Ancient Mesoamerica, **11** (2000), 27–38
Copyright © 2000 Cambridge University Press. Printed in the U.S.A.

CLIMATIC CHANGE AND LACUSTRINE RESOURCES AT THE PERIOD OF INITIAL AZTEC DEVELOPMENT

Thomas E. Berres
Department of Anthropology, Northern Illinois University, DeKalb, IL 60115, USA

Abstract

Explanations for the emergence of the Aztec state need to consider changes in the climate and the potential effects resulting from these changes on the productivity of the lake network in the Valley of Mexico. Change in the human ecosystem is a complex process of interactions between multiple cultural variables and the environment. In this study, I examine the nature of three primary resources, fish, salt, and waterfowl, available for Early Aztec–period exploitation within the valley lake system. The intensification of lacustrine resource exploitation appears to be correlated with changing climatic conditions that occurred about A.D. 1150. Although the focus of this study is be on the cause-and-effect relationship between culture and environment, it is acknowledged that the environment is just one factor that must be considered to fully understand initial Aztec development.

Global climatic fluctuation and change have affected the whole geographic space and history of human lives, the abiotic and biotic components, and their interrelationships (see Goudie 1992; Jones et al. 1999; Lamb 1995; Mooney et al. 1993; Wendland and Bryson 1974). Climatic changes documented throughout the late Holocene were important influences affecting vegetation, and thus they were critical determinants of animal biogeography and human adaptation. There is growing scientific evidence that such changes were often abrupt and caused by changes in air mass locations and frequencies (Fischman 1996; Wendland and Bryson 1974). In the Valley of Mexico, climatic changes would have altered the distribution, abundance, and composition of biotic communities associated with the lake system. This paper focuses on the terminal Mazapan–Early Aztec transition (ca. A.D. 1150–1200), a time of cool, dry conditions (Messenger 1990:31) that caused a significant drop in lake levels (Armillas 1971). My objective is to identify and describe the various bony fish and waterfowl species inhabiting the Valley of Mexico lake habitats. I then provide insights on how changes in climate and lower lake levels could have increased populations of bony fish and waterfowl and show how the Early Aztec inhabitants could have favorably exploited this highly productive environment by preserving meats through salting and efficiently capturing animals by using seine-nets.

The Aztec empire was centered in the Valley of Mexico, a plain measuring 130 km north–south by 60 km east–west (7,800 km^2). The valley is a large internal hydrographic basin bounded on three sides by high volcanic mountain ranges: to the east is the Sierra de Nevada, to the west is the Sierra de Las Cruces, and to the south is the Sierra del Ajusco. Forming the northern boundary is a series of low, discontinuous hill ranges that separate the Valley of Mexico from the more arid Mezquital drainage in Hidalgo. The valley floor lies at slightly less than 2240 m above sea level (m asl), and the rugged volcanic mountain elevations exceed 5000 m asl in the southeast. Meltwater from the two main volcanoes, Popocatepetl and Ixtaccihuatl, springs from porous volcanic materials, and runoff from the summer rains flow toward the center of the valley, which at the time of the Spanish Conquest formed a large, continuous, shallow lake system about 1000 km^2 in extent (Bradbury 1971; Parsons et al. 1982:6; Sanders et al. 1979).

The Valley of Mexico usually experiences cold, relatively dry winters and warm, wet summers, although extreme variation in precipitation and temperature may occur on a seasonal basis. Precipitation is localized and monsoonal. As part of the highland climatic region (McGregor and Nieuwolt 1998:252, 254), mean annual precipitation generally increases from north to south and from lower to higher altitudes. The drier northern third of the basin receives an annual precipitation low between 500 and 600 mm, whereas the southern edge of the basin at an elevation of 2500 m asl receives more than 1000 mm. Precipitation usually is erratic and variable both in time and space within a locality. The rainy season generally occurs between May and October (providing 80 to 94% of annual rainfall). In some years, however, it may be delayed until mid-June and mid-summer droughts can also occur. The temperature of the valley is inversely correlated with altitude: elevations below 2800 m asl have a mean annual temperature between 12 and 18°C; elevations between 2800 and 4000 m asl have a mean annual temperature between 5 and 12°C; and elevations above 4000 m asl have a mean annual temperature below 0°C. Of particular importance to the Early Aztecs (and other populations) were the onset and cessation of frosts in the spring and fall. The unpredictability of frosts is of major significance for agricultural productivity (Parsons et al. 1982; Sanders et al. 1979; Vivo Escoto 1964).

At the time of the Spanish Conquest, the basin floor consisted of a chain of five large lakes that extended across nearly its entire length from north to south: Xaltocan and Zumpango in the north, Lake Texcoco in the center, and lakes Chalco and Xochimilco in

https://doi.org/10.1017/S0956536100111101 Published online by Cambridge University Press

the south (Figure 1). The northern chain of lakes was saline, whereas the southern two were freshwater lakes. All were shallow, ranging in depth from 1 to 3 m, and throughout a portion of the year consisted of a series of interconnected ponds. Lake Texcoco represented the largest and lowest lake (approximately 2235 m asl) (Parsons et al. 1982; Tamayo and West 1964:111), thus it received the overflow from the other lakes. It was extremely saline because of evaporation and the inflow of saline waters from thermal springs (Bradbury 1971:181). Lakes Chalco and Xochimilco were fresh because they were fed by numerous springs along the southern shore. The lake network provided an important means of transportation and communication, and it offered a variety of important resources (Figure 2) (Sanders et al. 1979; Sanders 1981). Probably the most significant resources were fish, salt, and waterfowl, along with horticultural produce harvested from the *chinampas* in the Xochimilco–Chalco lake basin (Armillas 1971; Brumfiel 1991; Parsons 1991).

The intensive and efficient exploitation of the lake system resources by the Early Aztec inhabitants may have been dependent on climatic changes that lowered the water table during the interval A.D. 1150 to 1200–1250. Wendland and Bryson (1974) provided evidence of significant globally synchronous discontinuities in the botanic record that is correlated with cultural change through time. They contend that the Neo–Atlantic/Pacific transitional episode of A.D. 1100 to 1120 brought about distinct changes in the

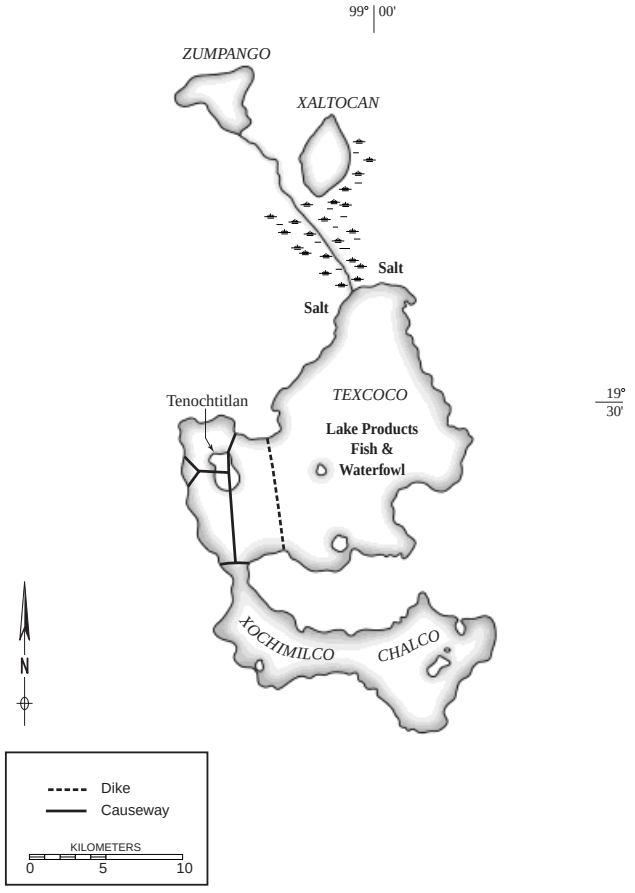


Figure 1. The lakes in the Valley of Mexico in Aztec times (after Armillas 1971:Figure 1).

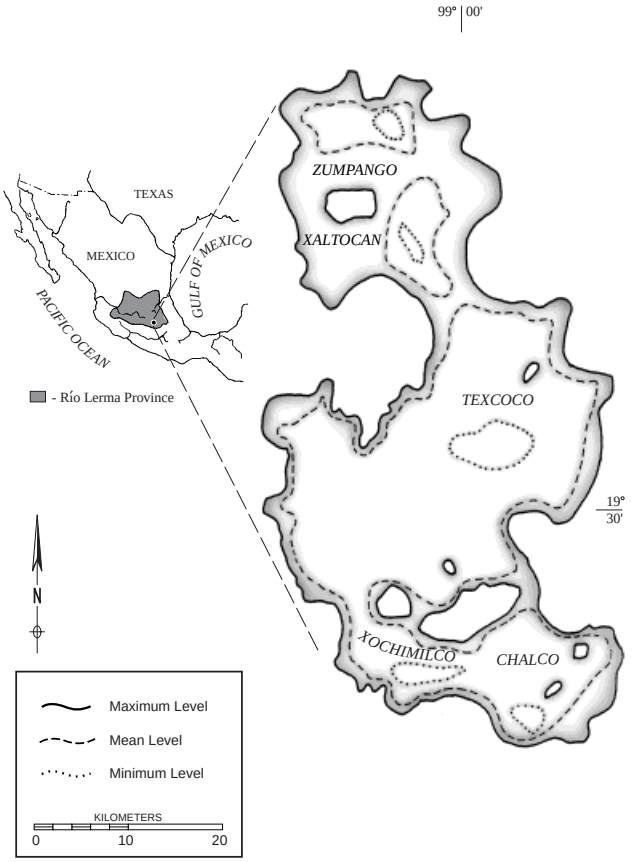


Figure 2. Valley of Mexico lakes and the Río Lerma fish province (after Bradbury 1971:Figure 1; Miller and Smith 1986:Figure 6).

subsistence strategies of the Mill Creek culture of northwestern Iowa that can be related to other cultures throughout the world. The changes in precipitation and temperature were probably abrupt and caused by changes in global wind circulation as a result of a long period of marked glacial contraction (Goudie 1992:163). Cooler, drier conditions that apparently characterized the Valley of Mexico (Messenger 1990:33) parallel periods of drought documented in the Midwestern and Western regions of the United States (Goudie 1992:165; Jones et al. 1999). Current evidence indicating a correlation between drought conditions and Aztec development, however, has not proven causation.

There are several lines of evidence suggesting that climatic change impacted lake levels and human adaptation in the Valley of Mexico. Sanders et al. (1979:192) have proposed that the settlement pattern data during the Second Intermediate Phase One (A.D. 700–950) indicates a heavy focus on lacustrine locales, which was followed during the Second Intermediate Phase Two (A.D. 950–1150) by a population shift to higher elevations. During the Second Intermediate Phase Three (A.D. 1150–1350), there was a subsequent return to lacustrine locations. Armillas (1971), citing findings from survey and excavations in the Xochimilco–Chalco basin, related changes in the *chinampa* system as evidence for a drop in the lake level about A.D. 1200. Parsons et al. (1982) and Parsons (1991:Table 1.2) have shown that dramatic demographic changes occurred in the Xochimilco–Chalco basin during the Middle Postclassic period (A.D. 1150–1400), along with a fivefold pop-

https://doi.org/10.1017/S0956536100111101 Published online by Cambridge University Press

ulation increase that clustered in the lakeshore–lakebed zone. Both the ability to construct the *chinampa* system and the increased human population could denote a dramatic increase in the carrying capacity of the lake system caused by lowering the water table. Sociopolitical developments, however, may also be considered a causal variable (Parsons 1991:31, 1996:442). Perhaps the most compelling evidence indicating lower lake levels during the Early to Late Aztec periods (A.D. 1200–1500) comes from geomorphological data obtained in the Chalco Valley. This evidence led Parsons et al. (1996:227) to propose that earlier "[r]ising lake levels in Late Toltec times may have inhibited consistent, heavy occupation of Mound 65, constructed on the Coyotlatelco-period lakeshore." The only other evidence of climatic change is derived from Aztec legends of Huemac and Quetzalcoatl (a fertility deity associated with the rainy season), which involved their exile from Tula and subsequent droughts terminating the Tula empire and rise of the Aztec (Gillespie 1989:151). The section below focuses on the identification and description of fishes within the Valley of Mexico, and their potential as an economic source.

FISHES

The classified fishes of the Valley of Mexico are within the Río Lerma Province of the Nearctic region (Meek 1904; Regan 1906–1908; Stuart 1964:359–360). This province consists of the Río Lerma plateau and its associated lakes and tributaries as well as several headwaters of the Río Panuco. The Río Lerma is bounded by the Balsas Province to the south, the Río Grande Province to the north, the Veracruz Province to the east, and the Sinaloan system to the west (Figure 2). The Lerma system supports a large number and diversity of fishes consisting of 43 species divided into 20 genera and 7 families, with the family Cyprinidae (Minnows) predominant. Poeciliidae, Goodeidae, and Atherinidae families are also common and diverse within this system. Noticeably absent are the family Cichlidae (spiny-rayed fishes exemplified by perch), which are abundant in Central and South American waters (Nelson 1976:249–250), and the characin genus *Astyanax* (Stuart 1964).

Meek (1903, 1904) separated the Valley of Mexico from the Río Lerma drainage basin primarily on present hydrographic conditions. The similarities in fish faunas and the general topography, however, indicate that in the distant geological past (e.g., late Pleistocene) the Valley of Mexico may actually have been part of this drainage system (Barbour 1973a:539, 544; Meek 1903:782, 1904:xli; Tamayo and West 1964:109). Volcanism, urbanization, and changes in climate have dramatically altered the hydrology. In this study, I recognize this separation and restrict my focus to only those species identified in the Valley of Mexico. Early studies by Jordan and Evermann (1896–1900), Meek (1903, 1904), and Regan (1906–1908) provide information on the types of species inhabiting the Valley of Mexico during the 1800s and early 1900s, which can be used as estimates of those present during Aztec times.

At least three orders of bony fishes (Osteichthyes) once inhabited the lakes, including Cypriniformes (minnows), Cyprinodontiformes (killifishes, topminnows, and relatives), and Atheriniformes (silversides, priapiumfishes, and relatives). It is estimated that 12 species divided among 8 genera and 4 families comprise these orders. A list of fishes identified within the Basin of Mexico lakes is provided in Table 1, and illustrations of these fishes from Niederberger (1987), Jordan and Evermann (1896–1900), and Meek (1904) are provided in Figures 3, 4, and 5.

Table 1. Fishes of the Valley of Mexico

Class Osteichthyes: bony fishes
- Order Cypriniformes: minnows, carps, roaches, suckers, and allied forms
  - Family Cyprinidae: minnows
    - *Algansea tincella* Cuvier & Valenciennes (Chalco, Texcoco, Viga Canal)
    - *Evarra bustamantei* (Valley of Mexico)
    - *Evarra eigenmanni* Woolman (Valley of Mexico)
    - *Evarra tlahuacensis* Meek (Valley of Mexico)
    - *Notropis sallei* Gunther (= *Aztecula vittata* Girard): Aztec Shiner (Chalco; Texcoco; Xochimilco; Viga Canal; upper tributaries of Río Lerma, Río Balsas, and Río Panuco)
- Order Cyprinodontiformes: killifishes, topminnows or toothcarps, and relatives
  - Family Goodeidae: springfishes and poolfishes
    - *Girardinichthys viviparus* Bustamente (= *G. inominatus* Bleeker) (Chalco, Texcoco, Xochimilco, Viga Canal)
    - *Skiffia variegata* Meek (= *S. lermae* Meek) (Chalco)
- Order Atheriniformes: silversides, priapiumfishes, and relatives
  - Family Atherinidae: silversides
    - *Chirostoma jordani* Woolman (Chalco, Texcoco, Xochimilco, Viga Canal)
    - *Chirostoma humboldtianum* Cuvier & Valenciennes (Chalco, Xochimilco, Viga Canal)
    - *Chirostoma estor estor* Jordan (Xochimilco)

Order Cypriniformes

This order consists of minnows, carps, roaches, suckers, and allied forms that dominate the freshwater environments of North America and Eurasia and, to a lesser extent, Africa (Bond 1996; Mayden 1991; Moyle and Cech 1996; Myers 1966; Winfield and Nelson 1991). The nearly 2700 species in the order are the principal forage fishes on which large predators feed. Although they are diverse in their external appearances, most possess protractile mouths without teeth and specialized pharyngeal (throat) teeth. They are also characterized by the presence of a Weberian apparatus (a chain of small bones that connects the swimbladder to the inner ear) that gives the fishes a sensitive sound-reception system particularly useful in turbid waters or at night (Knapp 1953:42; Moyle and Cech 1996; Wheeler and Jones 1989:18). Their small sizes (50 to 80 mm standard length for adults) appear to be advantageous for the occupation of the numerous microhabitats in fresh water (e.g., among the aquatic vegetation in lakes), ability to reach maturity quickly resulting in high reproductive rates that can produce rapid population expansion under favorable conditions, and feeding on small invertebrates (Moyle and Cech 1996:254). The cypriniforms are of great importance, both ecologically and economically.

The family Cyprinidae (minnows) is the largest family of freshwater teleost fishes, with about 286 recent species in 53 genera inhabiting North America from the Arctic to Guatemala (Bond 1996:150; Mayden 1991; Moyle and Cech 1996:255). In Mexico, there are about 66 species in 16 genera, with the genus *Notropis* containing the most species (Miller 1982:490). They are distinguished from other members of the suborder by soft fin rays, thin lips (upper jaw usually bordered only by the premaxilla), abdom-

https://doi.org/10.1017/S0956536100111101 Published online by Cambridge University Press

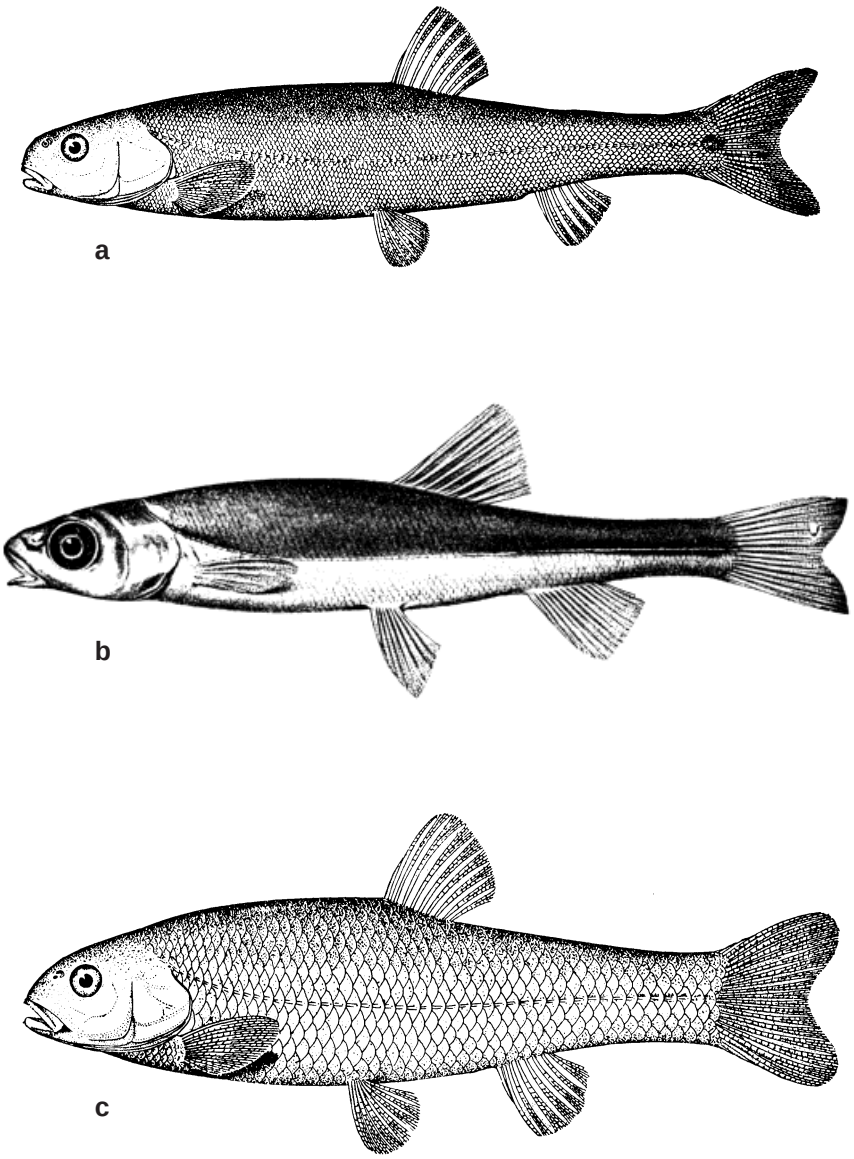


Figure 3. Representatives of the genus *Evarra*—(a) *E. eigenmanni*, (b) *E. tlahuacensis*—and the genus *Notropis*—(c) *N. sallei* (from Meek 1904).

inal pelvic fins, forked or notched tail fins, and uniquely toothed pharyngeal arches (one to three rows, but never more than eight teeth per row), which grind food against a horny pad on the basioccipital bone. Cyprinids are valuable because some feed on aquatic insects, like mosquitoes, whereas others provide ecological indicators of water quality (Knapp 1953; Smith 1979). They also have been used as bait for fishing and for farming and forage.

The Central Plateau of Mexico is characterized by four endemic genera: *Algansea*, *Evarra*, *Notropis*, and *Yuriria* (Mayden 1991:246; Miller and Smith 1986:501). Three species in the cyprinid genus *Evarra* were once present in the lakes of the Valley of Mexico but are now extinct (*E. bustamantei*, *E. eigenmanni*, and *E. tlahuacensis*) (Miller and Smith 1986). The Aztec shiner, *Notropis sallei* (Gunther), is restricted to the Río Lerma system. Chernoff and Miller (1981) noted that this species has had a confused taxonomic history, with assignment to no fewer than 8 genera, 7 species, and 16 nominal taxa. It is distinguished from other species of *Notropis* by small scales (39–64 in lateral line), small fins, short head with blunt snout, and urohyals (bones of the outer bronchial skeleton) that exhibit ventral surfaces with lateral projections joining the ventral midline to form V-shaped notches.

Order Cyprinodontiformes (Microcyprini)

This order comprises killifishes, topminnows, and relatives widely distributed throughout the tropical and temperate world. They are small (<15 cm) and often chunky omnivores, ideal for living in shallow, isolated habitats. The fishes are distinguished by a single dorsal fin, absence of spines, and abdominal fins restricted to seven or fewer rays. Cyprinodontiform fishes are very hardy and versatile, capable of tolerating very high temperatures, depletion of dissolved oxygen, and radical changes in water salinity (Knapp 1953:85; Moyle and Cech 1996:293–294). The family Goodeidae is the only one that inhabited the lakes of the Valley of Mexico.

The family Goodeidae is a dominant family of viviparous freshwater fishes that includes 35 or more species in 15 genera. They

https://doi.org/10.1017/S0956536100111101 Published online by Cambridge University Press

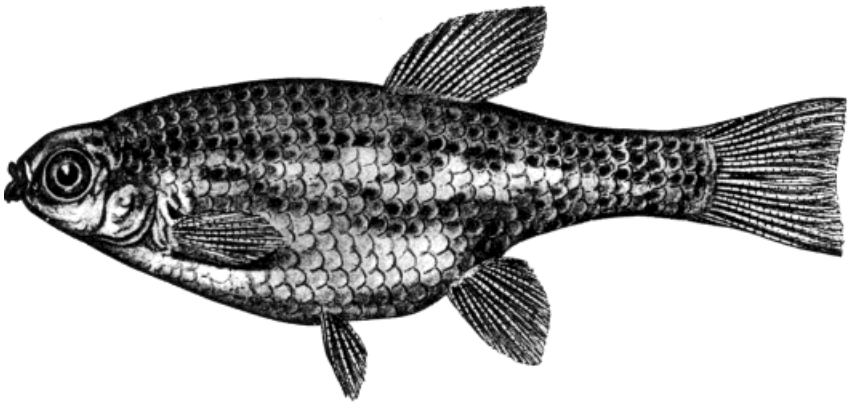


Figure 4. Representative of the family Goodeidae, *Skiffia variegata* (from Meek 1904).

are largely restricted to the Río Lerma basin in the highlands of Central Mexico, where the various species are specialized for a variety of niches as indicated by their many diverse body forms (deep-bodied to long-bodied forms) and feeding habits (carnivores to herbivores) (Fitzsimons 1972; Miller and Smith 1986:495; Rosen and Bailey 1963:490; Stuart 1964:334). They have a fossil history in this part of Mexico that extends back to the Miocene. *Girardinichthys viviparus* Bustamente and *Skiffia variegata* Meek are the only goodeids inhabiting the Valley of Mexico (Miller 1976:16).

Order Atheriniformes

The Silversides, Priapriumfishes, and relatives consist of primarily elongate species with prominent eyes, small pelvic fins, terminal mouths, and two dorsal fins (the first fin is weak but composed of true spines followed by a soft-rayed one). Both ctenoid and cycloid scales are present in the order. The lateral line is poorly developed or absent (Bond 1996:193; Moyle and Cech 1996:290).

The family Atherinidae (Silversides) are slender, silvery fishes with abdominal pelvic fins (consisting of a spine and five soft rays), two widely separated dorsal fins, and relatively large scales. They are schooling, diurnal planktivores that are often extremely abundant in shoreline habitats of lakes, estuaries, and various shallow marine environments. Most silversides are marine-dwelling fishes, although there are many species inhabiting fresh water. All are important food fishes (Bond 1996). Only the atherine genus *Chirostoma* is geographically concordant with the southern portion of the Mexican plateau. Of the 18 species found here (Barbour 1973a, 1973b; Miller and Smith 1986:508), 3 are known to have existed in the Valley of Mexico including *C. jordani* Woolman, *C. humboldtianum* Cuvier & Valenciennes, and *C. estor estor* Jordan.

The fishes of the Valley of Mexico were vital in providing an abundant, predictable, and reliable food resource on the third trophic level of the food pyramid. This may not, however, have always been the case. Only with the climatic changes that coincided with the transitional terminal Mazapan–Early Aztec period was a more profitable foraging habitat created within the vast lake system for fish and predator alike. The lowering of the water table created large marshlands favorable for mosquito larvae, a preferred food item for Cyprinidae and Goodeidae families. With more insect larvae, a common response is an increase in the growth rate and decrease in the age of maturity of the fish. Earlier sexual maturation has been demonstrated experimentally with Pacific herring, brown trout, and threespine sticklebacks (Wootton 1990). More rapid reproduction, of course, would lead to a greater population capable of being exploited by the Aztec people.

Magnuson et al. (1979) demonstrated that temperature is also an important contributing factor to the fitness of temperate freshwater fishes. The reduction in water volume and increased solar radiation penetrating the lake surface provided an increase in water temperature. This condition provided less competition for thermal resources; therefore, growth and perhaps measures of fitness were maximized. It must be noted that the thermal niche can be defined by lethal limits, but temperatures would have to be extreme to effect the families inhabiting the lakes, especially the Cyprinodonts and Cyprinids that have a thermal niche breadth ranging from cold to warm (Knapp 1953:85; Magnuson et al. 1979:334).

Fluctuating salinity conditions also acted as an important environmental factor on the types and distribution of fish inhabiting the Valley of Mexico lakes. Such fluctuations can pose a lethal or limiting factor to most fishes, causing higher energy costs (i.e., by increasing oxygen consumption) and reducing energy available for reproduction (Wootton 1990).

As stated previously, Lakes Zumpango, Xaltocan, and Texcoco were saline, with high concentrations confined to the eastern side of Lake Texcoco. This portion of the lake represents the lowest point within the lacustrine system, into which fresh water flowed during periods of low precipitation. One must ask the question, what effect higher precipitation levels and flooding would pose on plants and fish within the system. According to Palerm (1955), greater precipitation meant higher decomposition of soda and potash contained within feldspars in the mountain-rock strata lining the valley, which added salts to the lakes. The nitrous waters of eastern Lake Texcoco flooded the fresh waters; this seriously damaged the *chinampa* area to the west (Tenochtitlan) and threatened those of Xochimilco. The fishes may have been relatively unaffected because of their high tolerances to salinity (characteristic of Cyprinodontiformes and Atheriniformes). Apparently, the nitrous water could be beneficial to their health because salt has been used as a treatment against anchor worms, Pillularis disease, and velvet disease, all of which can infect fish (van Duijn 1973). The major problem involves the food supply of the fish: Can insect larvae survive high salinity to provide the essential nutrients for fish populations?

https://doi.org/10.1017/S0956536100111101 Published online by Cambridge University Press

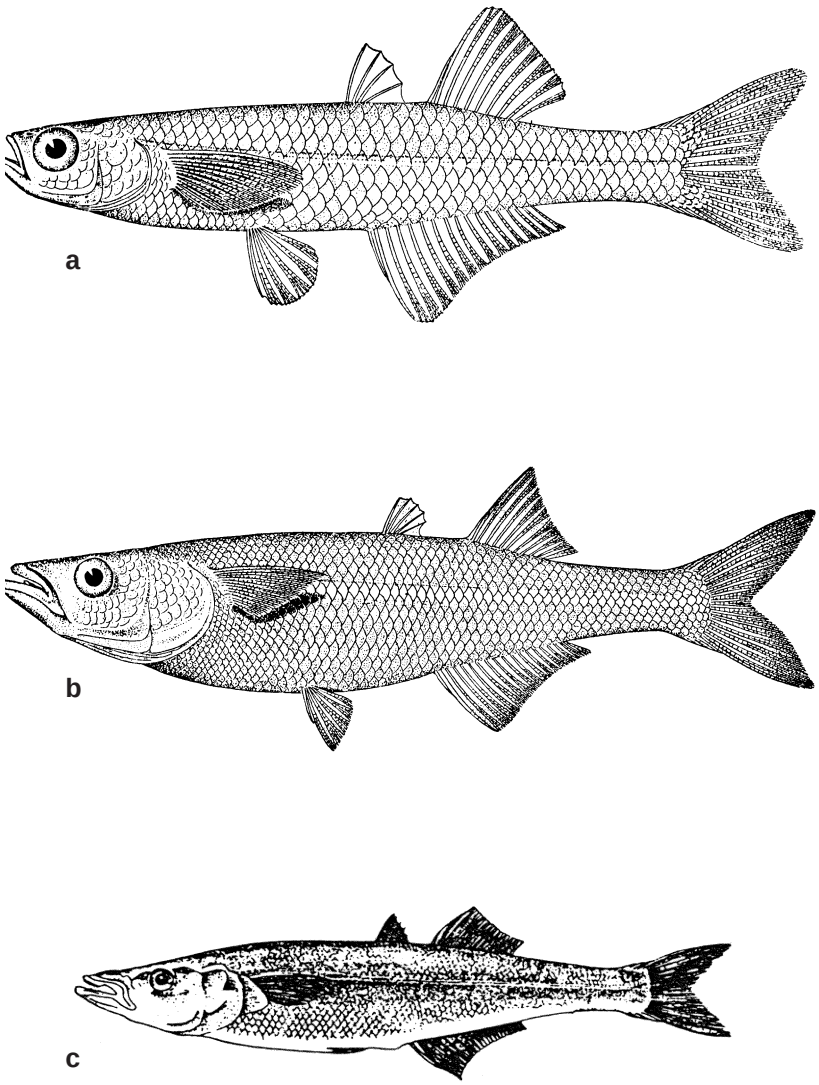


Figure 5. Representatives of the genus *Chirostoma*: (a) *C. jordani* (from Meek 1904), (b) *C. humboldtianum* (from Jordan and Evermann 1902), and (c) *C. estor estor* (from Niederberger 1987).

Fishes as a Food Source

The Cyprinidae and Atherinidae families probably provided important first-line food resources for the Aztecs and other inhabitants of the Valley of Mexico through time. Several *Chirostoma* species are known as excellent food fishes. In fact, they are so highly prized that their common name was "fishes of the king," or *pescados del rey*, *pesce re*, or *peixe rey* (Jordon and Evermann 1902). The most important food species of the genus *Chirostoma* was *C. humboldtianum* (*pescado blanco de chalco*) with a flesh firmer and coarser than the whitefishes (*pescados blancos*), which comprise a smaller *Chirostoma* species (Jordan and Evermann 1902:248). The maximum length of *C. humboldtianum* is about 200 to 250 mm for adults, and the maximum length of *C. Jordani* is approximately 70 mm for adults (Barbour 1973b). The importance of the whitefishes is reflected by a depiction of two fish on the bottom of a Formative-period (1150–1300 B.C.) plate recovered from the Chalco–Xochimilco area (Figure 6). Interestingly, *Chirostoma* represents the only genera belonging to a salt-water family inhabiting the Mexican plateau (Meek 1903, 1904).

The family Cyprinidae was extremely abundant within the Valley of Mexico, with *Algansea tincella* providing an important food source. This species normally reaches a length of about 18 to 28 cm (Niederberger 1987:119). They are currently used by residents as an ingredient in *tamales* (Meek 1904:liii).

Ethnohistorical sources indicate that fishing was an important subsistence activity at the time of the Spanish Conquest and throughout the Colonial period (Gibson 1964; Tamayo and West 1964:109). Apparently, professional fishermen exploited fishes in Lake Chalco–Xochimilco, residing at Tlahuac, Mix quic, Chalco Atenco, and other communities within these environs. It is reported that in the early seventeenth century "over a million fish were being taken annually from Lake Chalco and Lake Xochimilco" (Gibson 1964:340). Linne (1948:126–138) and Meek (1904:liii) reported the existence of commercial fisheries in the Valley of Mexico during the early 1900s, with whitefishes dried in large quantities and shipped to various parts of Mexico.

Undoubtedly, a drop in the water table, which probably occurred about A.D. 1150, would have provided a more efficient means of exploiting a valuable (predictable and dense) meat resource in

https://doi.org/10.1017/S0956536100111101 Published online by Cambridge University Press

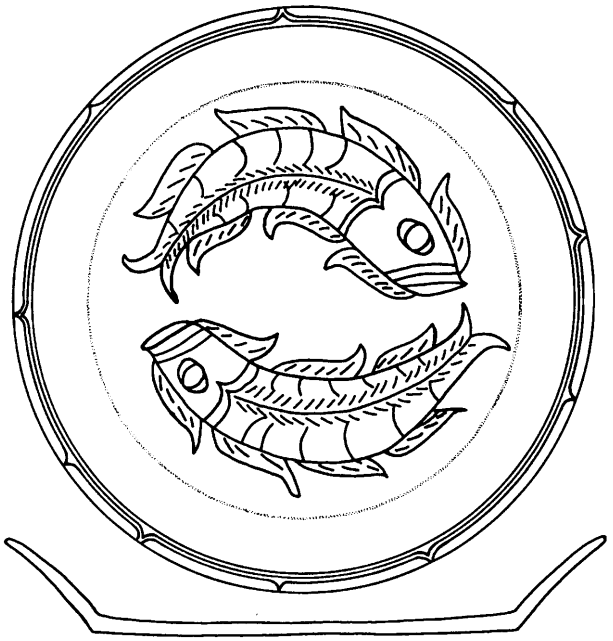


Figure 6. Manantial Epoch plate (29 cm in diameter) decorated with two whitefish in inverse position (from Niederberger 1987:586, Figure 497).

fish; necessary to offset the depletion of another first-line protein food, the white-tailed deer. Deer had become overexploited as early as the Middle Horizon (A.D. 300–750) and significantly declined as a food source thereafter (Sanders et al. 1979:286–287). Why fish were not exploited more intensively before the transitional period is an interesting question (see Sanders et al. 1979:Table 7.2). The answer appears to be related to the opportunity of using nets as a more efficient method of capturing fish. Rather than relying on spearing, dip-nets, or cast-nets from canoes, which probably were used during times of high lake levels, it is hypothesized that seine-nets could have been hauled by large teams of fishermen wading in shallow lakes. According to Welcomme (1979:185), a seine-net is "the gear of the professional *par excellence*." Such a change in strategies would have been cost efficient because the lake bottoms may have been unencumbered by obstacles to snag the nets and the fish sufficiently concentrated to give a good chance of capture.

Schooling, or shoaling, behavior (formed by social attraction) has been reported in fish populations of minnows and characins (Wheeler and Jones 1989) as well as silversides (Meek 1904). Fish schooling through synchronized and polarized group movements may have provided many benefits to the fish. Particular avoidance patterns may reduce their vulnerability, and certain defense maneuvers disorient predatory fish, which feed at a high light intensity, by showing multiple and shifting targets. In addition, Nikol'skii (1955) demonstrated that a school of minnows detects a predator at a greater distance than a single individual can, and schools enable continuous, all-round monitoring for the presence of predators. Thus, it is more difficult for a predator to approach a school than an individual. Another postulated benefit of schooling, or shoaling, is the ability to acquire food more quickly in groups. For example, schooling planktivores, like *Chirostoma*, appear to be more efficient at feeding among dense patches of plankton than individual planktivores are (Bond 1996:543). There may also be greater hydrodynamic efficiency when foraging in groups. Schooling, however, can have a negative value when fishermen utilize large nets for their capture. For fishermen, costs would have been high in manufacturing and maintaining the seine-nets but the benefits of capturing enormous numbers of fish in a short span of time would have been much higher. Certainly, using a spear, hand-held dip-net, or a hook line would be a poor investment of time, labor, and material. A fishing line provided the least effective means of catching fish, although early Spanish historical maps depict natives with fish on their lines (Figure 7). Meek (1904:liii) stated that none of the *Chirostoma* species will take the hook, so are we to believe Spanish depictions of native anglers at the bow of a canoe?

SALT

Salt has played an important role in the history of the Valley of Mexico. It was probably used as a flavoring agent, in glazing and tanning processes, a necessary physiological element, and in the preservation of foods, especially meats. The procurement of a large quantity of fish presents the problem of preserving it. Fish are subject to rapid spoilage because of bacterial and autolytic changes which lead to increases in the amounts of free amino acids and polypeptides and later, secondary decomposition (Wing and Brown 1979:63–64). Simply drying the fish after having been eviscerated and scaled is one method, but if there is high atmospheric humidity the flesh will still decompose. Thus, preservation is aided by adding salt. This type of treatment may be used after sun-drying as exemplified by the preparation of *Lycengraulis olidus*, *Hoplias malabaricus*, and *Pseudoplatystoma* spp. in the Parana River of South America (Welcomme 1979).

Several sixteenth- and seventeenth-century documentary sources and archaeological evidence indicate that saltmaking was important along the shoreline of Lake Texcoco–Xaltocan–Zumpango at the time of initial European contact and in pre-Hispanic times. This area provided the only significant source of salt within the Basin of Mexico (Parsons 1996). Notably, salt panning was carried out at the south edge of Tenochtitlan, in an area currently occupied by modern Mexico City (Sanders et al. 1979). The urbanization of this area has made it difficult to assess the role of salt production in the domestic and political economy of the Amerindian inhabitants. Also, it has been difficult to determine exactly when salt production became an important activity (Parsons 1996).

Ethnoarchaeological studies conducted by Jeffrey Parsons (1989, 1994), within the Valley of Mexico, and Eduardo Williams (1999), at Lake Cuitzeo, Michoacan, have provided insights into salt production and its commodity value. Parsons (1989, 1996:447) proposed that there was a shift from solar evaporation of water from saline wells or pools to leaching saline lakebed earth and boiling the resulting brine for salt production occurring sometime after A.D. 1200. The impetus for this change appears to have included "(1) substantial and sustained regional population growth, and (2) the need to preserve large quantities of lake fish for exchange in expanding market and tributary economies" (Parsons 1989:132).

WATERFOWL

Waterfowl (ducks and geese), which belong to the order Anseriformes, provided another abundant and predictable aquatic-food resource important to the development of Aztec society (Gibson 1964:341–343). Undoubtedly, waterfowl procurement was conducted throughout pre-Hispanic times. The lacustrine system of

https://doi.org/10.1017/S0956536100111101 Published online by Cambridge University Press

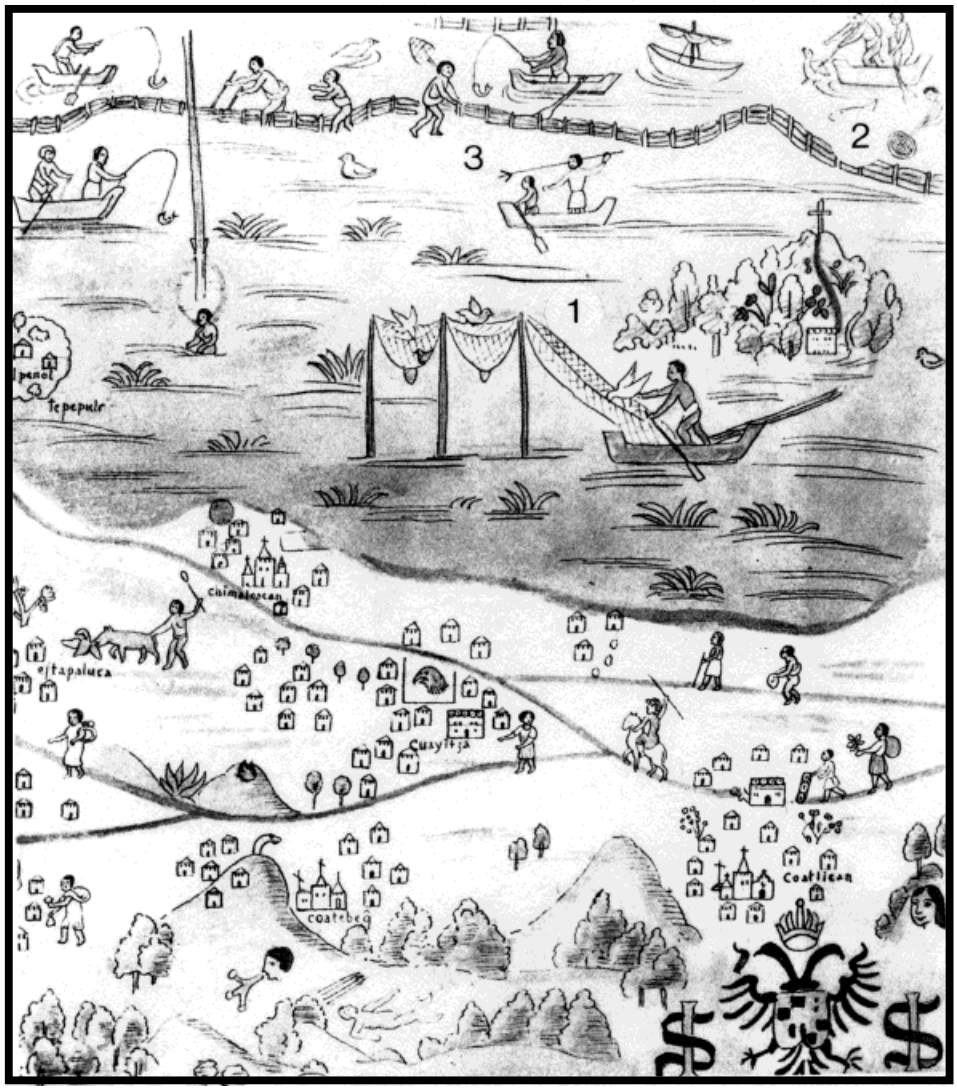


Figure 7. Native American fish and waterfowl procurement in Lake Texcoco (from Santa Cruz Map 1550, reproduced in Niederberger 1987:166, Figure 51). 1 = netting waterfowl, 2 = seine fishing with dip-net, 3 = spear fishing.

the Valley of Mexico was a terminal point for the Central Flyway: a major annual migration route for waterfowl that forms a broad, relatively straight line from northeastern Alaska diagonally southward across the prairie marshes of western Canada and the Continental Divide to the Texas coast, Mexico, Central America, and northern South America (see Leopold 1959:Figure 53). Various waterfowl species used the Valley of Mexico wetlands as wintering grounds, with flocks arriving in late fall (from October to November) and migrating northward between February and May to their breeding grounds (Heintzelman 1978:70–71). Gibson (1964:342) pointed out that the most important part of the hunting season for ducks was the dry period between October and March.

The winter population density of migratory waterfowl is difficult to estimate because of the impact of weather conditions as well as declining populations attributed to loss and degradation (pollution and siltation) of natural wetland habitats. We can use, however, a count of more than 33,000 migratory ducks visiting Lake Texcoco during the 1952 season to estimate pre-Columbian populations in the millions, based primarily on a much larger lake system (Leopold 1959:129–148; Sanders et al. 1979). Even with Spanish over-hunting in the eighteenth century (through the use of firearms), the average annual duck consumption in Mexico City was estimated between 900,000 and 1,000,000 birds (Gibson 1964:343).

Both Canadian and White-fronted geese were available for exploitation. Small numbers of Canadian geese may have strayed south from winter concentration points in the southern and western United States (Leopold 1959). The White-fronted Goose once migrated regularly in large numbers to their wintering grounds in the Basin of Mexico (Kortright 1953:117–122; Leopold 1959:152–154). Only five, however, were identified in the Basin of Mexico in 1952 because of the drainage of most lakes and marshes. This species was known as a desirable food source among Native Americans (Kortright 1953:121), and Sahagún (1963:27), in the *Florentine Codex*, stated that the down of this goose was used by the native inhabitants for capes.

A wide variety of duck species was available in central Mexico for human exploitation (food and featherwork). The area supported 14 species that are subsumed into 4 tribes within the subfamily Anatinae: tribe Anatini (dabbling ducks), tribe Aythyini (diving ducks), tribe Mergini (sea ducks), and tribe Oxyurini (stiff-tailed ducks). A species list is presented in Table 2. Anatini or dab-

https://doi.org/10.1017/S0956536100111101 Published online by Cambridge University Press

Table 2. Waterfowl present in the Valley of Mexico

Family Dendrocygnidae: whistling ducks
Tribe Dendrocygnini (whistling ducks)
Fulvous whistling Duck (*Dendrocygna bicolor*)
Black-bellied whistling Duck (*Dendrocygna autumnalis*)
Family Anatidae: swans, geese, and ducks
Subfamily Anserinae: geese and swans
Tribe Anserini (geese)
White-fronted goose (*Anser albifrons*)
Canada goose (*Branta canadensis*)
Subfamily Anatinae: typical ducks
Tribe Anatini (dabbling or surface-feeding ducks)
Green-winged teal (*Anas crecca carolinensis*); *cerceta aliverde*
Mexican mallard (*Anas [platyrhyncos?] diazi*); *pato mexicano*
Northern pintail (*Anas a. acuta*); *pato golondrino norteno*
Blue-winged teal (*Anas discors*); *cerceta aliazul*
Cinnamon teal (*Anas cyanoptera septentrionalium*); *pato castana*
Northern shoveler (*Anas clypeata*); *pato cucharon norteno*
Gadwall (*Anas strepera*); *pato pinto*
American wigeon (*Anas americana*); *pato chalcuan*
Tribe Aythyini (diving ducks)
Canvasback (*Aythya valisineria*); *pato coacoxtle*
Redhead (*Aythya americana*); *cabaza cabecirrojo*
Ring-necked duck (*Aythya collaris*); *pato piquianillado*
Lesser scaup (*Aythya affinis*); *pato-boludo menor*
Tribe Mergini (sea ducks)
Bufflehead (*Bucephala albeola*); *pato monja*
Tribe Oxyurini (stiff-tailed ducks)
Ruddy duck (*Oxyura j. jamaicensis*); *pato tepalcate*

Note: Data compiled from Howell and Webb (1995), Johnsgard (1975, 1978), Leopold 1959:158–201), and Niederberger (1987:125–126).

bling ducks are the most successful of all waterfowl and constitute the most important game species throughout the world. The northern-hemisphere species are highly migratory and often winter in large, mixed concentrations (Madge and Burn 1988:194). They are generally adapted to shallow marshes and ponds where food (e.g., aquatic vegetation, insects, and seeds) can be obtained at or near the water surface by dabbling and up-ending, although they also feed by grazing. Aythyini, or diving ducks, require more permanent waters and are adept at diving (to depths of 6 m), often at night, to feed on submergent vegetation, insects, molluscs, and crustaceans. Sea ducks (Mergini) are winter visitors to the large lakes and river systems of the region. They are superb divers (to depths of more than 15 m) that feed primarily on molluscs, crustaceans, and aquatic insects. The stiff-tailed ducks (Oxyurini) are small, compact, marshland forms with long and often upright tails that serve as underwater rudders when diving. They feed primarily on submergent vegetable matter and midge larvae (Howell and Webb 1995:159–173; Johnsgard 1978).

Ducks provided a desirable combination of large clutch size and large body size, resulting in a balance between biomass accumulation and reproductive capacity. Thus, they offer high potential yields, with live-weight averages ranging between .36 and 1.22 kg. Ducks would have been a seasonal first-line food.

Father Bernardino Sahagún's sixteenth century work *Florentine Codex* (Sahagún 1963:34–38) provided information on each species of duck in central Mexico in terms of adult plumage, breeding behavior, migration behavior, and status as a game bird. Most species are listed simply as "edible," although the Mexican Mallard, Northern Pintail, and American Wigeon are viewed as "good-tasting." Canvasback is ranked as the most highly valued meat source being "very savory," and it currently maintains a worldwide reputation as the "choice of the epicure" (Kortright 1953:244). The meat of the canvasback, however, may have a strong, undesirable fishy taste if the bird consumes too many shellfish. Because this occurs more often in salt than fresh water (Leopold 1959:186), the meat from flocks procured from the Chalco–Xochimilco region may have had a better flavor than those from the northern Valley of Mexico.

Both archaeological and historical accounts attest that waterfowl were hunted or trapped with varying degrees of success within the Valley of Mexico. The bow-and-arrow technique was probably the most common means of procurement prior to the Aztec I phase (A.D. 1150–1300), exemplified by numerous projectile points recovered at First Intermediate Two Loma Torremote (Sanders et al. 1979). They could also have been captured by swimmers whose heads were concealed in pumpkins, which occurred during the seventeenth century. Other techniques used include the atlatl, snares, slingstones, and nets. The netting technique probably would have been most productive when the lake levels dropped. Only then could large quantities of waterfowl be captured by setting nets on posts driven into the lake bottom at intervals, and then scaring the ducks into them at dawn or dusk with shouts and sticks, and retrieving those that had become entangled (Gibson 1964:342). Initial costs in labor investment would have been high but production efficiency would be significant (high output).

Long-term drought conditions associated with the Medieval Warm period (A.D. 800–1350) in western North America (Jones et al. 1999) probably played a major role in increasing waterfowl populations in the Basin of Mexico. Significant wetland habitat losses would have occurred across the wintering range of geese and ducks, like the wintering grounds of the White-fronted Goose in the interior valleys of California and the Northern Shoveler with their main winter range in the southern United States and northern Mexico. Because waterbirds are adaptable and seek better habitats through migration (Weller 1999:175–176), one would expect enormous increases in populations in the valley wetland systems. One would also expect that with shallower lakes, Bufflehead and diving ducks of the genus *Aythya* would decrease in population while dabbling ducks would increase. We lack, however, analyses of bird remains from a multitude of sites that might provide demonstrable differences between Early Postclassic (A.D. 950–1150) and Middle Postclassic (A.D. 1150–1400) times.

SUMMARY AND CONCLUSIONS

The climate during the terminal Mazapan–Early Aztec transitional period (ca. A.D. 1150–1200) may have been characterized by more pronounced cooler, drier conditions that lowered the Valley of Mexico lake levels, perhaps as part of a longer trend beginning as early as A.D. 900 (Messenger 1990). Consequently, there could have been a dramatic increase in the carrying capacity for fish and waterfowl when a more profitable foraging marshland was created. The wetlands would have provided a favorable larval habitat for the mosquito (e.g., mosquito larvae do not occur in open water since they require the protection of vegetation [Bates 1949:170–171]) and brine shrimps (*Artemia*), which are excellent fish-food sources.

https://doi.org/10.1017/S0956536100111101 Published online by Cambridge University Press

Perhaps more importantly, less precipitation may have meant more sunlight for high growth rates in phytoplankton resulting in high levels of animal plankton and fish production. A result would be an increase in the carrying capacity for Early Aztec peoples. The rapid expansion of land reclamation associated with *chinampa* agriculture and dramatic demographic increase within the Xochimilco–Chalco Basin (and throughout much of the Valley of Mexico) that began about A.D. 1150 may be used to substantiate such claims. In this study, I have shown that fish and ducks provided an abundant, predictable food source for Early Aztec development, and that saltmaking was essential to preserve the large quantities of meat for exchange in expanding market and tributary economies. Such commercial activities have a long history here.

More research is needed to model the past record of climate and human adaptation to changing climatic/environmental conditions in the Valley of Mexico. Intensive research regarding changes in fish and waterfowl productivity and exploitation patterns from the archaeological record can contribute new insights (see Sugiura 1998) similar to Parsons' (1989, 1996) study of salt-production intensification in the Lake Texcoco–Xaltocan–Zumpango environs. Fish remains should be prolific in all excavated samples from habitation areas if flotation is implemented. We are dealing with bony (teleost) fishes and not cartilaginous ones (Class Chrondrichthys). Netting of some sort was probably used to catch schooling zooplanktivorous *Chirostoma* species, with the lake whitefishes providing an important food source. Analyses of the incremental growth structures of these fishes (e.g., scales and vertebrae) may be used to derive seasonal and climatic information (see Brewer 1987, 1992; Monks 1981; Wing and Brown 1979:116), much like the yearly growth rings of trees. Also, climatic change may be confirmed by analyses of pollen cores taken directly from the Basin of Mexico (Elizabeth Brumfiel, personal communication 2000).

RESUMEN

Los arqueólogos trabajando en el Valle de México no han podido comprender los incrementos de la población, de la intensificación económica, y el desarrollo sociopolítico asociado con el primer período azteca (1150–1400 d.C.). Esta época marca inmediatamente un tiempo crítico siguiendo la última era de Tenochtitlan llamada el postclásico. Los aztecas movieron hacia hubicaciones lacustres. Las explicaciones para el desarrollo de los Aztecas necesitan considerar el clima y la productividad resultante del lago en el Valle de México. Después de todo, los cambios climáticos después del Holoceno tardío han sido documentados, importantes influencias afectaron la vegetación y críticamente determinó la biografía del animal y la adaptación humana. El frío de época aparentemente causo un decrecimiento importante en los niveles del lago. Consecuentemente hubo un incremento dramático de la capacidad para cargar el pescado cuando se creó un pantano más favorable. Este estudio identifica y describe la variedad de peces y aves especies de agua dulce y salada lacustre habitante, los cuales dieron abundantes y predicables recursos de comida para el comienzo del desarrollo cultural azteca. De particular importancia en la dieta nativa era pescado blanco y grandes cantidades de patos migratorios que usaron los lagos como sus refugios de invierno. Grandes cantidades de carne pudieron ser preservadas en la obtención de sal desde las orillas de los lagos Texcoco–Xaltocan–Zupango para intercambio en los expansión de los mercados económicos. Muchos trabajos arqueólogos deben llevarse a cabo para ganar la comprensión del medio ambiente como una causa potencial de cambio cultural en el Valle de México.

ACKNOWLEDGMENTS

Much of this paper was written while I was at the University of Illinois at Urbana–Champaign. I benefited greatly from discussions with David Grove concerning the archaeology and Douglas Brewer about the fauna of the Basin of Mexico. Attending a limnology course by Edwin Herricks of the Illinois Natural History Survey led to a better understanding of lake organism/habitat relationships in both spatial and temporal dimensions. Elizabeth Brumfiel, Winifred Creamer, and Jeffrey R. Parsons provided important recent published materials that found their way into the manuscript. Barbara J. Williams pointed out the importance of using the *Florentine Codex* and other ethnohistorical sources. The figures were prepared by Susan Brannock-Gaul whose work and creativity are much appreciated. Finally, I especially thank all three *Ancient Mesoamerica* reviewers for raising questions and offering many incisive comments and helpful suggestions that contributed to significant improvements in the organization and clarity of this paper.

REFERENCES

Armillas, Pedro
1971 Gardens on Swamps. *Science* 174(4010):653–661.
Barbour, Clyde D.
1973a A Biogeographical History of *Chirostoma*, a Species Flock from the Mexican Plateau. *Copeia* 1973(3):533–556.
1973b The Systematics and Evolution of the Genus *Chirostoma* Swainson (Pisces, Atherinidae). *Tulane Studies in Zoology and Botany* 18(3):97–141.
Bates, Marston
1949 *The Natural History of Mosquitoes.* MacMillan, New York.
Bond, Carl E.
1996 *Biology of Fishes*. 2nd ed. Harcourt Brace, Orlando.
Bradbury, John P.
1971 Paleolimnology of Lake Texcoco, Mexico. Evidence from Diatoms. *Limnology and Oceanography* 16(2):180–200.
Brewer, Douglas J.
1987 Seasonality in the Prehistoric Faiyum Based on the Incremental Growth Structures of the Nile Catfish (Pisces: Clarias). *Journal of Archaeological Science* 14:459–472.
1992 Incremental Growth Structures in Nile Fish and Molluscs from Archaeological Sites as Indicators of Holocene Environmental Change in Egypt. *Holocene* 2:30–36.
Brumfiel, Elizabeth M.
1991 Agricultural Development and Class Stratification in the Southern Valley of Mexico. In *Land and Politics in the Valley of Mexico: A Two Thousand Year Perspective*, edited by H.R. Harvey, pp. 43–62. University of New Mexico Press, Albuquerque.
Chernoff, Barry, and Robert Rust Miller
1981 Systematics and Variation of the Aztec Shiner, *Notropis sallei*, a Cyprinid fish from Central Mexico. *Proceedings of the Biological Society of Washington* 94(1):18–36.
Fischman, J.
1996 California Social Climbers: Low Water Prompts High Status. *Science* 272:811–812.
Fitzsimons, John Michael
1972 A Revision of Two Genera of Goodeid Fishes (Cyprinodontiformes, Osteichthyes) from the Mexican Plateau. *Copeia* 1972(4): 728–756.

https://doi.org/10.1017/S0956536100111101 Published online by Cambridge University Press

Gibson, Charles
1964 *The Aztecs Under Spanish Rule*. Stanford University Press, Stanford.
Gillespie, Susan
1989 *The Aztec Kings*. University of Arizona Press, Tucson.
Goudie, Andrew
1992 *Environmental Change*. 3rd ed. Clarendon Press, Oxford.
Heintzelman, Donald S.
1978 *North American Ducks, Geese, and Swans*. Winchester Press, New York.
Howell, Steven N.G., and Sophie Webb
1995 *A Guide to the Birds of Mexico and Northern Central America*. Oxford University Press, Oxford.
Johnsgard, Paul A.
1975 *Waterfowl of North America*. Indiana University Press, Bloomington.
1978 *Ducks, Geese, and Swans of the World*. University of Nebraska Press, Lincoln.
Jones, Terry L., Gary M. Brown, L. Mark Raab, Janet L. McVickar, W. Geoffrey Spaulding, Douglas J. Kennett, Andrew York, and Philip L. Walker
1999 Environmental Imperatives Reconsidered: Demographic Crises in Western North America during the Medieval Climatic Anomaly. *Current Anthropology* 40(2):137–170.
Jordan, David Starr, and Barton Warren Evermann
1896–1900 The Fishes of North and Middle America. *Bulletin of the United States National Museum* 47(1–4):1–3136.
1902 *American Food and Game Fishes*. Doubleday, Page, New York.
Knapp, Frank Tyrwhitt
1953 *Fishes Found in the Freshwaters of Texas*. Ragland Studio and Litho, Brunswick, Georgia.
Kortright, Francis H.
1953 *The Ducks, Geese, and Swans of North America: A Vade Mecum for the Naturalist and the Sportsman*. 7th printing. Telegraph Press, Harrisburg, Pennsylvania.
Lamb, H.H.
1995 *Climate, History and the Modern World*. 2nd ed. Routledge, London.
Leopold, A. Starker
1959 *Wildlife of Mexico: The Game Birds and Mammals*. University of California Press, Berkeley.
Linne, Sigvald
1948 *El valle y la ciudad de Mexico en 1550*. The Ethnographical Museum of Sweden Publications, New Series, no. 9. Ethnographical Museum of Sweden, Stockholm.
Madge, Steve, and Hilary Burn
1988 *Waterfowl: An Identification Guide to the Ducks, Geese, and Swans of the World*. Houghton Mifflin, Boston.
Magnuson, John J., Larry B. Crowder, and Patricia A. Medvick
1979 Temperature as an Ecological Resource. *American Zoologist* 19:331–343.
Mayden, R.L.
1991 Cyprinids of the New World. In *Cyprinid Fishes: Systematics, Biology, and Exploitation*, edited by Ian J. Winfield and Joseph S. Nelson, pp. 240–263. Chapman and Hall, London.
McGregor, Glenn R., and S. Nieuwolt
1998 *Tropical Climatology: An Introduction to the Climate of the Low Latitudes*. 2nd ed. John Wiley & Sons, New York.
Meek, Seth Eugene
1903 Distribution of the Fresh-Water Fishes of Mexico. *American Naturalist* 37(443):771–784.
1904 The Fresh-Water Fishes of Mexico North of the Isthmus of Tehuantepec. *Publications of the Field Columbian Museum. Zoological Series* 5:1–252.
Messenger, Lewis C., Jr.
1990 Ancient Winds of Change: Climatic Settings and Prehistoric Social Complexity in Mesoamerica. *Ancient Mesoamerica* 1:21–40.
Miller, Robert Rush
1976 An Evaluation of Seth E. Meek's Contributions to Mexican Ichthyology. *Fieldiana Zoology* 69(1):1–31.
1982 Pisces. In *Aquatic Biota of Mexico, Central America and the West Indies*, edited by S.H. Hurlbert and A. Villalobos-Figueroa, pp. 486–501. San Diego State University, San Diego.
Miller, Robert Rush, and M.L. Smith
1986 Origin and Geography of the Fishes of Central Mexico. In *The Zoogeography of North American Freshwater Fishes*, edited by Charles H. Hocutt and E.O. Wiley, pp. 487–518. John Wiley & Sons, New York.
Monks, Gregory G.
1981 Seasonality Studies. In *Advances in Archaeological Method and Theory*, vol. 4, edited by Michael B. Schiffer, pp. 177–240. Academic Press, New York.
Mooney, Harold A., Eduardo R. Fuentes, and Barbara I. Kronberg
1993 *Earth System Responses to Global Change*. Academic Press, San Diego.
Moyle, Peter B., and Joseph J. Cech, Jr.
1996 *Fishes: An Introduction to Ichthyology*. Prentice-Hall, Englewood Cliffs, NJ.
Myers, George S.
1966 Derivation of the Freshwater Fish Fauna of Central America. *Copeia* 1966(4):766–772.
Nelson, Joseph S.
1976 *Fishes of the World*. John Wiley & Sons, New York.
Niederberger Betton, Christine
1987 Paleopaysages et archeologie pre-urbaine du bassin de Mexico, vol. 1. *Collection Etudes Mesoamericaines* 1–11. Mexico City.
Nikol'skii, G.V.
1955 Biological Value of Fish Schools. Trudy Soveshchaniya po voprosam povedeniya I razvedki ryb. Izdatel'stvo AN SSSR, Moscow.
Palerm, Angel
1955 The Agricultural Basis of Urban Civilization in Mesoamerica. In *Irrigation Civilization: A Comparative Study*, edited by Julian H. Steward. Pan American Union Social Science Monographs No. 1. Washington, DC.
Parsons, Jeffrey R.
1989 The Last Saltmakers of Nex quipayac, Mexico: An Archaeological Ethnography. Preliminary Report Submitted to the National Geographic Society.
1991 Political Implications of Prehispanic Chinampa Agriculture in the Valley of Mexico. In *Land and Politics in the Valley of Mexico: A Two Thousand Year Perspective*, edited by H.R. Harvey, pp. 17–42. University of New Mexico Press, Albuquerque.
1994 Late Postclassic Salt Production and Consumption in the Basin of Mexico. In *Economics and Politics in the Aztec Realm*, edited by M.G. Hodge and M.E. Smith, pp. 257–290. Studies on Culture and Society, vol. 6. Institute for Mexoamerican Studies. State University of New York, Albany.
1996 *Tequesquite* and *Ahuahtle*: Rethinking the Prehispanic Productivity of Lake Texcoco–Xaltocan–Zumpango. In *Arqueologia Mesoamericana: Homenajea William T. Sanders*, vol. 1, pp. 439–459. Instituto Nacional de Antropología e Historia, Mexico.
Parsons, Jeffrey R., Elizabeth Brumfiel, and Mary Hodge
1996 Developmental Implications of Earlier Dates for Early Aztec in the Basin of Mexico. *Ancient Mesoamerica* 7:217–230.
Parsons, Jeffrey R., Elizabeth Brumfiel, Mary H. Parsons, and David J. Wilson
1982 *Prehispanic Settlement Patterns in the Southern Valley of Mexico: The Chalco–Xochimilco Region*. Memoirs No. 14. Museum of Anthropology, University of Michigan, Ann Arbor.
Regan, C. Tate
1906–1908 Pisces. In *Biologia Centrali-Americana* 8:i–xxxiii, 1–203.
Rosen, Donn Eric, and Reeve M. Bailey
1963 The Poeciliid Fishes (Cyprinodontiformes), Their Structure, Zoogeography, and Systematics. *Bulletin of the American Museum of Natural History* 126(1):1–176.
Sahagún, Fray Bernardino de
1963 Book 11—Earthly Things, No. 14, Pt. XII. In *Florentine Codex: General History of the Things of New Spain*. English translation by Charles E. Dibble and Arthur J.O. Anderson. The School of American Research and the University of Utah, Provo.
Sanders, William T.
1981 Ecological Adaptation in the Basin of Mexico: 23,000 B.C. to the Present. In *Archaeology*, edited by Jeremy A. Sabloff, with the assistance of Patricia A. Anrdews, pp. 147–197. Supplement to Handbook of Middle American Indians, vol. 1. University of Texas Press, Austin.
Sanders, William T., Jeffrey R. Parsons, and Robert S. Santley
1979 *The Basin of Mexico: Ecological Processes in the Evolution of a Civilization*. Academic Press, New York.
Smith, Philip W.
1979 *The Fishes of Illinois*. University of Illinois Press, Urbana.

https://doi.org/10.1017/S0956536100111101 Published online by Cambridge University Press

Stuart, L.C.
1964 Fauna of Middle America. In *Natural Environment and Early Cultures*, edited by Robert C. West, pp. 316–383. Handbook of Middle American Indians, vol. 1. Robert Wauchope, general editor. University of Texas Press, Austin.
Sugiura, Yoko Yamamoto
1998 *La Caza, La Pesca y La Recoleccion: Etnarqueologia del modo de subsistencia lacustre en las cienegas del Alto Lerma*. Universidad Nacional Autónoma de México, Mexico.
Tamayo, Jorge L., and Robert C. West
1964 The Hydrogeography of Middle America. In *Natural Environment and Early Cultures*, edited by Robert C. West, pp. 84–121. Handbook of Middle American Indians, vol. 1. Robert Wauchope, general editor. University of Texas Press, Austin.
van Duijn, Cornelis
1973 *Diseases of Fishes*. Charles C. Thomas, Springfield.
Vivo Escoto, Jorge A.
1964 Weather and Climate of Mexico and Central America. In *Natural Environment and Early Cultures*, edited by Robert C. West, pp. 187–215. Handbook of Middle American Indians, vol. 1. Robert Wauchope, general editor. University of Texas Press, Austin.
Welcomme, Robin L.
1979 *Fisheries Ecology of Floodplain Rivers*. Longman, London.
Weller, Milton W.
1999 *Wetland Birds: Habitat Resources and Conservation Implications*. Cambridge University Press, Cambridge.
Wendland, Wayne M., and Reid A. Bryson
1974 Dating Climatic Episodes of the Holocene. *Quaternary Research* 4:9–24.
Wheeler, Alwyne, and Andrew K. G. Jones
1989 *Fishes*. Cambridge University Press, Cambridge.
Williams, Eduardo
1999 The Ethnoarchaeology of Salt Production at Lake Cuitzeo, Michoacan, Mexico. *Latin American Antiquity* 10:400–414.
Winfield, Ian J., and Joseph S. Nelson (editors)
1991 *Cyprinid Fishes: Systematics, Biology, and Exploitation*. Chapman and Hall, London.
Wing, Elizabeth S., and Antoinette B. Brown
1979 *Paleonutrition: Method and Theory in Prehistoric Foodways*. Academic Press, New York.
Wootton, Robert J.
1990 *Ecology of Teleost Fishes*. Chapman and Hall, London.

https://doi.org/10.1017/S0956536100111101 Published online by Cambridge University Press