

## Exploring Texas Archaeology with a Model of Intensification

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*A theoretically grounded model is used to map expectations for the locations of the earliest intensification across Texas. The absence of agriculture in much of prehistoric Texas versus the widespread adoption of farming in Mesoamerica is explored utilizing a theory of intensification recently proposed by Binford in Constructing Frames of Reference. Availability of either aquatic or high quality wild plant resources are expected to delay intensification on plants which might lead to agriculture. Hunter-gatherer population models suggest where intensification processes may occur early in prehistoric sequences. These models are compared with archaeological stable isotope and burned rock midden data from Texas which indicate hunter-gatherers on the Texas coastal plain made substantial use of aquatic resources and that burned rock middens likely reflect intensified use of wild plants. The temporal and spatial distribution of these strategies is consistent with the expectations of the models. This approach may have utility for exploring both the absence as well as the presence of agricultural adaptations through time; however, further research on resource distributions and archaeological indicators of intensification are needed.*

**Keywords:** *intensification, hunter-gatherer, agriculture, aquatic resources, Texas archaeology*

A potentially rich pattern for analysis in prehistoric Texas is variability in the adoption of domesticated plants and intensification upon wild resources. Binford (2001) presents methodological tools archaeologists can use in their search for explanations of such patterns in the archaeological record and this study applies such an approach to Texas. Texas is of particular interest because of: 1) its transitional geography between major agricultural culture areas; 2) the generally slight role of maize in prehistoric Texas, excepting far western, northeastern and northern Texas; 3) the significant use of plant roasting indicated by the multitude of burned rock middens in western and central Texas; 4) the intensive use of a number of other key plant resources; and 5) the

relatively early and intensive use of marine and freshwater resources along the Gulf Coastal Plain (Hard and Katzenberg 2008; Huebner 1994). These patterns contrast with the processes of intensification and adoption of agriculture in other areas. The prehistory of Mesoamerica, with its rapid development of agriculture, will be briefly referred to as a point of comparison.

### FARMING AND INTENSIFICATION

Intensification is a widely recognized process through which more and more resources are extracted from smaller and smaller segments of the landscape through increased labor or capital investment (e.g. Binford 1999:6; Boserup 1965; Morrison 1996; Netting 1993). While the domesti-

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cation and cultivation of plants is one obvious example which has received considerable archaeological attention, it is far from the only strategic shift in resource use which would be considered intensification. Intensification includes shifts in subsistence strategies in which more labor is invested in collecting and processing aquatic resources or plant foods. The process of intensification typically occurs as a response to shifts in the ratio between resource productivity and population demands. Examples include increased investment in fishing technology such as nets, weirs, or hooks; increasing the harvest of shellfish; or focusing on smaller prey size such that labor investment increases. Plant intensification may include pressing, leaching, grinding or parching nuts, collecting and roasting large quantities of plants, or utilizing greater quantities of small seeds, which take more work to collect and grind than previously utilized resources. However, since maize agriculture is one of the earliest and archaeologically the most prominent forms of intensification in the archaeological record of North America and Mexico, it is reasonable to begin our exploration with a brief survey of the use of maize in Texas.

Maize is well represented only in the archaeological record of the southern Jornada Mogollon, northeast Texas and parts of the Panhandle Plains region; elsewhere it is virtually absent (Figure 1). In the Southern Jornada Mogollon region in the vicinity of El Paso, maize is present by ca. 1200 B.C., a date consistent with widespread early

maize from the Late Archaic record in other parts of the American Southwest and northwest Mexico (Bohrer 2007; Hard and Roney 2005; Tagg 1996; Upham et al. 1987; Wills 1988). However, unlike much of the rest of the Southwest, maize played only a minor role in the subsistence base until ca. A.D. 1100–1200 (Hard et al. 1996:298; Miller and Kenmotsu 2004:249; Whalen 1994). Moving eastward through the eastern Trans-Pecos region, maize is only occasionally found and is, at best, a minor element in the economy. In the La Junta de los Rios area (Figure 1), where the Río Conchos joins the Rio Grande, small villages were utilizing a moderate level of maize as well as a substantial degree of hunted and gathered resources after ca. A.D. 1200 and into the early Historic period (Kelley, et al. 1940; Kenmotsu 1994; Miller and

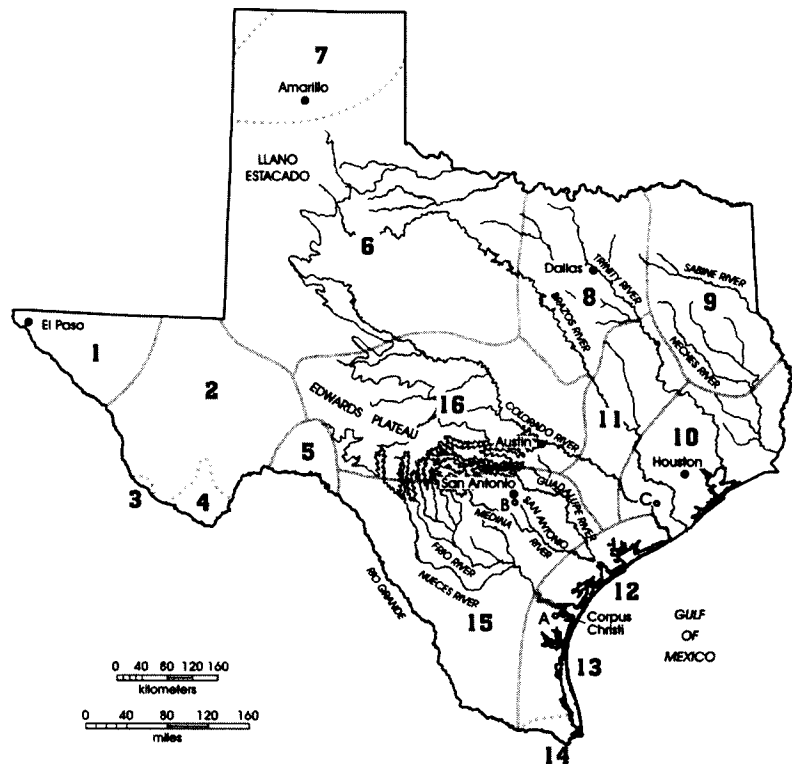


Figure 1. Archaeological and geographic regions in the state of Texas: 1) Southern Jornada Mogollon, 2) Eastern Trans-Pecos, 3) La Junta de los Rios, 4) Big Bend National Park, 5) Lower Pecos, 6) Panhandle Plains, 7) Antelope Creek phase, 8) East-central Texas, 9) Northeast Texas, 10) Southeast Texas, 11) Savanna and Prairic, 12) Central Coast, 13) Lower Coast, 14) Rio Grande Delta, 15) South Texas, 16) Central Texas (modified from Pertulla 2004a:7). Dotted lines are areas within larger regions. Isotope data are from the following prehistoric sites: A) 41NU2, B) 41BX1, C) 41WH39.

Kenmotsu 2004). The easternmost record of maize from the arid regions of west Texas, in the vicinity of the Rio Grande, is from a single locale in the Lower Pecos region (Phil Dering, personal communication 2005). Similarly, rare maize pieces are reported in the vicinity of Big Bend National Park (Cloud, personal communication 2007; Mallouf 1985). Maize is infrequently recovered but there is no evidence that it played anything other than an incidental role in the prehistoric economy. In the Texas Panhandle Plains region maize is found in a number of contexts. Drass (this volume) details widespread maize use in the Plains Village period (A.D. 900–1750) from sites in Texas and Oklahoma. Boyd (this volume) describes the economy at Antelope Creek phase sites (Figure 1) that date to A.D. 1200–1500, where maize horticulture and bison hunting were key elements of the subsistence base (see also Brooks 2004; Habicht-Mauche et al. 1994; Hard et al. 1996). Farming was not adopted in central Texas, either, as there is but a single report of a maize cob from a Late Prehistoric period context between San Antonio and Austin at Timmeron Rockshelter (Collins 2004; Harris 1985). In northeast Texas maize is typically recovered from post-A.D. 800 Caddo contexts but stable isotope and dental caries data indicate variable rates of maize adoption, with notable widespread maize reliance after A.D. 900 and peak utilization along major streams after A.D. 1300 (Perttula 1996:321–322, 2004:383). In the northern portion of the east-central Texas region, maize played a variable role after A.D. 800 (Fields 2004). For example, maize is recorded in Dallas County on a tributary of the Trinity River (Fritz 1993) and south of Dallas on the Brazos River, approaching the periphery of central Texas (Jelks 1962). Reports from the seventeenth to nineteenth centuries, from the Brazos River to the Nueces River, refer to scattered indigenous maize production in multiple contexts (e.g., Foster 1998:183–184; Smith 2005:154–246). Excepting isolated occurrences, maize did not play a role in the prehistoric economy of the Big Bend, Lower Pecos, central Texas, Savanna and Prairie, southeast Texas, Central Coast, Lower Coast, and south Texas regions (Figure 1). Hunter-gatherer adaptations dominated the entire prehistory of Texas except during

the Late Prehistoric period in far western, northern, and northeastern Texas when agriculture did play a prominent role.

These patterns pose challenges to explanatory models that address the adoption and spread of farming as explanations should be able to address the absence as well as occurrence of agriculture. Given the development of farming as a significant subsistence strategy late in prehistory in the extreme corners of Texas, why was it not used more widely in the remainder of prehistoric Texas? By placing the adoption of farming within the larger framework of plant intensification, the archaeological record of Texas presents an unusual opportunity to evaluate the differing conditions under which wild and domesticated resources are the focus for intensification.

Since at least the 1920s, this basic question has been the foundation for much anthropological discussion of the ethnographic pattern in Texas and neighboring regions in northeastern Mexico (see for example Newcomb 1956 and references therein). The problem for the early anthropologists derived from their assumption that diffusion was the primary process of culture change—that knowledge about farming technology and access to plants was the primary cause of its adoption. Since the knowledge could reasonably be assumed to be present given the proximity to farmers to the west and east, it was argued that environmental limitations or perhaps motivation were the limiting factors (Newcomb 1956:150–151; Shiner 1976:502). In recent years, the topic has received little attention although certainly the spotlight on diffusion and motivation has been largely abandoned or modified. Contemporary approaches primarily consider ecological trade-offs at the local level (Dering 2005; Doleman 2005; Hard and Roney 2005; Vierra 2005). For central Texas, Black and Creel (1997:302) suggest earth oven plant processing was used in lieu of domesticates, and Collins (2004:124) points to the rich and diverse wild resource base. However, environmental limiting explanations still occur and can readily be tested.

#### **EVALUATING FARMING POTENTIAL**

Binford (2001:55–113) describes utilizing primarily climatic data (e.g. latitude, soil, monthly tem-

perature and precipitation) from modern weather stations in a series of formulas to calculate water balance following Thornwaite and Mather (1955). Water balance is related to soil properties, solar radiation, precipitation, evaporation, and plant transpiration. Calculated water balance values then become a basis for estimating primary productivity of plants and projecting animal biomass. In warm temperate latitudes, where solar radiation does not limit horticultural potential, water balance is a critical factor for plant growth. The number of months during the growing season in which water is retained in the soil (WATRGRG) is an index of the potential productivity of dry-farmed maize (Binford 2001:75–79 discusses variables similar to WATRGRG). More months indicate greater potential for plant growth, including the growth of maize and other domesticates. Figure 2 plots the number of months during the growing season in which water is retained in the soil (WATRGRG). In comparison to areas to the west where intensification leads to early farming, the majority of Texas has a relatively *high* number of growing season months with water stored in the soil. Related indices including annual water deficit and plant growth potential yield parallel results (see Binford 2001:75, 85).

Given the maize use in the southern Jornada Mogollon region and early farming in regions of southern Arizona and northern Chihuahua, all locations where water retention, water deficits and potential plant growth are less favorable, it seems unlikely that native horticulture would have been impossible in the coastal plains region as Newcomb (1956:153) suggests. The occasional early historic observations of indigenous maize use and early European farming also indicate maize horticulture was indeed possible, although certainly

not without problems (e.g., Collins 2004:124; Foster 1998:183–184; Smith 2005:154–246).

Having shown environmental limitations are unlikely explanations for the virtual absence of farming, a model is presented suggesting where intensification on aquatic and terrestrial plants is likely to occur. This model is based on global environmental and hunter-gatherer databases developed by Binford (2001) that link hunter-gatherer behavior to ecological conditions. Locations where particular ecological conditions converge that foster intensification may be areas where intensification becomes evident in the archaeological record (Hard et al. 2004; Johnson 2004, 2008). This model is then compared with archaeological patterning in Texas with regard to evidence for plant intensification and aquatic resource use. We suggest such an analytical procedure is a productive research strategy in that it situates Texas prehistory within continental and global frameworks that consider long-term processes of cultural change and stability.

### THE INTENSIFICATION MODEL

Intensification is a response to local or regional scale interaction between populations and their habitats (e.g. Boserup 1965; Netting 1993; Morrison 1996). While the details of arguments differentially focus on problems relating specifically to either resource availability (see discussion by

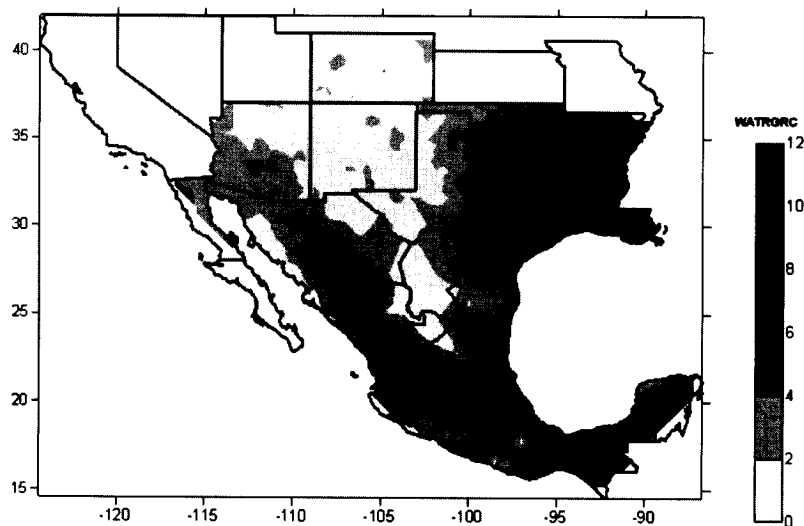


Figure 2. Number of growing season months with water retention in the soil (WATRGRG).

Binford 1983:199–203 of the Garden of Eden proposition) or mobility tactics (Binford 1983, 1999, 2001), nearly all arguments about intensification recognize that the relationship between population and resources is a key factor driving change in subsistence strategies. One aspect of this relationship is population growth. In fact, Binford's (2001) recent research on hunter-gatherer adaptations has identified a specific value of population density, the packing threshold, which marks the population density (about 9 persons/100 sq km) at which there is one minimal group (about 21 people) per foraging area (about 225 sq km), meaning that there are no empty foraging areas for hunter-gatherers to move into to exploit fresh resources [(about 21 people/225 sq km) \* 100 sq km]. At this density, Binford (2001:373–399) recognizes: 1) the end of hunting terrestrial animals as a dominant subsistence strategy; 2) increasing use of aquatic resources, based on availability; and 3) trends toward increasing diet breadth among terrestrial plant-dependent hunter-gatherers. In the context of introducing a model similar to the one we will use here, Binford (1999:11) has argued that

"Other things being equal, the packing threshold should appear across geographic space at different times depending upon the *length of time that populations had been increasing in a region and the dynamics responsible for different rates of population growth*. One would therefore anticipate culture change to be both chronologically and geographically patterned" [emphasis added].

This application of Binford's approach uses two of his models to predict which parts of Texas should experience early intensification. Mexico is also briefly considered as a point of contrast given its rapid intensification via maize agriculture. The terrestrial model focuses on the relative productivity of wild resources and the second models population growth rates. These models, despite their complexity, only address some of the variables that may affect intensification. This broad-scale comparative approach requires the simplifying assumption that all other potential variables are equal.

The terrestrial model predicts the number of humans which could be supported in a particular habitat and is derived from a series of equations

that utilize modern climatic data and that estimate terrestrial plant productivity and animal biomass (Binford 2001:187–188). The terrestrial model assumes that: 1) the abundance and accessibility of food is the only limiting factor on population density; 2) all food comes from terrestrial species; and 3) technology plays a minimal role in obtaining and processing food. The terrestrial model is based on relative availability and abundance of wild resources in different environments rather than on technological capacity.

Assuming that initial populations in a given region will prefer those locations with the most abundant and accessible resources, the terrestrial model reflects relative values of population density associated with early occupations. According to the terrestrial model [TERMD2], locations with higher values of population density, measured in number of individuals per 100 sq km, are expected to attract earlier initial populations and larger initial population densities (Figure 3).

The dynamics of population growth is modeled using: 1) the results of the terrestrial model to predict the baseline population for a region given the resources available; 2) an index of disease rates; and 3) the length of time that populations have been increasing in a region. This strategy is a simplified version of that used by Binford (1999). Instead of using paleoclimatic models to reconstruct temporal variability in patterns of long-term growth rates, this approach depends on patterns derived from modern environments to describe regional variability<sup>1</sup>.

Given that growth rates of human populations are not only accelerated by abundance and accessibility of resources but also limited by disease, Binford (1999:12–13; 2001:440–441) models annual population growth rate (REPRATE) by using the terrestrial model as a starting point for reproductive potential and factors in the likely pathogen load given information summarized by Low (1988). Variability in this growth rate model is directly related to variability in the terrestrial model and to modeled variability in pathogen loads. Since the comparisons are all within the continent it can be assumed that all regions have been occupied for roughly the same amount of time.

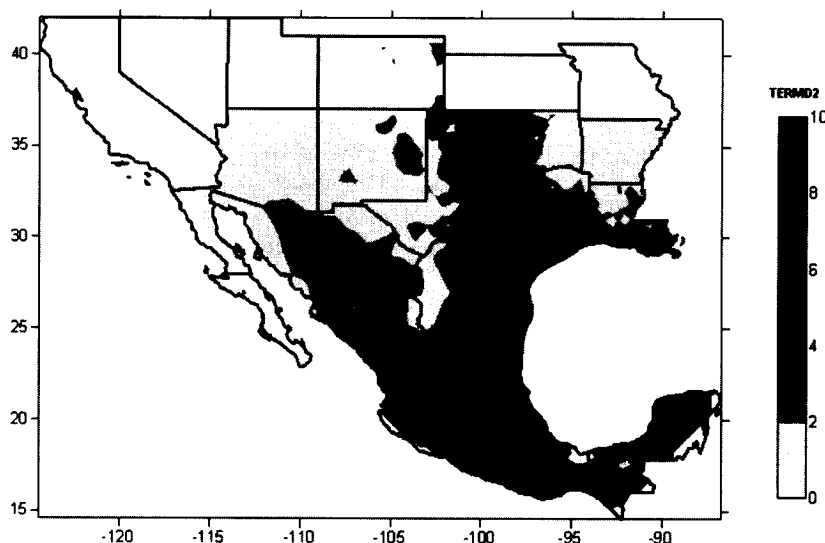


Figure 3. Terrestrial Model Population Density expressed in number of individuals per 100 sq km (TERMD2).

Locations with higher model values of population growth rates are expected to cross demographic thresholds leading to intensification earlier and yield archaeologically visible changes in subsistence and settlement patterns. Figure 4 is a plot of the growth rate model (REPRATE).

There are a few features of the terrestrial model and the growth rate model which are worth emphasizing. First, the growth rate model is only a slightly modified version of the terrestrial model. At the regional scale of comparison, the structures of these patterns are largely similar if one compares Figures 3 and 4. Second, the locations with the highest expectation of early intensification are mostly in the tropical regions of Mexico—both in the

central highlands and along the coasts (Figure 4). In Texas relatively high values extend into south Texas and the Lower Coast, with relatively high values in central Texas. The second and third highest values are found throughout these areas as well as into the Central Coast, southeast Texas and the Panhandle Plains regions (Figures 1 and 4). Since intensification on farming did not occur in most of these regions, what are some of the alternative patterns of intensification using only

wild resources?

A number of generalizations regarding these processes of intensification can be made based on global patterns among contemporary hunter-gatherers as well as archaeological sequences

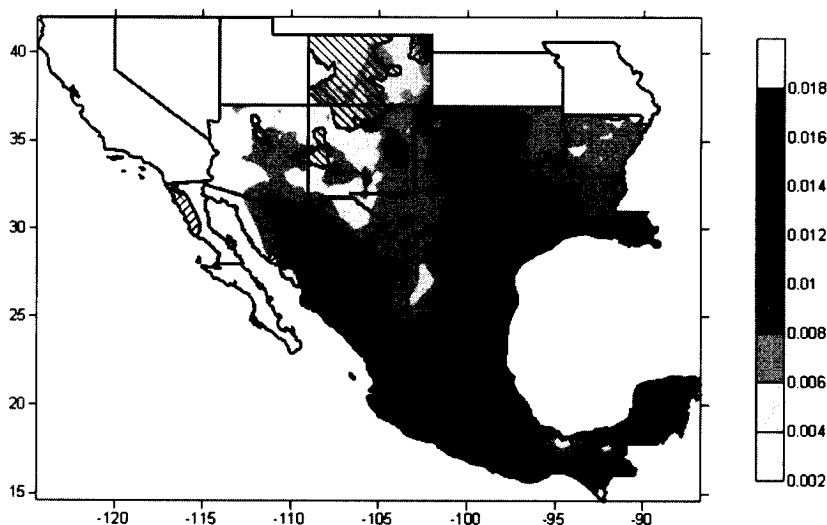


Figure 4. Growth rate model (REPRATE) expressed in population growth rate per year. The area where the aquatic dependence under packed conditions is modeled as 30 percent or greater is indicated by forward hachure along the coasts. The region with  $ET < 12.75^{\circ}C$  and therefore the potential for plant intensification is limited is indicated by backward hachure in high elevation areas.

(Binford 2001; Johnson 2008). Binford (2001:222) suggests:

"that if selective forces (such as a reduction in the area needed to sustain a group) are favoring intensification of production, there may be a progression in resource exploitation down the trophic scale in the direction of lower-level resources. In such a successional sequence, other things being equal, hunter-gatherers would shift from terrestrial animals to aquatic resources to, finally, terrestrial plants in settings in which each of these options is feasible."

Therefore we can expect that 1) once the packing threshold is reached, intensification on terrestrial animals is no longer an option; 2) other things being equal<sup>2</sup>, there will be a bias toward intensification on aquatic resources versus plants, if the former are sufficiently available; 3) access to aquatic resources increases the duration of intensified hunting and gathering, provides subsistence opportunities with fewer mobility costs, and supports higher hunter-gatherer population densities than terrestrial animal or plant adaptations alone; and 4) in the absence of adequate aquatic resources or if further intensification is required, intensified use of wild or domestic plant resources occurs, assuming it is a sufficiently warm climate to support minimal plant growth.

Binford (2001:267) identifies several thresholds at which hunter-gatherer behaviors regularly change. For this study, the *terrestrial plant threshold* occurring at an Effective Temperature (ET) value of 12.75° C is of primary interest (Binford 2001:59). In settings warmer than an ET of 12.75° C, plant-dominated subsistence strategies can be expected among hunter-gatherers; in cooler settings plant growth is more limited and plant-dominated subsistence strategies are not expected except in rare instances in which temperateness of climate extends the growing season despite lower temperatures during the growing season (Binford 2001:267). No region in Texas experiences such cool temperatures (see Figure 4).

A projection of the dependence on aquatic resources for hunter-gatherers at the packing threshold (just over 9 persons per 100 sq km) is calculated as a means of assessing the potential of these resources<sup>3</sup>. Where hunter-gatherers are more than 30 percent dependent on aquatic resources, these resources become a primary subsistence strategy.

Where the modeled value of dependence on aquatic resources [D1PFISHP] is greater than 30 percent, hunter-gatherers should intensify with an emphasis towards aquatic resources and only secondarily pursue substantial intensification on plants. Figure 4 also shows the regions where the model projects 30 percent and more dependence on aquatic resources by hunter-gatherers who are at the packing threshold.

Thus our intensification model projects that the earliest intensification will be in the regions with the highest growth rates and that the targets of intensification will vary with availability of aquatic resources and the seasonality of plant productivity. The Texas locations with modeled annual reproductive rates greater than 1 percent ( $REPRATE \geq .01$ ) are notably high values and these are the medium shaded areas in Figures 4 and 5. Only Texas and Mexico have any areas with values above 1.2 percent. In Texas, as seen in Figure 5, the region of expected intensification extends roughly, in a north northwest-east southeast direction extending from the panhandle to the southern coasts. Excluded are northeastern Texas and most of the western half of the state. The model predicts that there will be a bias towards aquatic resource intensification where modeled annual dependence on aquatic resources ( $D1PFISHP \geq 30$  percent and the population growth rate ( $REPRATE \geq .01$ ). This area extends inland about 60 km, in a strip from the Rio Grande delta to the Houston area and includes the archaeological regions of the Lower Coast, Central Coast, and the southwestern portion of southeast Texas (Figure 1). Despite being located along the coast, the eastern portion of southeast Texas is projected not to have such early intensification; it is modeled as having a lower growth rate. The remaining, inland areas of high growth rate are expected to reflect early intensification on plants.

### EVALUATION OF THE MODEL

Does archaeological evidence provide support for the utility of this model? Since evidence for domestication and cultivation of plants is one of the best studied archaeological indicators of intensification, the analysis first returns to Figure 4 and surveys its utility in Mexico with respect to known areas of intensification with the use of do-

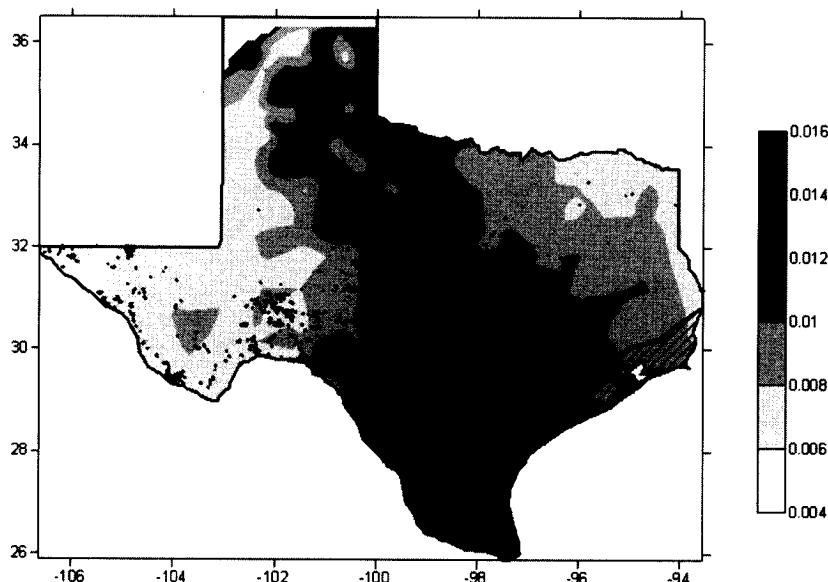


Figure 5. The growth rate model (REPRATE) and areas indicated by forward hachure where aquatic dependence is 30 percent or greater for Texas. Dots represent burned rock middens

mesticated plants. The best evidence of early intensification includes the early presence of domesticated plants as well as relatively early evidence (ca. 1500–1200 B.C.) of substantial dependence on agriculture, although previous research has shown that the ecological context in which initial intensification occurs is not necessarily the same as that in which intensified resources become the primary economic focus (Johnson 1997; 2004:277–279). Early use of domesticated plants is well documented in the Valley of Oaxaca, Tehuacan Valley and southwestern Tamaulipas prior to 2000 B.C. (Long, et al. 1989; Piperno and Flannery 2001; Smith 1997, 2001), all areas with modeled rapid growth rates (Figure 4). Early adoption of a farming economy is generally recognized in many parts of highland and lowland Mesoamerica including the Tehuacan Valley, Oaxaca, Valley of Mexico, Colima, Michoacan, Jalisco, Guanajato, and the Yucatan Peninsula, among others, with the widespread emergence of nucleated farming villages by 1600–1400 B.C. (e.g., Clark and Cheetham 2002; Flannery 1976; Hastorf and Johannessen 1994; Marcus and Flannery 2004; Pohl et al. 1996; Smith 2001). This known archaeo-

logical pattern follows the expectations of both the terrestrial and growth rate models as these parts of Mesoamerica have high values (Figures 3 and 4).

How well does the occupation of Texas compare with our model of early intensification? While ethnohistoric observations are millennia removed from early processes of intensification, exploration of the relationship between modeled early population growth and historic population densities and land use

strategies provide a preliminary comparison between the current model and the real world. Records from Francisco Garay's expedition into the Rio Grande delta in 1523 "indicate a remarkable population density for hunting and gathering groups. If we take the reports at face value, at least forty separate Indian encampments were seen by a single Spanish exploring party while traveling eighteen miles upstream" (Salinas 1990:23). Population estimates from 1747–1757 are that there were approximately 15,000 individuals living in the Rio Grande delta. Salinas (1990:138) argues most were indigenous to the area and not displaced.

Using Salinas's description of the Rio Grande delta as a roughly triangular area 137 km (85 mi) along the Rio Grande and 161 km (100 mi) along the coast, we estimate it to be an area of approximately 13,000 sq km (5,000 sq mi), thus yielding a population density estimate of about 115 persons per 100 sq km, equivalent to 3 persons per sq mi. Compared to Binford's packing threshold of just over 9 persons per 100 sq km this is clearly a remarkable population density for hunting and gathering groups—in fact, this localized popula-

tion density is comparable to densities recorded for some California cases dependent upon a combination of aquatic resources and acorns (Binford 2001:Table 5.01, pp. 118–129). However, populations were not dense everywhere. Some of the southern part of the lower coastal region and adjacent parts of south Texas were sparsely occupied during the middle eighteenth century due to the absence of perennial streams and related resources (Salinas 1990:72). This region includes a portion of the south Texas sand sheet, a formation that limits both resources as well as archaeological knowledge (Hester 2004; Ricklis 2004a:177). Discontinuous distribution of dense populations is not inconsistent with our model as we would expect high densities where the potential for intensification is the greatest.

Based upon numerous descriptions of fishing technology and the use of fish and shellfish as food, Salinas (1990:117) suggests that, “fishing was probably the main source of food for Indians of the Rio Grande delta area.” This was supplemented with hunting (especially deer and peccary) and gathering wild plants (primarily prickly pear fruit, mesquite bean pods, and maguey root crowns). High historic population densities in the Rio Grande delta followed a subsistence strategy of intensified hunting and gathering, focused upon aquatic resources and plants. References to pit baking prickly pear reflect substantial labor investment in processing plant resources (Salinas 1990:118). The archaeological record from the Rio Grande delta is not well enough known to establish dates for the earliest intensification (Hester 2004).

In the Central Coast region in the Historic period, the Karankawa also maintained an emphasis on aquatic resources. A number of authors have reviewed demographic data for the Karankawa with somewhat differing conclusions, but all indicate high population densities were present in the early Colonial period (Aten 1983; Ricklis 1996). Ricklis (1996:130) concludes that Karankawa population densities were on the order of 1 person per 1 sq km or 100 per 100 sq km, a figure on par with those groups in the Rio Grande delta. Historic period coastal and delta high population densities that emphasize aquatic resources are consistent with the expectations of the model. The

greater challenge is evaluating archaeological data with respect to the model. A preliminary review of collagen stable isotope data from prehistoric cemeteries and burned rock midden distributions suggests the model has some utility.

### **Prehistoric Cemeteries and Stable Isotope Data**

In south Texas and along the Texas coast there are sizable prehistoric cemeteries which may be indicative of aquatic resource use and intensification (see Hall 1998; Hester 1981, 2004; Martin 1930; Pertulla 2001; Ricklis and Weinstein 2005). Ethnology suggests sizable hunter-gatherer cemeteries are an indirect signal of land use intensification and elevated population density. Binford (2004:8) identifies 81 hunter-gatherer groups out of a global sample of 263 hunter-gatherers that make use of cemeteries—that is, burial locations for social units larger than the family. Seventy-nine percent (64 out of 81) live under packed conditions; that is with populations greater than 9 people per 100 sq km. Reduced mobility is also indicated as 77 percent have total annual residential moves of less than 150 km (Binford 2004:8; Binford 2007). Finally 63 percent of groups that use communal cemeteries focus on aquatic resources (Binford 2007). Generally hunter-gatherer communal cemeteries are associated with packed populations, reduced mobility, and aquatic resource use.

Do the Texas cemeteries contain evidence of substantial aquatic resource use? Stable isotope data from prehistoric cemeteries in the Central Coast and southeast Texas suggest the prehistoric populations experienced relatively early use of riverine and marine resources consistent with the model. Results from a study of bone stable carbon and nitrogen isotope data from a series of Texas prehistoric cemeteries suggest aquatic resources were a key part of the subsistence base (Hard and Katzenberg 2008). One hundred fifty-four individuals from eight cemeteries dating from the Early Archaic (ca. 5000 B.C.) to the Late Prehistoric period (ca. A.D. 1400) reflect strong patterning in both  $\delta^{15}\text{N}$  and  $\delta^{13}\text{C}$  values and a clear separation in resource use among inland, riverine, and coastal zones. The coastal zone is about a 50 km wide strip providing access to shellfish and

fish from bays and estuaries while the riverine zone is a region of wide floodplains with oxbow lakes, sloughs and swamps lying just west of the coastal zone. West of the riverine zone is the inland region where terrestrial resources dominate (Hard and Katzenberg 2008). In addition stable isotope values of 168 animal bone samples from archaeological sites representing 29 taxa were examined in order to obtain baseline isotope ecology data from these zones (Hard and Katzenberg 2008). Here we summarize the results from just three sites representing each of the three zones.

The isotopic variation among prehistoric human groups will be primarily due to differential exploitation of terrestrial, freshwater and marine estuary resources. A diet based on inland terrestrial resources that are dominated by consumption of  $C_3$  plants will yield lowest  $\delta^{15}N$  and  $\delta^{13}C$  human collagen values. Consumption of bison that feed on  $C_4$  grasses will tend to elevate both  $\delta^{15}N$  and  $\delta^{13}C$  in human collagen. Exploitation of freshwater fish will be reflected in elevated  $\delta^{15}N$  but depleted  $\delta^{13}C$  collagen. A diet of estuary resources that are enriched in both  $\delta^{15}N$  and  $\delta^{13}C$  will result in elevated human collagen values (Ambrose 1993; Hard and Katzenberg 2008; Schwarcz and Schoeninger 1991).

The Oso Bay site (41NU2) is a large cemetery in Corpus Christi, on the edge of the bay, from which over 200 individuals were removed during the early part of the twentieth century (Martin 1930; Jackson et al. 2004; Ricklis 1997). Fifteen individuals, dating from the early Late Prehistoric period (A.D. 650–1000), yielded a mean  $\delta^{13}C$  collagen value of -9.7‰ and a  $\delta^{15}N$  value of 11.5‰, consistent with a diet containing substantial levels of estuarine resources (Hard and Katzenberg 2008). These values also suggest the Oso Bay individuals had little in the way of freshwater resources in their diet, although the site is only 25 km from the mouth of the Nueces River (Hard and Katzenberg 2008).

These elevated values contrast with those from riverine zone sites. The Crestmont site (41WH39) is on a tributary of the Colorado River, in the city of Wharton only 70 km from coastal Lavaca Bay. At least 31 individuals were excavated during utility line construction and analyzed by Vernon (1989). This Late Archaic site has an

estimated age between 500 B.C. and A.D. 400, which is confirmed by recent radiocarbon dates (Hard and Katzenberg 2008). The mean  $\delta^{13}C$  value of -18.9‰ and  $\delta^{15}N$  of 10.6‰ of 15 individuals indicate a diet rich in freshwater riverine resources as well as terrestrial  $C_3$  resources. These values also indicate that estuarine resources, despite the site's proximity to the coast, are apparently not being used. Other similarly situated riverine sites yield similar results (Hard and Katzenberg 2008; Huebner and Comuzzie 1992; Terneny 2005).

In contrast to these aquatic settings, the Olmos Dam site (41BX1) is inland in San Antonio, on Olmos Creek, a tributary of the San Antonio River (Lukowski 1988). Eleven individuals were excavated from this prehistoric cemetery which also dates to the Late Archaic period with radiocarbon dates between 400 B.C. and A.D. 260 (Lukowski 1988). Six individuals yielded a mean  $\delta^{13}C$  collagen value of -18.4‰ and  $\delta^{15}N$  of 8.9‰. These data indicate a diet of  $C_3$  plants and herbivores that feed on a mix of  $C_3$  and  $C_4$  plants and are consistent with the faunal assemblage. The fauna includes a high frequency of white-tailed deer as well as some turtle and bison (Lukowski 1988; Scott 1988).

The clear isotopic distinctions between individuals in cemeteries from coastal, riverine and inland zones, despite their physical proximity to adjacent zones, suggests these groups had fairly well-established territories—at least that populations living along rivers and coast could exclude others from access to these resources and these results confirm previous expectations (Hall 1998; Hard and Katzenberg 2008; Ricklis 2004a). This evidence indicates substantial use of aquatic resources along the central Texas coast and is consistent with the intensification model. In fact, large cemeteries are not found in the area where intensification is not expected, such as the eastern half of southeast Texas (Pertulla 2001).

The model projects early plant intensification where aquatic resources are less accessible. The intensification areas outside of the aquatic resource zone include portions of south Texas, central Texas, the Panhandle Plains, and Lower Pecos archaeological regions. In contrast, it does not include east-central Texas, northeast Texas, the eastern Trans-Pecos, the southern Jornada Mogollon region, or

the western portions of central Texas and the western Panhandle Plains.

The Lower Pecos region is one of the best studied in the state with an impressive array of relevant studies, much of it on material from intensively used dry rockshelters. Data from stable isotope analyses, coprolites, other ethnobotanical work, osteological investigations, and the ubiquitous burned rock plant roasting features all indicate that succulents, including sotol, agave and prickly pear were heavily utilized in prehistory beginning in the Early Archaic period and continuing to the Late Prehistoric period (e.g. Dering 1999, 2005, this volume; Huebner 1991; Powell 1991; Sobolik 1991; Turpin 2004). These data clearly support a pattern of early intensification consistent with the model.

The model also anticipates plant intensification in central Texas, a region that is relatively well-documented with a substantial record of excavation and survey. High labor investment in processing a few plants species may be evidence of plant use intensification. Earth oven use, as represented by burned rock middens, represents high labor investment in plant processing (e.g., Dering 1999, 2005; Ellis 1997; Kludt 2006; Mauldin 2003; Thoms this volume). Bulbs and tubers (known as geophytes) and leafy succulents, such as agave and sotol, are the most likely targets of roasting in these ovens. Significant investment in other plant resources is likely but may not leave such visible archaeological evidence, and may include intensive use of mesquite pods, small seeds from grass and forbs, pecans, prickly pear, and others. The archaeological record in this region is dominated by features commonly referred to as burned rock middens which are rock-lined earth ovens thought to have primarily been used to roast plant materials (Black, et al. 1997; Dering 2003, this volume; Mauldin, et al. 2003; Thoms this volume). In central Texas the evidence suggests the primary plants being roasted were geophytes such as eastern camas and onion (Dering 2003, this volume; Mauldin 2003). Camas distribution extends from central Texas into northeastern Texas. However, burned rock midden features are also common in areas that are generally too arid for camas, which is from roughly the Lower Pecos region through much of west Texas including the

eastern Trans-Pecos, and southern Jornada Mogollon regions. These regions include both areas where early intensification is expected and those where it is not. In these more arid areas it is likely that succulents, including agave, sotol, and yucca were being processed in many of these features (e.g. Dering 1999; Hard 1983; Mauldin 2003; Turpin 2004).

The labor requirements involved in using these features are high, including gathering the prodigious amounts of fuel and the quantities of small bulbs or succulents and constructing and utilizing the oven (Kludt 2006; Thoms this volume). Low food returns on the labor invested are consistent with the characteristics for plant intensification (Black and Creel 1997; Dering 1999; Ellis 1997; Mauldin 2003; Thoms 1989, this volume; Yu 2006; but cf. Kludt 2006). The high frequency of these features is also evidence of plant intensification (Black and Creel 1997). In central Texas, dates on these features extend from ca. cal 6000 B.C. (Black and Creel 1997:278; Stafford 1998:1054; Thoms this volume) to the Late Prehistoric period and document a long record of plant roasting. Analyses of radiocarbon dates suggest that Middle and Late Archaic burned rock use is widespread in central Texas but frequency of use increases during the Late Prehistoric period (Black and Creel 1997; Collins 2004; Mauldin 2003; Thoms this volume). In one review of radiocarbon assays from 35 central Texas burned rock middens in 13 counties, 49 percent were used during the Archaic period (prior to A.D. 800) but 74 percent were used during the Late Prehistoric period counting the 8 middens that were used in both periods (Black and Creel 1997:275). Six of the Archaic middens were used prior to 2000 B.C.

However, as Figure 5 indicates, burned rock middens occur in west Texas in regions where early intensification is not anticipated. Mallouf (1985:29–33) lists radiocarbon assays from 32 roasting features (burned rock middens, ring middens, and large, 1 m or greater, stone-lined hearths) from four counties in the eastern Trans-Pecos region. In this data set only 9 percent showed use prior to A.D. 800 and none showed use prior to 2000 B.C. Although these radiocarbon data support the intensification model, in that early use of large plant roasting features is present

in central Texas and rare in the eastern Trans-Pecos region, surface data from unexcavated sites suggest Archaic use of roasting features in the latter region occurs and deserves closer scrutiny (Mallouf 1985). Further investigation of the variability in roasting and other hot-rock features is required to assess the role of these features in the process of intensification.

Freeman's (2007) detailed analysis of earth oven use in both ethnographic and archaeological contexts persuasively argues that earth ovens may not only be a product of intensification but may also simply be responses to variability in seasonal resource availability. We do not assume that every burned rock midden is a product of plant use and/or intensification (e.g. Stark 2002; Thoms 1989; Yu 2006). However, the increasing frequency of burned rock middens through time and the Archaic period use of burned rock middens in high reproductive rate regions are both consistent with the patterns of intensification suggested by the model. Recent research on roasting features has made progress in understanding the variability and potential roles of these features and deserves continued scrutiny (Black, et al. 1997; Dering 1999; Freeman 2007; Mauldin 2003; Stark 2002; Thoms 1989, this volume; Wandsnider 1997).

## DISCUSSION AND CONCLUSION

This paper has addressed two main questions. First, under what conditions should we expect archaeological evidence of plant-based intensification? Second, to what extent does the archaeological record confirm or refute modeled expectations? Thus far, the growth rate model, constrained by information on the projected dependence on aquatic resources and Binford's plant dependence threshold [ $ET=12.75$ ], provides us with provocative expectations for early plant intensification when mapped across large regions (Figure 4). The theoretical framework for this model is straightforward; other things being equal, hunter-gatherers will only intensify their use of resources when their residential mobility options are constrained. In general, population density is the primary constraint on residential mobility. Regional population density is a function of the size of the initial population, local rates of population growth and

the length of time the population has been growing in a region. Therefore, variability in the timing and density of initial occupation and in population growth rates should contribute to variability in the timing of intensification documented in the archaeological record.

Other things being equal, it is assumed that there will be earlier and/or denser occupations in locations with greater abundance and accessibility of resources as estimated by the terrestrial model [TERMD2]. Population growth rates [REPRATE] are enhanced by the availability of these resources but constrained by pathogen load, which is higher in warmer, wetter settings and lower in cooler and/or dryer settings. Thus, the earliest intensification is modeled to occur in locations with the highest modeled growth rate values.

Anticipating plant-based intensification requires the recognition that other things are not always equal. When aquatic resources are abundant, it is expected that hunter-gatherers will intensify primarily on aquatic resources and secondarily on plants. We expect the earliest plant-based intensification in locations with the highest modeled growth rate values and where aquatic resources are not a good intensification option, but plants are a possibility for intensification.

Both strategies occurred in Texas in locations predicted by the models. In central Texas intensification included costly processing of wild plants in large earth ovens. In the central Coast and southeast Texas regions, intensification included the use of riverine and estuarine aquatic resources. These intensification strategies were likely alternatives to the use of domesticated plants (Black and Creel 1997:302; Freeman 2007; Yu 2006).

While agricultural intensification receives a huge amount of archaeological attention, other options—options that may be preferable to hunter-gatherers from the standpoint of labor investment or quality of resources—could benefit from further research consideration as alternate intensification strategies. Other types of plant intensification as well as aquatic intensification, the archaeological signatures associated with them, and their spatial and temporal distribution become critical avenues of research to which Texas archaeology can contribute as well as to the develop-

ment of theories addressing the absence and the adoption of agriculture.

In the model presented here, early plant intensification is predicted for areas which do not have burned rock middens and where access to aquatic resources is not great, including parts of south Texas and the Panhandle Plains regions. Small burned rock features are found in both regions, but it is not clear if these are indeed signatures of plant intensification and further consideration of these features is needed (Boyd 2004; Hester 2004). The chronology, frequency, reuse, and function of plant roasting features in the eastern Trans-Pecos and southern Jornada Mogollon regions, where early intensification is not predicted, are also appropriate (e.g. Hard 1983; Mauldin 1995). Other things being equal, the model would anticipate little use of these features early in the prehistory of these regions. Research is needed to develop ways of discriminating between seasonal, unintensified use of plant processing features versus their use in systems that are undergoing population packing and resource intensification (Freeman 2007; Yu 2006).

There is an array of evidence suggesting other wild resources may also have been the targets of intensification. Intensive exploitation of prickly pear found in dense patches in south Texas is documented from the Historic period and there is clear evidence of its importance in the Lower Pecos region along with sotol and lecheguilla (e.g. Dering 1999; Hall 1998; Huebner 1991; Sobolik 1991). Hall (1998, 2000) argues that native pecan production along the stream side gallery forests in the Savanna and Prairie region and south, central, and east-central Texas regions was among the highest in North America and was a critical prehistoric resource. The combination of wild plant resources including geophytes, succulents, prickly pear, mesquite pods, and pecans seems to have provided opportunities for hunter-gatherers to intensify on plants without the need to invest labor directly in cultivation.

Recent research on earth oven cooking of geophytes and succulents and the development of data on return rates for pecans and other resources also contribute significantly to the potential for learning how to measure intensification under different circumstances (e.g. Dering 1999, this vol-

ume; Freeman 2007, Thoms this volume). Research designs for field projects can strategically expand our knowledge of the archaeological record in those under-documented regions where we have specific expectations for the pattern of prehistoric intensification. Finding ways to measure plant intensification across a variety of intensification strategies remains a significant research problem that requires attention so that both regions where early plant intensification is expected and not expected can be scrutinized and compared. Advances in the examination of aquatic resource use are also needed. Stable isotope studies can continue to contribute to questions of aquatic resource use as well as those regarding intensified use of  $C_4$  and CAM plants (Hard and Katzenberg 2008; Huebner 1991). Inevitably the intensification model presented here will need to be refined and revised as data accumulate and other important variables are identified. However, this approach provides a framework for consideration of long term change and stability, variability in the adoption of agriculture, comparisons with other regions, insights into known patterns, and suggestions for future research.

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## NOTES

1. We recognize that environments have changed over the last several thousand years. However, so much of the regional variability is structured by basic geography that even if the absolute values of model parameters are imprecise, the overall pattern of high and low values across the region is likely to be accurate. One can test this assertion by noting the strong similarities in the basic pattern among Binford's maps of growth rates across Europe, which are based on paleoclimatic reconstructions (Binford 1999: Figures 4, 6 and 8).
2. One of the other things that might not be equal is the amount of time between harvest and spoilage for aquatic resources. See Binford 2001:430-431 for a discussion of the cod-fish equation which calculates this value. In settings where aquatic resources are expected to spoil very quickly, they may not be the first intensification option.
3. The hunter-gatherer subsistence projections in Binford 2001 allow population density to vary as projected for a given region. In order to control for density, we have set DENSITY = 9.09 persons per 100 sq km. Otherwise, the strategy for calculating D1PFISHP is exactly the same as that for calculating Binford's WFISHP in the ENVCALC program. See Binford 2001:154 for a discussion of the basic strategy of calculating relational projections. Contact Amber Johnson for more information about the ENVCALC program.