Reservoirs and tectonic lakes were mostly shallow (< 6 m) while volcanic lakes were the deepest (> 25 m). Most were freshwater bodies with alkaline waters (pH > 7.5) dominated by [Ca^{2+}] or [Na^+] and [HCO_3^-]. Subsaline (6) and hyposaline (2) lakes were dominated by [Cl^-] - [HCO_3^-] and [Na^+]. In thirteen lakes, nutrient levels could be limiting primary productivity, mostly P, but also N and Si. Half of the lakes (16) were eutrophic or hypertrophic and most of these were also shallow (< 8 m) and correlated with warm, moist conditions. Ninety-seven taxa of aquatic organisms (phytoplankton, and surface sediment diatoms, testate amoebae, cladoceran and ostracodes) were reported, which could potentially be used as bioindicators. Principal component analysis (PCA) showed that temperature and precipitation were the main environmental gradients related to the lakes' limnological characteristics: colder climates related with lowest TDS (< 100 mg/L); dry climates with subsaline and hyposaline lakes, and warm-moist climates with eutrophic and hypertrophic lakes. Through the Procrustes technique we obtained indications that general geographic variables were important for some of the lakes, whereas the local factors were significant for others. It is through the knowledge of the basic limnology and biodiversity of Mexican lakes that more complex or detailed studies can be proposed leading to a better understanding, management, and conservation of water resources.

Keywords: Hydrochemistry, salinity, trophic state, benthos, plankton.

RESUMEN

Empleando metodologías estandarizadas se estudiaron 30 cuerpos de agua en la Faja Volcánica Transmexicana a lo largo de un gradiente altitudinal (737 a 4283 msnm) y climatológico. Los lagos se incluyen en tres categorías: tectónicos (4), volcánicos (11 cráteres o maars, 7 represas volcánicas) y presas (8). Los cuerpos más someros (< 6 m) fueron principalmente presas y lagos tectónicos y los más profundos (> 25 m) volcánicos. La mayoría fueron lagos de agua dulce y alcalina (pH > 7.5) dominados por [Ca^{2+}] o [Na^+] y [HCO_3^-]. Los lagos subsalinos (6) e hiposalinos (2) estuvieron dominados por [Cl^-] - [HCO_3^-] y [Na^+]. En trece lagos los niveles de nutrientes pudieron ser limitantes de la productividad primaria, principalmente el P, pero también N y Si. La mitad (16) fueron lagos eutróficos o hipertróficos y estos fueron predominantemente someros (< 8 m) y correlacionaron con climas cálido-húmedos. Se reportaron 97 taxa acuáticos (fitoplancton y diatomeas, amebas testadas, cladoceros y ostrácodos en sedimento superficial) que potencialmente pudieran ser usados como bioindicadores. Un análisis de componentes principales (PCA) demuestra que la temperatura y precipitación fueron los gradientes ambientales más importantes ligados con las características limnológicas: climas relativamente fríos correlacionaron con los lagos más diluidos (TDS < 100 mg/L); climas secos con los subsalinos e hiposalinos y climas cálido-húmedos con los eutróficos e hipertróficos. Un análisis de Procrustes indica que para algunos lagos los factores geográficos generales fueron más importantes mientras para otros los factores locales fueron determinantes. El estudio y conocimiento de la limnología y biodiversidad de los lagos mexicanos permitirán plantear estudios más detallados y/o complejos que lleven a mejores estrategias de conservación y manejo de los recursos acuáticos.

Palabras clave: hidroquímica, salinidad, estado trófico, bentos, plancton.

1. Introduction

Central Mexico is characterized by the presence of a volcanic chain that crosses the country from E to W at around 18° to 22°N. This volcanic chain is known as the Trans-Mexican Volcanic Belt (TMVB) and is the largest Neogene volcanic arc of North America, with a length of 1000 km and an area of 160000 km^2 (Ferrari *et al.*, 2012). Along this wide surface, topographic heterogeneity favors the presence of several lacustrine basins across a broad range of climatic conditions which are determined mostly by the significant altitudinal gradient (the highest peaks reach > 5000 masl). Besides temperature, this topographic gradient is also associated with differences in precipitation and/or evaporation, with generally drier climates on the western, lower altitude basins; but the driest region, under a rain shadow effect, is on the easternmost high-altitude basin (Oriental).

Throughout the history of the region the lakes along the TMVB have been core areas for cultural development (Faugère-Kalfon, 1996; Niederberger, 1979; Serra-Puche, 1988) as they are favorable locations for agriculture, fishing, hunting, and recreational activities. Thus, human impact around these lakes has also a long history, which in modern times has been sharpened by stressors such as global warming, urban development and widespread changes in land use (Alcocer and Bernal-Brooks, 2010).

Lakes are sensitive ecosystems to changes in their environment (Adrian *et al.*, 2009) and we know that in several of these lakes the impact of modern stressors has already caused, for example, important reductions in lake levels or increases in turbidity and trophic status (Alcocer *et al.*, 2000a; Caballero *et al.*, 2006; Kienel *et al.*, 2009; Komárková and Tavera, 2003). These changes can generate social and economic problems as well as a significant reduction in the biodiversity of these ecosystems, so it is important to have basic limnological information that allows a better understanding of these aquatic systems as a basis for further ecological studies, and also for the management and restoration of the water resources they represent. In some of these lakes the changes have been very quick, but the rate of change is difficult to evaluate as there are relatively few limnological studies undertaken in the area to allow understanding the degree and speed of such transitions. Limnological information about these lakes is therefore relevant to document their current status, which is necessary as a reference when evaluating past conditions. In the same way, it is important to identify the organisms that live in these waterbodies, especially those that can be used as bioindicators in modern and paleo-environmental research given their high potential of preservation in the sediments. Phytoplankton is probably the most sensitive but also the remains of diatoms, testate amoebae, cladocerans and ostracodes preserved in sediments can be very useful to determine the conditions of the water body in which they lived. All these groups have short life cycles, so they quickly respond to environmental changes, enabling to understand the present conditions of the lacustrine ecosystem and open the possibility of evaluating recent changes through paleolimnological methods by, for example, comparing the bioindicators contents in modern and pre-human impact sediment samples.

Previous limnological studies in the TMBV region have focused on a few of its lakes, mainly the largest and/or deepest (*e.g.* Alchichica: Alcocer *et al.*, 2000b; Kaźmierczak *et al.*, 2011, Chapala: Hansen and van Afferden, 2001; Quiroz *et al.*, 2008, Pátzcuaro: Alcocer and Bernal-Brooks, 2002; Bischoff *et al.*, 2004, Zirahuén: Chacon-Torres and Rosas-Monge, 1998; Bernal-Brooks and MacCrimmon, 2000a). Scarce limnological information is available for most of the smaller waterbodies, but even for the best characterized lakes, results are often difficult to compare, as studies are carried out following different methodologies and/or only report results on specific physico-chemical characteristics or biological groups. Only a handful of studies have been performed simultaneously in more than one lake to allow for regional comparisons (*e.g.* Armienta *et al.*, 2008; Davies *et al.*, 2002).

The aims of this study are, therefore (1) to describe the main morphometric and limnological characteristics of 30 waterbodies on the TMVB in central Mexico using standardized analytical methods so that the data are easily comparable, (2) to provide information about their current nutrient levels and trophic state, (3) to report the dominant aquatic bioindicator taxa (phytoplankton and sedimentary diatoms, testate amoebae, cladocerans and ostracodes) present at each site as a contribution to future ecological and paleoecological research, (4) to assess the influence of climate and geographic location over the limnological variables of these waterbodies.

2. Materials and methods

Thirty waterbodies located along the TMVB (Figure 1) were sampled once from late summer to early autumn (lakes El Sol and La Luna in August 2010 and the rest of the lakes between June and October 2011). The geographical location (latitude, longitude, altitude) of each site was taken using a handheld navigator (GARMIN GPSMAP 62 stc) and confirmed in Google Earth®. All of them were studied following uniform methodologies for field work, laboratory analyses and taxonomic determinations of bioindicators (phytoplankton and sedimentary diatoms, testate amoebae, cladocerans and ostracodes). The limnological and biological data thus obtained were complemented with additional information and compiled to generate an individual chart for each lake, summary data are also presented in Table 1. Charts display information on climate, limnology, main aquatic bioindicator taxa present, and previous published work. Finally, numerical analyses were used to synthesize and analyze the limnological and climatic information. Description of items included in charts, and of numerical analysis performed follows:

2.1. CLIMATE

For all sites, meteorological data such as mean annual temperature, annual temperature range, total annual precipitation and annual evaporation were taken from the closest meteorological stations (SMN, 2015). Climate types for each site were identified according to the INEGI climate map (INEGI, 2008) which follows García, 2004.

2.2. LIMNOLOGY

The lake's origin was determined following bibliographical sources or inferred from field observations and Google Earth® satellite images in the case that there were not previous studies. The categories identified were: tectonic (by faulting), volcanic (crater, maars and natural dam) and reservoir (dike, artificial dam and river diversion). The surface of each water body was measured in the Google Earth® satellite images and when possible confirmed with bibliographical data.

Water depth (m) was measured in the field using a portable depth sounder (Speedtech Instruments), but not always the maximum depth spot at each site was located. Maximum water depth for all sites was taken from bibliographical data when available or from our own depth measurements. Relative depth (Z_r in %) was calculated with the formula:

$$Zr = 50 * Zmax * \sqrt{\pi}/\sqrt{(Ao)} \qquad \text{Equation 1}$$

where Z_{max}= maximum depth, and A_o= surface area (Wetzel and Likens, 1991).

The lake's mixing pattern was taken from bibliographic data when available, otherwise it was assumed to be warm monomictic if water depth was > 8 m, relative depth was >1 % and our temperature depth profiles confirmed stratification; if these criteria were not fulfilled, the lake was assumed to be warm polymictic (Lewis, 2000). If a thermocline and/or oxycline were detected, the depth (m) at which they occurred was specified. Water transparency was measured in the field as visibility (m) using a Secchi disk.

Temperature (°C), oxygen concentration (mg/L), pH and electric conductivity (μS/cm) depth

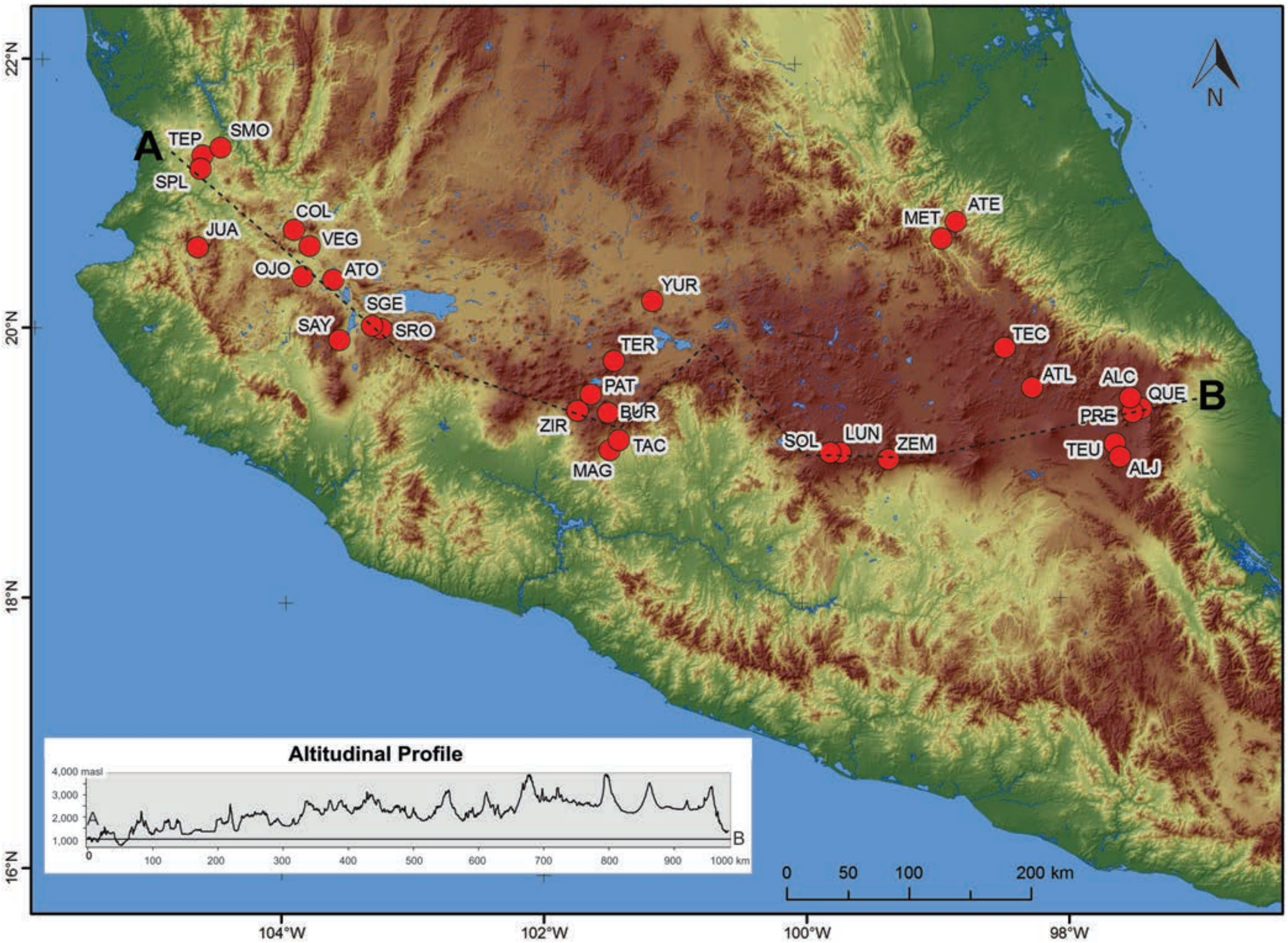


Figure 1 Map with the location of the 30 lakes studied along the Trans-Mexican Volcanic Belt, central Mexico. Abbreviations correspond to those in Table 1.

profiles were also measured in the field using a multiparametric probe (Hydrolab Quanta G). Temperature and oxygen data are presented as depth profiles in lakes where the sampling site was > 6 m deep, or in table format for shallower locations. Electric conductivity and pH are presented in tables, showing a littoral site (only measurement in small, shallow lakes), and a centric site which could have only surface (shallow lakes), or surface and bottom data (if depth ≥ 3 m).

Water samples for chemical determinations and for phytoplankton analyses were collected using a Van Dorn-type sampling bottle from a littoral and from a centric site, with samples from surface (0.5 m) and bottom of the water column (1 m above the sediments if depth ≥ 3 m). Samples for cation determinations were acidified using concentrated (55 %) HNO_3. All samples were kept in refrigeration until analyzed in the laboratory. Major ions analyses were performed following standard procedures (APHA, 1995, 1998; APHA *et al.*, 2005; Armienta *et al.*, 2008).

Major ions concentrations are expressed in mg/L but these data were also transformed to meq/L and then to percentages to determine ionic dominance (ion's relative concentrations), which was determined merging $[HCO_3^-]$ + $[CO_3^{2-}]$ and $[Na^+]$ + $[K^+]$.

Total dissolved inorganic carbon (DIC) was measured with an AutoMate carbonate preparation

Table 1. Main limnological characteristics of 30 lakes studied along the Trans-Mexican Volcanic Belt, central Mexico. Salinity and trophic categories as defined in Table 1.

Lake	Tag	Type	Area (ha)	Maximum depth (m)	Relative depth (%)	Dominant anions	Dominant cations	pH	Salinity category	Trophic category
Alberca de Tacámbaro	TAC	Volcanic (crater)	8.2	28	8.7	HCO_3^-	Mg^{2+}	7.8	Freshwater	Eutrophic
Alberca de Teremendo	TER	Volcanic (crater)	15	9	2.1	HCO_3^-	Na^+ - Mg^{2+}	8.3	Freshwater	Hypertrophic
Alchichica	ALC	Volcanic (maar)	200	62	3.8	Cl^-	Na^+	8.3	Hyposaline	Mesotrophic
Aljojuca	ALJ	Volcanic (maar)	42	51	7	HCO_3^-	Na^+	9.5	Subsaline	Mesotrophic
Atezca	ATE	Volcanic (dam)	27	16	2.7	HCO_3^-	Ca^{2+}	9.3	Freshwater	Mesotrophic
Atlangatepec	ATL	Reservoir (dike)	800	7	0.2	HCO_3^-	Na^+	7.7	Freshwater	Eutrophic
Atotonilco	ATO	Tectonic	1370	0.5	<0.1	HCO_3^-	Na^+	9.6	Hyposaline	Mesotrophic
Burro	BUR	Probably volcanic	9	1	0.3	HCO_3^-	Na^+	6.9	Freshwater	Eutrophic
Colorada	COL	Reservoir (dike)	410	3	0.1	HCO_3^-	Ca^{2+}	7.8	Freshwater	Hypertrophic
El Sol	SOL	Volcanic (crater)	18	15	3.2	HCO_3^-	Ca^{2+}	7.2	Freshwater	Oligotrophic
Juanacatlán	JUA	Volcanic (dam)	20	25	5	HCO_3^-	Ca^{2+}	9.2	Freshwater	Mesotrophic
La Luna	LUN	Volcanic (crater)	2.5	10	5.6	HCO_3^-	Ca^{2+}	7.7	Freshwater	Ultra-oligotrophic
La Magdalena	MAG	Reservoir (dike)	22	4	0.8	HCO_3^-	Ca^{2+}	8.8	Freshwater	Hypertrophic
La Preciosa	PRE	Volcanic (maar)	91	46	4.3	HCO_3^-	Mg^{2+}	9.3	Subsaline	Oligotrophic
La Vega	VEG	Reservoir (dike)	1610	6	0.1	HCO_3^-	Na^+	8.5	Freshwater	Hypertrophic
Metztitlán	MET	Tectonic	2940	10	0.2	HCO_3^-	Ca^{2+}	8.9	Freshwater	Eutrophic
Ojo de Agua	OJO	Reservoir (dam)	58	1.5	0.2	HCO_3^-	Ca^{2+}	8.5	Freshwater	Eutrophic
Pátzcuaro	PAT	Volcanic (dam)	10000	9.4	0.1	HCO_3^-	Na^+	8.3	Subsaline	Hypertrophic
Quechulac	QUE	Volcanic (maar)	64	40	4.4	HCO_3^-	Mg^{2+}	9	Freshwater	Oligotrophic
San Pedro Lagunillas	SPL	Volcanic (dam)	296	7	0.4	HCO_3^-	Na^+	8.2	Freshwater	Hypertrophic
Santa Gertrudis	SGE	Reservoir (dike)	50	2.3	0.3	HCO_3^-	Ca^{2+} - Mg^{2+} - Na^+	8	Freshwater	Eutrophic
Santa María del Oro	SMO	Volcanic (crater)	370	65	3	HCO_3^- - Cl^-	Na^+	8.6	Subsaline	Mesotrophic
Santa Rosa	SRO	Reservoir (dam)	1.3	1.8	1.4	HCO_3^-	Mg^{2+}	9	Freshwater	Mesotrophic
Sayula	SAY	Tectonic	10700	1	<0.1	HCO_3^- - Cl^-	Na^+	9.3	Subsaline	Mesotrophic
Tecocomulco	TEC	Tectonic	1900	2	0.1	HCO_3^-	Na^+	8.8	Freshwater	Eutrophic
Tecuitlapa	TEU	Volcanic (maar)	18	2.5	0.1	CO_3^{2-}	Na^+	10.3	Subsaline	Hypertrophic
Tepetiltic	TEP	Volcanic (crater)	132	2.5	0.2	HCO_3^-	Ca^{2+}	8.3	Freshwater	Hypertrophic
Yuriria	YUR	Reservoir (dam and river diversion)	5000	2.3	<0.1	HCO_3^-	Na^+	8	Freshwater	Eutrophic
Zempoala	ZEM	Volcanic (dam)	10	8	2.2	HCO_3^-	Ca^{2+}	8.8	Freshwater	Mesotrophic
Zirahuén	ZIR	Volcanic (dam)	930	40	1.2	HCO_3^-	Ca^{2+} - Mg^{2+} - Na^+	6.5	Freshwater	Oligotrophic

device. Approximately 5 mL of sample were weighed into septum top tubes and placed into the carousel. To purge the sample vial of atmospheric gas, a double needle assembly and CO_2-free nitrogen carrier gas were used. The sample vial was injected with acid and evolved CO_2 was carried through a silver nitrate scrubber to the coulometer where total C was measured.

Samples for ammonium and nitrates were acidified using concentrated (98 %) H_2SO_4. Ammonium ($N\text{-}NH_4$, Nessler's method), nitrites (NO_2, diazotization), nitrates ($N\text{-}NO_3$, brucine colorimetric method), total phosphorus (PT, persulfate digestion) and orthophosphate ($P\text{-}PO_4$, ascorbic acid method) were determined in a Thermo Scientific GENESYS 20 Visible spectrophotometer. Silica (SiO_2) was colorimetrically determined by the molybdosilicate method. Nutrients concentrations are expressed as mg/L, merging [$N\text{-}NH_4$] + [$N\text{-}NO_3$] + [$N\text{-}NO_2$] as dissolved inorganic nitrogen (DIN). Nutrient concentrations were also transformed to µM and molar nutrient ratios were calculated (DIN:PT, DIN:$P\text{-}PO_4$, SiO_2:DIN, SiO_2:$P\text{-}PO_4$).

Samples for chlorophyll *a* determinations were filtered in the field with a Whatman GF/C membrane and filters were kept in refrigeration and darkness until arriving to the laboratory. Extraction was made using methanol (90 %), concentrations were measured with a spectrophotometer (Thermo Scientific Genesys 20 Visible) and determined using Holden's equations (Meeks, 1974); chlorophyll *a* concentrations are expressed as mg/m^3.

Salinity category for each lake was determined following their total dissolved solids (TDS) values (Fritz, 2007; Kolbe, 1927) and trophic category was determined based on their superficial chlorophyll *a* concentrations (OECD, 1982) (Table 2).

2.3. BIOLOGICAL ANALYSIS

Water samples for phytoplankton analyses were collected at the same time as those for chemical determinations and preserved using Lugol's solution. Two aliquots of 0.1 mL from each phytoplankton sample were analyzed using a compound microscope (Nikon Eclipse 80i) at 600x to 1000x. Semiquantitative abundance determinations were based on the following rankings: rare (1 specimen), scarce (2 – 10), abundant (11 – 50) and very abundant (> 50). In this study, only the species falling in the last two categories (abundant and very abundant) are reported. Organisms were identified using specialized bibliography for each (Komárek and Anagnostidis, 1999, 2005; Komárek *et al.*, 1983; Krammer and Lange-Bertalot, 1991a, b; Krammer and Lange-Bertalot, 1997; Krammer and Lange-Bertalot, 1999; Prescott, 1962).

Surface sediments were collected from all lakes at a littoral (only sample in small, shallow lakes) and a central station for biological (diatoms, testate amoebae, cladocerans and ostracodes) determinations; if water depth was very shallow (< 1 m) sediment was collected directly with a spatula and if deeper with an Ekman dredge, taking care of collecting only the topmost sediment. Sediments samples for testate amoebae and ostracodes were preserved with anhydrous ethanol and all samples were kept refrigerated until analyzed in the laboratory.

Table 2. Boundary values criteria for salinity (Kolbe, 1927; Fritz, 2007) and trophic (OECD, 1982) categories.

Salinity					
Category	Freshwater	Subsaline	Hyposaline	Mesosaline	Hypersaline
TDS (mg/L)	≤ 500	500 – 3000	3000 – 20000	20000 – 50000	> 50000
Trophic category					
Category	Ultra-oligotrophic	Oligotrophic	Mesotrophic	Eutrophic	Hypertrophic
Chl *a ** [mg/m^3]	≤ 2.5	2.5 – 8.0	8.0 – 25	25 – 75	≥ 75

*annual maximum of chlorophyll

Diatoms were extracted from 1 cm^3 sediment samples. Sediment was freeze-dried, weighed and treated with HCl, H_2O_2 and HNO_3 to eliminate carbonates and organic matter. Permanent slides were mounted with 200 µL aliquots of final solution, using Naphrax® as mounting medium. Counts of a minimum of 400 individuals were performed using an Olympus BX50 microscope (1000x). Species relative abundances were calculated and only the most abundant species, those accounting for 50 % of the counts in each sample, were reported. Species identification was based on specialized literature (Gasse, 1986; Krammer and Lange-Bertalot, 1991a, b; Krammer and Lange-Bertalot, 1997; Krammer and Lange-Bertalot, 1999).

Testate amoebae were extracted from 2 cm^3 samples with a fine brush under a stereomicroscope (Zeiss STEMI 2000-C Schott SeriesEasyLED) at 64x to 100x. Identification was made following specialized literature (Alcocer *et al.*, 2000b; Charman *et al.*, 2000; Kumar and Dalby, 1998; Lee *et al.*, 2000; Ogden and Hedley, 1980). All the tests found were counted, but only the genera or species for which more than 100 specimens were found are included in this study.

For cladocerans analysis, 1 cm^3 of sediment was heated in a 10 % KOH solution and stirred for 20 – 30 min. Treated samples were washed through a 38 µm sieve, and then analyzed using an Olympus BX50 microscope at 100x to 400x. All Cladocera remains were counted (headshields, shells, ephippia, postabdomens) and the most abundant body part of each species was considered representative of the number of individuals, with a minimum of 200 individuals counted per sample. Identification and nomenclature of Cladocera remains was based on specialized literature (Cervantes-Martinez *et al.*, 2000; Elías-Gutiérrez *et al.*, 2008; Sinev and Zawisza, 2013). In this study, only the taxon with the highest frequency in each sample was reported, except in the samples were two species had equally high abundances, in these cases both taxa were reported.

Ostracode abundance was determined in 50 cm^3 sediment samples by washing them through a 63 µm mesh sieve and separating adult valves using fine brushes under an Olympus SZX12 stereoscope (40x to 60x). Ostracodes valves were stored in micropaleontological slides, specimens with well-preserved soft parts were kept at 5 °C in small Eppendorf vials filled with 96 % ethanol. For identification to genus level, hard parts were studied in detail and well-preserved specimens were dissected (Meisch, 2000). Identifications followed specialized literature (Forester *et al.*, 2015; Pérez *et al.*, 2011; Pérez *et al.*, 2015). In this work, only the three most abundant genera (> 100 adult and juvenile valves in 50 cm^3 of sediment) at each site were reported.

2.4. PREVIOUS WORK

A bibliography search for published papers for each lake was done; if the waterbodies had been extensively studied, only some of the most recent publications were selected.

2.5. NUMERICAL ANALYSIS

The dataset was synthesized through a Principal Component Analysis (PCA), which was performed using geographic (latitude, longitude, altitude), climatic (mean annual temperature, mean annual precipitation, mean annual evaporation) and limnological data (lake area, maximum depth, water transparency, chlorophyll *a*, average surface and bottom TDS, DIN and TP and average water column temperature, dissolved oxygen, pH and electric conductivity) from the 30 studied localities. Subsequently, another PCA was run excluding geographic location (latitude, longitude and altitude). The ordination of sites in both PCAs was compared through the Procrustes technique, a method that consists of fixing the first ordination, whereas the second is rotated using its origin as the vertex and aiming to minimize the distance between the same sites in both ordinations (Borcard *et al.*, 2011). All analyses were performed using Package 'vegan' (Oksanen *et al.*, 2015) in R (R Development Core Team, 2009).

3. Results

An example of the charts made for each lake is presented in Figure 2, and the full set of individual charts for all the lakes is presented in alphabetic order in Electronic Supplement 1. Several of these waterbodies have been listed as Ramsar sites (Atotonilco, Sayula, Atlangatepec, Tecocomulco, Yuriria, La Vega, Metztitlán and Pátzcuaro), which shows the increasing concern for studying and preserving these ecosystems. However, to the best of our knowledge, this is the first published record of the basic limnological characteristics of some of the lakes (Alberca de Teremendo, Burro, Colorada, La Magdalena, Ojo de Agua, Santa Rosa, Santa Gertrudis, Tepetiltic) and for many this is the first record of their aquatic bioindicator's diversity, mostly for testate amoebae and cladocerans (full taxonomic and distribution list in Electronic Supplement 2). A summary of the lake's main characteristics is presented in Table 1.

Alberca de Tacámbaro (TAC), Michoacán
19°12'38" N, 101°27'33" W, 1475 masl

Climate
Warm, sub-humid, summer rains
(A)C(w_1)(w)
Mean Annual Temperature 19.1 °C
Temp. Range 16.8 (Jan) - 21.8 (May) °C
Annual Precipitation 1172 mm
Annual Evaporation 1452 mm

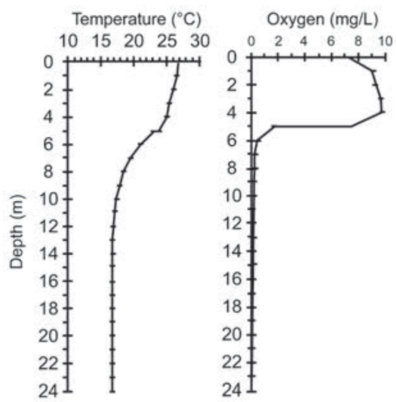
Limnology

Lake type	Volcanic (crater)
Area	8.2 ha
Maximum Depth	28 m[b]
Relative Depth	8.7 %
Mixing pattern	Warm monomictic[c]
Thermocline and oxycline	~5m
Transparency	0.7 m
Ionic dominance	[HCO_3^-] [Mg^{2+}] > [Ca^{2+}] > *[Na^+]*
Salinity category	Freshwater
Trophic category	Eutrophic
Nutrient ratios	DIN:TP 0.1:1
	DIN:P-PO_4 17:1
	SiO_2:DIN 530:1
	SiO_2:P-PO_4 8400:1

Chemical parameters

Variable	Littoral	Surface	Bottom
pH	ND	7.8	7.3
EC	ND	182	208
Total Alk	128	115	122
CO_3^{2-}	27	31	LDL
HCO_3^-	102	76	149
SO_4^{2-}	4.1	4.0	LDL
Cl^-	4.3	3.1	2.7
Na^+	9.2	8.7	7.8
K^+	3.2	3.0	2.9
Ca^{2+}	16	16	19
Mg^{2+}	14	14	14
TDS	163	143	139

Units: EC in µS/cm, Total Alkalinity in mg/L $CaCO_3$, ionic concentrations and TDS in mg/L



Trophic parameters

Variable	Littoral	Surface	Bottom
DIC	26	23	36
SiO_2	53	52	51
DIN	ND	0.02	1.93
TP	ND	0.10	0.10
P-PO_4	ND	0.003	0.01
Chlorophyll *a*	ND	38.9	15.8

Units: DIC in µgC/g, SiO_2, DIN, TP, P-PO_4 in mg/L and Chlorophyll *a* in mg/m³

Main taxa in this study
Phytoplankton. *Achnanthidium minutissimum*, *Staurastrum* sp., *Woronichinia* sp.
Diatoms. *Achnanthidium minutissimum*
Testate amoebae. *Centropyxis aculeata*
Cladocerans. *Bosmina longirostris*
Ostracodes. *Cypridopsis*, *Potamocypris*

Previous work
Ortíz-Rubio, 1906; Hernández-Morales *et al.*, [b]2008, 2009, [c]2011, 2014; Caballero *et al.*, 2016.

Figure 2 Climatic and limnological data of Alberca de Tacámbaro. *a* and *b* indicate the bibliographical source of the data. Ionic dominance includes ions present at >5 % relative concentrations in meq/L, in italics are ions between 5 and 25 %; "-" was used when ionic relative concentrations were similar; ">" when they were less than double and ">>" when they were higher than double. LDL = Lower Detection Limit: 0.01 mg/L CO_3^{2-}, 4 mg/L SO_4^{2-}. ND = Not Determined. Date of sampling: June 17, 2011.

4. Discussion

4.1. DISTRIBUTION AND MORPHOMETRIC CHARACTERISTICS

The study covered 30 lakes within a latitudinal band from 19° 00' to 21° 20' N and in longitude from 97° 20' to 104° 40' W. They were distributed along a ~ 3550 m altitudinal gradient, from 737 masl (Santa María del Oro) to 4283 masl (La Luna and El Sol). Most of the lakes were volcanic in origin (5 maars, 6 crater lakes and 7 volcanic dams), followed by reservoirs (8) and tectonic lakes (4). About a third of the lakes were shallow (< 6 m), some of them with just or under 1 m deep, these shallower lakes were mostly reservoirs (*e.g.* Ojo de Agua) or tectonic in origin (*e.g.* Atotonilco). Another third included some of the deepest lakes (> 25 m) in central Mexico, and these were mostly volcanic craters or maars, like Alchichica and Santa María del Oro (62 and 65 m deep, respectively).

There was a good agreement between the measured and the bibliographic depths in all the lakes. Regarding areas, those estimated using Google Earth® also had a good agreement with the available bibliographical data, with discrepancies only at four sites. For lake Tecocomulco the bibliography reports a slightly smaller surface (1900 *vs.* 1769 ha, Ramsar, 2003), this relatively small difference (< 10 %) can be explained as Tecocomulco is a large lake with ample inundation areas which can be flooded or dry depending on season and/or inter-annual climatic variability. For La Vega and Yuriria the bibliography reports larger areas (La Vega: 1610 *vs.* 1950 ha, Ramsar, 2011; and Yuriria: 7200 *vs.* 9500 ha, Ramos and Novelo, 1993) however, these water bodies are dams, which areas can easily change due to human management. For lake La Luna, the bibliography also reports a larger area (2.5 *vs.* 3.1 ha, Alcocer *et al.*, 2004), but there is no discrepancy regarding its depth to confirm any change in this lake's morphometry.

4.2. HYDROCHEMISTRY

Waterbodies covered a wide range of hydrochemical characteristics; at the time of sampling (rainy season) most of them were alkaline (pH > 7.5), and some even reached extremely alkaline pH values (> 9.5, Alchichica, Aljojuca, Atotonilco, Atezca, Tecuitlapa); only a few had pH values around or below 7 (El Sol 7.2, Burro 6.9, Zirahuén 6.5, La Luna 6.3).

Most of them were freshwater lakes, nine with particularly low mineralization (TDS < 100 mg/L, Atezca, Burro, El Sol, Juanacatlán, La Magdalena, La Luna, Tepetiltic, Zempoala, Zirahuén) but there were also six subsaline (Aljojuca, La Preciosa, Pátzcuaro, Santa María del Oro, Sayula, Tecuitlapa) and two hyposaline (Alchichica, Atotonilco).

Except for Colorada, the lakes had low proportions of sulfates (< 25 %) and, except for Alchichica, they were dominated by carbonates and bicarbonates (Figure 3). The high sulfate proportion in Colorada is very unusual and could be a sign of anthropogenic pollution (Davies *et al.*, 2002). Amongst the subsaline and hyposaline lakes there is a trend towards higher [Cl^-] proportions, with Alchichica, the only lake dominated by chlorides, towards the end of this trend. Subsaline and hyposaline waterbodies had also low [Ca^{2+}] proportions (Figure 3) and except for La Preciosa (which was [Mg^{2+}] dominated) they were dominated by [Na^+] + [K^+]. Freshwater lakes do not have a clear ionic dominance, some were dominated by [Na^+] + [K^+] (La Vega, San Pedro Lagunillas, Tecocomulco, Yuriria, Alberca de Teremendo, Atlangatepec), some by [Ca^{2+}] (Colorada, El Sol, La Luna, La Magdalena, Juanacatlán, Metztitlán, Ojo de Agua, Santa Gertrudis Tepetiltic, Zempoala, Zirahuén), and others by [Mg^{2+}] (Santa Rosa, Tacámbaro, Quechulac); however, those with the lowest TDS (< 100 mg/l) were mostly [Ca^{2+}] dominated. This ionic dominance pattern suggest that the lowest TDS lakes represent the least evolved waters (Hardie and Eugster, 1970; Kilham, 1990), with ionic dominance determined mostly by weather-

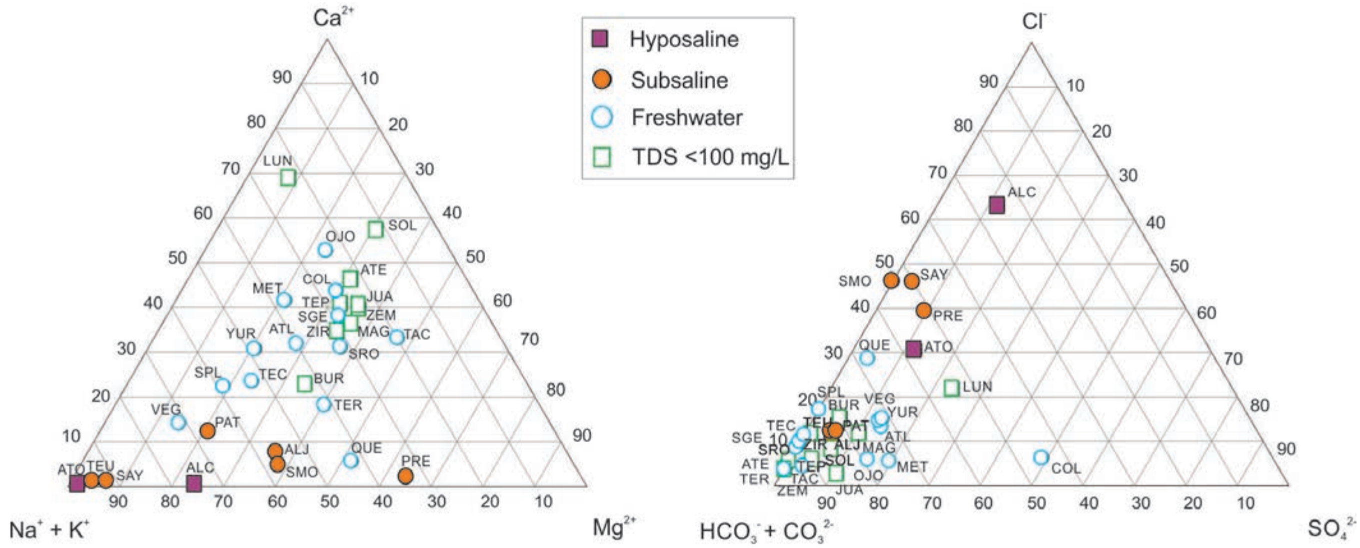


Figure 3 Triangular diagrams showing major cations and anions proportions in the 30 lakes studied along the Trans-Mexican Volcanic Belt, central Mexico. Abbreviations correspond to those in Table 1.

ing processes of the basaltic andesite rocks that dominate in the TMVB (Guilbaud *et al.*, 2012), while the ionic composition of subsaline and hyposaline lakes is mostly controlled by evaporative concentration and carbonate precipitation (Eugster and Hardie, 1978; Kilham, 1990) leading to [Cl^-] -[CO_3^{2-}] - [Na^+] brines such as in Sayula or Alchichica.

4.3. NUTRIENTS AND TROPHIC STATE

According to the Redfield ratio (N:P = 16:1) half of the waterbodies could have their primary productivity limited by nitrogen (DIN:P-PO_4 < 16:1) at the time of sampling, while the other half by phosphorus. However, several lakes had concentrations of these elements above the limiting values of 0.1 µM for P-PO_4 and 7 µM for DIN proposed by Reynolds (Reynolds, 1999) and therefore their productivity could not be considered to be P or N limited (Figure 4A). Most of the lakes had also high concentrations of SiO_2 (SiO_2:P-PO_4 < 16:1 and SiO_2:DIN < 1:1, Xu *et al.*, 2008, Figure 4B). Following these primary productivity nutrient limitation criteria (Redfield, 1958; Reynolds, 1999; Xu *et al.*, 2008) 13 lakes could have some kind of primary productivity nutrient limitation at the time of sampling. Phosphorus limitation was the most frequent (8 lakes), followed by nitrogen (6) and silica (5); some of these lakes were co-limited by more than one of these nutrients: one lake was co-limited by nitrogen, phosphorus and silica (Zirahuén); two by phosphorus and nitrogen (Alberca de Tacámbaro and El Sol) and one by nitrogen and silica (Alchichica) (Figure 4). Atotonilco and Sayula were notable for having very high DIN and P-PO_4 concentrations but a relatively low trophic level (both were mesotrophic), suggesting that productivity in these shallow lakes could be limited by other (unknown) factors.

Most of the lakes where nutrient levels showed possible limitation of primary productivity were mesotrophic (9), oligotrophic (4) or ultraoligotrohpic (1) and nearly half of the studied lakes (16) were either eutrohpic (8) or hypertrophic (8). It is worth noticing that in general the eutrophic to hypertrophic lakes were shallow (< 8 m) and/or had low relative depth (< 1 %). This raises the question of whether this high trophic level is a natural feature of the shallow lakes in the TMVB or if it is a response to antropogenic impact. Besides, shallow water bodies are probably the most sensitive to climatic changes, therefore this kind of lakes should be monitored regularly (at least once a year), to record changes in temperature, pH, salinity, major ions and nutrient levels.

4.4. BIOINDICATORS

We report the distribution of 97 taxa of aquatic bioindicators: 40 corresponding to phytoplankton, 30 to diatoms in surface sediments, 8 testate

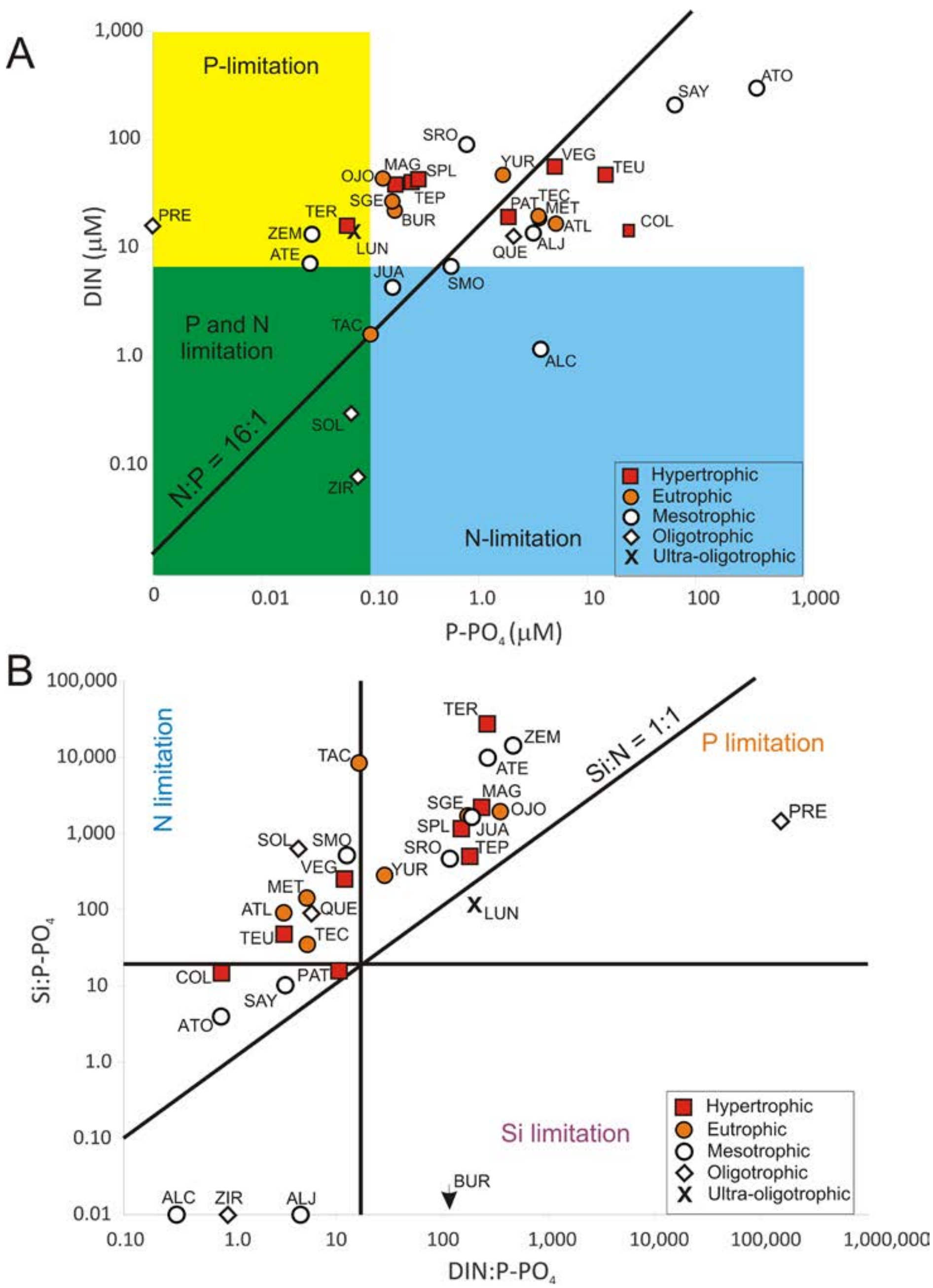


Figure 4 Nutrients in surface waters from the 30 lakes studied along the Trans-Mexican Volcanic Belt, central Mexico. A) $P\text{-}PO_4$ and DIN molar concentrations diagram, diagonal line represents the Redfield (1958) N:P 16:1 ratio, shaded areas define nutrient limiting values according to Reynolds (1999) ($P\text{-}PO_4 < 0.1$ μM; DIN < 7 μM). B) Nutrient molar ratios showing areas of Si, N or P limitation according to Xu *et al.* (2008), diatom growth could be limited by Si availability if Si:P<16 and/or Si:N<1. Abbreviations correspond to those in Table 1.

amoebae, 11 cladocerans and 8 ostracodes (see Electronic Supplement 2).

Considering that only the most abundant taxa in each lake are reported in this work, we found that more than half of them (65) were abundant only at one site; this applies particularly to the phytoplankton and sedimentary diatom taxa. Amongst the phytoplankton, *Peridinium* Ehrenberg had the highest frequency of occurrence (abundant in 5 lakes) while in the sedimentary diatoms it was *Aulacoseria granulata* (Ehrenberg) Simonsen (abundant in 6 lakes). Testate amoeba, cladocerans and ostracoda had a higher number of taxa common to more than one lake and, taxa like *Centropyxis aculeata* (Ehrenberg) Stein, *Alona quadrangularis* (O.F. Müller), *Bosmina longirostris* (O.F. Müller), *Daphnia longispina*- group (O.F. Müller), *Candona* Baird and *Limnocythere* Brady had relatively high occurrence frequencies (abundant in ≥ 6 lakes). Surprisingly some of the lakes that shared these high frequency taxa were located at opposite extremes in the TMVB; for example La Preciosa (east of TMVB) and Atotonilco (west of TMVB, Figure 1). However, this is only a first approach on the distribution of these bioindicators, and detailed, species level identifications supported by molecular studies would be necessary.

4.5. CLIMATIC AND ENVIRONMENTAL GRADIENTS

The PCA performed using geographical as well as climatic and limnological data (Figure 4A) showed a close correlation between both sets of variables. The longest environmental vectors, which correlate closely with the first axis (PC1 27.17 %), were mean annual temperature and water temperature. Altitude on the other hand correlates negatively with PC1 and with temperature, as higher altitudes are associated with cooler climates. The second axis (PC2 20.39 %) showed a positive correlation with precipitation and a negative correlation with total dissolved solids and electric conductivity. This relationship between lower precipitation and higher water ionic concentration has already been identified in previous works (Alcocer and Hammer, 1998; Armienta *et al.*, 2008; Hernández-Avilés *et al.*, 2007) and is associated with the process of evaporative concentration that lake water undergoes in relatively dry climates, where evaporation exceeds precipitation (Hardie and Eugster, 1970).

Following these environmental gradients (temperature and precipitation) the PCA biplot (PC1 *vs*. PC2) separates the studied lakes into four quadrants (Q) according to climate and limnological conditions (Figure 5). Cool, wet climates are associated with the lakes with the lowest TDS (< 100 mg/l) in QII (*e.g.* La Luna and El Sol). Lakes in cool and relatively dry climates are in QIII (*e.g.* Alchichica, Aljojuca, Quechulac) and those in warmer and relatively dry climates are in QIV (Atotonilco, Sayula), both groups of lakes showing the highest TDS and EC values. Finally, lakes in warm, wet climates, with medium TDS are located in QI (Colorada, La Vega, San Pedro Lagunillas, Tepetiltic). Taking into account the chlorophyll *a* vector, another ecological gradient becomes evident, with the eutrophic or hypertrophic lakes located in QI (moist and warm climates) while the (ultra)oligotrophic lakes are located in QII or QIII (cooler climates). High trophic levels in our data set seem to be at least partially related with climatic conditions, to warmer and moister climates where chemical weathering is intense and favors faster mobilization of chemical elements, including nutrients (N, P, Si) from the basement rocks into the lakes (Lewis, 1996; Malmaeus *et al.*, 2006; Xia *et al.*, 2015).

It is interesting to note that in the PC1 *vs.* PC2 graph the lakes from opposite sides of the TMVB lie at adjacent quadrants (QIII and QIV) as they share high electric conductivities and total dissolved solids, associated to relatively dry climatic conditions. The bioindicator distribution previously discussed could be explained, therefore, as geographically distant lakes such as La Preciosa and Atotonilco share some physicochemical characteristics.

When the PCA is performed excluding geographical location (latitude, longitude and altitude) (Figure 4B) the variables associated to each axis

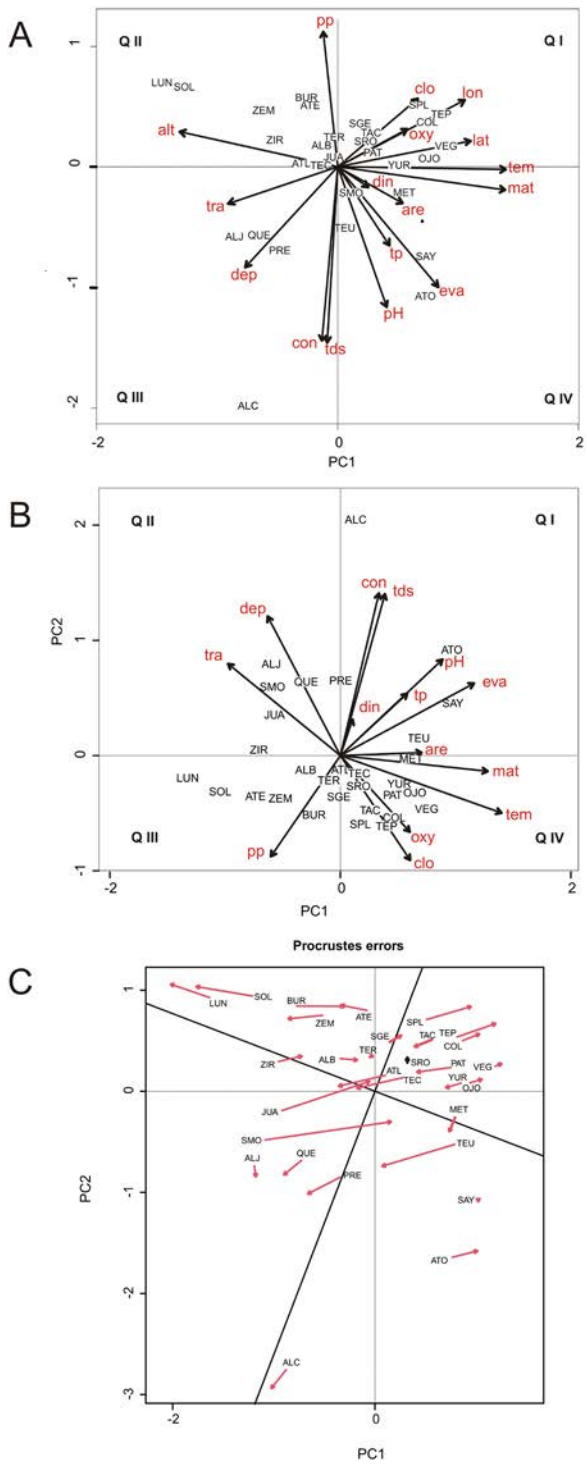


Figure 5 Principal component analysis (PCA) ordination of the 30 lakes studied along the Trans- Mexican Volcanic Belt, central Mexico; arrows indicate the geographic, climatic and limnological variables. A) PCA including latitude, longitude and altitude. B) PCA without latitude, longitude and altitude. C) Procrustes analysis showing the displacement of the sites between both ordinations. Abbreviations of waterbodies correspond to those in the chart of each waterbody (Figure 2 – 3). Abbreviations of environmental variables: alt, altitude; are, area; clo, chlorophyll *a*; con, electric conductivity; dep, maximum depth; din, dissolved inorganic nitrogen; eva, mean annual evaporation; lat, latitude; lon, longitude; mat, mean annual temperature; oxy, dissolved oxygen; pH, pH; pp, mean annual precipitation; tds, total dissolved solids; tem, water temperature; tp, total phosphorus; tra, transparency. Abbreviations correspond to those in Table 1.

(PC1 25.32 %, PC2 23.69 %) do not change, even though the PC2 orientation does. The Procrustes test allows us to determine which lakes are influenced the most by their geographic location, results are represented by arrows with their base indicating the location of the site in the first ordination, whereas the tip of the arrow indicates the localization of the same site in the second ordination. The lakes with the longest arrows (Figure 5C, *e.g.* Santa María del Oro, Juanacatlán and Tecuitlapa) are the ones that are more influenced by regional variables associated with their location (latitude, longitude and altitude) and would be the best choices for palaeoclimatic research while the shorter arrows (Alberca de Teremendo, Sayula, Santa Rosa, La Vega) indicate lakes which characteristics depend more on their local rather than regional variables.

It is only through the knowledge of the basic limnology and biodiversity of our lakes, generated via unified methodologies that guarantee comparable datasets, that more complex or detail studies can be proposed and developed leading to a better understanding, management and conservation of our country's water resources.

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Electronic Supplement 1

Alberca de Tacámbaro (TAC), Michoacán
19°12'38" N, 101°27'33" W, 1475 masl

Climate
Warm, sub-humid, summer rains
(A)C(w_1)(w)

Mean Annual Temperature	19.1 °C
Temp. Range	16.8 (Jan) - 21.8 (May) °C
Annual Precipitation	1172 mm
Annual Evaporation	1452 mm

Limnology

Lake type	Volcanic (crater)
Area	8.2 ha
Maximum Depth	28 m[b]
Relative Depth	8.7 %
Mixing pattern	Warm monomictic[c]
Thermocline and oxycline	~5m
Transparency	0.7 m
Ionic dominance	[HCO_3^-] [Mg^{2+}] > [Ca^{2+}] > *[Na^+]*
Salinity category	Freshwater
Trophic category	Eutrophic
Nutrient ratios	DIN:TP 0.1:1; DIN:$P\text{-}PO_4$ 17:1; SiO_2:DIN 530:1; SiO_2:$P\text{-}PO_4$ 8 400:1

Chemical parameters

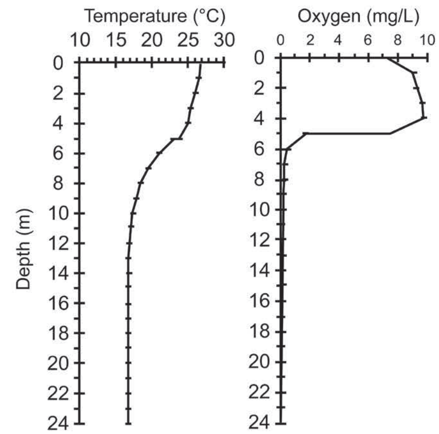
Variable	Littoral	Surface	Bottom
pH	ND	7.8	7.3
EC	ND	182	208
Total Alk	128	115	122
CO_3^{2-}	27	31	LDL
HCO_3^-	102	76	149
SO_4^{2-}	4.1	4.0	LDL
Cl^-	4.3	3.1	2.7
Na^+	9.2	8.7	7.8
K^+	3.2	3.0	2.9
Ca^{2+}	16	16	19
Mg^{2+}	14	14	14
TDS	163	143	139

Units: EC in µS/cm, Total Alkalinity in mg/L $CaCO_3$, ionic concentrations and TDS in mg/L

Trophic parameters

Variable	Littoral	Surface	Bottom
DIC	26	23	36
SiO_2	53	52	51
DIN	ND	0.02	1.93
TP	ND	0.10	0.10
$P\text{-}PO_4$	ND	0.003	0.01
Chlorophyll *a*	ND	38.9	15.8

Units: DIC in µgC/g, SiO_2, DIN, TP, $P\text{-}PO_4$ in mg/L and Chlorophyll *a* in mg/m³



Main taxa in this study
Phytoplankton. *Achnanthidium minutissimum*, *Staurastrum* sp., *Woronichinia* sp.
Diatoms. *Achnanthidium minutissimum*
Testate amoebae. *Centropyxis aculeata*
Cladocerans. *Bosmina longirostris*
Ostracodes. *Cypridopsis*, *Potamocypris*

Previous work
Ortíz-Rubio, 1906; Hernández-Morales *et al.*, [b]2008, 2009, [c]2011, 2014; Caballero *et al.*, 2016.

Figure A1-1 Climatic and limnological data of Alberca de Tacámbaro. *b* and *c* indicate the bibliographical source of the data. Ionic dominance includes ions present at > 5 % relative concentrations in meq/L, in italics are ions between 5 and 25 %; "-" was used when ionic relative concentrations were similar; ">" when they were less than double and ">>" when they were higher than double. *LDL* = Lower Detection Limit: 0.01 mg/L CO_3^{2-}, 4 mg/LSO_4^{2-}. *ND* = Not Determined. Date of sampling: June 17, 2011.

Alberca de Teremendo (TER), Michoacán
19°48'21" N, 101°27'15" W, 2058 masl

Climate
Temperate, sub-humid, summer rains
C(w_1)(w)
Mean Annual Temperature 16.8 °C
Temp. Range 13.9 (Jan) – 20.0 (May) °C
Annual Precipitation 695 mm
Annual Evaporation 1626 mm

Limnology

Lake type	Volcanic (crater)
Area	15 ha
Maximum Depth Recorded	9 m
Rel. Depth	2.1 %
Mixing pattern	Warm monomictic
Thermocline and oxycline	~2 m
Transparency	0.2 m
Ionic dominance	$[HCO_3^-]$ $[Na^+]$ - $[Mg^{2+}]$ > *$[Ca^{2+}]$*
Salinity category	Freshwater
Trophic category	Hypertrophic
Nutrient ratios	DIN:TP 4:1 DIN:P-PO_4 269:1 SiO_2:DIN 102:1 SiO_2:P-PO_4 27400:1

Chemical parameters

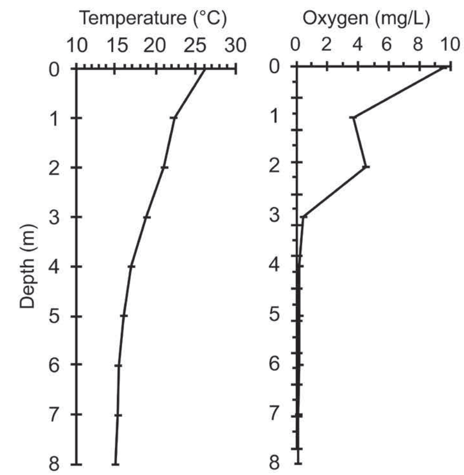
Variable	Littoral	Surface	Bottom
pH	ND	8.3	7.4
EC	ND	353	442
Total Alk	228	228	258
CO_3^{2-}	35	36	LDL
HCO_3^-	207	205	315
SO_4^{2-}	LDL	LDL	LDL
Cl^-	6.9	7.0	7.0
Na^+	37	36	32
K^+	15	15	13
Ca^{2+}	18	18	29
Mg^{2+}	23	23	22
TDS	309	309	327

Units: EC in µS/cm, Total Alkalinity in mg/L $CaCO_3$, ionic concentrations and TDS in mg/L

Trophic parameters

Variable	Littoral	Surface	Bottom
DIC	53	54	72
SiO_2	102	101	89
DIN	ND	0.23	5.46
TP	ND	0.12	0.28
P-PO_4	ND	0.002	0.18
Chlorophyll *a*	ND	244.5	23.0

Units: DIC in µgC/g, SiO_2, DIN, TP, P-PO_4 in mg/L and Chlorophyll *a* in mg/m^3



Main taxa in this study
Phytoplankton. *Botryococcus* sp., *Ceratium* sp., *Peridinium* sp.
Diatoms. *Gomphonema lagenula*, *Nitzschia amphibia*
Testate amoebae. Below critical value
Cladocerans. *Bosmina longirostris*, *Bosmina* (E.) *longispina*
Ostracodes. *Cypria*, *Potamocypris*

Previous work
No previous studies.

Figure A1-2 Climatic and limnological data of Alberca de Teremendo. Ionic dominance includes ions present at > 5 % relative concentrations in meq/L, in italics are ions between 5 and 25 %; "-" was used when ionic relative concentrations were similar; ">" when they were less than double and ">>" when they were higher than double. *LDL* = Lower Detection Limit: 0.01 mg/L CO_3^{2-}, 4 mg/LSO_4^{2-}. Below critical value Testate amoebae < 100 specimens. Date of sampling: June 18, 2011.

Alchichica (ALC), Puebla
19°24'44" N, 97°24'07" W, 2321 masl

Climate
Dry, temperate, summer rains
BS_1 k'w
Mean Annual Temperature 13.9 °C
Temp. Range 10.4 (Jan) - 16.3 (May) °C
Annual Precipitation 388 mm
Annual Evaporation 1741 mm

Limnology
Lake type Volcanic (maar)
Area 200 ha
Maximum Depth 62 m[b]
Relative Depth 3.8 %
Mixing pattern Warm monomictic[c]
Thermocline and oxycline ~14 m
Transparency (Alcocer, *per. com.*) 5 m
Ionic dominance
$[Cl^-] >> [CO_3^{2-}] >> [SO_4^{2-}]$ (*$[SO_4^{2-}]$* in italics)
$[Na^+] >> [Mg^{2+}]$ (*$[Mg^{2+}]$* in italics)
Salinity category Hyposaline
Trophic category Mesotrophic
Nutrient ratios DIN:TP 0.3:1
DIN:$P-PO_4$ 0.3:1
SiO_2:$P-PO_4$ 0.01:1

Chemical parameters

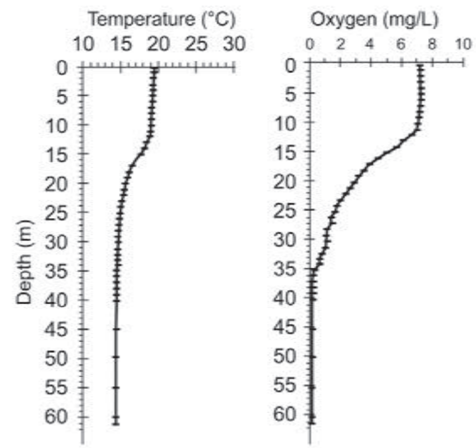
Variable	Littoral	Surface	Bottom
pH	ND	8.3	10.2
EC	ND	14960	14730
Total Alk	2193	2225	2172
CO_3^{2-}	940	971	959
HCO_3^-	765	739	701
SO_4^{2-}	997	1013	1116
Cl^-	3915	3900	3820
Na^+	2573	2645	2595
K^+	238	242	239
Ca^{2+}	20	20	20
Mg^{2+}	462	462	453
TDS	8882	9039	8809

Units: EC in µS/cm, Total Alkalinity in mg/L $CaCO_3$, ionic concentrations and TDS in mg/L

Trophic parameters

Variable	Littoral	Surface	Bottom
DIC	437	427	420
SiO_2	LDL	LDL	LDL
DIN	ND	0.02	0.06
TP	ND	0.12	0.07
$P-PO_4$	ND	0.12	0.05
Chlorophyll *a*	ND	10.5	3.9

Units: DIC in µgC/g, SiO_2, DIN, TP, $P-PO_4$ in mg/L and Chlorophyll *a* in mg/m^3



Main taxa in this study
Phytoplankton. *Ankistrodesmus* sp., *Nodularia spumigena*
Diatoms. *Amphora pediculus*, *Hyppodonta hungarica*, *Navicula erifuga*
Testate amoebae. Below critical value
Cladocera. Absent
Ostracodes. *Candona*, *Limnocythere*

Previous work*
Vilaclara *et al.*, 1993; Alcocer *et al.*, [c]2000, 2008, 2014, [b]2015; Oliva et al., 2001, 2008; Alcocer and Lugo 2003; [a]Filonov *et al.*, 2006; Alcocer and Filonov, 2007; Adame *et al.*, 2008; Armienta *et al.*, 2008; Ramos-Higuera *et al.*, 2008; Kaźmierczak *et al.*, 2011; Oseguera *et al.*, 2011; Couradeau *et al.*, 2011; Ortega-Mayagoitia *et al.*, 2011; Ardiles *et al.*, 2012; Gérard *et al.*, 2013; Hernández *et al.*, 2014; Mancilla *et al.*, 2014; Filonov *et al.*, 2015; Pérez *et al.*, 2015.

* Older studies cited within these references.

Figure A1-3 Climatic and limnological data of Alchichica. *b* and *c* indicate the bibliographical source of the data. Ionic dominance includes ions present at > 5 % relative concentrations in meq/L, in italics are ions between 5 and 25 %; "-" was used when ionic relative concentrations were similar; ">" when they were less than double and ">>" when they were higher than double. *LDL* = Lower Detection Limit: 3 mg/LSiO_2. *ND* = Not Determined. *Below critical value* Testate amoebae < 100 specimens. Date of sampling: June 11, 2011.

Aljojuca (ALJ), Puebla
19°05'23" N, 97°32'05" W, 2371 masl

Climate
Temperate, dry sub-humid, summer rains $(C)(w_0)(w)$
Mean Annual Temperature 14.7 °C
Temp. Range 12.0 (Jan) - 16.7 (May) °C
Annual Precipitation 851 mm
Annual Evaporation 1644 mm

Limnology
Lake type Volcanic (maar)
Area 42 ha
Maximum Depth 51 m[b]
Relative Depth 7 %
Mixing pattern Warm monomictic[c]
Thermocline and oxycline ~ 11 m
Transparency 11.5 m
Ionic dominance
$[HCO_3^-]$ >> *$[Cl^-]$ > $[SO_4^{2-}]$*
$[Na^+]$ > $[Mg^{2+}]$ >> *$[Ca^{2+}]$*
Salinity category Subsaline
Trophic category Mesotrophic
Nutrient ratios DIN:TP 3:1
DIN:P-PO_4 5:1

Chemical parameters

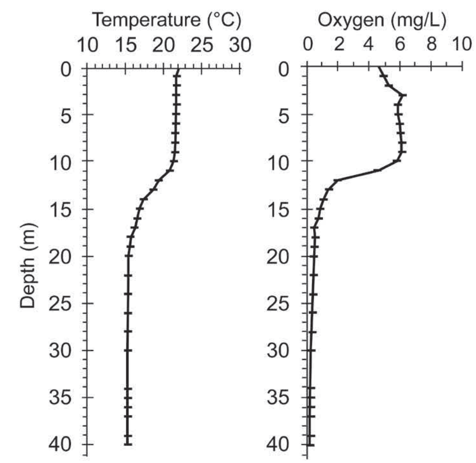
Variable	Littoral	Surface	Bottom
pH	ND	9.5	9.5
EC	ND	1152	1147
Total Alk	651	649	635
CO_3^{2-}	157	140	102
HCO_3^-	475	506	568
SO_4^{2-}	43	43	41
Cl^-	60	59	58
Na^+	189	185	183
K^+	27	27	26
Ca^{2+}	24	24	24
Mg^{2+}	70	70	68
TDS	705	699	735

Units: EC in µS/cm, Total Alkalinity in mg/L $CaCO_3$, ionic concentrations and TDS in mg/L

Trophic parameters

Variable	Littoral	Surface	Bottom
DIC	142	140	144
SiO_2	LDL	LDL	8.0
DIN	ND	0.20	0.83
TP	ND	0.15	0.32
P-PO_4	ND	0.10	0.31
Chlorophyll *a*	ND	11.9	14.5

Units: DIC in µgC/g, SiO_2, DIN, TP, P-PO_4 in mg/L and Chlorophyll *a* in mg/m^3



Main taxa in this study
Phytoplankton. *Botryococcus* sp.
Diatoms. *Cyclotella meneghiniana*
Testate amoebae. *Centropyxis aculeata*, *Centropyxis constricta*
Cladocerans. *Alona quadrangularis*, *Daphnia longispina*-group
Ostracodes. *Cypridopsis*, *Fabaeformiscandona*

Previous work
Arredondo-Figueroa *et al.*, 1983; [b]Vilaclara *et al.*, 1993; Arredondo, 2002; Alcocer *et al.*, 2002; Peralta *et al.*, 2002; [c]Armienta *et al.*, 2008; Bhattacharya, 2015; Pérez *et al.*, 2015.

Figure A1-4 Climatic and limnological data of Aljojuca. *b* and *c* indicate the bibliographical source of the data. Ionic dominance includes ions present at > 5 % relative concentrations in meq/L, in italics are ions between 5 and 25 %; "-" was used when ionic relative concentrations were similar; ">" when they were less than double and ">>" when they were higher than double. *LDL* = Lower Detection Limit: 3 mg/LSiO_2. *ND* = Not Determined. Date of sampling: June 13, 2011.

Atezca (ATE), Hidalgo
20°48'22" N, 98°44'47" W, 1316 masl

Climate
Temperate, humid, summer rains
C(m)
Mean Annual Temperature 18.3 °C
Temp. Range 15.1 (Jan) - 25.2 (May) °C
Annual Precipitation 1713 mm
Annual Evaporation 1034 mm

Limnology
Lake type Volcanic (dam)
Area 27 ha
Maximum Depth 16 m[b]
Relative Depth 2.7 %
Mixing pattern Warm monomictic[c]
Thermocline and oxycline ~5 m
Transparency 2 m
Ionic dominance $[HCO_3^-]$ $[Ca^{2+}] > [Mg^{2+}] > [Na^+]$ (*$[Na^+]$* in italics)
Salinity category Freshwater
Trophic category Mesotrophic
Nutrient ratios
DIN:TP 43:1
$DIN:P\text{-}PO_4$ 267:1
SiO_2:DIN 37:1
$SiO_2:P\text{-}PO_4$ 9900:1

Chemical parameters

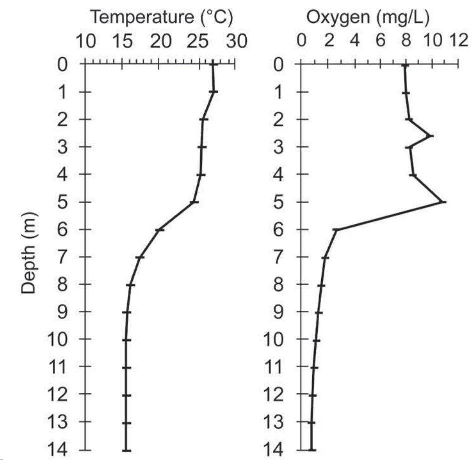
Variable	Littoral	Surface	Bottom
pH	9.9	9.3	7.7
EC	97	105	174
Total Alk	52	59	75
CO_3^{2-}	14	5.0	LDL
HCO_3^-	36	61	92
SO_4^{2-}	LDL	LDL	LDL
Cl^-	2.1	2.4	2.1
Na^+	5.1	5.0	4.8
K^+	1.8	2.1	2.1
Ca^{2+}	11	12	12
Mg^{2+}	4.6	5.1	6.7
TDS	46	65	64

Units: EC in µS/cm, Total Alkalinity in mg/L $CaCO_3$, ionic concentrations and TDS in mg/L

Trophic parameters

Variable	Littoral	Surface	Bottom
DIC	12	13	25
SiO_2	18	17	24
DIN	ND	0.11	0.34
TP	ND	0.01	0.05
$P\text{-}PO_4$	ND	0.001	0.03
Chlorophyll *a*	ND	11.2	43.5

Units: DIC in µgC/g, SiO_2, DIN, TP, $P\text{-}PO_4$ in mg/L and Chlorophyll *a* in mg/m^3



Main taxa in this study
Phytoplankton. *Aphanizomenon flosaquae*
Diatoms. *Discostella stelligera*, *Planothidium rostratum*
Testate amoebae. *Cucurbitella* sp., *Difflugia protaeiformis*
Cladocerans. *Daphnia pulex*-group
Ostracodes. *Cypridopsis*

Previous work
[c]Díaz-Pardo *et al.*, 1998, [b]2002; Vázquez and Favila 1998; Conserva and Byrne, 2002; Pérez *et al.*, 2015.

Figure A1-5 Climatic and limnological data of Atezca. *b* and *c* indicate the bibliographical source of the data. Ionic dominance includes ions present at > 5 % relative concentrations in meq/L, in italics are ions between 5 and 25 %; "-" was used when ionic relative concentrations were similar; ">" when they were less than double and ">>" when they were higher than double. *LDL* = Lower Detection Limit: 0.01 mg/LCO_3^{2-}, 4 mg/LSO_4^{2-}. *ND* = Not Determined.Date of sampling: June 09, 2011.

Atlangatepec (ATL), Tlaxcala
19°33'35" N, 98°10'38" W, 2511 masl
Ramsar site 1986

Climate
Temperate, sub-humid, summer rains
$C(w_1)(w)$

Mean Annual Temperature	12.8 °C
Temp. Range	9.6 (Jan) - 15.4 (May) °C
Annual Precipitation	680 mm
Annual Evaporation	1889 mm

Limnology

Lake type	Reservoir (dike)	
Area	800 ha	
Maximum Depth	7 m[b]	
Relative Depth	0.2 %	
Mixing pattern	Warm polymictic	
Thermocline and oxycline	No	
Transparency	0.1 m	
Ionic dominance	$[HCO_3^-]$ >> *$[SO_4^{2-}]$ - $[Cl^-]$*	
	$[Na^+]$> $[Ca^{2+}]$ > $[Mg^{2+}]$	
Salinity category	Freshwater	
Trophic category	Eutrophic	
Nutrient ratios	DIN:TP	3:1
	DIN:P-PO_4	3:1
	SiO_2:DIN	27:1
	SiO_2:P-PO_4	90:1

Chemical parameters

Variable	Littoral
pH	7.7
EC	292
Total Alk	128
CO_3^{2-}	LDL
HCO_3^-	157
SO_4^{2-}	24
Cl^-	17
Na^+	23
K^+	16
Ca^{2+}	22
Mg^{2+}	12
TDS	212

Units: EC in µS/cm, Total Alkalinity in mg/L $CaCO_3$, ionic concentrations and TDS in mg/L

Trophic parameters

Variable	Littoral
DIC	34
SiO_2	29
DIN	0.24
TP	0.18
P-PO_4	0.16
Chlorophyll *a*	33.6

Units: DIC in µgC/g, SiO_2, DIN, TP, P-PO_4 in mg/L and Chlorophyll *a* in mg/m^3

Depth (m)	Temperature (°C)	Oxygen (mg/L)
0	19.6	7.0
1	15.4	6.3

Main taxa in this study
Phytoplankton. Below critical value
Diatoms. *Amphora pediculus*, *Navicula* sp., *Nitzschia palea* var. *debilis*, *Stephanodiscus minutulus*
Testate amoebae. *Difflugia* spp.
Cladocerans. *Bosmina longirostris*, *Chydorus* cf. *sphaericus.*
Ostracodes. *Candona*, *Darwinula*, *Limnocythere*

Previous work
Pérez-Rodríguez 1995; Pérez-Rodríguez *et al.*, 2001; Salomón-Serna *et al.*, 2003; Sánchez-Santillán *et al.*, 2004; [b]Rodríguez and Ritter, 2007; García-Nieto *et al.*, 2011; Ramsar, 2011b; Castilla-Hernández *et al.*, 2014; Pérez *et al.*, 2015.

Figure A1-6 Climatic and limnological data of Atlangatepec. *b* indicate the bibliographical source of the data. Ionic dominance includes ions present at > 5 % relative concentrations in meq/L, in italics are ions between 5 and 25 %; "-" was used when ionic relative concentrations were similar; ">" when they were less than double and ">>" when they were higher than double. *LDL* = Lower Detection Limit: 0.01 mg/LCO_3^{2-}. *Below critical value* Phytoplankton < 11 specimens. Date of sampling: June 11, 2011.

Atotonilco (ATO), Jalisco
20°23‘57" N, 103°39‘55" W, 1355 masl
Ramsar site 1607

Climate
Warm, dry sub-humid, summer rains
(A)C(w_0)(w)

Mean Annual Temperature	20.5 °C
Temp. Range	16.4 (Jan) - 23.7 (June) °C
Annual Precipitation	805 mm
Annual Evaporation	1865 mm

Limnology

Lake type	Tectonic	
Area	1400 ha[a]	
Maximum Depth Recorded	0.5 m[b]	
Relative Depth	<0.1 %	
Mixing pattern	Warm polymictic	
Thermocline and oxycline	No	
Transparency	0.1 m	
Ionic dominance	$[HCO_3^-] > [Cl^-] >> [SO_4^{2-}]$ $[Na^+]$	
Salinity category	Hyposaline	
Trophic category	Mesotrophic	
Nutrient ratios	DIN:TP	1:1
	DIN:P-PO_4	1:1
	SiO_2:DIN	5:1
	SiO_2:P-PO_4	4:1

Chemical parameters

Variable	Littoral	Surface
pH	9.6	9.6
EC	5550	5500
Total Alk	2082	2092
CO_3^{2-}	747	729
HCO_3^-	1021	1071
SO_4^{2-}	372	414
Cl^-	696	727
Na^+	1490	1863
K^+	74	75
Ca^{2+}	13	10
Mg^{2+}	12	11
TDS	3839	3905

Units: EC in µS/cm, Total Alkalinity in mg/L $CaCO_3$, ionic concentrations and TDS in mg/L

Trophic parameters

Variable	Littoral	Surface
DIC	389	390
SiO_2	87	88
DIN	ND	4.27
TP	ND	12.19
P-PO_4	ND	11.35
Chlorophyll *a*	ND	18.5

Units: DIC in µgC/g, SiO_2, DIN, TP, P-PO_4 in mg/L and Chlorophyll *a* in mg/m³

Depth (m)	Temperature (°C)	Oxygen (mg/L)
0	20.9	4.7

Main taxa in this study
Phytoplankton. Below critical value
Diatoms. Absent
Testate amoebae. Absent
Cladocerans. *Alona quadrangularis*, *Daphnia longispina*-group
Ostracodes. *Candona*, *Limnocythere*, *Potamocypris*

Previous work
Pérez-Arteaga *et al.*, 2002; Conant, 2003; [a,b]Ramsar 2006.

Figure A1-7 Climatic and limnological data of Atotonilco. *a* and *b* indicate the bibliographical source of the data. Ionic dominance includes ions present at > 5 % relative concentrations in meq/L, in italics are ions between 5 and 25 %; "-" was used when ionic relative concentrations were similar; ">" when they were less than double and ">>" when they were higher than double. *ND* = Not Determined. *Below critical value* Phytoplankton < 11 specimens. Date of sampling: October 09, 2011.

Burro (BUR), Michoacán
19°25'07" N, 101°30'09" W, 2708 masl

Climate
Temperate, humid sub-humid, summer rains
C(w_2)(w)
Mean Annual Temperature 16.2 °C
Temp. Range 12.7 (Dec) - 18.6 (May) °C
Annual Precipitation 902 mm
Annual Evaporation 1286 mm

Limnology

Lake type	Probably volcanic
Area	9.0 ha
Maximum Depth Recorded	1 m
Relative Depth	0.3 %
Mixing pattern	Warm polymictic
Thermocline and oxycline	No
Transparency	0.3 m
Ionic dominance	$[HCO_3^-]$ >> *$[Cl^-]$* $[Na^+]$ > $[Mg^{2+}]$ > *$[Ca^{2+}]$*
Salinity category	Freshwater
Trophic category	Eutrophic
Nutrient ratios	DIN:TP 7:1 DIN:P-PO_4 136:1

Previous work
No previous studies.

Chemical parameters

Variable	Littoral
pH	6.9
EC	27
Total Alk	16
CO_3^{2-}	LDL
HCO_3^-	19
SO_4^{2-}	LDL
Cl^-	2.3
Na^+	1.9
K^+	3.6
Ca^{2+}	1.6
Mg^{2+}	1.5
TDS	21

Units: EC in µS/cm, Total Alkalinity in mg/L $CaCO_3$, ionic concentrations and TDS in mg/L

Trophic parameters

Variable	Littoral
DIC	6.7
SiO_2	LDL
DIN	0.32
TP	0.11
P-PO_4	0.01
Chlorophyll *a*	45.4

Units: DIC in µgC/g, SiO_2, DIN, TP, P-PO_4 in mg/L and Chlorophyll *a* in mg/m^3

Depth (m)	Temperature (°C)	Oxygen (mg/L)
0	19.7	5.3

Main taxa in this study
Phytoplankton. *Aulacoseira granulata*, *Coelastrum sphaericum*, *Staurodesmus* sp.
Diatoms. *Aulacoseira ambigua*, *Caloneis aerophila*, *Eunotia monodon*, *Eunotia naegelii*
Testate amoebae. Below critical value
Cladocerans. *Alona rectangula*, *Bosmina longirostris*
Ostracodes. Absent

Figure A1-8 Climatic and limnological data of Burro. Ionic dominance includes ions present at > 5 % relative concentrations in meq/L, in italics are ions between 5 and 25 %; "-" was used when ionic relative concentrations were similar; ">" when they were less than double and ">>" when they were higher than double. *LDL* = Lower Detection Limit: 0.01 mg/LCO_3^{2-}, 4 mg/LSO_4^{2-}. *Below critical value* Testate amoebae < 100 specimens. Date of sampling: June 17, 2011.

Colorada (COL), Jalisco
20°45'56" N, 103°58'49" W, 1366 masl

Climate
Warm, sub-humid, summer rains
(A)C(w_1)(w)

Mean Annual Temperature	19.2 °C
Temp. Range	13.7 (Jan) - 23.8 (June) °C
Annual Precipitation	982 mm
Annual Evaporation	1745 mm

Limnology

Lake type		Reservoir (dike)
Area		410 ha
Maximum Depth Recorded		3 m
Relative Depth		0.1 %
Mixing pattern		Warm polymictic
Thermocline and oxycline		No
Transparency		0.6 m
Ionic dominance	$[HCO_3^-] > [SO_4^{2-}]$	
	$[Ca^{2+}] > [Mg^{2+}]$ - $[Na^+]$	
Salinity category		Freshwater
Trophic category		Hypertrophic
Nutrient ratios	DIN:TP	1:1
	DIN:P-PO_4	1:1
	SiO_2:DIN	2:1
	SiO_2:P-PO_4	15:1

Previous work
No previous studies.

Chemical parameters

Variable	Littoral	Surface	Bottom
pH	8.1	7.8	7.4
EC	615	611	618
Total Alk	239	235	236
CO_3^{2-}	10	15	11
HCO_3^-	120	157	265
SO_4^{2-}	120	115	115
Cl^-	11	11	11
Na^+	33	33	34
K^+	21	21	21
Ca^{2+}	66	67	66
Mg^{2+}	27	27	27
TDS	457	469	462

Units: EC in µS/cm, Total Alkalinity in mg/L $CaCO_3$, ionic concentrations and TDS in mg/L

Trophic parameters

Variable	Littoral	Surface	Bottom
DIC	56	55	56
SiO_2	32	32	32
DIN	ND	0.21	0.82
TP	ND	0.76	0.81
P-PO_4	ND	0.70	0.76
Chlorophyll *a*	ND	141.0	102.8

Units: DIC in µgC/g, SiO_2, DIN, TP, P-PO_4 in mg/L and Chlorophyll *a* in mg/m^3

Depth (m)	Temperature (°C)	Oxygen (mg/L)
0	28.7	8.8
1	25.0	8.2
2	24.2	4.4

Main taxa in this study
Phytoplankton. *Actinastrum* sp., *Planktothrix* sp.
Diatoms. *Aulacoseira* sp., *Aulacoseira ambigua*, *Cyclotella meneghiniana*
Testate amoebae. *Centropyxis aculeata*
Cladocerans. *Alona quadrangularis*
Ostracodes. *Candona*, Cyprididae sp.1

Figure A1-9 Climatic and limnological data of Colorada. Ionic dominance includes ions present at > 5 % relative concentrations in meq/L, in italics are ions between 5 and 25 %; "-" was used when ionic relative concentrations were similar; ">" when they were less than double and ">>" when they were higher than double. *ND* = Not Determined. Date of sampling: October 06, 2011.

El Sol (SOL), Estado de México
19°06'29" N, 99°45'34" W, 4283 masl

Climate

High-altitude cold	
E(T)H	
Mean Annual Temperature 3.9 °C	
Temp. Range	-2.5 (Jan) – 10.2 (Apr) °C
Annual Precipitation	1227 mm
Annual Evaporation	970 mm

Limnology

Lake type		Volcanic (crater)
Area		23.7 ha[a]
Maximum Depth		15 m[b]
Relative Depth		3.2 %
Mixing pattern		Warm polymictic[c]
Thermocline and oxycline		No and ~8 m
Transparency		2.2 m
Ionic dominance		
	$[HCO_3^-]$ >> *$[Cl^-]$ - $[SO_4^{2-}]$*	
	$[Ca^{2+}] > [Mg^{2+}]$ >> *$[Na^+]$*	
Salinity category		Freshwater
Trophic category		Oligotrophic
Nutrient ratios	DIN:TP	0.2:1
	DIN:P-PO_4	4:1
	SiO_2:DIN	120:1
	SiO_2:P-PO_4	500:1

Chemical parameters

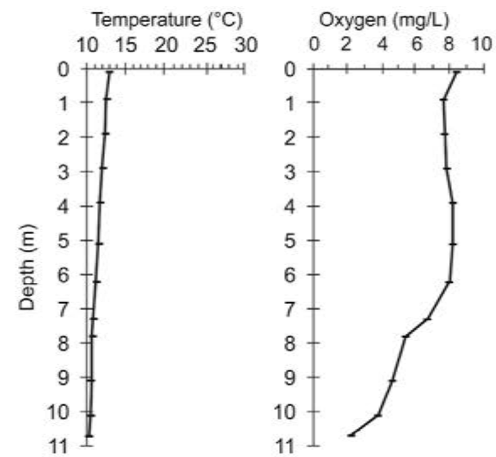
Variable	Surface	Bottom
pH	7.2	7.0
EC	57	87
Total Alk	34	36
CO_3^{2-}	LDL	LDL
HCO_3^-	41	44
SO_4^{2-}	LDL	LDL
Cl^-	2.2	2.2
Na^+	0.4	0.5
K^+	0.4	0.3
Ca^{2+}	11	12
Mg^{2+}	3.6	3.7
TDS	19	48

Units: EC in µS/cm, Total Alkalinity in mg/L $CaCO_3$, ionic concentrations and TDS in mg/L

Trophic parameters

Variable	Surface	Bottom
DIC	ND	ND
SiO_2	LDL	LDL
DIN	0.004	0.03
TP	0.04	0.01
P-PO_4	LDL	LDL
Chlorophyll *a*	4.7	6.7

Units: DIC in µgC/g, SiO_2, DIN, TP, P-PO_4 in mg/L and Chlorophyll *a* in mg/m^3



Main taxa in this study

Phytoplankton. *Ankistrodesmus* sp., *Botryococcus braunii*, *Monoraphidium minutum*, *Oocystis lacustris*

Diatoms. *Cavinula pseudoscutiformis*, *Navicula* NTB, *Psammothidium levanderi*

Testate amoebae. Below critical value

Cladocerans. *Alona manueli*, *Daphnia longispina*-group

Ostracodes. Sample not analyzed

Previous work

Banderas *et al.*, 1991; Caballero, 1996; Sarma *et al.*, 1996; Banderas-Tarabay, 1997; González-Villela *et al.*, 2000; Banderas and González, 2002; [a,b]Alcocer *et al.*, 2004; Armienta *et al.*, 2008; [c]Dimas-Flores *et al.*, 2008; Sinev and Zawisza, 2013; Cuna *et al.*, 2015.

Figure A1-10 Climatic and limnological data of El Sol. *a*, *b* and *c* indicate the bibliographical source of the data. Ionic dominance includes ions present at > 5 % relative concentrations in meq/L, in italics are ions between 5 and 25 %; "-" was used when ionic relative concentrations were similar; ">" when they were less than double and ">>" when they were higher than double. *LDL* = Lower Detection Limit: 0.01 mg/LCO_3^{2-}, 4 mg/LSO_4^{2-}, 3 mg/LSiO_2, 0.005 mg/L P-PO^4. *ND* = Not Determined. *Below critical value* Testate amoebae < 100 specimens. Date of sampling: August 21, 2010.

Juanacatlán (JUA), Jalisco
20º37'37" N, 104º44'20" W, 1981 masl

Climate
Temperate, humid sub-humid, summer rains
$C(w_2)(w)$
Mean Annual Temperature 19.7 ºC
Temp. Range 15.7 (Jan) - 23.1 (May) ºC
Annual Precipitation 885 mm
Annual Evaporation 1528 mm

Limnology
Lake type Volcanic (dam)
Area 20 ha
Maximum Depth Recorded 25 m
Relative Depth 5 %
Mixing pattern Warm monomictic
Thermocline and oxycline ~9 and 7 m
Transparency 6.1 m
Ionic dominance
$[HCO_3^-]$ >> *$[SO_4^{2-}]$*
$[Ca^{2+}]$ > $[Mg^{2+}]$ > *$[Na^+]$*
Salinity category Freshwater
Trophic category Mesotrophic
Nutrient ratios
DIN:TP 7:1
DIN:P-PO_4 187:1
SiO_2:DIN 60:1
SiO_2:P-PO_4 1640:1

Chemical parameters

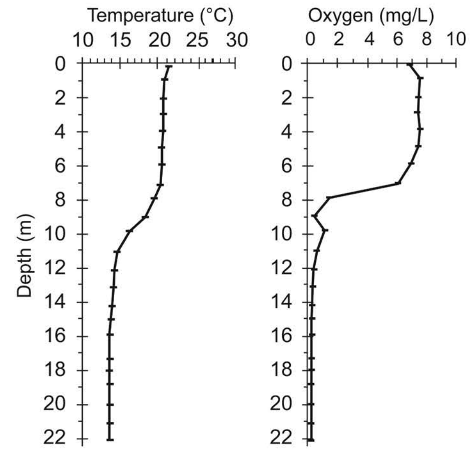
Variable	Littoral	Surface	Bottom
pH	9.3	9.2	7.7
EC	123	123	178
Total Alk	64	63	94
CO_3^{2-}	7.4	4.9	LDL
HCO_3^-	64	67	115
SO_4^{2-}	7.6	7.2	LDL
Cl^-	1.3	1.5	1.7
Na^+	7.4	7.4	7.1
K^+	1.6	1.7	2.2
Ca^{2+}	12	13	17
Mg^{2+}	6.6	6.8	6.6
TDS	113	86	91

Units: EC in µS/cm, Total Alkalinity in mg/L $CaCO_3$, ionic concentrations and TDS in mg/L

Trophic parameters

Variable	Littoral	Surface	Bottom
DIC	13	13	24
SiO_2	17	16	20
DIN	ND	20.0	5.3
TP	ND	0.02	0.33
P-PO_4	ND	0.01	0.26
Chlorophyll *a*	ND	11.2	11.2

Units: DIC in µgC/g, SiO_2, DIN, TP, P-PO_4 in mg/L and Chlorophyll *a* in mg/m³



Main taxa in this study
Phytoplankton. *Fragilaria crotonensis*, *Lyngbya* sp., *Oscillatoria margaritifera*, *Scenedesmus obtusus*
Diatoms. *Fragilaria crotonensis*
Testate amoebae. Below critical value
Cladocerans. *Bosmina longirostris*, *Daphnia pulex*-group
Ostracodes. Absent

Previous work
Davies *et al.*, 2002, 2005; Metcalfe *et al.*, 2010; Jones *et al.*, 2015.

Figure A1-11 Climatic and limnological data of Colorada. Ionic dominance includes ions present at > 5 % relative concentrations in meq/L, in italics are ions between 5 and 25 %; "-" was used when ionic relative concentrations were similar; ">" when they were less than double and ">>" when they were higher than double. *ND* = Not Determined. Date of sampling: October 06, 2011.

La Luna (LUN), Estado de México
19°06'24" N, 99°45'09" W, 4283 masl

Climate
High-altitude cold
E(T)H

Mean Annual Temperature	3.9 °C
Temp. Range	-2.5 (Jan) – 10.2 (Apr) °C
Annual Precipitation	1227 mm
Annual Evaporation	970 mm

Limnology

Lake type	Volcanic (crater)	
Area	2.5 ha	
Maximum Depth Recorded	10 m[b]	
Relative Depth	5.6 %	
Mixing pattern	Warm polymictic[c]	
Thermocline and oxycline	No	
Transparency	10 m	
Ionic dominance	$[HCO_3^-]$ >> *$[SO_4^{2-}]$ - $[Cl^-]$*	
	$[Ca^{2+}]$ >> *$[Na^+]$* >> *$[Mg^{2+}]$*	
Salintiy category	Freshwater	
Trophic state	Ultra-oligotrophic	
Nutrient ratios	DIN:TP	33:1
	DIN:P-PO_4	200:1
	SiO_2:DIN	1:1
	SiO_2:P-PO_4	110:1

Chemical parameters

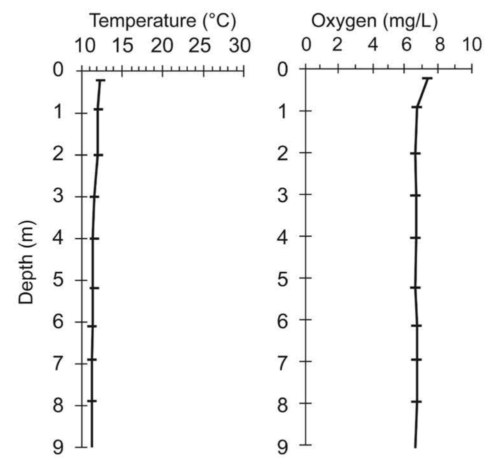
Variable	Surface	Bottom
pH	6.3	6.1
EC	10	9
Total Alk	4.6	4.2
CO_3^{2-}	LDL	LDL
HCO_3^-	5.6	4.2
SO_4^{2-}	LDL	LDL
Cl^-	1.3	2.2
Na^+	0.4	0.5
K^+	0.4	0.3
Ca^{2+}	1.6	1.5
Mg^{2+}	0.1	0.1
TDS	20	60

Units: EC in µS/cm, Total Alkalinity in mg/L $CaCO_3$, ionic concentrations and TDS in mg/L

Trophic parameters

Variable	Surface	Bottom
DIC	ND	ND
SiO_2	0.5	0.6
DIN	0.2	0.2
TP	0.01	0.01
P-PO_4	LDL	LDL
Chlorophyll *a*	0.3	0.9

Units: DIC in µgC/g, SiO_2, DIN, TP, P-PO_4 in mg/L and Chlorophyll *a* in mg/m³



Main taxa in this study
Phytoplankton. Pico-cyanoprokaryota, *Chrysochromulina* aff. *parva*, *Gymnodinium* sp.
Diatoms. *Encyonema perpusillum*
Testate amoebae. Below critical value
Cladocerans. *Alona manueli*, *Alonella pulchella*
Ostracodes. Sample not analyzed

Previous work
Caballero, 1996; Sarma *et al*., 1996; Cervantes-Martínez *et al*., 2000; Davies *et al*., 2002; [b]Alcocer *et al*., 2004; Vilaclara *et al*., 2005; Armienta *et al*., 2008; [c]Dimas-Flores *et al*., 2008; Zawisza *et al*., 2012; Sinev & Zawisza 2013; Cuna *et al*., 2014; Cuna *et al*., 2015.

Figure A1-12 Climatic and limnological data of La Luna. *b* and *c* indicate the bibliographical source of the data. Ionic dominance includes ions present at > 5 % relative concentrations in meq/L, in italics are ions between 5 and 25 %; "-" was used when ionic relative concentrations were similar; ">" when they were less than double and ">>" when they were higher than double. *LDL* = Lower Detection Limit: 0.01 mg/LCO_3^{2-}, 4 mg/LSO_4^{2-}, 3 mg/LSiO_2, 0.005 mg/L P-PO_4. *ND* = Not Determined. *Below critical value* Testate amoebae < 100 specimens. August 21, 2010.

La Magdalena (MAG), Michoacán
19°12'30" N, 101°28'22" W, 1517 masl

Climate
Warm, sub-humid, summer rains
(A)C(w_1)(w)
Mean Annual Temperature 19.1 °C
Temp. Range 16.8 (Jan) - 21.8 (May) °C
Annual Precipitation 1172 mm
Annual Evaporation 1452 mm

Limnology
Lake type Reservoir (dike)
Area 22 ha
Maximum Depth Recorded 4 m
Relative Depth 0.8 %
Mixing pattern Warm polymictic
Thermocline and oxycline ~2m
Transparency 0.5 m
Ionic dominance
$[HCO_3^-]$ >> *$[Cl^-]$ - $[SO_4^{2-}]$*
$[Ca^{2+}]$ - $[Mg^{2+}]$ > $[Na^+]$
Salinity category Freshwater
Trophic category Hypertrophic
Nutrient ratios
DIN:TP 11:1
DIN:P-PO_4 233:1
SiO_2:DIN 10:1
SiO_2:P-PO_4 2 208:1

Chemical parameters

Variable	Littoral	Surface	Bottom
pH	ND	8.8	8.3
EC	ND	128	129
Total Alk	58	58	58
CO_3^{2-}	LDL	11	LDL
HCO_3^-	71	48	71
SO_4^{2-}	7.8	7.6	7.4
Cl^-	6.2	6.9	6.5
Na^+	7.1	7.5	7.2
K^+	4.1	4.0	4.1
Ca^{2+}	11	11	11
Mg^{2+}	6.8	6.8	6.8
TDS	86	85	94

Units: EC in µS/cm, Total Alkalinity in mg/L $CaCO_3$, ionic concentrations and TDS in mg/L

Trophic parameters

Variable	Littoral	Surface	Bottom
DIC	15	15	16
SiO_2	23	23	24
DIN	ND	0.56	1.23
TP	ND	0.11	0.14
P-PO_4	ND	0.01	0.01
Chlorophyll *a*	ND	173.9	31.0

Depth (m)	Temperature (°C)	Oxygen (mg/L)
0	26.0	8.8
1	26.0	9.1
2	24.4	2.3
3	24.2	0.4

Main taxa in this study
Phytoplankton. *Aulacoseira granulata*, *Botryococcus* sp.
Diatoms. *Discostella stelligera*
Testate amoebae. Below critical value
Cladocerans. *Bosmina longirostris*
Ostracodes. Absent

Previous work
No previous studies.

Figure A1-13 Climatic and limnological data of La Magdalena. Ionic dominance includes ions present at > 5 % relative concentrations in meq/L, in italics are ions between 5 and 25 %; "-" was used when ionic relative concentrations were similar; ">" when they were less than double and ">>" when they were higher than double. *LDL* = Lower Detection Limit: 0.01 mg/LCO_3^{2-}. *ND* = Not Determined. *Below critical value* Testate amoebae < 100 specimens. June 17, 2011.

La Preciosa (PRE), Puebla
19°22'24" N, 97°23'07" W, 2340 masl

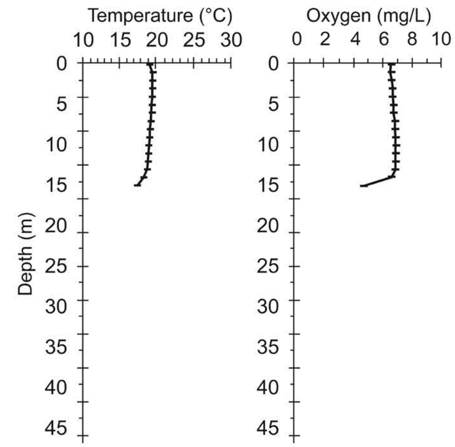
Climate
Dry, temperate, summer rains
$BS_1k'w$
Mean Annual Temperature 13.9 °C
Temp. Range 10.4 (Jan) - 16.3 (May) °C
Annual Precipitation 388 mm
Annual Evaporation 1741 mm

Limnology
Lake type Volcanic (maar)
Area 91 ha
Maximum Depth 46 m[b]
Relative Depth 4.3 %
Mixing pattern Warm monomictic[c]
Thermocline and oxycline ~15 m (?)
Transparency 4.6 m
Ionic dominance
[HCO_3^-] > [Cl^-] >> *[SO_4^{2-}]*
[Mg^{2+}] > [Na^+]
Salinity category Subsaline
Trophic category Oligotrophic
Nutrient ratios DIN:TP 48:1
SiO_2:DIN 30:1

Chemical parameters

Variable	Littoral	Surface	Bottom
pH	ND	9.3	ND
EC	ND	2070	ND
Total Alk	715	721	713
CO_3^{2-}	194	188	185
HCO_3^-	478	497	494
SO_4^{2-}	127	128	123
Cl^-	392	390	388
Na^+	206	200	198
K^+	18	18	18
Ca^{2+}	10	12	12
Mg^{2+}	213	211	211
TDS	1 308	1333	1296

Units: EC in µS/cm, Total Alkalinity in mg/L $CaCO_3$, ionic concentrations and TDS in mg/L



Trophic parameters

Variable	Littoral	Surface	Bottom
DIC	154	155	155
SiO_2	29	28	30
DIN	ND	0.22	0.06
TP	ND	0.01	0.01
$P\text{-}PO_4$	ND	LDL	LDL
Chlorophyll *a*	ND	6.6	4.6

Units: DIC in µgC/g, SiO_2, DIN, TP, $P\text{-}PO_4$ in mg/L and Chlorophyll *a* in mg/m³

Main taxa in this study
Phytoplankton. *Chaetoceros* sp., *Peridinium* sp.
Diatoms. *Cyclotella meneghiniana*
Testate amoebae. Sample not analyzed
Cladocerans. *Alona quadrangularis*, *Daphnia longispina*-group
Ostracodes. *Candona*, *Limnocythere*

Previous work
Arredondo-Figueroa *et al.*, 1983; [b]Vilaclara *et al.*, 1993; Alcocer *et al.*, 1998; Alcocer *et al.*, 2002; Arredondo, 2002; Davies *et al.*, 2002; Peralta *et al.*, 2002; [c]Armienta *et al.*, 2008; Cohuo-Durán *et al.*, 2014; Barrera-Moreno *et al.*, 2015; Pérez *et al.*, 2015.

Figure A1-14 Climatic and limnological data of La Preciosa. *b* and *c* indicate the bibliographical source of the data. Ionic dominance includes ions present at > 5 % relative concentrations in meq/L, in italics are ions between 5 and 25 %; "-" was used when ionic relative concentrations were similar; ">" when they were less than double and ">>" when they were higher than double. *LDL* = Lower Detection Limit: 0.005 mg/L $P\text{-}PO_4$. *ND* = Not Determined. June 11, 2011.

La Vega (VEG), Jalisco
20°38'49" N, 103°51'9" W, 1274 masl
Ramsar site 2026

Climate
Warm, sub-humid, summer rains
(A)C(w_1)(w)
Mean Annual Temperature 21.7 °C
Temp. Range 17 (Jan) - 25.7 (June) °C
Annual Precipitation 773 mm
Annual Evaporation 1698 mm

Limnology
Lake type Reservoir (dike)
Area 1610 ha
Maximum Depth 6 m[b]
Relative Depth 0.1 %
Mixing pattern Warm polymictic
Thermocline and oxycline No
Transparency 0.4 m
Ionic dominance
[HCO_3^-] >> *[Cl^-] - [SO_4^{2-}]*
[Na^+] >> *[Ca^{2+}] - [Mg^{2+}]*
Salinity category Freshwater
Trophic category Hypertrophic
Nutrient ratios
DIN:TP 6:1
DIN:P-PO_4 12:1
SiO_2:DIN 21:1
SiO_2:P-PO_4 252:1

Chemical parameters

Variable	Littoral	Surface	Bottom
pH	8.8	8.5	8.2
EC	396	421	425
Total Alk	186	195	189
CO_3^{2-}	11	32	17
HCO_3^-	205	173	196
SO_4^{2-}	21	30	27
Cl^-	22	25	24
Na^+	70	76	76
K^+	11	12	12
Ca^{2+}	14	14	14
Mg^{2+}	8.7	8.7	9.2
TDS	328	340	342

Units: EC in µS/cm, Total Alkalinity in mg/L $CaCO_3$, ionic concentrations and TDS in mg/L

Depth (m)	Temperature (°C)	Oxygen (mg/L)
0	31.1	15.3
1	26.3	8.3
2	25.4	2.9

Trophic parameters

Variable	Littoral	Surface	Bottom
DIC	40	36	42
SiO_2	73	74	74
DIN	ND	0.81	0.95
TP	ND	0.28	0.35
P-PO_4	ND	0.15	0.20
Chlorophyll *a*	ND	110.0	93.6

Units: DIC in µgC/g, SiO_2, DIN, TP, P-PO_4 in mg/L and Chlorophyll *a* in mg/m^3

Main taxa in this study
Phytoplankton. Below critical value
Diatoms. *Aulacoseira granulata* var. *angustissima*, *Cyclostephanos* sp., *Cyclotella meneghiniana*
Testate amoebae. Below critical value
Cladocerans. *Alona quadrangularis*, *Bosmina longirostris*
Ostracodes. Absent

Previous work
Favari *et al.*, 2003; INGESA, 2007; [b]Ramsar, 2011; De la Mora *et al.*, 2013.

Figure A1-15 Climatic and limnological data of La Vega. ***b*** indicate the bibliographical source of the data. Ionic dominance includes ions present at > 5 % relative concentrations in meq/L, in italics are ions between 5 and 25 %; "-" was used when ionic relative concentrations were similar; ">" when they were less than double and ">>" when they were higher than double. *ND* = Not Determined. ***Below critical value*** Phytoplankton < 11 specimens; Testate amoebae < 100 specimens. October 06, 2011.

Metztitlán (MET), Hidalgo
20°40'53" N, 98°51'56" W, 1258 masl
Ramsar site 1337

Climate

Dry, warm, summer rains	
BS_0hw	
Mean Annual Temperature	20.7 °C
Temp. Range	16.5 (Jan) – 24.0 (May) °C
Annual Precipitation	406 mm
Annual Evaporation	1788 mm

Limnology

Lake type		Tectonic
Area		2937.4 ha[a]
Maximum Depth		10 m[b]
Relative Depth		0.2 %
Mixing pattern		Warm polymictic[c]
Thermocline and oxycline		No
Transparency		0.2 m
Ionic dominance	$[HCO_3^-]$ >> *$[SO_4^{2-}]$* >> *$[Cl^-]$*	
	$[Ca^{2+}]$ > $[Na^+]$ > *$[Mg^{2+}]$*	
Salinity category		Freshwater
Trophic category		Eutrophic
Nutrient ratios	DIN:TP	4:1
	DIN:P-PO_4	5:1
	SiO_2:DIN	27:1
	SiO_2:P-PO_4	142:1

Chemical parameters

Variable	Surface	Bottom
pH	8.9	8.8
EC	505	508
Total Alk	240	378
CO_3^{2-}	29	LDL
HCO_3^-	234	461
SO_4^{2-}	57	95
Cl^-	14	20
Na^+	44	75
K^+	11	14
Ca^{2+}	59	81
Mg^{2+}	17	25
TDS	310	484

Units: EC in µS/cm, Total Alkalinity in mg/L $CaCO_3$, ionic concentrations and TDS in mg/L

Trophic parameters

Variable	Surface	Bottom
DIC	56	85
SiO_2	31	41
DIN	0.27	ND
TP	0.17	ND
P-PO_4	0.11	ND
Chlorophyll *a*	42.2	ND

Units: DIC in µgC/g, SiO_2, DIN, TP, P-PO_4 in mg/L and Chlorophyll *a* in mg/m³

Depth (m)	Temperature (°C)	Oxygen (mg/L)
0	30.0	5.8
1	24.6	5.7
2	24.3	5.4
3	23.9	5.0

Main taxa in this study
Phytoplankton. *Peridinium* sp.
Diatoms. *Cyclostephanos* spp.
Testate amoebae. Below critical value
Cladocerans. *Bosmina longirostris*
Ostracodes. Below critical value

Previous work
Ibañez *et al.*, 2002, 2008; Juárez & Ibáñez, 2003; [a]Ramsar, 2004c; Monks *et al.*, 2005; Fernández-Bringas *et al.*, 2008; [b]Mendoza *et al.*, 2011; [c]Barrera-Escorcia *et al.*, 2013; Pérez *et al.*, 2015.

Figure A1-16 Climatic and limnological data of Metztitlán. *a*, *b* and *c* indicate the bibliographical source of the data. Ionic dominance includes ions present at > 5 % relative concentrations in meq/L, in italics are ions between 5 and 25 %; "-" was used when ionic relative concentrations were similar; ">" when they were less than double and ">>" when they were higher than double. *LDL* = Lower Detection Limit: 0.01 mg/LCO_3^{2-}. *ND* = Not Determined. *Below critical value* Testate amoebae < 100 specimens; Ostracodes < 100 adult and juvenile valves. June 10, 2011.

Ojo de Agua (OJO), Jalisco
20°25'17" N, 103°54'27" W, 1340 masl

Climate
Warm, dry sub-humid, summer rains
(A)C(w_0)(w)
Mean Annual Temperature 20.9 °C
Temp. Range 16.7 (Jan) - 24.5 (June) °C
Annual Precipitation 866 mm
Annual Evaporation 1971 mm

Limnology

Lake type	Reservoir (dam)
Area	58 ha
Maximum Depth Recorded	1.5 m
Relative Depth	0.2 %
Mixing pattern	Warm polymictic
Thermocline and oxycline	No
Transparency	0.5 m
Ionic dominance	$[HCO_3^-]$ >> *$[SO_4^{2-}]$* >> *$[Cl^-]$* $[Ca^{2+}]$ >> *$[Na^+]$* - *$[Mg^{2+}]$*
Salinity category	Freshwater
Trophic category	Eutrophic
Nutrient ratios	DIN:TP 63:1 DIN:P-PO_4 346:1 SiO_2:DIN 6:1 SiO_2:P-PO_4 2000:1

Previous work
No previous studies.

Chemical parameters

Variable	Surface
pH	8.5
EC	277
Total Alk	137
CO_3^{2-}	7.7
HCO_3^-	151
SO_4^{2-}	24
Cl^-	7.3
Na^+	14
K^+	7.4
Ca^{2+}	35
Mg^{2+}	9.5
TDS	190

Units: EC in µS/cm, Total Alkalinity in mg/L $CaCO_3$, ionic concentrations and TDS in mg/L

Trophic parameters

Variable	Surface
DIC	31
SiO_2	15
DIN	0.63
TP	0.02
P-PO_4	0.01
Chlorophyll *a*	28.3

Units: DIC in µgC/g, SiO_2, DIN, TP, P-PO_4 in mg/L and Chlorophyll *a* in mg/m^3

Depth (m)	Temperature (°C)	Oxygen (mg/L)
0	28.1	8.1
1	28.0	9.1

Main taxa in this study
Phytoplankton. Below critical value
Diatoms. Sample not analyzed
Testate amoebae. *Centropyxis aculeata*, *Cucurbitella* sp.
Cladocerans. *Alona quadrangularis*, *Daphnia longispina*- group
Ostracodes. Absent

Figure A1-17 Climatic and limnological data of Ojo de Agua. Ionic dominance includes ions present at > 5 % relative concentrations in meq/L, in italics are ions between 5 and 25 %; "-" was used when ionic relative concentrations were similar; ">" when they were less than double and ">>" when they were higher than double. *Below critical value* Phytoplankton < 11 specimens. October 07, 2011.

Pátzcuaro (PAT), Michoacán
19°33'18" N, 101°38'17" W, 2041 masl
Ramsar site 1447

Climate
Temperate, humid sub-humid, summer rains
$C(w_2)(w)$

Mean Annual Temperature	16.8 °C
Temp. Range	13.1 (Jan) - 19.7 (June) °C
Annual Precipitation	1004 mm
Annual Evaporation	1495 mm

Limnology

Lake type		Volcanic (dam)
Area		13000 ha[a]
Maximum Depth		9.4 m[b]
Relative Depth		0.1 %
Mixing pattern		Warm polymictic[c]
Thermocline and oxycline		No
Transparency		0.2 m
Ionic dominance	$[HCO_3^-]$ >> *$[Cl^-]$ > $[SO_4^{2-}]$*	
	$[Na^+]$ >> *$[Mg^{2+}]$ > $[Ca^{2+}]$*	
Salinity category		Subsaline
Trophic category		Hypertrophic
Nutrient ratios	DIN:TP	450:1
	DIN:$P\text{-}PO_4$	11:1
	SiO_2:DIN	23:1
	SiO_2:$P\text{-}PO_4$	243:1

Chemical parameters

Variable	Littoral	Surface
pH	8.3	8.2
EC	830	988
Total Alk	427	552
CO_3^{2-}	19	88
HCO_3^-	483	496
SO_4^{2-}	29	31
Cl^-	46	54
Na^+	139	169
K^+	38	48
Ca^{2+}	26	22
Mg^{2+}	27	36
TDS	557	647

Units: EC in μS/cm, Total Alkalinity in mg/L $CaCO_3$, ionic concentrations and TDS in mg/L

Trophic parameters

Variable	Littoral	Surface
DIC	107	123
SiO_2	32	27
DIN	ND	0.28
TP	ND	0.17
$P\text{-}PO_4$	ND	0.06
Chlorophyll *a*	ND	107.4

Units: DIC in μgC/g, SiO_2, DIN, TP, $P\text{-}PO_4$ in mg/L and Chlorophyll *a* in mg/m^3

Depth (m)	Temperature (°C)	Oxygen (mg/L)
0	23.4	6.2
1	21.8	5.6
2	21.7	5.5

Main taxa in this study
Phytoplankton. *Anabaena* sp., *Leptolyngbya* sp., *Staurastrum* sp.
Diatoms. Absent
Testate amoebae. Below critical value
Cladocerans. *Alona quadrangularis*, *Bosmina longirostris*
Ostracodes. *Cypria*, *Limnocythere*

Previous work*
Bradbury, 2000; Alcocer & Bernal-Brooks, 2002; Gomez-Tagle *et al.*, 2002; [b,c]Orbe & Acevedo 2002; Bernal-Brooks *et al.*, 2002, 2003; Bischoff *et al.*, 2004; Israde-Alcántara *et al.*, 2005; [a]Ramsar, 2005, Metcalfe *et al.*, 2007; González-Sosa *et al.*, 2010; Berry *et al.*, 2011; Tomasini-Ortiz *et al.*, 2012; Huerto & Vargas, 2014.
* Older studies cited within these references.

Figure A1-18 Climatic andlimnological data of Pátzcuaro. a, b and c indicate the bibliographical source of the data. Ionic dominance includes ions present at > 5 % relative concentrations in meq/L, in italics are ions between 5 and 25 %; "-" was used when ionic relative concentrations were similar; ">" when they were less than double and ">>" when they were higher than double. ND = Not Determined. *Below critical value* Testate amoebae < 100 specimens. June 18, 2011.

Quechulac (QUE), Puebla
19°22'28" N, 97°21'06" W, 2345 masl

Climate

Dry, temperate, summer rains
$BS_1k'w$

Mean Annual Temperature	13.9 °C
Temp. Range	10.4 (Jan) - 16.3 (May) °C
Annual Precipitation	388 mm
Annual Evaporation	1741 mm

Limnology

Lake type		Volcanic (maar)
Area		64 ha
Maximum Depth Recorded		40 m[b]
Relative Depth		4.4 %
Mixing pattern		Warm monomictic[c]
Thermocline and oxycline		~10 m
Transparency		4.2 m
Ionic dominance	$[HCO_3^-] >> [Cl^-]$	
	$[Mg^{2+}] > [Na^+] >> [Ca^{2-}]$	
Salinity category		Freshwater
Trophic category		Oligotrophic
Nutrient ratios	DIN:TP	5:1
	DIN:$P\text{-}PO_4$	6:1
	SiO_2:DIN	15:1
	SiO_2:$P\text{-}PO_4$	90:1

Chemical parameters

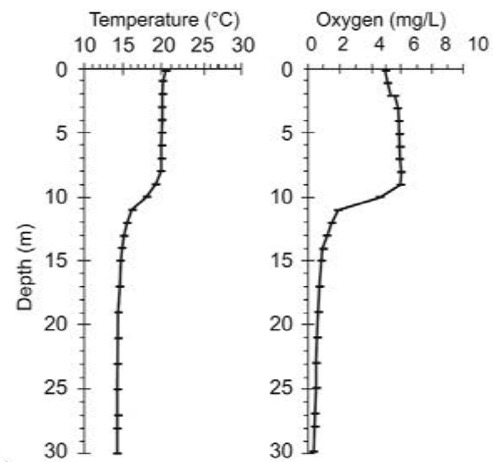
Variable	Littoral	Surface	Bottom
pH	ND	9	9.2
EC	ND	756	781
Total Alk	330	328	338
CO_3^{2-}	50	66	29
HCO_3^-	301	265	354
SO_4^{2-}	18	18	17
Cl^-	99	102	97
Na^+	90	91	86
K^+	8	8	8
Ca^{2+}	11	11	16
Mg^{2+}	61	61	60
TDS	445	439	445

Units: EC in µS/cm, Total Alkalinity in mg/L $CaCO_3$, ionic concentrations and TDS in mg/L

Trophic parameters

Variable	Littoral	Surface	Bottom
DIC	73.6	73.5	83.9
SiO_2	11	12	14
DIN	ND	0.18	0.66
TP	ND	0.08	0.20
$P\text{-}PO_4$	ND	0.07	0.17
Chlorophyll *a*	ND	7.2	9.2

Units: DIC in µgC/g, SiO_2, DIN, TP, $P\text{-}PO_4$ in mg/L and Chlorophyll *a* in mg/m³



Main taxa in this study

Phytoplankton. *Fragilaria crotonensis*, *Peridinium gatunense*
Diatoms. *Aulacoseira granulata*, *Fragilaria crotonensis*
Testate amoebae. Below critical value
Cladocerans. *Chydorus* cf. *sphaericus*, *Daphnia longispina*-group
Ostracodes. Below critical value

Previous work

Arredondo-Figueroa *et al.*, 1983; Vilaclara *et al.*, 1993; [b]Arredondo, 2002; Alcocer *et al.*, 2002; Davies *et al.*, 2002; Peralta *et al.*, 2002; [c]Armienta *et al.*, 2008; Cohuo-Durán *et al.*, 2014; Pérez *et al.*, 2015.

Figure A1-19 Climatic and limnological data of Quechulac. b and c indicate the bibliographical source of the data. Ionic dominance includes ions present at > 5 % relative concentrations in meq/L, in italics are ions between 5 and 25 %; "-" was used when ionic relative concentrations were similar; ">" when they were less than double and ">>" when they were higher than double. ND = Not Determined. Below critical value Testate amoebae < 100 specimens; Ostracodes < 100 adult and juvenile valves. June 12, 2011.

San Pedro Lagunillas (SPL), Nayarit
21°12'33" N, 104°43'37" W, 1261 masl

Climate
Warm, humid sub-humid, summer rains
(A)C(w_2)(w)
Mean Annual Temperature 22.9 °C
Temp. Range 19.8 (Jan) - 25.3 (June) °C
Annual Precipitation 971 mm
Annual Evaporation 1033 mm

Limnology

Lake type	Volcanic (dam)
Area	296 ha
Maximum Depth Recorded	7 m
Relative Depth	0.4 %
Mixing pattern	Warm polymictic
Thermocline and oxycline	No
Transparency	0.7 m
Ionic dominance	$[HCO_3^-]$ >> *$[Cl^-]$*
	$[Na^+]$ >> *$[Ca^{2+}]$ - $[Mg^{2+}]$*
Salinity category	Freshwater
Trophic category	Hypertrophic
Nutrient ratios	DIN:TP 21:1
	DIN:P-PO_4 152:1
	SiO_2:DIN 8:1
	SiO_2:P-PO_4 1200:1

Previous work
Brown, 1985.

Chemical parameters

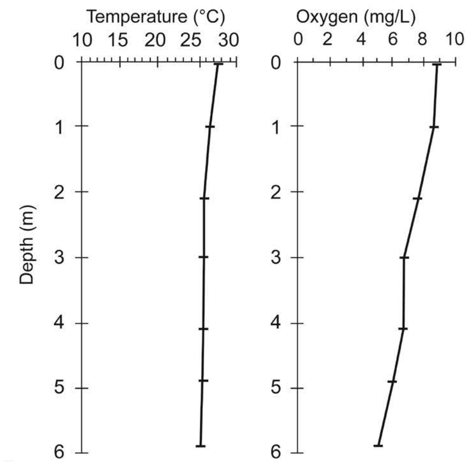
Variable	Littoral	Surface	Bottom
pH	8.0	8.2	7.9
EC	273	269	269
Total Alk	125	123	121
CO_3^{2-}	LDL	6.1	6.1
HCO_3^-	153	137	135
SO_4^{2-}	LDL	LDL	6.3
Cl^-	18	18	17
Na^+	28	28	28
K^+	24	24	24
Ca^{2+}	14	14	13
Mg^{2+}	7.0	7.3	7.0
TDS	182	182	182

Units: EC in µS/cm, Total Alkalinity in mg/L $CaCO_3$, ionic concentrations and TDS in mg/L

Trophic parameters

Variable	Littoral	Surface	Bottom
DIC	30	27	29
SiO_2	ND	20	20
DIN	ND	0.60	0.49
TP	ND	0.06	0.06
P-PO_4	ND	0.01	0.01
Chlorophyll *a*	ND	81.7	92.2

Units: DIC in µgC/g, SiO_2, DIN, TP, P-PO_4 in mg/L and Chlorophyll *a* in mg/m³



Main taxa in this study
Phytoplankton. *Dictyosphaerium* sp., *Planktolyngbya* sp.
Diatoms. *Aulacoseira ambigua*
Testate amoebae. Below critical value
Cladocerans. *Bosmina longirostris*
Ostracodes. Absent

Figure A1-20 Climatic and limnological data of San Pedro Lagunillas. Ionic dominance includes ions present at > 5 % relative concentrations in meq/L, in italics are ions between 5 and 25 %; "-" was used when ionic relative concentrations were similar; ">" when they were less than double and ">>" when they were higher than double. *LDL* = Lower Detection Limit: 0.01 mg/LCO_3^{2-},4 mg/LSO_4^{2-}. *ND* = Not Determined. *Below critical value* Testate amoebae < 100 specimens. October 05, 2011.

Santa Gertrudis (SGE), Jalisco
20°03‘43" N, 103°21‘14" W, 1743 masl

Climate
Warm, dry sub-humid, summer rains
(A)C(w_o)(w)
Mean Annual Temperature 16.4 °C
Temp. Range 13.8 (Jan) - 18.7 (June) °C
Annual Precipitation 967 mm
Annual Evaporation 1496 mm

Limnology
Lake type Reservoir (dike)
Area 50 ha
Maximum Depth Recorded 2.3 m
Relative Depth 0.3 %
Mixing pattern Warm polymictic
Thermocline and oxycline No
Transparency 0.5 m
Ionic dominance
[HCO_3^-] >> *[Cl^-]*
[Ca^{2+}] - [Mg^{2+}] - [Na^+]
Salinity category Freshwater
Trophic category Eutrophic
Nutrient ratios
DIN:TP 20:1
DIN:P-PO_4 173:1
SiO_2:DIN 10:1
SiO_2:P-PO_4 2000:1

Previous work
No previous studies.

Chemical parameters

Variable	Littoral	Surface
pH	7.6	8.0
EC	156	155
Total Alk	80	80
CO_3^{2-}	LDL	LDL
HCO_3^-	97	97
SO_4^{2-}	LDL	LDL
Cl^-	6.3	6.9
Na^+	8.0	8.1
K^+	7.4	7.2
Ca^{2+}	14	14
Mg^{2+}	7.5	7.3
TDS	104	110

Units: EC in µS/cm, Total Alkalinity in mg/L $CaCO_3$, ionic concentrations and TDS in mg/L

Trophic parameters

Variable	Littoral	Surface
DIC	21	19
SiO_2	17	17
DIN	ND	0.39
TP	ND	0.04
P-PO_4	ND	0.01
Chlorophyll *a*	ND	38.9

Units: DIC in µgC/g, SiO_2, DIN, TP, P-PO_4 in mg/L and Chlorophyll *a* in mg/m^3

Depth (m)	Temperature (°C)	Oxygen (mg/L)
0	22.8	5.5
1	22.7	5.5

Main taxa in this study
Phytoplankton. *Peridiniopsis elpatiewskyi*
Diatoms. *Aulacoseira ambigua*
Testate amoebae. *Centropyxis aculeata*
Cladocerans. *Bosmina longirostris*
Ostracodes. Absent

Figure A1-21 Climatic and limnological data of Santa Gertrudis. Ionic dominance includes ions present at > 5 % relative concentrations in meq/L, in italics are ions between 5 and 25 %; "-" was used when ionic relative concentrations were similar; ">" when they were less than double and ">>" when they were higher than double. *LDL* = Lower Detection Limit: 0.01 mg/LCO_3^{2-}, 4 mg/LSO_4^{2-}. *ND* = Not Determined. October 08, 2011.

Santa María del Oro (SMO), Nayarit
21°22'10" N, 104°34'09" W, 737 masl

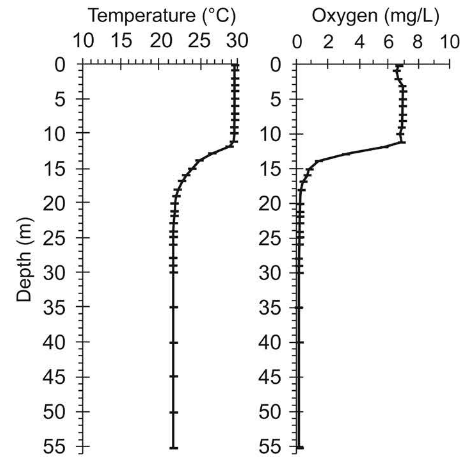
Chemical parameters

Variable	Littoral	Surface	Bottom
pH	8.6	8.6	7.8
EC	1347	1354	1430
Total Alk	439	441	480
CO_3^{2-}	80	89	58
HCO_3^-	374	358	467
SO_4^{2-}	LDL	LDL	LDL
Cl^-	266	262	279
Na^+	196	196	188
K^+	19	19	19
Ca^{2+}	16	16	28
Mg^{2+}	73	72	70
TDS	789	792	831

Units: EC in µS/cm, Total Alkalinity in mg/L $CaCO_3$, ionic concentrations and TDS in mg/L

Climate
Hot, dry sub-humid, summer rains
$Aw_0(w)$
Mean Annual Temperature 20.9 °C
Temp. Range 16.4 (Jan) - 24.9 (June) °C
Annual Precipitation 1220 mm
Annual Evaporation 1708 mm

Limnology
Lake type: Volcanic (crater)
Area: 370 ha[a]
Maximum Depth: 65 m[b]
Relative Depth: 3 %
Mixing pattern: Warm monomictic[c]
Thermocline and oxycline: ~12 m
Transparency: 11.8 m
Ionic dominance: $[HCO_3^-]$ - $[Cl^-]$; $[Na^+] > [Mg^{2+}] > [Ca^{2+}]$
Salinity category: Subsaline
Trophic categpry: Mesotrophic
Nutrient ratios: DIN:TP 4:1; DIN:P-PO_4 13:1; SiO_2:DIN 41:1; SiO_2:P-PO_4 516:1



Trophic parameters

Variable	Littoral	Surface	Bottom
DIC	ND	96	58
SiO_2	18	17	21
DIN	ND	0.10	1.92
TP	ND	0.06	0.22
P-PO_4	ND	0.02	0.04
Chlorophyll *a*	ND	17.2	1.1

Units: DIC in µgC/g, SiO_2, DIN, TP, P-PO_4 in mg/L and Chlorophyll *a* in mg/m³

Main taxa in this study
Phytoplankton. *Aulacoseira granulata*, *Oscillatoria* sp., *Staurastrum* sp.
Diatoms. *Aulacoseira granulata*
Testate amoebae. Below critical value
Cladocerans. *Alona quadrangularis*, *Daphnia longispina*-group
Ostracodes. *Candona*, *Darwinula*, *Potamocypris*

Previous work
[a,b,c]Serrano *et al.*, 2002; Armienta *et al.*, 2008; Vázquez-Castro *et al.*, 2008; Sosa-Nájera *et al.*, 2010; Caballero *et al.*, 2013; Rodríguez-Ramírez *et al.*, 2015.

Figure A1-22 Climatic and limnological data of Santa María del Oro. *a*, *b* and *c* indicate the bibliographical source of the data. Ionic dominance includes ions present at > 5 % relative concentrations in meq/L, in italics are ions between 5 and 25 %; "-" was used when ionic relative concentrations were similar; ">" when they were less than double and ">>" when they were higher than double. *LDL* = Lower Detection Limit: 4 mg/LSO_4^{2-}. *ND* = Not Determined. *Below critical value* Testate amoebae < 100 specimens. October 05, 2011.

Santa Rosa (SRO), Jalisco
20°02'27" N, 103°16'58" W, 1879 masl

Climate
Temperate, sub-humid, summer rains
$C(w_1)(w)$

Mean Annual Temperature	16.1 °C
Temp. Range	12.6 (Jan) – 19.0 (May) °C
Annual Precipitation	983 mm
Annual Evaporation	1497 mm

Limnology

Lake type		Reservoir (dam)
Area		1.3 ha
Maximum Depth Recorded		1.8 m
Relative Depth		1.4 %
Mixing pattern		Warm polymictic
Thermocline and oxycline		No
Transparency		0.3 m
Ionic dominance		
	$[HCO_3^-]$ >> *$[Cl^-]$*	
	$[Mg^{2+}]$ > $[Na^+]$ - $[Ca^{2+}]$	
Salinity category		Freshwater
Trophic category		Mesotrophic
Nutrient ratios	DIN:TP	36:1
	DIN:$P\text{-}PO_4$	120:1
	SiO_2:DIN	4:1
	SiO_2:$P\text{-}PO_4$	467:1

Previous work
No previous studies.

Chemical parameters

Variable	Littoral	Surface
pH	9.2	9.0
EC	224	224
Total Alk	120	123
CO_3^{2-}	11	10
HCO_3^-	125	123
SO_4^{2-}	LDL	LDL
Cl^-	8.2	8.4
Na^+	15	15
K^+	10	10
Ca^{2+}	18	18
Mg^{2+}	13	13
TDS	178	175

Units: EC in μS/cm, Total Alkalinity in mg/L $CaCO_3$, ionic concentrations and TDS in mg/L

Trophic parameters

Variable	Littoral	Surface
DIC	30	22
SiO_2	21	22
DIN	ND	1.29
TP	ND	0.08
$P\text{-}PO_4$	ND	0.02
Chlorophyll *a*	ND	18.5

Units: DIC in μgC/g, SiO_2, DIN, TP, $P\text{-}PO_4$ in mg/L and Chlorophyll *a* in mg/m^3

Depth (m)	Temperature (°C)	Oxygen (mg/L)
0	22.7	8.4
1	21.6	7.0

Main taxa in this study
Phytoplankton. *Botryococcus* sp., *Pediastrum simplex*
Diatoms. *Aulacoseira ambigua*
Testate amoebae. *Difflugia* sp
Cladocerans. *Bosmina longirostris*, *Chydorus* cf. *sphaericus*
Ostracodes. *Potamocypris*

Figure A1-23 Climatic and limnological data of Santa Rosa. Ionic dominance includes ions present at > 5 % relative concentrations in meq/L, in italics are ions between 5 and 25 %; "-" was used when ionic relative concentrations were similar; ">" when they were less than double and ">>" when they were higher than double. *LDL* = Lower Detection Limit: 4 mg/LSO_4^{2-}. *ND* = Not Determined. October 08, 2011.

Sayula (SAY), Jalisco
19°57'04" N, 103°36'33" W, 1347 masl
Ramsar site 1338

Climate
Dry, warm, summer rains
$BS_1hw(w)$
Mean Annual Temperature 21.1 °C
Temp. Range 18.0 (Jan) - 24.2 (May) °C
Annual Precipitation 658 mm
Annual Evaporation 1960 mm

Limnology

Lake type	Tectonic
Area	16800 ha[a]
Maximum Depth Recorded	1 m
Relative Depth	<0.1%
Mixing pattern	Warm polymictic
Thermocline and oxycline	No
Transparency	0.1 m
Ionic dominance	$[HCO_3^-]$ - $[Cl^-]$ $[Na^+]$ >> *$[Mg^{2+}]$*
Salintiy category	Subsaline
Trophic category	Mesotrophic
Nutrient ratios	DIN:TP 3:1
	DIN:$P\text{-}PO_4$ 3:1
	SiO_2:DIN 3:1
	SiO_2:$P\text{-}PO_4$ 10:1

Chemical parameters

Variable	Littoral	Surface
pH	9.4	9.3
EC	3890	3980
Total Alk	1179	1250
CO_3^{2-}	349	331
HCO_3^-	728	853
SO_4^{2-}	96	94
Cl^-	774	803
Na^+	979	1 039
K^+	34	33
Ca^{2+}	31	11
Mg^{2+}	22	15
TDS	2530	2658

Units: EC in µS/cm, Total Alkalinity in mg/L $CaCO_3$, ionic concentrations and TDS in mg/L

Trophic parameters

Variable	Littoral	Surface
DIC	247	264
SiO_2	58	39
DIN	LDL	3.00
TP	LDL	1.98
$P\text{-}PO_4$	LDL	1.97
Chlorophyll *a*	LDL	20.4

Units: DIC in µgC/g, SiO_2, DIN, TP, $P\text{-}PO_4$ in mg/L and Chlorophyll *a* in mg/m^3

Depth (m)	Temperature (°C)	Oxygen (mg/L)
0	22.5	4.6

Main taxa in this study
Phytoplankton. *Amphora* sp.
Diatoms. Absent
Testate amoebae. Below critical value
Cladocerans. Absent
Ostracodes. *Candona*, *Limnocythere*

Previous work
Delgadillo, 1957; [a]Ramsar, 2004a; Munguia *et al.*, 2005.

Figure A1-24 Climatic and limnological data of Sayula. a indicate the bibliographical source of the data. Ionic dominance includes ions present at > 5 % relative concentrations in meq/L, in italics are ions between 5 and 25 %; "-" was used when ionic relative concentrations were similar; ">" when they were less than double and ">>" when they were higher than double. *LDL* = Lower Detection Limit. *Below critical value* Testate amoebae < 100 specimens. October 08, 2011.

Tecocomulco (TEC), Hidalgo
19°51'37" N, 98°23'13" W, 2535 masl
Ramsar site 1322

Climate
Temperate, sub-humid, summer rains
$C(w_1)(w)$

Mean Annual Temperature	13.3 °C
Temp. Range	10.4 (Jan) - 15.4 (May) °C
Annual Precipitation	635 mm
Annual Evaporation	1540 mm

Limnology

Lake type	Tectonic
Area	1900 ha
Maximum Depth	2 m[b]
Relative Depth	0.1 %
Mixing pattern	Warm polymictic
Thermocline and oxycline	No
Transparency	0.4 m
Ionic dominance	$[HCO_3^-]$ >> *$[Cl^-]$*
	$[Na^+]$ >> *$[Ca^{2+}]$ - $[Mg^{2+}]$*
Salinity category	Freshwater
Trophic category	Eutrophic
Nutrient ratios	DIN:TP 4:1
	DIN:P-PO_4 5:1
	SiO_2:DIN 7:1
	SiO_2:P-PO_4 35:1

Chemical parameters

Variable	Surface
pH	8.8
EC	341
Total Alk	177
CO_3^{2-}	LDL
HCO_3^-	215
SO_4^{2-}	LDL
Cl^-	16
Na^+	34
K^+	26
Ca^{2+}	19
Mg^{2+}	12
TDS	213

Units: EC in µS/cm, Total Alkalinity in mg/L $CaCO_3$, ionic concentrations and TDS in mg/L

Trophic parameters

Variable	Surface
DIC	45
SiO_2	8
DIN	0.27
TP	0.17
P-PO_4	0.11
Chlorophyll *a*	50.1

Units: DIC in µgC/g, SiO_2, DIN, TP, P-PO_4 in mg/L and Chlorophyll *a* in mg/m^3

Depth (m)	Temperature (°C)	Oxygen (mg/L)
0	21.2	5.9

Main taxa in this study
Phytoplankton. *Kirchneriella obesa*
Diatoms. *Cocconeis placentula*, *Epithemia sorex*, *Navicula tenelloides*
Testate amoebae. *Arcella discoides*, *Centropyxis aculeata*, *C. constricta*, *Cucurbitella* sp., *Difflugia oblonga*
Cladocerans. *Alona quadrangularis*, *Chydorus* cf. *sphaericus*
Ostracodes. *Cypridopsis*

Previous work*
Ramsar, 2003; Caballero *et al.*, 2005; De la Lanza & Rodríguez, 2005; [b]Huizar & Ruiz, 2005; Bautista-Hernández *et al.*, 2008; Vázquez-Rodríguez *et al.*, 2008; Roy *et al.*, 2009; De la Lanza-Espino *et al.*, 2011; Quiroz-Flores *et al.*, 2014; Quisehuatl-Tepexicuapan, *et al.*, 2014; Rico-Sánchez *et al.*, 2014; Pérez *et al.*, 2015.
* Older studies cited within these references.

Figure A1-25 Climatic and limnological data of Tecocomulco. *b* indicate the bibliographical source of the data. Ionic dominance includes ions present at > 5 % relative concentrations in meq/L, in italics are ions between 5 and 25 %; "-" was used when ionic relative concentrations were similar; ">" when they were less than double and ">>" when they were higher than double. *LDL* = Lower Detection Limit: 0.01 mg/LCO_3^{2-}, 4 mg/LSO_4^{2-}. June 10, 2011.

Tecuitlapa (TEU), Puebla
19°07'30" N, 97°32'36" W, 2368 masl

Climate
Temperate, dry sub-humid, summer rains
(C)(w_0)(w)

Mean Annual Temperature	14.7 °C
Temp. Range	12.0 (Jan) - 16.7 (May) °C
Annual Precipitation	851 mm
Annual Evaporation	1644 mm

Limnology

Lake type	Volcanic (maar)	
Area	18 ha	
Maximum Depth	2.5 m[b]	
Relative Depth	0.1 %	
Mixing pattern	Warm polymictic	
Thermocline and oxycline	No	
Transparency	0.1 m	
Ionic dominance	[CO_3^{2-}] >> *[Cl^-]* [Na^+]	
Salinity category	Subsaline	
Trophic category	Hypertrophic	
Nutrient ratios	DIN:TP	2:1
	DIN:P-PO_4	3:1
	SiO_2:DIN	15:1
	SiO_2:P-PO_4	48:1

Chemical parameters

Variable	Littoral
pH	10.3
EC	3710
Total Alk	2047
CO_3^{2-}	815
HCO_3^-	841
SO_4^{2-}	119
Cl^-	218
Na^+	971
K^+	107
Ca^{2+}	12
Mg^{2+}	22
TDS	2700

Units: EC in µS/cm, Total Alkalinity in mg/L $CaCO_3$, ionic concentrations and TDS in mg/L

Trophic parameters

Variable	Littoral
DIC	392
SiO_2	42
DIN	0.68
TP	0.71
P-PO_4	0.46
Chlorophyll *a*	92.9

Units: DIC in µgC/g, SiO_2, DIN, TP, P-PO_4 in mg/L and Chlorophyll *a* in mg/m^3

Depth (m)	Temperature (°C)	Oxygen (mg/L)
0	26.2	5.7

Main taxa in this study
Phytoplankton. Sample not analyzed
Diatoms. Sample not analyzed
Testate amoebae. Below critical value
Cladocerans. Sample not analyzed
Ostracodes. Below critical value

Previous work
[b]Arredondo-Figueroa *et al.*, 1983; Arredondo-Figueroa & Aguilar, 1987; Ramírez-García & Vázquez-Gutiérrez, 1989; Vilaclara *et al.*, 1993; Arredondo, 2002; Peralta *et al.*, 2002; Armienta *et al.*, 2008; Pérez *et al.*, 2015.

Figure A1-26 Climatic and limnological data of Tecuitlapa. b indicate the bibliographical source of the data. Ionic dominance includes ions present at > 5 % relative concentrations in meq/L, in italics are ions between 5 and 25 %; "-" was used when ionic relative concentrations were similar; ">" when they were less than double and ">>" when they were higher than double. *Below critical value* Testate amoebae < 100 specimens; Ostracodes < 100 adult and juvenile valves. June 13, 2011.

Tepetiltic (TEP), Nayarit
21°16'30" N, 104°41'18" W, 1430 masl

Climate
Warm, humid sub-humid, summer rains
(A)C(w_2)(w)
Mean Annual Temperature 21.8 °C
Temp. Range 18.4 (Jan) - 24.3 (June) °C
Annual Precipitation 1327 mm
Annual Evaporation 1899 mm

Limnology
Lake type Volcanic (crater)
Area 132 ha
Maximum Depth Recorded 2.5 m
Relative Depth 0.2 %
Mixing pattern Warm polymictic
Thermocline and oxycline ~2 m
Transparency 0.5 m
Ionic dominance
[HCO_3^-] >> *[Cl^-]*
[Ca^{2+}] > [Mg^{2+}] - [K^+]
Salinity category Freshwater
Trophic category Hypertrophic
Nutrient ratios
DIN:TP 21:1
DIN:P-PO_4 181:1
SiO_2:DIN 3:1
SiO_2:P-PO_4 503:1

Previous work
No previous studies.

Chemical parameters

Variable	Littoral	Surface
pH	8.0	8.3
EC	110	111
Total Alk	61	64
CO_3^{2-}	LDL	LDL
HCO_3^-	75	78
SO_4^{2-}	LDL	LDL
Cl^-	2.8	2.8
Na^+	3.8	3.8
K^+	8.1	8.1
Ca^{2+}	11	11
Mg^{2+}	5.3	4.9
TDS	69	75

Units: EC in µS/cm, Total Alkalinity in mg/L $CaCO_3$, ionic concentrations and TDS in mg/L

Trophic parameters

Variable	Littoral	Surface
DIC	16	15
SiO_2	7	7
DIN	ND	0.60
TP	ND	0.06
P-PO_4	ND	0.01
Chlorophyll *a*	ND	76.4

Units: DIC in µgC/g, SiO_2, DIN, TP, P-PO_4 in mg/L and Chlorophyll *a* in mg/m^3

Depth (m)	Temperature (°C)	Oxygen (mg/L)
0	26.6	8.3
1	26.6	8.2
2	25.2	5.7

Main taxa in this study
Phytoplankton. *Aulacoseira granulata*, *Pediastrum simplex*, *Tetraedron gracile*
Diatoms. *Aulacoseira ambigua*
Testate amoebae. Below critical value
Cladocerans. *Bosmina longirostris*
Ostracodes. Absent

Figure A1-27 Climatic and limnological data of Tepetiltic. Ionic dominance includes ions present at > 5 % relative concentrations in meq/L, in italics are ions between 5 and 25 %; "-" was used when ionic relative concentrations were similar; ">" when they were less than double and ">>" when they were higher than double. *LDL* = Lower Detection Limit: 0.01 mg/LCO_3^{2-}, 4 mg/LSO_4^{2-}. *ND* = Not Determined. *Below critical value* Testate amoebae < 100 specimens. October 05, 2011.

Yuriria (YUR), Guanajuato
20°14'51" N, 101°08'58" W, 1730 masl
Ramsar site 1631

Climate
Warm, dry sub-humid, summer rains
(A)C(w_0)(w)

Mean Annual Temperature	19.7 °C
Temp. Range	15.3 (Jan) - 23.5 (May) °C
Annual Precipitation	638 mm
Annual Evaporation	1802 mm

Limnology

Lake type	Reservoir (dam and river diversion)	
Area	7200 ha	
Maximum Depth	2.6 m[b]	
Relative Depth	<0.1 %	
Mixing pattern	Warm polymictic	
Thermocline and oxycline	No	
Transparency	0.2 m	
Ionic dominance	$[HCO_3^-]$ >> *$[Cl^-]$ - $[SO_4^{2-}]$*	
	$[Na^+]$> $[Ca^{2+}]$ > *$[Mg^{2+}]$*	
Salinity category	Freshwater	
Trophic category	Eutrophic	
Nutrient ratios	DIN:TP	9:1
	DIN:P-PO_4	29:1
	SiO_2:DIN	10:1
	SiO_2:P-PO_4	283:1

Chemical parameters

Variable	Surface
pH	8.0
EC	624
Total Alk	279
CO_3^{2-}	7.8
HCO_3^-	324
SO_4^{2-}	50
Cl^-	42
Na^+	73
K^+	23
Ca^{2+}	48
Mg^{2+}	20
TDS	447

Units: EC in µS/cm, Total Alkalinity in mg/L $CaCO_3$, ionic concentrations and TDS in mg/L

Trophic parameters

Variable	Surface
DIC	69
SiO_2	29
DIN	0.68
TP	0.16
P-PO_4	0.05
Chlorophyll *a*	73.8

Units: DIC in µgC/g, SiO_2, DIN, TP, P-PO_4 in mg/L and Chlorophyll *a* in mg/m^3

Depth (m)	Temperature (°C)	Oxygen (mg/L)
0	26.2	7.2
1	22.4	4.6

Main taxa in this study
Phytoplankton. *Euglena* sp., *Lepocinclis* sp., *Pediastrum duplex*
Diatoms. *Aulacoseira granulata*
Testate amoebae. Below critical value
Cladocerans. *Alona affinis*, *Bosmina longirostris*
Ostracodes. *Candona*, *Cypria*

Previous work
[b]Ramos & Novelo, 1993; Davies *et al*., 2002; Conant, 2003; Ramsar, 2004b; López-López *et al.*, 2011; Ruiz-Picos & López-López, 2012; Espinal *et al*., 2013.

Figure A1-28 Climatic and limnological data of Yuriria. b indicate the bibliographical source of the data. Ionic dominance includes ions present at > 5 % relative concentrations in meq/L, in italics are ions between 5 and 25 %; "-" was used when ionic relative concentrations were similar; ">" when they were less than double and ">>" when they were higher than double. *Below critical value* Testate amoebae < 100 specimens. June 16, 2011.

Zempoala (ZEM), Estado de México
19°03'00" N, 99°18'50" W, 2804 masl

Climate

Cool, humid, summer rains
C(E)(m)(w)

Mean Annual Temperature	12.0 °C
Temp. Range	9.5 (Jan) - 14.1 (May) °C
Annual Precipitation	1187 mm
Annual Evaporation	1402 mm

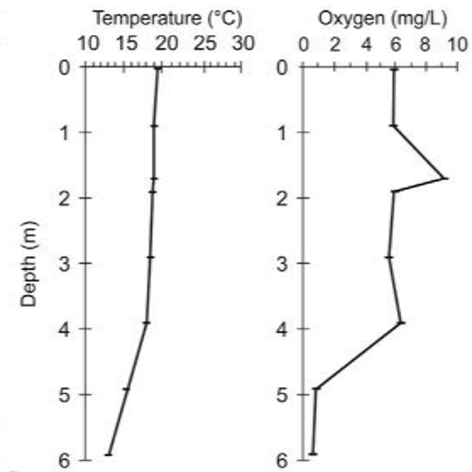
Limnology

Lake type	Volcanic (dam)
Area	10 ha
Maximum Depth	8 m[b]
Relative Depth	2.2 %
Mixing pattern	Warm monomictic[c]
Thermocline and oxycline	~4 m
Transparency	3.3 m
Ionic dominance	$[HCO_3^-]$ $[Ca^{2+}] > [Mg^{2+}] > [Na^+]$
Salinity category	Freshwater
Trophic category	Mesotrophic
Nutrient ratios	DIN:TP 62:1
	SiO_2:DIN 30:1

Chemical parameters

Variable	Littoral	Surface	Bottom
pH	9.2	8.8	7.7
EC	96	93	229
Total Alk	48	48	56
CO_3^{2-}	LDL	LDL	LDL
HCO_3^-	59	59	69
SO_4^{2-}	LDL	LDL	LDL
Cl^-	1.4	1.4	1.6
Na^+	5.5	5.5	5.3
K^+	1.6	1.5	2.6
Ca^{2+}	9.2	9.6	9.2
Mg^{2+}	5.1	4.1	6.6
TDS	71	68	76

Units: EC in µS/cm, Total Alkalinity in mg/L $CaCO_3$, ionic concentrations and TDS in mg/L



Trophic parameters

Variable	Littoral	Surface	Bottom
DIC	12	11	ND
SiO_2	27	25	32
DIN	ND	0.20	0.26
TP	ND	0.01	0.03
P-PO_4	ND	LDL	LDL
Chlorophyll *a*	ND	9.2	271.7

Units: DIC in µgC/g, SiO_2, DIN, TP, P-PO_4 in mg/L and Chlorophyll *a* in mg/m^3

Main taxa in this study

Phytoplankton. *Asterionella formosa*, *Ceratium* sp., *Fragilaria crotonensis*, *Peridinium* sp.
Diatoms. *Achnanthidium minutissimum*, *Asterionella formosa*
Testate amoebae. *Centropyxis* spp.
Cladocerans. *Bosmina longirostris*, *Daphnia longispina*-group
Ostracodes. Below critical value

Previous work

Bonilla-Barbosa & Novelo, 1995; [c]García-Rodríguez & Tavera, 2002; Almeida-Lenero *et al.*, 2005; [b]Díaz-Vargas *et al.*, 2005; Quiroz *et al.*, 2008; García *et al.*, 2010; Hansen, 2012; Trejo-Albarrán *et al.*, 2014; Pérez *et al.*, 2015.

Figure A1-29 Climatic and limnological data of Zempoala. b and c indicate the bibliographical source of the data. Ionic dominance includes ions present at > 5 % relative concentrations in meq/L, in italics are ions between 5 and 25 %; "-" was used when ionic relative concentrations were similar; ">" when they were less than double and ">>" when they were higher than double. *LDL* = Lower Detection Limit: 0.01 mg/LCO_3^{2-}, 4 mg/LSO_4^{2-}, 0.005 mg/L P-PO_4. *ND* = Not Determined. *Below critical value* Ostracodes < 100 adult and juvenile valves. June 08, 2011.

Zirahuén (ZIR), Michoacán
19°26'07" N, 101°44'22" W, 2082 masl

Climate
Temperate, humid sub-humid, summer rains
C(w_2)(w)

Mean Annual Temperature	16.0 °C
Temp. Range	12.6 (Jan) - 18.4 (June) °C
Annual Precipitation	1102 mm
Annual Evaporation	1217 mm

Limnology

Lake type	Volcanic (dam)
Area	930 ha
Maximum Depth Recorded	40 m[b]
Relative Depth	1.2 %
Mixing pattern	Warm monomictic[c]
Thermocline and oxycline	~14 m
Transparency	2.5 m
Ionic dominance	[HCO_3^-] >> *[Cl^-]*
	[Ca^{2+}] - [Mg^{2+}] - [Na^+]
Salinity category	Freshwater
Trophic category	Oligotrophic
Nutrient ratios	DIN:TP 0.02 :1
	DIN:P-PO_4 1:1

Chemical parameters

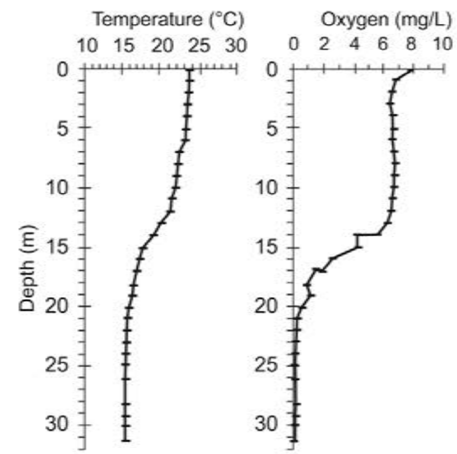
Variable	Littoral	Surface	Bottom
pH	ND	6.5	7.4
EC	ND	119	120
Total Alk	65	63	63
CO_3^{2-}	LDL	5.0	LDL
HCO_3^-	79	66	76
SO_4^{2-}	LDL	LDL	LDL
Cl^-	5.9	5.8	5.2
Na^+	8.6	8.1	7.9
K^+	4.8	4.3	4.1
Ca^{2+}	11	10	10
Mg^{2+}	6.8	5.9	6.8
TDS	79	77	88

Units: EC in µS/cm, Total Alkalinity in mg/L $CaCO_3$, ionic concentrations and TDS in mg/L

Trophic parameters

Variable	Littoral	Surface	Bottom
DIC	ND	20	18
SiO_2	LDL	LDL	LDL
DIN	ND	0.001	0.10
TP	ND	0.11	0.09
P-PO_4	ND	LDL	LDL
Chlorophyll *a*	ND	4.6	2.6

Units: DIC in µgC/g, SiO_2, DIN, TP, P-PO_4 in mg/L and Chlorophyll *a* in mg/m³



Main taxa in this study
Phytoplankton. *Ceratium* sp., *Pediastrum simplex*, *Peridinium* sp., *Staurastrum* spp.
Diatoms. *Cyclotella ocellata*
Testate amoebae. Below critical value
Cladocerans. *Bosmina longirostris*, *Leydigia leydigii*
Ostracodes. *Cypria*

Previous work*
Chacon-Torres & Rosas-Monge, 1998; Bernal-Brooks & MacCrimmon, 2000a, 2000b; Bernal-Brooks, 2002; Davies *et al.*, 2004, 2005; [c]Martínez-Almeida & Tavera, 2005; Bernal-Brooks & Ruiz, 2007; Armienta *et al.*, 2008; Ortega *et al.*, 2010; Ortiz & Rendón, 2010; [b]Torres-Rodríguez *et al.*, 2012.
* Older studies cited within these references.

Figure A1-30 Climatic and limnological data of Zirahuén. *b* and *c* indicate the bibliographical source of the data. Ionic dominance includes ions present at > 5 % relative concentrations in meq/L, in italics are ions between 5 and 25 %; "-" was used when ionic relative concentrations were similar; ">" when they were less than double and ">>" when they were higher than double. *LDL* = Lower Detection Limit: 0.01 mg/LCO_3^{2-}, 3 mg/LSiO_2, 0.005 mg/L, 4 mg/LSO_4^{2-}, P-PO^4. *ND* = Not Determined. *Below critical value* Testate amoebae < 100 specimens. June 18, 2011.

Electronic Supplement 2. Taxonomic lists of the main phytoplankton, diatoms in sediments, testate amoebae, cladocerans and ostracodes species in 30 continental water bodies studied along the Trans-Mexican Volcanic Belt.

	Alberca de Tacámbaro	Alberca de Teremendo	Alchichica	Aljojuca	Atezca	Atlangatepec	Atotonilco	Burro	Colorada	El Sol	Juanacatlán	La Luna	La Magdalena	La Preciosa	La Vega	Metztitlán	Ojo de agua	Pátzcuaro	Quechulac	San Pedro Lagunillas	Santa Gertrudis	Santa María del Oro	Santa Rosa	Sayula	Tecocomulco	Tecuitlapa	Tepetiltic	Yuriria	Zempoala	Zirahuén
Phytoplankton																														
Achnanthidium minutissimum (Kützing) Czarnecki 1994	x																													
Actinastrum Lagerheim 1882									x																					
Amphora C.G. Ehrenberg ex F.T. Kützing 1844																								x						
Anabaena Bory de Saint-Vincent ex Bornet & Flahault 1886																		x												
Ankistrodesmus Corda 1838			x							x																				
Aphanizomenon flosaquae Ralfs ex Bornet & Flahault 1886					x																									
Asterionella formosa Hassall 1850																													x	
Aulacoseira granulata (Ehrenberg) Simonsen 1979								x					x									x					x			
Botryococcus Kützing 1849		x		x									x										x							
Botryococcus braunii Kützing 1849										x																				
Ceratium F. Schrank 1793		x																											x	x
Chaetoceros Ehrenberg 1844														x																
Chrysochromulina aff. *parva* Lackey 1939												x																		
Coelastrum sphaericum Nägeli 1849								x																						
Dictyosphaerium Nägeli 1849																				x										
Euglena Ehrenberg 1830																												x		
Fragilaria crotonensis Kitton 1869											x								x										x	
Gymnodinium F. Stein, 1878												x																		
Kirchneriella obesa (West) West & G.S. West 1894																									x					
Lepocinclis Perty 1849																												x		
Leptolyngbya Anagnostidis & Komárek 1988																		x												
Lyngbya C. Agardh ex Gomont, 1892											x																			
Monoraphidium minutum (Nägeli) Komárková-Legnerová 1969										x																				

	Alberca de Tacámbaro	Alberca de Teremendo	Alchichica	Aljojuca	Atezca	Atlangatepec	Atotonilco	Burro	Colorada	El Sol	Juanacatlán	La Luna	La Magdalena	La Preciosa	La Vega	Metztitlán	Ojo de agua	Pátzcuaro	Quechulac	San Pedro Lagunillas	Santa Gertrudis	Santa María del Oro	Santa Rosa	Sayula	Tecocomulco	Tecuitlapa	Tepetlitic	Yuriria	Zempoala	Zirahuén
Phytoplankton																														
Nodularia spumigena Mertens ex Bornet & Flahault 1888			x																											
Oocystis lacustris Chodat 1897										x																				
Oscillatoria Vaucher ex Gomont, 1892																						x								
Oscillatoria margaritifera Kützing ex Gomont 1892											x																			
Pediastrum simplex Meyen 1829																							x				x			x
Pediastrum duplex Meyen 1829																												x		
Peridinium Ehrenberg 1830		x												x		x													x	x
Peridinium gatunense Nygaard 1925																			x											
Peridiniopsis elpatiewskyi (Ostenfeld) Bourrelly 1968																					x									
Pico-cyanoprokaryota												x																		
Planktolyngbya Anagnostidis & Komárek 1988																				x										
Planktothrix K.Anagnostidis & J.Komárek, 1988									x																					
Scenedesmus obtusus Meyen 1829											x																			
Staurastrum Meyen ex Ralfs 1848	x																	x				x								x
Staurodesmus Teiling 1948								x																						
Tetraedron gracile (Reinsch) Hansgrig 1889																											x			
Woronichinia A.A.Elenkin 1933	x																													

Diatoms in sediment	Alberca de Tacámbaro	Alberca de Teremendo	Alchichica	Aljojuca	Atezca	Atlangatepec	Atotonilco	Burro	Colorada	El Sol	Juanacatlán	La Luna	La Magdalena	La Preciosa	La Vega	Metztitlán	Ojo de agua	Pátzcuaro	Quechulac	San Pedro Lagunillas	Santa Gertrudis	Santa María del Oro	Santa Rosa	Sayula	Tecocomulco	Tecuitlapa	Tepetiltic	Yuriria	Zempoala	Zirahuén
Achnanthidium minutissimum (Kützing) Czarnecki 1994	x																												x	
Amphora pediculus (Kützing) Grunow ex A.Schmidt 1875			x			x																								
Asterionella formosa Hassall 1850																													x	
Aulacoseira Thwaites 1848									x																					
Aulacoseira ambigua (Grunow) Simonsen 1979								x	x											x	x		x				x			
Aulacoseira granulata (Ehrenberg) Simonsen 1979																			x			x						x		
Aulacoseira granulata var. angustissima (O. F. Müller) Simonsen 1979															x															
Caloneis aerophila W.Bock 1963								x																						
Cavinula pseudoscutiformis (Hustedt) D.G.Mann & A.J.Stickle 1990										x																				
Cocconeis placentula Ehrenberg 1838																									x					
Cyclostephanos Round 1987															x	x														
Cyclotella meneghiniana Kützing 1844				x					x					x	x															
Cyclotella ocellata Pantocsek 1901																														x
Discostella stelligera (Cleve & Grunow) Houk & Klee 2004					x								x																	
Encyonema perpusillum (Cleve) D.G.Mann 1990												x																		
Epithemia sorex Kützing 1844																									x					
Eunotia monodon Ehrenberg 1843								x																						
Eunotia naegelii Migula 1907								x																						
Fragilaria crotonensis Kitton 1869											x								x											
Gomphonema lagenula Kützing 1844		x																												
Hyppodonta hungarica (Grunow) Lange-Bertalot, Metzelin & Witkowski 1996			x																											
Navicula Bory de Saint-Vincent 1822						x																								
Navicula NTB (according to Caballero 1996)										x																				
Navicula erifuga Lange-Bertalot 1985			x																											
Navicula tenelloides Hustedt 1937																									x					

Diatoms in sediment	Alberca de Tacámbaro	Alberca de Teremendo	Alchichica	Aljojuca	Atezca	Atlangatepec	Atotonilco	Burro	Colorada	El Sol	Juanacatlán	La Luna	La Magdalena	La Preciosa	La Vega	Metztitlán	Ojo de agua	Pátzcuaro	Quechulac	San Pedro Lagunillas	Santa Gertrudis	Santa María del Oro	Santa Rosa	Sayula	Tecocomulco	Tecuitlapa	Tepetiltic	Yuriria	Zempoala	Zirahuén
Nitzschia amphibia Grunow 1862		x																												
Nitzschia palea var. *debilis* (Kützing) Grunow 1880						x																								
Psammothidium levanderi (Hustedt) Bukhtiyarova & Round 1996										x																				
Planothidium rostratum (Østrup) Lange-Bertalot 1999					x																									
Stephanodiscus minutulus (Kützing) Cleve & Möller 1882						x																								

	Alberca de Tacámbaro	Alberca de Teremendo	Alchichica	Aljojuca	Atezca	Atlangatepec	Atotonilco	Burro	Colorada	El Sol	Juanacatlán	La Luna	La Magdalena	La Preciosa	La Vega	Metztitlán	Ojo de agua	Pátzcuaro	Quechulac	San Pedro Lagunillas	Santa Gertrudis	Santa María del Oro	Santa Rosa	Sayula	Tecocomulco	Tecuitlapa	Tepetiltic	Yuriria	Zempoala	Zirahuén
Testate amoebae																														
Centropyxis Stein 1857																													x	
Centropyxis aculeata (Ehrenberg) Stein 1859	x			x					x								x				x				x					
Centropyxis constricta (Ehrenberg, 1841) Penard 1890				x																					x					
Cucurbitella Penard 1902					x												x								x					
Difflugia Leclerc 1815						x																	x							
Difflugia oblonga Ehrenberg 1838																									x					
Difflugia protaeiformis Lamarck 1816					x																									
Cladocerans																														
Alona affinis Leydig 1860																												x		
Alona manueli Sinev & Zawisza 2013										x		x																		
Alona quadrangularis (O. F. Müller 1785)				x			x		x					x	x		x	x				x			x					
Alona rectangula Sars 1862								x																						
Alonella pulchella Herrick, 1884												x																		
Bosmina longirostris (O. F. Müller 1776)	x	x				x		x			x		x		x	x		x		x	x		x				x	x	x	x
Bosmina (E.) *longispina* Leydig 1860		x																												
Chydorus cf. *sphaericus* (O. F. Müller 1785)						x													x				x		x					
Daphnia longispina- group (O. F. Müller 1785)				x			x			x				x			x		x			x							x	
Daphnia pulex- group Leydig 1860					x						x																			
Leydigia leydigii (Schoedler, 1858)																														x
Ostracodes																														
Candona Baird 1845			x			x	x		x					x								x		x				x		
Cypria Zenker 1854		x																x										x		x
Cyprididae Baird 1845									x																					
Cypridopsis Brady 1867	x			x	x																				x					
Darwinula Brady and Robertson 1885						x																x								
Fabaeformiscandona Krstic 1972				x																										
Limnocythere Brady 1867			x			x	x							x				x						x						
Potamocypris Brady 1870	x	x					x															x	x							