Introduction

Archaeologists and geographers have emphasized the role of agricultural intensification in sustaining complex prehispanic societies in the Valley of Mexico (Figure 1), the core of Mesoamerica’s largest urbanized polities after ca. 100 BC (e.g., Gorenflo and Gale 1986; Nichols 1987; Palerm and Wolf 1961; Parsons 1976; Sanders 1972; Sanders, Parsons, and Santley 1979). By the early sixteenth century, the Valley of Mexico contained well over a million inhabitants, a population size and density that were not exceeded again until the late nineteenth century. Only for pre-urban Archaic and Formative societies (pre–300 BC) have aquatic resources been recognized as highly significant for sedentary populations in this region (McClung de Tapia, Serra, and Limon 1986; Niederberger 1979; Serra 1988).

Nevertheless, following the lead of Santley and Rose (1979), I have come to believe that certain nonagricultural resources may also have to be factored, much more systematically than they have been, into our thinking about later prehispanic subsistence in this...
region. Part of my interest in these resources relates to the absence in Mesoamerica of a domestic herbivore analogous to llamas and alpacas in Andean South America and to sheep and goats in much of the Old World. Unique among the world’s ancient primary civilizations, Mesoamerica lacked a pastoral component that could have extended productive landscapes into agriculturally marginal terrain. Furthermore, as Harris (1979:335) has noted, protein from domesticated animal sources would have been scarce by comparison to other parts of the ancient urbanized world. We might thus expect unusually well-developed efforts by ancient Mesoamericans to exploit high-protein, nonagricultural resources that would have truly complemented, not merely supplemented, the basic agricultural staples.

**Protein in the Aztec diet**

In his argument for the importance of human cannibalism as the main source of animal protein in the Aztec diet, Marvin Harris (1979) challenged Marshall Sahlins’s (1978) view that plenty of animal protein was available from aquatic fauna. According to Harris, the problem lay in the impossibility of harvesting the

[S]mall, patchy, and trophically subordinate [aquatic] invertebrates on a scale sufficient to provide a dense urbanized population with significant amounts of animal protein. Ordinarily people let the fish and the birds eat the worms, and then they eat the birds and the fish. The only sensible conclusion to be drawn from the fact that the Aztecs ate more worms than anything else is that they had eaten up most of the birds and fish, and having eaten up most of the birds and fish, they ate people as well. (1979:338)
Harris calculated that the total protein contribution from aquatic fauna would have amounted to no more than 2.7 grams per person per year (1979:339).

**Objectives**

This paper is an elaboration and extension of some ideas I proposed much more tentatively a few years ago (Parsons 1996). Following the lead of Ortiz de Montellano (1978, 1990), Sahlin (1978), and Price (1978)—all of whom effectively criticized Harris’ position—one of my objectives in this paper is to indicate the degree to which aquatic resources were significant in pre-columbian subsistence in the Valley of Mexico. These resources included salt, waterfowl, fish, edible insects, a variety of amphibians and reptiles, algae, reeds, and certain other aquatic plants. I emphasize anew that these resources were energetically, nutritionally, and economically so important as to attract large numbers of people engaged full-time in their extraction, processing, and distribution during the Middle and Late Postclassic, if not earlier. Such an attraction would necessarily have been significant in socio-political terms.

Going beyond Harris’s earlier critics, I suggest that the extensive saline ponds and marshes in the Aztec heartland should be considered in much the same way as agricultural land in terms of their contribution to prehispanic subsistence. This is a radical idea at the present time. Drawing upon archaeological data, I also suggest that the economic role of the saline marshlands changed significantly after Early Postclassic times as a result of larger shifts in socio-political organization. It remains difficult to specify the precise nature of these larger shifts or to explain them, but increasing productive specialization and new forms of regional distribution were undoubtedly involved (e.g., Blanton and Feinman 1984). I
Michigan Discussions in Anthropology

conclude by calling for new archaeological attention to the remnants of the saline lakes and marshlands that remain unstudied long after regional surveys and site-specific archaeological studies have been completed or implemented elsewhere.

The aquatic landscape in the Valley of Mexico

The Valley of Mexico is an internal-drainage basin about 7000 km² in area. Lacking natural external drainage, it forms a great topographic saucer, rimmed on all sides by higher ground that surrounds a central depression. Today, after 400 years of extensive artificial drainage, this is virtually all dry land. In prehistoric times, however, rainfall on the surrounding slopes and plains drained into the lowest part of the basin to form a series of interconnected shallow lakes and marshes: from north to south, Lake Zumpango, Lake Xaltocán, Lake Texcoco, Lake Xochimilco, and Lake Chalco (Figure 1).

Lake Texcoco, at the bottom of the drainage gradient at ca. 2238 m asl, was saline; Lakes Zumpango and Xaltocán were brackish, while Lakes Chalco and Xochimilco were freshwater. Beginning ca. 1200 AD, the ponds and marshes of Lake Chalco-Xochimilco were drained and transformed into productive agricultural plots (chinampas) (Armillas 1971; Parsons et al. 1982, 1985). Except around some of its peripheries (Ávila 1991), saline Lake Texcoco remained un-cultivated, and there was only minor development of agriculture in the brackish northern lakes and marshes (Nichols and Frederick 1993).

The uncultivated expanse of saline ponds and marshland in the central and northern lakes—some 600 km² in area—attracted a high proportion of urban settlement after the thirteenth century AD: the Aztec/Spanish capital (Tenochtitlán/Mexico City) was
Aquatic Component of Aztec Subsistence

Figure 1. The Valley of Mexico. Shading indicates the still non-urbanized sector of the former lakebed.
Table 1. Valley of Mexico Chronology

<table>
<thead>
<tr>
<th>Date</th>
<th>Period</th>
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<tbody>
<tr>
<td>2000 BC</td>
<td>Archaic (pre-ceramic)</td>
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<tr>
<td>900 BC</td>
<td>Early Formative</td>
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<tr>
<td>500 BC</td>
<td>Middle Formative</td>
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<tr>
<td>250 BC</td>
<td>Late Formative</td>
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<tr>
<td>50 BC</td>
<td>Terminal Formative</td>
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<tr>
<td>150 AD</td>
<td>Classic</td>
</tr>
<tr>
<td>750 AD</td>
<td>Epiclassic</td>
</tr>
<tr>
<td>950 AD</td>
<td>Early Postclassic</td>
</tr>
<tr>
<td>1150 AD</td>
<td>Middle Postclassic</td>
</tr>
<tr>
<td>1350 AD</td>
<td>Late Postclassic</td>
</tr>
<tr>
<td>1520 AD</td>
<td>Spanish Colonial</td>
</tr>
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<td>1810 AD</td>
<td></td>
</tr>
</tbody>
</table>
situated within western Lake Texcoco, and many major Middle Postclassic, Late Postclassic, and Spanish Colonial towns were located around its shoreline (Figure 1). In contrast, earlier prehispanic populations during Early Postclassic, Epiclassic, Classic and Formative times (Table 1) were much less highly concentrated in or around this same area (Sanders, Parsons, and Santley 1979). What was the basis for this dramatic shift in settlement patterning?

Scholars have provided two very different kinds of answers to this question. One provides a supernatural explanation, following Aztec mythology, in which the founders of Tenochtitlán established themselves in a sparsely settled saline swamp (e.g., Davies 1973). A second emphasizes the efficiency of a water-borne transportation-communication network (Hassig 1985). Both perspectives provide important insights, but I think it is also necessary to consider the contribution of the aquatic resources to human subsistence.

**The historic evidence of saline lake and marsh exploitation**

Gibson (1964), Rojas (1985), Ramos-Elorduy and Pino (1989), Ortiz de Montellano (1990), and Parsons (2001, 2003) have discussed at some length the historically documented uses of aquatic resources in the Valley of Mexico from the early sixteenth through the mid-twentieth centuries. Sahagun's sixteenth-century account (1963:63-65), for example, provides detailed descriptions of five types of fish, at least 38 types of waterfowl, 14 categories of “small animals that live in the water,” and at least 18 categories of edible and medicinal aquatic plants. Spanish eyewitness observers of pre-conquest Tenochtitlán in 1519 (e.g., Diaz del Castillo 1908(2):71-73) describe aquatic foods (fish, ducks, and pastes made from algae and insects) available in the urban marketplace.
A remarkable mid-sixteenth-century map graphically illustrates a variety of fishing and bird-netting activities in Lake Texcoco, with other tasks of uncertain function (Figure 2) (Apenes 1947; Linne 1948). Figure 2 clearly shows two major subdivisions of the “lake” separated by what appears to be a linear barrier made of interwoven reeds: an inner (westward) section, with no aquatic plants, and where no waterfowl are netted; an outer (eastward) section, with numerous aquatic plants, and where the dominant activity is netting waterfowl. This dichotomy suggests control over water depth in order to facilitate the exploitation of different kinds of aquatic resources.

Most of the aquatic resources mentioned in the sixteenth-century sources are animals, including very large quantities and varieties of waterfowl, mainly seasonal migratory species but also some year-round residents, plus several kinds of fish and fish eggs, several kinds of edible aquatic insects and insect eggs, and a range of amphibians, reptiles, and crustaceans. Except for migratory waterfowl, which were present in prodigious numbers only during the winter months, most of the other aquatic fauna were available year-round.

In the sixteenth century, waterfowl were hunted and trapped in a variety of ways, especially with the use of nets and snares and well-designed approach-and-follow tactics that tired the birds so that they were unable to fly away from the approaching hunters, who then simply seized, speared, clubbed, or netted them. Insects were also collected with a variety of nets. Fish were speared, hooked, or netted. The production of insect eggs was facilitated through the construction of nurseries in shallow waters where the eggs were deposited on conveniently placed reed bundles pushed into the lake bottom, or on thick submerged ropes.
Aquatic Component of Aztec Subsistence

Figure 2. Mid-sixteenth century map (1550), section showing the southeast corner of Lake Texcoco and adjacent piedmont. North is to the right. Circled numbers show the following: 1) men spearing (fish?, salamanders?) from a canoe; 2) man fishing (?) with a pole and line; 3) man capturing waterfowl in large, upright nets suspended from poles; 4) man walking with a push-net over his shoulder; 5) man pushing a net through the water (to capture insects?); 6) two men engaged in uncertain activity (building or repairing the reed barrier?). Adapted from Apenes 1947.
Only one lake plant, algae, is frequently mentioned as a sixteenth-century food source, although the seeds, stalks, and roots of three or four other types of aquatic plants are also described as edible. There are also references to the use of reeds, rushes, and cane as raw materials for mats and houselot fences.

Canoes are often mentioned as essential for many kinds of hunting and collecting on and around the lakes in the sixteenth century. Netting of fish and waterfowl was commonly carried out in canoes. These boats were also commonly used for transporting lakeshore residents, together with their harvested ducks, fish, reeds and reed mats, and insect products to places where they paid their tribute/taxes in the form of lake products, or to urban marketplaces where they exchanged their aquatic products for complementary agricultural and craft goods.

The sixteenth-century sources do not provide many details about the specific spaces and facilities where marsh or lacustrine resources were prepared and processed. Nevertheless, there are some general hints about activities such as storing, drying, thickening, grinding, cooking, and mixing. Masses of algae, for example, were sun-dried on flat lakeshore surfaces ca. 3-5 m on a side.

The occasional mention of “water folk” (e.g., Sahagun 1963:31, 33, 36, 65) suggests a significant degree of specialization in the exploitation of aquatic resources by lakeshore communities. The products of aquatic specialists would have nicely complemented those of urban artisans or full-time agriculturalists living farther inland—as references to market exchange indicate. The occasional mention of the individual ownership of fishing and algae-collection plots (Gibson 1964:339-340; Hernandez 1959:408-409) is further testimony to the economic importance of aquatic resources and aquatic specialists in the sixteenth-century economy. Such territorial control is also common, for example, among traditional Uru
communities in the extensive marshes around Lake Titicaca in Peru and Bolivia (Levieil and Orlove 1990:367-368). There is good reason to suspect that there was also controlled access to specific lake and marsh locales prior to European contact in the Valley of Mexico.

By the early twentieth century, large-scale drainage in the Valley of Mexico had been underway for three centuries (Gurría 1978), and the sixteenth-century lake area had been reduced by more than half. Nevertheless, throughout this long period the lakes and marshes continued to provide very substantial quantities of the same foods and raw materials that had formerly been significant. Furthermore, these resources continued to be collected, hunted, or harvested with much the same techniques and organizational infrastructure as those described in the sixteenth-century sources.

Throughout the eighteenth and nineteenth centuries more than a million waterfowl annually made their way into the urban marketplaces (Gibson 1964:343). Their eggs probably provided an additional significant source of protein, nutrients, and calories. Sahagun (1963:26-39) noted that seven types of waterfowl raised their young in the Lake Texcoco marshes.

Other estimates hint that annual harvests of edible aquatic insect products might have amounted to thousands of metric tons (e.g., Peñafiel 1884:129-130). The documented use for agricultural fertilizer of huge masses of these insects periodically washed up along the shorelines indicates the prodigious quantities that were formerly available (Orozco y Berra 1864:154). The potential annual harvests of fish, larval salamanders, frogs, crustaceans, molluscs, algae and other aquatic plants are more difficult to quantify, but they were probably very substantial. Gibson (1964:339-340), for example, found that in the early seventeenth century “over a million fish were being taken annually from Lake Chalco and Xochimilco.” Gibson also noted the presence at that time of “professional Indian
fishermen” in many towns around the freshwater and saline lakes, and emphasized that “fishing jurisdictions were as carefully demarcated and as jealously guarded as land jurisdictions in native society.”

The nineteenth- and twentieth-century sources reveal that the same aquatic resources continued to be used in more recent times. Similar products, similar uses, similar extractive and processing technology, and the similar importance of market exchange among lacustrine, agricultural, and craft producers have characterized the aquatic economy over four centuries. Marsh reeds and rushes continued to be noted as raw material for mats, and there are also some suggestions of use of these plants for food. Many aquatic food products were effectively dried for long-term storage, greatly facilitating the accumulation and exchange of surpluses from one year to the next.

A sample of quotes from historic-period sources

To add some empirical substance to the foregoing generalizations, I now provide quotes from a sample of historical sources. Unless otherwise noted, the English translations of the original Spanish sources are mine.

Pedro Martir de Angeleria (1965[1523]) obtained information from several conquest eyewitnesses. In one account, he described saltmaking around the lakeshore to the south and southeast of Tenochtitlán, and hinted that access to this salt was regulated by the Aztec state:

They go from Ixtapalapa to Tenustitan [Tenochtitlán] upon a walkway of stone...The towns adjoining the bridge produce salt, which everybody in that region uses. They take the lake
Aquatic Component of Aztec Subsistence

water, which is salty, and lead it through ditches into depressions where they thicken it. Once thickened, they boil it, and then form it into balls and loaves which they take to markets or fairs to exchange for other things. Only the subjects of Moctezuma have access to this salt, and never those who disobey his commands.

In his mid-sixteenth-century account, Fernando Hernandez described the collection, processing, and consumption of several types of aquatic insects and insect eggs from Lake Texcoco.

The *axacayácatl* is a small, lacustrine fly…which in certain seasons is collected with nets from the lake in such great quantities that great numbers of them are cut up and mixed together to form little balls, which are sold in the markets throughout the year; the indians cook them in salty water wrapped up in maize husks, and prepared in this way they comprise a good food, abundant and agreeable…There are two species of these flies, one large and the other smaller. (Hernandez 1959:390)

[A] great quantity of a certain substance called *ahuauhtli*, with a fishy taste, is taken from the Mexican lake [Lake Texcoco]. It looks like a poppy seed, and it is the eggs of the *axacayácatl* …It is gathered by throwing into the lake, where the waters are most turbulent, loosely twisted cables as thick as a man's arm or thigh. The [eggs] shaken and swirled, adhere to these, from which the fishermen remove them and store them in large vessels. They make tortillas [from it] similar to corn ones, or the balls they call tamales…or they save it, split into portions
Michigan Discussions in Anthropology

and wrapped in corn husks, toasting or cooking it at a later time. (Hernandez 1959:393)

The Mexicans refer by this term [ocuiliztac] to certain little worms that live in Lake Texcoco...When raw these are black, but once toasted in plates or on comales they promptly turn white. The Indians eat them with salt...Every year, primarily during the rainy season, they occur in abundance and it is easy to capture them...they are not found on the tables of rich people...but amongst those who do not have an abundance of better food. (Hernandez 1959:393)

Izabiti is a mass of small worms that, captured with nets in Lake Texcoco and stored in large vessels, are sold in the markets... When cooked by the sellers they acquire a blackish color, an odor like fish eggs, and a consistency like compressed bread crumbs. They increase the quantity of milk in nursing mothers, for which purpose some make them into tortillas that they dry and store...When these worms are half cooked, spices are added to improve their flavor. (Hernandez 1959:395)

Hernandez also described the use of fish eggs:

This white lacustrine product, formed by the multitude of fish that live in Lake Texcoco...and which at certain times of the year is taken from the same lake...appears like a mass of small fish, no bigger than tiny nits, that moves through the middle part of the lake without being carried to either shore, and is so abundant that it occupies a space of five or more cubits...the fishermen...catch it in their nets...They then
cook it in copper or clay vessels, and, together with added
spices or chile, it forms part of their meals. Prepared in this
way it is a good and agreeable food which both the indians
and spaniards residing here eat with pleasure. (1959:396)

Another mid-sixteenth-century Spanish writer, Toribio de
Motolinia (1971), described the collection and processing of algae
(tecuitatl):

There breeds upon the water of the Lake of Mexico [Lake
Texcoco] a sort of very fine slime [algae], and at a certain
time of the year when it is the thickest, the Indians gather it
with very fine nets until their acales, or boats, are full. On
shore they make a very smooth plot 2 or 3 brazas [3.4-5.1 m]
long and a little less wide on the earth or on very fine sand.
They throw it [the tecuitatl] down to dry until it makes a loaf 2
dedos [3.6 cm] thick. A few days later it dries to the thickness
of a used ducat [coin]. The Indians cut this loaf into wide
bricks and eat a lot of it and think it good. This merchandise
is carried by all the merchants of the land as cheese is among
us. Those of us, who share the tastes of the Indians, find it
very tasty. It has a salty flavor. I think particularly that this
substance is the bait which brings great multitudes of birds
to the Mexican lagoon. There are so many, that in many parts,
it looked like a solid lake made up of birds. This happens in
winter and the Indians harvest many of the birds. (English
translation by Ortiz de Montellano 1990:104)

Writing in the late eighteenth century, Clavijero took note
of the numerous waterfowl and the techniques used to hunt them:
in the lakes around Mexico City there are an incredible number of ducks, widgeons, and other aquatic birds...[the hunters] leave floating on the lake surface, in spots where the birds congregate, hollow gourds that are left in place during the hunting season so that the birds become accustomed to them. The hunter enters the water and hides beneath the hollow gourds, with only his head above water, where it is hidden by the gourds; the ducks come to pick at the gourds, and the hunter seizes them by the feet and pulls them under water, and in this fashion he easily seizes as many as he wishes.(1964:234)

Orozco y Berra provided a detailed description of how aquatic insect eggs were harvested and prepared in the mid-nineteenth century:

The Indians form small bundles of reeds, which they place in shallow parts of the lake at intervals of about one meter, in such a way that one end of the reed bundle rests on the lake bottom, while the other end projects above the surface. The female *axayacatl* comes there to deposit its eggs, and soon not only do the eggs cover the entire reed bundle, but they also form bunches of eggs lying one atop the other. Once the egg-covered reed bundles are pulled out of the water and dried, they are shaken over a cloth; the eggs fall off with this action, it being sufficient to brush the reeds with the hand in order to loosen those eggs that may have remained attached. The product thus prepared is known as *ahuautle*...it is prepared and eaten in several ways, ground up and mixed with chicken eggs, as cakes fried in grease, that are either eaten alone or in
particular dishes…Ahuanle has a taste similar to that of fish caviar…

…The larva that forms from the egg is a small white or yellowish worm; it is collected in great quantities, and is prepared by cooking the entire insect in maize husks, or grinding them into a paste, and thus taken to market wrapped in husks. This product is called by the Mexican name of puxi, and is reputed to be a very good food.(1864:152-153)

As previously mentioned, Orozco y Berra (1864:154) also noted that during the nineteenth century great masses of lacustrine insects were systematically collected for use as agricultural fertilizer from where they accumulated naturally through wind and wave action on the lakeshores. Thirty years later, Herrera reported a successful experiment aimed at evaluating these aquatic insects as agricultural fertilizer:

Sr. Segura planted maize seeds, some in land fertilized with requezón [bodies of Ephydra hians], others in unfertilized land. The result was very conclusive; all the fertilized plants developed with unusual vigor. The plants in unfertilized land were rickety and weak.

Sr. Segura determined that requezón contains 29% organic matter and 61% mineral material. (1895:46)

In the late nineteenth century, Antonio Peñañuel attempted to quantify the aquatic insect populations of Lake Texcoco:

[A]t a point intermediate between Chimalhuacán and the Peñón los Baños [Fig. 1]…on its surface we observed an infinite number of the larvae, that produce ahuanle…
According to what we saw, we calculate that there are 200 larvae in each square decimeter of lake water; consequently, 20,000 larvae per square meter, and 3,650,000,000,000 larvae in the whole of Lake Texcoco. The weight of each larva, dried at 108° F, is about 5 milligrams, which gives us a total weight [in the whole of Lake Texcoco] of 18,250,000 kilos; the weight of 100 abuante eggs, dried at the same temperature, is 6 milligrams; calculating at 100 eggs per square decimeter, would give a total of 109,500 kilos for the entire lake, which added to the weight of the larvae, would give us 18,359,500 kilos of material in this immense deposit; and we are confident that our calculations, rather than being exaggerated, actually are less than the true figures. (1884:129-130)

At about that same time, Frederick Ober noted that aquatic products continued to be a subsistence mainstay:

[T]he poor people [in the lakeshore towns] subsist almost entirely upon the products of the water and marshes...[the] marsh fly called azayacatl (Ahuatlea mexicana), which deposits its eggs in incredible quantities upon flags and rushes, and which are eagerly sought out and made into cakes which are sold in the markets...

...These cakes...are sold in the markets to this day, and the black heaps of the abuante, or 'water wheat,' may be frequently seen dotting the mud flats about the lakes, Texcoco especially. The insects themselves (which are about the size of a house-fly) are pounded into a paste—as they are collected in myriads—, boiled in corn husks, and thus sold. The eggs, resembling fine fish roe, are compressed into a paste, mixed
Aquatic Component of Aztec Subsistence

with eggs of fowls, and form a staple article of
food.(1884:339)

In the course of two summer trips during 1902 and 1904, Hans Gadow (1908:15) encountered substantial numbers of larval salamanders (*axolotl*) for sale in the Mexico City marketplace. He also learned about how they lived and how they were collected:

The fishermen who punted us about in dug-outs knew all about the *axolotl*—how they bred early in the spring, about February; how their eggs were fastened singly to the water-plants; how soon afterwards the little larvae swarmed about in thousands like other tadpoles; how they grew at a great rate, always remaining dark and never becoming piebald or marbled over with yellow, until by the month of June they were all grown-up, ready for market…Later in the summer they take to the rushes, and in the autumn they seem to become scarcer…Sometimes they are caught in nets, more frequently they are speared with a pronged fork. (Gadow 1908:11)

As noted by Ancona, the consumption and market sale of aquatic insects and their eggs continued to be important well into the 1930s:

The insects are placed in baskets, where they are dried in the sun. Prepared in this way, they are commonly sold in the streets and marketplaces of the city…Well pounded and ground up, they are sold in small cakes…not only in the markets of Texcoco, Chimalhuacán, Xochitenco, Sochiaca and Los Reyes, but even in Mexico City itself…The *ahuautle* eggs…are also
commonly consumed by local people: they are sold during the months of May, June, and July, and when fried they provide a delicious food with a taste like shrimp. In their dried state they are stored in homes for months…In the communities bordering Lake Texcoco the people help support themselves by collecting and exporting the *ahuautle* eggs and insects.(1933:63)

**Recent ethnographic and experimental evidence**

In the late 1930s and early 1940s, Scandinavian ethnographers recorded some details of traditional saltmaking, bird hunting, and insect collection along the eastern sectors of Lake Texcoco, from Nexquipayac to Chimalhuacán (Figure 1) (Apenes 1943, 1944; Linne 1937, 1940, 1948). Their published accounts dramatically underscore the remarkable continuity between these early-twentieth-century activities and their sixteenth-century counterparts illustrated in Figure 2.

In 1988 and 1992 I observed traditional saltmaking and aquatic-insect collecting in the last remnants of the saline marshlands of Lake Texcoco at the modern villages of Nexquipayac and Chimalhuacán (Parsons 2001, 2003) (Figure 1). These observations amplify and extend some of the historic sources, and facilitate the interpretation of relevant archaeological data.

**Saltmaking**

Modern saltmakers carefully combine several different types of soil from sources around the old lakeshore. This mixture is then placed in a special conical pit into which water is poured so as to drain slowly through the soil mixture and leach out its salt content. The resulting brine is boiled in large metal pans to obtain the
crystalline salt. The leached soil is subsequently removed from the conical pit, tossed aside, and the process begins anew.

Salt has also been produced by means of solar evaporation during the dry season from shallow pools along the lake margins. During the dry season (October-May), substantial salt crusts formed naturally over large areas along the lake’s margin. These crusts are simply removed, broken up or pulverized, and cleaned for use. These simple operations may be extended and intensified by means of preparing artificial evaporating beds along the lakeshore, or by enlarging natural ones. The two production methods (solar evaporation and leaching-boiling) have been employed concurrently during historic times (Apenes 1944), and it is likely that they were both used in the prehispanic era as well.

Saltmaking by solar-evaporation requires little specialized knowledge, and no complex technology or fuel costs. By contrast, the leaching-boiling technique involves specialized knowledge (about soil chemistry, soil mixing procedures, soil compaction in the leaching pit, and proper boiling operations), specialized technology (for digging, transporting, and mixing soils, and for boiling the brine), and high fuel costs (Parsons 2001).

There are many known archaeological sites around the margins of Lake Texcoco. Most of them are of Late Postclassic age. Typically these are low irregular mounds, usually small but sometimes extending over several hectares, always heavily littered with a distinctive fabric-marked surface pottery. Many of these sites are suspected to have been associated with prehispanic saltmaking. We can associate the ancient mounding with the discarded leached soil of the leaching-boiling process. The associated fabric-marked pottery probably had less to do with actually making salt than with packaging it for distribution through marketplaces (Baños and Sanchez 1998; Minc 1999).
Modern saltmakers who use the leaching-boiling method typically spend considerable time searching for good deposits of saline lakebed soil at distances up to several kilometers away from the workshops, skimming the soil from the ground surface, and transporting it back to the workshop. Such activities leave subtle material traces in many parts of the lakebed-lakeshore area, and all probably have prehispanic analogs which might have found some form of (still unrecognized) archaeological expression.

Because of high fuel costs and the need for great knowledge and technical expertise which only specialized production could provide, it seems unlikely that the ethnographically observed leaching-boiling method was very significant prior to Middle Postclassic times in the Valley of Mexico. The stimulus for the shift from a more generalized form of salt production based upon solar evaporation to a more specialized form based on leaching-boiling may have been a combination of two factors that produced a need for significantly higher salt production after ca. 1200 AD:

(1) Substantial and sustained regional population growth.

(2) Changes in the larger political economy such that much larger quantities of preserved meat (fish and waterfowl), dyed textiles (salt is a common mordant in dyeing cloth), cleansing agents, and uniformly packaged salt were required for use by an expanding and increasingly urbanized population, and for new kinds of market and tributary economies in which packaged salt became a standard of value for new kinds of material exchanges (Hicks 1987).

**Insect collecting**

Four varieties of aquatic insects (members of the *Coraxidae* family, in both larval and adult stages) continue to be collected with a net mounted on a wooden frame fastened to a long handle and pushed by a man walking through shallow water where the insects
live and breed. This activity duplicates that depicted in scenes from
the 1930s recorded by Linne (1948:134), and illustrated on the mid-
sixteenth-century map (Figure 2). Occasionally, small fish are netted
along with the insects. The insects and fish are ground to a paste
with a mano and metate. The paste is then wrapped in maize husks
and cooked in tamale form on a griddle (comal).

Insect eggs (ahuauhtle) are naturally deposited in great
quantities throughout the year on the surfaces of aquatic vegetation.
The harvested eggs are ground to a paste and then either cooked
and eaten in tamale form, or, more commonly, mixed with other
foods. Precisely as Ancona (1933:63) described two generations ago,
the usual practice today is to encourage the insects to deposit their
eggs in artificial lakebed “nurseries”—long lines of U-shaped clumps
of grass inserted by hand with the aid of a wooden or iron stake
into the shallow lake bottom at intervals of about one meter. The
grass surfaces provide places where large masses of insect eggs are
deposited and from whence they are periodically collected.

I found that up to 16 kg (dry weight) of aquatic insects can
be netted in two or three hours from a ponded area approximately
one hectare in area. Assuming that approximately 100 km² (10,000
hectares) of the original lake surface (ca. 500 km²) might have been
available for this type of activity, and that one hectare could produce
an average of 10 kg of edible insects and five kg of eggs every two
weeks, then a very rough estimate of maximum total annual insect/
egg harvest would be 3,900 metric tons during pre-columbian times.
As previously noted, Peñañuelo (1884:129-130) had estimated that
more than five times this quantity would have been potentially
available. These figures are particularly impressive considering the
high protein and amino-acid content of these products (Tables 2, 3).
Table 2. Protein content of some edible lacustrine insects from Lake Texcoco (adapted from Ramos-Elorduy and Pino 1989:49, 54, 55)

<table>
<thead>
<tr>
<th>Insect</th>
<th>% Protein</th>
<th>% Protein Digestible</th>
<th>% Total Digestible</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corixidae: ahualtli (eggs)</td>
<td>56.55</td>
<td>89.34</td>
<td>61.56</td>
</tr>
<tr>
<td>Corixidae: axayacatl (adult)</td>
<td>62.80</td>
<td>98.02</td>
<td>86.95</td>
</tr>
<tr>
<td>Abedus ovatus S. (adult)</td>
<td>67.69</td>
<td>no data</td>
<td>no data</td>
</tr>
<tr>
<td>Ephydra hians S. (larvae)</td>
<td>35.81</td>
<td>no data</td>
<td>no data</td>
</tr>
</tbody>
</table>

Table 3. Essential amino acid content of some edible lacustrine insects (adapted from Ramos-Elorduy and Pino 1989:51-52)

<table>
<thead>
<tr>
<th>Insect</th>
<th>Essential amino acid* content (mg/16 g)</th>
<th>FAO Daily Requirement (mg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Krizousacorixa spp. and Notonecta spp.</td>
<td>43.6</td>
<td>-</td>
</tr>
<tr>
<td>Corisella spp.</td>
<td>38.9</td>
<td>-</td>
</tr>
<tr>
<td>Ephydra hians</td>
<td>50.62</td>
<td>-</td>
</tr>
<tr>
<td>-</td>
<td>-</td>
<td>36.0</td>
</tr>
</tbody>
</table>

*These amino acids include isoleucine, leucine, lycine, metionine + cisteine, phenylalanine + tironsine, threonine, triptophane, and valine.

Experimental algae production

The nutritional value of algae (Spirulina) is outstanding. According to Furst (1978:60), for example, it is 65-70% protein by weight, “a higher percentage than any other natural food…,” and it
contains all eight essential amino acids. Dillon and Phad report that “the essential amino acids comprise 47% of the protein.” (1993:103) Gallegos (1993:135-137) also notes the high vitamin and mineral content of *Spirulina*. Furthermore, because of its cellular structure, algae is highly digestible without chemical or physical processing (Dillon and Phad 1993:105). Notably, the area of a “pond devoted to the cultivation of *Spirulina* can produce 125 times as much protein as the same amount of area devoted to corn, 70 times as much as to farmed fish, and 600 times as much as to cattle” (Furst 1978:62).

Since the 1960s there has been commercial production of *Spirulina* at a large evaporation plant (Sosa de Texcoco, abandoned in the mid 1990s) on the north side of Lake Texcoco. Here, by the 1970s a pilot program had succeeded in producing about one metric ton per day of dry *Spirulina* (Furst 1978), and this production was expected to rise soon thereafter to about five metric tons per day. By the early 1990s annual productivity of this facility had expanded to 600 metric tons (amounting to 14 tons of protein per year per hectare) from an evaporation facility of some 800 hectares (Gallegos 1993:135). The overall potential production is far higher:

[Spirulina] multiplies rapidly, dividing three times daily, and flourishes in waters that are too salty for irrigation or human consumption. All that is needed is the right amount of solar radiation and a high level of salinity. The Valley of Mexico…has about 240 days of sunshine per year and the water of Lake Texcoco has a pH factor between 9 and 10, which indicates a high salt content. Under these conditions, a single hectare can produce from 12,000 to 20,000 kilograms of dried protein [12–20 metric tons] per year from *Spirulina.* (Furst 1978:63)
Under ideal conditions, the potential daily output of protein from *Spirulina* on 500 hectares of Lake Texcoco would amount to 48,835 kilograms (Furst 1978:64).

Durand-Chastel (1980:57) and Gallegos (1993:137) observe that the *Spirulina* produced by La Sosa Texcoco also contains substantial quantities of several essential minerals: calcium, phosphorous, iron, sodium, chloride, magnesium, manganese, zinc, potassium, copper, and chromium—many of them in significantly higher proportions than other common plant foods.

**Conclusions**

It remains difficult to quantify aquatic productivity at any point in the past, or to specify spatial or seasonal variability in the past output of salt, insects, fish, amphibians, waterfowl, algae, or reeds in and around Lake Texcoco-Xaltocán-Zumpango. Nevertheless, there is considerable documentary, ethnographic, and archaeological evidence indicating that these products have been important for many centuries in terms of subsistence and market exchange, and that they are capable of providing very large quantities of high-quality proteins and other essential nutrients. Recalling Orozco y Berra's (1864:154) nineteenth-century descriptions of insects as agricultural fertilizer, we might even consider the direct linkages between aquatic and agricultural production.

Just as archaeologists and ethnohistorians have factored the agricultural landscape into their thinking about prehispanic subsistence, so too should they think about how this might be accomplished for the nonagricultural aquatic component. We might one day be able to estimate the potential caloric and nutritional value for any given area of Lake Texcoco-Xaltocán-Zumpango, just as has already been done for agricultural land. I expect that any
Aquatic Component of Aztec Subsistence

given area of saline lake or marshland had an average productive significance approaching that of a comparable area of agricultural land. What we cannot yet do is quantify existing impressions with any confidence or to project the historic patterns back into prehispanic time.

One giant step forward in this effort would be to complete systematic, intensive archaeological surveys over what remains of the former lakebed: this is still a comparatively large and intact landscape, where a few partial surveys (Blanton 1972; Parsons 1971, 1974; Sanders 1976) and many casual walk-abouts have revealed surficial archaeological remains. These remains are typically small sherd and lithic scatters on the order of 5–50 m in diameter (Figure 3). The surface pottery I have seen at such sites ranges in age from Late Formative (ca. 400 BC) to Late Postclassic, with a predominance of Middle and Late Postclassic materials. Numerous buried mammoth-kill/butchering/natural-death sites have been reported from around the shores of Lake Texcoco and on its surface. One such mammoth was discovered in 1972 on the lakebed surface a few kilometers north of Chimalhuacán, with no overlying alluvial deposit and no signs of eolian deflation (Mirambell 1972). This find indicates that parts of the lakebed have had no significant alluviation for several millennia: an ideal natural laboratory for the study of archaeological surface remains.

Historic and ethnographic sources indicate that activities associated with the exploitation of aquatic resources are widely distributed over the lakebed surface. Saltmakers, insect netters, duck hunters, reed cutters, fishers, and salamander spearers all range over the ponds and marshes in the course of their daily tasks. These activities must have left some physical traces, however subtle (Tables 4, 5, 6). An intensive survey of the non-urbanized lakebed (ca. 50 km²) should reveal scores of such localities. This archaeological
record should provide a sensitive material record of the exploitation of aquatic resources over several millennia. Ethnographically known marsh dwellers in other parts of the world may provide useful analogies for interpreting these remains—for example, the Marsh Arabs (Thesiger 1964) and the Uru (LaBarre 1941).

Figure 3. Example of small archaeological site on east-central Lake Texcoco.
### Table 4. activities associated with saltmaking (leaching-boiling method)

<table>
<thead>
<tr>
<th>Activity</th>
<th>Predictable Locational and Surficial Archaeological Manifestations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digging the saline soil</td>
<td>Scattered locations accessible to canoe transport, with seasonal and cyclical shifting of these locations according to changing water levels and shifting locations of lakeshore. Diffuse concentrations of ceramic and lithic remains associated with short-term camping and digging operations: probably cooking (comal, olla, hearthstones) and shoveling (?) implements, and crude shelters (maybe windbreaks formed by rows of large rocks).</td>
</tr>
<tr>
<td>Transporting the soil to the workshop</td>
<td>Canoe accessibility, especially for the more distant sources.</td>
</tr>
<tr>
<td>Processing the soil</td>
<td>Well-defined workshop, probably accessible by canoe, and probably with a significant residential function, with indications of fairly permanent adobe or stone architecture and large, clean surfaces for mixing different parent soils; dumps of leached soils forming irregular mounding; conical leaching pits (maybe invisible at ground surface?); charred fuel remnants and ashes; masses of large ollas suitable for boiling brine, with high frequencies of blackened surfaces (chemical analyses might show salt impregnation?); large hearth stones. Significant mixing and re-mixing of soil deposits.</td>
</tr>
<tr>
<td>Packaging the salt</td>
<td>Probably done at or near the soil-processing workshop. Masses of cheap, &quot;throw away&quot; pottery (e.g., fabric-marked?).</td>
</tr>
<tr>
<td>Consumption of salt</td>
<td>Small quantities of packaging ware at consumption sites throughout the Valley of Mexico.</td>
</tr>
</tbody>
</table>
Table 5. Activities associated with saltmaking (solar evaporation method)

<table>
<thead>
<tr>
<th>Activity</th>
<th>Predictable Locational and Surficial Archaeological Manifestations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evaporation</td>
<td>May have been facilitated by preparation of artificial evaporation ponds (low earth or stone walls?) and/or masses of large, shallow ceramic basins; such vessels would show no indication of heating or burning.</td>
</tr>
<tr>
<td></td>
<td>Rough alignment of collection loci along seasonally or cyclically shifting shorelines. These loci, because of relatively high salt content, may appear as distinctly lighter zones on airphotos. Predominantly dry-season occupation should mean placement at relatively low, lakeward locations.</td>
</tr>
<tr>
<td></td>
<td>Loci may partially overlap in space with wet-season loci of insect-collection activities (see below).</td>
</tr>
<tr>
<td></td>
<td>Diffuse scatters of ceramic and lithic debris associated with short-term, seasonal occupation: some cooking implements (comales, ollas), but probably no permanent architecture or hearths.</td>
</tr>
<tr>
<td>Digging/cutting/scraping the salt crust</td>
<td>Digging/cutting/scraping activities may be manifested by broken heavy chipped-stone &quot;knives&quot;, or chipping implements, or smooth-edged scraping tools, perhaps suitable for hafting on wooden poles.</td>
</tr>
<tr>
<td>Processing the salt</td>
<td>Processing workshops probably located at or near salt sources.</td>
</tr>
<tr>
<td></td>
<td>Biggest unknowns: proportion of earth matrix and cleaning procedures required to remove dirt and other impurities; extent to which product may have been transported to more permanent workshops for pulverizing, cleaning, etc. If there was transportation in bulk, canoe accessibility would have been important.</td>
</tr>
<tr>
<td></td>
<td>Associated tools and implements difficult to predict.</td>
</tr>
<tr>
<td>Transportation of product from source</td>
<td>? (further explanation required)</td>
</tr>
</tbody>
</table>
## Table 5 (continued)

<table>
<thead>
<tr>
<th>Activity</th>
<th>Predictable Locational and Surficial Archaeological Manifestations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Packaging of product</td>
<td>Packaging may have been unnecessary if salt was removed and transported in block form. If salt was powdered prior to transport, then some sort of cheap, readily available container (ceramic, basketry, textile?) would probably have been used.</td>
</tr>
<tr>
<td>Residence of saltmakers</td>
<td>For seasonal production: virtually anywhere within a half-day's walk of the evaporation-processing loci. For permanent production: probably in the same lakeshore settlements where full-time saltmakers, using the leaching-boiling method, reside. Larger workshops might show traces of permanent residential architecture.</td>
</tr>
<tr>
<td>Consumption of salt</td>
<td>Uncertain. If ceramic packaging was used, then there should be small quantities of this ware at consumption sites throughout the Valley of Mexico.</td>
</tr>
</tbody>
</table>
Table 6. Procurement and processing of aquatic fauna and flora.

<table>
<thead>
<tr>
<th>Resources</th>
<th>Procurement Techniques</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waterfowl</td>
<td>Netting, noose-trapping, and pursuing until the birds tire and can be seized or clubbed. Canoes were in common use. Stationary nets on high poles were also employed. Both individual and cooperative techniques were used. Primarily a winter activity, but with some exploitation year-round.</td>
</tr>
<tr>
<td>Fish</td>
<td>Netting, spearing, and hooking from canoes or platforms, possibly associated with reed or twine weirs; hooks on set lines; netting in artificial pools that are emptied of water by hand.</td>
</tr>
<tr>
<td>Fish Eggs</td>
<td>Netting in shallow water, either afoot or in canoes. Apparently a year-round activity (?).</td>
</tr>
<tr>
<td>Salamanders</td>
<td>No information. Probably netted or speared.</td>
</tr>
<tr>
<td>Algae</td>
<td>Netted on water surface, or removed from there with shovels, both afoot and from canoes. Apparently a year-round activity (?).</td>
</tr>
<tr>
<td>Reeds (for mats, boats, or food)</td>
<td>No information, but presumably individually cut with knives or sickles.</td>
</tr>
<tr>
<td>Other Aquatic Plants</td>
<td>No information.</td>
</tr>
<tr>
<td>Residences of collectors</td>
<td>Small reed huts, some on floating reed platforms.</td>
</tr>
</tbody>
</table>
### Aquatic Component of Aztec Subsistence

<table>
<thead>
<tr>
<th>Processing Techniques</th>
<th>Predictable Archaeological Manifestations</th>
</tr>
</thead>
<tbody>
<tr>
<td>No information. Perhaps some butchering after capture.</td>
<td>Lakeshore and shallow lake. Thin scatter of ceramics or lithics associated with meal preparation or overnight camping at temporary residences. Obsidian blades, knives, scrapers, and debitage associated with butchering and processing.</td>
</tr>
<tr>
<td>Butchering and filleting after capture.</td>
<td>Obsidian blades, knives, scrapers, and debitage associated with processing in camps or fishing locations. Bone hooks and stone weights for lines and nets.</td>
</tr>
<tr>
<td>Cooked in metal or clay vessels.</td>
<td>Archaeological remains uncertain.</td>
</tr>
<tr>
<td>Fried, roasted, or boiled, usually with seasonings.</td>
<td>Obsidian blades, knives, scrapers, and debitage associated with butchering and processing.</td>
</tr>
<tr>
<td>Sun-dried on prepared surfaces on the lakeshore, then formed into thin &quot;loaves&quot; or cakes. Sometimes wrapped in leaves.</td>
<td>Thin scatter of ceramics or lithics associated with meal preparation or overnight stays at temporary residences around drying operations.</td>
</tr>
<tr>
<td>No information. Probably cut and dried on the lakeshore.</td>
<td>Thin scatter of ceramics or lithics at temporary residences or encampments. Obsidian blades or knives at localities where plants were habitually cut.</td>
</tr>
<tr>
<td>Some mention of cooking in ollas.</td>
<td>Thin scatter of ceramics or lithics associated with meal preparation or overnight stays at temporary residences or encampments.</td>
</tr>
</tbody>
</table>

Residue of stones, ash, and potsherds. Obsidian blades, knives, scrapers, and debitage associated with butchering and processing.
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