# AQUATIC RESOURCES USED BY THE GULF COAST OLMEC: CARRYING CAPACITY ANALYSIS BASED ON COMMERCIAL FISHING CATCH DATA

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A Thesis

Presented to

The Faculty of the Department

of Comparative Cultural Studies

University of Houston

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In Partial Fulfillment

Of the Requirements for the Degree of

Master of Arts

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By

Ernesto Maycotte

May, 2015

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## ABSTRACT

The Olmec have long been considered one of the first complex societies to develop in Mesoamerica. Scholars have traditionally believed that the Olmec relied on maize agriculture since their initial development during the Early Formative period. New research however, is providing information that is pointing to a subsistence strategy that was not dominated by maize agriculture but rather a mixed subsistence based mostly on aquatic resources. These emergent models for Early Formative Olmec subsistence have been developed primarily from the recovery of faunal remains, archaeobotanical analysis, settlement patterns, and the study of artifacts and tools. There is a need for a study to measure the availability of the local aquatic resources and the population they can support. This thesis presents a carrying capacity analysis of the fish and other aquatic resources present in the Olmec Heartland region, based on commercial fishing catch data. The end result of this study is an estimate of the population that can be supported with these resources, and a comparison of this number with population estimates for the Olmec during the Early Formative period. The result shows that aquatic resources in the region could have provided all or most of the caloric requirements of the Olmec population during their emergence in the Early Formative, and thus showing that maize agriculture does not necessarily have to be a prerequisite for complexity.

**TABLE OF CONTENTS**

## Introduction

The Olmec are considered to be one of the first complex societies to emerge in Mesoamerica (Pool 2007). Famous for their colossal carved stone heads and monumental architecture, there are still many topics of Olmec daily life that are not well understood. The Olmec developed from the Early Formative into the Middle Formative period (ca. 1500-400 B.C.) in the tropical region of the Southern Gulf Lowlands in Mexico's Gulf Coast. In an area characterized by hot and humid temperatures for the most part of the year (*tierra caliente*), there are still many unanswered questions about the origins and early development of the Olmec in this type of environment, especially concerning their subsistence base. Research has shown that the Olmec practiced extensive maize agriculture and that throughout part of their history maize was considered the most important subsistence resource (Arnold III 2009). There are also well-established theories to explain the transition of the Early Formative Olmec to sedentism and complex organization based on the reliance on maize agriculture (e.g. Coe and Diehl 1980a); in other words, these theories assert that the practice of extensive maize agriculture was a pre-requisite for complex development and that it was not until maize had become the main subsistence resource that the Olmec could then become sedentary and develop a complex culture.

Recent research, however, is challenging that well-established theory. Several scholars that have worked in the Olmec heartland region in the last couple of decades (Rust and Sharer 1988, Borstein 2001, Arnold III 2009, Killion 2013, among others) have found data that supports a different story; one in that the Early Formative Olmec had already established in villages and began developing into a complex society, well before agriculture was sufficiently advanced as to provide the necessary resources needed for a growing sedentary population. Furthermore, these data show that it was a mixed subsistence, relying mostly on aquatic resources and with maize just as a supplement in the diet, that allowed these early groups to transition, and it was not until the end of the Early Formative or the beginning of the Middle Formative that agriculture started to provide the yields needed to support the population and became the main subsistence method.

In the pages that follow, after a brief background on the Olmec culture, I present a summary of the work of several scholars that have proposed the different theories for Olmec development, from the original maize agriculture-based theory to the more recent mixed subsistence theories. These emergent models for Early Formative Olmec subsistence have been developed primarily from the recovery of faunal remains, archaeobotanical analysis, settlement patterns, and the study of artifacts and tools, and are based on one underlying assumption; that the aquatic resources in the Olmec heartland region were sufficient to support a growing population that had become sedentary and was developing into a complex culture during the Early Formative period. While this assumption seems reasonable given the apparent high productivity of the riverine and estuarine environment in the southern Gulf Coast lowlands where the Olmec first developed, none of these studies analyzes in depth the nature of the local aquatic resources, the amounts available for exploitation by local communities, and whether these amounts were enough to support the estimated Olmec population during the Early Formative period.

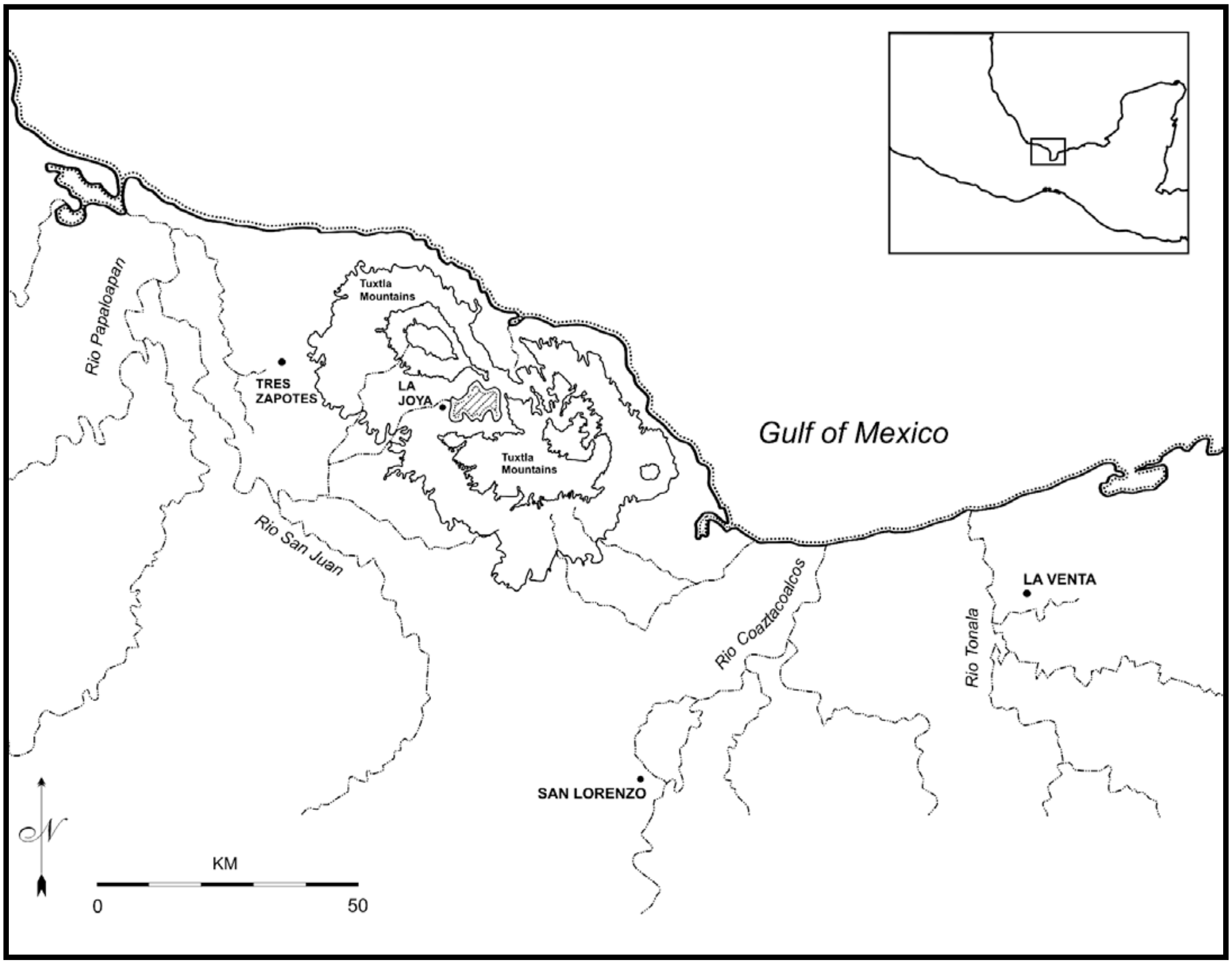
In an effort to answer these questions, I present this work, which is a carrying capacity study of the aquatic resources, primarily fish but also crustaceans and mollusks, in the Olmec heartland region. This study is based on a methodology that has been used to evaluate and measure the resource base of aquatic resources available for a non-agricultural chiefdom that flourished in southwestern Florida (Widmer 1988). The final objective of this work is to provide additional information to evaluate the viability of these emerging theories of Olmec subsistence and development by determining the population level that the fish resources available in the region could really have supported.

## **Background on the Olmec**

The Olmec culture flourished during the Early Formative period and the Middle Formative period (ca. 1500-400 B.C.) in the Southern Gulf Coast lowlands of Mexico and is considered by many scholars to be one of the first complex societies to emerge in Mesoamerica. The term "Olmec" derives from the Nahuatl word *Olman*, (or *Ulman*) which means "Land of Rubber", and its the term that the Aztecs used to refer to the region comprising the Gulf lowlands of southern Veracruz and Tabasco states; they in turn referred to the people who inhabited Olman as *Olmeca* or *Ulmeca* (Pool 2007).

The Gulf Coast Olmec region, also called the Olmec "heartland" (see Figure 1), comprises a total area of about 11,000 square kilometers and extends for close to 200 kilometers along the Gulf coast from the Papaloapan River to the west to the Chontalpa region of Tabasco and the Grijalva River to the east (Grove 1997). This region is in a tropical environment characterized by high temperatures and humidity for most of the year, and it includes the southern portion of the modern state of Veracruz as well as the west portion of its neighboring Tabasco state. It is in this area where the most extensive Olmec sites and the largest number of Olmec monuments are concentrated (Coe and Koontz 2008).

Figure 1 - Olmec Heartland region




Adapted from: Arnold III, Philip J. 2009. "Settlement and subsistence among the Early Formative Gulf Olmec." Journal of Anthropological Archaeology 28 (4):397-411, Figure 1.

The Olmec are famous for the colossal heads carved in stone and their monumental architecture as represented in their largest urban centers of San Lorenzo, La Venta, Laguna de los Cerros, and Tres Zapotes (VanDerwarker 2009, Pool 2007). San Lorenzo was the largest center in Mesoamerica during the Early Formative period, and it is estimated that it covered about 700 hectares and had a population of several thousand residents (Diehl 2005). It is considered the first capital of the Olmec and it flourished from ca. 1150-900 B.C. (Cyphers, Zúñiga, and Castro 2005), although occupation started much earlier. The name San

Lorenzo has traditionally been given to a cluster of three settlements located on an island in the swamps and marshes west of the Coatzacoalcos River and south of the Chiquito River, which is a branch of the Coatzacoalcos. The dates of occupation for the site have been established as starting ca. 1750 B.C. (what is called the Ojochi phase) during the Initial Formative, to ca. 50 B.C. during the Late Formative Remplás phase (Pool 2007). La Venta was established on an area on the far eastern frontiers of the Olmec heartland, on what is today the basin of the Tonalá River in western Tabasco state (Pool 2007). A series of radiocarbon dates from the site span the period from ca. 1200 to 400 B.C., placing the florescence of this center entirely within the Middle Preclassic (Coe and Koontz 2008). La Venta is especially important for the study of early writing systems in Mesoamerica. The La Venta Monument 13 contains four symbols that may have functioned as actual glyphs (Grove 1997), one of only two examples from the Olmec world of possible writing symbols; the other being the more recently discovered "Cascajal block", from a site near San Lorenzo. Laguna de los Cerros was the largest center in the upper San Juan River basin. Founded ca. 1400-1200 B.C., it might have covered as much as 150 ha during its initial development and was surrounded by numerous satellite villages and hamlets. Many of the twenty-eight monuments from Laguna de los Cerros date from the period 1200-1000 B.C., when the site reached its heyday and grew to about 300 ha (Pool 2007). Finally, Tres Zapotes was a center established at the western edge of the Tuxtla Mountains, covering an area of about 80 ha. It eventually grew to about 500 ha during the Middle Formative period (Pool 2007), and reached its florescence towards the Late Formative period (VanDerwarker 2009). Remarkably, the only two colossal heads that have been found at the site are believed to be from early in the Middle Formative period (Pool et al. 2010).

The sociopolitical system achieved by the Olmec is still a hotly debated issue (McCormack 2002). The discussion is shaped by the “mother culture” theory debate and relates to the complexity of the maximal stages of political organization achieved relative to their contemporaries elsewhere in Mesoamerica. By most definitions, the sociopolitical level achieved by the Olmec correspond to the upper range of complex “chiefdoms”, as supported by the recent findings that the largest Olmec polities were socially stratified and contained at least two tiers of administrative control above the level of rural hamlets and villages (Pool 2006). However, the debate continues on whether the Olmec crossed the boundary from “chiefdom” to “state”.

The “mother culture” theory proponents assert that the Olmec created a set of advanced institutions, practices, and symbols, which they transmitted to their less advanced neighbors, who in turn passed them on to their successors (Pool 2007). This theory dates back to the 1940’s, during the early days of Olmec archaeological research (Stirling 1940).

## Introduction to the general problem

The archaeological study of the Olmec culture was started in the late 1930’s by Matthew Stirling from the Smithsonian Institution (Stirling 1940), when he started excavations at Tres Zapotes, the location of the first reported Olmec colossal head. However, despite several projects since then, and an increase in the research in the last few decades, few subsistence studies have been conducted in the region, and there is a need for a better understanding of the region’s subsistence strategies during the Formative period (VanDerwarker 2006).

Rust and Sharer (1988) state that although theories about the evolution of Olmec civilization have been prevalent, archeological data useful for the evaluation of those theories has been sporadic. Research at La Venta had been concentrated on monumental architectural and sculptural remains. Investigations at San Lorenzo provided the first detailed cultural sequence for an Olmec site, but much was based on ceramics collected from redeposited construction fills. This highlights the lack of crucial settlement research that specifically targets evidence from undisturbed remains representing the full range of ancient human activities (Rust and Sharer 1988).

According to Grove (1997), after five decades of research, scholars remain in sharp disagreement on what the archaeological record means with regards to the impact the Olmec had on social and political evolution in Mesoamerica. A review of the history of the excavations in the area shows that, until recently, knowledge of the Olmec has been based primarily on two limited pre-1970 data sets. Some scholars have pointed out that data on the Olmec have accumulated slowly and unevenly, for the history of Olmec archaeology has been characterized by small periods of intensive site-specific excavations separated by long intervals of inactivity (Grove 1997).

Some of the areas of research that need further study relate to questions such as why did the Olmec culture developed at all into a complex society? What environmental factors influenced that development? And, which subsistence practices did the Olmec use during their initial development in the Early Formative period?

Many archaeologists have long asserted that the production of crops in Mesoamerica, especially maize, was a necessity for the transition to village life to allow the growth of large populations and, eventually, develop social and political complexity. Dietary reconstructions have demonstrated that this assumption is valid for the highlands of Mexico. However, few such studies have been undertaken for coastal regions, where there is also abundant evidence for early settled village life and the early appearance of complex society (Blake et al. 1992).

Borstein (2001, 2005) has also suggested that the traditional view of agriculture as the cornerstone for the early sedentary village and the subsequent emergence of sociopolitical complexity in Mesoamerica appear valid for highlands areas such as the Tehuacán Valley and the Valley of Oaxaca. Recent excavations, however, have provided data indicating that the transition from hunting and gathering to agriculture appears different in other regions of Mesoamerica. In the southern gulf coast lowlands, for example, these recent data suggests that sedentism occurred before the transition to an agricultural-based economy (Borstein 2001).

Arnold III (2009) concludes that mounting archaeological evidence suggests that floodplain resources, including fish, turtles, and waterfowl, and not maize agriculture, were instrumental in the emergence of Early Formative (ca. 1500–900 B.C.) complexity across Mesoamerica's isthmian lowlands.

Furthermore, there are other examples of groups of people in the coastal plains of the Gulf of Mexico that became sedentary by relying mostly on aquatic resources. The multi-mound site of Watson Brake in Northeast Louisiana is an example of a place where sedentary community life and large population developed relying primarily on aquatic resources (Widmer 2005). Another example is the site of Poverty Point, also in Northeast Louisiana, where sedentary life developed amongst a group of people that constructed several mounds and did not practiced maize agriculture (Widmer 2005). Finally the Calusa of Southwestern

Florida is another example of a sedentary culture relying on aquatic resources for their development (Widmer 1988).

It is out of this ongoing and very important debate, grounded in the most recent research, that I propose the present study with the aim of assessing the viability of these recent theories. These recently developed models state that aquatic resources were essential for the Early Formative Olmec and it was their use and ready availability that allowed the Olmec groups the initial transition to a sedentary life and complex society, even before agriculture could provide enough resources to sustain a growing population.

**Background on the specific problem**

Following is a literature review of the work of several scholars who have performed research in the Olmec area regarding settlement and subsistence patterns during the Early Formative period.

Michael Coe and Richard Diehl directed extensive archaeological excavations at San Lorenzo for three years, from 1966 to 1968. They were able to establish a long archaeological sequence backed up with many radiocarbon dates, and established the San Lorenzo phase (1,150 to 900 B.C.) as the period of higher development of the center (Coe and Diehl 1980a). During the project, named Rio Chiquito Project, they also conducted a study of the human ecology of the area. They researched the history of the area, its vegetation, land classification including soil analysis, as well as the relationship of the local residents with their environment. They studied local agricultural practices, as well as the nature of the relationship of the residents with the local fauna, wild and domesticated.

Subsistence practices besides agriculture were studied as well, including hunting, fishing, and collecting (Coe and Diehl 1980b). The project generated valuable information on soil productivity, land use patterns, and carrying capacity of the local environment. This carrying capacity study was based on their analysis of the soil series in the region as well as contemporary maize agricultural practices. It did not included fish, game, or other crops. They set out to calculate the number of people that could be supported by maize agriculture in their survey zone, both in modern times and in Olmec times. They calculated the maximum potential maize yield for each of the soil series present in the research area, and also determined that the Olmec would have cultivated on only two of the four soil types defined (Coatzacoalcos series soils and Tenochtitlan series soils), due to their land use patterns and available technology. In the end, they calculated that between 2,778 and 5,556 people could have been supported by the total potential maize production of the area (Coe and Diehl 1980b).

Coe and Diehl theorized that competition and maize agriculture were at the base of economic power and inequality within the Olmec, and suggested that power from Olmec elites was based on the control of highly fertile river-levee farmland. People controlling these lands would have been able to sponsor festivals and other events, as well as helping other communities in times of scarcity (Coe and Diehl 1980b). Aquatic resources were not considered to have played an important role in Olmec development because, based on the ethnographic study performed, fishing was described as a relatively unorganized activity that did not required large groups of people working together. Also, the dispersion of fishing locations and their general availability prevented the need for individuals or groups to gain control over them. Coe and Diehl stressed this point by writing that “If one is looking for entailable resources to explain the rise of the Olmec elite, fish and other aquatic life can be excluded" (Coe and Diehl 1980b).

Rust and Sharer (1988) performed important research at the site of La Venta which revealed evidence of initial occupation, from about 1750 to 1400 B.C., along levees of the silted-in Rio Bari, north of the site core in a transitional estuarine-riverine environment. They further assert that the data provides evidence for a model that presents riverine resource concentration as a significant factor in the evolution of the Olmec culture. This settlement suggests that La Venta evolved as a network of populations that exploited the rich marine resources of both estuary and river and the timing and distribution of the new La Venta evidence provide some support for a riverine resource concentration model proposed to explain the evolution of another Olmec center, San Lorenzo. Most importantly, Rust and Sharer conclude that their findings indicate that growth in population size and density in resource-rich estuarine and riverine environments preceded local emergence of social ranking or stratification and other archeological hallmarks of civilization (Rust and Sharer 1988).

Borstein (2001) has indicated that the Early Formative Olmec at San Lorenzo relied heavily on aquatic resources with a shift to maize agriculture during the Middle Formative. He reached the conclusion that it is not necessarily agriculture that allows for the emergence of sociopolitical complexity but rather a subsistence regime that permits for sedentism and sufficient surplus to support institutions. Agriculture often, but not always, fulfilled this role (Borstein 2001). The author has inferred this from a settlement pattern analysis of site location as compared to the local environmental setting. He discovered through his surveys and excavations that people within the San Lorenzo area were adapted to living near large rivers and their floodplains, and that aquatic resources were an important part of their subsistence. He also presents data that suggests maize was not very productive during the early phases of San Lorenzo (Borstein 2001).

Borstein also performed a carrying capacity analysis for the San Juan and lower Coatzacoalcos River drainages. He estimated the subsistence potential of aquatic resources from that specific region within the Olmec heartland. He followed a methodology similar to the one presented in this study, in which he calculated the amount of people that can be supported based on the available calories from the catch of certain local fish species. His source of information was an environmental impact study performed by Bozada (1986) in which local fish catch data is presented. His final conclusion was that a single fisherman in these rivers could have supported one to three people based on caloric needs (Borstein 2001).

Pool (2006) provides a clear picture of the local environment and asserts that the numerous rivers that flow out of the mountains help provide water in the dry season, increase soil fertility by depositing nutrients during annual floods, and provide abundant aquatic subsistence resources. Additionally, botanical and faunal remains indicate that a mixed horticultural/collecting economy that included maize cultivation was established in the south Gulf Coast late in the Archaic period, but Formative and later populations varied significantly in their reliance on aquatic, terrestrial, and cultivated resources (Pool 2006). This is an important study because it highlights the availability of aquatic resources in the area but most importantly establishes that botanical and faunal remains from the Formative period show a mix use of resources, and not a reliance on maize as has traditionally been suggested.

In another very important study, Arnold III (2009) presents data that supports a non-agricultural alternative to traditional models of Gulf Olmec emergence at San Lorenzo, the premier Early Formative Gulf lowlands center. He presents the results of his most recent research where he shows how these Early Formative groups were practicing a thoroughly mixed subsistence strategy, characterized by a primary reliance on floodplain resources and only limited maize cultivation. Additionally, his data on the site of La Joya indicates that maize farming was not an important economic activity throughout much of the Early Formative period. He argues that instead of an agricultural base, the control and exploitation of floodplain and wetland resources provided the foundations for the initial Gulf Olmec political economy. According to Arnold III, all these recent archaeological data from southern Veracruz highlights the possibility that floodplain resources played a much larger role in the emergence of the Gulf coast Olmec, and maize farming a considerably reduced role as previously thought. He strongly asserts that the data suggest the Gulf Olmec relied more extensively on floodplain/riparian resources than domesticated staples at the beginning and throughout much of the Early Formative period. Although maize was certainly cultivated by Early Formative Gulf lowland occupants, it does not appear to have become a staple food resource until after the development of significant socio-political differentiation at San Lorenzo. The aquatic resources provided the impetus for Gulf Olmec development until the latter portion of the Early Formative period (Arnold III 2009). If this theory is proven correct, it will be a significant accomplishment because it will rewrite long established models that identify maize agriculture as the basis for the emergence of Gulf Olmec politico-economic inequality. The data also suggest that the adoption of maize agriculture was associated with significant settlement re-organization at the end of the Early Formative period.

VanDerwarker and Kruger (2012) have also provided us with a valuable study on the relative importance of maize for the Early and Middle Formative Olmec, as well as the regional variations in its use. They used data from the site of San Carlos and provide a quantitative comparison with existing archaeobotanical data from the Olmec heartland, which has become more widely available in recent years. They used data sets from other southern Veracruz sites with components during the Early and Middle Formative, mainly La Joya and Tres Zapotes. Their analysis reveals that all sites vary considerably in their use of maize. La Joya, apparently had little use for maize during the Early Formative and did not greatly increase their maize consumption even in the Middle Formative period, when other areas were adopting it as a fundamental staple. Sixty-two percent of the Middle Formative Tres Zapotes faunal assemblage is composed of aquatic fauna, which is more comparable to that from San Lorenzo (60 percent aquatic fauna) (VanDerwarker and Kruger 2012).

The authors assert that while comparing the importance of aquatic fauna and maize separately among these sites (with the exception of aquatic fauna at San Carlos) is possible, it is difficult to know the importance of each resource relative to the other. They further propose that the denser populations in the areas around San Lorenzo (and perhaps Tres Zapotes), may have resulted in the depletion of various wild resources, inducing the inhabitants of these zones to adopt maize as an alternative food source towards the Middle Formative. Several scholars document large populations in the areas on and around the San Lorenzo Plateau during the Early Formative period, a size that may have strained the local environment. Despite this relatively heavy population density, however, the hinterland site of San Carlos shows only a moderate presence of maize. If maize were an important staple crop for the populations dependant on San Lorenzo, one would expect a much more intense presence of maize there (VanDerwarker and Kruger 2012).

The authors further propose that maize production and consumption along the southern Gulf Coast during the Early Formative and into the Middle Formative periods were at least partially linked to activities occurring around centers of sociopolitical power. Maize production may have been important around these central zones of power as a supplementary food source, perhaps necessary in order to attract political followers to the social order and/or to sustain laborers dedicated to public works. However, they also point out that the relatively small size of cobs and cupules of Early Formative *Zea mays* strains would have provided a relatively low caloric yield, so this crop had not yet crossed its "productivity threshold" and so would not have been attractive as a staple food crop at this time. Most importantly, they propose that maize, like cacao, was a prestige or luxury commodity during this period, used in rituals and feasting as part of a sociopolitical system maintaining the social order of the day (VanDerwarker and Kruger 2012).

The authors point out that what is emerging from these accumulated data is a general pattern across early coastal southern Mesoamerica of a relatively low-yield primitive maize variety being adopted by Early Formative communities, not as a subsistence crop but, rather, as an exotic commodity for use in specialized activities such as competitive feasts and ceremonies. Furthermore, while the use of maize in the Early Formative period along the Olmec Gulf Coast and the Soconusco region of Chiapas may have begun with this principal function (Blake et al. 1992), the development, evolution, or introduction of more productive forms of maize eventually changed the fundamental relationship between humans and *Zea mays* in these regions (VanDerwarker and Kruger 2012).

They conclude by stating that far more work needs to be done in order to understand the nature and importance of maize among the Early Formative Olmec. More residue studies and paleoethnobotanical comparisons need to be performed at different sites and in different cultural contexts. There is a need for more comparative studies of maize usage both between regions and between sites, and also to examine possible variations within sites (VanDerwarker and Kruger 2012).

Another recent and important study on this subject was performed by Thomas W. Killion (2013), who argues convincingly for a nonagricultural model of subsistence for the Early Formative Olmec. He focuses on the importance of differentiating the terms agriculture and gardening, and proposes that while the early Olmec consumed domesticated maize, it was in low quantities and cultivated in small gardens, rather than practicing true field agriculture. He proposes the term hunter-fisher-gardeners (HFG's) for the subsistence model of the early Olmec and asserts that maize played only a supplemental role in their diet that was mainly composed of wild fauna (especially aquatic resources) and flora with some domesticated plants, including maize.

Killion (2013) proposes that the Olmec did not begin to practice extensive field agriculture until the Middle Formative, and that the environment was abundant enough in wild resources to support the emergence of complexity among the Olmec during the Early Formative. To support his theory, Killion argues that the current archaeological evidence does not support the expectations of an agricultural model. Among other things, he mentions the lack of significant maize cobs excavated from this period, the fact that most settlement locations from this period are not situated in the best lands for practicing agriculture, and that stone tools used in agriculture and grain processing (axes, hoes, and grinding stones) and cooking vessels that would be expected from an agricultural society do not appear with the frequency expected. He also mentions the fact that is not until the Middle Formative that

Olmec iconography shows maize and related imagery with the expected frequency and importance (Killion 2013).

A very useful feature of Killion's article referenced here is that it includes, at the end, the comments from many Olmec scholars (Phillip J. Arnold III, Michael Blake, Michael D. Coe, Ann Cyphers, Judith Zurita, Marcianna Lane Rodriguez, Augusto Oyuela-Caycedo, Christopher A. Pool, Bruce D. Smith, Amber VanDerwarker) who provided him feedback, as well as agreement and criticism, on his HFG's theory. While most researchers that commented on his theory agree for the most part with the argument made by Killion, Michael Coe strongly disagreed with the conclusions reached. Coe not only explained his many reasons for disagreement, but also provided suggestions for future research on the topic. His main suggestion is "to calculate the carrying capacity of the environment of an Early Preclassic polity like that of San Lorenzo, assuming that these people practiced a mixed subsistence mode of production and not maize agriculture" (Killion 2013).

To look for examples elsewhere in Mesoamerica of Early Formative transition to sedentism and complex organization while subsisting mainly on aquatic resources is of extreme importance to understand such possible scenario in the Gulf Coast lowlands. Arnold III, in his article described above, concludes by indicating that much more research is necessary in the Olmec heartland to be able to prove or disprove this theory, and that so far, evidence of Early Formative complex development based on subsistence on marine resources has come from elsewhere in Mesoamerica, especially from the Pacific side of the isthmus, in the region known as the Soconusco (Arnold III 2009).

One such study on the Soconusco region during the Early and Middle Formative period has been carried out by Rosenswig (2006). The findings showed that the overall diet was very broad-based with extensive resources exploited from the nearby swamp and estuary systems. During the Middle Formative a transition took place to increased plant production. Therefore, there was over half a millennium during which these villagers developed political rank prior to the adoption of agriculture. The available data suggests that some of these archaic inhabitants of the region were sedentary and that this was possible due to the rich local environment of closely packed river, swamp, estuary, and tropical forest (Rosenswig 2006).

Another such study in the Soconusco area was carried out by Blake and colleagues (1992), in which they find a large number of fish remains, as well as frequent finds of ceramic fishing-net weights and bone hooks, which led them to think that river and swamp fishing was of primary importance in Early Formative subsistence in the Mazatan zone of the Soconusco. The groups in the area seem to have relied on the brackish/freshwater swamp and estuary species. They continue by stating that for the Early Formative in the Mazatan zone, the pattern is clearly one of permanent sedentary villages subsisting primarily on fishing and hunting and gathering. Although research indicated that they had access to some maize, it was not an important part of the diet. Analysis of faunal remains representing a wide range of estuary fish and amphibians, terrestrial animals and birds further demonstrates that these villagers derived a large part of their diet from naturally available resources (Blake et al. 1992). The researchers argue that the Early Formative people of the Mazatan region were among the first Mesoamericans to undergo the transformation to chiefdoms. The results of this study show that this transformation took place in the context of a largely hunting-fishing-gathering economy, with only minor reliance on maize. They conclude that in certain environments, such as rich estuaries and marine settings, large sedentary populations with complex social and political organizations could be supported without significant reliance on the agricultural production of maize. This pattern has been identified for only a few prehistoric people in the New World, for example various tribes along the Pacific Northwest coast of North America, the Calusa of southwestern Florida, and some groups of coastal Peru (Blake et al. 1992).

The Calusa of southwestern Florida that Blake and colleagues mention as an example of a group that developed complex social and political organizations without relying on agriculture has been thoroughly studied by Widmer (Widmer 1988, 2005). Based on his research he found that environments like barrier islands, lagoons, and swamps, are conductive to the development of large, dense populations and that since these types of environments are present along the coastal plain of the Gulf of Mexico, they should have functioned as important high-food-density natural foraging habitats. These environments provided an increased amount of natural food resources such as fish, reptiles, and crustaceans. In addition, populations can become larger and denser as the food supply increases and becomes reliable and more accessible in these environments (Widmer 2005).

Regarding the Gulf Coast Olmec, Widmer (2005) points out that maize might have been merely a carbohydrate complement to a largely faunal (fish and reptile) diet in the early years of Olmec culture. Although maize was domesticated by 6000 B.C. and remains of it have been found in the Olmec area, there is a lack of complex sociopolitical development in the Archaic period, whereas it occurred in the later Formative period (Widmer 2005). He continues by stating that nowhere in Mesoamerica sedentary habitation, monumental architecture, or ceramics emerge until after about 1500 B.C., the beginning of the Formative period, in spite of the fact that maize and other crops were clearly domesticated thousands of years before and were grown in the Olmec region. He further states that before 1500 B.C., the ability of any domesticated crop to support a population large and dense enough to develop a chiefdom with monumental architecture is suspect. He concludes that the underlying explanation for the rising population size and density in the Formative is its adaptation to highly productive aquatic environments in the Gulf Coast, with complementary rich alluvial soils well suited to maize agriculture (Widmer 2005).

## Objective

As stated above, my objective with this study is to estimate the population levels that could have been supported by the fish component of the aquatic resources in the Olmec heartland region. I whish to contribute to the discussion on the importance of aquatic resources as sustenance in the Early Formative and the Gulf Coast Olmec's possible reliance on these resources to transition to sedentary life and complex organization even before agriculture was advanced enough to provide the required resources of a growing population. With this study, I also attempt to follow through with Michael Coe's main suggestion for future research in this topic, as stated above, of performing a carrying capacity analysis of the local environment assuming a subsistence mode not based on maize agriculture.

It is clear from the articles referenced above that this is an important and current topic in Anthropology and Archaeology because it has far-reaching implications for well-established models of development in Mesoamerica. This new model is providing an alternative scenario for the development of Formative cultures in Mesoamerica that is not based on maize agriculture, especially in lowland coastal areas.

Most of the studies referenced above that support this proposed new model were based on analysis of faunal and botanical remains or on settlement patterns for the Olmec. Most of them are assuming that the perceived abundance of aquatic resources in the region would have been sufficient to support the emergent Olmec and the population increase that accompanies the development in to a complex society. While this is a reasonable assumption to make, given the highly productive riverine and estuarine environment in the region, there is a need for an analysis that specifically addresses the actual magnitude and availability of these resources and to determine the amount of people they could have supported. This project provides such analysis via a carrying capacity study of the fish component of the aquatic resources in the Olmec heartland area.

My approach is based on the methodology used by Randolph J. Widmer to study the Calusa of southwestern Florida (Widmer 1988). The Calusa was a non-agricultural chiefdom that developed in the southwestern coast of Florida from the Charlotte Harbor area southward, and which principal town, Calos, is thought to be the site of Mound Key, a shell mound complex in Estero Bay (Widmer 1988). Widmer used commercial fish catch data from the Florida counties representing the area where the Calusa flourished, to determine the approximate amount of fish resources available for human consumption in the region. He gathered commercial catch data from 1966 to 1975 for a selected number of coastal fish that had been determined, from archaeological excavations, to have been important to the Calusa (Widmer 1988).

The use of longitudinal data for a ten-year period of fishing catch in the region minimizes seasonal variation and is useful to provide a rough calculation of the carrying capacity of the local ecosystem as it pertains to fish resources. In addition, it shows trends in yield through time as a result of contemporary fishing methods. If the yield remains fairly constant or if it increases, it can be assumed that the catch rate is not impacting the availability of the specific resource in the area of study; in other words, the rate of catch is sustainable (Widmer 1988). With mean annual fish catch data, in kilograms, estimated for the relevant species, the caloric contribution from the usable fish meat was estimated using U.S. Department of Agriculture data. Finally, with the amount of calories available from fish resources on an annual basis, an estimate of the population that could be supported by these resources was calculated (Widmer 1988).

This methodology was used because of the similar environments in which the Calusa and the Olmec developed. Although the Calusa did not practiced agriculture, and it is clear that the Olmec eventually practiced extensive agriculture, the application of this method on the Olmec is still valid because the hypothesis being tested is that the Early Formative Olmec achieved sedentary status and a level of complexity without relying on extensive agriculture to satisfy a significant portion of their caloric needs. The fact that later, during the Middle Formative, agriculture techniques advanced enough as to provide more resources and eventually replace aquatic resources as the main sustenance, does not impact the validity of this project or the methodology being used.

## Methodology

As I have mentioned, this work is a carrying capacity analysis of the fish and other aquatic resources in the Olmec heartland region, using as a guide portions of the methodology used by Widmer (1988) pertaining to fishing and fish resources.

The main variables utilized in my study are:

- Recent fish catch data from the region: I gathered the fish catch figures from the last ten years from the states of Veracruz and Tabasco, using official sources from the Mexican government, specifically from the *Comisión Nacional de Acuacultura y Pesca* (CONAPESCA), which is the Mexican government agency tasked with capturing and publishing statistical data regarding fishing and aquaculture across the country. CONAPESCA produces enough detailed information allowing me to narrow down the figures to the specific information needed, including fish catch data by region in each state, which will allow me to collect the numbers only for the approximate Olmec heartland region. It also gives the statistics for each specific fish caught, allowing me to correlate with zooarchaeological information collected in the field by many of the researchers mentioned above. Having the details for each specific fish will also allow me to "clean" the data – take out the fishing information that should not be part of the analysis; deep sea fishes, for example.
- Nutritional contribution from fish resources: Once the fish catch data has been narrowed down to the desired detail as explained above, it needs to be transformed to nutritional information, to determine the available calories, and finally the number of people those calories could support. It is here that I follow Widmer's (1988) method to calculate the quantity of edible flesh or percentage of usable meat, the amount of calories available in this edible meat, and the number of people that could be supported by these calories in a given timeframe.
- Population estimates for the Olmec heartland region: The carrying capacity figure calculated from the step described above was compared to published estimates of the

population in the region during the Early Formative. At the end this work will produce an estimate of the population that the fish resources could support in the area, and this can be used to asses the viability of the emerging models for a non-agricultural based economy for the Olmec during the Early Formative, by comparing it with population numbers estimated from the ongoing archaeological work in the region.

In addition to the main variables described above, I use the following supporting information in my analysis:

- Description of local riverine /estuarine environment: summary of the main physiographic characteristics of the local ecosystem to describe its high potential for aquatic resource procurement.
- Modern fishing practices in the area: description of current fishing techniques and equipment used by local populations.
- Fishing technology used by the Olmec: description of fishing implements recovered during archaeological excavations.
- Aquatic fauna remains recovered during archaeological excavations: a summary of the aquatic species that have been identified during excavations at several Olmec sites.

## **Description of local environment**

The Olmec developed and flourished in the tropical coastal lowlands of the southern Gulf Coast, in what is now southern Veracruz and western Tabasco states. Archaeologists have traditionally called this region the "Olmec heartland" (Pool 2007). The region falls within what is officially classified as *Provincia Fisiográfica XIII – Llanura Costera del Golfo Sur*, or Physiographic Province XIII - Coastal Plain of the Southern Gulf, which is characterized for the most part, as its name implies, by coastal lowlands where hot temperatures and high humidity dominate (INEGI 2014).

The broader area comprised by both Veracruz and Tabasco follows virtually the same weather pattern except for a small portion of Veracruz with less humidity and milder climate located in the west-central part of the state (INEGI 2014). Veracruz and Tabasco combined have an area of approximately 96,500 square kilometers, representing almost 5% of the total area of Mexico. Located adjacent to the Gulf, they have a combined coastline length of 920 km. The National Institute for Statistics and Geography of Mexico - INEGI – classifies the Mexican territory into five types of natural regions or environments: Temperate, Tropical Humid, Tropical Dry, Arid, and Semiarid. One hundred percent of the territory of Tabasco is classified as Tropical Humid, with a mean annual temperature in the range of 22 to 28 degrees Celsius and with an average annual rainfall in the range of 1,500 to 4,500 mm, making it the state with the highest amount of precipitation in all of Mexico (INEGI 2014b). As for Veracruz, 70.5% of its territory falls in the Tropical Humid classification, with the rest classified as Tropical Dry (17.8%), Temperate (11.5%), and a small fraction (0.2%) as Semiarid. Due to all the environment types represented in the state, its mean annual temperature ranges between 0 and 28 degrees Celsius, depending on the region, and the average annual rainfall ranges between 500 to more than 4,500 mm. In the southern portion of the state however, where most of the Olmec heartland is located, the mean annual temperature ranges between 20 and 28 degrees Celsius, and the average annual rainfall from approximately 1,500 to more than 4,500 mm. One of the regions with the highest level of precipitation in Veracruz is the Tuxtla Mountains and surrounding area, which is located inside the Olmec heartland and where several important Olmec centers are located (INEGI 2013, Pool 2007). The heavy precipitation of the Olmec heartland is not limited to the rainy season, which occurs from late May through November, since the dry season can bring heavy rainfall as well and is generally very poorly defined. From December at the start of the dry season and through March, cold, wet *nortes* arrive through the coast at fairly regular intervals, bringing consistent rain. Only April and May bring really dry weather, and this time is generally the hottest of the year (Coe and Diehl 1980a).

Some of Mexico's largest rivers flow through Veracruz and Tabasco. From the Pánuco in northern Veracruz to the Usumacinta in eastern Tabasco, these rivers are part of extensive basins and create large deltas where they flow into the Gulf of Mexico. Table 1 lists the major rivers flowing through Veracruz and Tabasco on their way to the Gulf of Mexico sorted by volume of average annual runoff. Listed is also the area covered by the basins of each river, as well as the length. Some rivers, like the Usumacinta for example, do not originate in one of these two states, so portions of it are outside the study area. Similarly, portions of the basins of some of the rivers lie outside Veracruz or Tabasco (INEGI 2014). Nonetheless, it is clear from the number of large rivers flowing through the area, the extension of their basins – 264,237 $km^2$, which equals about 13.5% of the total area of Mexico – as well as from the precipitation figures described above, that this is an area with plenty of water resources and a high potential for human exploitation of aquatic resources for consumption.

Three of the five largest rivers by volume run through the Olmec heartland. These are the Papaloapan, Coatzacoalcos, and Tonalá (shown in table 1 in bold letters). The Olmec heartland covers approximately 11,000 $km^2$ and has the shape of a semicircle formed by the four major Olmec sites of Tres Zapotes, Laguna de los Cerros, San Lorenzo, and La Venta running west to east from the Papaloapan river to the Tonalá basin (Pool 2007). Although some of these rivers originate outside the area, by the time they reach their lower courses near the Gulf Coast in the Olmec heartland, the river channels are deep and smooth and the speed of the water is slow, forming wide basins and deltaic systems. In some of these basins, the heavy rain during the rainy season transform the entire region into a system of shallow lakes with only a few areas remaining above the floodline (Borstein 2001).

**Table 1 - Major rivers flowing through Veracruz and Tabasco**

| River | Average Annual Runoff ($hm^3$) | River Basin Area ($km^2$) | Length (km) | Veracruz / Tabasco |
|---|---|---|---|---|
| Grijalva - Usumacinta | 115,535 | 83,553 | 1,521 | Tabasco |
| **Papaloapan** | **42,887** | **46,517** | **354** | **Veracruz** |
| **Coatzacoalcos** | **28,679** | **17,369** | **325** | **Veracruz** |
| Pánuco | 19,673 | 84,956 | 510 | Veracruz |
| **Tonalá** | **11,389** | **5,679** | **82** | **Tabasco** |
| Tecolutla | 6,098 | 7,903 | 375 | Veracruz |
| Nautla | 2,218 | 2,785 | 124 | Veracruz |
| La Antigua | 2,139 | 2,827 | 139 | Veracruz |
| Tuxpan | 2,072 | 5,899 | 150 | Veracruz |
| Jamapa | 2,066 | 4,061 | 368 | Veracruz |
| Cazones | 1,712 | 2,688 | 145 | Veracruz |

In addition, the fourth largest natural lake in Mexico, by volume capacity, is located within the Olmec heartland. Lake Catemaco, with a volume of 454 $hm^3$ and a basin area of 75 $km^2$, is situated in the Tuxtlas region of Veracruz. This region is comprised by the volcanic peaks of the same name and the area around them (Pool 2007), and is the only geologic feature within the Olmec heartland that breaks the lowland plains characteristic of the region. This is an ecologically diverse region abundant in faunal and floral resources, the result of regional climatic variables such as high temperatures, frequent rainfall, and year-round frost-free conditions. In addition, its rich soils derived from volcanic activity make the Tuxtlas an ideal place for the practice of agriculture (VanDerwarker 2005).

This brief description of the local environment provides a background for subsequent information and discussion about available aquatic resources in the area and their potential for human sustenance. It is clear that the local climate, geography, and hydrology features combine to create the conditions for a landscape abundant in fish and other aquatic resources that human groups in the region continue to exploit.

## Modern fishing practices in the Olmec heartland area

Current inhabitants of the Olmec heartland area still take advantage of the riverine and estuarine environment described in the previous section to obtain part of their sustenance. Fishing is an important activity and is practiced not only at a bigger commercial scale but also in a more local artisanal way. The level to which fishing contributes to the local diet has varied over time and across regions and on some specific areas has declined dramatically in recent decades, for example in the San Lorenzo Tenochtitlan area (Coe and Diehl 1980b). The reasons for these declines are numerous but for the most part have to do with alterations to the physical environment and pollution (Bozada and Paez 1986, Coe and Diehl 1980b).

When Michael Coe and Richard Diehl excavated at San Lorenzo and also conducted human ecological research of the area in the 1960's, fishing was still a very important activity and far more significant than hunting to obtain animal protein. Most families carried out the activity on a year-round basis to obtain fish both for personal consumption and for selling at the local market. They also report that there were even a few people that were full-time fishermen who moved up and down the river channels and sold their catch at the local market (Coe and Diehl 1980b).

The local inhabitants of the San Lorenzo Tenochtitlan area make extensive use of the Rio Chiquito system, both for fishing and as a means of communication. From it they extract several very desirable fish species like Atlantic tarpon, Snook, different types of catfish, Gar, several species of Cichlids or *Mojarras* as well as turtles. Most of the fishing seems to be performed using nets. Three types of nets are used; the seine or *paño,* the cast net or *atarraya,* and the dip net called *matayahual* (Coe and Diehl 1980b). The use of a *paño* is a more communal activity, as several people are required to set up the net and then to frighten the fish towards the net by beating the water with poles. The catch is then split among the members of the seining party. Fishing with an *atarraya* or a *matayahual* is often an individual or two-person endeavor, and in the case of the *atarraya* is usually done from a dugout canoe were one member casts the net while the other paddles (Coe and Diehl 1980b).

Other fishing technology reported by Coe and Diehl includes the fish and turtle trap, harpoons, and vegetable poisons. The trap has a barrel shape and is called a *naza*. It is constructed out of vine and bamboo in such a way that when fish or other fauna enters the trap, it is difficult for them to come back out. Harpoons usually have a head made of iron, and have a socket and a barb, that allow the harpoon head to detach when it hits the target, and then the fish is played from a cord. Finally, fish are also caught by poisoning them with vegetable poisons. Locals use the term *barbasco* to refer to two types of vegetable poisons from the area. Vines of these are cut up and pounded with rocks or sticks in the water of small ponds to release the venom (Coe and Diehl 1980b).

Kruger (1996) also reports on the importance of fish and other aquatic resources such as birds and turtles for the modern residents of the Olmec heartland region. These resources are available throughout the year, although the strategies to capture them must change according with the seasonal conditions. Fishing equipment such as hand-held, thrown, and dragging nets are all being used by different members of the communities. Particularly productive for them are the oxbow and other small lakes where fish and turtles get trapped as waters recede and they become easier to catch, and these current residents of the area willingly travel several kilometers to take advantage of good fishing spots (Kruger 1996).

All across Mexico, groups of both *mestizo* and indigenous populations still practice small-scale fishing. Brockmann (2004) presents a thorough examination of fishing techniques practiced by Mexico's contemporary indigenous population. Two of the largest indigenous groups still inhabiting the Olmec heartland area are the Popolucas in southern Veracruz and the Chontales in Tabasco. The Popolucas use harpoons, which they call *kapi,* similar to the ones described earlier, in which the metal tip with a hook detaches from the wooden shaft when it hits the fish. The hook and the shaft are tied together by a rope, which is used to bring in the catch. A similar implement, but with no hook at the end, only the metal tip, is used to harpoon turtles. They also use bow and arrow to fish. Their arrows, which they call *piksi,* are usually 2 meters long and are made out of reed (*carrizo*), with a metal wire tip. The bows, called *jimba*, are 1 to 1.5 meters long. Popolucas also use the *barbasco* venom described earlier, obtained from toxic plants and dispersed in the water, after which the fish are killed or numbed and float to the surface, where they are easily gathered. They also use traps, especially to capture shrimp, and the *atarraya* net described earlier. Finally, Popolucas also use modern commercial metal hooks tied to nylon monofilament line to fish. They do not use a rod though, just hand lines; they just grab the line directly and wait for the fish to bite the bait in the hook (Brockmann 2004).

As for the Chontales in Tabasco, Brockmann reports the use of lances or spears that can have one or more tips and are thrown from dugout canoes or from rocks in the rivers. They also use the fishing traps or *nazas*, and the *atarraya* net. Finally, Chontales use modern lines and hooks, just as Popolucas do (Brockmann 2004).

Significant amounts of the fish resources harvested in the region by the peasant population are traditionally dried and smoked to prepare them for prolonged storage and then also used for family consumption as well as for sale (Cyphers and Zurita-Noguera 2012). They are processed with slow heat and smoke after briefly soaking them in salt water, a technique that discourages bacterial growth and extends preservation time. Drying and smoking these protein resources is critical to the local population to better withstand the annual crisis time, which extends from July to October, during the mid-summer drought and subsequent high flood. The mid-summer drought, occurring after the rainy season, is characterized by high water in the rivers, decreased rainfall, and high temperatures. Fish and turtles disperse in the high volume of water and are difficult to catch. The same happens during the largest annual flood in late September to October. In addition, this period is also one of maize scarcity, because upland crops have just been planted in June and the stored reserves from the last harvest have been almost depleted. Surviving this long hardship periods requires the procurement and preparation of storable sources of calories (Cyphers and Zurita-Noguera 2012).

## **Olmec fishing technology**

Coe and Diehl (1980a) reported that no archaeological remains of fishing equipment were found during their excavations. They suggest though, that natural materials that are used in historic times to make traps and nets were also very likely used in prehistoric times. Likewise, modern fishing methods used locally, like angling and netting, could have very likely been used in Olmec times (Coe and Diehl 1980a). Olmec fishing gear likely included dugout canoes that were probably waterproofed with bitumen, lines, bone hooks, spears, and nets (Coe and Diehl 1980b). They do discuss though, the finding of several potsherds of various shapes and sizes and which are sometimes drilled. They suggest that at least one type of these sherds may had functioned as a net weight (Coe and Diehl 1980a).

Carl Wendt unearthed this same type of potsherds during his excavations at the sites of El Bajio and Paso de los Ortices, in the San Lorenzo Tenochtitlan region. He referred to these artifacts as bow-tie shaped notched sherds (Wendt 2003). During the excavations, 65 of these types of potsherds were discovered. All of these are roughly oval in shape, with most of them having notches on their long side, and all were worn around their edges, especially at the notches. The notches were used to tie something around the sherd's center, and the pattern of wear suggests they were ground against an abrasive surface or substance, like sand or clay, suggesting their use as fishing net weights (Wendt 2003, 2005).

Wendt also excavated remains of *chapopote* or bitumen, which is a tar-like substance that could have served many purposes. One of these could have been, as Coe and Diehl also wrote, to waterproof canoes and other watercraft (Wendt 2003, 2005, Coe and Diehl 1980b).

**Aquatic faunal remains recovered during archaeological excavations**

In this section I present information on the aquatic fauna remains unearthed from several archaeological excavations in the Olmec heartland area. I will list not only information on fish (and crustaceans and mollusks, if available), which are the main topic of this study, but also of other aquatic mammals, birds, reptiles, or amphibians, to have a more complete picture of how the Olmec took advantage of the highly prolific riverine and estuarine local environment.

During excavations at San Lorenzo, Coe and Diehl uncovered the skeletal remains of several species of animals. From these remains, the most abundantly represented animals are the Narrow-bridged Musk Turtle (*Claudius angustatus*), and the Snook (Centropomidae) (Coe and Diehl 1980a). Table 2 below lists the aquatic fauna uncovered during their excavations.

Table 2 - Faunal remains from excavations at San Lorenzo

| **Fish** | | **Other aquatic fauna** | |
|---|---|---|---|
| Scientific Name | Common name | Scientific Name | Common Name |
| *Megalops atlanticus* | Tarpon | Anatidae | Ducks and other waterfowl |
| Ariidae | Sea catfishes | *Bufo marinus* | Marine toad |
| *Rhamdia guatemalensis* | Neotropical catfish | Dermatemyidae, Chelydridae, Testudinidae | Turtles |
| Centropomidae | Snook | | |
| Lutjanidae | Snappers | | |
| Cichlidae | Mojarras | | |
| Carangidae | Jacks | | |

Archaeological excavations conducted by Kevin Pope and colleagues at the site of San Andres also uncovered the remains of some aquatic fauna used for consumption. The small site of San Andres, in the state of Tabasco, is located 15km south of the coast and 5 km northeast of La Venta (Pope et al. 2001). Table 3 summarizes the findings.

Excavations in the Tuxtla Mountains region of the Olmec heartland have also yielded aquatic faunal remains. Projects conducted by Amber VanDerwarker at the sites of La Joya and Bezuapan, located about 20 km south of the Gulf Coast in the Tuxtlas, produced remains of fish, amphibians, reptiles, birds, and mammals (VanDerwarker 2006). Table 4 summarizes the findings of aquatic fauna at these sites.

**Table 3 - Faunal remains from excavations at San Andres, near La Venta**

| **Fish & Mollusks** | | **Other aquatic fauna** | |
|---|---|---|---|
| Scientific Name | Common name | Scientific Name | Common Name |
| *Lepisosteus* | Gar | *Trichechus manatus* | Manatee |
| *Rangia cuneata* | Marsh clam | | |
| *Ostrea* | Oysters | | |

**Table 4 - Faunal remains from excavations at La Joya and Bezuapan, in the Tuxtla mountains**

| **Fish** | | **Other aquatic fauna** | |
|---|---|---|---|
| Scientific Name | Common name | Scientific Name | Common Name |
| *Lepisosteus spatula* | Alligator gar | Anatidae | Ducks |
| Catostomidae | Sucker family | *Bufo* | Toad |
| Pimelodidae | Catfish family | *Rana* | Frogs |
| Centropomidae | Snook | *Staurotypus triporcatus* | Mexican giant musk turtle |
| Lutjanidae | Snappers | Emydidae | Box/pond turtle family |
| Cichlidae | Mojarras | *Iguana iguana* | Green iguana |
| Carangidae | Jacks | | |

The site of Tres Zapotes has also yielded numerous aquatic faunal remains. Tanya Peres and colleagues summarize and discuss the faunal remains discovered at this site during excavations led by Christopher Pool in 2003 (Peres, VanDerwarker, and Pool 2010). Table 5 below presents the aquatic fauna recovered at this site.

Table 5 - Faunal remains from excavations at Tres Zapotes

| **Fish** | | **Other aquatic fauna** | |
|---|---|---|---|
| Scientific Name | Common name | Scientific Name | Common Name |
| Ariidae | Marine catfish | *Trichecus manatus* | Manatee |
| Ictaluridae | Catfish | Testudines | Turtles |
| Pimelodidae | Catfish – flat-nosed and long-whiskered | | |
| *Mugil* | Mullet | | |
| Lutjanidae | Snappers | | |
| *Centropomus* | Snook | | |
| *Caranx hippos* | Jack crevalle | | |
| Chondrichthyes | Sharks, rays, skates | | |

**<u>Carrying Capacity Study based on commercial catch data from Veracruz and Tabasco</u>**

I have described in the initial section of this work how emerging models for Early Formative Olmec subsistence call for a non-agricultural-based economy, which instead relied heavily on aquatic resources to support the Olmec's rise into complexity. In the description of the environment of the area, I have presented information that illustrates how the hot and humid climate of the area, the heavy rainfall, and its numerous rivers with extensive deltas and large basins create a riverine and estuarine environment with high potential for aquatic resource exploitation. I have also described the current or recent fishing practices of the local population to show that this is still a very important economic and subsistence activity in the area, as well as the available evidence for fishing implements and technology that may have been used by the Olmec. I then described the species of fish and other aquatic fauna recovered from recent archaeological excavations in the area. In this section I now present the central work of this thesis, which is a carrying capacity analysis of aquatic resources in the region, based on species and volume reported on official commercial catch data.

The methodology used in this analysis is based on the one used by Dr. Randolph Widmer (1988) in his study of the Calusa, a non-agricultural chiefdom on the southwest coast of Florida. The method's objective is to calculate the approximate population that can be supported with the available calories produced from the commercial catch volume of fish and other aquatic resources in the study area. The main steps of this methodology are:

1. Gather the information on fish and other aquatic resources from official commercial catch data reports for the study area. The information needs to be longitudinal, meaning it has to cover more than just a few years, so as to reflect any short-term trends in volume.
2. The next step is to obtain information on meat yield percentages for the species in the report. The raw data from the commercial catch reports contains information on volume based on "live weight", or kilograms of resources procured. However, only a portion of that total weight is considered to be "edible flesh".
3. Having calculated the total volume of edible flesh, the next step is to obtain information on the amount of calories available in each kilogram of edible flesh. This information should be obtained, as much as possible, for each specific species of fish and other resources being considered in the data. Multiplying these figures by the

kilograms of edible flesh will give us the available calories from the total volume of usable meat.

4. The final step is to calculate the number of people that can be supported by the available calories. The amount of available calories per year is divided by the amount of calories needed by a human in a year.

Gathering the catch data

The most reliable source for fish catch data from Mexico is the official commercial catch data reported by the Mexican government through its Ministry of Agriculture, Ranching, Rural Development, Fishing, and Nutrition - *SAGARPA* as is known in Mexico. The fishing portion is managed by a department of *SAGARPA* known as *CONAPESCA*, which is the National Committee on Aquaculture and Fishing. This department produces an annual report, called *Anuario,* with extensive statistics on fishing and fish farming presented both by the most important species of aquatic resources (commercially speaking) as well as by state. This report is available for downloading in PDF format at CONAPESCA's website. Along with the formal report, or *Anuario*, they also provide a database that can be downloaded in Excel format. This of course served the purpose of this analysis better since the data was already summarized by state, species, volume, and other helpful fields that made it easier to manage and analyze. If these were not available, and the data had to be extracted directly from the *Anuarios* in PDF format, it would have been an extremely tedious and time-consuming endeavor. Of course, as can be expected, the database contains many issues and errors, and the analysis was not straightforward. I will be discussing the issues encountered with the data and how they were overcome throughout this section.

As mentioned above, we need longitudinal data, so I performed this analysis with the available information for the past 10 years. The latest database available at the time of this writing was for 2013, so this analysis is based on data from 2004 to 2013. After an initial analysis of the data, two important issues became apparent; the first one was that the databases do not contain a field for the scientific name of each of the species in the report. This of course is a big challenge when trying to correctly identify a species and obtain the common name in English. Anyone familiar with fishing in Mexico or fishes of Mexico knows that one type of fish can have multiple common names in Spanish, and that these common names change region to region. Furthermore, several of the most widely used common names in reality encompass several different but related species of fish, each with its own common name that can change region by region. This makes the task of obtaining the correct scientific name and English name for each species difficult and prone to errors.

The second big issue with the initial dataset is the level of geographic detail for the information. Only the state in Mexico where the resource was procured is given; there is no additional detail as far as region or area within a state, for example municipality. This creates a problem because although the Olmec heartland is confined to two Mexican states; Veracruz and Tabasco, it only covered the southern portion of Veracruz and a small section of western Tabasco. Using the information as is would mean to consider the catch volume for all of Veracruz and all of Tabasco, or alternatively, trying to perform a rough transformation based on the area covered by the Olmec heartland versus the complete area for both states.

Fortunately, a solution was found so solve these two initial problems. After further inspection of CONAPESCA's website, I found an online search tool that allows searching for catch volume specifying several different criteria, like year, state, and species or *Nombre*

*Principal,* which is the most widely used common name for that type of fish. In addition, there is another field called *Nombre Comun* which lists all of the common names for the species of fish cataloged under the main common name or *Nombre Principal*. The most valuable aspect of this feature is that once you do a search, the actual scientific names for all of the species under that main common name appear on top of the search results table. Lastly, this search tool has another field called *Oficina* or Office, which indicates the regional office of CONAPESCA that recorded and reported the catch volume for that specific region within the state. This allowed for further definition of the data selected for this analysis based on the offices located within the Olmec heartland. I will discuss the selection of the specific offices later in this section.

Further search within CONAPESCA for an Excel database with the information used by the search tool proved fruitless. There was no success either in finding a database that integrated all the information found both on the search tool and on the database initially consulted which was part of the annual reports. Given the importance of the scientific name and office information provided only through the online search tool, I decided to use this information instead of the databases downloaded originally. I started performing searches by state and main common name, and then copying and pasting the information of the search results into an Excel spreadsheet. At the end, the tedious and time-consuming work could not be avoided.

After compiling my own database with information from the search tool containing all the details needed, my first priority was to develop an accurate list of all the species of fish and other aquatic resources reported for Veracruz and Tabasco with correct scientific and English name. The initial list contains 48 types of fish, crustaceans, mollusks, and echinoderms caught and reported within the two states (see table A1 in Appendix A). It is important to note though, that the database contains two additional lines; one is classified as *Fauna de Acompañamiento,* which refers to the incidental catch of fish and other fauna by the shrimping fleet. The total catch volume in this category is very low, and there are no additional details given as far as the specific species included in this classification. The catch volume in this classification was not included in this analysis. The second line is simply named *Otras*; "Other". This line contains considerable volume distributed among many species. The details for the species included in this classification and their scientific names are included in the database. Later in this section I explain in detail how I determined the species from *Otras* that were included in the study.

Of course, not all of the species in this original list were part of the final analysis. To be able to refine the list, I first needed to ascertain the correct identification, by scientific name, of each species in the list. As mentioned above, when conducting the online search, the scientific name or names were provided, however, when investigating that information for the purpose of corroboration and to identify the common name in English, many issues were encountered. There were numerous cases where some of the scientific names provided belonged to related species native to the Pacific Ocean. In some cases even species inhabiting only in the North Sea or Mediterranean were provided. Fortunately I was able to find other official sources of information on fish species from the Mexican Gulf Coast containing details such as common and scientific names. One particularly useful source was the website for CONABIO, which is the government's National Committee for the Study of Biodiversity. It contains an extensive searchable database of fish from all regions of Mexico. With the correct scientific name identified for each species, the common name in English was easy to obtain.

I had now the information needed to refine the list until only the species that should be part of the study were left. I classified each species either as In Scope or Out of Scope. The first big cut was easy to do; all of the volume procured through aquaculture or fish farming was filtered out. This procedure was straightforward because the original data from CONAPESCA already classified each record as either aquaculture or wild caught. By applying this filter, some of the fauna were automatically removed. The one with the biggest volume was Tilapia (*Tilapia* genus), which was included under the *Mojarra* (*Cichlids*) category. Tilapia is an imported fish originating in Africa and the Middle East that has become very important in the aquaculture industry of Mexico. Another example is the Rainbow Trout (*Oncorhynchus mykiss*), which is being farmed in some regions, especially the highlands of Central Mexico. Finally, considerable volume of farmed oysters and shrimp were removed as well.

With only the wild caught volume left, which represents about 60% of the original total volume, I then identified and assigned as Out of Scope a few species that have been introduced to the region. One was the Common Carp (*Cyprinus carpio*), which is a freshwater fish native to Europe and Asia. The other one was the Largemouth Bass (*Micropterus salmoides)*, which in Mexico is only native to the Northeast area of the country. I was now left with a list of aquatic resources native to the region and with catch volumes representing only wild capture. The next step was to select only the resources that could have reasonably been procured by the Olmec. This meant filtering out oceanic species that are caught for the most part offshore in the deep sea. The end result is a list of 26 in-scope resources that either live in freshwater, or that inhabit or spend considerable time in estuaries, coastal lagoons, or inshore.

I have mentioned that the database contains one classification named *Otras,* where a large number of species are grouped, mostly with very low catch volumes. All the volume in this group is classified as wild-caught, and it represents a significant portion of the total catch volume for both states combined. In fact, considering only the wild-caught volume, the group *Otras* has the highest volume, being almost 4 times that of the second highest which belongs to the swimming crabs (Portunidae). Considering this numbers, this group cannot simply be ignored and left out of the analysis. There are a total of 180 species classified within this group. This, however, represents only 40% of the total volume within *Otras*, creating another complication. The other 60% is classified as *Otras Especies*, or Other Species, and there are no further details about the species included within this group. So we have 60% of the *Otras* volume classified as *Otras Especies* with no further details given, and the remaining 40% of the volume between 180 species for which scientific names are given. The approach I decided to take was to leave the *Otras Especies* volume out of the study, and use the Pareto principle to evaluate the remaining volume. Eighty percent of this volume is represented by only 8 species, so for these I gathered the scientific name, corroborated it against my other sources, and obtained the name in English, just as I did with the rest of the database. With this information I classified each species as either in scope or out of scope. Only one species in this group was classified as out of scope, for being a deep-sea species.

From the previous section dealing with fauna identified from archaeological excavations in the Olmec heartland, we can see that there are a few species of fish that are ubiquitous to almost all of the datasets presented. Two of these species, the gar (*Atractosteus* genus), and the tarpon (*Megalops atlanticus*), are part of the *Otras* group, but with not enough high volume to be in the 8 species included in the analysis. Because of their presence in archaeological remains, I decided to add this two species to the analysis. The final list of In Scope species, including the ones identified within the *Otras* group, is given in Table A2 in Appendix A.

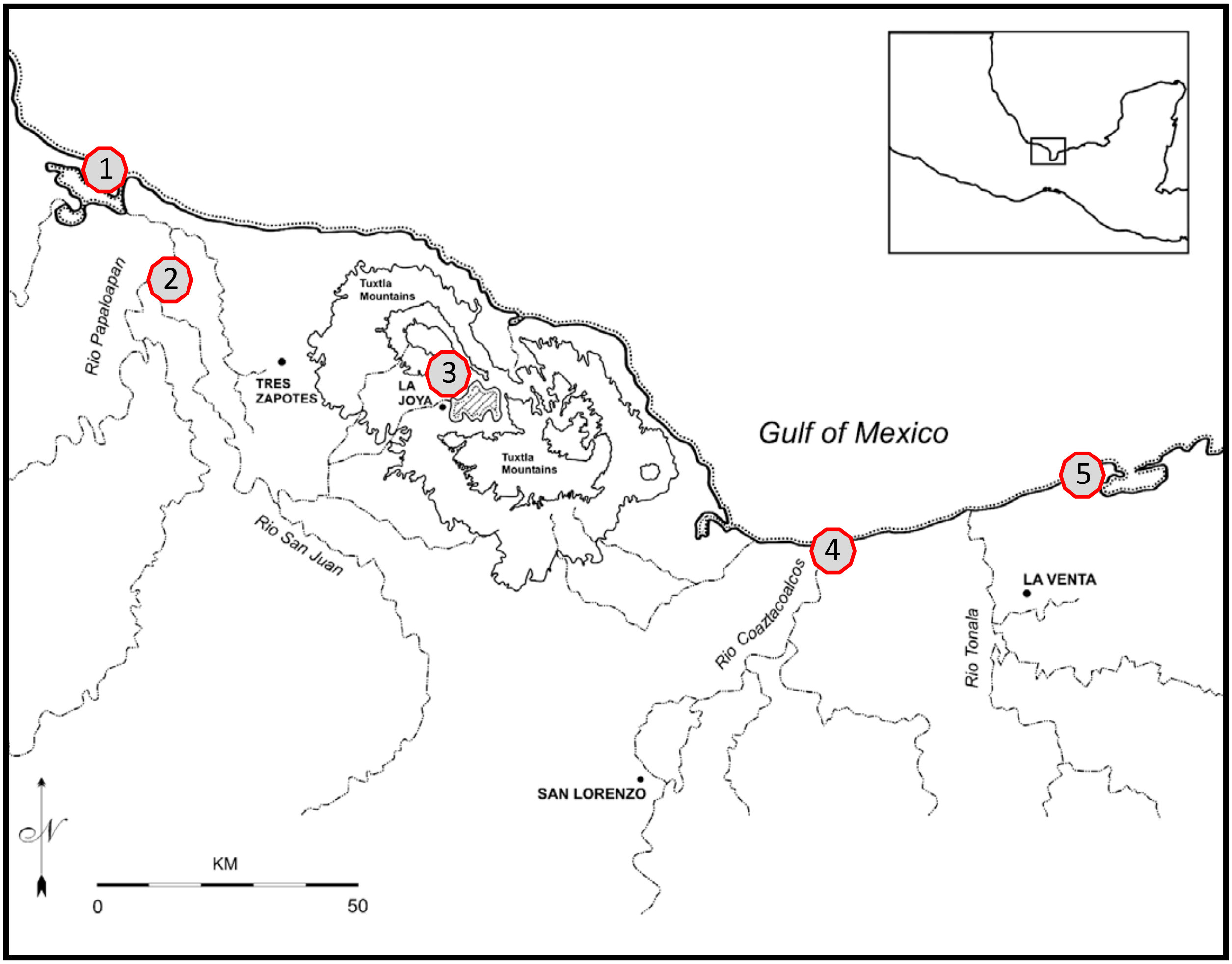
I mentioned above that the online search tool contains information on the specific office reporting the catch volume. Within each state, there are several government offices in charge of reporting the catch data for its region. The state of Veracruz has 13 regional offices and Tabasco has 7. Table 6 below lists all the offices for each state, arranged in order from North to South for the Veracruz offices, and from West to East for the Tabasco offices. The offices in bold italic lettering are the ones located within the Olmec heartland.

Table 6 – Regional CONAPESCA offices in Veracruz and Tabasco

| Veracruz | Tabasco |
|---|---|
| 1. Villa Cuauhtemoc | ***1. Sanchez Magallanez*** |
| 2. Panuco | 2. Puerto Ceiba |
| 3. La Laja | 3. Villahermosa |
| 4. Naranjos | 4. Frontera |
| 5. Tamiahua | 5. Macuspana |
| 6. Tuxpan | 6. Jonuta |
| 7. Tecolutla | 7. Emiliano Zapata |
| 8. Nautla | |
| 9. Veracruz | |
| ***10. Alvarado*** | |
| ***11. Tlacotalpan*** | |
| ***12. Catemaco*** | |
| ***13. Coatzacoalcos*** | |

These are the four southernmost offices in Veracruz, starting with the office located in the city of Alvarado by the mouth of the Papaloapan River, to the Coatzacoalcos city office located by the mouth of the river of the same name. As for Tabasco, only the westernmost office falls within the Olmec heartland. It is located in the village of Sanchez Magallanez on the Gulf Coast; about 27 km (16.5 mi) northeast from the site of La Venta (see Figure 2 below).

**Figure 2 - Location of CONAPESCA's Regional Offices. 1: Alvarado, 2: Tlacotalpan, 3: Catemaco, 4: Coatzacoalcos, 5: Sanchez Magallanez**




**Adapted from: Arnold III, Philip J. 2009. "Settlement and subsistence among the Early Formative Gulf Olmec." Journal of Anthropological Archaeology 28 (4):397-411, Figure 1.**

The catch volume reported by these 5 offices, after refining the information as described above to define the in scope species plus adding the *Otras* species, is the total catch volume included in the final carrying capacity analysis. The final list of in scope species from the five offices located within the Olmec heartland contains 34 species with a total volume of 178,954,664 kg reported during the ten years from 2004 to 2013. See table A3 in Appendix A.

Meat yield or edible flesh percentages

The calories available form the resources described above cannot be calculated based on the whole weight of fish, mollusk, and crustaceans presented in the catch information. Just based on the fact that fish bones are unearthed during archaeological excavations, we know that at least the weight of the bones needs to be subtracted from the total weight of the fish; the weight of the shells of oysters and clams cannot be considered either, and so on. To simplify this process, I used published data on yield percentages of what is called "edible flesh" for fish and other aquatic fauna. My experience trying to obtain this information was that reliable sources are not easy to come by, especially for a large dataset of fish and other aquatic resources. I used a report from the Food and Agriculture Organization (FAO) of the United Nations, the Yearbook of Fishery Statistics, Catches and Landings. This report includes a comprehensive table on yield and composition percentages for many aquatic species. The yield is a percentage of the whole weight of the fish or shellfish, and is presented both based on a skinless fillet or edible flesh for fish, and meat percentage for crustaceans and mollusks. As mentioned above, for the fish percentage I used the edible flesh figure, and not the skinless fillet, because the former is assumed to be closer to the way the Olmec population would have consumed fish.

Although the table presented in the FAO report provides information on many aquatic fauna, it is based on the species that are most important commercially on a global scale; so about half the species in my list are not included in that report. For these, I assigned a number based on the figures provided for similar species. For the fish species not found in the report, I assigned the average of the percentages for fish that I did find on the report, which is 54%. To crayfish, I assigned the same percentage as shrimp; 57%. To snail, I assigned 11%, same percentage as that for clams. The one species for which I was not able to find, after extensive search, a reliable published source for yield percentage, was rays. To this I assigned 50%, based on scattered information found online and comments from people familiar with this resource. Finally, the figure for blue crabs was not included in the FAO report either. This was the only species for which I found another reliable source of information; a report from the Institute of Food and Agricultural Sciences at the University of Florida. The percentage given there is 14%, and I assigned this same number to the only other crab in my list, the swamp ghost crab.

Having obtained the yield percentages for all of the species in the list, I multiply them by the average annual catch in kilograms. This gave me the kilograms of edible flesh available per year for each species.

Calories in edible flesh

The next step is to obtain the calories in each kilogram of edible flesh. I found this number for most of the species on my list from the National Nutrient Database tables provided by the United States Department of Agriculture (USDA). A report from the National Oceanic and Atmospheric Administration (NOAA) as well as the FAO report used for the yield provided the information for a few others. The number of calories in the edible flesh of rays was not found on either of those reports. I used the number of calories in shark meat, as they are in the same Elasmobranchii subclass of cartilaginous fishes. Also, for some of the species classified within *Otras*, the information on calories was not found on either of these reports. I used the average number of calories for the fish species that I did find and assign it to those not found. Multiplying the number of calories by the kilograms of edible flesh available per year for each species gives us the available calories on an annual basis for each species.

Population

The final step is to estimate how many people can be supported, on an annual basis, with the resources available, based on the calories they provide. I considered a daily requirement of 2,000 calories per person, as suggested by the Food and Drug Administration (FDA) of the United States, and then multiplied this figure by 365, to get the annual caloric needs of one person. A simple division of the available calories on an annual basis for each species as obtained in the previous step, by the annual caloric requirements of one person, gives us the population that can be supported by the resources analyzed. Adding this number for each of the species gives a total population of approximately 10,745. This is the number of people in the Olmec heartland that could be supported by the aquatic resources available in the area, considering only the species reported in official commercial catch reports. The final table with yield, calories, and population information is presented in Appendix A as Table A4.

## Discussion

The population number arrived at of almost 11,000 people should not be regarded as the upper limit of what the local aquatic resources can support but rather as a baseline to consider and add upon if one were to add all of the additional aquatic fauna of the area that is not part of this dataset but that is known to have been used by the Olmec and it is still used in modern times, for example turtles. It is important to remember that the origin of this dataset comes from recent commercial catch data and is not necessarily designed for a carrying capacity study. As such, many species that could have potentially been exploited by the Olmec may not be included here because they are currently not commercially important, or if they are included, their catch numbers may be low and not representative of use in Olmec times. One example is the sucker fish (Catostomidae), whose remains have been found during archaeological excavations at La Joya, as can be seen in table 4 above, but it is not part of the dataset. This fish species is widely distributed with high potential for human exploitation . Additionally, some of the local fishermen reporting their catch volume to CONAPESCA officials are likely putting aside a portion of their catch for personal consumption and not reporting it, or officials not recording it.

There are a few additional factors that make the number arrived at a conservative estimate. The first is that when I was analyzing the information on ecology and biology for each specific fish in the original dataset, to be able to assign an in-scope or out-of-scope status to each species, the information was not clear-cut for several species of fish. For example, some of the fish species in the original dataset spend most of their time offshore, traveling inshore to estuaries or lagoons only infrequently. In these cases, I did not included the catch volume for this species, although a fraction of the volume is clearly available in the analyzed environment from time to time, and thus could have been exploited in Olmec times as well.

The second factor that makes this number a conservative estimate is the source used to obtain the percentages of edible flesh. As mentioned previously, I used a report from the FAO that includes a comprehensive list of species commercially important worldwide, including about half of the species in my analysis. The average percentage for edible flesh from that report, for the fish species in my dataset, was 54%. This number is significantly lower than other figures found in the literature. For example, Elizabeth Wing analyzed the faunal remains recovered from several archaeological sites in coastal Veracruz, as well as the assemblage recovered from San Lorenzo during excavations by Michael Coe. Most of the fish species analyzed by her are included in my analysis. For all of the fish, she calculated 90% usable meat, except for the catfishes, which she estimated at 77% (Wing 1978). Wing's figures were used by Joshua Borstein to estimate that a single fisherman in the lower Coatzacoalcos river could catch enough fish to support 1 to 3, people based on caloric needs (Borstein 2001). If I apply the usable meat percentages calculated by Wing to my dataset, my estimate would increase from 10,745 to 16,488 people.

The third factor that makes the number arrived in this analysis a conservative estimate has to do with pollution. The Olmec heartland area, especially the lower Coatzacoalcos and Tonalá river basins, have been an important industrial center for the petrochemical industry since the beginning of modern oil exploitation in Mexico. However, the dumping of industrial waste to the local water systems, the traffic of oil tankers to the local ports and the related accidents and leaks, as well as the discharge of municipal waste from the cities in the region into the water system, have drastically reduced the numbers of commercially and nutritionally important fish. Industrial and domestic waste especially, have drastically altered the local environment, and local aquatic fauna no longer have adequate conditions for reproduction and survival (Bozada and Paez 1986). Although specific percentage estimates of the amount of fish catch reduction in the region caused by pollution are difficult to come by or calculate, there is little doubt of the considerable effect that environment degradation due to pollution has had on local fish stocks.

Researchers have developed a few population estimates for Olmec centers over the years. As for San Lorenzo and its surrounding area, a comprehensive study and population estimate were developed by Stacey Symonds, Ann Cyphers, and Roberto Lunagomez as part of the *Proyecto Arqueológico San Lorenzo Tenochtitlan*. They estimated that the population of San Lorenzo and its surrounding area, during the San Lorenzo phase (1,200 – 850 B.C) in the Early Formative, which represents the heyday of the center with the highest number of settlements and population, to be between 8,554 and 18,735, with a median of 13,644 people (Symonds, Cyphers, and Lunagomez 2002).

Regarding La Venta, Michael Coe, citing Robert Heizer, states that this center was supported by a hinterland population of no less than 18,000 people (Coe and Koontz 2008). The heyday of La Venta, however, happened between the years 1000 and 400 B.C., during the Middle Formative period, and by then it has been documented that extensive maize agriculture was being practiced (Rust and Leyden 1994).

## Conclusion

As stated in the first section of this work, my objective was to calculate the amount of people that can be supported by the aquatic resources available in the Olmec heartland. The purpose is to add to the current discussion about Early Formative Olmec subsistence, and the emerging theories stating that aquatic resources, and not maize agriculture, were the basis for Olmec complexity. I believe that these new theories can be better evaluated by having more concrete data on the amount of resources available in the area and their sustenance potential. In addition, I whished to address Michael Coe's suggestion of performing a carrying capacity analysis of the local environment, based on a non maize-agriculture mode of subsistence, as referenced in Killion (2013).

The Olmec developed into a complex society during the Early Formative, and during this period San Lorenzo was the biggest and most important urban center. By the time San Lorenzo had declined, La Venta had risen as the most important Olmec center. By then it was the Middle Formative and the Olmecs already practiced extensive maize agriculture. So these emerging theories need to be evaluated against the estimated population during the Early Formative, especially in and around San Lorenzo, compared to the potential population that can be supported by the aquatic resources in the area. The estimated population of San Lorenzo and its hinterland during the Early Formative was, as stated above, 13,644. My estimate of the population that can be supported with the aquatic resources in the area is 10,745. This is, I believe, a very conservative estimate for the reasons I have outlined above, and it has a potential upward revision to 16,488 people, just by adjusting the usable meat percentages to be in line with other estimates in the archaeological literature. Considering all the other factors referenced above that have an impact in the catch volume, as well as the additional aquatic resources that were not part of this study, I think that the number of people that can be supported with aquatic resources in the area can easily be revised upward to at least 20,000.

I believe these results show that maize agriculture does not necessarily have to be a prerequisite for complexity. The aquatic resources available in the region could have been sufficient to provide a considerable portion of the calories needed by an emerging Olmec population becoming a complex society during the Early Formative period in the Southern Gulf Coast Lowlands.

# Appendix A

### Table A1 – Initial list of all resources caught in Veracruz and Tabasco

| Scientific Name | Common Name (English) | Common Name (Spanish) |
|---|---|---|
| *Rangia cuneata* | Clam | Almeja |
| Engraulidae | Anchovies | Anchoveta |
| *Thunnus albacares* | Yellowfin tuna | Atún |
| Ariidae, Ictaluridae, *Rhamdia* | Catfish | Bagre |
| *Bagre marinus* | Gafftopsail sea catfish | Bandera |
| Serranidae | Sea basses and groupers | Baqueta |
| *Katsuwonus pelamis* | Skipjack tuna | Barrilete |
| *Menticirrhus littoralis* | Gulf kingcroaker | Berrugata |
| *Rhomboplites aurorubens* | Vermilion snapper | Besugo |
| *Euthynnus alletteratus* | Little tunny | Bonito |
| *Mycteroperca bonaci / Cephalopholis cruentata* | Black grouper, Graysby | Cabrilla |
| Loliginidae | Squid | Calamar |
| Penaeidae | Shrimp | Camarón |
| *Pomacea patula / Strombus gigas* | Apple snails / Queen conch | Caracol |
| *Cyprinus carpio* | Common carp | Carpa |
| *Carcharhinus porosus / Rhizoprionodon terraenovae* | (Juvenile sharks) - Smalltail shark / Atlantic sharpnose shark | Cazón |
| *Chirostoma arge* | Largetooth silverside | Charal |
| *Trichiurus lepturus* | Atlantic cutlassfish or Largehead hairtail | Cintilla |
| *Cynoscion nebulosus* | Spotted seatrout | Corvina |
| *Seriola dumerili* | Greater amberjack | Esmedregal |
| N/A | N/A | Fauna |
| Lutjanidae | Snappers | Guachinango or Huachinango |
| Portunidae | Swimming crabs | Jaiba |
| *Caranx crysos / Caranx hippos* | Blue runner / Crevalle jack | Jurel |
| Nephropidae, Palinuridae | Lobster | Langosta |
| *Macrobrachium carcinus* | Bigclaw river shrimp | Langostino |
| *Mugil liza / Mugil curema* | Lebranche mullet / White mullet | Lebrancha |
| Achiridae, Paralichthyidae, Pleuronectidae | American Soles / Large-tooth Flounders / Righteye Flounders | Lenguado |
| Mugilidae | Mullets | Lisa |
| *Micropterus salmoides* | Largemouth bass | Lobina |
| Scombridae | Mackerels | Macarela |
| *Epinephelus adscensionis / Epinephelus morio* | Red grouper / Rock hind | Mero |
| *Petenia splendida / Cichlasoma urophthalmus / Diapterus auratus* | Bay snook / Mayan cichlid / Irish mojarra | Mojarra |
| Ostreidae | Oysters | Ostion |
| N/A | N/A | Otras |
| *Trachinotus falcatus* | Permit | Pámpano |
| *Lutjanus apodus / Lutjanus griseus* | Schoolmaster snapper / Grey snapper | Pargo |
| Holothuriidae, Stichopodidae | Sea Cucumber | Pepino de Mar |
| *Scomberomorus cavalla / Acanthocybium solandri* | King mackerel / Wahoo | Peto |
| Malacanthidae | Tilefishes | Pierna |
| *Octopus* | Octopus | Pulpo |
| *Dasyatis, Gymnura* | Stingrays | Raya |
| *Centropomus undecimalis / Centropomus poeyi* | Common snook / Mexican snook | Robalo |
| Haemulidae | Grunts | Ronco |
| *Lutjanus synagris / Ocyurus chrysurus* | Lane snapper / Yellowtail snapper | Rubia Y Villajaiba |
| *Haemulon sciurus / Haemulon plumieri / Haemulon flavolineatum* | Bluestriped grunt / White grunt / French grunt | Rubio |
| Clupeidae | Sardines | Sardina |
| *Scomberomorus maculatus* | Atlantic spanish mackerel | Sierra |
| Carcharhinidae/Rhincodontidae/Squatinidae/Echinorhinidae | Sharks | Tiburón |
| *Cynoscion arenarius* | Sand seatrout | Trucha |

## Table A2 – Final list of In Scope resources

| Scientific Name | Common Name (English) | Common Name (Spanish) |
|---|---|---|
| *Rangia cuneata* | Clam | Almeja |
| Engraulidae | Anchovies | Anchoveta |
| *Rachycentron canadus* | Cobia | Bacalao |
| Ariidae, Ictaluridae, *Rhamdia* | Catfish | Bagre |
| *Bagre marinus* | Gafftopsail sea catfish | Bandera |
| *Menticirrhus littoralis* | Gulf kingcroaker | Berrugata |
| *Euthynnus alletteratus* | Little Tunny | Bonito |
| Penaeidae | Shrimp | Camaron |
| *Ucides cordatus* | Swamp ghost crab | Cangrejo Moro |
| *Pomacea patula / Strombus gigas* | Apple snails / Queen Conch | Caracol |
| *Carcharhinus porosus / Rhizoprionodon terraenovae* | (Juvenile sharks) - Smalltail Shark / Atlantic Sharpnose Shark | Cazon |
| *Trichiurus lepturus* | Atlantic Cutlassfish or Largehead Hairtail | Cintilla |
| *Cynoscion nebulosus* | Spotted Seatrout | Corvina |
| *Eleotris pisonis* | Spinycheek sleeper | Guabina |
| Portunidae | Swimming crabs | Jaiba |
| *Caranx crysos / Caranx hippos* | Blue runner / Crevalle Jack | Jurel |
| *Macrobrachium carcinus* | Bigclaw river shrimp | Langostino |
| *Mugil liza / Mugil curema* | Lebranche Mullet / White Mullet | Lebrancha |
| Achiridae, Paralichthyidae, Pleuronectidae | American Soles / Large-tooth Flounders / Righteye Flounders | Lenguado |
| Mugilidae | Mullets | Lisa |
| *Petenia splendida / Cichlasoma urophthalmus / Diapterus auratus* | Bay snook / Mayan cichlid / Irish Mojarra | Mojarra |
| *Dormitator maculatus* | Fat sleeper | Naca |
| Ostreidae | Oysters | Ostion |
| *Trachinotus falcatus* | Permit | Pampano |
| *Lutjanus apodus / Lutjanus griseus* | Schoolmaster snapper / Grey snapper | Pargo |
| *Atractosteus tropicus* | Tropical Gar | Peje Lagarto |
| *Dasyatis, Gymnura* | Stingrays | Raya |
| *Centropomus undecimalis / Centropomus poeyi* | Common Snook / Mexican Snook | Robalo |
| *Megalops atlanticus* | Tarpon | Sabalo |
| Clupeidae | Sardines | Sardina |
| *Archosargus probatocephalus* | Sheepshead | Sargo |
| *Scomberomorus maculatus* | Atlantic Spanish Mackerel | Sierra |
| *Sphyraena guachancho* | Guachanche barracuda | Tolete |
| *Cynoscion arenarius* | Sand Seatrout | Trucha |

### Table A3 – In Scope catch volume from the five offices within the Olmec heartland

| Scientific Name | Common Name (English) | Common Name (Spanish) | Total Catch 2004 - 2013 (kg) | Average Annual catch (kg) |
|---|---|---|---|---|
| *Rangia cuneata* | Clam | Almeja | 23,660,060 | 2,366,006 |
| *Caranx crysos / Caranx hippos* | Blue runner / Crevalle Jack | Jurel | 16,965,891 | 1,696,589 |
| Portunidae | Swimming crabs | Jaiba | 15,122,029 | 1,512,203 |
| *Centropomus undecimalis / Centropomus poeyi* | Common Snook / Mexican Snook | Robalo | 14,633,174 | 1,463,317 |
| *Scomberomorus maculatus* | Atlantic Spanish Mackerel | Sierra | 12,486,428 | 1,248,643 |
| *Macrobrachium carcinus* | Bigclaw river shrimp | Langostino | 11,741,719 | 1,174,172 |
| *Sphyraena guachancho* | Guachanche barracuda | Tolete | 10,934,806 | 1,093,481 |
| *Mugil liza / Mugil curema* | Lebranche Mullet / White Mullet | Lebrancha | 9,942,740 | 994,274 |
| Penaeidae | Shrimp | Camaron | 8,903,136 | 890,314 |
| *Trichiurus lepturus* | Atlantic Cutlassfish or Largehead Hairtail | Cintilla | 8,151,805 | 815,181 |
| *Petenia splendida / Cichlasoma urophthalmus / Diapterus auratus* | Bay snook / Mayan cichlid / Irish Mojarra | Mojarra | 5,734,685 | 573,468 |
| *Bagre marinus* | Gafftopsail sea catfish | Bandera | 5,552,443 | 555,244 |
| *Cynoscion arenarius* | Sand Seatrout | Trucha | 3,655,885 | 365,589 |
| *Eleotris pisonis* | Spinycheek sleeper | Guabina | 3,197,319 | 319,732 |
| *Euthynnus alletteratus* | Little Tunny | Bonito | 3,137,075 | 313,708 |
| *Pomacea patula / Strombus gigas* | Apple snails / Queen Conch | Caracol | 3,071,022 | 307,102 |
| Mugilidae | Mullets | Lisa | 3,046,581 | 304,658 |
| *Ucides cordatus* | Swamp ghost crab | Cangrejo Moro | 2,960,412 | 296,041 |
| Ariidae, Ictaluridae, *Rhamdia* | Catfish | Bagre | 2,398,849 | 239,885 |
| *Archosargus probatocephalus* | Sheepshead | Sargo | 2,345,260 | 234,526 |
| *Carcharhinus porosus / Rhizoprionodon terraenovae* | (Juvenile sharks) - Smalltail Shark / Atlantic Sharpnose Shark | Cazon | 1,853,661 | 185,366 |
| *Dasyatis, Gymnura* | Stingrays | Raya | 1,747,125 | 174,713 |
| *Dormitator maculatus* | Fat sleeper | Naca | 1,717,864 | 171,786 |
| *Trachinotus falcatus* | Permit | Pampano | 1,269,442 | 126,944 |
| *Lutjanus apodus / Lutjanus griseus* | Schoolmaster snapper / Grey snapper | Pargo | 908,582 | 90,858 |
| Ostreidae | Oysters | Ostion | 785,032 | 78,503 |
| *Rachycentron canadus* | Cobia | Bacalao | 746,471 | 74,647 |
| *Cynoscion nebulosus* | Spotted Seatrout | Corvina | 620,224 | 62,022 |
| Clupeidae | Sardines | Sardina | 373,154 | 37,315 |
| Engraulidae | Anchovies | Anchoveta | 364,597 | 36,460 |
| *Menticirrhus littoralis* | Gulf kingcroaker | Berrugata | 337,639 | 33,764 |
| Achiridae, Paralichthyidae, Pleuronectidae | American Soles / Large-tooth Flounders / Righteye Flounders | Lenguado | 297,938 | 29,794 |
| *Atractosteus tropicus* | Tropical Gar | Peje Lagarto | 282,566 | 28,257 |
| *Megalops atlanticus* | Tarpon | Sabalo | 9,048 | 905 |
| | | | **178,954,664** | **17,895,466** |

## Table A4 – Final carrying capacity analysis

| Scientific Name | Common Name (English) | Common Name (Spanish) | Total Catch 2004 - 2013 (kg) | Average Annual catch (kg) | Percentage of edible flesh | Edible flesh (kg) | Cal/Kg of edible flesh | Available calories per year | Human caloric needs per year | Carrying capacity (population) |
|---|---|---|---|---|---|---|---|---|---|---|
| *Scomberomorus maculatus* | Atlantic Spanish Mackerel | Sierra | 12,486,428 | 1,248,643 | 54% | 674,267 | 1,390 | 937,231,315 | 730,000 | 1,284 |
| *Caranx crysos / Caranx hippos* | Blue runner / Crevalle Jack | Jurel | 16,965,891 | 1,696,589 | 56% | 950,090 | 966 | 917,786,860 | 730,000 | 1,257 |
| *Centropomus undecimalis / Centropomus poeyi* | Common Snook / Mexican Snook | Robalo | 14,633,174 | 1,463,317 | 54% | 790,191 | 825 | 651,907,895 | 730,000 | 893 |
| *Trichiurus lepturus* | Atlantic Cutlassfish or Largehead Hairtail | Cintilla | 8,151,805 | 815,181 | 59% | 480,957 | 1,210 | 581,957,377 | 730,000 | 797 |
| *Mugil liza / Mugil curema* | Lebranche Mullet / White Mullet | Lebrancha | 9,942,740 | 994,274 | 50% | 497,137 | 1,170 | 581,650,313 | 730,000 | 797 |
| *Sphyraena guachancho* | Guachanche barracuda | Tolete | 10,934,806 | 1,093,481 | 54% | 590,480 | 940 | 555,050,765 | 730,000 | 760 |
| *Macrobrachium carcinus* | Bigclaw river shrimp | Langostino | 11,741,719 | 1,174,172 | 57% | 669,278 | 770 | 515,344,039 | 730,000 | 706 |
| Penaeidae | Shrimp | Camaron | 8,903,136 | 890,314 | 57% | 507,479 | 850 | 431,356,952 | 730,000 | 591 |
| *Bagre marinus* | Gafftopsail sea catfish | Bandera | 5,552,443 | 555,244 | 54% | 299,832 | 842 | 252,458,467 | 730,000 | 346 |
| *Rangia cuneata* | Clam | Almeja | 23,660,060 | 2,366,006 | 11% | 260,261 | 860 | 223,824,171 | 730,000 | 307 |
| *Cynoscion arenarius* | Sand Seatrout | Trucha | 3,655,885 | 365,589 | 54% | 197,418 | 1,040 | 205,314,525 | 730,000 | 281 |
| *Petenia splendida / Cichlasoma urophthalmus / Diapterus auratus* | Bay snook / Mayan cichlid / Irish Mojarra | Mojarra | 5,734,685 | 573,468 | 37% | 212,183 | 960 | 203,696,003 | 730,000 | 279 |
| *Euthynnus alletteratus* | Little Tunny | Bonito | 3,137,075 | 313,708 | 58% | 181,950 | 1,090 | 198,325,900 | 730,000 | 272 |
| *Eleotris pisonis* | Spinycheek sleeper | Guabina | 3,197,319 | 319,732 | 54% | 172,655 | 1,114 | 192,337,937 | 730,000 | 263 |
| Portunidae | Swimming crabs | Jaiba | 15,122,029 | 1,512,203 | 14% | 211,708 | 870 | 184,186,317 | 730,000 | 252 |
| Mugilidae | Mullets | Lisa | 3,046,581 | 304,658 | 50% | 152,329 | 1,170 | 178,224,976 | 730,000 | 244 |
| *Archosargus probatocephalus* | Sheepshead | Sargo | 2,345,260 | 234,526 | 54% | 126,644 | 1,080 | 136,775,567 | 730,000 | 187 |
| *Carcharhinus porosus / Rhizoprionodon terraenovae* | (Juvenile sharks) - Smalltail Shark / Atlantic Sharpnose Shark | Cazon | 1,853,661 | 185,366 | 54% | 100,098 | 1,300 | 130,127,029 | 730,000 | 178 |
| Ariidae, Ictaluridae, *Rhamdia* | Catfish | Bagre | 2,398,849 | 239,885 | 54% | 129,538 | 896 | 116,065,927 | 730,000 | 159 |
| *Dasyatis, Gymnura* | Stingrays | Raya | 1,747,125 | 174,713 | 50% | 87,356 | 1,300 | 113,563,129 | 730,000 | 156 |
| *Trachinotus falcatus* | Permit | Pampano | 1,269,442 | 126,944 | 54% | 68,550 | 1,640 | 112,421,777 | 730,000 | 154 |
| *Dormitator maculatus* | Fat sleeper | Naca | 1,717,864 | 171,786 | 54% | 92,765 | 1,114 | 103,339,820 | 730,000 | 142 |
| *Lutjanus apodus / Lutjanus griseus* | Schoolmaster snapper / Grey snapper | Pargo | 908,582 | 90,858 | 54% | 49,063 | 1,000 | 49,063,410 | 730,000 | 67 |
| *Rachycentron canadus* | Cobia | Bacalao | 746,471 | 74,647 | 54% | 40,309 | 1,114 | 44,904,684 | 730,000 | 62 |
| Clupeidae | Sardines | Sardina | 373,154 | 37,315 | 65% | 24,255 | 1,580 | 38,322,951 | 730,000 | 52 |
| *Pomacea patula / Strombus gigas* | Apple snails / Queen Conch | Caracol | 3,071,022 | 307,102 | 11% | 33,781 | 1,100 | 37,159,371 | 730,000 | 51 |
| *Ucides cordatus* | Swamp ghost crab | Cangrejo Moro | 2,960,412 | 296,041 | 14% | 41,446 | 870 | 36,057,821 | 730,000 | 49 |
| *Cynoscion nebulosus* | Spotted Seatrout | Corvina | 620,224 | 62,022 | 54% | 33,492 | 1,040 | 34,831,755 | 730,000 | 48 |
| Engraulidae | Anchovies | Anchoveta | 364,597 | 36,460 | 62% | 22,605 | 1,310 | 29,612,566 | 730,000 | 41 |
| *Menticirrhus littoralis* | Gulf kingcroaker | Berrugata | 337,639 | 33,764 | 54% | 18,233 | 1,040 | 18,961,817 | 730,000 | 26 |
| *Atractosteus tropicus* | Tropical Gar | Peje Lagarto | 282,566 | 28,257 | 54% | 15,259 | 1,114 | 16,998,044 | 730,000 | 23 |
| Achiridae, Paralichthyidae, Pleuronectidae | American Soles / Large-tooth Flounders / Righteye Flounders | Lenguado | 297,938 | 29,794 | 49% | 14,599 | 700 | 10,219,258 | 730,000 | 14 |
| Ostreidae | Oysters | Ostion | 785,032 | 78,503 | 10% | 7,850 | 510 | 4,003,662 | 730,000 | 5 |
| *Megalops atlanticus* | Tarpon | Sabalo | 9,048 | 905 | 54% | 489 | 1,114 | 544,276 | 730,000 | 1 |
| | | | **178,954,664** | **17,895,466** | | | | | | **10,745** |

**Bibliography**

Arnold III, Philip J. 2009. "Settlement and subsistence among the Early Formative Gulf Olmec." *Journal of Anthropological Archaeology* 28 (4):397-411.

Blake, Michael, Brian S. Chisholm, John E. Clark, Barbara Voorhies, and Michael W. Love. 1992. "Prehistoric Subsistence in the Soconusco Region." *Current Anthropology* 33 (1):83-94.

Borstein, Joshua A. 2001. "Tripping over colossal heads: Settlement patterns and population development in the upland Olmec heartland." Ph.D., The Pennsylvania State University.

Borstein, Joshua A. 2005. "Epiclassic Political Organization in Southern Veracruz, Mexico: Segmentary versus centralized integration." *Ancient Mesoamerica* 16 (01):11-21

Bozada, Lorenzo, and Margarito Paez. 1986. *La Fauna Acuática del Rio Coatzacoalcos*. 15 vols. Vol. 8, *Medio Ambiente en Coatzacoalcos*. Mexico, D.F.: Centro de Ecodesarrollo. Universidad Veracruzana.

Brockmann, Andreas. 2004. *La Pesca Indigena en Mexico*. Mexico, D.F.: Universidad Nacional Autonoma de Mexico.

Coe, Michael D., and Richard A. Diehl. 1980a. *In the Land of the Olmec, Vol. 1, The Archaeology of San Lorenzo Tenochtitlan*. Austin: University Of Texas Press.

Coe, Michael D., and Richard A. Diehl. 1980b. *In the Land of the Olmec, Vol. 2, The People of the River*. Austin: University of Texas Press.

Coe, Michael D., and Rex Koontz. 2008. *Mexico*. Sixth ed. USA: Thames & Hudson.

CONABIO. 2012. "Peces Marinos Comerciales." Comision Nacional para el Conocimiento y Uso de la Biodiversidad.

CONAPESCA. 2013. "Registro y Estadistica Pesquera y Acuicola." Comision Nacional de Acuacultura y Pesca.

Cooke, Steven J., Christopher M. Bunt, Steven J. Hamilton, and Cecil A. Jennings. 2004. "Threats, conservation strategies, and prognosis for suckers (Catostomidae) in North America." *Biological Conservation* 121 (2005):317-331.

Cyphers, Ann, and Judith Zurita-Noguera. 2012. "Early Olmec Wetland Mounds." In *Early New World Monumentality*, edited by Richard L. Burger and Robert M. Rosenswig. Gainesville, FL.: University Press of Florida.

Cyphers, Ann, Belem Zúñiga, and Anna di Castro. 2005. "Another Look at Bufo marinus and the San Lorenzo Olmec." *Current Anthropology* 46 (S5):S129-S133.

Diehl, Richard A. 2005. "Patterns of Cultural Primacy." *Science* 307 (5712):1055-1056.

FAO. 1989. "Yield and Nutritional Value of the Commercially More Important Fish Species." Food and Agriculture Organization of the United Nations.

FDA. 2015. "Nutrition Information for Raw Fruits, Vegetables, and Fish." U.S. Food and Drug Administration.

Grove, David C. 1997. "Olmec archaeology: A half century of research and its accomplishments." *Journal of World Prehistory* 11 (1):51-101.

INEGI. 2013. Anuario Estadístico y Geográfico de Veracruz de Ignacio de la Llave. Mexico: Instituto Nacional de Estadística y Geografía.

INEGI. 2014. Anuario Estadístico y Geográfico de los Estados Unidos Mexicanos. Mexico: Instituto Nacional de Estadística y Geografía.

INEGI. 2014b. Anuario Estadístico y Geográfico por Entidad Federativa. Mexico: Instituto Nacional de Estadística y Geografía.

Killion, Thomas W. 2013. "Nonagricultural Cultivation and Social Complexity: The Olmec, Their Ancestors, and Mexico's Southern Gulf Coast Lowlands." *Current Anthropology* 54 (5):569-606.

Kruger, Robert P. 1996. "An Archaeological Survey in the Region of the Olmec, Veracruz, Mexico." Doctor of Philosophy, Anthropology, University of Pittsburgh.

McCormack, Valerie J. 2002. "Sedentism, site occupation and settlement organization at La Joya, a Formative village in the Sierra de los Tuxtlas, Veracruz, Mexico.", ProQuest Dissertations and Theses, University of Pittsburgh.

Peres, Tanya M., Amber M. VanDerwarker, and Christopher A. Pool. 2010. "The Farmed and the Hunted: Integrating Floral and Faunal Data from Tres Zapotes, Veracruz." In *Integrating Zooarchaeology and Paleoethnobotany*, edited by Amber M. VanDerwarker and Tanya M. Peres. New York: Springer.

Pool, Christopher A. 2006. "Current Research on the Gulf Coast of Mexico." *Journal of Archaeological Research* 14 (3):189-241.

Pool, Christopher A. 2007. *Olmec Archaeology and Early Mesoamerica*. New York: Cambridge University Press.

Pool, Christopher A., Ponciano Ortiz Ceballos, Maria del Carmen Rodriguez Martinez, and Michael L. Loughlin. 2010. "The Early Horizon at Tres Zapotes: Implications for Olmec Interaction." *Ancient Mesoamerica* 21 (01):95-105.

Pope, Kevin O., Mary E. D. Pohl, John G. Jones, David L. Lentz, Nagy Christopher von, Francisco J. Vega, and Irvy R. Quitmyer. 2001. "Origin and Environmental Setting of

Ancient Agriculture in the Lowlands of Mesoamerica." *Science* 292 (5520):1370-1373.

Rosenswig, Robert M. 2006. "Sedentism and Food Production in early Complex Societies of the Soconusco, Mexico." *World Archaeology* 38 (2):330 - 355.

Rust, William F., and Barbara W. Leyden. 1994. "Evidence of Maize Use at Early and Middle Preclassic La Venta Olmec Sites." In *Corn and Culture in the Prehistoric New World*, edited by Sissel Johannessen and Christine A. Hastorf. USA: Westview Press.

Rust, William F., and Robert J. Sharer. 1988. "Olmec Settlement Data from La Venta, Tabasco, Mexico." *Science* 242 (4875):102-104.

Sidwell, Virginia D., Pauline R. Foncannon, Nancy S. Moore, and James C. Bonnet. 1974. "Composition of the Edible Portion of Raw (Fresh or Frozen) Crustaceans, Finfish, and Mollusks." *Marine Fisheries Review* 36 (3).

Stirling, M. W. 1940. "Great stone faces of the Mexican jungle." *National Geographic Magazine*, 309 - 334.

Symonds, Stacey, Ann Cyphers, and Roberto Lunagomez. 2002. *Asentamiento Prehispanico en San Lorenzo Tenochtitlan*. Mexico, D.F.: Universidad Nacional Autonoma de Mexico.

USDA. 2011. "National Nutrient Database for Standard Reference." United States Department of Agriculture.

VanDerwarker, Amber M. 2005. "Field Cultivation and Tree Management in Tropical Agriculture: A View from Gulf Coastal Mexico." *World Archaeology* 37 (2):275-289.

VanDerwarker, Amber M. 2006. *Farming, Hunting, and Fishing in the Olmec World*. Austin: University of Texas Press.

VanDerwarker, Amber M. 2009. "Farming and Catastrophe at La Joya: a Consideration of Agricultural Intensification and Risk in the Formative Sierra de Los Tuxtlas." *Arqueologia Iberoamericana* (1):17-40.

VanDerwarker, Amber M., and Robert P. Kruger. 2012. "Regional Variation in the Importance and Uses of Maize in the Early and Middle Formative Olmec Heartland: New Archaeobotanical Data from the San Carlos Homestead, Southern Veracruz." *Latin American Antiquity* 23 (4).

Wendt, Carl J. 2003. "Early Formative Domestic Organization and Community Patterning in the San Lorenzo Tenochtitlan Region, Veracruz, Mexico." Doctor of Philosophy, Anthropology, The Pennsylvania State University.

Wendt, Carl J. 2005. "Excavations at El Remolino: Household Archaeology in the San Lorenzo Olmec Region." *Journal of Field Archaeology* 30 (2):163 - 180.

Widmer, Randolph J. 1988. *The Evolution of the Calusa*. Tuscaloosa: The University of Alabama Press.

Widmer, Randolph J. 2005. "A New Look at the Gulf Coast Formative." In *Gulf Coast Archaeology: The Southeastern United States and Mexico*, edited by Nancy White, 68-86. University of Florida Press.

Wing, Elizabeth S. 1978. "Use of Dogs for Food: An Adaptation to the Coastal Environment." In *Prehistoric Coastal Adaptations; the Economy and Ecology of Maritime Middle America*, edited by Barbara L. Stark and Barbara Voorhies. New York: Academic Press.