A METHOD FOR ANTICIPATING PATTERNS IN ARCHAEOLOGICAL SEQUENCES

Projecting the Duration of the Transition to Agriculture in Mexico—A Test Case

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Discussions of early agriculture have long been synonymous with historical arguments about the timing of migration of farmers or the diffusion of crops and technology from centers of domestication, as well as interpretive arguments about whether the spread of new subsistence strategies was more likely the result of the migration of farming people or the adoption of new strategies by local populations. Yet there are no good arguments about the conditions under which people do not migrate or crops and technology do not diffuse. Therefore, we have many interpretive arguments that accommodate what is known and tell a nice story but little development of the theoretical principles that allow us to specify the conditions under which we do and do not expect to find agriculture. Developing the generalizations that could form the foundation of this kind of theory requires fairly substantial knowledge of variability both in the archaeological record of early agriculture and in the hunting-gathering adaptations such as those that regularly precede food-producing economies. Lewis Binford's (2001:363–399) long-term research on the environmental and demographic factors that impact hunter-gatherer subsistence and settlement strategies provides one foundation for this research. Recent archaeological research on early agriculture provides another.
Within the last decade, archaeological research in the large and diverse geographic region that includes the U.S. Southwest and Mexican borderlands has greatly expanded our knowledge of the variability in the timing of intensive plant utilization and mix of resources included in the earliest horticultural adaptations in this region. Several of the authors included in this volume have made significant contributions to the documentation and synthesis of data on a variety of intensively used native plants and earlier dates on water control features and maize across this region (also see Dochter and Mahy 2006:109-110). The growing body of evidence indicates: (1) intensive use of wild plants long before the earliest maize is present; (2) considerable variety within individual sites combined with considerable variance among sites in the types of plants present even after maize is present; (3) earlier dates for the presence of maize across this region; and (4) earlier dates on water control features in this arid region than in the tropical regions of Mesoamerica.

This new knowledge of the archaeological record relating to early agriculture challenges what Dochter and Mahy (2006:110-111) refer to as "The Simplex Paradigm"—the conventional model of a "relatively sudden shift from hunting and gathering to agriculture" that occurred by either diffusion or migration. Further, they argue, "No longer is it useful or realistic to assume that Southwestern agriculture began with maize, or that there was initially a single kind of early farming that spread across the Southwest prior to the development of other cultivation techniques. Rather than thinking in simple, specific, single-process, single-event terms, we need to think about the early history of maize in the greater Southwest should be framed in the context of complex, diverse, and evolutionary processes over an extended period of time" (Dochter and Mahy 2006:118).

The most common research strategy to develop our knowledge of such processes is continued fieldwork combined with periodic synthesis. Together, these further increase the archaeological data available to researchers. Another productive research strategy is to continue to develop knowledge of the specific subsistence options available and their relative cost/benefit to people living in different environmental settings and under different demographic conditions (e.g., Barrow 2002:20-34). These strategies produce and synthesize increasingly detailed knowledge of particular places at particular times and thus contribute to significant increases in specific knowledge of the archaeological record at local and regional scales of comparison. However, such detailed knowledge accommodates for multiple regions around the world, it becomes increasingly difficult to compare largescale patterns of change in subsistence and settlement systems. Thus, there is also a need to develop generalizations that can be applied globally to allow us to learn how these "complex, diverse, and evolutionary processes" compare from one region of the world to another.

The primary goal of this chapter is to develop general theoretical principles regarding the conditions under which hunter-gatherer subsistence strategies are expected to change into horticultural subsistence strategies. Such generalizations can provide a global framework for anticipating variability in basic features of the archaeological record related to the transition to agriculture. Results of a preliminary attempt to work with archaeological data at this global scale of comparison are reported and then used to illustrate a method for anticipating variability in durations of basic subsistence adaptations across Mexico. That is, generalizations based on knowledge of hunter-gatherer subsistence and patterns of subsistence change in archaeological sequences around the world are used to predict when in Mexico the earliest and later horticultural adaptations are expected. It is unlikely that these predictions are absolutely accurate. However, having predictions based on current knowledge will put the field in a productive posture to learn what we might need to know.

THE TRANSITION TO AGRICULTURE

Although in the archaeological literature the end point of the transition to agriculture has received much greater attention than the beginning point, any explanation for the process of becoming dependent upon agriculture must start with knowledge of variability in the initial conditions of hunting-gathering adaptations. Binford (2001) has recently demonstrated just how variable hunting-and-gathering adaptations are. Ecological variables and both population density and residential group sizes all contribute significantly to the range of observed hunter-gatherer system states (Binford 2001:164-174, 382-387). In regions of the world where agriculture does become an important subsistence strategy, the change from hunting and gathering to agricultural subsistence may be very early or very late in actual date and very rapid or very slow in its pace. Variability in the transition to agricultural subsistence provides an opportunity to learn about cultural processes at many different scales. In global perspective, why does food production become the main subsistence strategy in many regions but not others? Where food production does become important, why is the transition to agriculture in some regions very early but rather slow while in others it is very late but rather fast? Why is there so much variation within a region in both the timing and the organization of subsistence strategies during this transition? At a smaller scale, what can we learn from local variability in settlement patterns and site context about the cultural context in which food production becomes important? How can we learn enough from what we already (think we) know about global-scale patterning in archaeological sequences to be able to say something about what we would expect to see in a region where we have less archaeological knowledge?

Given what we know about the broad range of variability in basic subsistence and sediment patterns, as well as in the organization of marriage, politics, trade, warfare, and many other aspects of hunter-gatherer systems, variation is expected in the timing, duration, and details of both the transition to agricultural subsistence and the organization of those systems once established. Even if the process governing the transition to agriculture is similar in most parts of the world, the way it operates should vary as the initial conditions it operates upon vary. If we can establish generalizations that, other things being equal, allow us to anticipate
variability in a broad range of archaeological sequences, we will be in a position to evaluate claims that something (for example, the mode of introduction of agriculture) was not equal. If we can use Binford’s environmental frame of reference to calculate an ecologically informed (and thus variable) expected duration for the transition to agriculture, observations that deviate from that expected value can be treated analytically to determine what other factors contribute to the variance. As an example, Binford’s frames of reference is used to calculate expected durations for three distinct phases of archaeological sequences, and these equations are then used to project expected values onto Mexico, using the calculated frames of reference for weather station locations in that country. A comparison of projected sequences demonstrates how much variability in sequence patterns is expected to exist based on variance in local conditions alone.

I begin by briefly reviewing the method Binford used to construct his environmental and hunter-gatherer frames of reference that are central to this research. Next, I summarize global patterns relating to the duration of archaeological phases leading up to the transition to agriculture and place Mexico in a global perspective. That is, I use generalizations at the global scale to see how various locations in this region would be expected to pattern, given what we know about the transition elsewhere. Following a discussion of these global patterns, in which I explore the general cultural processes underlying variability in the duration of intensified hunting and gathering, intensified hunting and gathering, and the transition to agriculture in a variety of settings, I then explore the potential use of this analytical strategy for developing a method for recognizing patterns that would not be expected to arise out of local conditions alone.

FRAMES OF REFERENCE

This research uses both the environmental and hunter-gatherer frames of reference described in Binford’s 2001 Constructing Frames of Reference as a framework for exploring archaeological variability. Briefly, the environmental frame of reference is calculated on the basis of simple geographical and climate data (latitude, elevation, distance to the nearest coast, soil type, mean monthly temperature, and rainfall). In all, there are about fifty-five annual summary values ranging from the mean annual temperature (MAT) to such variables as the percentage of months during the growing season with a water deficit (PWTWDP), standing plant biomass (BONE), and net aboveground plant productivity (NAGP). Several of these variables measure the same property of the environment in subtly different ways, and nearly all are derived from either data or equations extant in the ecological literature. The advantages of this environmental frame of reference are that (1) it can be calculated for any location for which basic weather station data are available, (2) the results are directly comparable because the calculations are standardized, and (3) it can be used to calculate multiple regression equations for other properties we might be interested in projecting elsewhere.

Using Binford’s standard calculations, two types of data have been projected using regression equations calculated from environmental variables. The first is a value for expected prey biomass (EXPREY) based on measured ungulate biomass from 104 locations around the globe. The second is the hunter-gatherer frame of reference, including values for expected population density (WIDEN); percentage subsistence dependence on hunting (WHUNT), gathering (WGAITH), and aquatic resources (WFISH); number of moves (EXNOMO) and distance moved per year (EXNOMO); and several other continuous variables recorded in Binford’s 339-case hunter-gatherer data set. These projections make it possible to characterize the organizational variability that would be expected if the world were populated by hunter-gatherers like those known ethnographically. These projections are not analogies based on only a few cases thought to be relevant in a given region, nor are they intended to represent a “true” picture of the past; rather, they are based on relationships developed from data on most of the documented hunter-gatherers around the world. As such, they offer a baseline for comparing both the distributions of archaeological materials and the properties of archaeological sequences over large areas. They are especially relevant to the question of variability in the transition to agriculture, since the demographic and organizational variability of hunter-gatherer groups provides the initial conditions for variability in the transition to agriculture.

Of course, archaeologists are well aware that neither environments nor human adaptations remain constant over time. In the best of all possible worlds, there would be a standardized and reliable strategy for modeling paleoclimates that would provide mean monthly temperature and precipitation values that could serve as the basis for calculating a dynamic environmental frame of reference for a given location over the span of the archaeological record (for one potential strategy, see Bryson and Bryson 1995). Because this type of modeling strategy is not yet fully developed, I use the frames of reference calculated for the modern period as a tool for exploring variability in archaeological sequences. It is understood, then, that this environmental frame of reference is more directly applicable to our pattern recognition goals in regions and during time periods in which environments have not changed dramatically. Regions or time periods for which this is not the case should be treated with caution. Whereas the absolute values for environmental variables cannot be expected to be accurate for all archaeological time periods across the Greater Southwest, the strong influence of geography on environmental patterning ensures that mountains will get relatively more rainfall and have relatively cooler temperatures than neighboring lowlands. Thus, the geographic patterns within a region are expected to be genuine even to periods in the past, when the absolute values of environmental variables would have been different. In short, while the current frame of reference is not the best data we can imagine for archaeological research, it is the best we have right now, so let us see what happens when we use it.
A GLOBAL COMPARISON OF ARCHAEOLOGICAL SEQUENCE DURATIONS

The patterns of change recorded in archaeological sequences around the world are fascinating for both the similarities in patterns among widely separated places and the differences in pattern within a limited area. I have recently begun to organize archaeological information in such a way as to make direct comparison of archaeological sequences possible at a global scale of analysis. The first step is to position sequences into broadly comparable adaptations—unintensified hunting and gathering, intensified (bread-spectrum) hunting and gathering, transition to agriculture, and agriculture. Each sequence is based on the current summary literature for a region to establish dates for each stage as the earliest regular occupation, earliest use of seed-grinding equipment, fishhooks or fishnets, pottery vessels, house types, settlement sizes, mortuary practices, and the earliest evidence of domestication. In general, intensified hunting and gathering is marked by either a shift in plant-processing equipment (for example, the introduction of stone-grounding equipment or a shift in the prevalence or surface area of grinding equipment) or investment in equipment for accessing aquatic resources (for example, fishhooks, fishnets, or harpoons). The transition to agriculture is marked at the early end by the earliest evidence of cultivars or domesticates (formally as one component of a model hunting-and-gathering adaptation) and at the later end by the apparent dominance of agriculture in the economy and subsistence of a region (indicated by change in settlement pattern or artifacts such as hoes).

To date, I have assembled a very preliminary data set based on fairly well-documented sequences from sixteen locations around the world (Table 6.1). Whereas the sequences themselves are developed using the most accurate data available, the dates are recorded as durations of each broad phase of adaptation. This makes it possible to directly compare sequences with dramatically different starting dates in terms of the length of time it takes to get from one transition to another. For example, using a standard historical method of comparison, we might comment on how much earlier agriculture emerged in the Near East (ca. 10,000 B.C.) than in Mesoamerica (ca. 7000 B.C.). However, if we compare durations of time from initial occupation to the emergence of agriculture, we are struck by how much more quickly things happened in Mesoamerica (only 4,000 years of strictly hunting and gathering) compared to the Near East (at least 5,000 years of strictly hunting and gathering). Interestingly, the basic pattern of change from un-intensified to intensified hunting and gathering and through the transition to agriculture to a dominantly agricultural economy is very similar for both the Near East and the Valley of Oaxaca. In these sequences, the relative durations for intensified hunting and gathering and the transition to agriculture are very similar—that is, they take up roughly equal portions of the overall archaeological sequence. In contrast, sequences from Japan and the Illinois and Ohio valleys have much longer durations of intensified hunting and gathering and very rapid transitions to agriculture.

[Table 6.1 Comparison of observed and expected archaeological sequence durations in years used for global comparison.]

<table>
<thead>
<tr>
<th>Location of Sequence</th>
<th>Unintensified Hunting and Gathering</th>
<th>Intensified Hunting and Gathering</th>
<th>Transition to Agriculture</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>observed</td>
<td>expected</td>
<td>observed</td>
</tr>
<tr>
<td>Taiwan</td>
<td>12,000</td>
<td>-</td>
<td>8,000</td>
</tr>
<tr>
<td>Southeastern Alaska</td>
<td>3,000</td>
<td>1,397</td>
<td>5,000</td>
</tr>
<tr>
<td>Central European Plain*</td>
<td>N/A</td>
<td>-</td>
<td>2,500</td>
</tr>
<tr>
<td>Hokkaido, Japan*</td>
<td>7,000</td>
<td>-</td>
<td>5,000</td>
</tr>
<tr>
<td>Illinois Valley</td>
<td>5,000</td>
<td>5,466</td>
<td>5,000</td>
</tr>
<tr>
<td>Total</td>
<td>2,500</td>
<td>-</td>
<td>4,800</td>
</tr>
<tr>
<td>Eastern Sahara</td>
<td>N/A</td>
<td>-</td>
<td>2,200</td>
</tr>
<tr>
<td>Bhimbetka</td>
<td>N/A</td>
<td>-</td>
<td>4,000</td>
</tr>
<tr>
<td>Southeastern America</td>
<td>5,000</td>
<td>6,863</td>
<td>1,800</td>
</tr>
<tr>
<td>Chacoan</td>
<td>5,000</td>
<td>5,029</td>
<td>5,000</td>
</tr>
<tr>
<td>Mesoamerica</td>
<td>4,000</td>
<td>4,095</td>
<td>0</td>
</tr>
<tr>
<td>Basin of Mexico</td>
<td>4,500</td>
<td>3,918</td>
<td>1,200</td>
</tr>
<tr>
<td>Near East</td>
<td>2,000</td>
<td>-</td>
<td>2,500</td>
</tr>
<tr>
<td>Colorado Plateau</td>
<td>4,500</td>
<td>4,911</td>
<td>800</td>
</tr>
<tr>
<td>Coast of Peru</td>
<td>N/A</td>
<td>-</td>
<td>4,000</td>
</tr>
<tr>
<td>Teotihuacan and Oaxaca valley</td>
<td>600</td>
<td>3,335</td>
<td>3,000</td>
</tr>
</tbody>
</table>

* Source state values separately to avoid introduction of archaeology into the analysis.
** Dispersed values are adjusted from calculated values and are determined as in 13.5, see Note 3 for equations and statistical description of each sequence.

The contrast between sequences with relatively long durations of the transition to agriculture and those with relatively long durations of intensified hunting and gathering are clearly represented in Figure 6.1, which shows a global comparison of archaeological sequence durations in years scored by the length of the growing season. In locations characterized by a twelve-month growing season, the pattern of growth in intensified hunting and gathering and a longer transition to agriculture is common throughout the sequence in the Near East and the Valley of Oaxaca, is common in the Near East and the Valley of Oaxaca, and is common in the Near East and the Valley of Oaxaca. In contrast, shorter growing seasons, the pattern in which the transition to agriculture occurs in sequences with a twelve-month growing season, and all are found in arid settings with highly seasonal rainfall patterns. Where the growing season is shorter than twelve months, as, for example, in the Illinois Valley and Japan, this pattern is reversed, with longer durations of the intensified hunting-and-gathering phase and much shorter durations for the transition to agriculture. The only exception to the longer duration for intensified hunting and gathering among these sequences is...
derived from the Colorado Plateau, the only such region among those with short growing seasons with little potential for intensifying on aquatic resources. The next step toward developing generalizations that would allow us to predict the basic structure of archaeological sequences is to determine the ecological conditions under which longer or shorter durations of unintensified hunting and gathering, intensification hunting and gathering, and the transition to agriculture occur.

GENERALIZATIONS REGARDING ECOLOGICAL CONTEXT

How can we learn about the ecological context conditioning the variable durations of these three distinct phases of archaeological sequences? A good place to start is to summarize the basic relationships suspected to condition much of the archaeological variability on the hunting and gathering end of archaeological sequences. All scientific generalizations are preceded by the phrase "other things being equal" to acknowledge that we cannot address all sources of variability simultaneously or be certain of every boundary condition that must be specified.

- Generalization 1: Other things being equal, the duration of unintensified hunting and gathering (generally with high mobility and focused on terrestrial resources) is longer in regions where the initial intensifications are on terrestrial plants rather than aquatic resources. Why should the duration of unintensified hunting and gathering, emphasizing residential mobility to access resources, be longer in such cases? There is a strong relationship between the length of the growing season and huntergatherer subsistence and intensification options. Where growing seasons are longer, unintensified huntergatherers are mostly dependent on terrestrial plants and more likely to intensify on plants. Where growing seasons are shorter, unintensified huntergatherers are mostly dependent on terrestrial animals than on either terrestrial plants or aquatic resources. Birdsell (1990:169) has argued that where aquatic resources are an option, they are often associated with specific points of access (such as a beach) and therefore reduce mobility costs. Thus, unintensified huntergatherers shifting from hunting to aquatic resources may begin to intensify at lower population densities than unintensified huntergatherers mostly dependent on terrestrial plants may intensify their use of those plants.

- Generalization 2: Other things being equal, the higher the terrestrial model density, the shorter the duration of unintensified hunting and gathering. Terrestrial model density indicates the population density of culturally unaltered humans that is, those not using technology to process edible foods or to access inaccessible foods that could be supported based simply on the accessibility and abundance of edible plants and animals (Birdsell 2001:160-209). This model value is expected to predict not huntergatherer densities but rather the density of an agricultural population better built like us and dependent only on terrestrial resources. Nevertheless, places with higher terrestrial model densities have more abundant and accessible resources, thus they probably supported higher population densities of unintensified huntergatherers from early in the sequences. Other things being equal, huntergatherer populations in areas of high terrestrial model densities have more room to grow before they put population pressure on terrestrial resources than those in areas of low terrestrial model densities. High terrestrial model densities may also foster higher rates of population growth, although this is still speculative. As these more densely populated regions experience population growth at an average rate, they become packed much more quickly than neighboring regions with lower initial population densities. Unlike population pressure or carrying capacity, concepts that focus on the balance between population densities and available resources, packing is a mechanical effect of increasing population densities (Birdsell 1983:203-213). At some point, huntergatherers who use residential mobility to access resources reach a population density such that there is already one foraging group in each foraging area. For terrestrial plant-dependent huntergatherers, Birdsell (2001:129-130) has modeled this population density as just over nine people per 100 square kilometers (about twenty-one people per 225 square kilometers of foraging area). Regardless of the abundance of terrestrial resources, packing causes auto
form of intensification as it becomes necessary to feed more people in less space and thus brings an early end to unirrigated hunting and gathering. The local structure of resources (abundance and scale of aquatic habitats, types, diversity and abundance of terrestrial plant species) affects the general intensification options available.

- Generalization 3: Other things being equal, access to aquatic resources increases the duration of intensified hunting and gathering. In addition to providing a subsistence opportunity with lower mobility costs, aquatic resources support higher hunter-gatherer population densities than do terrestrial animals or terrestrial plant-based adaptations (see Baldwin 2001:314). Therefore, aquatic resources may extend the duration of intensified hunting and gathering on both ends by providing a way to our mobility costs early on and by supplementing higher regional population density than a strictly terrestrial adaptation does. However, once aquatic-dependent groups switch to agriculture, they tend to switch much more quickly. Durations of transition to agriculture are generally very short.

- Generalization 4: Other things being equal, in areas where hunter-gatherers intensively farm on terrestrial plants, some form of plant cultivation is likely to occur, and the duration of the transition to agriculture is relatively long compared with areas where the first intensification is on aquatic resources. A comparison of hunter-gatherer subsistence adaptations above and below the poverty threshold (Baldwin 2001:315), that is, 0.998 persons per 100 square kilometers, demonstrates that below this population density there are a far number of hunter-gatherer groups dominantly dependent on terrestrial animals, especially in environments above 40 degrees latitude. Above this population density, there are no hunter-gatherer groups dominantly dependent on terrestrial animals. Above 40 degrees latitude, most hunter-gatherer populations are dominantly dependent on aquatic resources, whereas below 40 degrees latitude, they are dominantly dependent on terrestrial plants. Thus, there is a strong geographically correlated rate of intensification that we should expect to see in an archaeolcal sequence.

**EXPECTATIONS FOR MEXICO**

In global perspective, most of Mexico would be expected to support hunter-gatherers dominantly dependent on terrestrial plants, with relatively low terrestrial model densities in the arid north and much higher terrestrial model densities in the tropical regions in the south. Therefore, we would expect moderate to long durations for unirrigated terrestrial hunting and gathering in the north and shorter durations for unirrigated hunting and gathering in the tropics. Once intensification begins, we would expect relatively long durations of intensified hunting and gathering and relatively short transitions to agriculture near the coasts, where aquatic resources would be more available, and the opposite pattern of relatively short durations of intensified hunting and gathering and relatively long durations of the transition to agriculture in the interior, where aquatic resources are less available. Let us see what happens when we project values for sequence duration from equations run on the global sequences onto Mexico. I have listed the locations of the archaeological sequences used for global comparison to the environmental frame of reference to use environmental variables to calculate regression equations for the duration of (1) unirrigated hunting and gathering, (2) intensified hunting and gathering, and (3) the transition to agriculture. Some archaeological sequences are eliminated from the regression analyses to maintain as much consistency as possible in the data. The equation for the duration of unirrigated hunting and gathering was run only on the New World sequences because of the difficulty of determining when to begin a modern hunting-gathering adaptation in many Old World sequences, which are complicated by the presence of previous horticulturists and archeic modern humans. The equation for the duration of intensified hunting and gathering uses all available sequences. The equation for the duration of the transition to agriculture uses only those sequences where there is an archaeologically visible transition to agriculture (Tasmania, Southeast Peninsula, Central European plain, and Japan are eliminated by this criteria—they either have no agricultural component or are clearly instances of rapid introduction of agricultural dependence on already domesticated plant and a continuous occupation of the region across the transition from hunting and gathering to agriculture (eastern Sahara is omitted because of occupational hiatus). The resulting equations are then used with data collected from 254 Mexican weather stations to project the durations of each of these phases onto locations not used to derive the original equations (with the exception of the Valley of Oaxaca and Basin of Mexico). Figure 6.2 maps the variability in projected duration for the transition to agriculture over all of Mexico, given what we know about the relationships between environmental variables and the duration of the transition to agriculture in eleven locations around the world. Values calculated strictly from environmental variables project a wide range of variability, with some locations expected to make the transition in much less than 600 years, whereas others are expected to take longer than 3,600 years. With these calculated values for expected duration of unirrigated hunting and gathering, intensified hunting and gathering, and the transition to agriculture, it is possible to develop expectations for differences in overall patterns of sequence variability across the study region. Figure 6.3 compares these projected sequences for several locations in Mexico. Note the dramatic difference between projected sequences where hunter-gatherers are expected to be either less than or greater than 30 percent dependent on aquatic resources (WITS/ISHP). Although this variable (WITS/ISHP) is not used in any of the equations to calculate sequence durations, the projected durations are distributed according to expectations derived from the global-scale generalizations with respect to aquatic dependence outlined earlier. Longer durations for intensified hunting and gathering are projected for locations where hunter-gatherers would be expected to depend largely on aquatic resources. If the
Figure 6.2. Map of projected duration of transition to agriculture for Mexico. Shading represents values of expected duration of transition to agriculture (DTRANS) projected from an equation using a measure of seasonality of rainfall (RRCORR), log of elevation (LMEANELV), and log of the coefficient of variability in mean monthly rainfall (LCVRAIN). (See note 5 for further discussion of equation.) Diamonds mark locations of weather stations used for the projected sequence comparison in Figure 6.3. From north to south, they are Ensenada, Tijuana, Casas Grandes, Guerrero, Matamoros, Mazatlan, Misañita, Mexico City, Veracruz, and Tehuacán.

Figure 6.3. Projected sequence comparison for a few locations in Mexico. Durations of intensified hunting and gathering, intensified hunting and gathering, and the transition to agriculture are projected from equations derived from global data (note 5) and are stacked to provide a picture of the projected preagricultural sequence for ten locations in Mexico. Stations are sorted by projected hunting-and-gathering dependence on aquatic resources (WFISHP). Locations were chosen to represent a wide range of variability in projected hunter-gatherer adaptations.

DISCUSSION

I began this chapter by establishing a research goal that should put us in a better position to evaluate arguments regarding the transition from hunting and gathering to agriculture. The primary goal was to develop general theoretical principles regarding the conditions under which hunter-gatherer subsistence strategies are expected to change into horticultural subsistence strategies. This was accomplished by combining data recorded for archaeological sequences around the globe with Binford’s (2001) environmental frame of reference and generalizations derived from his study of variability in hunter-gatherer systems states.

We have seen that when archaeological sequences are compared at a global scale of analysis, there are numerous regularities in the pattern of these sequences. These regularities can be generalized as follows: other things being equal, (1) the
duration of unintensified hunting and gathering is longer where the initial intensification is on terrestrial plants rather than aquatic resources; (2) the higher the terrestrial model density, the shorter the duration of unintensified hunting and gathering; (3) access to aquatic resources increases the duration of intensified hunting and gathering; and (4) in areas where hunter-gatherers intensify first on terrestrial plants, some form of plant cultivation is likely to occur, and the duration of the transition to agriculture is relatively long compared with areas where the first intensification is on aquatic resources. Combining these generalizations regarding the process of intensification with Binford’s discussion of intensification related to population packing (Binford 2001:363–399), transitions to agriculture are expected to develop based on local conditions where these conditions hold: (1) hunter-gatherer population densities exceed the packing threshold, decreasing the area within which a local group can exercise residential mobility for accessing resources, thus increasing the need for intensification; and (2) plants are the most likely targets for intensification. There is likely to be further variability in the timing of what we recognize as agriculture related to the types of plants intensiﬁed. For example, I would expect agriculture to arise earlier where intensification is on annuals (e.g., grains) than where it is on perennials (e.g., nuts). 6

Given that a predictable intensification process is operating to produce transition from hunting and gathering to agriculture, there is no reason to believe the “invention” or “origin” of agriculture was a rare event or that knowledge of this subsistence strategy had to spread out from the centers of domestication through either diffusion or migration. Under similar local conditions of increasing population density and the possibilities for intensifying on plants, plant cultivation and domestication would be expected to occur in many different places without relying on migration of farming populations to bring the knowledge with them. The growing archaeological record of plant intensification preceding the introduction of maize across the Mexican borderlands and the U.S. Southwest confirms this part of the argument.

Nevertheless, some crops, like maize, have well-documented, fairly narrow geographic origins. When these crops begin to be found across a larger region, we would like unambiguous criteria for diagnosing the mode of transmission. Thus, a secondary goal of this chapter was to develop analytical tools that allow us to predict the pattern of culture change we would expect to see if there were no external pressure on the system. Analytical exploration of the divergence between the observed archaeological sequence and these expectations serves as a first step toward developing unambiguous criteria for recognizing cases where there is external pressure (for example, migrations of successful farmers) from the archaeological record. To accomplish this goal, I used data recorded for sixteen globally distributed archaeological sequences to calculate equations that can be used to project expected values for the duration of various phases of archaeological sequences anywhere modern weather station data are available. This strategy allows us to use existing archaeological information as leverage for further knowledge growth.

Let us consider the equation projecting the duration of the transition to agriculture (see note 5). Given the strength of the relationship between the duration of the transition to agriculture and environmental variables, if the transition is thought to be inﬂuenced signiﬁcantly by migration, then either migration must respond predictably to the environmental setting or cultural changes must be more strongly inﬂuenced by local developments than by external inﬂuences.

Of the sixteen sequences used in the global comparison, only eleven were used to calculate this equation. In two locations—Tasmania and the Seward Peninsula in Alaska—there was no archaeologically recorded transition to agriculture. Rather, intensiﬁed hunting and gathering continues to the end of the sequence. In two other locations—Honshu, Japan, and the Central European plain—the transition to agriculture is not measurable in the archaeological record because the change from hunting and gathering to agricultural economies was too rapid for this transition to appear as a distinct archaeological system state. One could argue that this was the result of migration, diffusion, or, following Binford (1999), niche ﬁlling when some new combination of resources became available. In any case, these are exceptional patterns and were not used to generate the equations. Finally, the data from the eastern Sahara were eliminated from this equation because of an occupational hiatus between the transition to agriculture and fully agricultural phases, indicating that the duration of the transition to agriculture in the larger region must have been longer than that recorded at Nabta Playa (Wendorf and Schild 2001), and because agriculture is an inaccurate description of the mobile, pastoral adaptation that caps this sequence. Thus, the equation for the duration of the transition to agriculture relies only on data from archaeological sequences where there is a clear, continuous, archaeologically measurable transition from hunting and gathering to agriculture.

This, then, is one of the boundary conditions that must be equal for the projected value to be accurate. Therefore, we could use the projected value as a model of what we would expect if the transition to agriculture was based on local conditions alone. If the archaeological sequences in some region were to demonstrate signiﬁcant deviation from this projected value, migration would be an acceptable explanation for this unexpected pattern of change.

The key to being able to evaluate arguments about migration lies in understanding what the pattern should look like in the absence of migration. The method developed here is a ﬁrst step toward doing this. It could be further developed by using relevant criteria for adding sequences to the global comparison and for partitioning data for archaeological sequences where migrations are known to occur and there is no suspicion of a migration. The point of this discussion is that the debate regarding the importance of migration in transitions to agricultural economies need not remain a matter of debate. There are analytical strategies that could be used to develop unambiguous criteria for recognizing the impact of migration versus indigenous adoption of new economic strategies.
CONCLUSION

This study demonstrates how we can develop intellectual tools that allow us to ground our analysis of change in human adaptive strategies documented in the archaeological record. It is a first step, based on a preliminary comparison of a global sample of archaeological sequences. Nevertheless, the strategy of projecting actual values for expected durations of distinct system states using an environmental frame of reference has real potential for putting us in a position to further our ability to explain variability in the archaeological record at many different scales of analysis. Whether the projections are used within a region to guide research design and choice of field locations for further study, or whether these global patterns are used as a frame of reference for arguing about the likelihood of migration as a contributing factor in what seems a rapid pattern of culture change, the greatest learning opportunities come when our observations about the archaeological record fail to match our expectations. Should significant differences between observed and expected values be found, the next challenge is figuring out what we must know to explain the variability. Regions such as the Mexican borderlands and the U.S. Southwest, where rigorous fieldwork is rapidly contributing new knowledge about local and regional variability in adaptations throughout an intensification sequence, provide ideal settings for developing these methods further.

NOTES

1. The modeling strategy developed by Reid Bryson and colleagues (1995) has the potential to become such a strategy. While temperature models are firmly grounded in knowledge of factors contributing to patterns of climate change, precipitation models are simply fitted using modern monthly variability as a model for interannual variability over the last several thousand years. Further, no standard method is available for calculating these models; therefore, considerable room exists for fitting the model to other known paleoenvironmental indicators. My own working models developed by the Bryson strategy using pollen data has yielded considerable support for temperature models and very little support for rainfall models. There are likely to be regions where this strategy works well as currently designed and others where it does not. At this time, this strategy does not meet the criteria for a globally applicable, standardized modeling strategy, although it does yield mean monthly temperature and rainfall estimates as output.

2. There is insufficient space in this chapter to fully document the development of these sequences. Readers with questions about the durations or their documentation are encouraged to contact the author.

3. Binford (2001 chapter 6) developed the terrestrial model density to estimate the number of culturally unaided people the environment could support to serve as a baseline against which to measure the population densities achieved by hunter-gatherers.

4. Projections for northern Mexico are based on the most basic suite of input variables, which do not allow us to anticipate the presence of unearned water, that is, water that fell as precipitation elsewhere, which may be flowing through an area in a river. There are likely spots in the interior where some aquatic resources would have been available in sources of unearned water. With a bit more work measuring the lengths of drainages and the distance of particular locations from the headwaters, we will be able to use equations to project subsistence dependence that do take such resources into consideration. This will yield a more accurate picture of likely adaptations, which, in turn, will revise our expectations for durations of the phases of intensification. Thus, these projections should be considered a provocative first pass rather than a best possible final result.

5. Duration of intensified hunting and gathering (HG) is calculated from an equation run using only the New World sequences (see Table 6.1) because of the difficulty in determining when to begin a modern HG adaptation in many of the Old World sequences. For this equation: R=0.950, R²=0.902, Adj. R²=0.863. The standard error of the predicted value is 570 years.

\[ \text{DUNINHG} = 10.145.643 - (1.870.561 \times \text{REVEN}) - (12.894 \times \text{BARS}) \]

Where, REVEN measures evenness of rainfall throughout the year and BARS measures biomass accumulation ratio (in addition to standing biomass from new growth).

Duration of intensified HG is an equation run on all sequences in Table 6.1: R=0.921, R²=0.849, Adj R²=0.811. The standard error of the predicted value is 1,112 years.

\[ \text{DINTNSHO} = 7.128.24 - (1.312.075 \times \text{LWATD}) - (0.715 \times \text{ELEV}) + (1.130.312 \times \text{TERMG2}) \]

Where, LWATD = log10 of annual water deficit measured in millimeters, ELEV = elevation in feet, and TERMG2 = number of culturally unaided people per hundred square kilometers who could be supported by available and accessible plant foods (from Binford’s terrestrial model; Binford 2001 chapter 6).

Duration of transition to agriculture is an equation run on all sequences where there is an archaeologically visible transitional phase (Tasmania, Seward Peninsula, Central European plain, and Japan are omitted from analysis) and a continuous occupation of the region across the transition from HG to agriculture (eastern Sahara omitted from analysis). For this equation: R=0.984, R²=0.968, AdjR²=0.955. The standard error of the predicted value is 120 years.

\[ \text{DTTRANS} = -156.675 + (665.535 \times \text{RRCORR2}) + (665.59 \times \text{LMEANELY}) - (2.462.16 \times \text{LCVRAIN}) \]

Where, RRCORR2 = the number of months separating peak temperatures and peak rainfall, LMEANELY = log (10) of elevation, measured in feet, and LCVRAIN = log (10) of the coefficient of variation of precipitation, measured in millimeters.

6. Current research, including collaborations with Robert Hard, University of Texas–San Antonio, and Adolfo Gil, CONDORCET, Argentina, explore these ideas further.

REFERENCES CITED

Binford, K. R.

Binford, L. R.
THE CASE FOR AN EARLY FARMER MIGRATION INTO THE GREATER AMERICAN SOUTHWEST

Steven A. LeBlanc

Humans are fascinated with humans. Our fascinations include: How did we get where we are? How did we fill up the earth? Why and how did we become farmers? Why do we speak so many languages, or perhaps, why do we speak so few? Addressing these and similar questions helps us place ourselves in the world. Sometimes the answers come in small pieces; sometimes they are what we expect. In other cases, however, unexpected insights change our perceptions markedly, and the answers are far from what we predicted. The unexpected nature of the behavior in the wild of our close relatives, the chimpanzees, is a classic case in point. Perhaps not of that scale, but certainly paradigm breaking, is the idea that farming was invented only a handful of times in a handful of places, and it was the farmers themselves who rapidly spread farming to much of the world from these core places. We have long thought about the significance of the initial adoption of agriculture, yet the story of its spread may be every bit as fascinating.

This chapter was not presented at the 2004 Southwest Symposium and is a later addition to the volume. It is included here at the suggestion of the organizers of the Agricultural Adaptations session.
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