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FARMING AND CATASTROPHE AT LA JOYA: A CONSIDERATION OF AGRICULTURAL INTENSIFICATION AND RISK IN THE FORMATIVE SIERRA DE LOS TUXTLAS

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ABSTRACT. *This paper examines the process of agricultural intensification as it occurred during the Formative period (1400 BC-AD 300) along the southern Gulf Coast of Mexico. Over the course of two millennia, rural villagers living in the Olmec hinterland of the Sierra de los Tuxtlas invested more time and labor into farming activities as they became increasingly sedentary and dealt with episodic volcanic eruptions and ash fall. This period of time witnessed the development of a regional political hierarchy in the Tuxtlas, which also had consequences for village-level subsistence. In examining agricultural intensification in the context of volcanic catastrophe and political development, I analyze archaeological plant and animal data from the site of La Joya, a farming village located in southern Veracruz, Mexico spanning the Formative period. The subsistence data indicate that maize intensification was a long, incremental process that began in the Middle Formative period, hundreds of years before political development and the establishment of a regional center. At the close of the Late Formative period, after the region's political consolidation, a severe volcanic eruption blanketed the region with ash, leading to significant, if temporary, environmental circumscription. La Joya villagers responded to this catastrophe by intensifying maize production on infields and expanding their hunting and fishing territories to exploit a wider range of animal prey.*

KEYWORDS: *Olmec, Formative, zooarchaeology, paleoethnobotany, agricultural intensification, risk.*

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TITULO: *Agricultura y catástrofe en La Joya: un examen de la intensificación agrícola y riesgo en el período Formativo de la Sierra de los Tuxtlas.*

RESUMEN. *Este estudio examina el proceso de sedentarización, intensificación agrícola y desarrollo de una jerarquía política regional durante el período Formativo (1400 a. C.-300 d. C.) a lo largo de la costa meridional del Golfo de México, en la zona olmeca de la Sierra de los Tuxtlas. Los resultados obtenidos analizando los datos de animales y plantas provenientes del sitio de La Joya, un pueblo agrícola ubicado en el sur de Veracruz (México) que abarca todo el Formativo, indican que la intensificación del maíz fue un proceso largo y gradual que se inició en la fase media de esta etapa, cientos de años antes del establecimiento de un centro regional. A finales del Formativo Tardío, después de su consolidación política, una severa erupción volcánica cubrió con ceniza la región. Los aldeanos de La Joya respondieron a esta catástrofe incrementando la producción de maíz en las inmediaciones y ampliando sus territorios de caza y pesca para explotar una gama más amplia de animales.*

PALABRAS CLAVE: *olmeca, Formativo, zooarqueología, paleoetnobotánica, intensificación agrícola, riesgo.*

THE RELATIONSHIP BETWEEN AGRICULTURAL INTENSIFICATION and the emergence of political complexity has received a great deal of archaeological attention (Boserup 1965, Clark and Blake 1994, Cohen 1977, Scarry 1986). This paper examines agricultural intensification during the Formative period (1400 BC-AD 300) along the southern Gulf Coast of Mexico (fig. 1). This is the time and the place of the Olmec, one of the earliest complex societies in Mesoamerica. Because the terms *intensification* and *complexity* have been used in a myriad of different ways, it is necessary to clarify the manner in which I use them here. By *agricultural intensification*, I refer to an increased investment of time and labor by humans into farming increasingly smaller areas of land. I use the phrase *emergence of political complexity* to refer to the development of a regional political hierarchy characterized by administrative centralization and institutionalized social inequality.

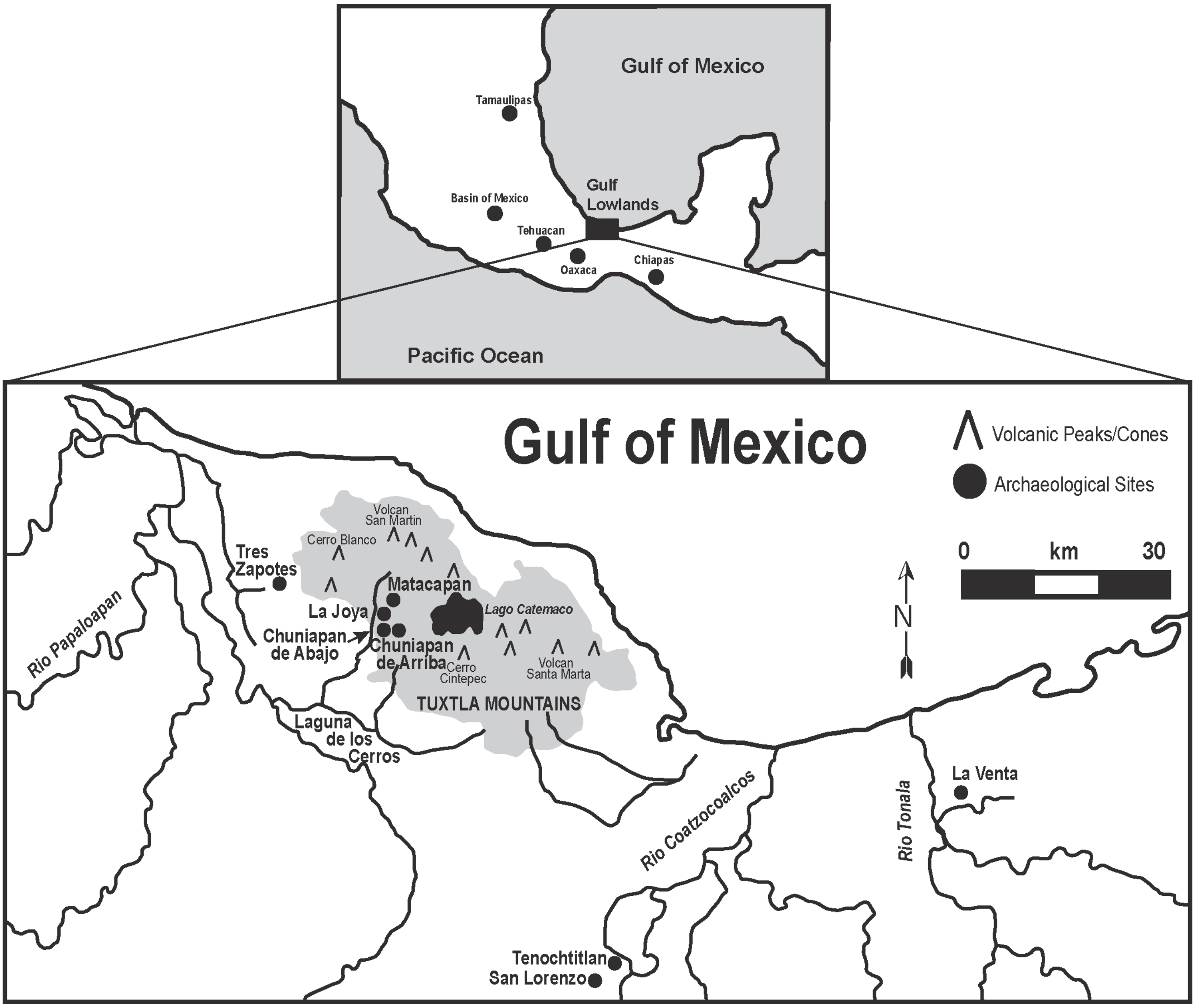

Fig. 1. Map of Gulf Coastal Mexico including the Sierra de los Tuxtlas.

To examine agricultural intensification in the context of political development, I analyze archaeological plant and animal data from the La Joya site, a farming village located in southern Veracruz, Mexico that spans the Formative period (Arnold 1999, 2000, 2002; McCormack 2002, VanDerwarker 2006a). Plant and animal data are rarely considered together, and almost never by the same analyst, which often creates a false dichotomy between plant and animal subsistence. The research I present here is one of an increasing number of studies to ask similar questions of both data sets (see also Bakels *et al.* 1992, Bendremer 1999, Cartwright 1998, Cooke *et al.* 1996, Crane and Carr 1994, Di Lernia 2001, Fischer 1998, Jackson 1989, Kidder and Fritz 1993, Lovis *et al.* 2001, Martin and Parks 1994, Mbida 2000, Moore *et al.* 1994, Newsom and Wing 2004, Pauketat *et al.* 2002, Reitz *et al.* 1985, Scarry and Reitz 2005, Sobolik 1994, Spielmann and Angstadt-Leto 1996, Smith and Egan 1990, VanDerwarker 2006a, VanDerwarker and Detwiler 2000, Wetterstrom 1994, Walker *et al.* 2001).

The development of political complexity occurred very early along the southern Mexican Gulf Coast. Large civic-ceremonial centers were established at places like San Lorenzo during the Early Formative (1400-1000 BC) (Coe and Diehl 1980a, 1980b; Cyphers Guillén 1994; Cyphers 1996, 1997), La Venta during the Middle Formative (1000-400 BC) (Drucker *et al.* 1959; Gonzalez Lauck 1989, 1996), and Tres Zapotes during the Late Formative (400 BC-AD 100) (Pool 2003). These large political centers served as seats of power for regional elites who oversaw large labor projects like extensive earthen mound-building and monument construction in the form of colossal heads, stone altars, and stelae (Pool 2007). Most explanations for social organization and the emergence of political complexity in the Olmec lowlands hinge on economic control through possession of prime levee lands, trade in basic subsistence tools, and maize surplus and tribute (Coe 1981; Coe and Diehl 1980a, 1980b; Heizer 1960, 1962; Rust and Leyden 1994). Unfortunately, the lack of reported subsistence data from these sites inhibits our ability to support or refute explanations linking agriculture and political complexity.

Subsistence data from the neighboring Sierra de los Tuxtlas, however, make it possible to trace the relationship between agricultural intensification and the development of political complexity during the Formative period. Located approximately 60-100 km northwest of San Lorenzo and La Venta, the Sierra de los Tuxtlas served as the source for basalt used in carving Olmec heads and other monuments (Williams and Heizer 1965). Despite is geographical proximity to the lowland centers, however, the Sierra de los Tuxtlas did not experience its own regional political development until after the fall of La Venta, during the Late Formative period. In this paper, I document the process whereby rural Olmec inhabitants intensified maize production at the Formative site of La Joya through the analysis of macrobotanical and zooarchaeological assemblages spanning this 2,000 year period. The subsistence data indicate that maize intensification was a long, incremental process that began in the Middle Formative period, hundreds of years before political development and the establishment of a regional center.

AGRICULTURAL INTENSIFICATION IN THE OLMEC WORLD

Michael Coe and Richard Diehl (1980a, 1980b) have argued that kin groups occupying the levee lands around San Lorenzo rose to power as a direct result of the greater agricultural potential of these lands. Because river levees offered higher maize productivity in terms of yields, these lands probably achieved renown as prime maize-producing areas (Coe and Diehl 1980b:148). Kin groups farming these lands would have been able to generate and store more surplus maize than other farming groups in the region, which may have translated into the increased ability to underwrite feasts and other prestige-building events (Coe and Diehl 1980a, 1980b; see also Clark and Blake 1994). In other words, the disparity in maize production between groups occupying levee lands and groups located elsewhere would have ultimately led to increasing social inequality among these groups, with the former achieving political eminence over the region.

Joshua Borstein's (2001) recent settlement analysis, however, suggests that people were not so much focused on agriculture prior to 1000 BC as they were on the exploitation of aquatic resources. He argues that aquatic foods, not maize, underwrote the rise to power by Olmec elites—the exploitation of which would have still made land along river levees important to this process (Borstein 2001, see also Wendt 2003). In all probability, levee lands were important both for farming maize and for access to aquatic resources. Blake *et al.* (1992) and Rosenswig (2006) make similar arguments for the Formative-period Soconusco.

The Olmec have often been characterized in terms of a tribute-based political economy. Presumably, political elite would have commanded tribute from villages and farmsteads in the form of maize, and labor for monument transport and mound-building (Bernal 1971, Coe 1965; Heizer 1960, 1962, 1971). Assessing the validity of these tribute models is difficult. Most archaeological research has focused on the civic-ceremonial centers, and as a result, we know very little of those sites comprising other portions of the settlement system (but see Arnold 1999, 2000, 2002; Borstein 2001; Kruger 1996, 1999, 2000; Pool 1997, Pool and Britt 2000, Wendt 2003). Another problem with these tribute models is the lack of supporting subsistence data (but see Rust and Leyden 1994, Rust and Sharer 1998; Wing 1980, 1981; Zurita-Noguera 1997). Most regional studies that have related political complexity to agriculture have explored this relationship using indirect methods such as carrying capacity calculations, ecological and settlement studies, analogy to modern farming practices, and non-subsistence material culture (Borstein 2001, Coe 1981; Coe and Diehl 1980a, 1980b; Drucker and Heizer 1960, Grove 1981, McCormack 2002).

The use of indirect methods for assessing agriculture is largely a product of a lack of available subsistence data. Preservation of organic remains in tropical environments like the Gulf Coast is often poor. Thus, there have been few analyses of plant and animal data (but see Rust and Leyden 1994, Rust and Sharer 1998; Wing 1980, 1981; Zurita-Noguera 1997), and many analyses that have been conducted are not adequately reported. So although most regional studies have modeled the relationship between farming and political complexity *in the absence* of direct subsistence evidence, they have nevertheless been critical for exploring the possibilities of this relationship. The next step, however, must involve testing these possibilities with actual subsistence data, which is precisely the goal of this paper (see also VanDerwarker 2006a).

In addressing the relationship between intensification and political development, I focus on key questions regarding the timing of intensification related to the development of a settlement hierarchy in the Sierra de los Tuxtlas, approximately 60-100 km from the lowland Olmec sites (fig. 1). Did villagers intensity their cultivation systems? If so, how and why did they intensify, and what were the consequences of intensification for the subsistence economy, and for local and regional political development? And finally, how did volcanic eruptions affect this process of intensification? I address these questions by considering subsistence practices at the site of La Joya, a farming village that spans the Formative period (1400 BC-AD 300). Following a description of regional history and site background, I organize my analysis around the discussion of two datasets: the maize remains from flotation samples and the zooarchaeological remains from the screened assemblage.

SIERRA DE LOS TUXTLAS AND THE SITE OF LA JOYA

The Sierra de los Tuxtlas is a volcanic uplift located approximately 60-100 km from San Lorenzo and La Venta (see fig. 1). Recent excavations in the Olmec hinterland region by Robert Santley, Philip Arnold, and Christopher Pool make this an ideal place for examining Formative Olmec foodways (Arnold 1999, 2000; Arnold *et al.* 1992; Pool 1997, 2007; Santley 1992, Santley *et al.* 1997). Though settlement in the Tuxtlas does not appear to have been controlled or dominated by the lowland Olmec, Tuxtlas residents were not unaware of their neighbors to the southeast (McCormack 2002, Santley and Arnold 1996). It is noteworthy that political development in the Tuxtlas occurred much later than in the lowlands, after the fall of La Venta at the end of the Middle Formative (Santley *et al.* 1997, see also Stark and Arnold 1997). This later development may be related in part to severe and recurrent volcanic eruptions in the Tuxtlas (Santley *et al.* 1997). Indeed, there were at least three major eruptions in the Tuxtlas during the Formative period (see below).

Tuxtlas Settlement Surveys

Settlement surveys by Santley and colleagues (Santley 1991, Santley and Arnold 1996, Santley *et al.* 1997) have laid the foundation for current archaeological research in the Sierra de los Tuxtlas. In the 1970s, Robert Santley began a project of combined survey and excavation, employing techniques similar to those used in the Basin of Mexico (Sanders *et al.* 1979) and the Valley of Oaxaca (Blanton *et al.* 1982). They surveyed an area of approximately 400 km^2, locating 182 sites representing 577 components (Santley *et al.* 1997).

These regional survey data provide critical information regarding the emergence of a settlement hierarchy. During the Early Formative, the Tuxtla regional settlement system was composed only of villages and hamlets. By the Middle Formative, people began to aggregate into larger villages and mounded architecture appeared, but sites remained functionally undifferentiated (Santley *et al.* 1997). Given these data, social organization in the Tuxtlas during the Early and Middle Formative has been characterized as relatively egalitarian with only minor socioeconomic differentiation (Santley *et al.* 1997). During the Late Formative, a small regional center emerged at the site of Chuniapan de Abajo (see fig. 1), although most people still resided in small villages and hamlets. This period may mark the beginnings of a differentiated sociopolitical system with Chuniapan de Abajo representing a level of hierarchy above the village tier (Santley *et al.* 1997). A three-tiered settlement hierarchy has also been identified during the Terminal Formative period, with a regional political center located at the site of Chuniapan de Arriba, just a few kilometers east of Chuniapan de Abajo (Santley *et al.* 1997:183).

Both Stark (1997) and Pool (2000) have argued for increasing regional political fragmentation during the Terminal Formative period. Indeed, the Terminal Formative period in the Tuxtlas is marked by a radical decrease in regional population. Nevertheless, settlement data indicate the continued presence of a three-tiered regional political hierarchy during this time (Santley *et al.* 1997). Santley *et al.* (1997; see also Santley 2000, 2003) link this episode of regional depopulation with volcanic activity during the Late and Terminal Formative periods. The implication is that volcanic eruptions and their aftereffects were severe enough that many of the regional inhabitants chose to leave. But why did some people choose to flee the region while others chose to stay? Though volcanic ash may affect the entire area surrounding the blast, it does not fall in a homogenous fashion—because of wind and precipitation, areas will be differentially affected. Were the people who left the region living at sites that were the most severely affected by ash fall? Possibly. The decision to stay or to go may have also been influenced by social ties to central administrators. Perhaps regional elites offered benefits and incentives for people to stay, or perhaps people simply remained out of a sense of obligation to their leaders (e.g., tribute demands) and/or kin groups. While we may never know the full range of factors that influenced peoples' decisions about staying or leaving, we can assume that people were probably motivated by a combination of social, environmental, and political factors.

Volcanism in the Tuxtlas

The volcanic eruptions that blanketed parts of the Sierra de los Tuxtlas with ash during the Formative period originated from vents near Cerro Mono Blanco. The first eruption coincided with the end of the Early Formative

(1250–900 BC), the second towards the end of the Late Formative (150 BC), and the third during the Terminal Formative (AD 150–250) (Santley 2000, 2003; Santley *et al.* 1997). Volcanic eruptions and subsequent ash falls undoubtedly impacted local climate, ecology, agriculture, and human health and livelihood. The accumulation of ash in the sky reduces the amount of solar radiation that can penetrate the lower atmosphere, resulting in changes in air pressure, temperature, and precipitation, among other climatological factors (Gill 2000:199). Eruptions and ash fall also destroy vegetation, crops, buildings, and in some cases human and animal life. Based on a study of the 1943 eruption of El Paricutín in Central Mexico, Eggler (1948:426–427) found that it was not the lava, but the volcanic ash that most negatively impacted vegetation. The deposition of volcanic ash can reduce the amount of oxygen that plants absorb into their root systems, in addition to causing mechanical breakage from the weight of the ash (Eggler 1948:427).

Volcanic ash can also be dangerous to humans and animals—heavy ash fall can result in death, and light to moderate ash fall can irritate eyes and respiratory systems (Chase 1981:63). Moreover, gases released from both the eruption and the volcanic ash combine with atmospheric water, resulting in acid rains, which are detrimental to humans, plants, and animals (Chase 1981:63; Warrick 1975:11–12). Acid rains also contaminate water sources and thus reduce the abundance of aquatic resources and fresh drinking water (Chase 1981:64). The weight of the ash on buildings can collapse roofs, especially during the rainy seasons—Chase (1981:64) calculates that 1 inch (2.5 cm) of ash on a roof adds 10 pounds of weight per square foot (14.7 kg per m^2). If ash fall occurs during the rainy season, it can also lead to flooding, erosion, mudflows, and landslides (Chase 1981:64).

Regional recovery from such a major environmental disaster would be a slow process. It would take approximately 30 to 40 years after ash fall, or 1 to 2 generations, for soils to weather sufficiently to support climax vegetation (Chase 1981:64). While larger trees might survive and continue to fruit, most plant life would require time to regenerate (Eggler 1948:427). The potential for local terrestrial fauna to rebound is directly dependent on the succession of plant life. We can also expect that smaller mammals with shorter reproductive cycles (e.g., rabbits) would rebound more quickly than larger mammals with longer reproductive cycles (e.g., deer). Aquatic resources, on the other hand, tend to rebound more quickly than terrestrial plants and animals (Chase 1981:64). Thus, in the short term, people would have had to adjust their subsistence strategies in order to survive. This may have meant a reduction in large game hunting, and an increase in the exploitation of small mammals and aquatic resources. Overall, we can expect that people would have diversified their subsistence strategies (see Morton and Shimabukuro 1974) and expanded their collecting and hunting ranges to extend beyond the area of volcanic impact. Indeed, those villagers who had begun to diversify their subsistence base prior to volcanic eruption and ash fall would have had a distinct advantage for weathering the new environment. Despite these immediate issues, however, volcanic eruption and ash fall has a positive long-term impact on agricultural production, in that volcanic ash significantly contributes to soil fertility (Giller 2000). Once soils have weathered sufficiently for plant life to regenerate, we would expect that Formative people would have gradually invested more time and labor towards farming activities.

While active volcanism certainly had ill effects, the long-term result of repeated ash fall was ultimately positive in terms of creating fertile soils for farming. The best farmland in the adjacent lowlands was located along the major rivers, such that annual flooding renewed soil fertility. The only significant river in the Tuxtlas, however, is the Catemaco, which in no way compares in size to the Coatzocoalcos or the Papaloapan; indeed the Catemaco River lacks the levee lands so characteristic of these lowland rivers. In the absence of significant expanses of annually renewed river levees, Formative Tuxtla farmers would have had to practice shifting cultivation, alternating between fields located close to the residence and others located at a distance (e.g., infields versus outfields). Thus, since much of the farmland in the Tuxtlas was not situated along water sources, farming and fishing tasks would have been exclusive activities requiring differential scheduling. In other words, as farmers invested more time and labor into farming, they would have fewer opportunities for fishing excursions. Such a scheduling problem could be offset through coordinating fishing trips during lulls in the farming cycle, or through establishing and/or strengthening existing trading relationships with coastal groups. Nevertheless, and *contra* to the lowland case, it is reasonable to expect an inverse relationship between fishing and farming activities in the Tuxtlas.

La Joya

The site of La Joya represents a sizable Formative occupation in the Sierra de los Tuxtlas. Excavations uncovered substantial evidence of domestic occupation, including domestic architecture, hearths, and storage pits. Excavated by Philip J. Arnold III during 1995 and 1996, the site covers approximately 25 ha and is located on the alluvial flatlands along the Catemaco River in the southern portion of the Tuxtlas. La Joya was occupied throughout the Formative period (1400 BC-AD 300), although settlement intensity varies over the site's occupation (Arnold 2002). Despite this variation in settlement intensity, there is clear cultural continuity in the people living at La Joya throughout this period, as demonstrated by Arnold's (1999) recent ceramic analysis that has revealed a gradual stylistic change indicative of an *in situ* cultural transition.

Analysis of residential patterns from La Joya indicates that the site's residents were sedentary by the end of the Early Formative period (McCormack 2002:192). Prior to that, people were moving seasonally or annually, occupying multiple locations (Arnold 2000, McCormack 2002:192). Architecture during this time was mostly ephemeral, consisting mainly of "packed earthen surfaces" with associated low-density sheet midden (Arnold 2000:126). McCormack (2002:192) relates the transition towards sedentism at the end of the Early Formative to the eruption of Cerro Mono Blanco around 1250–900 BC. La Joya was located along the edge of the area impacted by the eruption, evidenced by a paltry 8-10 cm of ash, which may have influenced the decision to settle down (McCormack 2002:193). Given new constraints on arable land as a result of ash fall, McCormack (2002:193) suggests that households located on "good agricultural land [that] abandoned the location for a season [could] risk losing claim to that land". By the Late Formative period, architecture was more substantial and included a small residential mound approximately 1 m high (Arnold 2000; Arnold *et al.* 1997).

Indirect evidence of subsistence suggests an increasing reliance on maize throughout the site's occupation. An increase in the presence and size of subsurface storage pits from the Early to Late Formative periods indicates that La Joya residents may have been producing, accumulating, and storing more maize (and perhaps other foodstuffs) through time (see Arnold 2000). Moreover, the remains of ridged agricultural fields were identified in several excavations units—these fields were overlaid with a layer of volcanic ash from the Terminal Formative eruption (Arnold 2000). Thus, by the end of the Terminal Formative period, residents of La Joya were investing more labor into field maintenance.

Analysis of the ground stone artifacts from La Joya demonstrates that the design and use of grinding tools became more specialized from the Early to Middle Formative periods (Arnold 2000:127; McCormack 2002: 169). McCormack (2002:175, 178) has identified a shift from one- to two-handed manos and an increase in the quantity of two-sided metates from the Early to Late Formative periods—both patterns suggest an increase in the use of grinding implements which likely reflects an increase in maize processing (see also Arnold 2000:127). An increase in the use of naturally rougher basalt (vesicular) through time also indicates more intensive maize processing (McCormack 2002). These changes in the La Joya ground stone assemblage suggest a shift to a set of tools geared toward maize processing. Moreover, this pattern may be reflective of a broader trend seen throughout Mesoamerica during the Early to Middle Formative transition (see Rosenswig 2006).

Overall, the artifactual and architectural evidence from La Joya reveals a long history of settlement marked by increases in sedentism, maize reliance, and social differentiation (Arnold 1999, 2000, 2002; McCormack 2002). Throughout the site's tenure, people became increasingly sedentary and eventually intensified maize production. The emergence of social differentiation at the site during the Late Formative occurs within the context of regional political change—a three-tiered settlement hierarchy emerged at this time, centered at Chuniapan de Abajo (see fig. 1). How closely were the residents of La Joya integrated into this regional political system? Were people dependent on regional elites for access to esoteric media? Did they provide tribute to regional elites in the form of food and/or labor? Lithic evidence from La Joya reveals that the site's Late Formative residents were procuring non-local obsidian from several sources (McCormack 1996). Moreover, the high percentage of obsidian debitage relative to finished blades at La Joya suggests that people were producing obsidian blades on site (McCormack 1996). These data suggest that the people living at La Joya maintained their own obsidian exchange networks and thus were not dependent on regional elites for access to long-distance exchange (McCormack 1996). But were La Joya residents obligated to provide maize tribute to regional leaders? An increase in storage area through time suggests that people were producing and storing surplus maize (see above). Without a comparative analysis of plant datasets from different sites in the regional settlement hierarchy, however, it is impossible to trace the movement of surplus grain. Identifying the shift to maize intensification at La Joya and its correlation to the establishment of a regionally-consolidated political order, however, may provide clues as to the cause of increased production. If people intensified maize production *after* the establishment of the regional settlement hierarchy (which occurred during the Late Formative period), then one might argue that elites spurred intensification through their demands for tribute. With this in mind, I now turn to the subsistence data.

THE ARCHAEOBOTANICAL DATA

The details of the recovery and analysis of the carbonized plant materials, as well as the raw data, are reported

Table 1. Plant Taxa identified at La Joya.

Common Name	Taxonomic Name
FIELD CROPS	
Maize	*Zea mays*
Tepary bean cf.	*Phaseolus acutifolius cf.*
Bean	*Phaseolus sp.*
Bean cf.	*Phaseolus sp. cf.*
Bean family	*Fabaceae*
Bean family cf.	*Fabaceae cf.*
TREE CROPS	
Avocado	*Persea americana*
Avocado cf.	*Persea americana cf.*
Coyol	*Acrocomia mexicana*
Sapote	*Pouteria sapote*
MISCELLANEOUS	
Trianthema	*Trianthema sp.*
Achiote cf.	*Bixa orellana cf.*

and published elsewhere (VanDerwarker 2006a). Thus, I limit my present discussion of these issues to very basic information. More than 600 flotation samples were taken during the excavations of La Joya; the present analysis includes all those samples that derive from features and well-defined activity areas (n = 318). The volume of soil sampled was not standardized, but it was systematically recorded, with most samples measuring 3-8 liters. Soil was floated using a modified SMAP system, and carbonized remains from both the light and heavy fractions are included in the analysis. Because of the extremely fragmented nature of the specimens, I identified carbonized remains down to the 0.71 mm sieve size. Samples from Early and Terminal Formative contexts were the most numerous, thus resulting in greater quantities of carbonized remains. There were fewer samples from Middle and Late Formative contexts, making it more difficult to assess changes in plant use during these periods (see below).

All plant specimens were identified to the lowest possible taxonomic level. Once the plant specimens were sorted and identified, I recorded counts, weights (in grams), portion of plant (e.g., maize kernels versus cupules), and provenience information. Nearly all maize kernels were too fragmentary to obtain length or width measurements or to determine variety. Other than solitary maize cupules, no cob fragments were identified, thus prohibiting additional observations regarding variety.

Modern botanical guides were used to determine what taxa might occur in the assemblages (Manriquez and Colin 1987, Soriano *et al.* 1997); the serial journal *Flora de Veracruz* was extremely helpful in this pursuit. Identifications were made with reference to modern comparative specimens housed in the paleoethnobotanical laboratory at the University of North Carolina at Chapel Hill. I collected most of the relevant comparative specimens during a trip to southern Veracruz, Mexico in May 2000. In addition, several specimens were sent to Dr. Lee Newsom at the Pennsylvania State University for identification.

Preservation of carbonized plant remains in tropical environments is generally poor. The archaeobotanical assemblage from La Joya is no exception, and the diversity of species recovered and identified probably does not reflect the diversity of plant resources originally exploited by the site's inhabitants (Table 1). Of the plant taxa identified at La Joya, maize (*Zea mays*) is ubiquitous throughout the site's occupation. Moreover, maize, beans (*Phaseolus* sp.), avocado (*Persea americana*), coyol (*Acrocomia mexicana*), and mamey sapote (*Pouteria sapote*) appear to be the most common food resources at the site. The latter three resources are all fruits from tropical trees. Two other taxa identified in the La Joya plant assemblage include trianthema (*Trianthema* sp.) and a possible achiote specimen (*Bixa orellana* cf.). Both plants were probably used to season other foods. Given the current topic of agricultural intensification, I focus this discussion around maize. Please refer to VanDerwarker (2005, 2006a:79-89) for a more thorough discussion of broader plant resources and plant subsistence at La Joya.

A variety of quantitative techniques were used in the analysis of the archaeobotanical data, including ubiquity measures, relative percentages, species diversity indices, independent ratios, box plots, and multivariate analyses (see VanDerwarker 2006a, 2006b). Because this paper primarily addresses agricultural intensification, I restrict the present analysis to measures that deal specifically with the production and consumption of maize.

Expectations of Maize Intensification

There are a variety of methods for assessing the intensification of maize production in the archaeological past, most of which involve measures of non-food data, such as changes in ground stone tool assemblages, increases in storage volume, carrying capacity calculations for a particular site or region, etc. It is far trickier to assess intensification from the maize remains themselves (but see Scarry 1986). In considering the process through which maize cultivation becomes intensified, there are two basic outcomes that can be expected: (1) an increase or stability in the overall quantity of maize through time; and (2) an increase in the evidence of maize processing through time.

If people begin to invest more time and labor into farming maize, we might expect levels of maize consumption to increase. Indeed, the whole point of intensification is to increase crop yields on a given plot of land through strategies that reduce competitors and encourage plant growth (Netting 1993). Thus, with expectations of higher yields also comes the expectation of more maize appearing in the archaeological record through time. While this may be a simple and compelling picture, it is not, however, the whole picture. Intensive farming strategies lead to a reduction in shifting cultivation, and longer periods of cropping the same plot of land. Declining soil fertility on a given plot of land is in part mitigated through construction of field ridges, small-scale irrigation, intercropping with nitrogen-fixing plants (e.g., beans), weeding to reduce competitors, and fertilizing with human and animal waste. Despite all these efforts to maintain high yields on a plot of land, yields will decline, and eventually the plot will be allowed to fallow. The point here is that in the short term, yields will increase dramatically for a single plot (Conelly 1992), but given declining yields on that plot over the long term, the net increase in overall yields may not be much higher than more extensive farming methods, such as field scattering and annual crop rotation (Boserup 1965). Thus, in terms of the archaeological plant data, we can expect maize intensification to be represented by either an *increase* or *continuity* in the overall quantity of maize remains through time.

In addition to considering the overall quantity of maize remains through time, I also address maize production through a consideration of one of the initial stages of maize processing, that of shelling. Before maize can be ground into flour, the kernels must first be removed from the cob, leaving the cobs and cupules as byproducts of the removal process. Because kernels represent the part of the maize plant meant for consumption and cupules represent processing discard, lower ratios of kernel counts to cupule counts would be indicative of elevated levels of maize processing (Scarry and Steponaitis 1997:117). If we were to compare maize kernel to cupule ratios from different temporal periods, we could determine the relative degree of maize processing through time.

I consider maize processing in the context of Killion's houselot model of residential activity. Thomas Killion (1987, 1990) has examined subsistence farming as it relates to residential space among contemporary Tuxtlas farmers and has developed an ethnoarchaeological model relating agriculture to the organization of household labor and residential patterns. Specifically, Killion (1987, 1990) links cultivation intensity (defined as the increasing frequency of cultivation on a constant area of land over time) with residential organization, presenting a farming system he refers to as infield/outfield cultivation. Infields refer to plots located near the settlement, and outfields to plots located at a distance from the settlement.

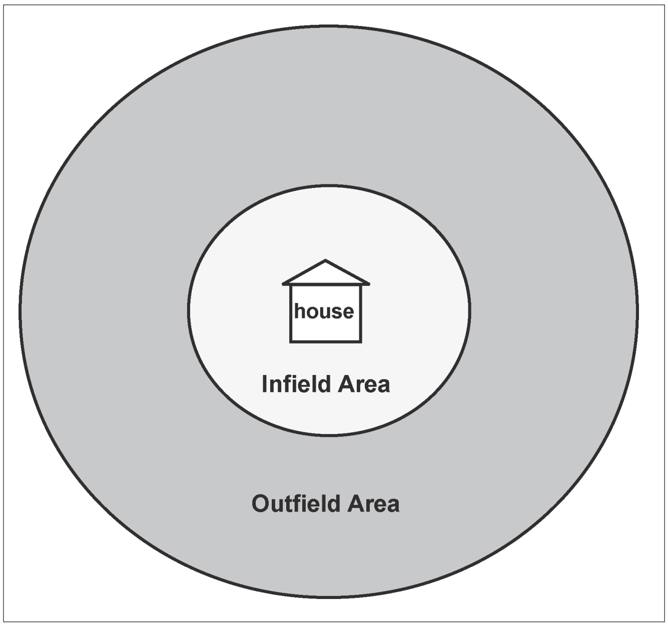

Fig. 2. Schematic representation of relative space in infield vs. outfield areas (not to scale).

When infields are cultivated more intensively than outfields, most farming tasks are conducted near or at the residence, including crop processing, tool manufacture/repair, and storage. Outfield cultivation, however, requires travel and a temporary shelter away from the primary residence. When outfields are cultivated more intensively, farmers must perform harvest-related tasks in the fields, including initial processing, drying, bundling, and storage of crops. Thus, the spatial location of farm fields relative to the residence conditions the types of activities conducted at the residence, which in turn conditions the organization of residential space (Killion 1987).

Killion's (1987, 1990) analysis of modern Tuxtleco households has revealed certain insights into the relationship between agricultural and residential space that are of particular relevance here. First, he found that when infields are cultivated intensively most farming-related tasks are performed at the houselot, thus requiring a larger residential work area (Killion 1990:205). In other words, because infields are located closer to the residence, it makes sense to transport harvested maize ears to the residential areas and shell them there. This would result in more evidence of maize processing at the site, namely a

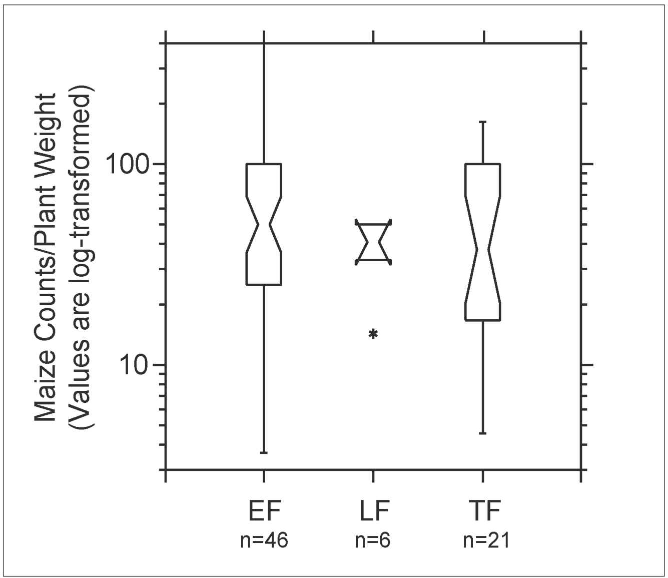

Fig. 3. Box plot of standardized maize counts by period (EF: Early Formative, LF: Late Formative, TF: Terminal Formative).

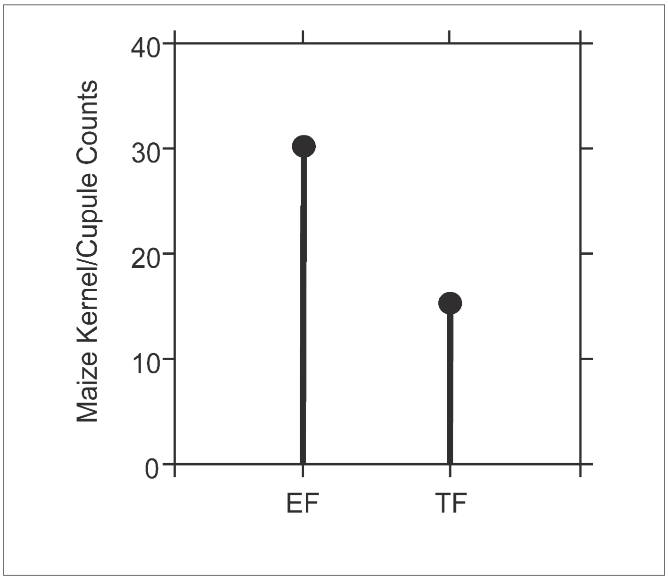

Fig. 4. Dot chart of maize kernel to cupule ratios by period (EF: Early Formative, TF: Terminal Formative).

higher proportion of maize cupules. If farmers were more focused on cultivating outfields than infields, then we can expect that maize shelling would take place in the outfields; presumably, farmers would return to the residential area with baskets of already-shelled maize kernels. This would result in less evidence of maize processing on site, with proportionately fewer maize cupules.

How do differences in infield/outfield cultivation relate to maize intensification? Let's imagine a diagram of nested concentric circles with the residential core at the center, ringed by infields, which are in turn ringed by outfields—the outfield ring consists of more area than the infield ring (fig. 2). More land translates into more potential for shifting (extensive) cultivation, allowing plots to fallow for a time before cropping them again. The infield ring, on the other hand, has a limited amount of potential farmland. A focus on infield production limits the possibility of field rotation, which limits the amount of time a plot can remain in fallow. Thus, unless residences are moved periodically, a focus on infield production would require more intensive labor in the form of weeding and fertilizing in order to make sure that plots continue to produce maximum yields. Thus, infield production would entail a more intensive cultivation strategy than outfield cultivation. We can identify changes in infield/outfield cultivation strategies through time by considering maize kernel to cupule ratios. According to Killion's model, intensification of maize production would mean an increased focus on infield production. More infield production leads to more maize processing on site, which results in elevated levels of maize cupules. Thus, if farmer at La Joya were intensifying maize production, we can expect a reduction in maize kernel to cupule ratios through time.

Maize Consumption: Overall Quantity of Maize

To assess the overall quantity of maize remains at La Joya through time, I employ box plots (see also Cleveland 1994, McGill *et al.* 1978, Scarry and Steponaitis 1997, Wilkinson *et al.* 1992). Box plots summarize distributions of data using several key features. The median is marked by the area of maximum constriction at the center of the box. The edges of the box, or hinges, represent the 25th and 75th percentiles of the distribution—the approximate middle 50% of the data fall between the hinges (Cleveland 1994:139). Vertical lines, or whiskers, extend outward from the box and represent the tails of the distribution. Outliers are depicted as asterisks and far outliers as open circles. Box plots also allow for a quick visual assessment of statistical significance through comparison of "notched" areas; notches are recognizable in that they give the box plot its characteristic hourglass shape. If the notches of any two boxes do not overlap, then the medians of the two distributions are significantly different at the 0.05 level (McGill *et al.* 1978:14; Scarry and Steponaitis 1997:113; Wilkinson *et al.* 1992:198).

Maize counts are standardized by plant weight for each sample. Unlike the density measure that uses soil volume as a standardizer, standardizing by plant weight considers the contribution of a specific plant or category of plants solely in terms of *plant-related activities*. As a result, a plant weight ratio more accurately reflects spatial and temporal differences in plant use. Because I am primarily interested in the importance of maize *relative to other plant resources* at the site, standardizing maize counts by plant weight is the most appropriate measure (see also Scarry 1986).

The box plots reveal no significant differences in the distribution of maize through time (fig. 3). Given that maize only occurs in two samples from Middle Formative contexts, these data are excluded from the analysis. The box plots from the remaining periods illustrate that the contribution of maize relative to the overall plant assemblage remained relatively consistent through time. Generally, it appears that the residents of La Joya consumed comparable amounts of maize throughout the Formative period, which conforms to the first expectation for intensification that is outlined above.

Maize Processing: Kernel to Cupule Ratios

Kernel to cupule ratios were calculated and expressed as a dot chart (fig. 4). The Middle and Late Formative periods at La Joya were excluded from this calculation—sample sizes for these periods were low, and these contexts yielded no cupules, making the calculation impossible. The resulting dot chart shows a dramatic decrease in maize kernels versus cupules through time. This ratio decreases by a factor of 15 from the Early to Terminal Formative periods, suggesting that La Joya residents increasingly processed more maize at the residential locus.

Given Killion's houselot model presented above, I argue that the change in maize kernel to cupule ratios at La Joya indicates a shift over time to a focus on infield production, which would have required a more intensive cultivation strategy. While this measure makes it possible to identify a shift towards maize intensification, it is difficult to narrow down the timing of this shift. The small sample sizes of plant remains from Middle and Late Formative contexts makes it impossible to determine whether this intensification of maize production began earlier in time.

Summary

Overall, the plant data from La Joya indicate a focus on maize by the Early Formative period. Kernel to cupule ratios, however, reveal that Early Formative people were not processing much (or any) maize at, or adjacent to, the site itself. Because the Early Formative period at La Joya represents part of a larger seasonally-based settlement system, it is possible that people chose to settle at La Joya after the maize harvest, bringing an abundant supply of already shelled maize with them. Thus, what appears to be a focus on maize during the Early Formative may simply reflect a more seasonal subsistence strategy.

People stopped moving seasonally and settled permanently at La Joya by the end of the Early Formative (Arnold 2000, McCormack 2002:192). By the Terminal Formative period at La Joya, people had intensified maize production. The kernel to cupule ratios indicate that people were processing significantly more maize at the site by this time. This increased maize processing probably reflects both the shift to settled life and the shift to infield production. People were also investing time and labor into ridging their fields by the Terminal Formative period (Arnold 2000). Stable Carbon and Nitrogen Isotope data from human skeletal remains confirm a focus on maize in the Terminal Formative Tuxtlas; unfortunately human skeletal remains from the earlier periods in the Formative were either lacking or did not yield enough bone collagen to determine isotopic signatures (see VanDerwarker 2006a). Thus, in order to elucidate the process of intensification of maize production as it unfolded during the Middle and Late Formative periods, I now turn to the other half of the subsistence system at La Joya, represented by the zooarchaeological remains.

THE ZOOARCHAEOLOGICAL DATA

The zooarchaeological assemblage from La Joya comes from features, well-defined activity areas, and levels within excavation units. All specimens that could be firmly assigned to a clear temporal period were included in the analysis. A total of 4,585 bone specimens weighing 2,920 g were recovered from screened contexts; an additional 2,425 bone specimens weighing 62 g were recovered from the 318 flotation samples that were selected for analysis. For the purposes of this analysis, I restrict my discussion to the screened assemblage; please refer to VanDerwarker (2006a:123-140) for a fuller discussion of the zooarchaeological remains, including bones from flotation samples. Identification and analysis followed standard zooarchaeological procedures (Reitz and Wing 1999). Specimens that could not be identified with reference to the zooarchaeological comparative collections at the University of North Carolina at Chapel Hill Research Laboratories of Archaeology were taken to the Zooarchaeology Comparative Collection at the Florida Museum of Natural History for comparison.

Although not discussed here, a thorough taphonomic analysis was conducted on the faunal assemblage (see VanDerwarker 2006a:152-153). This analysis (and associated chi-square tests) revealed that the bone assemblage from the Middle Formative period may have been more ravaged by taphonomic processes than the Early, Late, and Terminal Formative samples; the Middle Formative sample also had the smallest sample size of all periods. Thus, we must be cautious in attributing too much meaning to patterns identified in the Middle Formative zo-

Table 2. Animal Taxa Identified at La Joya (asterisk * indicates preferences for disturbed environments, such as secondary growth, agricultural fields and gardens, and human habitations).

Common Name	Taxonomic Name
FISH	
Alligator gar	*Lepisosteus spatula*
Sucker family	Catostomidae
Catfish family	Pimelodidae
Snook	*Centropomus sp.*
Jack	*Caranx sp.*
Snapper	*Lutjanus sp.*
Mojarra	*Cichlasoma sp.*
AMPHIBIANS	
Toad*	*Bufo sp.*
Frog	*Rana sp.*
REPTILES	
Mexican giant musk turtle	*Staurotypus triporcatus*
Box/Pond turtle family	Emydidae
Slider	*Trachemys scripta*
Green iguana	*Iguana iguana*
Boa constrictor	*Boa constrictor*
BIRDS	
Duck family	Anatidae
Muscovy duck	*Cairina moschata*
Duck	*Anas sp.*
Hawk*	*Buteo sp.*
Falcon family	Falconidae
Turkey/Pheasant family	Phasianidae
Wild turkey	*Meleagris gallopavo*
Northern bobwhite	*Colinus virginianus*
Yellow-bellied sapsucker	*Sphyrapicus varius*
MAMMALS	
Opossum*	*Didelphis sp.*
Nine-banded armadillo	*Dasypus novemcinetus*
Squirrel*	*Sciurus sp.*
Mouse/Rat family	Muridae
Coues' rice rat*	*Oryzomys couesi*
Hispid cotton rat*	*Sigmodon hispidus*
Mexican wood rat	*Neotoma mexicana*
Mouse*	*Peromyscus sp.*
Rabbit*	*Sylvilagus sp.*
Domestic dog	*Canis familiaris*
Skunk/Weasel family	Mustelidae
Ocelot*	*Leopardus pardalis*
Peccary family	Tayassuidae
Collared peccary*	*Tayassu tajacu*
Deer family	Cervidae
White-tailed deer*	*Odocoileus virginianus*
Red brocket deer	*Mazama americana*

oarchaeological assemblage. The Early, Late, and Terminal Formative assemblages, however, produced similar results in terms of the taphonomic measures used to assess the data, indicating that these assemblages were affected similarly and are thus comparable for the sake of further analysis (see also VanDerwarker 2006a:152).

A variety of animals was identified in the La Joya bone assemblage and represent all five vertebrate taxonomic classes (fish, amphibians, reptiles, birds, and mammals) (see Table 2). The vast number of species identified in the assemblage prohibits a detailed discussion of each animal and its habitat preferences here. Suffice it to say that mammalian taxa were the most abundant and ubiquitous species identified at the site during all time periods. Nevertheless, a diversity of fish, reptiles, and birds also contributed to the Formative diet at La Joya. The amphibian remains (represented mostly by toads), however, probably do not represent food remains; the bufotoxins produced in the skin of these toads would have made the flesh too bitter for consumption. Moreover, the possible species to which these toad remains could be assigned (based on local biogeography) tend to prefer living in close proximity to human habitations, thus making them probable commensals.

Expectations: The Garden-Hunting Model

The analysis of the plant remains revealed that residents of La Joya had become more invested in farming by the Terminal Formative period. In order to use the zooarchaeological data to assess earlier shifts in agricultural intensification, I frame my discussion and analysis around the garden-hunting model. As humans disturb vegetation through the clearing and planting of fields and gardens, they provide new habitats for a wide variety of weedy pioneer plants that thrive in open habitats (Emslie 1981:317; Neusius 1996:276). The diversity and concentration of crops and weedy species, in turn, attracts insects, which attract animals that prey on those insects (Emslie 1981:317; Neusius 1996:276). Browsing animals are attracted to the new diversity of highly edible vegetation, which may include both wild and cultivated species. Ultimately, the changes wrought on the local environment through farming activities create habitats that favor a greater diversity and density of small animals than found in forested environments (Emslie 1981:317; Linares 1976:332; Neusius 1996:276; Speth and Scott 1989:71; Szuter 1994:55). While large animals, like deer, are also attracted to disturbed environments, the overall quantity and diversity of smaller animals is much greater. This anthropogenic process results in a local pool of readily available animal protein that humans can easily exploit.

Thus, a new predator/prey cycle is established in disturbed environments that is qualitatively and quantitatively different than those in undisturbed, primary environments.

An increasing commitment to farming to meet basic subsistence needs likely involved the reorganization of the larger subsistence system, which would have affected the organization of domestic labor. As people devoted more time to farming activities, scheduling other subsistence activities like hunting and fishing would have become more difficult. The garden-hunting model proposes that people dealt with new scheduling conflicts by hunting and trapping animals inhabiting their fields and gardens (Emslie 1981:306; Linares 1976:331; Neusius 1996:276). Since many of these animals were crop pests, garden-hunting served the dual purpose of providing protein to the diet and protecting crops from competitors (Emslie 1981:306; Neusius 1996:276; Szuter 1994:60). Following this line of reasoning, Neusius (1996:276) has argued that as farming became a more prominent subsistence activity, hunting, in turn, became a non-selective, opportunistic activity that increasingly occurred during other subsistence-related tasks. This change in hunting patterns would be reflected archaeologically by an increase in smaller prey and an increase in species diversity (Neusius 1996:276). This scenario supposes that people would have exploited a representative sample of the animals inhabiting agricultural fields, gardens, edge locales, and local areas of secondary vegetation, including animals that have traditionally been considered commensals (see also Szuter 1994, Szuter and Bayham 1989).

Linares (1976), who first proposed the garden-hunting model, argued for a more *selective* hunting strategy in which people focused their efforts on the larger species (in this case, white-tailed deer and peccary) attracted to their cleared and cultivated fields. She argued that white-tailed deer could withstand intensive harvesting by people (Linares 1976:347). Moreover, she suggested that an increased focus on garden-hunting might displace the exploitation of aquatic fauna (Linares 1976:347). As ethnographic studies in Amazonia have shown, however, local populations of large game surrounding farming communities soon become depleted by over-hunting (Griffin 1989:69; Rai 1982:184–188; Speth and Scott 1989:75; Vickers 1980). Once people have depleted local levels of preferred larger game, they can either focus on less desirable smaller species (*sensu* Neusius 1996), or they can travel farther away from the residence to continue exploiting larger prey. Focusing on smaller game inhabiting fields and gardens adjacent to the houselot may have been a more attractive option in that it would: (1) effectively deal with scheduling conflicts between farming and hunting during key periods in the farming cycle; (2) involve little effort or risk in that procurement strategies would probably involve traps and snares (Coe and Diehl 1980b:106; Hovey and Rissolo 1999:261); (3) constitute a self-sustaining system in that smaller mammals (e.g., rabbits) have high reproductive rates and would not become locally depleted like deer; and (4) help control losses to animals feeding on young plants or ripe crops.

Whether farmers choose selective versus opportunistic hunting strategies may in part depend on how predictable their farming returns are. Maintaining a focus on large mammals is a risky venture in that it requires a well-coordinated long-distance hunt that takes farmers away from their fields for a period of time. This type of high-risk selective hunting may imply a certain confidence in the farming cycle. As Speth and Scott (1989:77) state, “the increased emphasis on large species among groups who obtain a substantial proportion of their total calories from cultivated plants may be a response… to the greater predictability of their horticultural food base.” Thus, the high risk involved in a selective hunting strategy is offset by the minimal risk involved in the farming subsistence base. Of course, a few “well-coordinated long-distance” hunts could easily be scheduled around the farming calendar. Moreover, if people were practicing a gendered-division of labor in which women were farming and men were hunting, occasional hunting trips would probably not have significantly impacted farming. If farming evolved as an outgrowth of women’s plant collection and management activities, then men would have been relatively free to continue their hunting and fishing activities without scheduling conflicts. However, in a region where people may have practiced year-round farming, there undoubtedly would have been critical times in the farming cycle when men and women alike would have participated in farming-related activities—these times may have precluded extended hunting or fishing trips.

One could also argue that an opportunistic garden-hunting strategy implies that the subsistence economy may be somewhat stressed. For example, if people are eating any animal they come across, then this suggests a “take what you can get” attitude in which people do not have the luxury of being selective. Rather than being selective about the animals they exploit, people may choose to diversify—and diversification often represents a strategy of risk management or risk response (Fenoaltea 1976, Guillet 1981, Netting 1993, Walker and Jodha 1986). Thus, it is possible that a shift towards garden-hunting may reflect a response to a set of new risks associated with the transition to farming. However, the entire premise of the garden-hunting strategy is the economy of resources. This conflict between garden-hunting as risky and garden-hunting as economical can be resolved if we simply uncouple “garden-hunting” and “opportunistic” (see also Rosenswig 2005).

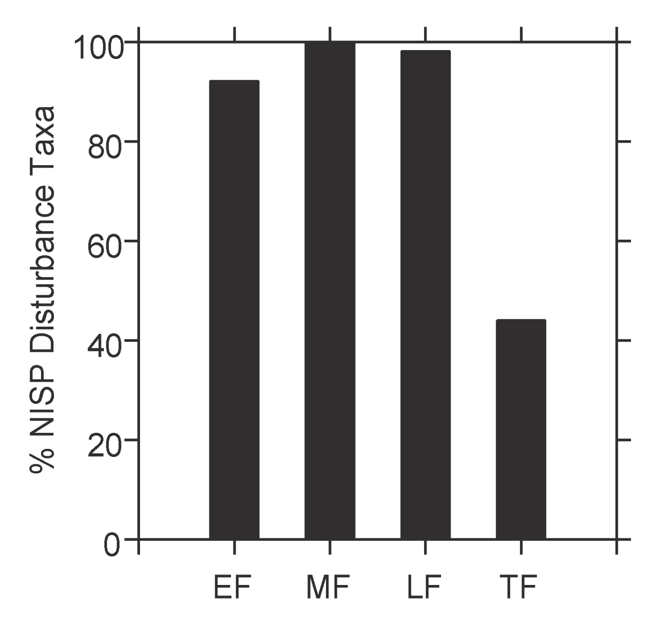

Fig. 5. Bar graph of disturbance fauna (%NISP) by period (EF: Early Formative, MF: Middle Formative, LF: Late Formative, TF: Terminal Formative).

Does garden-hunting have to be opportunistic? Just because local resources of large prey may become depleted and agricultural fields abound with small animals does not mean that farmers will not be selective about what they put in their mouths. While they may increasingly focus on the exploitation of small animals using a garden-hunting strategy, they may still be selective about which small animals they choose to eat. Thus, we might expect that farmers were more selective in their garden-hunting practices when farming was more predictable and harvests were good. In times of crop failure, however, people would have been faced with food shortages—they may have turned to opportunistic garden-hunting as a way to buffer against shortages. This would be reflected archaeologically by high animal species diversity.

Given the environmental context of the present case study, I propose the following expectations of La Joya's zooarchaeological assemblage if the site's residents shifted their hunting/fishing subsistence strategy to focus on garden hunting. First, we can expect an increase in fauna that prefer environments disturbed by human activities: edge locales, farm fields, house gardens, etc. Second, since most disturbance fauna tend to be mammals, we can expect a decrease in the proportion of birds, reptiles, and fish in the diet, and hence in the zooarchaeological assemblage through time. Third, because farmland adjacent to La Joya is not contiguous with prime bodies of water (e.g., Catemaco Lake and the Gulf Coast), we can expect that an increased focus on farming would result in a restriction on fishing/turtling opportunities, thus resulting in a decrease in aquatic fauna in the diet. Finally, we can expect a decrease in species diversity (richness), as people would focus their animal diet primarily on mammals.

Disturbance Fauna

The presence of disturbance taxa in an assemblage represents two different processes. When people clear land to farm, they create new "disturbed" habitats which support a greater diversity and density of terrestrial fauna than primary habitats. Thus, an increase in disturbance fauna in an archaeological assemblage reflects both an anthropogenic modification of the local environment (e.g., field clearance) and a choice made by people to exploit animals inhabiting local disturbed environments. A decrease in disturbance fauna, however, does not necessarily reflect a decrease in the creation of disturbed habitats, or by extension a decrease in agricultural field clearance. Rather, a decrease in disturbance fauna may simply reflect a choice made by people to exploit fauna from other habitats.

To examine this process at La Joya, I began by assigning each species identified to primary and secondary habitats (see also VanDerwarker 2006a). Information on habitat preferences was collected from modern field guides and ecological studies from the region (Coe and Diehl 1980b, Howell and Webb 1995, Lee 2000, Reid 1997, Soriano *et al.* 1997). Because animals are not fixed onto the landscape, this was not a straightforward task. Many animals identified in the assemblages inhabited as many as five habitat zones. As a result, I simplified my approach by creating a simple dichotomy of animals that prefer disturbed habitats and those that do not (see Table 2). Disturbance species include animals that prefer secondary growth and forest edge areas, animals that can be considered agricultural pests, and animals that take refuge in and around human habitations. The disturbance species include both commensal taxa and food species. Because dogs are domestic animals and aquatic taxa are restricted to bodies of water, they are excluded from these measures. While dogs were certainly being eaten by the site's residents (evidenced by burning, disarticulation, and butcher marks on the remains), they would not have been hunted and trapped in the same way as wild fauna. Indeed, perhaps it is best to think about dogs as meat stored "on the paw." It may also be worth mentioning that there was a slight increase in dog NISP at La Joya during the Terminal Formative period; a chi-square test, however, did not reveal this pattern to be statistically significant.

I calculated the percentage of disturbance fauna by time period using NISP (number of identified specimens), MNI (minimum number of individuals), and presence (see VanDerwarker 2006a:162). All three measures produced similar patterns; given constraints on time and space, I restrict my presentation to %NISP (fig. 5). The percentages for the Middle Formative period equal 100% for all three measures, likely a result of small sample size. If we simply ignore the Middle Formative values, we find that the percentage of disturbance fauna is roughly comparable (and quite high) during the Early and Late Formative periods. After the Late Formative, there is a subsequent decline in the %NISP of disturbance fauna in the Terminal Formative period. A chi-square test confirms this drop in the percentage of disturbance fauna to be statistically significant (χ^2 = 234.6, p > 0.001).

This pattern suggests a high level of field clearance through time, accounting for the high percentages of disturbance fauna through the Late Formative period. Not only were the residents of La Joya creating anthropogenic habitats through field clearance, they were also choosing to exploit the animals inhabiting those niches. In some cases, they were probably just getting rid of pests like mice and rats, but in other cases they were procuring animal protein through garden-hunting. The subsequent decrease in disturbance fauna during the Terminal Formative period does not necessarily mean that people were clearing fewer fields and creating fewer anthropogenic habitats. Rather, this decline in disturbance fauna probably reflects a response to a landscape altered by volcanic eruption and subsequent ash fall occurring at the close of the Late Formative.

Animal Class Ratios

I consider the contribution of birds, reptiles, and fish to the Formative diet through the use of animal class ratios (fig. 6). I use independent ratios instead of relative percentages to avoid the effects of dependency (e.g., if one percentage increases, another must decrease). I calculate ratios of bird, reptile, and fish NISP standardized to white-tailed deer NISP. There are both advantages and disadvantages to using white-tailed deer as a standardizer for class-based comparisons. Two advantages to using deer for this measure are: (1) white-tailed deer is independent of the other taxonomic classes; and (2) white-tailed deer was identified during all time periods. However, if deer NISP is not a constant variable throughout the sequence, then changes in the abundance of deer would affect the resulting ratios. However, based on the %NISP of white-tailed deer from La Joya, the abundance of deer is roughly comparable throughout the sequence (see VanDerwarker 2006a:134).

These ratios are presented in fig. 6 and mirror patterns presented elsewhere that use relative percentages of NISP, MNI, bone weight, and flotation NISP (see VanDerwarker 2006a:137-138, 141). The contribution of birds and fish declines markedly after the Early Formative and re-

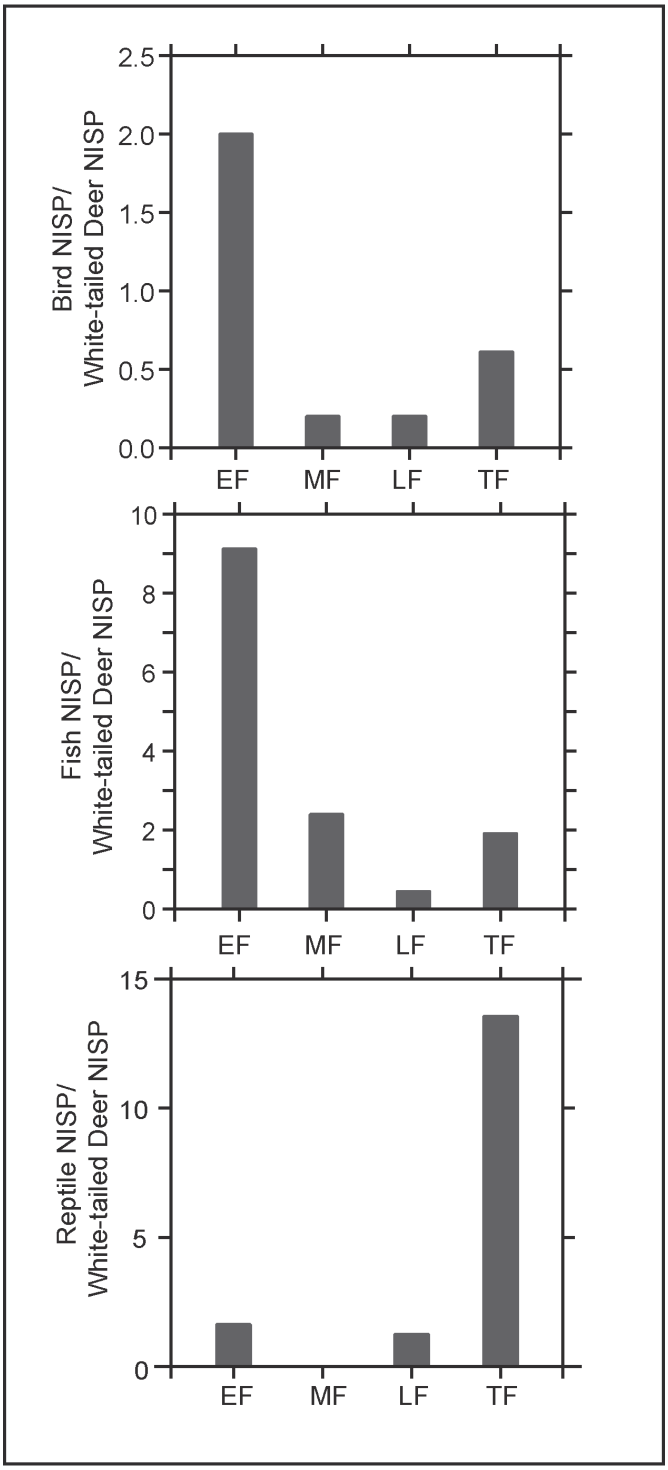

Fig. 6. Bar graphs of animal class ratios standardized to white-tailed deer (NISP) by period (EF: Early Formative, MF: Middle Formative, LF: Late Formative, TF: Terminal Formative).

mains low throughout the Late Formative, only to increase again during the Terminal Formative period. Reptiles (mostly aquatic turtles) are fairly unimportant throughout the Early, Middle, and Late Formative periods, but increase dramatically during the Terminal Formative period.

These patterns suggest a trend toward an increasing focus on mammals from the Early to Late Formative periods. After the Late Formative period, however, people

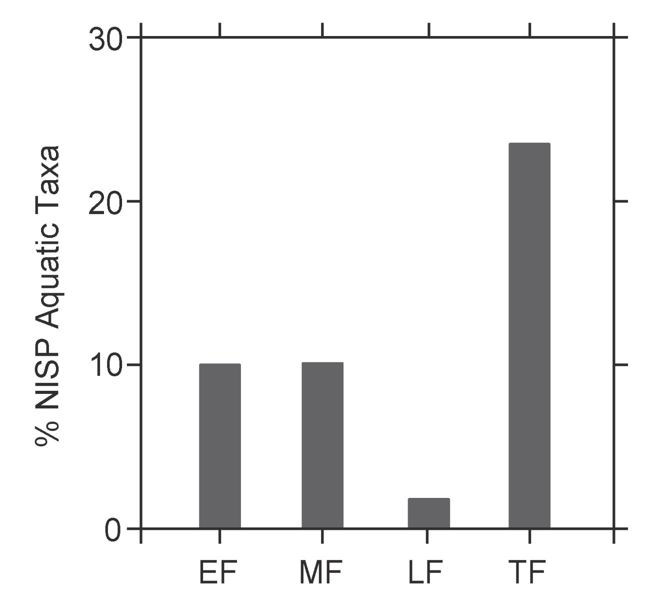

Fig. 7. Bar graph of aquatic fauna (%NISP) by period (EF: Early Formative, MF: Middle Formative, LF: Late Formative, TF: Terminal Formative).

appear to have widened their net by exploiting proportionally more birds, fish, and reptiles. The diversification of animal procurement during the Terminal Formative period may represent a response to either a decline in yields from primary resources (e.g., mammals), or an increase in subsistence risk, both potentially linked to volcanic activity towards the end of the Late Formative period.

Aquatic Fauna

Linares (1976:347) suggests that as people became more committed to farming, they would have increasingly procured terrestrial disturbance fauna, a subsistence shift that would have displaced the reliance on aquatic fauna. I test this expectation by calculating the %NISP of aquatic taxa through time at La Joya (fig. 7). Aquatic taxa identified at La Joya include fish, turtles, and waterfowl. The unidentified turtles were not included in this measure as they might represent terrestrial species. However, all bird specimens identified to the family Anatidae were included, as this family is composed entirely of waterfowl. Figure 7 reveals that the Early, Middle, and Late Formative residents of La Joya exploited fewer aquatic taxa through time. Aquatic taxa compose only 10% of the NISP during the Early and Middle Formative periods, and even less during the Late Formative. During the Terminal Formative period, however, this figure increases dramatically to 24%, a pattern that is statistically significant (χ^2 = 192.7, p > 0.001). It appears that La Joya residents decreasingly focused on aquatic species until the Terminal Formative period when they began to exploit aquatic habitats to a greater extent than before. Given that aquatic fauna would have rebounded more quickly than terrestrial fauna after volcanic eruption and ash fall (see above), it makes sense that La Joya villagers would have increased their exploitation of aquatic habitats after the eruption at the close of the Late Formative period.

Faunal Species Diversity

The final expectation I address is species diversity, specifically richness. Richness refers to the number of taxa in a given assemblage; the more taxa present, the richer the assemblage (Kintigh 1984, 1989; Reitz and Wing 1999). It stands to reason that larger assemblages will yield a richer array of taxa than smaller assemblages (Baxter 2001, Jones *et al.* 1983, Kintigh 1989, Rhode 1988). Moreover, larger samples are more likely to yield rare taxa than smaller samples. Thus, it is problematic to assume that assemblages with more taxa have greater diversity than assemblages with fewer taxa without first ruling out whether differences in richness are structured by differences in sample size (Baxter 2001, Jones *et al.* 1983, Kintigh 1989, Rhode 1988).

In order to deal with issues of sample size with respect to measuring species diversity, I use DIVERS, a statistical program designed to measure the diversity of assemblages of different sample sizes (Kintigh 1984, 1989, 1991). The DIVERS program simulates a large number of assemblages based on the categories and sample size of a given archaeological assemblage and produces expectations that can be compared with the actual data (Kintigh 1984, 1989). Thus, it is possible to judge whether the archaeological assemblage is more or less diverse than expected by comparing the richness of the actual assemblage to the expected values that are randomly generated by the simulation (Kintigh 1984, 1989). Archaeological assemblages, then, are not directly compared to each other. Rather, actual diversity values are compared with expected values for the same sample. The actual values are then plotted against sample size with a 90% confidence interval that is based on the expected values. If a value falls above the confidence interval, then it is more diverse than expected. Conversely, if a value falls below the confidence interval, then it is less diverse than expected.

Figure 8 reveals that the Early Formative animal assemblage is significantly richer than expected. The Middle and Late Formative assemblages fall below the expected range of richness values. The Terminal Formative assemblage falls well within the expected range of richness values given its sample size. In terms of richness, the Early Formative assemblage is significantly more diverse than later assemblages, representing a broad-based

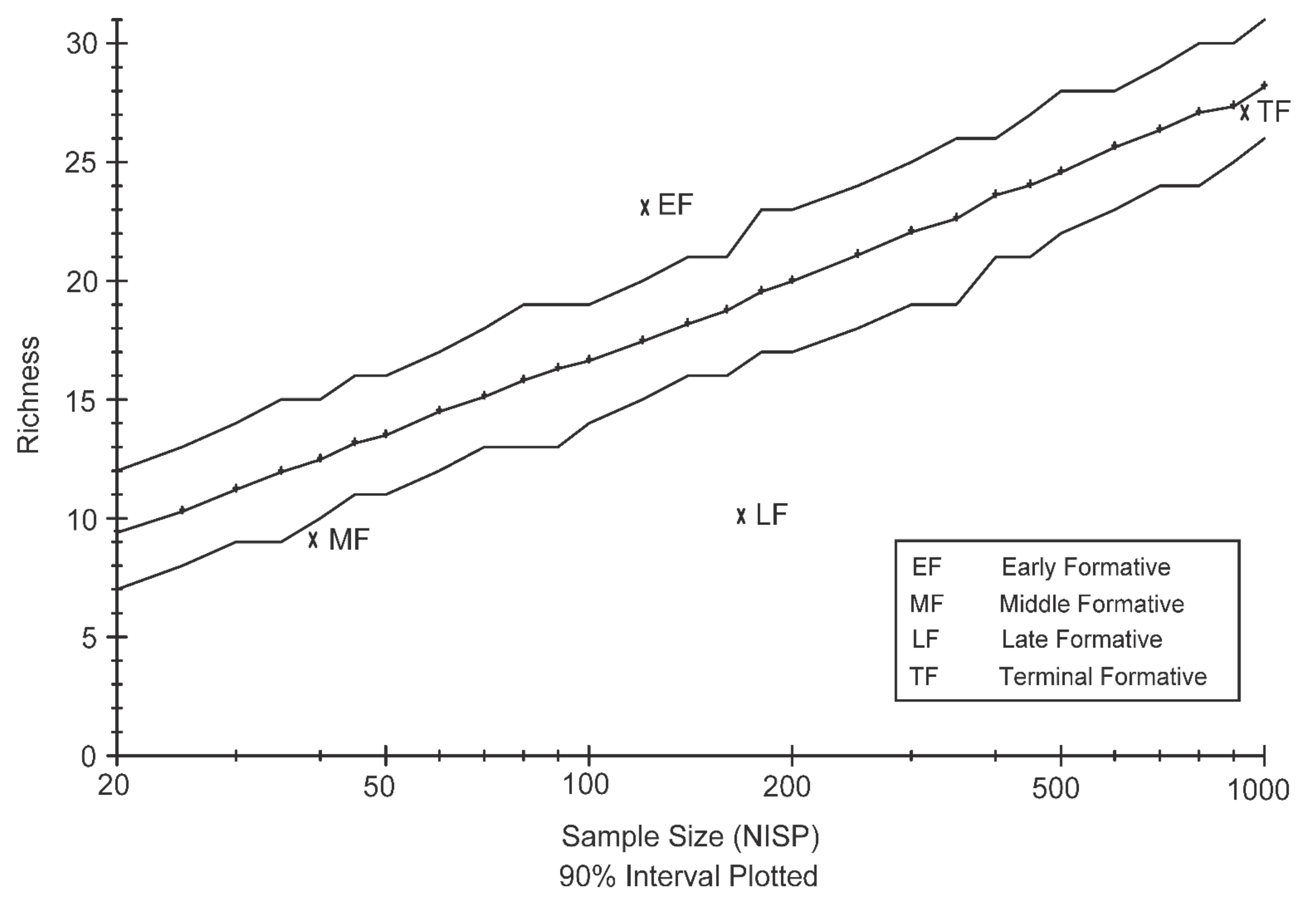

Fig. 8. Species diversity plot of richness against sample size by period (NISP).

diet. After the Early Formative period, assemblage richness drops well below expected values, a pattern which corresponds with the intensification of agriculture. During the Terminal Formative period, animal assemblage diversity increases again, though this value is still not as high as during the Early Formative period.

Overall, the DIVERS results suggest that the Middle and Late Formative residents of La Joya exploited fewer types of prey than the preceding Early Formative residents. After the Late Formative period, La Joya residents began exploiting a wider range of species again, a strategy similar to the one employed during the Early Formative occupation at the site. This pattern may reflect the level of risk that the residents of La Joya perceived to be a factor in their subsistence system. During the Early Formative period, the residents of La Joya were still mobile and relatively new farmers. They may have chosen to offset the risk of a new venture by exploiting a wide range of potential food sources (*sensu* Speth and Scott 1989: 77). As they became more adept at farming, the risk of failure lessened and people became more selective in the animals they chose to exploit for food. During the Terminal Formative period, however, it appears that La Joya residents may have perceived a new risk, one that led them to diversify their animal resource base again, this time capturing more birds, reptiles, and fish than during earlier periods, or perhaps increasing subsistence-related trade with groups less affected by the consequences of eruption.

Summary

These data reveal several interesting trends in faunal procurement at La Joya. From the Early through Late Formative periods, residents of La Joya appear to have increasingly focused on terrestrial taxa, and mammals in particular. The high percentages of disturbance fauna in the Early through Late Formative assemblages point to a focus on garden-hunting throughout this time. Because most of the hunting took place in disturbed habitats near the settlement, people probably did not travel far to procure faunal resources. Thus, this focus on garden-hunting indicates that hunting was largely embedded in farming-related tasks. The decrease in species richness during this span of time also suggests that people became more selective about the animals they chose to exploit. Based on the garden-hunting model presented above, this increase in prey selectivity from the Early through Late Formative periods may indicate that farming had become a more dependable and less risky venture.

During the Terminal Formative, however, these trends in animal use reverse. At this time the residents of La Joya began to exploit a wider range of habitats, procuring more animals from aquatic and primary forest habitats. An increase in species richness during the Terminal Formative supports this pattern. This expansion of the hunting territory may have involved more time away from the houselot and fields. Nevertheless, an increase in food storage (see Arnold 2000) may indicate that La Joya residents intensified maize production at this time. Volcanic eruptions at the end of the Late Formative period would have affected the abundance of local fauna and may have limited the availability of good farmland during the subsequent Terminal Formative period. Residents of La Joya may have responded to these new subsistence limitations by focusing more intensively on fewer maize fields and widening their hunting range. People probably dealt with scheduling conflicts between hunting and farming by dividing subsistence-related tasks among different genders and age groups. Overall, these patterns suggest that the Terminal Formative residents of La Joya may have been faced with increasing subsistence risk, possibly related to local environmental catastrophe (volcanic eruptions and ash fall), in addition to potential tribute demands by regional leaders in the face of local recovery from environmental catastrophe (see below).

DISCUSSION: LA JOYA IN REGIONAL CONTEXT

Analyses of the archaeobotanical and zooarchaeological data have offered a means through which to better understand changing subsistence in the Sierra de los Tuxtlas. Patterning in the plant data from La Joya suggests an intensification of maize production by the Terminal Formative period. This shift towards intensification may have begun earlier, but the small sample sizes of plant materials from Middle and Late Formative contexts at La Joya prohibit documenting the timing of this process with macrobotanical data alone. Fortunately, the zooarchaeological data allow us to further narrow the timing of agricultural intensification at La Joya. Evidence of garden hunting in the animal data suggests that people became increasingly committed to farming during the Middle and Late Formative periods. Changes in faunal patterning during the Terminal Formative period suggest that this was a time of increased subsistence risk, probably associated with volcanic eruptions. Combined, these subsistence data paint a picture of changing subsistence economy throughout almost two millennia.

Tuxtla residents were relatively mobile during the Early Formative, moving seasonally or annually (Arnold 2000, McCormack 2002). It was not until the end of this period that people began to establish more permanent settlements. They grew maize using a shifting cultivation strategy, and their plots were probably scattered across the landscape in areas adjacent to prime foraging areas. In addition to planting maize, Early Formative people harvested wild and domesticated tree fruits, hunted a wide variety of terrestrial animals, and fished a great deal (VanDerwarker 2006a). Although the diet was highly diversified, the plant data indicate that maize was an important plant resource during the Early Formative. In addition to being mobile forager-farmers, early Early Formative people were also relatively egalitarian (Arnold 2000, McCormack 2002:267). As population levels increased and people began to settle down towards the end of the Early Formative period, they retained an ethos of egalitarianism. A volcanic eruption coincided with this shift toward sedentism and may have influenced the decision to settle down—ash fall following the eruption would have blanketed parts of the region, thereby limiting land available for foraging and farming (McCormack 2002:193; Santley *et al*. 1997). Moreover, the abundance and distribution of wild plants and animals would have been negatively impacted.

By the Middle Formative period, people were fully sedentary, and they began altering their subsistence practices and material culture. Although the subsistence data from Middle Formative contexts are few, some trends are nevertheless apparent. Tuxtla residents began to shift their faunal procurement strategies away from fish and other aquatic fauna and towards terrestrial mammals that prefer disturbed habitats, which suggests that the process of intensification began during the Middle Formative (*sensu* Rosenswig 2006). They continued to cultivate maize and to harvest avocados and coyol palm fruits (VanDerwarker 2006a:88). Ceramic assemblages became more diverse, indicating the development of a wider range of cooking and serving practices (McCormack 2002:84). The manufacture and use of ground stone tools was also more specialized than during the Early Formative period, suggesting an increased focus on maize grinding, and by extension, maize production and consumption (McCormack 2002:175-178).

Although the faunal data suggest an increase in garden hunting which may be indicative of an increased commitment to maize-based farming and the ground stone data suggest an increase in maize production, the plant data from Middle Formative contexts are simply too sparse to speak to changing farming strategies at La Joya. Nevertheless, it appears that maize-based farming may have become a more important subsistence strategy than it was during the Early Formative period. Villages and hamlets formed the basis of the Middle Formative settlement system in the Tuxtlas, with no known political centers established at this time (Santley *et al*. 1997). Individual households appear to have been independent and self-sufficient, and society at large continued to be relatively egalitarian (McCormack 2002).

The Late Formative period heralded the emergence of social ranking in the Tuxtlas. Regional population increased, and the first regional center was established at the site of Chuniapan de Abajo (Santley *et al*. 1997). Despite these changes in settlement and social ranking, the level of socio-political complexity in the Tuxtlas was not nearly as pronounced as among the lowland Olmec (McCormack 2002; Santley and Arnold 1996). Archaeobotanical evidence points to a continued focus on maize; standardized counts of maize did not change significantly at La Joya, indicating that maize consumption may have been relatively stable through time. The faunal data suggest an increased focus on terrestrial disturbance animals indicative of garden-hunting, suggesting that people intensified their farming activities even more than they had during the Middle Formative. Indeed, a decrease in faunal species diversity suggests that farming had become a less risky subsistence strategy.

Regional population declined dramatically during the Terminal Formative period, and a new regional center was established at the site of Chuniapan de Arriba (Santley *et al*. 1997). Volcanic activity towards the end of the Late Formative and during the Terminal Formative likely influenced peoples' decisions to leave the region (Santley *et al*. 1997). Those who stayed in the Tuxtlas continued to grow maize, focusing on fields adjacent to their settlements. Moreover, people further intensified maize production through the construction and maintenance of ridged fields. It is interesting that Terminal Formative residents of La Joya focused their farming on less land (which in turn required them to intensify production even more), when regional depopulation likely freed up much potential farmland. I suggest that ash fall blanketing the region during the Late and Terminal Formative eruptions of Cerro Mono Blanco affected the viability of farmland throughout the region, leading to significant (if temporary) environmental circumscription (see also VanDerwarker 2006a: 202-203). The site of La Joya appears to have been on the edge of this ash fall zone, with relatively shallow ash deposits from these eruptions. Hunting strategies also changed drastically from earlier periods. Residents of La Joya diversified their faunal procurement by exploiting a wider range of habitats than they had during Middle and Late Formative times. This shift in hunting strategy points to a decrease in species selectivity that I argue to be indicative of increasing subsistence risk catalyzed by volcanic activity.

It has been suggested that regional elites centered at Chuniapan de Arriba and Tres Zapotes may have commanded agricultural tribute from villages in the region (McCormack 2002, Pool 1997). Increases in storage volume at La Joya point to the accumulation of agricultural surplus, which may have been used to help support regional leaders (Arnold 2000, Pool 1997). Whether or not tribute demands from regional elites could have precipitated this period of risk is another issue. Did regional elites have sufficient power that their tribute demands alone could have stressed village-level subsistence? Given the scale of regional political complexity during the Terminal Formative period and the nature of chiefly power, it seems unlikely that excessive tribute demands could have been enforced and even less likely that tribute would have been paid in the form of subsistence goods. Indeed, if people were dissatisfied with elite demands, they could have left the region, as many others chose to do at the end of the Late Formative period.

It is more likely that volcanic eruptions at the end of the Late Formative and the middle of the Terminal Formative influenced peoples' decisions to alter their subsistence strategies. The short-term effects of volcanic eruptions and ashfall on maize production would have been devastating. It is possible that, despite increasing subsistence risk precipitated by volcanic activity, Tuxtlas villagers were still encouraged to provide tribute to regional elites. Determining the flow of tribute from villages to centers, however, requires the excavation and analysis of additional data.

CONCLUSION

The data presented in this paper suggest that maize was an important staple crop in the Tuxtlas by the time people settled into permanent villages. Sedentism and the initial intensification of maize production (during the Middle Formative) preceded the rise of regional leaders (during the Late Formative) by approximately 600 years. After repeated volcanic activity in the region following the emergence of political complexity, the continued intensification of maize production (seen in the construction of ridged fields) appears to have been a product of increasing environmental circumscription brought about by active volcanism.

The timing and nature of agricultural intensification and the emergence of political complexity in the Sierra de los Tuxtlas, as represented at La Joya, suggest that regional developments are best explained by both political and environmental factors. The subsistence data indicate that maize intensification was a long, incremental process that began in the Middle Formative period, hundreds of years before political development and the establishment of a regional center. Farmers at La Joya do appear to have intensified production even more during the Late Formative period, evidenced by an increased shift towards garden-hunting. It is possible that elites centered at Chuniapan de Abajo encouraged rural people to produce more maize, which would have led people to spend more time in their fields, thus increasing their capture of animal prey lurking nearby. After the volcanic eruption at the end of the Late Formative period, however, the cause of increased maize intensification (evidenced by field ridging and maize kernel to cupule ratios during the Terminal Formative period) appears to have been primarily environmental in nature. While some may criticize this explanation as environmentally deterministic, environmentally catastrophic events like volcanic eruptions cannot be ignored by archaeologists—nor could they have been ignored by Formative Tuxtlas villagers trying to make a living.

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