Chapter 20
Diversity and Endemisms

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20.1 Introduction

The total number of species and the number of exclusive, endemic species inhabiting a geographic area or even a single environment are two fundamental elements in the sphere of management and conservation policies. For example, biodiversity hotspots are relatively small areas where species richness and endemism levels are high, and organisms are facing a strong threat of habitat loss (Reid 1998). Therefore, the biological diversity inventory is a mandatory first step that in a relatively small and geologically young lake such as Alchichica could resemble a simple task. However, it has been a quite complex and slow process.

20.2 Diversity and Endemic Species: A Fascinating, Never-Ending Story

The number of species that a single lake can host depends on several factors acting at different temporal and spatial scales. These factors range from local interactions such as competition and predation to long-term continental processes such as

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glaciation, speciation/extinction rates, and dispersal barriers originated by plate tectonics (Brönmark and Hansson 2005). Further, inside a lake itself, the environment is not homogeneous, and there are species with different adaptations to exploit different ecological opportunities. Usually, the littoral zone is the most heterogeneous due to the physical structures produced by riparian and submerged vegetation, different kinds of sediments, and substrates, among others. It hosts a higher number of species compared to the water column (Schindler and Scheuerell 2002). However, the diversity observed in the water column may increase when including detailed analyses of microstratified, microaerobic, and anaerobic zones of the water column, with plenty of resource-rich niches controlled by the position of thermocline, as well as the anoxic hypolimnion (see Chap. 11 Bacterioplankton and Chap. 13 Protozooplankton).

In Lake Alchichica, an additional element increases the environmental complexity, enhancing species richness. The ring of tufa (i.e., stromatolites) circling the littoral zone, which creates small, isolated ponds, offers a myriad of microhabitats itself, and forms high vertical, underwater walls (see Chap. 10, The littoral community, and Chap. 22, Microbialites: diversity hotspots in the Mexican Plateau).

There is, however, another factor that heavily influences the number of species we know in each environment: the human factor. Each human scholar has the free will to choose the biological group she/he will investigate. Some biological groups are more attractive than others, producing an uneven understanding of the different branches of the tree of life. Also, and for practical uses, each scholar decides what a species is, how to name it, how to classify it, and how, when, and where to look for it. Inadvertently, such decisions are strongly impinged not only by personal and academic backgrounds but by technical advances and even by philosophical and sociopolitical settings.

Throughout the years, the practice of identifying species within each biological group has evolved at a different pace and followed slightly different paths due to the available technology. For hundreds of years, the best-studied species were animals, land plants, and fungi, which were defined mainly in terms of morphological discontinuities (Paterlini 2007). The number of records of these three groups in current electronic catalogs of life is a testimony of this historical bias. However, thanks to the advent of the microscope first and molecular tools more recently, life has revealed an astonishingly diverse microbial treasure: the immense majority of life forms on Earth are eukaryotic single-celled species (traditionally called protists), Bacteria, and Archaea (Burki et al. 2020; Yilmaz et al. 2014). Although in many groups, identifications still rely heavily on morphological characters, the biologist's toolkit nowadays can include cultures, molecular markers, ecophysiological experiments, and reproductive compatibility trials.

Following this historical path, the first records of the biological diversity in Lake Alchichica were animals and were based mainly on morphological characters. The copepod *Leptodiaptomus* (*Diaptomus*) *garciai* (Osorio-Tafall) and the silverside *Poblana alchichica* De Buen were described according to the current systematic standards and announced as new species in 1942 and 1945, respectively (Osorio-Tafall 1942; de Buen 1945; see also Chap. 14, Metazooplankton, and Chap. 15, Alchichica silverside). These two cases illustrate how systematics and personal points of view influence the perceived diversity and endemicity in an environment.

As early as 1953, Wilson and Yeats decided that the copepod inhabiting Alchichica was a population of the North American *Diaptomus novamexicanus* and considered *D. garciai* a synonym, extending the ecological range of the freshwater copepod to saline waters (Wilson and Yeats 1953). Later, when the genus *Diaptomus* underwent a major systematic revision and was split into smaller genera, it was assigned to *Leptodiaptomus*. Thus, the first paper on the ecology of the population inhabiting Alchichica was published as *L. novamexicanus* (Lugo et al. 1999). More than 50 years later, a study applying COI barcoding, reproductive trials, and eco-physiological tests showed that despite morphological differences are subtle, the copepod from Alchichica, now *Leptodiaptomus garciai,* was a valid name assigned to a species that is genetically, reproductively, and ecologically isolated from *L. novamexicanus* (Montiel-Martínez et al. 2008). Although he used only morphological traits, Osorio-Tafall was right from the start.

The silverside *Poblana alchichica* has been the subject of several studies regarding its taxonomic status and diversification patterns in Atherinidae in North America. There are other silversides in the neighboring lakes that were initially recognized as different, microendemic species: *P. letholepis* Alvarez, 1950 in Lake La Preciosa and *P. squamata* Alvarez, 1950 in Lake Quechulac. The status of the three species has been controversial because others have qualified their morphological divergence as non-significant, and their COI sequences are identical (Valdez-Moreno et al. 2009). Attending these criteria, they have been considered conspecific (*P. alchichica* with three subspecies) or members of the genus *Menidia*, given their low COI divergence with *M. menidia*. Later phylogenetic studies have shown that all members of the genus *Poblana* do form a monophyletic group closer to *Chirostoma* than to *Menidia*. However, the proper delimitation of the three genera and species within *Poblana* still awaits clarification (Bloom et al. 2009).

Meanwhile, the three species with their original names are regarded as valid in FishBase (Froese and Pauly 2020). To summarize, the story goes like this: the number of fish species in the three crater lakes went from three new species belonging to a new genus to a single species with three sub-species belonging to a pre-existing, widely distributed genus. In the end, the original taxonomic assignment prevailed, but the story is far from concluded.

From the early studies of the 1940s to recent years, the number of species found in Alchichica increased as new generations of researchers interested in the littoral, the stromatolites, the pelagic, and deep benthic zones (see next section). Remarkably, several species that in the subsequent decades would be recognized as new, endemic species, initially were misidentified: the now emblematic diatom *Cyclotella alchichicana* Oliva et al. 2006 was first identified as *Stephanodiscus niagarae* (Arredondo et al. 1984) or *Cyclotella quillensis* (Oliva et al. 2001); the rotifer *Brachionus* sp.

'Mexico' that inhabits Alchichica, Atexcac and La Preciosa (Alcántara-Rodríguez et al. 2012) appeared in a paper as *Brachionus rotundiformis* (Sarma et al. 2002); the insect *Chironomus alchichica* Acosta & Prat, 2017 was incorrectly identified as *Chironomus stigmaterus* (Alcocer et al. 2016); the ostracod *Limnocytherina axalapasco* Cohuo-Durán, Pérez & Karanovic (2014) was in a first moment confounded with *Limnocythere inopinata* (Hernández et al. 2010). Sometimes the discovery they were new, endemic species came after an observation during the peer-review process, or with a newcomer looking for cryptic diversity, or simply a well-trained eye that was able to see beyond the -apparently- obvious.

Other species have been uncovered straightforwardly, thanks to easily observable traits like in the case of the amphipod *Caecidotea williamsi* Escobar-Briones & Alcocer 2002, or by the intervention of young specialists as happened with *Candona alchichica* Cohuo, Hernández, Pérez & Alcocer (2017), or by renowned authorities in the field, like the description of *Cletocamptus gomezi* Suárez-Morales, Barrera-Moreno & Ciros-Pérez (2013), and the cyanobacterial species *Entophysalis litophila, E. atrata, Chamaesiphon halophilus, Heteroleibleinia profunda, Mantellum rubrum* and *Xenococcus candelariae* Tavera & Komárek (1996), and *Gloeomargarita litophila* Moreira et al. (2017).

Overall, up to date, there are 18 recognized endemic species (7 cyanobacteria, 11 eukaryotes) inhabiting Lake Alchichica (16 exclusive, 2 shared with neighboring lakes), but we can foreshadow that the list will grow in the short term. Systematic studies have invigorated recently with the use of molecular markers, as part of a polyphasic approach to uncover the diversity of prokaryotes in Alchichica (Aguila et al. 2021; Moreira et al. 2017; Chaps. 11 and 22, Bacterioplankton and Microbialites: Diversity hotspots in the Mexican Plateau). An ongoing project on metabarcoding suggests that there are nearly 8600 Amplicon Sequence Variants (ASVs of the 16S rRNA gene with 100% sequence identity) related to Bacteria and Archaea (unpublished data). These data suggest that from these sequences, 14 Archaea and 544 Bacteria genera are present in the sediment, microbialites, and water samples from the littoral and pelagic zones of Lake Alchichica. However, most of the sequences cannot be assigned at the genus level, leaving a considerable task pending identifying Lake Alchichica prokaryotes by polyphasic approaches in the future.

The preceding paragraphs show that knowing how many species there are in a lake is an arduous process. New, endemic species are frequently overlooked, and their status can be controversial. With such considerations in mind, we present the most comprehensive list ever published of the known specific diversity of Lake Alchichica.

20.3 How Many Species Do We Know in Lake Alchichica?

The species list that closes this chapter gathers the species richness of Lake Alchichica, known after 80 years of research. Most species have appeared previously in peer-reviewed papers, and others are mentioned for the first time in the preceding chapters of this book.

Modern systematics pursues a unified three-domain taxonomy, making classification consistent with phylogeny (Yilmaz et al. 2014). To organize the species list in a coherent whole, we adopted the phylogenomic classification framework of the SILVA rRNA database project (Yilmaz et al. 2014), which integrates the classification system of Eukarya proposed by Adl et al. (2005, 2012, 2019). Within the framework of the phylogenomic approach of Adl et al. (2019), the classification of unicellular organisms is well resolved. However, inevitably we had to draw upon the most recent Linnean-based classifications to integrate the names of Metazoa (animals) and Streptophyta (charophytes and plants) species. Current supraspecific classification, valid/correct binomina, and authorities were confirmed in Catalogue of Life (https://www.catalogueoflife.org/), World Register of Marine Species (http://www.marinespecies.org/), AlgaeBase (https://www.algaebase.org/) and the SILVA database (https://www.arb-silva.de/), using the version 138 released in November 2020.

Although some biological groups still await proper study (birds, fungi, parasites of invertebrates, etc.), the known biological diversity of Lake Alchichica encompasses distant branches of the three domains of life: Bacteria (37 genera and species reported), Archaea (8 genera identified) and Eukarya (196 genera and species), rendering a list of 241 taxa identified thus far. Inevitably, the length and composition of the list show not only the outcome of natural processes, but the expertise and experience of the researchers attracted to Lake Alchichica, in addition to the array of tools they had applied.

The task of comparing the taxonomic richness in the three domains of life is not straightforward due to the different species concepts and tools applied in each field (de Queiroz 2007). In prokaryotes, 18 bacterial and archaeal genera were detected exclusively with metabarcoding techniques. The remaining prokaryotes and eukaryotes were diagnosed with morphological or polyphasic approaches.

The most integral project for surveying Bacteria and Archaea in Lake Alchichica includes samples from the sediments, microbialites, and water column, all of them collected during the stratification period of the lake (unpublished data). Most of the identified bacterial taxa are Cyanobacteria (89%), with minor proportions of Bacteroidota and Proteobacteria (5.5% each). Members of the phylum Cyanobacteria are the most often identified due to their biogeochemical functions (C and N fixation) and relative abundance in the lake (see Chaps. 11 and 12). Archaeal diversity and its taxonomic affiliation are just being explored. In this case, the phylum Euryarchaeota was the most represented with 75% of the ASVs.

Table 20.1 Specific richness (S) of eukaryotic supergroups found in Lake Alchichica

	S	%
TSAR	96	49.0
Amorphea	73	37.2
Archaeplastida	12	6.6
Discoba	11	5.6
Haptista	1	0.5
Cryptista	1	0.5
Incertae sedis	1	0.5
Total	196	

In Eukarya, the supergroup TSAR is by far the most diverse (Table 20.1). The largest share are ciliates (42) and diatoms (45). The second most important supergroup is Amorphea, which includes 66 metazoan species (animals). In Archaeplastida, six species are embryophytes (plants). Interestingly, 63% of all Eukarya species here reported are protists (unicellular eukaryotes), constituting a more balanced view of the actual distribution of life forms across the eukaryotic tree of life (Burki et al. 2020).

Concerning habitats, 150 species are considered exclusively littoral and amount a significant proportion of taxa (62%), as expected due to the heterogeneous composition and morphometry of Lake Alchichica. The reported taxa found in the microbialites constitute nearly 58% of the prokaryotic diversity. In Chap. 10 (The littoral benthic community), the number of species, including macroinvertebrates, protozoans, and diatoms, is considered moderate compared to other lakes. In contrast, the pelagic environment is inhabited by 53 species (22%), a number considered low regarding phytoplankton (15 species, Chap. 12, Phytoplankton of Alchichica), ciliates (25 species, Chap. 13, Protozooplankton), metazooplankton (3 species, Chap. 14), fish (1 species Chap. 15, Alchichica silverside). The parasites of the silverside *P. alchichica* amount to 4% of the species.

20.4 Concluding Remarks

Given the relatively low species richness in Lake Alchichica, the number of endemic species is a striking and attractive attribute. This geologically young (13.3 to 6.3 ka) and small (2.4 km^2) lake holds a known overall richness of 241 taxa (Tables 20.2 and 20.3), among which 18 (7.5%) are endemic (Tables 20.2 and 20.3). Given the disparity in the sampling effort and the identification methods employed across biological groups, this figure is relative. For example, if only plants and animals were considered, endemicity rises to 14% (total richness = 73; endemic = 10). Even more, if we use the common approximation of focusing on particular taxa, the share of endemicity soars: if only vertebrates are accounted (*P. alchichica*, and *A. taylori*), then 100% of species are endemic; four out of six species (67%) of crustaceans thus far recorded (*C. williamsi*, *L. garciai, C. gomezi, C. alchichica*) are also exclusive of this lake. As more unique, endemic eukaryotic and especially prokaryotic taxa are found, species richness and global endemicity indicators will surely rise.

Another interesting indicator of the importance of endemic species in Lake Alchichica is that endemic species do not restrict to a single group but belong in several distant branches of the tree of life, including bacteria, diatoms, crustaceans, insects, and vertebrates. Additionally, they are present in – or even dominate – every functional community and possess unique biological or ecological features: the only pelagic predator, *P. alchichica* is endemic, as are the two main components of the plankton biomass: the copepod *L. garciai* and the diatom *C. alchichicana* (Chaps. 14 and 12, respectively). The amphipod *C. williamsi* is the first asellid recorded in saline environments and is highly specialized in inhabiting crevices in the stromatolites (Escobar-Briones and Alcocer 2002). *G. litophila*, associated with the microbialites, was the first known cyanobacterium with intracellular carbonate inclusions (Moreira et al. 2017). The salamander *A. taylori* is a model for the evolution of obligated paedomorphy (Percino-Daniel et al. 2016). The list goes on.

The evolution of neoendemic species is favored by high diversification rates, limited dispersal capabilities, and local conditions hampering the invasion of cosmopolitan taxa (Martens and Segers 2014). In Lake Alchichica, the study of the evolutionary processes behind endemicity began just a few years ago. As far as we know, the peculiar ionic conditions and geographical isolation could have played a key role in the diversification process, promoting local adaptation and genetic isolation from other populations (Percino-Daniel et al. 2016; Bloom et al. 2013; Chaps. 12, Phytoplankton of Alchichica, and Chap. 14, Metazooplankton). Moreover, ionic conditions also seem to restrict the establishment of species from geographically close lakes. To acquire a better understanding of these diversification processes, we should extend our efforts to, at least, the neighboring lakes. Surely, they will provide many answers and, we hope, new questions, so we can continue this never-ending story.

Finally, it is important to note that all this exciting effort to discover the wonders still hidden in Alchichica may be dramatically interrupted by the increasing threats to the conservation of the lake habitats and, with it, the peculiar biota adapted to this unique environment (see Chap 5, Hydrogeology and Hydrochemistry, and Chap. 21, Conservation actions).

Table 20.2 Main Archaea and Bacteria detected in Lake Alchichica

ARCHAEA	Habitat	Identified by
● Archaea		
● ● Altiarchaeota (Silva rRNA database project)		
● ● ● Altiarchaeia		
● ● ● ● Altiarchaeales		
● ● ● ● ● Altiarchaeaceae		
Candidatus Altiarchaeum	Sed	M
● ● Crenarchaeota (Silva rRNA database project)		
● ● ● Nitrososphaeria		
● ● ● ● Nitrosopumilales		
● ● ● ● ● Nitrosopumilaceae		
Candidatus Nitrosotenuis	Sed	M
● ● Euryarchaeota (Silva rRNA database project)		
● ● ● Methanobacteria		
● ● ● ● Methanobacteriales		
● ● ● ● ● Methanobacteriaceae		
Methanobacterium	Sed	M
● ● ● Thermococci (Silva rRNA database project)		
● ● ● ● Methanofastidiosales		
● ● ● ● ● Methanofastidiosaceae		
Candidatus Methanofastidiosum	Sed	M
● ● ● Methanomicrobia (Silva rRNA database project)		
● ● ● ● Methanomicrobiales		
● ● ● ● ● Methanocorpusculaceae		
Methanocalculus	Sed	M
● ● ● ● ● Methanoregulaceae		
Methanolinea	Sed	M
● ● ● Methanosarcinia (Silva rRNA database project)		
● ● ● ● Methanosarciniales		
● ● ● ● ● Methanosaetaceae		
Methanosaeta	Sed	M
● ● ● ● ● Methanosarcinaceae		
Methanolobus	Sed	M
BACTERIA		
● Bacteria		
● ● Bacteroidota (Silva rRNA database project)		
● ● ● Bacteroidia		
● ● ● ● Flavobacteriales		
● ● ● ● ● Flavobacteriaceae		
Flavobacterium	P	M
Planktosalinus	P	M
● ● Cyanobacteria		
● ● ● Cyanobacteriia (Silva rRNA database project)		

(continued)

Table 20.2 (continued)

●●●●Cyanobacteriales		
●●●●●Cyanobacteriaceae		
Chroococcus sp.	Mi, Sed	PA, M
●●●●●Nostocaceae		
Calothrix sp.	Mi	M
Calothrix cf. *parietina* Thuret ex Bornet & Flahault 1886	Mi	PA
Nodularia sp.	P, Sed	M
Nodularia aff. *spumigena* Mertens ex Bornet & Flahault 1888	P	PA
Rivularia sp.	Mi	M
Rivularia cf. *haematites* C. Agardh ex Bornet & Flahault 1886	Mi	PA
Trichormus sp. Tavera & Komárek 1996	Mi, P	PA
●●●●●Phormidiaceae		
Tychonema sp.	Sed, Mi	PA, M
●●●●●Xenococcaceae		
Chroococcidium sp.	Mi	PA
Chroococcidium gelatinosum Geitler 1933	Mi	PA
Myxosarcina sp.	Mi	PA
Xenococcus sp.	Sed, Mi	M
* ***Xenococcus candelariae* Tavera & Komárek 1996**	E	PA
●●●●Eurycoccales		
●●●●●Eurycoccales *Incertae Sedis*		
Candidatus Gloeomargarita	Mi	M
* ***Gloeomargarita lithophora* Moreira et al. 2017**	Mi	PA
●●●●Phormidesmiales		
●●●●●Nodosilineaceae		
Haloleptolyngbya sp.	Mi	PA
Halomicronema sp.	Mi	PA, M
Leptolyngbya sp.	Mi, Sed	PA, M
Nodosilinea sp.	Mi, Sed	PA, M
●●●●Pseudanabaenales		
●●●●●Pseudanabaenaceae		
Pseudanabaena sp.	P	M
●●●●Synechococcales		
●●●●●Cyanobiaceae		
Cyanobium/Synechococcus sp.	P, Mi, Sed	PA, M
Prochlorococcus sp.	Mi	PA
Synechocystis sp.	P	M
●●●●Thermosynechococcales		
●●●●●Acaryochloridaceae		
Acaryochloris sp.	Mi	M

(continued)

Table 20.2 (continued)

● ● ● Cyanophyceae (Algaebase)		
● ● ● ● Chroococcales		
● ● ● ● ● Chroococcaceae		
Chroococcus schizodermaticus West 1892	Mi	PA
* ***Entophysalis atrata* Tavera & Komárek 1996**	Mi, P	PA
* ***Entophysalis lithophyla* Tavera & Komárek 1996**	Mi, P	PA
● ● ● ● Synechococcales		
● ● ● ● ● Chamaesiphonaceae		
* ***Chamaesiphon halophilus* Tavera & Komárek 1996**	E	PA
● ● ● ● ● Merismopediaceae		
Eucapsis cf. *starmachii* Komárek & Hindák 1989	Mi, P	PA
* ***Mantellum rubrum* Tavera & Komárek 1996**	E	PA
● ● ● ● ● Synechococcaceae		
Epigloeosphaera cf. *glebulenta* (Zalessky) Komárková-Legnerová 1991	P	PA
Lemmermanniella cf. *flexa* Hindák 1985	P	PA
● ● ● ● ● Synechococcales *Incertae sedis*		
* ***Heteroleibleinia profunda* Tavera & Komárek 1996**	E	PA
● ● Proteobacteria		
● ● ● Alphaproteobacteria		
● ● ● ● Rhodobacterales		
● ● ● ● ● Rhodobacteraceae		
Paracoccus sp.	P	M, PA
● ● ● Gammaproteobacteria		
● ● ● ● Chromatiales		
● ● ● ● ● Chromatiaceae		
Thiocapsa sp.	P	M, PA

The list includes species reported and identified by polyphasic approaches [see references and Chap. 12], while other genera have been detected by metabarcoding of the 16S rRNA gene (V4 region) (unpublished data). The classification system is according to the SILVA rRNA database project (https://www.arb-silva.de/) (v138, release 11–2020), and those species not found in the Silva database project are according to the Algaebase (https://www.algaebase.org/). For further information on the ecology and occurrence of these species, please refer to the corresponding chapters of this book.

Habitat, P: pelagic, Sed: sediment, Mi: littoral microbialite, E: Epiphyte. Identified by M: metabarcoding, PA: polyphasic approach. Endemic species are in bold characters and an (*)

Table 20.3 Eukaryotic diversity in Lake Alchichica

TSAR	Habitat
● Stramenopiles Patterson 1989, emend. Adl et al. 2005	
● ● Gyrista	
● ● ● Ochrophyta	
● ● ● ● Chrysista	
● ● ● ● ● Chrysophyceae	
● ● ● ● ● ● Ochromonadales	
Ochromonas sp.	P
Spumella (*Monas*) *guttula* (Ehrenberg, 1830)	L
Spumella (Monas) *minima* (Meyer, 1897)	L
Spumella (Monas) termo (Müller) Tanichev, 1993	L
Spumella (Monas) vivipara (Ehrenberg) Kent, 1881	L
● ● ● ● Diatomista	
● ● ● ● ● Diatomeae	
● ● ● ● ● ● Bacillariophytina	
● ● ● ● ● ● ● Mediophyceae	
● ● ● ● ● ● ● ● Chaetocerotophycidae	
Chaetoceros elmorei Boyer, 1914	P
● ● ● ● ● ● ● ● Thalassiosirophycidae	
*** *Cyclotella alchichicana* Oliva et al., 2006**	P
Cyclotella choctawhatcheeana Prasad, 1990	P
Cyclotella group *meneghiniana* Kützing, 1844	L
● ● ● ● ● ● ● Bacillariophyceae	
● ● ● ● ● ● ● ● Fragilariophycidae	
Pseudostaurosira brevistriata (Grunow) D.M.Williams & Round, 1988	L
● ● ● ● ● ● ● ● Bacillariophycidae	
Achnanthes sp.	L
Amphora libyca Ehrenberg, 1841	L
Amphora pediculus (Kützing) Grunow, 1875	L
*Anomoeoneis costata (*Kützing) Hustedt,1959	L
Anomoeoneis sphaerophora Pfitzer, 1871	L
Caloneis westii (W. Smith) Hendey, 1964	L
*Campylodiscus clypeus (*Ehrenberg) Ehrenberg ex Kützing, 1844	L
Cocconeis placentula var. *lineata* (Ehrenberg) Van Heurck, 1885	L
Cocconeis placentula var. *euglypta* (Ehrenberg) Grunow, *1884*	L
Craticula sp.	L
Cymbella cistula (Ehrenberg) O. Kirchner, 1878	L
Cymbella mexicana (Ehrenberg) Cleve, 1894	L
Denticula sp.	L

(continued)

Table 20.3 (continued)

TSAR		Habitat
	Diploneis pseudovalis Hustedt, 1930	L
	Entomoneis alata (Ehrenberg) Ehrenberg, 1845	L
	Epithemia argus (Ehrenberg) Kützing, 1844	L
	Epithemia sorex Kützing, 1844	L
	Epithemia turgida (Ehrenberg) Kützing, 1844	L
	Gomphoneis olivaceum (Hornemann) Ehrenberg, 1838	L
	Gomphonema clavatum Ehrenberg, 1832	L
	Gyrosigma acuminatum (Kützing) Rabenhorst, 1853	L
	Halamphora sp.	P
	Halamphora veneta (Kützing) Levkov, 2009	L
	Hippodonta sp.	L
	Mastogloia elliptica (C. Agardh) Cleve, 1893	L
	Mastogloia smithii Thwaites ex W. Smith, 1856	L
	Navicula cryptocephala Kützing, 1844	L
	Navicula radiosa Kützing, 1844	L
	Navicymbula pusilla (Grunow) Krammer, 2003	L
	Nitzschia vitrea G. Norman, 1861	L
	Nitzschia communis Rabenhorst, 1860	L
	Nitzschia frustulum (Kützing) Grunow, 1880	L
	Nitzschia gracilis Hantzsch, 1860	L
	Nitzschia vitrea Hantzsch ex Rabenhorst, 1862	L
	Pinnularia sp.	L
	Pinnularia brevissonii (Kützing) Rabenhorst, 1864	L
	Rhopalodia gibberula (Ehrenberg) O. Müller, 1895	L
	Stauroneis sp.	L
	Surirella ovalis Brébisson, 1838	L
	Surirella striatula Turpin, 1828	L
● ● ● Actinophryidae		
	Actinophrys sol Ehrenberg, 1830	L
	Actinosphaerium eichornii (Ehrenberg) Stein, 1857	L
● Alveolata Cavalier-Smith 1991		
● ● Dinoflagellata		
● ● ● Dinophyceae		
● ● ● ● Peridiniphycidae		
● ● ● ● ● Peridiniales		
	aff. *Parvodinium*	P
● ● Ciliophora		
● ● ● Postciliodesmatophora		
● ● ● ● Heterotrichea		
● ● ● ● ● Spirostomidae		
	Spirostomum teres Claparède & Lachmann, 1859	P

(continued)

Table 20.3 (continued)

TSAR	Habitat
●●●●● Stentoridae	
Stentor multiformis (Müller,1786) Ehrenberg 1838	P
●●● Intramacronucleata	
●●●● SAL (Spirotrichea (S), Armophorea (A) and Litostomatea (L))	
●●●●● Mesodiniidae Jankowski, 1980. *Incertae sedis*	
Mesodinium sp.	P
Mesodinium acarus Stein, 1863	L
●●●●● Spirotrichea	
●●●●●● Euplotia	
●●●●●●● Euplotida	
●●●●●●●● Aspidicidae	
Aspidisca cicada (O.F. Müller, 1786)	L
●●●●●●●● Euplotidae	
Euplotes euryhalinus Valbonesi & Luporini, 1990	P
●●●●●● Perilemmaphora	
●●●●●●● Hypotrichia	
●●●●●●●● Stichotrichida	
●●●●●●●●● Halteriidae	
Halteria grandinella (Müller, 1773)	L, P
●●●●●●●●● Oxytrichidae	
Oxytricha sp.	L
Stylonychia notophora Stokes, 1885	L
●●●●●●●●● Uroleptidae	
Uroleptus rattulus Stein, 1859	P
●●●●● Lamellicorticata	
●●●●●● Armophorea	
●●●●●●● Metopida	
●●●●●●●● Metopidae	
Brachonella sp.	P
●●●●●●● Caenomorphidae	
Caenomorpha cf. *lauterborni* Kahl, 1927	P
●●●●●● Litostomatea	
●●●●●●● Haptoria	
●●●●●●●● Lacrymariidae	
Phialina sp.	P
●●●●●●●● Didiniidae	
Monodinium cf. *balbianii* var. *nanum* Fabre-Domergue, 1888	P
●●●●●●●● Pleurostomatida	
●●●●●●●●● Litonotidae	
Litonotus sp.	P
Litonotus fasciola (Müller, 1773)	L

(continued)

Table 20.3 (continued)

TSAR	Habitat
●●●●●●●●Spathidiida	
●●●●●●●● ●Actinobolinidae	
Actinobolina sp.	P
Belonophrya sp.	P
●●●●●●●● ●Enchelydae	
Enchelys simplex Kahl, 1926	L
●●●●●●●● ●Trachelophyllidae	
Lagynophrya sp.	P
●●●●CONTHREEP (Colpodea (C), Oligohymenophorea (O), Nassophorea (N), Phyllopharyngea (P), Prostomatea (P), and Plagiopylea (P)	
●●●●●Phyllopharyngea	
●●●●●●Subkinetalia	
●●●●●●●Cyrtophoria	
●●●●●●●●Chlamydodontida	
●●●●●●●● ●Chilodonellidae	
*Chilodonella uncinata (*Ehrenberg, 1838)	L
●●●●●●●●Dysteriida	
●●●●●●●● ●Dysteriidae	
Trochilia minuta (Roux, 1899) Kahl, 1931	L
●●●●●●●Suctoria	
●●●●●●●●Exogenida	
●●●●●●●● ●Podophryidae	
Sphaerophrya canelli Clement, 1967	P
Sphaerophrya soliformis Lauterborn, 1908	L
●●●●●Prostomatea	
●●●●●●Prorodontida	
●●●●●●●Holophryidae	
Holophrya cf. *aklitolophon* Hiller & Bardele, 1988	P
Holophrya simplex Schewiakoff, 1893	L
●●●●●Plagiopylea	
●●●●●●Plagiopylida	
●●●●●●●Epalxellidae	
Epalxella sp.	P
●●●●●Oligohymenophorea	
●●●●●●Peritrichia	
●●●●●●●Sessilida	
●●●●●●●●Epistylididae	
Rhabdostyla sp.	P
●●●●●●●●Vorticellidae	
Pelagovorticella natans Jankowski, 1985	P
Vorticella sp.	P
Vorticella aquadulcis – complex	P
●●●●●●●●Vaginicolae	

(continued)

Table 20.3 (continued)

TSAR	Habitat
Cothurnia sp.	L
●●●●●● Scuticociliatia	
●●●●●●● Philasterida	
●●●●●●●● Uronematidae	
Uronema sp.	L, P
●●●●●●● Pleuronematida	
●●●●●●●● Cyclidiidae	
Cristigera sp.	P
Cyclidium sp.	P
Cyclidium glaucoma Müller, 1773	L, P
Cyclidum citrullus Cohn, 1865	L
Cyclidium porcatum Esteban, Guhl, Clarke, Finlay & Embley, 1993	P
Isocyclidium globosum Esteban, Finlay & Embley, 1993	P
●●●●●●●● Pleuronematidae	
Pleuronema sp.	P
●●●●●● Scuticociliatia	
●●●●●●● Loxocephalida	
●●●●●●●● Cinetochilidae	
Cinetochilum margaritaceum Perty, 1849	L, P
●●● Intramacronucleata	
Sathrophilus sp.	P
● Rhizaria Cavalier-Smith 2002	
●● Cercozoa	
Gymnophrys cometa Cienkowski, 1876	L
HAPTISTA	
● Haptista Cavalier-Smith 2003	
●● Haptophyta	
●●● Prymnesiophyceae	
●●●● Isochrysidales	
aff. *Tisochrysis*	P
CRYPTISTA	
● Cryptista Adl et al. 2019	
●● Cryptophyceae	
●●● Cryptomonadales	
Cryptomonas sp.	P
ARCHAEPLASTIDA	
● Chloroplastida Adl et al. 2005	
●● Chlorophyta	
●●● Ulvophyceae	
Cladophora sp.	L
●●● Trebouxiophyceae	

(continued)

Table 20.3 (continued)

TSAR		Habitat
	Monoraphidium dybowskii (Woloszynska) Hindák & Komárková-Legnerová, 1969	P
	Monoraphidim minutum (Naegeli) Komárková-Legnerová, 1969	P
	Oocystis parva West & G.S. West, 1898	P
	Oocystis submarina Lagerheim, 1886	P
	Picochlorum sp.	P
●● Streptophyta		
●●● Phragmoplastophyta		
●●●● Charophyceae		
	Chara canescens Loiseleur, 1810	L
●●●● Embryophyta		
●●●●● Magnoliopsida		
●●●●●● Poales		
●●●●●●● Cyperaceae		
	Amphiscirpus nevadensis (S. Wats.) Oteng-Yeb., 1974	L
	Cyperus laevigatus Linnaeus, 1771	L
	Eleocharis dombeyana Kunth, 1837	L
●●●●●●● Juncaceae		
	Juncus arcticus Willd., 1799	L
	Juncus sp.	L
●●●●●● Alismatales		
●●●●●●● Ruppiaceae		
	Ruppia maritima Linnaeus, 1753	L
AMORPHEA		
● Tubulinea Smirnov et al. 2005		
●● Elardia		
●●● Euamoebida		
	Amoeba sp.	L
	Trichamoeba osseosaccus Schaeffer, 1926	L
● Evosea Kang et al. 2017		
●● Variosea		
●●● Filamoeba		
	Filamoeba nolandii Page, 1967	L
● Discosea Cavalier-Smith et al. 2004, sensu Smirnov et al. 2011		
●● Flabellinia		
●●● Dermamoebida		
	Mayorella microeruca Bovee, 1970	L
●●● Dactylopodida		
	Vexillifera sp.	L
● Holozoa Lang et al. 2002		
●● Choanoflagellata		

(continued)

Table 20.3 (continued)

TSAR	Habitat
●●●Craspedida	
●●●●Salpingoecidae	
Monosiga ovata Kent, 1878	L, P
Monosiga sp.	P
●●Metazoa	
●●●Bilateria	
●●●●Arthropoda	
●●●●●Malacostraca	
●●●●●●Amphipoda	
●●●●●●●Hyalellidae	
Hyalella azteca Saussure, 1858	L
●●●●●●Isopoda	
●●●●●●●Asellidae	
*** *Caecidotea williamsi* Escobar-Briones & Alcocer, 2002**	Mi
●●●●●Hexanauplia	
●●●●●●Calanoida	
●●●●●●●Diaptomidae	
*** *Leptodiaptomus garciai* (Osorio-Tafall, 1942)**	P
●●●●●●Harpacticoida	
●●●●●●●Canthocamptidae	
*** *Cletocamptus gomezi* Suárez-Morales, Barrera-Moreno & Ciros-Pérez, 2013**	L
●●●●●Ostracoda	
●●●●●●Podocopida	
●●●●●●●Candonidae	
*** *Candona alchichica* Cohuo, Hernández, Pérez & Alcocer, 2017**	L, DB
●●●●●●●Limnocytheridae	
*** *Limnocytherina axalapasco* Cohuo-Durán, Pérez & Karanovic, 2014**	L
●●●●●Insecta	
●●●●●●Ephemeroptera	
●●●●●●●Baetidae	
Callibaetis montanus Eaton, 1885	L
●●●●●●Odonata	
●●●●●●●Aeshnidae	
Rhionaeschna dugesi (Calvert, 1905)	L
●●●●●●●Coenagrionidae	
Enallagma praevarum Hagen, 1861	L
●●●●●●Hemiptera	
●●●●●●●Corixidae	
*** *Krizousacorixa tolteca* Jansson, 1979**	L

(continued)

Table 20.3 (continued)

TSAR	Habitat
●●●●●●●Naucoridae	
Ambrysus sp.	L
●●●●●●●Notonectidae	
Buenoa sp.	L
●●●●●●Trichoptera	
●●●●●●●Limnephilidae	
Grensia sp.	L
●●●●●●●Leptoceridae	
Oecetis sp.	L
●●●●●●●Hydroptilidae	
Oxyethira sp.	L
●●●●●●●Polycentropodidae	
Polycentropus sp.	L
●●●●●●Coleoptera	
●●●●●●●Dytiscidae	
Hydroporus sp.	L
Laccodytes sp.	L
●●●●●●●Chrysomelidae	
Donacia sp.	L
●●●●●●●Hydrophilidae	
Berosus sp.	L
Tropisternus sp.	L
●●●●●●●Staphylinidae	
Stenus sp.	L
●●●●●●Diptera	
●●●●●●●Chironomidae	
Apedilum elachistus Townes, 1945	L
Chironomus sp.	L
* ***Chironomus alchichica* Acosta & Prat, 2017**	L, DB
Cryptochironomus fulvus gr. Johannsen, 1905	L
Cricotopus (Cricotopus) triannulatus Kieffer, 1909	L
Dicrotendipes neomodestus (Malloch, 1915)	L
Labrundinia pilosella (Loew, 1866)	L
Limnophyes sp.	L
Micropsectra sp. 1	L
Micropsectra sp. 2	L
Paratanytarsus sp.	L
Procladius sp.	L, DB
Psectrocladius sp.	L
Psectrotanypus sp.	L
Stictochironomus sp.	L
Tanypus (*Apelopia*) sp.	L

(continued)

Table 20.3 (continued)

TSAR	Habitat
●●●●●●●Ceratopogonidae	
Culicoides occidentalis sonorensis Jørgensen, 1969	L
●●●●●●●Culicidae	
Culex sp.	L
●●●●●●●Ephydridae	
Ephydra hians Say,1830	L
●●●●●●●Stratiomyidae	
Stratiomys sp.	L
●●●●Nematoda	
●●●●●Enoplea	
●●●●●●Triplonchida	
●●●●●●●Tobrilidae	
Neotobrilus sp.	L
Semitobrilus sp.	L
Tobrilus sp.	L
●●●●●Chromadorea	
●●●●●●Rhabditida	
●●●●●●●Hoplolaimidae	
Hoplolaimus sp. 1	L
Hoplolaimus sp. 2	L
●●●●●●●Rhabdochonidae	
Rhabdochona canadensis Moravec & Arai, 1971	Po
●●●●●●●Gnathostomatidae	
Spiroxys sp.	Po
●●●●●●Chromadorida	
●●●●●●●Cyatholaimidae	
Paracyatholaimus sp.	L
●●●●●●Monhysterida	
●●●●●●●Xyalidae	
Daptonema sp.	L
Monhystera sp.	L
●●●●Annelida	
●●●●●Clitellata	
●●●●●●Haplotaxida	
●●●●●●●Naididae	
Limnodrilus hoffmeisteri Claparède, 1862	L
Tubifex tubifex (Müller, 1774)	L
●●●●●●Rhynchobdellida	
●●●●●●●Glossiphoniidae	
Glossiphoniidae sp.	L
Helobdella stagnalis (Linnaeus, 1758)	L

(continued)

Table 20.3 (continued)

TSAR	Habitat
●●●●●●● Piscicolidae	
Myzobdella sp.	Po
●●●● Mollusca	
●●●●● Gastropoda	
●●●●●●● Physidae	
Physa sp.	L
●●●● Platyhelminthes	
●●●●● Trematoda	
●●●●●● Diplostomida	
●●●●●●● Diplostomidae	
Posthodiplostomum minimum (McCallum, 1921)	Po
Tylodelphys sp.	Po
●●●●● Cestoda	
●●●●●● Bothriocephalidea	
●●●●●●● Bothriocephalidae	
Schizocotyle acheilognati (Yamaguti, 1931)	Po
●●●●●● Diphyllobothriidea	
●●●●●●● Diphyllobothriidae	
Ligula intestinalis (Linnaeus, 1758)	Po
●●●● Rotifera	
●●●●● Eurotatoria	
●●●●●● Flosculariaceae	
●●●●●●● Hexarthridae	
Hexarthra cf. *jenkinae* (Beauchamp, 1932)	P
●●●●●● Ploima	
●●●●●●● Brachionidae	
*** *Brachionus* sp. 'Mexico'**	P
●●●● Chordata	
●●●●● Actinopterygii	
●●●●●● Atheriniformes	
●●●●●●● Atherinopsidae	
*** *Poblana alchichica* de Buen, 1945**	L, P
●●●●● Amphibia	
●●●●●● Caudata	
●●●●●●● Ambystomatidae	
*** *Ambystoma taylori* Brandon, Maruska & Rumph, 1982**	L, P
DISCOBA	
● Discoba Simpson in Hampl et al. 2009	
●● Heterolobosea	
●●● Tetramitia	
●●●● Eutetramitia	

(continued)

Table 20.3 (continued)

TSAR		Habitat
● ● ● ● ● Vahlkampfidae		
	Vahlkampfia sp.	L
● ● Euglenozoa		
● ● ● Euglenida		
● ● ● ● Heteronematina		
	Anisonema ovale Klebs, 1883	L
	Petalomonas steinii Klebs, 1893	L
	Notoselenus apocamptus Stokes, 1884	L
● ● ● Kinetoplastea		
● ● ● ● Metakinetoplastina		
● ● ● ● ● Neobodonida		
	Rhynchobodo sp.	P
	Rhynchomonas nasuta Klebs, 1892	L
● ● ● ● ● Eubodonida		
	Bodo caudatus (Dujardin) Stein, 1878	L
	Bodo globosus Stein, 1878	L
	Bodo minima Klebs, 1892	L
	Bodo repens Klebs, 1892	L
	Bodo saltans Ehrenberg, 1838	L
***Incertae sedis* EUKARYA**		
	Copromonas subtilis Dobell, 1908	L

Species organization follows the classification system of Eukarya by Adl et al. (2019), with supergroups as defined in Burki et al. (2020): TSAR (telonemids, stramenopiles, alveolates, Rhizaria), Haptista, Cryptista, Archaeplastida, Amorphea and Discoba. [Habitat: Pelagic (P), Littoral zone (L), Deep benthos (DB), Mi (Microbialites), parasites of *Poblana alchichica* (Po)]. Endemic species are in bold characters and an (*). For further information on the ecology and occurrence of these species, please refer to the corresponding chapters of this book

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References

Acosta R, Prat N, Ribera C, Michailova P, Hernandez-Fonseca MC, Alcocer J (2017) *Chironomus alchichica* n. sp. (Diptera: Chironomidae) from Lake Alchichica, Mexico. Zootaxa 4365(1): 053-070. https://doi.org/10.11646/zootaxa.4365.1.3

Adl SM, Simpson AGB, Farmer MA, Andersen RA, Anderson OR, Barta JR, Bowser SS, Brugerolle G, Fensome RA, Fredericq S, James TY, Karpov S, Kugrens P, Krug J, Lane CE, Leis LA, Lodge J, Lynn DH, Mann DG, McCourt RM, Mendoza L, Moesrup Om Mozley-Standridge SE, Nerad TA, Shearer CA, Smirnov AV, Spiegel FW, Taylor MFJR (2005) The new higher level classification of eukaryotes with emphasis on the taxonomy of protists. J Eukaryot Microbiol 52(5):399–451. https://doi.org/10.1111/j.1550-7408.2005.00053.x

Adl SM, Simpson AGB, Lane CE, Lukeš J, Bass D, Bowser SS, Brown MW, Burki F, Dunthorn M, Hampl V, Heiss A, Hoppenrath M, Lara E, Gall LL, Lynn DH, McManus H, Mitchell EAD, Mozley-Stanridge SE, Parfrey LW, Pawlowski J, Rueckert S, Shadwick, Schoch CL, Smirnov A, Spiegel FW (2012) The revised classification of eukaryotes. J Eukaryot Microbiol 59(5):429–514. https://doi.org/10.1111/j.1550-7408.2012.00644.x

Adl SM, Bass D, Lane CE, Lukeš J, Schoch CL, Smirnov A, Agatha S, Berney C, Brown MW, Burki F, Cárdenas P, Čepička I, Chistyakova L, del Campo J, Dunthorn M, Edvardsen B, Eglit Y, Guillou L, Hampl V, Heiss AA, Hoppenrath M, James TY, Karnkowska A, Karpov S, Kim E, Kolisko M, Kudryavtsev A, Lahr DJG, Lara E, Gall LL, Lynn DH, Mann DG, Massana R, Mitchell EAD, Morrow C, Park JS, Pawlowski JW, Powell MJ, Richter DJ, Rueckert S, Shadwick L, Shimano S, Spiegel FW, Torruella G, Youssef N, Zlatogurski V, Zhang Q (2019) Revisions to the classification, nomenclature, and diversity of Eukaryotes. J Eukaryot Microbiol 66(1):4–119. https://doi.org/10.1111/jeu.12691

Águila B, Alcántara-Hernández RJ, Montejano G, López-Martínez R, Falcón LI, Becerra-Absalón I (2021) Cyanobacteria in microbialites of Alchichica Crater Lake: a polyphasic characterization. Eur J Phycol. https://doi.org/10.1080/09670262.2020.1853815

Alcántara-Rodríguez JA, Ciros-Pérez J, Ortega-Mayagoitia E, Serrania-Soto CR, Piedra-Ibarra E (2012) Local adaptation in populations of a *Brachionus* group *plicatilis* cryptic species inhabiting three deep crater lakes in Central Mexico. Freshwat Biol 57(4):728–740. https://doi.org/10.1111/j.1365-2427.2012.02738.x

Alcocer J, Escobar E, Řezníčková P, Oseguera LA (2016) La comunidad de macroinvertebrados bentónicos litorales como un reflejo de la heterogeneidad ambiental. Hidrobiológica 26(3):403–418

Alvarez J (1950) Contribución al conocimiento de los peces de la región de los Llanos, estado de Puebla (México). An Esc Nac Cienc Biol 6:81–107

Arredondo JL, Vera O, Ortiz AO (1984) Análisis de componentes principales y cúmulos de datos limnológicos en el lago de Alchichica, Puebla. Biotica 9:23–39

Bloom DD, Piller KR, Lyons J, Mercado-Silva N, Medina-Nava M (2009) Systematics and biogeography of the silverside tribe Menidiini (Teleostomi: Atherinopsidae) based on the mitochondrial ND2 gene. Copeia 2:408–417. https://doi.org/10.1643/CI-07-151

Brönmark C, Hansson L-A (2005) The biology of lakes and ponds. Oxford Universitys Press, Oxford

Burki F, Roger AJ, Brown MW, Simpson AGB (2020) The new tree of Eukaryotes. TREE 35(1):43–55. https://doi.org/10.1016/j.tree.2019.08.008

Cohuo-Duran S, Perez L, Karanovic I (2014) On *Limnocytherina axalapasco*, a new freshwater ostracod (Podocopida: Limnocytheridae) from Mexican crater lakes. Rev Biol Trop 62(1):15–32

De Buen F (1945) Investigaciones sobre la ictiología mexicana I. Atherinidae de aguas continentales de México. An Inst Biol Univ Nac Autón Méx 16:475–532

De Queiroz K (2007) Species concepts and species delimitation. Syst Biol 56(6):879–886

Escobar-Briones E, Alcocer J (2002) *Caecidotea williamsi* (Crustacea: Isopoda: Asellidae), a new species from a saline crater-lake in the eastern Mexican Plateau. Hydrobiologia 477(1–3): 93–105

Froese R, Pauly D (eds) (2020) FishBase. http://www.fishbase.org, version (12/2020). Accessed 5 Apr 2021

Hernández MC, Escobar E, Alcocer J (2010) Ensamble de crustáceos bentónicos en un lago salino tropical. Rev Mex Biodiver 81:133–140

Lugo A, González ME, Sánchez MDR, Alcocer J (1999) Distribution of *Leptodiaptomus novamexicanus* (Copepoda: Calanoida) in a Mexican hyposaline lake. Rev Biol Trop 47(1 suppl):141–148. https://doi.org/10.15517/rbt.v47i1.26167

Martens K, Segers H (2006) Endemism in inland waters. In: Likens GE (ed) Encyclopedia of inland waters, vol 1. Elsevier, Oxford, pp 423–430

Montiel-Martínez A, Ciros-Pérez J, Ortega-Mayagoitia E, Elías-Gutiérrez M (2008) Morphological, ecological, reproductive and molecular evidence for *Leptodiaptomus garciai* (Osorio-Tafall

1942) as a valid endemic species. J Plankton Res 30(10):1079–1093. https://doi.org/10.1093/plankt/fbn067
Moreira D, Tavera R, Benzerara K, Skouri-Panet F, Couradeau E, Gérard E, Fonta CL, Novelo E, Zivanovic Y, López-García P (2017) Description of *Gloeomargarita lithophora* gen. nov., sp. nov., a thylakoid-bearing, basal-branching cyanobacterium with intracellular carbonates, and proposal for Gloeomargaritales ord. nov. Int J Syst Evol Microbiol 67(3):653–658. https://doi.org/10.1099/ijsem.0.001679
Oliva MG, Lugo A, Alcocer J, Peralta L, Sánchez MR (2001) Phytoplankton dynamics in a deep, tropical, hyposaline lake. Hydrobiologia 466:299–306
Oliva MG, Lugo A, Alcocer J, Cantoral-Uriza EA (2006) *Cyclotella alchichicana* sp. nov. from a saline mexican lake. Diatom Res 21:81–89
Osorio-Tafall BF (1942) Un nuevo *Diaptomus* del México Central (Copepoda, Diaptomidae). Rev Bras Biol 2:147–154
Paterlini M (2007) There shall be order. The legacy of Linnaeus in the age of molecular biology. EMBO Rep 8(9):814–816. https://doi.org/10.1038/sj.embor.7401061
Percino-Daniel R, Recuero E, Vázquez-Domínguez E, Zamudio KR, Parra-Olea G (2016) All grown-up and nowhere to go: Paedomorphosis and local adaptation in *Ambystoma* salamanders in the Cuenca Oriental of Mexico. Biol J Linn Soc 118(3):582–597. https://doi.org/10.1111/bij.12750
Reid W (1998) Biodiversity hotspots. TREE 13(7):275–280. https://doi.org/10.1016/B978-0-12-809665-9.09962-6
Sarma SSS, Elguea-Sánchez B, Nandini S (2002) Effect of salinity on competition between the rotifers *Brachionus rotundiformis* Tschugunoff and *Hexarthra jenkinae* (De Beauchamp) (Rotifera). Hydrobiologia 474:183–188. https://doi.org/10.1023/A:1016535821741
Schindler DE, Scheuerell MD (2002) Habitat coupling in lake ecosystems. Oikos 98(2):177–189. https://doi.org/10.1034/j.1600-0706.2002.980201.x
Suárez-Morales E, Barrera-Moreno O, Ciros-Pérez (2013) A new species of *Cletocamptus* Schmankewitsch, 1875 (Crustacea, Copepoda, Harpacticoida) from a high altitude saline lake in Central Mexico. J Limnol 72:313–325
Tavera R, Komárek J (1996) Cyanoprokaryotes in the volcanic lake of Alchichica, Puebla State, Mexico. Algol Stud für Hydrobiol (Suppl) 83:511–538
Valdez-Moreno M, Ivanova NV, Elías-Gutiérrez M, Contreras-Balderas S, Hebert PDN (2009) Probing diversity in freshwater fishes from Mexico and Guatemala with DNA barcodes. J Fish Biol 74(2):377–402
Wilson MS, Yeatman HC (1959) Free-living Copepoda. In: Edmonson WT (ed) Freshwater biology. Wiley, New York, pp 735–868
Yilmaz P, Parfrey LW, Yarza P, Gerken J, Pruesse E, Quast C, Schweer T, Peplies J, Ludwig W, Glöckner FO (2014) The SILVA and "all-species Living Tree Project (LTP)" taxonomic frameworks. Nucleic Acids Res 42(D1):D643–D648