Large Mammal Relative Abundance in Pithouse and Pueblo Period Archaeofaunas from Southwestern New Mexico: Resource Depression among the Mimbres-Mogollon?

Michael D. Cannon

Department of Anthropology, University of Washington, Seattle, Washington 98195

Received January 20, 1999; revision received September 8, 1999; accepted February 11, 2000

Archaeologists working in western North America have recently demonstrated temporal declines in the relative abundances of large mammals in archaeofaunal assemblages and have argued that these declines indicate resource depression, or reductions in the prey capture rates of prehistoric human hunters resulting from increases in harvest pressure. In the Mimbres-Mogollon region of southwestern New Mexico, evidence for resource depression has been controversial. Here, I employ a larger number of assemblages from this area than has been considered previously and show that large mammals are significantly more abundant at sites located in more mesic, wooded habitats. By taking this spatial patterning into account and by employing a model from foraging theory which indicates that temporal increases in large mammal relative abundance might also result from local resource depression in certain situations, I show that sites with samples large enough to produce statistically significant results do show temporal trends in large mammal relative abundance that are consistent with the hypothesis that they are due to changing intensities of human harvest pressure. This research has important implications for our understanding of prehistoric human impacts on biotic communities and may help to explain the increased reliance on agriculture that developed in the Mimbres-Mogollon region during the Pithouse and Pueblo time periods.© 2000 Academic Press

Key Words: agriculture; evolutionary ecology; foraging theory; hunting; Mimbres; Mogollon; zooarchaeology.

A growing body of research in archaeology and other fields has been directed at elucidating the ways in which nonindustrial peoples have structured the natural environments in which they live (e.g., Alv ard 1993, 1994; Blackburn and Anderson 1993; Broughton 1994a, 1994b, 1997, 1999; Delcourt et al. 1998; Grayson 1993; Hill et al. 1997; Kay 1994; Kirch and Hunt 1997; Minnis 1978, 1985; Redford and Robinson 1985; Winterhalder and Lu 1997). Research employing archaeofaunal data relating to such issues has been undertaken by several authors working in arid western North America (e.g., Bayham 1982; Grayson 1991; Janetski 1997; Speth and Scott 1989; Szuter 1991; Szuter and Bayham 1989), including the Mimbres-Mogollon region of southwestern New Mexico (e.g., Anyon and LeBlanc 1984; Nelson and LeBlanc 1986; Powell 1977; Schick 1995; Sanchez 1996). Several of these studies have addressed, in particular, the question of whether prehistoric peoples experienced exploitation resource depression (Charnov et al. 1976), or declines in their prey capture rates as the direct result of their own hunting of those prey, with a specific focus on large mammals.

This work is important in two respects. First, it has significant implications beyond the realm of traditional archaeological and anthropological interests, since much of modern North American wildlife management is predicated on the notion...
that animal populations should be re-
stored to "pristine" pre-Euroamerican con-
ditions (e.g., Leopold et al. 1963; see also Catton 1997; Lyman 1997). This point of view ignores the roles that native peoples have played for millennia in North American biotic communities (Kay 1994; see also Broughton 1997), the details of which are known thanks in large part to archaeological research.

Second, within the realm of traditional archaeological and anthropological interests, large mammal resource depression in the Mimbres-Mogollon region might help to explain the increased reliance on agriculture that developed here during the pithouse and pueblo time periods (e.g., Diehl 1996; Hard 1990; Lancaster 1986; Minnis 1985; Nelson 1986; Nelson and LeBlanc 1986). An explanation often invoked for increases in the importance of agriculture is that declines in the per capita energetic returns provided by wild resources resulting from human population growth led to an increased reliance on domesticates (e.g., Binford 1968, 1983:195-213; Boserup 1965; Cohen 1977; papers in Fish and Fish 1984; Glassow 1980; Larson 1996; see also Barlow 1997; Gremillion 1996; Winterhalder and Goland 1997). Diehl (1996) has proposed specifically that this may have been the case in the Mogollon region.

The attempts that have so far been made to test this explanation in arid western North America, however, rely only on correlations between measures of human population size and the intensity of agricultural production, without evaluating whether population growth actually led to declines in the rates at which people encountered wild resources (e.g., Binford 1968, 1983; Boserup 1965; Cohen 1977; papers in Fish and Fish 1984; Glassow 1980; Larson 1996; see also Barlow 1997; Gremillion 1996; Winterhalder and Goland 1997). Diehl (1996) has proposed specifically that this may have been the case in the Mogollon region.

In this paper I examine large mammal relative abundance in faunal assemblages from pithouse and pueblo period archaeological sites in southwestern New Mexico to evaluate whether Mimbres-Mogollon hunters experienced long-term resource depression in their exploitation of artiodactyls, primarily deer (Odocoileus spp.) and pronghorn (Antilocapra americana). While analysis of archaeological taxonomic relative abundance does not by itself demonstrate that resource depression and reduced foraging efficiency occurred (Grayson and Cannon 1999), documenting temporal changes in relative abundance is a crucial first step in this direction. In doing so, I employ a model from foraging theory and a statistical technique that are more appropriate than those used previously in archaeological resource depression studies, in an effort to strengthen
the theoretical and methodological basis of this kind of analysis.

Previous authors have presented conflicting results about temporal changes in artiodactyl relative abundance in the Mimbres-Mogollon region (e.g., Anyon and LeBlanc 1984; Nelson and LeBlanc 1986; Sanchez 1996; Shaffer 1991). Using data from a larger number of sites than has been considered previously, I will show that faunal samples from this area exhibit strong spatial patterning in artiodactyl relative abundance, patterning which is, in turn, significantly related to habitat type (see also Shaffer and Schick 1995). Taking this habitat effect into account, I will then show that two sites in this region display significant declines in artiodactyl relative abundance coincident with human population growth, that a third may show a temporal increase in artiodactyl relative abundance at this time that might also be indicative of resource depression, and that samples from remaining sites are too small to shed light on this issue. A significant rebound in artiodactyl relative abundance also occurs as human population density later declines (Nelson and LeBlanc 1986). Existing samples thus provide provisional evidence that prehistoric peoples in this region had tangible impacts on local large mammal populations.

**RESOURCE DEPRESSION AND FORAGING THEORY**

A number of archaeologists working in western North America have attempted to document cases of prehistoric exploitation resource depression, or reductions in the prey capture rates of human foragers that resulted from their own harvesting of those prey. These studies have focused on vertebrate resources, and their modus operandi has been to look for temporal declines in the abundances of larger bodied taxa relative to smaller ones, an approach pioneered by Bayham (1979, 1982; Szuter and Bayham 1989) and further developed by Broughton (1994a, 1994b, 1997, 1999). Studies of this kind have been undertaken in California (e.g., Broughton 1994a, 1994b, 1997, 1999; Hildebrandt and Jones 1992), the Great Basin (e.g., Grayson 1991; Janetski 1997), and the southwestern United States (e.g., Anyon and LeBlanc 1984; Bayham 1982; Szuter and Bayham 1989; for a more detailed overview see Grayson and Cannon 1999).

Most of these studies draw heavily on models from evolutionary ecology, which provides an explicit framework for testing ideas about interactions between people and their environments (Broughton and O’Connell 1999; Kelly 1995; O’Connell et al. 1982; O’Connell 1995; Smith 1991a; Smith and Winterhalder 1992; Stephens and Krebs 1986). In particular, they employ the prey model (also known as the prey choice or diet breadth model) of foraging theory (Stephens and Krebs 1986; Smith 1991a; Kaplan and Hill 1992; Kelly 1995). The prey model shows that, given certain assumptions (outlined in Broughton 1994a, 1997; Stephens and Krebs 1986), the most energy-efficient foraging strategy is to pursue resources with higher postencounter caloric return rates whenever they are encountered and to begin to pursue lower return resources as encounter rates with higher return resources decline.

Since postencounter return rate is positively correlated with body size for most vertebrate prey, it is thus argued that if efficient foraging were the relevant decision-making currency among a prehistoric group of foragers, larger bodied taxa should have been pursued by those foragers whenever they were encountered (Bayham 1979; Broughton 1994a, 1994b, 1997, 1999; Szuter and Bayham 1989).

* See NOTES section at end of paper for all footnotes.
From this it follows that temporal declines in the relative abundances of larger taxa in archaeological assemblages would indicate decreased encounter rates with them (Broughton and Grayson 1993). Assuming that other causes of reduced encounter rates such as climate change can be ruled out (see Grayson and Cannon 1999), these declines in archaeological relative abundance would indicate prehistoric resource depression and reduced foraging efficiency.

Foraging theory models, however, make very specific assumptions about the real-world cases to which they are applied, and using them in situations in which their assumptions are not met does not necessarily provide a test of any hypotheses that are derived from them (Haccou and van der Steen 1992; Stephens and Krebs 1986). In this regard, use of the prey model alone may be inappropriate in most archaeological situations.

One assumption of the prey model that is likely not to be met in many archaeological cases is that the probability of encountering any prey type is independent of previous encounters with it or with any other prey type (Stephens and Krebs 1986). This “fine-grained search assumption” will be violated in cases in which individuals of a given prey type have a better than random chance of being found near other individuals of that prey type within certain areas of a habitat—that is, when prey exhibit “patchy,” or heterogeneous, distributions. In such instances the prey model applies while a forager is foraging within a homogeneous resource patch, but an additional model is required to address the issue of which patches to exploit (Smith 1991a).

Another assumption of the prey model that will be violated in many cases involving human foragers stems from the fact that people often hunt from a central place to which they return with their prey. The prey model assumes that a forager travels through a habitat consuming prey as it goes, so that the cost of transporting resources can be assumed to be zero (Orians and Pearson 1979). In cases of central place foraging, however, substantial energetic costs are likely to be incurred in traveling between the central place and the point of capture, and these must be taken into account.

In the Mimbres-Mogollon case, it is quite probable that prey would have been distributed patchily in this region in the past since there is substantial biotic variability here (Brown and Lowe 1980; Minnis 1985, 1986). This case also certainly involves faunal assemblages that are the result of central place foraging since they come from large residential sites. A more appropriate foraging theory model for use in this kind of situation is Orians and Pearson’s (1979) model of optimal patch choice for central place foragers.

The Central Place Foraging Patch Choice Model

The patch choice model (Fig. 1) assumes a habitat that consists of some number of internally homogeneous resource patches located at varying distances from a central place, and it asks which of the available patches will maximize the rate of energy delivery to the central place. Individual patches (Fig. 1a) are characterized by curves of their expected energetic returns plotted as functions of their expected within-patch search times ("gain functions," denoted as $C'$), which are assumed to be negatively accelerated or to display diminishing marginal returns (see Charnov et al. 1976 and Stephens and Krebs 1986:25–27 for a discussion of this assumption). The cost of traveling to a patch and transporting prey back to the central place is measured in terms of travel time ($T_p$); this is assumed to be mutually exclusive of search time, which begins once a patch is entered.
FIG. 1. The patch choice model for central place foragers, after Orians and Pearson (1979). (a) For any patch $i$, $T_{ni}$ is the round-trip travel time to the patch and $C'_i$ is the gain function of the patch, which describes the expected energetic return from that patch per unit search time. Search time begins once the patch is entered. Gain functions are assumed to be negatively accelerated, which is to say that marginal energetic return diminishes as search time increases. Energetic return per total time (travel time plus search time) is maximized for any patch by foraging in that patch until time $T_{max}$, which is given by a line tangential to the gain function beginning at the origin of the graph. Patches with higher densities of high-return resources will, as a generalization, have “taller” gain functions, or higher maximum profitabilities. (b) The patch that provides the highest overall rate of energy delivery to the central place is the one that produces the steepest line between the origin and a point tangential to its gain function. Patch 2 is the delivery rate-maximizing patch for this hypothetical set of four patches.
The solution to the model can be seen graphically in Fig. 1b: the patch that provides the highest rate of energy delivery to the central place is the one that produces the steepest line running between the origin of the graph and a point tangential to its gain function. Note that this patch need not be the one that provides the greatest amount of energy per unit of within-patch search time (e.g., patch 4 in Fig. 1b), because closer patches may provide higher rates of energy delivery to the central place when transport costs are taken into account.

While a forager is in one of these patches, the prey model applies, and the rate-maximizing strategy is to take the highest ranked prey types within that patch upon encounter and to begin to take lower ranked prey as encounter rates with higher ranked prey in the patch decline (Heller 1980). Thus, the gain function of any patch will be determined by the specific combination of prey types found within it, the postencounter return rates of these prey types, the initial densities of these prey types, and the rates at which these densities decline due to predation during a foraging episode. As a generalization, patches containing higher densities of high-return prey types will have higher maximum profitabilities, or “taller” gain functions.

It is important to remember that the gain functions in this model apply to the returns obtained by a forager within a single foraging episode within a patch. If within-episode returns indeed diminish with search time, as the model assumes, then it is reasonable to assume further that the maximum profitability of a patch (the “height” of its gain function) will decline between foraging episodes, if the time between episodes is not too long (Fig. 2). That is, if encounter rates with high-return prey types decline while a forager is in a patch due to declining densities of those prey types, and if the time between foraging episodes is not long enough for these prey to return to their previous den-

FIG. 2. As the maximum profitability of the patch that initially provides the highest delivery rate declines due to long-term harvest within it, the delivery rate that it provides may fall below the delivery rates provided by other patches. Switching to a patch that is located farther away but which has a higher density of high-return prey types (patch 4 in this hypothetical case) will result in an increased archaeological relative abundance of high-return prey types, though overall foraging efficiency will be lower due to increased travel costs.
sities through reproduction or immigration, then the gain function experienced by the next forager to enter that patch will be lower. Thus, over the long term (i.e., over spans of time potentially accessible to archaeologists, as opposed to the spans of time generally considered by ecologists), the patch that provides the highest rate of energy delivery to the central place can change due to between-foraging episode declines in prey encounter rates.

As the maximum profitability of the patch that initially provides the highest delivery rate declines, the patch that will next come to provide the highest delivery rate will fall into one of three categories: (1) located nearer to the central place than the first patch, but with lower maximum profitability than was initially the case for the first patch (e.g., patch 1 in Figs. 1 and 2); (2) located farther away from the central place with lower maximum profitability (e.g., patch 3); or (3) located farther away with higher maximum profitability (e.g., patch 4).

In the first and second cases, the result of long-term depression within the patch that initially provides the highest delivery rate will often be a switch to a patch in which high-return prey are encountered less frequently than was initially the case in the first patch. This would appear archaeologically as a temporal decline in the relative abundance of high-return prey. In the third case, however, a delivery rate-maximizing forager would switch to a patch in which high-return prey are likely to be encountered more frequently than they were in the first patch, resulting in an increased archaeological relative abundance of high-return prey.

Thus, use of the patch choice model for central place foragers can lead to quite different predictions about the changes in archaeological relative abundance that will follow from resource depression than will use of the prey model alone. In some cases it is possible that resource depression will lead to reduced foraging efficiency because of increased travel costs, but also to temporal increases in the proportions of higher return resources that are taken. Such an occurrence, I should note, will be archaeologically indistinguishable from an increase in foraging efficiency that resulted from increased encounter rates with high-return prey in nearby patches unless additional analyses of such things as skeletal element representation and prey population age structure are performed (e.g., Broughton 1999): skeletal element representation because it may be informative about changes in body part transport resulting from changes in distance traveled and age structure because it will be indicative of changes in harvest rates.

The final thing to mention about the patch choice model is that, once all of the patches that might feasibly be exploited are in use, continued harvests within those patches may lead to declining encounter rates with high-return prey in all of them (Fig. 3). This will result in declining archaeological relative abundances of those prey types. The main implication here is that, while resource depression might not necessarily result in declining archaeological relative abundances of high-return prey types, declining archaeo-

FIG. 3. Sustained harvest in all of the patches within the foraging radius of a settlement may lead to long-term depression within all of those patches. Such a situation will result in declining archaeological relative abundances of high-return prey types.
ological relative abundances of those prey types should always indicate that resource depression occurred, assuming that other potential causes of changes in relative abundance can be controlled for (see Grayson and Cannon 1999).

To sum up so far, the use of temporal changes in the archaeological relative abundance of large-bodied taxa as an indicator of prehistoric resource depression, originally developed in the context of studies that employed only the prey model, is appropriate, provided that empirical expectations are modified to take into account the implications of Orians and Pearson's (1979) patch choice model for central place foragers. In particular, it should be recognized that temporal increases in the archaeological relative abundance of high-return, large-bodied taxa may be just as indicative of resource depression as temporal declines in relative abundance.

Many archaeologists have recognized, of course, that resource depression in nearby patches might lead to increased use of distant patches in which high-return resources like large mammals are more abundant (e.g., Broughton 1999; Speth and Scott 1989; Szuter and Bayham 1989). The patch choice model provides a theoretical framework that can be used to develop expectations about the conditions under which either temporal increases or temporal decreases in the archaeological relative abundance of high-return prey types will result from local resource depression. Temporal increases in the relative abundance of high-return prey types should result when depression of these prey occurs in patches that are located relatively close to a residential settlement and when patches containing higher densities of these prey exist in more distant areas that are still within the foraging radius of that settlement. If no such more distant patches with higher densities of high-return prey exist, or if all of the patches located within the foraging radius of a settlement are being exploited, then temporal declines in the relative abundance of high-return prey types will be the result of resource depression.

Factors Influencing the Severity of Resource Depression

In addition to providing generally higher postencounter return rates, larger bodied animals are, in general, more susceptible than smaller ones to exploitation resource depression and are less likely to recover from it quickly due to their typically lower population densities and lower population recruitment rates (Charnov et al. 1976; see also Brown 1995; Winterhalder and Lu 1997). Thus, since the very taxa that were most likely to have been taken by prehistoric human hunters are also those most likely to have exhibited long-term exploitation resource depression, this phenomenon may have occurred quite frequently in the past.

Resource depression should be more severe when and where human populations are larger because this will lead to higher harvest rates (e.g., Wilson and Bosc 1971; Winterhalder and Lu 1997). It should also be more severe when individual hunters are less mobile and/or when group residential locations are more permanent (e.g., Binford 1983). We can thus expect that prehistoric hunters in the Mimbres-Mogollon region would have experienced the lowest rates of encounter with artiodactyls at times when the human population was denser and/or when people were more sedentary. Of course, if human populations declined or if people became less sedentary for some reason, it should be expected that prey populations would have rebounded.

Temporal Scales of Resource Depression

Resource depression might occur over time periods as short as a few years (Gray-
son and Cannon 1999) and could conceivably be responsible in part for periodic “abandonments” of residential locations, such as those proposed for the Mimbres region by Nelson and Anyon (1996). To the extent that such short time scale events are unobservable in the archaeological record, though, they remain out of our grasp. Consequently, previous archaeological resource depression analyses have examined coarser scale changes in prey encounter rates occurring over hundreds of years, and this is the kind of temporal scale that I consider here.

Potential Confounding Factors

I have discussed how the general correlation between vertebrate prey body size and postencounter return rate provides a basis for using changes in the archaeological abundance of large-bodied taxa relative to small-bodied taxa to measure resource depression in the archaeological record (Bayham 1979; Broughton 1994a, 1994b, 1997, 1999). There may be some significant exceptions to this correlation, however, which is something that should be addressed on a case-by-case basis. In addition to body size, return rates can vary with specific characteristics of the animals involved (e.g., Hawkes et al. 1982) and with the technology used to capture them (e.g., Smith 1991a). Using body size as a proxy for return rate may also be inappropriate in cases in which certain taxa are captured in groups, thereby increasing the probability that they will be pursued relative to what might be predicted based only on their body size (Broughton 1994b; Madsen and Schmitt 1998; see also Grayson and Cannon 1999).

It is also important to realize that the use of archaeological relative abundance as a measure of resource depression assumes that the caloric efficiency of resource harvesting was the relevant decision-making currency in a particular prehistoric case. I note, though, that the use of many of the alternative currencies that have been proposed as being pertinent to human exploitation of vertebrates—whether nutrients such as protein and fat (e.g., Speth and Spielman 1983; Speth and Scott 1989), utility as raw materials for making tools (e.g., Sharp 1989), or social status attached to unpredictable resources that come in large packages (e.g., Hawkes 1996; Wood and Hill 2000)—would strengthen the assumption that large mammals would have been taken whenever they were encountered. That is, if any of these currencies were important in the Mimbres-Mogollon case, this would not lead to a spurious conclusion that depression of large mammal resources occurred; it might, however, help to explain why it did occur.

In the Mimbres region during the span of time that is the focus of this paper, there are no changes in projectile technologies that are easily interpretable in terms of changing hunting strategies (Nelson 1986). There is thus no reason to think that the return rates provided by large mammals varied during this time due to changes in the mode of capture. However, it is possible that my analysis of artiodactyl relative abundance might be affected by changes in the ways that other vertebrate taxa were harvested. My analysis is based on the proportion of artiodactyls relative to artiodactyls plus leporids [i.e., jackrabbits (Lepus spp.) and cottontail rabbits (Sylvilagus spp.); see also Anyon and LeBlanc 1984; Janetski 1997; Sanchez 1996; Szuter and Bayham 1989], and this ratio could easily vary due to changes in leporid procurement rather than changes in artiodactyl encounter rates (Grayson and Cannon 1999).

One way in which leporid exploitation might have changed through time could have been via an increase in the importance of “garden hunting,” or the capture of small animals attracted to agricultural
fields (e.g., Linares 1976). As noted above, several lines of evidence point toward an increased reliance on agriculture in the Mimbres region during the period I am studying, and these include indications of increased clearing of land for farming (e.g., Minnis 1978, 1985, 1986). To the degree that more extensive fields located close to residential settlements resulted in higher local abundances of leporids, this may have led to increased harvest of these animals. Moreover, it is possible that leporids attracted to fields might have been hunted for reasons other than immediate caloric returns, since they can be quite damaging to crops (e.g., Vorhies and Taylor 1933). It should be noted, however, that agricultural fields might also attract deer, which can themselves be quite destructive, in addition to attracting smaller taxa (e.g., Hesselton and Hesselton 1982:885; Mackie et al. 1982:874; Smith 1991b:5, 6). Thus, increases in the size and/or number of fields may not necessarily have led to an increase in the number of leporids taken relative to the number of artiodactyls taken.

Another way in which leporid exploitation might have changed could have been through a shift in emphasis away from capturing these animals individually and toward harvesting them in large groups or vice versa (Grayson and Cannon 1999; see also Madsen and Schmitt 1998). Jackrabbits, in particular, are especially prone to being captured in “rabbit drives” (e.g., Schmidt 1999; Shaffer and Gardner 1995), and an apparent portrayal of such an event is painted on at least one Mimbres ceramic bowl (Shaffer and Gardner 1997). Of course, what matters for my analysis is not simply whether mass capture of jackrabbits was practiced, but whether this practice changed in frequency during the time that I am studying. An increase in the importance of rabbit drives, for example, could cause the archaeological abundance of artiodactyls to decline relative to the abundance of leporids, thereby producing something that would resemble resource depression in the absence of any true decline in artiodactyl encounter rates.

Finally, in addition to these considerations, there are a variety of other well-known factors that might affect taxonomic relative abundances in archaeofaunal samples, including prehistoric butchering and processing practices, paleoclimatic changes, postdepositional taphonomic processes, and archaeological data collection techniques. Given these points, it should be clear that changes in relative abundance do not by themselves indicate resource depression and reduced foraging efficiency (Grayson and Cannon 1999). Ideally, attempts should be made to control for all of the potentially confounding factors listed here and to provide additional lines of evidence in support of the proposition that high-return prey were subject to increases in harvest pressure, which might be done through analysis of changes in prey population age structure or skeletal element representation (e.g., Broughton 1999).

Unfortunately, the data necessary to do all of these things are not currently available for any Mimbres-Mogollon site. Accordingly, I can only examine changes in raw relative abundance values here. Though not conclusive, this endeavor is worthwhile because the analysis of temporal changes in large mammal relative abundance is an essential component of any resource depression study and because previous authors have reached conflicting conclusions about the nature of such changes in the Mimbres-Mogollon area. Exploring when, where, and how such changes occur in this region is the focus of the remainder of this paper.

PREVIOUS RESEARCH IN THE MIMBRES REGION

A few researchers working in the Mimbres-Mogollon region have addressed the
issue of temporal change in the archaeological relative abundance of large mammals. Anyon and LeBlanc (1984) and Nelson and LeBlanc (1986), presenting the results of analyses performed by Powell (1977) and Powell and Langenwalter (1977), examined temporal and spatial variability in artiodactyl relative abundance at sites in the Mimbres Valley. They provide (Nelson and LeBlanc 1986:Table 13.4) \(^5\) values for the ratio of the number of artiodactyl specimens relative to the number of artiodactyl plus leporid specimens for samples from the Late Pithouse, Classic Mimbres, and Cliff phase time periods (a summary of the culture history of this region is presented in Table 1). Recognizing that there is substantial habitat variability within the valley, they also distinguish between sites in the more mesic upper valley and those in the more xeric middle valley; they present no samples for these time periods from the driest lower portion of the valley. These large mammal relative abundance values decline between the Late Pithouse and Classic Mimbres time periods in both the middle and upper parts of the valley and then rebound in both areas during the Cliff phase to levels even higher than those of the Late Pithouse period.

Population estimates based on the total floor area of pithouses and pueblo rooms from each time period indicate that prehistoric human population size in the Mimbres Valley was highest during the Classic Mimbres phase and lowest during the Cliff phase (Blake et al. 1986; see also Cameron 1990; Lekson 1992; Nelson et al. 1996). LeBlanc and colleagues thus note that there is a negative correlation through time between artiodactyl relative abundance and human population size, and they argue that this suggests that larger human populations were responsible for reductions in artiodactyl abundance on the landscape during the Classic phase.

Sanchez (1996) also examined temporal trends in artiodactyl relative abundance values from sites in the Mimbres Valley. She considered only the Late Pithouse and Early Pueblo periods, but used faunas from a larger number of sites than did Anyon and LeBlanc (1984) and Nelson and LeBlanc (1986), including the fauna from Old Town, which is located in the drier lower valley. Among individual sites, Sanchez found differences between the Late Pithouse and Early Pueblo periods that are statistically significant at the \(p \leq 0.05\) level only at the NAN Ruin and Old Town. However, while artiodactyl relative abundance decreases in the Classic phase at the middle valley NAN Ruin site, it increases at the lower valley site of Old Town. In an analysis of “site clusters” from the upper and middle parts of the valley, she found that artiodactyl relative abundance decreases in the Classic phase in both areas, but that these declines are not significant at \(p \leq 0.05\). Sanchez thus concluded, contrary to LeBlanc and colleagues, that there is no evidence of any

<table>
<thead>
<tr>
<th>Table 1: Mimbres-Mogollon Culture Historical Time Periods (after Nelson and Anyon 1996; Diehl 1994)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Period</td>
</tr>
<tr>
<td>Late Pueblo</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Early Pueblo</td>
</tr>
<tr>
<td>Late Pithouse</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Early Pithouse</td>
</tr>
</tbody>
</table>

* Nelson and Anyon (1996) place the start of the Early Pithouse period at 100 A.D., rather than at 200 A.D. as most authors do (following Anyon et al., 1981), but they provide no explanation for why they do this. Wills (1996) suggests that 400 A.D. may be a more appropriate starting date for the Early Pithouse period.
valleywide temporal trend in artiodactyl relative abundance between the Late Pithouse and Early Pueblo periods (see also Shaffer 1991).

Given Sanchez’s (1996) finding, based on a larger sample of sites than was used by LeBlanc and colleagues, that artiodactyl relative abundance values do not show any consistent temporal trend throughout the Mimbres Valley, it might appear difficult to make a case for the occurrence of artiodactyl resource depression in this region during the Late Pithouse and Early Pueblo periods. However, despite the recognition by these authors that habitat variability can interfere with analyses of temporal trends, and despite their efforts to deal with this issue, the conflicting conclusions they present may reflect a failure to completely separate spatial from temporal variability. Moreover, as I argued above, temporal increases in large mammal relative abundance may in some cases be just as indicative of resource depression as temporal declines in large mammal relative abundance. I will show that when spatial variability is more fully controlled, and when more complete consideration is given to the relationship between resource depression and archaeological relative abundance, existing samples do show temporal changes in artiodactyl relative abundance that are consistent with the hypothesis that resource depression occurred in the Mimbres-Mogollon region.

PITHOUSE AND PUEBLO PERIOD FAUNAL SAMPLES FROM SOUTHWESTERN NEW MEXICO

As noted above, survey data from the Mimbres area of southwestern New Mexico indicate that human populations here were larger during the Classic Mimbres phase than the Late Pithouse period (Blake et al. 1986; see also Cameron 1990; Lekson 1992; Nelson et al. 1996), and it is reasonable to assume that these population estimates are accurate on at least an ordinal level (see Ramenofsky 1987). Further, Gilman (1987) has argued that the shift to above-ground pueblo architecture that occurs with the beginning of the Classic Mimbres phase is indicative of increased sedentariness, and Diehl (1997) has suggested, based on changes in degrees of architectural investment, that a trend toward increased sedentariness began even earlier in the Late Pithouse period. It thus should be expected that harvest pressure on local artiodactyl populations increased throughout this region during the Late Pithouse and Early Pueblo periods. Did resource depression occur here? We can start to address this question by examining whether existing faunal samples really do show temporal changes in artiodactyl relative abundance that are consistent with the hypothesis that it did.

The Assemblages

Table 2 lists pithouse and pueblo period residential sites in southwestern New Mexico with published faunal samples, and Fig. 4 shows the locations of these sites. I follow the period-phase culture history scheme presented by Nelson and Anyon (1996) for this part of the Mogollon area, though I use the dates proposed by Diehl (1994) for the Georgetown/San Francisco and San Francisco/Three Circle phase “boundaries” (Table 1; see also Anyon et al. 1981). The Mangas phase (950–1050 A.D.) is used by some to denote a transitional period between the Late Pithouse and Early Pueblo periods; Anyon et al. (1981) argue that the Mangas phase concept does not fit the Mimbres Valley, though Woosley and McIntyre (1996) find use for it at Wind Mountain (see also Lekson 1988; Nelson and Anyon 1996; Shafer 1995). Both Sanchez (1992) and Shaffer (1991) also present data from contexts con-
sidered to be transitional between the Late Pithouse and Early Pueblo periods at Old Town and NAN, respectively.

All of the data used in this analysis come from previously published works, with the exception of those for the fauna from Mogollon Village. This material was recovered in excavations by the University of Washington Mogollon Village Field School (MVFS) (Linse 1997) and the Mogollon Village Archaeological Project (Mauldin et al. 1996). A more detailed description of this fauna is presented elsewhere (Cannon 1999a, 1999b). Occupation of this site spanned the Early and Late Pithouse periods and may have begun as early as the Late Archaic; the site is perhaps unique among those in the area in that it experienced lengthy pithouse period use without any subsequent pueblo occupation (Haury 1936; Mauldin et al. 1996; Linse 1997). Unfortunately, however, only a small portion of the fauna from this site can be assigned to either the Early or Late Pithouse periods with confidence (Cannon 1999b).

For the remainder of the sites used here I have relied on the authors’ attribution of faunal specimens to time period, with the exception of Wind Mountain. For this site, Woosley and McIntyre (1996) assign Pithouses and Pueblo rooms to time periods, and Olsen and Olsen (1996) and McKusick (1996) provide faunal counts for these houses and rooms. I have simply tallied faunal counts per time period based on the data provided by these authors and have combined the data from both the Wind Mountain and Ridout loci at this site. I stress that I have not attempted to account for the stratigraphic context of faunal specimens within houses or rooms: Olsen and Olsen (1996) do not provide this information, and though McKusick (1996) does, I have lumped specimens from all contexts within each house or room in her analysis.

Screen Mesh Size

It is well known that the use of different-sized screens in excavation can drastically affect the relative abundances of different-sized taxa in faunal samples.

<table>
<thead>
<tr>
<th>Site</th>
<th>Source (NISPs/time period)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Old Town (LA 1113)</td>
<td>Sanchez (1992:Table 4.2)</td>
</tr>
<tr>
<td>NAN Ruin (LA 2465)</td>
<td>Shaffer (1991:Table 5.9) and Sanchez (1992:Table 3.5)</td>
</tr>
<tr>
<td>Disert (NM Z:5:10)</td>
<td>Nelson and LeBlanc (1986:Appendix F, Table 1)</td>
</tr>
<tr>
<td>Galaz* (LA 635)</td>
<td>Nelson and LeBlanc (1986:Table 13.4)</td>
</tr>
<tr>
<td>Stailey (NM Z:1:78)</td>
<td>Nelson and LeBlanc (1986:Appendix F, Table 3)</td>
</tr>
<tr>
<td>Mattocks* (LA 676)</td>
<td>Late Pithouse: Powell (1977:Table 4); Classic Mimbres: Nelson and LeBlanc (1986:Table 13.4)</td>
</tr>
<tr>
<td>Janss (LA 12077)</td>
<td>Nelson and LeBlanc (1986:Appendix F, Table 2)</td>
</tr>
<tr>
<td>Mitchell* (LA 12076)</td>
<td>Nelson and LeBlanc (1986:Table 13.4)</td>
</tr>
<tr>
<td>Montezuma (NM Z:1:30)</td>
<td>Powell (1977:Table 4)</td>
</tr>
<tr>
<td>Beauregard* (NM Z:1:27)</td>
<td>Nelson and LeBlanc (1986:Table 13.4)</td>
</tr>
<tr>
<td>Mogollon Village (LA 11568)</td>
<td>Cannon (1999b)</td>
</tr>
<tr>
<td>Wind Mountain (NM Y:7:1 and NM Y:7:3)</td>
<td>NISPs: Olsen and Olsen (1996:Tables 3 and 4) and McKusick (1996:Table 1); dating: Woosley and McIntyre (1996:Table 3.5)</td>
</tr>
</tbody>
</table>

* Individual artiodactyl and leporid NISPs were not given directly for these samples by Nelson and LeBlanc (1986), but were calculated from the Artiodactyl Index values and artiodactyl + leporid NISPs that they provide.
(e.g., Cannon 1999a; James 1997; Nagaoka 1994; Shaffer and Sanchez 1994). At Mogollon Village, for example, MVFS screened a random 25% of the sediments from each stratum in each 1 m² excavation unit through 3.2-mm (1/8 in.) mesh and the rest through 6.4-mm (1/4 in.) mesh (Hoyer 1997). For the MVFS assemblage as a whole, the 6.4-mm screen samples produce a value for the abundance of artiodactyls relative to artiodactyls plus leporids of 0.33 (artiodactyl NISP + leporid NISP = 334), whereas the 3.2-mm screen samples produce one of 0.23 (artiodactyl NISP + leporid NISP = 267). The use of different sizes of screen between assemblages could thus severely bias artiodactyl relative abundances in analyses such as the one that I present here.

For Mogollon Village, I have used only specimens collected in 6.4-mm screens in order to facilitate comparison with the rest of the sites, at which this seems to have been the most common screen size used. Shaffer (1991:57) also states that only specimens collected in 6.4-mm mesh were
used in tallying the data he presents from NAN. Sanchez (1992) does not mention what screen size was used to collect the portion of the NAN fauna she analyzed, though she does say that at Old Town 82% of the fauna was collected in 6.4-mm screen, 3% in 1.6-mm (1/16 in.) screen, and the rest by “sight-screening” (1992:59). Woosley and McIntyre (1996) make no mention of the use of screens at Wind Mountain. The remainder of the sites analyzed here were excavated by the Mimbres Foundation; screen sizes are not presented for all of these sites, but Nelson and LeBlanc (1986:23) discuss the methods used at the three Cliff phase sites that they excavated and it may be reasonable to assume that similar methods were used in all of their excavations. They state that most of the sediments at the Cliff phase sites were screened through 6.4-mm mesh, though sometimes 12.8-mm (1/2 in.) screen or no screens were used.

Concerning the analysis of spatial trends presented below, the possible use of no screens or of screens larger than 6.4 mm at Wind Mountain might account for the higher artiodactyl relative abundance seen at this site than at the others. I will show, however, that such a bias does not seem to be driving the spatial patterns that I present. As for temporal trends, assuming that collection methods remained constant during the excavation of individual sites, the use of large screens or no screens would not be able to explain any apparent temporal decline in artiodactyl relative abundance at a given site unless there are large differences in bone fragmentation between the samples from different time periods at that site (Cannon 1999a).

Statistical Methods

Previous zooarchaeological resource depression studies have been based on demonstrations of temporal declines in measures of relative abundance like the “Artiodactyl Index,” which is calculated as the ratio of the number of specimens of artiodactyls in an assemblage relative to the total number of artiodactyls plus leporids. Whether such declines are “significant” has been determined through correlation analysis of the ages of assemblages and their values along the index of relative abundance (e.g., Broughton 1994a, 1994b, 1997, 1999; Janetski 1997). Correlation analysis of this sort is not the most appropriate statistical test for evaluating a trend in relative abundance, however. The use of a measure like the Artiodactyl Index, as opposed to raw NISP values, results in the loss of all information about sample size: numbers of specimens are converted into a simple proportion, and it is not possible to tell from that proportion whether it is derived from 10 bones or 10,000. Thus, correlation analysis of temporal or spatial trends in a measure like the Artiodactyl Index does not directly take sample size into account, and it is possible to find “significant” relationships when, in fact, samples are so small that sampling error cannot be ruled out with any degree of confidence as the cause of differences in relative abundance.

Many who have performed this sort of analysis have recognized that it is crucial to consider the sizes of the samples being used. Because they have not used a test for evaluating trends in proportions that takes sample size into account directly, though, these researchers have had to rely on an indirect method for determining whether variation in sample size is influencing the temporal patterns that they find. Following the work of Grayson (1984, 1989), Broughton (1994a, 1994b, 1997, 1999) and Janetski (1997), for example, look for correlations between sample size and relative abundance index value; when they find no significant correlations they conclude that sample size is not affecting the trends they discover. The assumption here is that the absence of a correlation
between sample size and relative abundance indicates that sample sizes are adequate. It is certainly possible, however, that even if relative abundance is not correlated with sample size in a particular case, samples may still be too small to infer with confidence that they come from populations that are any different.

I raise this issue not to call into question the analyses of previous researchers, but rather to point out that there are statistical methods available for evaluating temporal and spatial trends in taxonomic relative abundance that take sample size into account more directly. In the analyses that follow I use Cochran’s test of linear trends, a form of $\chi^2$ analysis that tests for trends among multiple ordinally ranked samples (Zar 1996:562–565). This test partitions the total $\chi^2$ value for a given $2 \times c$ contingency table into two portions: one that is due to a linear trend in the proportion and one that reflects departure from that trend. This test can also be thought of as a regression of the proportions on the ordinal ranks along the time or space scale in which the proportions are weighted by sample size (Zar 1996). The nature of this test is such that significant trends will not be found when samples are so small that random error cannot be ruled out at a specified confidence level as the cause of differences in relative abundance between samples. This approach can also be used in conjunction with analysis of residuals, as will be done below, to evaluate which of the cells within a contingency table contribute the most to the $\chi^2$ results obtained (see Everitt 1977:46–48).

**SPATIAL VARIABILITY IN ARTIODACTYL RELATIVE ABUNDANCE**

As I have noted, previous researchers working in the Mimbres region have recognized that spatial variability in taxonomic relative abundance might interfere with analyses of temporal change in which multiple sites from an environmentally heterogeneous region are included. These authors have dealt with this problem by dividing the Mimbres Valley into upper, middle, and lower portions that are intended to account for the fact that conditions become much drier as one moves down the valley (see Minnis 1985, 1986). In addition, Broughton (1994a, 1994b) and Janetski (1997) have both also recognized that spatial variability might introduce “noise” into regional-scale analyses of temporal trends in relative abundance and have shown that temporal trends can become more robust as a large region is divided into smaller areas. Here, I will demonstrate that there is substantial spatial variability in artiodactyl relative abundance in pithouse and pueblo period faunal samples from southwestern New Mexico that is significantly related to habitat variability. In the next section I argue that a failure to deal adequately with this spatial variability is responsible in part for the conflicting conclusions that have been reached about temporal changes in artiodactyl relative abundance in this region: it is not enough simply to divide the Mimbres Valley into three, still quite large, upper, middle, and lower sections.

Table 3 presents the modern vegetation community in which each of the sites used here is located, as well as the communities that occur within 15 km of each site, following the vegetation community classification presented by Brown and Lowe (1980) and Brown (1994). The sites in Table 3 are arranged in order of increasingly mesic habitat using vegetation as a measure of this; for sites within the Mimbres Valley this ordering also corresponds to their elevations. I note that the analysis that follows does not assume that vegetation communities have remained static over the entire span of time involved here. It does, however, assume that the rank
order of these sites along the xeric–mesic scale has not changed over this time.

Precipitation patterns and mean annual precipitation values within these vegetation communities are discussed in Brown (1994); these data provide the basis for the ordering of sites used here. The semidesert grassland community is a warm-temperate grassland with precipitation usually ranging between 250 and 450 mm/year; the weather station within this community nearest to the Mimbres Valley is at Lordsburg, New Mexico, with mean annual precipitation of 242 mm.

The Great Basin conifer (pinyon–juniper) woodland community is a cold-temperate woodland in which rainfall generally ranges between 250 and 500 mm/year; the weather station within this community nearest to the upper Mimbres Valley and Mogollon Village is at Ft. Bayard, New Mexico, with mean annual rainfall of 349 mm. The Madrean evergreen (oak–pinon–juniper) woodland community is a warm-temperate woodland with precipitation usually greater than 400 mm/year; the weather station within this community nearest to Wind Mountain is at Chiricahua National Monument, Arizona, with mean annual precipitation of 474 mm.

Table 4 presents assemblages ordered along the xeric–mesic scale for each of the Early Pithouse, Late Pithouse, transitional Late Pithouse/Classic, Classic, and Cliff phase time periods. Also presented are NISP values of artiodactyls and leporids and Artiodactyl Index values for these assemblages. No published samples are available for the Black Mountain phase that lies between the Classic phase and the Cliff phase. The four upper Mimbres Valley sites are all located within about 1.5 km or less of each other and since there is likely to be little habitat difference between them, I have combined samples from these sites within time periods.

For each of the Early Pithouse, Late Pithouse, transitional, and Classic period samples, total \( \chi^2 \) values are significant at \( p < 0.001 \) (Table 4). More important, within all of these time periods for which there are more than two assemblages,

<table>
<thead>
<tr>
<th>Site</th>
<th>Location</th>
<th>Elevation (m)</th>
<th>Modern vegetation community (communities within 15 km)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Old Town</td>
<td>Lower Mimbres Valley</td>
<td>1520</td>
<td>SG (CD)</td>
</tr>
<tr>
<td>NAN Ruin</td>
<td>Middle Mimbres Valley</td>
<td>1620</td>
<td>SG (CD, MEW, GBCW)</td>
</tr>
<tr>
<td>Disert</td>
<td>Middle Mimbres Valley</td>
<td>1690</td>
<td>SG (GBCW, MEW, RMMCF)</td>
</tr>
<tr>
<td>Galaz</td>
<td>Middle Mimbres Valley</td>
<td>1740</td>
<td>SG (GBCW, MEW, RMMCF)</td>
</tr>
<tr>
<td>Staley</td>
<td>Middle Mimbres Valley</td>
<td>1770</td>
<td>SG (GBCW, MEW, RMMCF)</td>
</tr>
<tr>
<td>Mattocks</td>
<td>Middle Mimbres Valley</td>
<td>1800</td>
<td>SG (GBCW, RMMCF)</td>
</tr>
<tr>
<td>Janss</td>
<td>Upper Mimbres Valley</td>
<td>1850</td>
<td>SG/GBCW (RMMCF)</td>
</tr>
<tr>
<td>Mitchell</td>
<td>Upper Mimbres Valley</td>
<td>1850</td>
<td>SG/GBCW (RMMCF)</td>
</tr>
<tr>
<td>Montezuma</td>
<td>Upper Mimbres Valley</td>
<td>1870</td>
<td>SG/GBCW (RMMCF)</td>
</tr>
<tr>
<td>Beauregard</td>
<td>Upper Mimbres Valley</td>
<td>1900</td>
<td>SG/GBCW (RMMCF)</td>
</tr>
<tr>
<td>Mogollon Village</td>
<td>San Francisco River</td>
<td>1570</td>
<td>GBCW (RMMCF, MEW)</td>
</tr>
<tr>
<td>Wind Mountain</td>
<td>Mangas Creek, Burro</td>
<td>1730</td>
<td>MEW (GBCW, RMMCF, SG, IC)</td>
</tr>
</tbody>
</table>

* From Brown and Lowe (1980; see also Brown, 1994). Abbreviations: SG, semidesert grassland; CD, Chihuahuan desert scrub; MEW, Madrean evergreen woodland; GBCW, Great Basin conifer woodland; RMMCF, Rocky Mountain montane conifer forest; IC, interior chaparral.

* Sites in the upper Mimbres Valley are located near what Brown and Lowe (1980) consider a boundary between semidesert grassland and Great Basin conifer woodland.
very large portions of the total $\chi^2$ values are due to increasing trends in artiodactyl relative abundance, which themselves are all significant at $p < 0.001$. Further, of the two Early Pithouse samples, the more mesic Wind Mountain site has a significantly higher relative abundance of artiodactyls than does Mogollon Village. Only for the Cliff phase sites is neither the total $\chi^2$ value nor the portion of it due to a trend significant, probably because these sites are not located far enough apart and/or because the sample from the Stailey site is quite small. For the time periods in which $\chi^2$ values are significant, analysis of residuals can be used to determine which sites

<table>
<thead>
<tr>
<th>Time period</th>
<th>Site</th>
<th>Leporids (NISP)</th>
<th>Artiodactyls (NISP)</th>
<th>Artiodactyls + leporids</th>
<th>Artiodactyl index</th>
<th>$\chi^2$ results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early Pithouse</td>
<td>Mogollon Village</td>
<td>36</td>
<td>13</td>
<td>49</td>
<td>0.27</td>
<td>38.49 ($p &lt; 0.001$)</td>
</tr>
<tr>
<td></td>
<td>Wind Mountain</td>
<td>16</td>
<td>68</td>
<td>84</td>
<td>0.81</td>
<td></td>
</tr>
<tr>
<td>Late Pithouse</td>
<td>Old Town</td>
<td>969</td>
<td>17</td>
<td>986</td>
<td>0.02</td>
<td></td>
</tr>
<tr>
<td></td>
<td>NAN Ruin</td>
<td>1808</td>
<td>144</td>
<td>1952</td>
<td>0.07</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Galaz</td>
<td>570</td>
<td>143</td>
<td>713</td>
<td>0.20</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mattocks</td>
<td>15</td>
<td>2</td>
<td>17</td>
<td>0.12</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Montezuma + Beauregard</td>
<td>47</td>
<td>29</td>
<td>76</td>
<td>0.38</td>
<td>Total, 1622.0 ($p &lt; 0.001$)</td>
</tr>
<tr>
<td></td>
<td>Mogollon Village</td>
<td>12</td>
<td>17</td>
<td>29</td>
<td>0.59</td>
<td>Linear trend, 1611.1 ($p &lt; 0.001$)</td>
</tr>
<tr>
<td></td>
<td>Wind Mountain</td>
<td>766</td>
<td>1008</td>
<td>1774</td>
<td>0.57</td>
<td>Departure from trend, 10.90 ($p = 0.053$)</td>
</tr>
<tr>
<td>Transitional</td>
<td>Old Town‘</td>
<td>121</td>
<td>3</td>
<td>124</td>
<td>0.02</td>
<td>Total, 46.37 ($p &lt; 0.001$)</td>
</tr>
<tr>
<td></td>
<td>NAN Ruin‘</td>
<td>328</td>
<td>13</td>
<td>341</td>
<td>0.04</td>
<td>Linear trend, 41.26 ($p &lt; 0.001$)</td>
</tr>
<tr>
<td></td>
<td>Wind Mountain‘</td>
<td>861</td>
<td>161</td>
<td>1022</td>
<td>0.16</td>
<td>Departure from trend, 5.11 ($p = 0.024$)</td>
</tr>
<tr>
<td>Classic Mimbres</td>
<td>Old Town</td>
<td>44</td>
<td>3</td>
<td>47</td>
<td>0.06</td>
<td></td>
</tr>
<tr>
<td></td>
<td>NAN Ruin</td>
<td>3654</td>
<td>149</td>
<td>3803</td>
<td>0.04</td>
<td>Total, 424.8 ($p &lt; 0.001$)</td>
</tr>
<tr>
<td></td>
<td>Mattocks</td>
<td>1219</td>
<td>232</td>
<td>1451</td>
<td>0.16</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mitchell + Montezuma</td>
<td>198</td>
<td>95</td>
<td>293</td>
<td>0.32</td>
<td>Linear trend, 397.5 ($p &lt; 0.001$)</td>
</tr>
<tr>
<td></td>
<td>Wind Mountain</td>
<td>19</td>
<td>6</td>
<td>25</td>
<td>0.24</td>
<td>Departure from trend, 27.36 ($p &lt; 0.001$)</td>
</tr>
<tr>
<td>Cliff Phase</td>
<td>Disert</td>
<td>150</td>
<td>356</td>
<td>506</td>
<td>0.70</td>
<td>Total, 2.48 ($p = 0.289$)</td>
</tr>
<tr>
<td></td>
<td>Stailey</td>
<td>7</td>
<td>30</td>
<td>37</td>
<td>0.81</td>
<td>Linear trend, 1.07 ($p = 0.301$)</td>
</tr>
<tr>
<td></td>
<td>Janss</td>
<td>56</td>
<td>157</td>
<td>213</td>
<td>0.74</td>
<td>Departure from trend, 1.41 ($p = 0.235$)</td>
</tr>
</tbody>
</table>

Note. Bold numbers indicate cells for which adjusted residuals are significant at $p < 0.05$. 
*Transitional Late Pithouse/Classic Mimbres. 
‘Transitional Late Three Circle/Classic Mimbres. 
‘Mangas phase.
are primarily responsible for the results obtained. Bold entries in Table 4 indicate cells for which adjusted residuals are significant at $p < 0.05$: only the fairly small samples from Mattocks during the Late Pithouse period and Old Town during the Classic Mimbres phase fail to provide significant residuals. We can thus conclude that, with the possible exception of the Cliff phase, there is a strong correlation in this region between habitat type and artiodactyl relative abundance.

This result assumes, of course, that these trends are not simply reflecting differences in data collection methods, and indeed this does not appear to be the case. Sites at which screens larger than 6.4 mm are known to have been used are distributed evenly along the xeric–mesic scale and are not biased toward one end of it or the other. Furthermore, if Wind Mountain, the one site for which screen size information is not available, is dropped from the analysis, significant trends still occur among samples from the Late Pithouse ($\chi^2_{\text{trend}} = 282.4, p < 0.001$) and Classic ($\chi^2_{\text{trend}} = 402.3, p < 0.001$) periods. The difference between the two remaining transitional period samples becomes insignificant ($\chi^2 = 0.531, p = 0.991$), however, when Wind Mountain is not included.

This result also assumes that the faunal specimens from all of the sites within each time period are distributed equally with respect to the span of time contained within that period. All of the periods considered here represent substantial amounts of time (up to 450 years in the case of the Late Pithouse) and, as I noted above, resource depression might occur over lengths of time much shorter than this. If artiodactyl abundance on the landscape declined across this region during any of these periods, and if the samples used here from more mesic areas also consisted of more specimens deposited earlier within that period than was the case for samples from more xeric areas, then my results might be reflecting temporal change as much as spatial variability.

Only three Late Pithouse sites allow this issue to be addressed directly; finer temporal control is not available for the rest of the Late Pithouse assemblages or for assemblages from other time periods. At both NAN (the second most xeric site) and Wind Mountain (the most mesic site) the large majority of the Late Pithouse specimens are from the Three Circle phase (Table 6); at Mogollon Village (the second most mesic site) most are from the preceding San Francisco phase (Cannon 1999b). Based on these three sites, there appears to be no systematic spatial bias among the Late Pithouse period assemblages in the age of faunal specimens. Beyond this, that the correlation between habitat and artiodactyl relative abundance is significant for all time periods except the Cliff phase (in which the sites are all located fairly close together) strongly suggests that true habitat-associated differences are being measured.

These results are in general agreement with the conclusions reached by Shaffer and Schick (1995). These authors examined spatial variability in artiodactyl relative abundance in assemblages from some of the Mimbres Valley sites in addition to the fauna from the WS Ranch site, which is located on the San Francisco River not far from Mogollon Village. [I have not included the WS Ranch fauna in my analysis because publications on this fauna (Shaffer and Neeley 1992; Shaffer and Schick 1995) do not list specimens by time period.] Shaffer and Schick noted that the WS Ranch assemblage shows a much higher abundance of artiodactyls relative to leporids and rodents than do faunas from sites in the Mimbres Valley and that sites in the drier, lower portions of the Mimbres Valley appear to have somewhat
lower artiodactyl relative abundances than do sites further up the valley.

Shaffer and Schick (1995) go on to suggest that this spatial patterning in artiodactyl relative abundance indicates that local artiodactyl populations in more xeric areas were subject to resource depression during the pithouse and pueblo time periods. This, however, is something that can only be demonstrated through analysis of temporal trends, which these authors do not perform. All that such a spatial pattern indicates by itself is that people who lived in some places took higher proportions of artiodactyls, averaged over some period of time, than did people who lived in other places. Shaffer and Schick present no temporal data to indicate that artiodactyls were less abundant anywhere in this region as a result of human predation than they would have been had they never been hunted at all—there may simply have been fewer artiodactyls in drier areas to begin with.

**TEMPORAL CHANGES IN ARTIODACTYL RELATIVE ABUNDANCE**

The analysis of spatial patterning I have presented demonstrates that artiodactyls are more abundant in Mimbres-Mogollon faunal assemblages from sites located in more mesic, wooded areas. Analysis of temporal change is required, however, to address the issue of whether the larger, probably more sedentary human populations of the Classic Mimbres phase were responsible for reductions in local large mammal populations. As I noted at the outset, previous researchers working in this area have presented conflicting results concerning temporal changes in artiodactyl relative abundance. By taking spatial variability into account and by giving more thorough consideration to the relationship between resource depression and temporal changes in archaeological relative abundance, I show here that existing samples tend to support the idea that artiodactyl resource depression occurred here during the Late Pithouse and Early Pueblo periods.

Table 5 presents artiodactyl and leporid NISPs from all of the sites in this analysis that have samples from two or more time periods; results of $\chi^2$ tests and tests for trends are also given. The NAN Ruin and Wind Mountain both produce declining trends in artiodactyl relative abundance that are significant at $p < 0.001$, and only the residuals from the time period with the smallest sample at each of these sites fail to be significant at $p < 0.05$. Since declining archaeological relative abundances of high-return prey should always indicate resource depression (assuming that the effects of confounding factors are not too great), these two sites provide support for the hypothesis that growing human communities substantially impacted local populations of artiodactyls.

It is also possible to subdivide the faunal materials from these two sites into finer scale time periods than are shown in Table 5; this is presented in Table 6. The NAN samples used here come only from that portion of the fauna from this site analyzed by Shaffer (1991); Sanchez (1992) provides no comparable division. Shaffer observed the Artiodactyl Index values in these samples and concluded that “artiodactyl exploitation was fairly stable through time” at this site (1991:106). $\chi^2$ analysis shows that it is true that the large majority of the variability in artiodactyl relative abundance at this site is not associated with a temporal trend when the fauna is divided into these finer scale time periods, and only half of these time periods provide residuals that are significant at $p < 0.05$. There is, however, a portion of the variability in artiodactyl relative abundance at NAN that is due to a significant declining trend ($p = 0.001$). At Wind Mountain there is also a smaller
portion of the total $\chi^2$ value that can be attributed to a linear trend compared to when a coarser scale temporal division is used, and the residuals from only four of the six time periods are significant, but the declining trend in artiodactyl relative abundance is still highly significant ($p < 0.001$).

At Old Town the total $\chi^2$ value is significant only at $p < 0.10$, but there is an increasing trend in artiodactyl relative abundance that is significant at $p < 0.05$ (Table 5). If these samples are reflecting a real trend at this site, this may, in fact, provide further support for the hypothesis that artiodactyl resource depression occurred in this region. Old Town is located in the most xeric setting of all of the sites in this analysis, and I have shown above that artiodactyls are significantly less abundant in assemblages from sites in drier, less wooded areas. Hunters from Old Town may thus have been forced to make more extensive use of distant patches containing higher abundances of artiodactyls due to local resource depression than were hunters from other sites in the region. In other words, it may be correct to argue that there is no Mimbres Valley-wide temporal decline in artiodac-

**TABLE 5**
Artiodactyl and Leporid NISP Values from Sites with Faunal Samples from Two or More Time Periods, with Results of $\chi^2$ Analysis of Temporal Trends at Each Site

<table>
<thead>
<tr>
<th>Site</th>
<th>Time period</th>
<th>Leporids NISP</th>
<th>Artiodactyls NISP</th>
<th>Artiodactyl + leporids index</th>
<th>$\chi^2$ results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Old Town</td>
<td>Late Pithouse</td>
<td>969</td>
<td>17</td>
<td>986</td>
<td>0.02</td>
</tr>
<tr>
<td></td>
<td>LP/CM&lt;sup&gt;a&lt;/sup&gt;</td>
<td>121</td>
<td>3</td>
<td>124</td>
<td>0.02</td>
</tr>
<tr>
<td></td>
<td>Classic Mimbres</td>
<td>44</td>
<td>3</td>
<td>47</td>
<td>0.06</td>
</tr>
<tr>
<td>NAN Ruin</td>
<td>Late Pithouse</td>
<td>1808</td>
<td>144</td>
<td>1952</td>
<td>0.07</td>
</tr>
<tr>
<td></td>
<td>LTC/CM&lt;sup&gt;b&lt;/sup&gt;</td>
<td>328</td>
<td>13</td>
<td>341</td>
<td>0.04</td>
</tr>
<tr>
<td></td>
<td>Classic Mimbres</td>
<td>3654</td>
<td>149</td>
<td>3803</td>
<td>0.04</td>
</tr>
<tr>
<td>Mattocks</td>
<td>Late Pithouse</td>
<td>15</td>
<td>2</td>
<td>17</td>
<td>0.12</td>
</tr>
<tr>
<td></td>
<td>Classic Mimbres</td>
<td>1219</td>
<td>232</td>
<td>1451</td>
<td>0.16</td>
</tr>
<tr>
<td>Montezuma</td>
<td>Late Pithouse</td>
<td>25</td>
<td>7</td>
<td>32</td>
<td>0.22</td>
</tr>
<tr>
<td></td>
<td>Classic Mimbres</td>
<td>69</td>
<td>16</td>
<td>85</td>
<td>0.19</td>
</tr>
<tr>
<td>Mogollon Village</td>
<td>Early Pithouse</td>
<td>36</td>
<td>13</td>
<td>49</td>
<td>0.27</td>
</tr>
<tr>
<td></td>
<td>Late Pithouse</td>
<td>12</td>
<td>17</td>
<td>29</td>
<td>0.59</td>
</tr>
<tr>
<td>Wind Mountain</td>
<td>Early Pithouse</td>
<td>16</td>
<td>68</td>
<td>84</td>
<td>0.81</td>
</tr>
<tr>
<td></td>
<td>Late Pithouse</td>
<td>766</td>
<td>1008</td>
<td>1774</td>
<td>0.57</td>
</tr>
<tr>
<td></td>
<td>Mangas phase</td>
<td>861</td>
<td>161</td>
<td>1022</td>
<td>0.16</td>
</tr>
<tr>
<td></td>
<td>Classic Mimbres</td>
<td>19</td>
<td>6</td>
<td>25</td>
<td>0.24</td>
</tr>
</tbody>
</table>

<sup>Note.</sup> Bold numbers indicate cells for which adjusted residuals are significant at $p < 0.05$.

<sup>a</sup> Transitional Late Pithouse/Classic Mimbres.

<sup>b</sup> Transitional Late Three Circle/Classic Mimbres.
tyl relative abundance between the Late Pithouse and Classic Mimbres time periods (e.g., Sanchez 1996), but this does not necessarily mean that resource depression and reduced foraging efficiency did not occur throughout the entire Mimbres Valley.

I should note, however, that the Classic phase sample from Old Town is quite small compared to the samples from earlier time periods, and it would be reasonable to question whether this sample is indeed representative of whatever spatial variability may exist in the population of faunal remains from the Classic phase at this rather large site (e.g., O’Neil 1993). Analysis of a larger sample of bones from Old Town, incorporating analyses of large mammal skeletal element representation and population age structure, might serve to demonstrate more conclusively whether hunters here experienced resource depression and precisely how their use of the landscape changed as a result.

A significant increase in artiodactyl relative abundance also occurs between the Early and Late Pithouse periods at Mogollon Village, where only a small number of specimens can be assigned to either time period (Cannon 1999b). As at Old Town, a much larger assemblage of faunal specimens from datable contexts is required to determine whether these samples are truly reflective of the spatial variability that may exist within this site. Samples from the Late Pithouse period at

<table>
<thead>
<tr>
<th>Site</th>
<th>Time period</th>
<th>Leporids (NISP)</th>
<th>Artiodactyls (NISP)</th>
<th>Artiodactyls + leporids</th>
<th>Artiodactyl index</th>
<th>( \chi^2 ) results</th>
</tr>
</thead>
<tbody>
<tr>
<td>NAN Ruin</td>
<td>SF/ETC (^b)</td>
<td>6</td>
<td>6</td>
<td>12</td>
<td>0.50</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Early Three Circle</td>
<td>32</td>
<td>5</td>
<td>37</td>
<td>0.14</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Three Circle</td>
<td>594</td>
<td>39</td>
<td>633</td>
<td>0.06</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Late Three Circle</td>
<td>634</td>
<td>76</td>
<td>710</td>
<td>0.11</td>
<td></td>
</tr>
<tr>
<td></td>
<td>LTC/CM (^c)</td>
<td>328</td>
<td>13</td>
<td>341</td>
<td>0.04</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Classic Mimbres</td>
<td>627</td>
<td>42</td>
<td>669</td>
<td>0.06</td>
<td></td>
</tr>
<tr>
<td>Wind Mountain</td>
<td>Early Pithouse</td>
<td>16</td>
<td>68</td>
<td>84</td>
<td>0.81</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Georgetown</td>
<td>22</td>
<td>22</td>
<td>44</td>
<td>0.50</td>
<td></td>
</tr>
<tr>
<td></td>
<td>San Francisco</td>
<td>125</td>
<td>17</td>
<td>142</td>
<td>0.12</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Three Circle</td>
<td>619</td>
<td>869</td>
<td>1488</td>
<td>0.58</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mangas</td>
<td>861</td>
<td>161</td>
<td>1022</td>
<td>0.16</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Classic Mimbres</td>
<td>19</td>
<td>6</td>
<td>25</td>
<td>0.24</td>
<td></td>
</tr>
</tbody>
</table>

Note. Bold numbers indicate cells for which adjusted residuals are significant at \( p < 0.05 \).

\(^a\) Data from Shaffer (1991:Table 5.9) only
\(^b\) Transitional San Francisco/Early Three Circle
\(^c\) Transitional Late Three Circle/Classic Mimbres.
Mattocks and the Late Pithouse and Early Pueblo periods at Montezuma are also fairly small; Mattocks shows a slight increase and Montezuma a slight decrease in artiodactyl relative abundance, but at neither site do \( \chi^2 \) tests give significant results.

Table 7 presents combined samples from the middle and upper portions of the Mimbres Valley in an analysis similar to the “site cluster” analysis performed by Sanchez (1996). The results of \( 2 \times 2 \chi^2 \) tests between consecutive time periods are shown; tests for linear trends were not performed due to the dramatic increases in artiodactyl relative abundance that occur in the Cliff phase samples.\(^9\) In the upper valley, where all four sites are located very close to one another and are not likely to be subject to differences in habitat, artiodactyl relative abundance declines between the Late Pithouse and Early Pueblo periods, though not significantly. Were samples much larger, however, this difference might well become significant.

In the middle valley, it appears that artiodactyl relative abundance undergoes a significant decrease between the Late Pithouse and transitional periods, only then to increase significantly (at \( p < 0.02 \)) in the Classic phase, something that was not evident in the samples from the NAN Ruin alone. When we consider the locations of the sites included in this combined middle valley sample, however, a possible explanation for this apparent temporal increase between the transitional and Classic periods becomes clear. Both Galaz and Mattocks are located considerably further up the valley than NAN and at elevations 120 and 180 m higher, respectively. The transitional period sample comes only from NAN, while the Classic sample comes from NAN and Mattocks and the Late Pithouse sample comes from NAN, Galaz, and Mattocks. Since it has already been shown that artiodactyl relative abundance is correlated with habitat type in this region, it is quite possible that the apparent differences between the three time periods in these samples are reflecting spatial variability as much as temporal change.

Thus, Sanchez’s finding of no significant decline in artiodactyl relative abundance in her combined middle valley samples may be due in part to the fact that only about 5% of her Late Pithouse sample for this portion of the valley comes from Galaz and Mattocks, while about 15% of her Classic phase sample comes from Mattocks, with the remainder of the specimens from both time periods coming

### Table 7

<table>
<thead>
<tr>
<th>Area</th>
<th>Time period</th>
<th>Site(s)</th>
<th>Leporids (NISP)</th>
<th>Artiodactyls (NISP)</th>
<th>Artiodactyl index</th>
<th>( \chi^2 ) with previous period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Middle valley</td>
<td>Late Pithouse</td>
<td>NAN, Galaz, Mattocks</td>
<td>2393</td>
<td>289</td>
<td>2682</td>
<td>0.11</td>
</tr>
<tr>
<td>LTC/CM(^a)</td>
<td>Classic</td>
<td>NAN</td>
<td>328</td>
<td>13</td>
<td>341</td>
<td>0.04</td>
</tr>
<tr>
<td></td>
<td>Mimbres</td>
<td>NAN, Mattocks</td>
<td>4873</td>
<td>381</td>
<td>5254</td>
<td>0.07</td>
</tr>
<tr>
<td>Cliff</td>
<td></td>
<td>Disert, Stailey</td>
<td>157</td>
<td>386</td>
<td>543</td>
<td>0.71</td>
</tr>
<tr>
<td>Upper valley</td>
<td>Late Pithouse</td>
<td>Montezuma, Beauregard</td>
<td>47</td>
<td>29</td>
<td>76</td>
<td>0.38</td>
</tr>
<tr>
<td></td>
<td>Classic</td>
<td>Mitchell, Montezuma</td>
<td>198</td>
<td>95</td>
<td>293</td>
<td>0.32</td>
</tr>
<tr>
<td>Cliff</td>
<td></td>
<td>Janss</td>
<td>56</td>
<td>157</td>
<td>213</td>
<td>0.74</td>
</tr>
</tbody>
</table>

\( \chi^2 \) with previous period:
- Middle valley:
  - Late Pithouse: NaN, Galaz, Mattocks: \( \chi^2 = 16.31 (p < 0.001) \)
  - LTC/CM\(^a\): NaN: \( \chi^2 = 5.79 (p = 0.016) \)
  - Classic: Mimbres: NaN, Mattocks: \( \chi^2 = 1746.8 (p < 0.001) \)
- Upper valley:
  - Late Pithouse: Montezuma, Beauregard: \( \chi^2 = 84.01 (p < 0.001) \)
  - Classic: Mimbres: Mitchell, Montezuma: \( \chi^2 = 0.889 (p = 0.346) \)

\( \chi^2 \) with previous period:
- Lower valley:
  - Late Pithouse: Montezuma, Beauregard: \( \chi^2 = 84.01 (p < 0.001) \)

\(^a\) Transitional Late Three Circle/Classic Mimbres.
from NAN (Sanchez 1996:Table 1). Clearly, whenever any spatial variability exists among sites, any analysis of temporal trends that lumps those sites together will be subject to some degree of spatial “noise.” In such cases, analysis of temporal changes at individual sites should be preferred over analysis of grouped sites (Janetski 1997), a logical conclusion that is given empirical support by Broughton’s (1994a, 1994b) and Janetski’s (1997) demonstration that temporal trends can become more robust as spatial focus is narrowed. The results from the single site of NAN are thus probably the most trustworthy reflection of temporal changes in artiodactyl abundance in this part of the valley.

Finally, as noted by Anyon and LeBlanc (1984) and Nelson and LeBlanc (1986), the samples from the Cliff phase, when human populations in the Mimbres Valley were apparently at their lowest, show dramatic and highly significant increases in artiodactyl relative abundance in both the middle and upper portions of the valley (Table 7). The middle valley samples may in part be reflecting habitat variability, since the Classic phase sample here comes mostly from NAN, while the Cliff phase sample comes from Disert and Stailey, which are located further up the valley. The large magnitude of this change, however, combined with the fact that a similar large increase occurs in the upper valley where the sites are all situated very close to each other strongly suggest that this is a real temporal trend. This could well reflect artiodactyl populations rebounding from intense harvest pressure.

DISCUSSION AND CONCLUSIONS

This analysis shows that there is a significant trend toward higher artiodactyl relative abundance at sites located in more mesic, wooded habitats within the Mimbres-Mogollon region. Since this is the case, any consideration of temporal change that lumps samples from different sites is likely to be measuring space as much as time. This fact is clearly not limited just to the Mogollon area, but is relevant to studies of temporal trends in taxonomic relative abundance in general. Whenever substantial spatial variability exists within a region, which is likely to be often, the preferred means of analysis should be to consider changes occurring at individual points on the landscape, insofar as the archaeological record allows (Janetski 1997).

Taking this spatial effect into consideration, the following conclusions about temporal changes in artiodactyl relative abundance and the occurrence of resource depression in the Mimbres-Mogollon region can be drawn from existing faunal samples. The two sites at which sample size is most adequate for evaluating differences between time periods, the NAN Ruin and Wind Mountain, both show significant declines between the Pithouse and Pueblo periods, no matter how finely or coarsely samples are aggregated. Old Town shows a weakly significant increase in artiodactyl relative abundance, which may simply be due to the small size of the Classic phase sample from this site or which might indicate increased use of more distant resource patches due to declining artiodactyl encounter rates in nearby patches. Assemblages from remaining sites are too small to provide meaningful results concerning temporal change leading up to and including the Classic Mimbres phase. The declines in artiodactyl relative abundance that occur at NAN and Wind Mountain, however, together with the rebound apparent in the Cliff phase samples from the Mimbres Valley, strongly suggest that prehistoric people in this region did have significant impacts on local large mammal populations.
If these conclusions are borne out by further research designed both to address the factors that might interfere with analyses of taxonomic relative abundance and to provide additional lines of evidence in support of the occurrence of resource depression, this would add to the growing body of work illustrating the roles that nonindustrial peoples can play in shaping the natural environments in which they live, particularly as regards the vertebrate taxa they exploit (e.g., Alvard 1993, 1994; Broughton 1994a, 1994b, 1997, 1999; Grayson 1993; Hildebrandt and Jones 1992; Hill et al. 1997; Janetski 1997; Kay 1994; Redford and Robinson 1985; see also Grayson and Cannon 1999; Winterhalder and Lu 1997). Perhaps the most important finding here is that artiodactyl relative abundance changes differently between the Late Pit-house period and the Classic Mimbres phase at Old Town than it does at the rest of the sites for which data are available. This may indicate that human impacts on large mammal populations, as well as human responses to those impacts, can be quite variable, playing out in different ways in different settings, depending on the spatial structure of resource availability.

This line of inquiry also represents an important first step toward more directly testing the hypothesis that the increased importance of agriculture that developed in the Mimbres-Mogollon region during the pithouse and pueblo time periods was the result of declines in the energetic returns provided by wild resources due to human population growth. By providing a measure of vertebrate resource foraging efficiency, the approach used here makes it possible to go beyond the use of correlations between population size and the intensity of agricultural production. Were more precise chronological detail on changes in vertebrate foraging efficiency available for the Mimbres-Mogollon region, the timing of these changes could be compared to the timing of changes in the importance of agriculture to determine whether declines in foraging efficiency preceded increases in agricultural reliance, as the population growth hypothesis requires. Finding, on the other hand, that declines in artiodactyl encounter rates occurred after an increased reliance on domesticates had already developed would suggest that large mammal resource depression was primarily the result of population growth spurred by the greater use of high-yield, storable crops, rather than the cause of increases in the use of these crops (see Winterhalder and Goland 1997). Explaining the increased importance of agriculture here would then demand that we look elsewhere, perhaps to depression in the realm of plant resources.

It is not presently possible to address these issues further given the coarse-grained chronological control over Mimbres-Mogollon faunal assemblages that is currently available. It should be apparent, however, that appropriately directed future zooarchaeological research has the potential to substantially improve our understanding of major economic changes that occurred prehistorically in this region.

ACKNOWLEDGMENTS

This paper has been greatly improved thanks to comments by or discussions with Jack M. Broughton, Dale S. Cannon, Darrell G. Creel, Patricia A. Gilman, Steven A. LeBlanc, Jennifer E. Nisengard, John M. O'Shea, Richard W. Redding, Brian S. Shaffer, Eric A. Smith, several anonymous reviewers, and especially Donald K. Grayson. Angela R. Linse was very helpful in providing references and sharing her knowledge of Mogollon archaeology. The University of Washington Mogollon Village Field School was supported by the University of Washington and the USDA Forest Service, Gila National Forest (Silver City, NM). The Mogollon Village Archaeological Project was supported by the USDA Forest Service, Gila National Forest (Silver City, NM). My analysis of the fauna from Mogollon Village was aided by a
travel grant from the Department of Anthropology, University of Washington.

NOTES

1 The net amount of energy gained from a resource unit per amount of time spent “handling” it between encounter and consumption.

2 This point also indicates the optimal patch residence time.

3 Stephens and Krebs (1986:25–27) imply that the concept of depression, as developed by Charnov et al. (1976), applies specifically to single foraging episodes within single patches in which the gain functions of those patches are eventually negatively accelerated. This conception of depression distinguishes it from resource depletion, which can occur without negative acceleration of the gain function, and the distinction here is important because negative acceleration of the gain function is a crucial assumption of the patch model (Stephens and Krebs 1986:24–34). However, I am using the term “resource depression” in the broader sense of the verbal definition provided by Charnov et al. (1976:247) and am applying it to declining encounter rates between foraging episodes. This usage is necessary for archaeological application since the individual foraging episodes of individual foragers within individual patches are far beyond the reach of archaeologists. Despite the potential for some confusion here, I would argue that “resource depression” is the best term to use for the phenomenon that is of interest. Archaeologists often use the term “resource depletion” without considering the different ways in which resources can become “depleted.”

4 It is also certainly possible that a decline in large mammal encounter rates might have led to an increase the frequency with which rabbit drives were carried out.

5 Some of the values in Nelson and LeBlanc (1986:Table 13.4) differ substantially from those in Anyon and LeBlanc (1994:Table 15.5) to the extent that some of the trends discussed here do not hold for the data presented in the earlier report. The reasons for these differences are not entirely clear since both tables are supposed to be based on the same assemblages (Anyon and LeBlanc 1984:215; Nelson and LeBlanc 1986:233), unless the later work reflects revised knowledge about the dating of faunal samples from these sites. I also note that the total number of artiodactyl plus leporids given for the upper valley Cliff phase in Nelson and LeBlanc (1986:Table 13.4) was apparently transposed; calculation of this value from the data presented in Nelson and LeBlanc (1986:Appendix F, Table 2) indicates that this should be 213, not 231.

6 I have also excluded from this analysis all specimens identified by McKusick to taxon but not to element and have excluded the one pithouse for which Woosley and McIntyre state that the phase designation is problematic. Assemblages from Old Town, NAN, Galaz, Mattocks, Mitchell, Montezuma, and Beauregard were used by Sanchez (1996) in her analysis of Mimbres Valley Late Pithouse and Early Pueblo period faunas. There are some important differences, though, between the samples she used and those I am using. For sites other than Old Town and NAN, Sanchez used data from Powell (1977). Nelson and LeBlanc (1986:Table 13.4), however, present artiodactyl and leporid data for four of these sites—Galaz, Mattocks (Classic phase only), Mitchell, and Beauregard—that differ from those presented by Powell (1977). I have used the data presented by Nelson and LeBlanc on the assumption that this later work reflects revised knowledge about the contexts from which these samples come. In one case (Beauregard) the data provided by Nelson and LeBlanc result in a smaller sample and change the Artiodactyl Index value from 0.41 to 0.50. In the other three cases Nelson and LeBlanc’s data result in larger samples and change the Artiodactyl Index by 0.04 points or less. In addition, for reasons that are not clear, the Artiodactyl Index values presented by Sanchez (1996:Table 4) for Old Town and NAN differ from the ones I have calculated; to derive these values I simply used the NISPs of artiodactyls and leporids per time period presented in Sanchez (1992:Tables 3.5 and 4.2) and Shaffer (1991:Table 5.9). Sanchez (1996) also does not discuss the transitional period samples from these two sites.

7 Note also that the Classic Mimbres phase analysis with Wind Mountain dropped includes only sites from the Mimbres Valley. If both Wind Mountain and Mogollon Village are dropped from the Late Pithouse period analysis, again leaving only sites from the Mimbres Valley, the trend for this time period is also still highly significant ($X^2_{\text{trend}} = 238.0, p < 0.001$).

8 The test for trends in proportions is more powerful than the test for differences in proportions; thus it is possible that a null hypothesis of no trend can be rejected even when a null hypothesis of no difference cannot be (Zar 1996:564).

9 Likewise, results of analysis of residuals are not presented since all of these tests involve only 2 × 2 contingency tables.

REFERENCES CITED

MIMBRES-MOGOLLON LARGE MAMMAL RESOURCE DEPRESSION


Anyon, Roger, Patricia A. Gilman, and Steven A. LeBlanc

Anyon, Roger, and Steven A. LeBlanc

Barlow, K. Renee

Bayham, Frank E.


Binford, Lewis R.

1983 *In pursuit of the past: Decoding the archaeological record*. Thames and Hudson, New York.

Blackburn, Thomas C., and Kat Anderson

Blake, Michael, Steven A. LeBlanc, and Paul E. Minnis

Boserup, Esther
1965 *Conditions of agricultural growth: The economics of agrarian change under population pressure*. Aldine, Chicago.

Broughton, Jack M.


Broughton, Jack M., and Donald K. Grayson

Broughton, Jack M., and James F. O’Connell

Brown, David E.

Brown, David E., and Charles H. Lowe

Brown, James H.

Cameron, Catherine M.

Cannon, Michael D.

1999b The faunal remains from Mogollon Village (LA 11568). Manuscript on file, USDA Forest Service, Gila National Forest, Silver City, New Mexico.

Catton, Theodore

Charnov, Eric L., Gordon H. Orians, and Kim Hyatt

Cohen, Mark Nathan

Diehl, Michael W.

Everitt, B. S.

Fish, Suzanne K., and Paul R. Fish

Gilman, Patricia A.

Glassow, Michael A.

Grayson, Donald K.

Grayson, Donald K., and Michael D. Cannon

Gremillion, Kristen J.
1996 Diffusion and adoption of crops in evolutionary perspective. *Journal of Anthropological Archaeology* 15:183–204.

Haccou, Patsy, and Wil J. van der Steen

Hard, Robert

Haury, Emil W.

Hawkes, Kristen

Hawkes, Kristen, Kim Hill, and James F. O'Connell

Heller, Rolf

Hesselton, William T., and RuthAnn Monson Hesselton

Hildebrandt, William R., and Terry L. Jones

Hill, Kim, Jonathan Padwe, Carlos Bejvagi, Ambrosio Bepurangi, Felipe Jakugi, Roberto Tykuarangi, and Tito Tykuarangi.
Hoyer, Martin E.

James, Steven R.

Janetski, Joel C.

Kaplan, Hillard, and Kim Hill

Kay, Charles E.

Kelly, Robert L.

Kirch, Patrick V., and Terry L. Hunt

Lancaster, James W.

Larson, Daniel O.

Lekson, Stephen H.


Leopold, A. Starker, Stanley A. Cain, Ira N. Gabrielson, Clarence M. Cottam, and Thomas L. Kimball

Lightfoot, Kent G., and Fred Plog

Linares, Olga F.

Linse, Angela R.

Lyman, R. Lee
1997 White goats, white lies: The misuse of science in Olympic National Park. Univ. of Utah Press, Salt Lake City.

McKusick, Charmion R.

Mackie, Richard J., Kenneth L. Hamlin, and David F. Pac

Madsen, David B., and Dave N. Schmitt

Mauldin, Raymond, Patricia A. Gilman, and Christopher M. Stevenson

Minnis, Paul E.


Shaffer, Brian S. 1991 The economic importance of vertebrate faunal remains from the NAN Ruin (LA 15049), a Classic Mimbres site, Grant County, New Mexico. Unpublished Masters thesis, Texas A&M University, College Station.


