Distinguishing environmental and density-dependent aspects of adaptation

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Abstract
The Middle Holocene was a period in which significant climate change and rapidly increasing population density are often both associated with dramatic changes in human subsistence and social organisation. Methodologically, it is interesting to ask: how can archaeologists learn to distinguish environmentally- and demographically-conditioned aspects of change in such strategies? Limiting the scope of the study to the Americas partially controls variation in the timing of initial occupation, although both the scale and impact of climate change vary widely. This provides a laboratory for testing expectations of analytical models which allow environmental and demographic variables to change independently. This exploration is founded on Binford’s (2001) environmental and hunter-gatherer frames of reference.

1 Introduction
Comparison of mid-Holocene behavioural strategies in the Americas presents ample opportunity to explore adaptive strategies of hunter-gatherers in a wide range of environmental settings. In contrast to Eurasian and African settings, there is much more consistency in the initial occupation dates across the Americas, minimising that source of variation in the relative timing of adaptive changes. Yet, including both North and South America introduces the possibility of contrasting patterns of adaptation in settings (northern hemisphere vs southern hemisphere) where mid-Holocene environmental change was structured differently. Theoretically, mid-Holocene temperature change is related to the interaction of several parameters relating to the Earth’s orbit, some of which, at any point in time, impact the northern and southern hemispheres differently. Therefore there should be some regular differences in the impact of temperature change on habitats and the people who exploit them in the northern and southern hemispheres. Methodologically, these differences could be exploited in research comparing sociocultural trajectories as evidenced in the archaeological record.

The focus of this paper is on drawing distinctions between environmental change and increasing population densities as contributing factors to changing hunter-gatherer adaptations, including the beginning of the transition to agricultural adaptations. Binford’s (2001) environmental and hunter-gatherer frames of reference form the foundation for this exploration. The general argument should be globally applicable but is focused here on the Americas.

2 Themes in archaeology of mid-Holocene Americas
A simple JSTOR survey of mid-Holocene archaeology in the Americas yields 19 articles published in either American Antiquity or Latin American Antiquity between 1990-2005 using the search terms [mid-Holocene AND population density n=14; 13 focused on Americas] or [mid-Holocene AND climate change n=19; 18 focused on Americas]. The results of these separate searches overlap by 12 articles; 11 of which are focused on the Americas. There are several themes which emerge from a review of these articles which are supplemented with discussion of some of the other papers presented in the session on Mid-Holocene Behavioral Strategies in the Americas at the 2008 Society for American Archaeology meetings, Vancouver BC.
2.1 Implications of mid-Holocene shoreline for archaeological investigation

A few of these articles focus on reconstructing palaeoshorelines (Fedje & Christensen 1999), determining palaeolandcape conditions for underwater sites (Faught 2004), or discussing impact of sea level change on archaeological site distributions (Lewis 2000). There is relatively little discussion of factors conditioning culture change in these settings where the primary issue is simply locating the sites. Nevertheless, Lewis argues that ‘dry-land archaeological sites on subsiding United States coastlines should be biased … against archaeological evidence of coastal adaptations older than approximately 2000-5000 years BP’ (2000:527). This argument is founded on the assumption that people would gravitate to coastal resources and that population density in coastal regions would generally increase over time (Lewis 2000:527). Thus, increasing population density is argued to be a response to resource potential.

2.2 Gourd-growing indicates increased fishing intensity

Reports of mid-Holocene occurrence of curcurbit remains in sites ranging from Minnesota (Perkl 1998) to Pennsylvania (Hart & Sidell 1997), and Maine (Petersen & Sidell 1996) question the relative importance of climate change and human cultivation in the spread of gourds through eastern North America. By arguing for human introduction of gourds to regions outside their natural range, or projected range during this time period, these reports suggest mid-Holocene curcurbit cultivation as one step toward agricultural economies. Fritz (1999) responds with a paper in which she argues that non-food uses of gourds should free ‘cultivation of Curcurbita pepo from any “progressive advance” along the pathway to agriculture (418)’.

Developing this argument further, she points out that not only were gourds likely used as floats for fishing nets, ‘All of the sites yielding mid-Holocene pepo fragments (with the possible exception of Cloudsplitter) are in river valley settings where fish could have been procured with nets at certain times of the year (424)’. Thus, gourds are argued to be an indication of more intensified use of riverine resources during the mid-Holocene in eastern North America.

2.3 Shifting loci of occupation indicates hunter-gatherers still mobile

Another suite of papers explores regional change in mobility over time (Odell 1998) or shifts in the use of locales within a region (Delcourt et al 1998; Sandweiss 1996). Together, these papers support the inference that mid-Holocene hunter-gatherers on the southern High Plains (Meltzer 1991), in the Illinois Valley (Odell 1998), Cumberland Plateau of eastern Kentucky (Delcourt et al 1998) and along the coasts of Ecuador and northwestern Peru (Sandweiss 1996) were still residentially mobile at a large geographic scale. This would be expected of hunter-gatherers at relatively low regional population densities where there was ample ‘unoccupied’ space into which to move when local resource availability altered. On both the Cumberland Plateau and on the coast of Peru, specific local environmental changes, related to mid-Holocene climate patterns, are referenced as the likely cause of the shifting loci of occupation.


Archaeologists working in the Channel Islands of California (Raab et al 1995; Arnold et al 1997; Colten & Arnold 1998) have been engaged in a lively debate over the importance of warming waters (mid-Holocene vs Late Period AD 1150-1300) in conditioning subsistence stress. Raab and colleagues argue that increasing sea surface temperature cannot be the cause of subsistence stress seen in the Late Period because a similar increase in sea surface temperature does not cause subsistence stress in the mid-Holocene (1996:304). One issue in this debate is the relationship between productivity, especially of kelp beds, and water temperatures. Another is the role of population density on the experience of subsistence stress. Arnold and colleagues draw a dis-
tinction between the context of Late Period and mid-Holocene populations in the Channel Islands, noting that larger populations living at higher population densities in the Late Period ‘certainly would respond differently to a period of resource disruption than a smaller Early period [mid-Holocene] population (1997:306)

2.4 Other papers from Mid-Holocene Behavioral Strategies in the Americas

Most of the other papers in the recent SAA session titled Mid-Holocene Behavioral Strategies in the Americas touch in one way or another on the latter theme. In arid regions of southern (Miotti 2009) and central-western (Garvey 2009, Neme & Gil 2009) Argentina and the western United States (Hildebrandt & McGuire personal communication), the mid-Holocene archaeological record indicates regional changes in the intensity of occupation. This suggests that hunter-gatherers in at least some parts of these regions were still operating at relatively low population densities and maintaining high mobility.

Studies at a smaller regional scale discuss both occupational hiatus (Neme & Gil 2009) and shifts in mobility strategies (Garvey 2009) as responses to environmental changes due to increasing aridity. Studies comparing multiple regions (such as Hildebrandt & McGuire personal communication; Miotti 2009), referred to by Miotti as ‘mesoscale’ (following Delcourt & Delcourt 1988:26), recognise that while the occupational intensity decreases in some areas, it increases in others during this time. Miotti (2009) argues that this reflects a change in the ideational realm of hunter-gatherers, with the use of landscape changing to reflect changes in beliefs about sacred places. While she suggests environmental change was probably the trigger for changing ideology, she does not discount independent change in ideology. Hildebrandt and McGuire (personal communication) suggest that increasing aridity in the interior of California and the Great Basin led to a shift in population from these regions to the California coast with significant use of estuary habitats, which reached mature levels of productivity as sea level rise slowed in the middle Holocene. Evidence of intensified use of resources, especially acorns, along the coast is seen as a response to increased population density along the coast. However, environmental change and the redistribution of population across the larger region is argued to be the ultimate cause of this increasing density.

In addition to arguments that environmental change caused large-scale redistribution of human populations mid-Holocene, there are also arguments that environmental change caused change in the subsistence strategies of hunter-gatherers. Rhode (2009) argues that in the Bonneville Basin of the western United States mid-Holocene environmental changes induced a shift in subsistence to the increased use of small seeds. Barrientos and Masse (2008, personal communication) argue that in addition to mid-Holocene climate change which may have impacted the reproductive success (and therefore abundance) of guanaco therefore leading to a decline in the population of humans who depended upon these camelids for food (Barrientos & Perez 2005), regional effects of meteorite showers between 6-4 14C ky BP also contributed to local hiatus for middle Holocene human populations in parts of central and northeastern Argentina.

In contrast with many papers focusing on environmental change as cause of archaeological patterns, only Wolverton et al (2009) rely on increasing population density as the primary cause for a pattern of intensified use of white tailed deer along the southeast Texas coast during the mid-to-late Holocene. Certainly in this survey of archaeological discussions of mid-Holocene behavioural change in the Americas, environmental change is referenced much more often than density-dependent change as the cause or conditioner of changes in human behaviour.

2.5 Bias towards environmental change as explanation in archaeological discourse

In discussions of mid-Holocene adaptations in the Americas, climatically conditioned environmental changes dominate over discussion of density-dependent adaptive changes. Population density is indicated as a cause of adaptive shifts only in settings with relatively high population densities, such as during the Late Period in the Channel Islands and California coast where Arnold et al cite densities of 3-5 people/sq km (1997:306) or along the southeast Texas coast (Wolverton et al 2009). Yet we know that the mid-Holocene was a period in
which regional population densities were generally rising and that hunter-gatherer adaptations begin to shift at much lower densities (e.g., Binford’s packing threshold of 9.09 people/100 sq km) than those referenced above. Binford (2001) has shown through multiple examples that hunter-gatherer subsistence and settlement strategies are very sensitive to population density, and that many aspects of hunter-gatherer social organisation are conditioned by subsistence and settlement strategies. So, is environmental change or increasing population density more likely to cause changes in hunter-gatherer adaptations? This paper will use models built on the foundation of Binford’s environmental and hunter-gatherer frames of reference in order to explore the impact of increasing population density vs changing climate on hunter-gatherer adaptations.

3 Building the models

To explore the relative importance of changes in climate and population density for significant adaptive shifts in hunter-gatherer subsistence, I have built two separate models using Binford’s (2001) environmental and hunter-gatherer frames of reference as the foundation. All variables are calculated using the Program for Calculating Environmental and Hunter-Gatherer Frames of Reference (ENVCALC2). Java Version, August, 2006 (Binford & Johnson 2006). To calculate the environmental and hunter-gatherer frames of reference requires a short list of input variables. The ability to model changes in hunter-gatherer subsistence related to population density is built into the program. Thus, all modelled values can be calculated for any location in the world where the required input data is either available or can be estimated.

3.1 Modelling density-dependent change in hunter-gatherer subsistence

Binford (2001: 154-156) describes a strategy for using multiple regression equations to project specific properties of hunter-gatherer systems. This model uses projections for percent dependence on hunting terrestrial animals (WHUNTP), gathering terrestrial plants (WGATHP), and use of aquatic resources (WFISHP). The resource domain with the greatest value for projected dependence is recorded as the subsistence speciality (SUBSPX: 1 = hunting, 2 = gathering, 3 = aquatics). Population density is projected separately, and the value for population density is one of the variables that contributes to the projected subsistence dependence. This original set of equations is designed to project the combination of hunter-gatherer density and subsistence mix that would be expected in a particular environmental setting given what we know about the relationships among the environmental frame of reference variables, density, and subsistence for observed hunter-gatherers.

In order to model density-dependent change in subsistence, I have created a new set of calculations which uses the projections described by Binford, but instead of allowing density to vary, the value of this variable is controlled. Hunter-gatherer subsistence projections are then made at several values of population density (table 1).

For each level of population density, the subsistence domain with the greatest projected value is recorded as the subsistence speciality (UPSUBSPX, D1PSUBSPX, etc.: 1 = hunting, 2 = gathering, 3 = aquatics). The resulting values can be mapped to show how geographic patterning in subsistence dependence changes as population density increases from 4.5 people to 100 sq km.

Table 1 Variables used to project hunter-gatherer subsistence dependence

<table>
<thead>
<tr>
<th>Variable names</th>
<th>Packing multiplier</th>
<th>Density (people per 100 sq km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>UPHUNTP, UPGATHP, UPFISHP</td>
<td>.5</td>
<td>4.5</td>
</tr>
<tr>
<td>D1PHUNTP, D1PGATHP, D1PFISHP</td>
<td>1</td>
<td>9.1</td>
</tr>
<tr>
<td>D1PHUNTP, D1PGATHP, D1PFISHP</td>
<td>1.5</td>
<td>13.6</td>
</tr>
<tr>
<td>D2PHUNTP, D2PGATHP, D2PFISHP</td>
<td>2</td>
<td>18.2</td>
</tr>
<tr>
<td>D2PHUNTP, D2PGATHP, D2PFISHP</td>
<td>2.5</td>
<td>22.7</td>
</tr>
<tr>
<td>D3PHUNTP, D3PGATHP, D3PFISHP</td>
<td>3</td>
<td>27.3</td>
</tr>
</tbody>
</table>

1 Expressed as percent hunter-gatherer dependence on hunting, gathering and fishing.
2 Rounded to nearest tenth.
up to 27.3 people per 100 sq km².

3.2 Modelling impact of mid-Holocene climate change on hunter-gatherer subsistence

Research in palaeoclimatology has determined that the mid-Holocene climate change was caused by regular periodicity in the earth’s orbit. These changes would have made mid-Holocene temperatures in the northern hemisphere warmer in summer and colder in winter. These changes were felt between 7000 to 5000 years ago. The intensity and exact timing is variable in the northern hemisphere and either did not occur at all in the southern hemisphere (NOAA 2008) or was such that summer temperatures were cooler and winter temperatures were warmer, reducing the seasonal temperature cycle (Braconnot et al 2007:269). It is estimated that in the regions of the northern hemisphere which felt the greatest impact the magnitude of this temperature change was 2-4 C different from today (Kerwin et al 1999).

I have used this basic information to modify contemporary weather station records in order to model mid-Holocene changes if temperature in the northern hemisphere were either 2 C or 4 C different from today while temperature in the southern hemisphere was like today. The model for a temperature difference of 2 C begins with the weather station input data for mean monthly temperature and adds 2 C in summer (TJUN +2, TJUL +2, TAUG +2) and subtracts 2 C in winter (TDEC -2, TJAN -2, TFEB -2). The model for a temperature difference of 4 C is constructed the same way, but adds or subtracts 4 C to the original values for these months. These modified data are used with the rest of the contemporary input data to calculate the frames of reference.

In these models there is no attempt to modify precipitation values or to test the impact of changing amounts or patterns of precipitation on either habitat or basic hunter-gatherer strategies. It would be possible to develop such a model in the future to compare impacts with both temperature and density models.

4 Analysis of model results

In order to assess general fit of the modified temperature models for mid-Holocene conditions, I will first compare expected vegetation classification calculated from these models with the best biome reconstructions available for the mid-Holocene.

4.1 Comparing modelled temperature regime to reconstructed data

The Binford and Johnson program includes a discriminant function calculation of both broad vegetation class and finer scale vegetation type. The vegetation class (VEGCLASS) variable is comparable to biome classification that has been used by researchers reconstructing late glacial and mid-Holocene vegetation (Prentice et al 1996; Boenisch et al 2001). Thus, it is also possible to compare calculated vegetation class using both modern weather station data and the modelled mid-Holocene temperature regime to other researchers inferences about biomes using actual palaeoenvironmental data. There are no data available from this source for South America, but there are data from Canada and eastern USA (Williams et al 2000) and for the western USA (Thompson & Anderson 2000).

A comparison of vegetation class from unmodified contemporary weather station data with reconstructed biomes (Prentice et al 1996) across the USA and Canada demonstrates a very good match (figure 1). Nearly 97 per cent of biome reconstructions match the calculated vegetation classification for the neighbouring weather stations (only 68 of 2481 reconstructions are different). More than 94 per cent of biome reconstructions from data at 6000 BP (only 34 of 583 are different) match calculated vegetation classification using the modified weather station input to model mid-Holocene climate with a 4 C difference (figure 2). Given that this model is a very simple approximation, a better match could hardly be expected!

4.2 Comparing changes using mid-Holocene modelled temperature

Using the environmental and hunter-gatherer frames of reference calculated for contemporary weather station data as a standard for comparison, I will now explore the scale of change in vegetation class and hunter-gatherer subsistence speciality using the frames of reference calculated for both mid-Holocene models (2C and 4C difference from modern). Since we have begun our exploration with a comparison of the calculated vegetation class and biome reconstructions, let us continue by quantifying the change in vegetation class for each model compared to our
Figure 1: Comparison of (A) modern biome reconstruction from Prentiss et al. 1996 and (B) modern vegetation class calculation using Binford & Johnson (2006) program. Only 2.74% of biome reconstructions differ from the vegetation class calculation at the closest analogue weather station.

Figure 2: Comparison of (A) 6000 BP biome reconstruction from Prentiss et al. 1996 and (B) vegetation class calculation using Binford & Johnson (2006) program with the 4C model. 5.83% of biome reconstructions differ from the vegetation class calculation at the closest analogue weather station.
Distinguishing environmental and density-dependent aspects of adaptation: Johnson

Table 2 Comparison of change indicated by temperature models with contemporary weather station vegetation and hunter-gatherer subsistence speciality in northern hemisphere

<table>
<thead>
<tr>
<th>Description</th>
<th>N</th>
<th>% weather stations with change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total weather stations northern hemisphere</td>
<td>6020</td>
<td>n/a</td>
</tr>
<tr>
<td>Change in vegetation class – 2 C model</td>
<td>1716</td>
<td>28.50%</td>
</tr>
<tr>
<td>Change in vegetation class – 4 C model</td>
<td>2072</td>
<td>34.39%</td>
</tr>
<tr>
<td>Change in projected hg subspx – 2 C model</td>
<td>222</td>
<td>3.69%</td>
</tr>
<tr>
<td>Change in projected hg subspx – 4 C model</td>
<td>436</td>
<td>7.24%</td>
</tr>
</tbody>
</table>

Table 3 Comparison of density dependent change in projected hunter-gatherer subsistence speciality

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contemporary standard (table 2). From there, we will move on to compare hunter-gatherer subsistence change using frames of reference calculated for each mid-Holocene model (table 2) and finally, subsistence change where environments stay the same and population densities increase (table 3). These comparisons use available weather station data from north of the equator in both North America and South America. Since the model did not allow temperature variation in the southern hemisphere, weather stations south of the equator are not included in the comparison.

The calculated vegetation type for 6020 contemporary weather stations in the northern hemisphere serves as a standard for comparison (table 3, figure 3). Using the modified temperature model adjusting

Calculated Vegetation Class from actual modern weather station data

Figure 3 Modern vegetation class calculation using Binford & Johnson (2006) program. There are 6327 weather stations, including 6020 in the northern hemisphere
Figure 4 Vegetation class for 2C model using Binford & Johnson (2006) program. Compared with the modern standard (figure 3), 13.94% of northern hemisphere weather stations change vegetation class.

Figure 5 Vegetation class for 4C model using Binford & Johnson (2006) program. Compared with the modern standard (figure 3), 27.51% of northern hemisphere weather stations change vegetation class.
contemporary summer and winter temperatures up and down by 2°C, calculated vegetation class changes for 1716 of the weather stations (28.50 per cent) (figure 4). When summer and winter temperatures are adjusted up and down by 4°C, calculated vegetation class changes for 2070 of the weather stations (34.39 per cent) (figure 5).

Using these same two models approximating mid-Holocene temperature conditions, we will now compare the subsistence specialties indicated by projections of hunter-gatherer dependence on hunting, gathering and aquatic resource use. The variables projecting subsistence dependence for unpacked hunter-gatherers (table 1) were used. Using the modified temperature model adjusting contemporary summer and winter temperatures up and down by 2°C, projected hunter-gatherer subsistence specialty changes for 222 of the weather stations (3.69 per cent). When summer and winter temperatures are adjusted up and down by 4°C, projected hunter-gatherer subsistence specialty changes for 438 of the weather stations (7.24 per cent) (figure 6). Thus, the same change in temperature is seen to have a much greater effect on vegetation class than on hunter-gatherer subsistence specialty. Such changes in vegetation could certainly impact the particular species targeted by hunter-gatherers. The scale of change involved in a shift of subsistence specialty is much greater than shifting the dominant species exploited within a subsistence specialty.

4.3 Comparing changes related to increasing population density
The model for density-dependent changes in subsistence specialty projects values for six levels of population density (table 1) ranging from 4.5 persons per 100 sq km (unpacked) to 27.3 persons per 100 sq km (3 x packing threshold of 9.1 persons per 100 sq km), all for contemporary weather station data (figure 7). These values were chosen specifically to explore the impact of crossing the ‘packing threshold’ (Binford 2001:238-239), identified as 9.098 (here rounded up to 9.1) persons/100 sq km, on hunter-gatherer subsistence strategies. The first value represents a density half of the packing threshold (the only unpacked value), the next represents the density of the packing threshold, density values increase by half intervals of the packing threshold (1.5, 2, 2.5 times threshold) to the last value which represents a density 3 times the packing threshold. Binford (2001:229-239) used empirical evidence from mobile plant-dependent hunter-gatherers to determine a minimal group size of 20.47 people and a foraging radius (for hunter-gatherers travelling on foot) of 225 sq km. The packing threshold is the value of population density at which there is one minimal group per foraging radius (20.47 persons/225 sq km = 9.1 persons/100 sq km), thus indicating a density value at which there is no longer unoccupied space into which mobile hunter-gath-
erers could move. In Binford’s subsequent pattern recognition work (2001:312-313, 367-68, 377, 418, 422-423), this threshold proved to mark significant changes in mobility, group size, and subsistence strategy of contemporary hunter-gatherers.

For this comparison (table 3), the unpacked projection (4.5 persons per 100 sq km) is used as a standard against which to compare the others. Just moving from 4.5 (unpacked) to 9.1 persons per 100 sq km (packing threshold), projected subsistence speciality changes for 3718 of 6020 northern hemisphere weather station locations (61.76 per cent). By a density three times packing (27.3 persons per 100 sq km), 4817 weather station locations (80.02 per cent) have experienced a change in projected subsistence speciality (some have changed twice!).

**Figure 7** Comparison of change in projected subsistence speciality for hunter-gatherers ranging in density from (A) unpacked [4.5 persons/ 100 sq km; standard], (B) packed [9.1 persons/ 100 sq km; 61.76% different from standard], (C) 1.5 x packing [13.6 persons/ 100 sq km], (D) 2 x packing [18.2 persons/ 100 sq km], (E) 2.5 x packing [22.7 persons/ 100 sq km], to (F) 3 x packing [27.3 persons/ 100 sq km; 80.02% different from standard]

**Figure 8** Comparison of geographic bias in projected hunter-gatherer subsistence speciality based upon (A) the 4C model of mid-Holocene temperature change in N hemisphere and (B) changing population density from unpacked hunter-gatherers [4.5 persons/100 sq km] to three times packing [27.3 persons/ 100 sq km]
Distinguishing environmental and density-dependent aspects of adaptation: Johnson

4.4 Summary of temperature and density dependent expectations
In addition to the substantial difference between the degree of impact changes in temperature and density have on projected hunter-gatherer subsistence specialty, there are striking geographic patterns (figure 8). Some regions are more likely to experience change in temperature that would cause a shift in basic hunter-gatherer subsistence specialty. Thus, while temperature-dependent climate change is generally not the most likely cause for change in subsistence specialty, there are some regions where it is. In North America, these regions are on the boundaries of projected hunter-gatherer subsistence specialty zones, where a small change in temperature moves the location of this boundary and subsistence is expected to shift from hunting to gathering or from fishing to hunting, for example. The northwest coast, northeast coast, and Great Lakes regions are all on the hunting-fishing subsistence complexity boundary. The hunting-gathering subsistence complexity boundary runs from California to Texas across the Great Basin. A similar boundary is not evident in eastern North America where, except along the coastlines, unpacked hunter-gatherers are all expected to be dominantly dependent on hunting. Similarly, there are regions where increasing density is not the most likely cause of a projected shift in hunter-gatherer subsistence specialty, although there are many more where it is likely to be the dominant factor. Table 4 provides a summary of this pattern.

5 Implications
Climatically conditioned environmental changes dominate discussion of mid-Holocene adaptations in the Americas, yet density dependent change dominates our model comparison. In the literature, change in population density or local aggregation sizes is more often seen as a result of changing subsistence or settlement (eg, Stafford 1994:233; Stafford et al 2000:318; Lewis 2000:527; Hildebrandt & McGuire 2002) than as a potential cause (Arnold et al 1997; Wolverton et al 2009). Particularly during this time period when there are widespread shifts in local distributions of resources, including change in basic vegetation class at local and regional scales, climate change seems to be the preferred explanation for changes in human adaptations whether or not it is the most likely cause.

Through this exploration of the likely change in basic aspects of hunter-gatherer adaptations, it has been shown that density-dependent changes in hunter-gatherer subsistence specialty are more than 10 times greater than changes seen under the most extreme temperature model (4 C) approximating the mid-Holocene (figure 8). Further, the most dramatic change (61.76 per cent weather stations) in hunter-gatherer subsistence occurs at population densities which are generally considered very low (9.1 persons per 100 sq km = 0.091 persons per sq km; an additional 18.26 per cent of weather stations change projected subsistence specialty from density = 9.1 to density = 27.3). Archaeologists tend to use population density as an explanation for culture change only in settings where population density is expected to be much greater (eg, in California where densities are estimated at 3-5 people per sq km [values 10-20 times our highest density value in this comparison] by Arnold et al 1997:306). Thus, it seems likely that relatively small changes in regional population densities are playing a much larger role in conditioning human adaptations in the mid-Holocene.
than is currently recognised in discussions of these changes.

Certainly there is more to climate change than temperature change and more to hunter-gatherer adaptations than subsistence speciality. It would be possible to create models of change in precipitation patterns – amount and/or seasonality – in isolation from or in combination with temperature change that could inform expectations. Using Binford’s frames of reference it would also be possible to compare the impact of temperature, precipitation and density models on projected hunter-gatherer mobility, group sizes, and size of areas occupied by an ethnic group. Identifying contexts in which different dimensions are likely to impact change in hunter-gatherer adaptations will allow controlled comparisons of the patterns of change in the archaeological record.

It is much easier to find clear evidence for inferences about palaeoclimate (pollen, microfauna, etc) than to find clear evidence for inferences about precise levels of population density. Further, with the contemporary focus on climate change in society at large, there is interest in supporting research on climate change. Nevertheless, if we seek to pursue relevant knowledge of the past, we should make an effort to refine our ability to monitor population density archaeologically. Demographic change is likely to have at least as great an impact on our societies in the future as will climate change. Preliminary research (Harrill 2006, personal communication) on the relationships among variables recorded for the shape and materials of hunter-gatherer houses, environmental setting, and population density suggest it would be possible to use houses as a clue to likely ranges of population density.

Other strategies for isolating the signatures of density dependent versus climate driven changes in adaptations could also be productive. Archaeologists working in a comparative way with data from North and South America are in an especially good position to begin collaborative research in this direction. Since research in palaeoclimatology has determined that mid-Holocene climate changes enhanced seasonality in the northern hemisphere, while reducing seasonality in the southern hemisphere, the archaeological record of climate-driven change in this time period should be different in these climatically-distinct settings. Assuming that densities are generally increasing in both hemispheres, we have the opportunity to exploit this difference. With appropriate controls for environmental setting, it should be possible to establish a comparative framework which allows us to learn whether we can distinguish patterns in adaptive change in the archaeological record of those portions of the northern hemisphere which are not found in comparable settings in the southern hemisphere. While we may not have enough knowledge to answer such questions at the present time, an appropriate analytical framework should help guide future research to maximise the learning potential for all researchers with an interest in mid-Holocene behavioural strategies in the Americas.

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Endnotes

1 In 2001, Lewis R Binford published Constructing Frames of Reference: An Analytical Method for Archaeological Theory Building Using Ethnographic and Environmental Data Sets based on a 30 year study of 339 ethnographically-documented hunter-gatherer societies around the globe. The data includes continuous variables, ordinal values, and nominal codes for properties of these societies ranging from local group size to total population, area occupied and population density, percent dependence on hunting, gathering and aquatic resources to distance moved per year, and coded data for organisational properties of aspects of settlement, subsistence, kinship, marriage, trade, warfare, ritual activity, etc. Modern weather station data was used to link each hunter-gatherer case to the environmental frame of reference and environmental variables were used as independent variables in regression equations to develop projections for hunter-gatherer properties based on known cases, controlled for their population density and environmental setting. Hunter-gatherer data is
available upon request from the author.

2 Program and standard weather station data is available upon request from the author.

3 Latitude, Longitude, Elevation, Distance to Coast, Soil, Vegetation, Mean Monthly Temperatures (Jan – Dec) and Mean Monthly Precipitation (Jan – Dec).

4 Complex hunter-gatherers as along the California coast have been recorded with densities 10 times higher than the highest modeled value used here. Thus these values are well within the range of hunter-gatherer adaptations.

5 Southern hemisphere weather stations (n=307) are included in the figures, but not used to calculate per cent change in the tables since the models being compared did not allow change in the southern hemisphere.

References


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