SHORT ARTICLES AND REVIEWS

(THE AQUATIC BIOTA OF THE NOW EXTINCT LACUSTRINE COMPLEX OF THE MEXICO BASIN

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Introduction

The Valley of Mexico is an endorheic basin (i.e. there is no natural outlet) lying on the highest portion of the Mexican Plateau (2240-2390 metres above sea level) between 19°01'18" to 20°09'12" N and 98°31'58" to 99°30'52" W. It is oval in shape, with a north-south axis 125 km in length and a shorter east-west axis of 90 km, averaging 7,868 km^2 in area (Alvarez & Navarro 1957; Mora 1991).

A lacustrine complex of six interconnected water-bodies occupied a large area of the valley when the Aztecs arrived in 1245 (Fig. 1). Today there are just sparse remnants of the complex (Alcocer & Escobar 1990), three of which are the best-known lakes: Texcoco, Xochimilco, and Lake Mexico where the island of Tenochtitlan was located (Fig. 1).

Temporary flood plains are the left-overs of the huge saline Lake Texcoco. Four large ponds have been constructed in the area and filled with saline groundwater and treated wastewater. All that remains of the freshwater Lake Xochimilco is a tangle of channels — the Mexican Venice, surrounded by agricultural areas and fed by treated wastewater. Lake Mexico, where the Aztecs founded Tenochtitlan, is now completely dried out and covered by Mexico City.

Water was profitable to the native Indians. They obtained food, water supply, transportation and raw materials (Alcocer-Durand & Escobar-Briones 1991; Alcocer & Escobar 1992a). The Mexico basin probably had the largest established population in the ancient world that was not mainly based on cultivating the soil. Instead, much of the food supply of the Indians came from the lakes: fish, waterfowl, turtles, frogs, salamanders, small crustaceans, molluscs, algae, aquatic plants, aquatic insects (eggs, larvae, pupae and adults), and salt extraction.

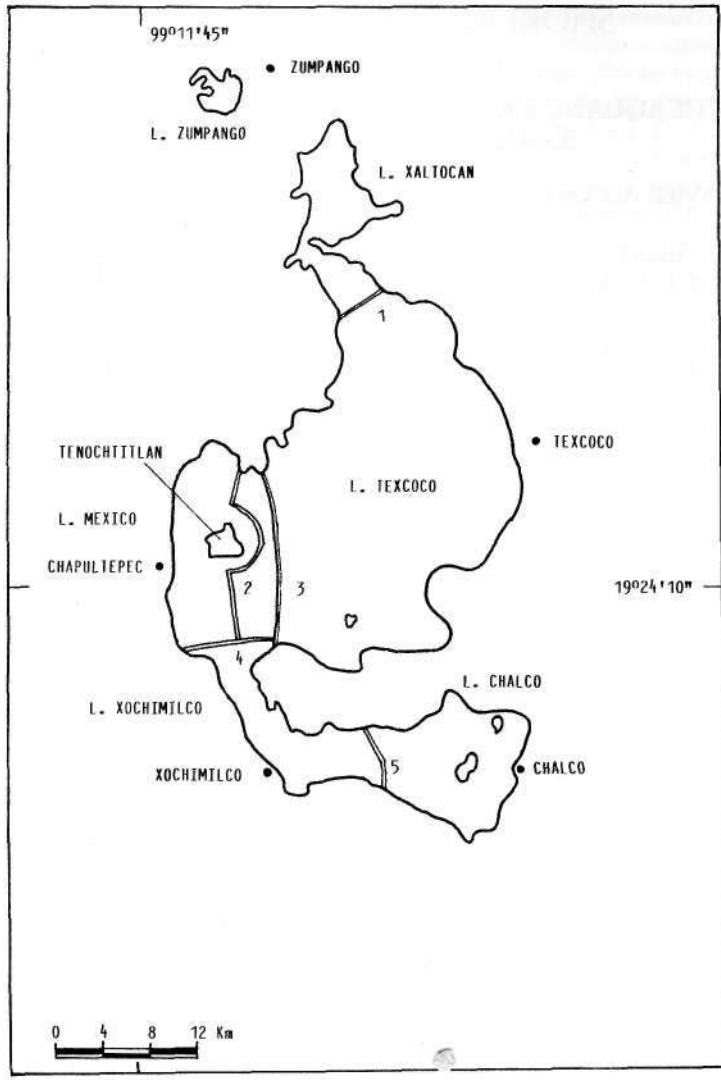

FIG. 1. The Mexico Basin lacustrine complex in 1519, showing the main hydraulic works constructed by the aztecs. (1) Dike between Lake Xaltocan and Lake Texcoco; (2) San Lázaro Albarradón; (3) Nezahualcóyotl Albarradón; (4) Mexicaltzingo Dike, which separated Lake Mexico from Lake Xochimilco; (5) Cuitláhuac Dike, which separated Lake Xochimilco from Lake Chalco. (Modified from Gurría 1978).

Brief hydraulic history of the Mexico basin

Control of fluctuating water levels by the inhabitants, through hydraulic works, acquired great importance. An example of this work was the building of the-Albarradon of Nezahualcoyotl in the 15th century. This 16 km long and 20 m wide wall or dike was constructed with stones and clay, covered by a palisade (Garcfa & Romero 1978). The dike divided the saline water of Lake Texcoco from the less saline waters of Lake Mexico, and prevented flooding in the city of Tenochtitlan, which had occurred in 1449 during the reign of Moctezuma Ilhuicamina (Bribiesca 1958a; Gurria 1978).

With the arrival and invasion by the Spanish conquerors in 1519, many of these dikes were destroyed. Afterwards, the growth of the city and the new Spanish way of life (e.g. horse and carriage transportation instead of canoes) changed the lakes from being a natural advantage into a problem, mainly due to floods which sometimes lasted for several years; the most famous of these floods occurred in 1555, 1579-80, 1604 and 1629 to 1635. Although several hydraulic works were constructed in the colonial epoch (Bribiesca 1958b), in the 17th century it was decided to eliminate the great enemy of the city, the lake complex.

It took four centuries and huge hydraulic works to finish the enterprise of drying up the lakes by constructing artificial drainage out of the north-west end of the basin. The first of five openings was the Tajo de Nochistongo (Nochistongo Cut), started in Huehuetoca in 1607; its construction lasted for twenty-five years (Currfa 1978). The Tajo de Nochistongo was not large enough to drain the basin, so in 1884 the Tunel de Tequixquiac (Tequixquiac Tunnel) was constructed to help in solving the problem (Currfa 1978). Nevertheless, more work was inaugurated in 1900, the Gran Canal del Desague (Great Drainage Channel) (Lemoine 1978). It was not until the second half of the 20th century (1976) that the enterprise was finished with the construction of a second Tunel de Tequixquiac and, finally, the Sistema de Drenaje Profundo (Deep Drainage System).

It is contradictory that while much money and a large workforce were invested in draining the Mexico basin, an equivalent effort has also been applied to obtain a water supply for the expanding city by extracting groundwater and by pumping water into the city from long distances outside the basin. Today, water scarcity is a real problem for Mexico City.

Chapultepec forest and the Lago Viejo

Before the natural hydrographic system of the Mexico basin was abruptly altered, the lakes were inhabited by many plants and animals, some of which are mentioned in the ancient nahuatl codexes (Alcocer-Durand &

Escobar-Briones 1991) and colonial manuscripts. Examples of these organisms are the tecuitlatl *(Spirulina),* the amoyotl (ephydrid insects, Diptera), and the canauhtli (waterfowl) (Alcocer & Escobar 1992b). When the lakes were drained, this great diversity of aquatic biota also disappeared.

Amazingly, however, we have found several typical organisms of the ancient lake complex inhabiting the Lago Viejo de Chapultepec (Old Lake of Chapultepec) (Alcocer et al. 1992a). It is probable that the proximity of Chapultepec to Lake Mexico, and the existence of springs in the area (e.g. Moctezuma Baths) which are now dried up, had favoured the persistence of these organisms.

Chapultepec is an urban forest located in the west-southwest portion of Mexico City (19°24' to 19°26' N and 99°11' to 99°13' W) at 2240 metres above sea level (Molina-Enrfquez 1979). The climate is temperate with a summer rainy season; mean annual precipitation is 672 mm, evaporation rate fluctuates between 965 and 1910 mm, and the mean temperature is 14°C (Jauregui 1975; Garcia 1988).

Table 1. Physical and chemical characteristics of the Lago Viejo in Chapultepec forest, Mexico.

Variable	*Mean*	*SD*
Temperature (°C)	16.9	2.4
pH	10.0	3.9
Dissolved oxygen (mg l^{-1})	9.8	4.1
Conductivity (µS cm^{-1})	214	53
Alkalinity (mg l^{-1})	90.9	23.2
Hardness (mg l^{-1})	80.9	31.3
Chloride (mg l^{-1})	8.0	3.3
Sulphate (mg l^{-1})	12.2	0.5
Total phosphorus (mg l^{-1})	2.2	0.5
Total nitrogen (mg l^{-1})	4.4	3.7
Suspended solids (mg l^{-1})	98.3	56.5
Chlorophyll-*a* (mg m^{-3})	457	187
BOD_5 (mg l^{-1})	19	6
COD (mg l^{-1})	92	36

The Lago Viejo is located in the oldest part of the Chapultepec forest. Its total surface area is 60,240 m^2, maximum length from north to south is 432 m, maximum width from east to west is 208 m and the shoreline measures 1,883 m. The basin holds 49,525 m^3 fresh water with a mean depth of 1 m and a maximum depth of 1.8 m (Alcocer et al. 1988).

Nutrient-rich secondary-treated wastewater and the waters of the Rio

Hondo feed the very shallow Lago Viejo. Consequently it is in an advanced state of eutrophication. Before treated wastewater was used to feed the lake (i.e. before 1956), water pollution had already been noticed due to the poor water-quality of the Rio Hondo (Anonymous 1935-36). According to Alcocer et al. (1992c) the Lago Viejo softwater characteristics are: poorly buffered, with relatively low alkalinity and high pH, high nutrient and chlorophyll-a concentrations, low organic matter content, great quantities of suspended solids, and high turbidity (Table 1). When comparing our temperature and pH data with those of Lopez-Ochoterena (1965), it appears that the lake was about 2°C warmer (19 ± 2.4) and slightly acid (pH 6.8 ± 0.2).

The aquatic biota of the Mexico lake complex — past and present

In the remainder of this article we would like to mention the commonest organisms of the original Mexico lake complex, including those that exist today in the Lago Viejo (Table 2), (Alcocer & Escobar 1992b; Alcocer et al. 1992a, b).

Table 2. Common organisms inhabiting the Lago Viejo of Chapultepec.

Family	*Species*
Amphibia	
Ambystomidae	*Ambystoma mexicanum* (Shaw)
Fish	
Atherinidae	*Chirostoma jordani jordani* Woolman
Goodeidae	*Girardinichthys viviparus* (Bustamante)
Invertebrates	
Cambaridae	*Cambarellus montezumae* (Saussure)
Talitridae	*Hyallela azteca* (Saussure)
Haemopidae	*Percymoorensis caballeroi* Richardson
Glossiphoniidae	*Helobdella* Blanchard
Erpobdellidae	*Mooreobdella microstoma* (Moore)
Pionidae	*Piona* (*Dispersipiona*) Viets
Physidae	*Physa* (Draparnaud)
Planorbidae	*Planorbella (Piersoma) tenuis* (Dunker)
Tubificidae	*Limnodrilus hoffmeisteri* Claparede
	Branchiura sowerbyi Beddard
Chironomidae	*Chironomus* Meigen
	Tanypus Meigen
Culicidae	*Chaoborus* Lichtenstein
Corixidae	*Corisella edulis* (Champion)
	Trichocorixella mexicana (Hungerford)
	Krizousacorixa femorata (Guérin)

Fishes

The Valley of Mexico contained three families of fish: Atherinidae, Goodeidae and Cyprinidae. The common species are listed in Table 3, modified from Martfn del Campo (1955), Alvarez & Navarro (1957), Alvarez (1970) and Rojas & Perez (1985).

The most appreciated fishes were the iztacmichin or white fishes (iztac = white, michin = fish), belonging to the family Atherinidae. According to body size they were called amilotl (the largest), xalmichin or sandy fish, and iztacmichin (the smallest). The yecapitzahuac or thin nose was also a silverside fish. Probably the largest fish or amilotl was *Chirostoma humboldtianum.* The xalmichin and the charal (iztacmichin) were either juveniles of *C. humboldtianum* or specimens of *C. regani* and *C. jordani* respectively. The yecapitzahuac have been associated with the last species.

The eggs of the silversides were called michpiltetei, especially the largest amilotl eggs (amilotetl), and were consumed along with the juveniles (michpilli). Silversides are so important in Mexican gastronomy that cookery books still contain recipes such as "fish tamales", "whitefish from Patzcuaro" and "whitefish with charal sauce" (Quintana 1986; Stoopen 1988).

Table 3. Common species of fish known to have existed in the ancient lake complex of the Mexico basin.

Family	*Species*
Atherinidae	*Chirostoma humboldtianum* (Cur. & Valenc.)
	Chirostoma jordani jordani Woolman
	Chirostoma regani Jordan & Hubbs
Goodeidae	*Girardinichthys viviparus* (Bustamante)
Cyprinidae	*Algansea tincella* (Cur. & Valenc.)
	Notropis aztecus (Woolman)
	Evarra eigenmanni (Woolman)
	Evarra tlahuacensis Meek
	Evarra bustamantei Navarro

The most abundant fishes in the Mexico basin lakes were the cuitlapetotl, surely the goodeid *Girardinichthys viviparus,* a species described by Bustamante (1837) and called mexclapique. In the same manuscript, Bustamante mentions the Indian denomination of yecapitzahuac or istacmichin for a tiny viviparous fish very similar to *G. viviparus,* although he explains that istacmichin could belong to another species. As mentioned above, both this and yecapitzahuac were used to

describe atherinids.

The xohuilin belonged to the family Cyprinidae. Two forms were recognized: the typical form and the black xohuilin or yayauhqui. The typical form was classified by size into xohuilin (the largest), tlacoxohuilin, and tepitonxohuilin (the smallest).

Most of the places from which these fish species were known are now dry, but the Lago Viejo still contains two species: the goodeid *G viviparus* and the atherinid *C. jordani.* The latter was described by Woolman (1894) from Chapultepec specimens, so the Lago Viejo is the type locality for *C. jordani.*

Amphibians and reptiles

The best-known amphibian of the Mexico basin is the famous axolotl (atl = water, xolotl = monster) or axoqui, the ambystomid salamander *Ambystoma mexicanum,* which is neotenous: the giant aquatic larva becomes sexually mature instead of metamorphosing into an air-breathing adult salamander. The axolotl was first described by Francisco Ximenez in 1615 (Alcocer-Durand & Escobar-Briones 1991). It was appreciated for its white meat and delicate flavour, and was also used as a medicine for respiratory diseases. Other species included under the same name were probably *A. tigrinum, A. lacustris, A. carolinae* and *Bathysiredon dumerilii.*

Frogs, e.g. *Rana esculenta, R. temporaria, R. pipiens, R. montezumae,* and probably *Bufo* and *Hyla,* were called cueyatl, zoquicueyatl, tecalatl and acacueyatl. Some were edible and much liked. Tadpoles (atepocatl) were also eaten by the Indians (Rojas & Perez 1985).

Water snakes, aneneztli or acohuatl (some species of *Tamnophis)* and turtles (probably belonging to the genera *Kinosternon* and *Pseudemys)* were also common inhabitants of the lakes, and a food source (Martfn del Campo 1979).

Ambystoma mexicanum is the only amphibian now living in the Lago Viejo. There used to be frogs, water snakes and turtles in the lake for the first third of this century, but then the shoreline was remodelled and vegetation was removed.

Crustaceans

In the Mexico basin there is a great variety of crayfishes, with endemic species in many of the reservoirs. The nahuatl names (acocili, acuitzil or acocillin) correspond to *Cambarellus montezumae,* a species described by Saussure (1857) with specimens collected from Chapultepec. The Lago Viejo is therefore the type locality for this widespread crayfish.

Several species of freshwater shrimps or prawns, *Macrobrachium* (chacalli, tepechacalli, achacalli) lived in the Mexico basin but not in Chapultepec. Shrimps and crayfish, as well as whitefish, have an important role in modern recipes of Mexican cuisine (Quintana 1986).

Molluscs

Although we have not found freshwater clams in the Lago Viejo they were once common in the Valley of Mexico. Among them (Contreras 1930) were *Anodonta impura, Sphaerium subtransversum* and *Valvata humeralis.* Rojas & Perez (1985) mentioned a freshwater clam about 5 cm in length (probably *A. impura)* which was eaten in the area of Lake Xochimiico.

Shells of *Physa* and *Planorbella* have been found, indicating that these snails once inhabited the Lago Viejo. The species could be similar to those reported for Lake Xochimiico (Contreras 1930) as *Physa osculans* and *Planorbis (Helisoma) tenuis* (= *Planorbella (Piersoma) tenuis).* Other species found in Lake Xochimiico by the same author are *Limnaea attenuata* and *Succinea campestris.*

Aquatic Insects

The larvae (aneneztli) of dragonflies and damselflies (Odonata) were abundant in the Mexico basin lakes. The larvae live amongst aquatic vegetation, and since this was removed from the Lago Viejo in 1965, Odonata have not been found there.

Lake Texcoco was famous for the saline shore-fly, *Ephydra hians* (Diptera). Although it is abundant in the remnants of the saline waters of Lake Texcoco it does not occur in the fresh water of the Lago Viejo. Since prehispanic times, native Indians used to consume the shore-fly in three of its life-stages: larvae (izcahuitl or lacustrine "worm"), pupae (puxi or poxi) and adult (amoyotl, moyotl, muyutl).

Doubtless the most famous Mexican aquatic insect group is the Corixidae (Hemiptera Heteroptera) or axayacatl. Five species have been reported from Chapultepec by Hungerford (1948) and Jackzewski (1931): *Graptocorixa gerhardi, Krizousacorixa azteca, K. femorata, Trichocorixella mexicana* and *Corisella edulis.* The last three species have been found recently in the Lago Viejo, but the first two have not.

The empty egg-shells (ahuautli) of corixids have been eaten since ancient times and much appreciated for their delicate seafood flavour. A typical Mexican Holy Week dish (romeritos or revoltijo) was prepared with ahuautli; nowadays dry shrimp powder is used as a substitute. Adult corixids or axayacatl are also caught for feeding domestic fowl.

Krizousacorixa azteca, K. femorata and *T. mexicana* were respectively described by Jackzewski (1931), Guerin-Meneville (1857) and Hungerford (1927) with specimens caught from Chapultepec (see Hungerford 1948). Thus the Lago Viejo is the type locality for these three species.

The ancient chronicles also mention the ocuiliztac (a black aquatic "worm", probably a corixid larva), the atetepiz (a water beetle), the ahuihuitla (referred to as a "worm" or insect), and the chilton. This is a tiny blackfly or midge which used to form immense swarms and, when they died, collected in great quantities on the water surface.

Aquatic vegetation

A diverse array of aquatic macrophytes occurred in Chapultepec (Table 4). However, this vegetation was destroyed when the shoreline of the Lago Viejo was remodelled and the earthy substratum was covered with cement in 1965. Subsequently a number of aquatic organisms have disappeared: frogs, tadpoles, water snakes, molluscs and diverse insects.

Table 4. Aquatic plants that formerly existed in the Lago Viejo of Chapultepec. (Modified from Rodríguez 1944).

Family	*Species*
Salviniaceae	*Azolla caroliniana* Willd.
Typhaceae	*Typha angustifolia* L.
Potamogetonaceae	*Potamogeton pectinatus* L.
Hydrocharitaceae	*Hydromystria laevigata* (Willd.) Hunziker
Cyperaceae	*Cyperus niger* Ruiz & Pavón
	Cyperus pycnostrachyus (HBK.) Kunth
	Cyperus rosei Britton
	Cyperus spectabilis Link
Lemnaceae	*Lemna minima* Philippi
	Lemna gibba L.
	Lemna minor L.
	Lemna trisulca L.
	Wolffia columbiana Karst.
Pontederiaceae	*Eichhornia crassipes* (Mart.) Solms.
Juncaceae	*Juncus arcticus* var. *mexicanus* (Willd.)
Nymphaeaceae	*Nymphaea alba* L.
Ceratophyllaceae	*Ceratophyllyum demersum* L.
Halorrhagidaceae	*Myriophyllum hippuroides* Nutt.

Table 5. List of algae reported from the Lago Viejo of Chapultepec by Samano (1934, 1935, 1940) and Rodrfguez (1944). Each alga is prefaced by its recent status in the lake (+, found recently; -, not found recently; ?, not sure about the species), as reported by Dr G. Vilaclara (pers. comm.).

Recent status	*Species*
+	*Micractinium pusillum* Fresenius
?	*Lagerheimia droescheri* (Lemmerman) Printz.
–	*Actinastrum gracillimum* G. M. Smith
?	*Selenastrum gracile* Reinsch.
?	*Selenastrum westii* Sámano
?	*Kirchneriella lunaris* (Kirchner) Moebius
+	*Kirchneriella obesa* (W. Sest) Schmidle
–	*Chlorobotrys limneticus* G. M. Smith
–	*Closterium jenneri* Ralfs.
–	*Closterium parvulum* Nag.
–	*Closterium leibleinii* Kutz
–	*Closterium moniliferum Ehrenberg*
–	*Closterium acerosum* (Schrank) Ehrenberg
–	*Closterium gracile* De Brébisson
–	*Closterium aciculare* T. West
–	*Closterium lineatum* Ehrenberg
–	*Closterium acutum* (Lyngb) De Brébisson
–	*Closterium malinvernianum* De Not.
–	*Pleurotaenium ehrenbergii* (De Brébisson) De Barry
–	*Pleurotaenium trabecula* (Ehrenberg) Naegekli
–	*Staurastrum paradoxum* var. *parvum* W. West
–	*Golenkinia paucispina* W. & G. S. West
+	*Pediastrum duplex* var. *clathratum* (A. Brawn) Lagerh
–	*Pediastrum simplex* var. *duodenarium* (Bailey) Raben
+	*Coelastrum microporum* Nageli
–	*Coelastrum reticulatum* (Dangeard) Senn.
+	*Scenedesmus acuminatus* (Lagerheim Chodat)
+	*Scenedesmus quadricauda* var. *longispina* G. M. Smi
?	*Scenedesmus abundans* var. *longicauda* G. M. Smith
+	*Scenedesmus opoliensis* R. Richter
–	*Spirogyra tenuissima* (Hassall) Ktz.
–	*Spirogyra inflata* (Vaucher) Rab.
–	*Spirogyra flavescens* (Hass.) Kützing
–	*Spirogyra communis* (Hassall) Ktz.
–	*Sirogonium sticticum* Ktz.
?	*Euglena sanguinea* Ehrenberg
–	*Euglena polymorpha* Dangeard
–	*Euglena acus* Ehrenberg
–	*Phacus pleuroctes* (O. F. Muelier)

A thick scum of the blue-green alga *Spirulina geitleri* (tecuitlatl, acuitlatl or azoquitl), used to be harvested and eaten by local people, mainly in the alkaline soda-lake Texcoco. Ortega (1972) includes tecuitlatl in her study of edible algae of the Valley of Mexico, but does not mention to which species it could correspond. Later (Ortega 1984) she establishes that tecuitlatl was probably composed of *Phormidium tenue.* Other algae included in the Aztec gastronomy were the "water jelly", amoxtle or amomoxtli *(Nostoc commune),* and the "water viscosity" or cuculin *(Phormidium tenue; Chroococcus turgidis).*

Massive growths of *Spirulina,* requiring a high pH and salinity, have not been recorded from the Lago Viejo, but other species occur there, especially the blue-green algae *Microcystis aeruginosa, Anabaena elenkinii* and *Oscillatoria rubescens* (Alcocer et al. 1988). Although common now, these species were not formerly recorded from the lake (Table 5). Additional records are given by Rodrfguez (1944) for *Mougeotia, Zygnema, Oedogonium, Cladophora* and *Pitophora.* Although they were identified by Samano, these taxa are not listed in the papers published by Samano in 1934, 1935 and 1940.

Acknowledgements

The authors would like to thank Dr C. Vilaclara for checking the list of algae found in the Lago Viejo of Chapultepec (Table 5) and adding her own observations. This research was partially supported by a SECEP-UNAM grant to J. Alcocer.

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