<Introduction>

Models of human adaptation can be tested either by excavation results, in which case the representativeness is in question, or by the production of settlement pattern models which are then tested by survey results. The Cedar Mesa Project is largely centered on the latter approach so it is in this section of the monograph that ideas about adaptation are tested and further developed. We start the Grand Gulch section by testing some basic ideas about the distribution of quadrats with habitation sites and those without, which demonstrates that the Basketmaker II occupation on Cedar Mesa was heavily reliant on agriculture. We then introduce our alternative approach, the n-dimensional hypervolume niche approach, and test further ideas about the distribution of quadrats. We then turn to the distribution of on site variables, going away from the quadrat model, and finally examine the implications of our findings for the size of the Grand Gulch population and community organization on Cedar Mesa.

<The Distribution of Grand Gulch Habitation Quadrats.>

Our main assumption about Anasazi settlement systems is that agriculture was the main subsistence activity, and
Matson, Lipe and Haase (Jun. 90) IX-2 therefore, was the main determinant of settlement location. This assumption implies that habitation or residential sites will be located in areas of concentrated arable land, which on Cedar Mesa would be in the higher elevation areas with deep soils. A test of this assumption would be simply to compare those quadrats with Grand Gulch habitation sites with those quadrats which do not have habitation sites. We would expect the quadrats with habitation sites to be at higher elevations than those quadrats lacking this type of site. A second, but not necessarily contradictory idea, is that in times of a cooler climate or with less cold tolerant crops, the highest portions of Cedar Mesa may not have been arable with the result that occupants would avoid both the lowest and highest elevations on Cedar Mesa.

Table IX-1 and Figure IX-1 contrast the elevations of those survey quadrats with and without habitation sites, with the combined class of all quadrats. The median elevation of quadrats with habitation sites is 1948 m (6390 ft), while those without have a median of 1900 m (6235 ft). The lower quartile of the habitation quadrats, 1887 m (6190 ft) is essentially the same as the nonhabitation median. According to the two-sample Wilcoxon test, this difference is significant at the .10 level, allowing the rejection of the null hypothesis, albeit with limited finality. The reason for the weak rejection is obvious when inspecting Figure IX-1; while habitation quadrats are located at higher elevations, they
are not located at the very highest elevations. In fact, the nine highest elevation quadrats lack evidence of Grand Gulch habitation sites. So we can reject the null hypothesis of equal elevation with confidence and move to the second idea.

Inspection of Figure IX-1 appears to indicate that Grand Gulch habitation sites avoid both the lower elevations and the very highest ones. Unfortunately, tests for dispersion (instead of location) are difficult to implement. In this case, since we have already pointed out the nine highest quadrats do not have habitation sites, we cannot use this observation in a test because we have already selected it out of all possible observations and thus we would have a tautology. A measure of dispersion we can use is the interquartile range or midbreadth. If we take the midbreadth of the habitation quadrats and place it over the distribution of the nonhabitation quadrats (Table IX-2a), we find a large difference. If we test for the difference using Chi-Square, we find a Chi-Square of 12.32 significant at .01 with two degrees of freedom. Note that this test does not take into account the difference already noted about the upper elevation quadrats.

A basically equivalent test would be to test the extremes of the two distributions, using the nonhabitation quadrats as the expected. This pattern (Table IX-2b) shows the "Quintiles" or highest and lowest 20%, to be very different with only one, rather than the expected 12, of the habitation
Matson, Lipe and Haase (Jun. 90) IX-4 quadrats in the combined highest and lowest elevations of the nonhabitation quadrat distribution.

To summarize the basic elevation trends of habitation sites, we find both initial hypotheses to be in accord with the data. Quadrats with habitation sites tend to cluster in the higher elevations, but are absent in the highest elevations on Cedar Mesa. In fact, three-fourths of the habitation quadrats are between 1890m (6195 ft) and 2025m (6640 ft) in elevation in contrast to the total 464m (1520 ft) range in elevation found in the Cedar Mesa quadrats. Half of the habitation quadrats are found between 1957 m (6420 ft) and 2025 m (6640 ft) in elevation, a midbreadth range of only 67 m (220 ft).

The absence of habitation sites in the highest elevations contrasts with site distributions during later periods, suggesting that higher and colder elevations were not as productive during the Grand Gulch phase as they were later. This may be indicative of a colder climatic during the Basketmaker II period or the use of less cold resistant crops. Additional independent information is needed to determine which of these two possible factors was most important.

If we examine the 32 habitation quadrats for trends in the total number of tools and elevation, we do not find much (Figure IX-2). If there are any trends, it is for the highest numbers of tools to be found in medium high elevations and
Matson, Lipe and Haase (Jun. 90) IX-5
not below 1830 m (6000 ft).

If the Grand Gulch habitation sites are located adjacent
to agricultural fields, we would expect other variables in
addition to elevation to be important. In our earlier
discussion of arable land, deep soil was also considered to
be necessary for all forms of agriculture. The amount of
pinyon-juniper is in part a measure of rainfall, since these
species do not grow on the drier, lower elevation parts of
the mesa. It also grows on shallow soils and moderately deep
soils, but not on the deepest soils in the higher elevations
where sagebrush flats occur instead. Pinyon-juniper forms a
thick canopy only on relatively deep soils on the higher
elevations, as reviewed in the environmental overview. If we
leave aside the problem of the high elevation deep-soil
sagebrush flats, the relative abundance of deep-soil
pinyon-juniper ought to be a measure of the arableness of the
land. By calculating the percentage of dense canopy
pinyon-juniper covering each quadrat, we should have a
variable that measures the amount of arable land in the
quadrat. If Grand Gulch habitations are located next to
agricultural fields, on the average, quadrats with
habitations should have more deep soil pinyon-juniper than
those quadrats lacking these sites.

The calculation of amount of dense pinyon-juniper on each
quadrat is based on vegetation maps produced from aerial
photographs and our botanical forms by W. Haase. Haase
Matson, Lipe and Haase (Jun. 90) IX-6 originally produced a map of vegetation classes in the west-to-east transect formed by the Hardscrabble-Bullet-North Road drainages for his M.A. thesis (1983a) used earlier in the environmental description. He later added the Upper Grand Gulch and West John’s drainages for this analysis. The vegetation maps were produced by mapping on enlarged U.S.G.S. quadrangle maps the vegetation seen on aerial photographs using a zoom transfer scope. The identity of the vegetation zones were checked by reference to the site and quadrat botanical forms and one brief field check in 1982. Once the maps have been produced, it is a relatively simple matter to determine the percentage of vegetation cover that is accurate to a percent or two by using a dot grid.

A test using percentage of dense pinyon-juniper is not fully independent of the previous elevation test since the amount of rainfall covaries with both. It might also be argued that certain quadrats that are largely bare rock will not have any sites and so should be eliminated from this comparison. However, the quadrat in the Bullet drainage with the most bare rock has no Grand Gulch sites, but does have two Pueblo sites. The one in the North Road drainage with the most slick rock does have a Grand Gulch habitation site and one of the ones in the West John’s drainage with the most bare rock has three Grand Gulch nonhabitation sites.

When using the Wilcoxon test to examine the differences between habitation and nonhabitation quadrats in amount of
deep soil pinyon-juniper coverage, we find the difference is significant at .005 (this unit normal deviate, 2.814, .005 unit deviate, 2.576). The median percentage of deep soil pinyon-juniper for habitation quadrats is 73% (mean, 68%) and only 41% (mean, 44%) for nonhabitation quadrats. So quadrats with Grand Gulch habitations tend to have more deep-soil pinyon-juniper present than those without, as illustrated in Figure IX-3. This finding is fully in accord with the agricultural model for Grand Gulch habitation sites.

One might expect quadrats that have only non-habitation Grand Gulch sites present to have lesser percentages of deep-soil pinyon-juniper than habitation quadrats. This follows from the idea that all habitation sites would be near arable soil while at least some non-habitation quadrats would be located away from arable soil, as some hunting and gathering activities would be expected to occur outside of the dense pinyon-juniper zone.

Again using the Wilcoxon test to compare the two, we find the difference is significant at the .05 level (this unit normal deviate 1.900, .03, 1.881). The median percentage of quadrats with only limited activity sites is 46% (mean, 47%) for compared with 73%(mean 68%) for habitation quadrats. Grand Gulch limited activity sites, then, are found in quadrats that have lower percentages of pinyon-juniper than habitation sites. In fact, the overall(using all 76 quadrats) expected median value for dense pinyon-juniper
Matson, Lipe and Haase (Jun. 90) IX-8 coverage is 61\%(mean, 53.8\%) which means that limited activity Grand Gulch sites found in quadrats without habitation sites are generally located in areas where deep soil pinyon-juniper coverage is less than usual, an impression one also gets from examining Figure IX-2.

To summarize, Grand Gulch habitation sites are concentrated in an elevation band that excludes the very highest elevations of Cedar Mesa and much of the lower elevations as well. This pattern is in accord with an agriculture subsistence model that assumes insufficient rainfall in the lower elevations and cold stress in the very highest elevations of the study area. In addition to climate, appropriate soils are also necessary and we found higher percentages of deep soil pinyon-juniper coverage on quadrats habitation sites. Finally, we demonstrated that the quadrats with only limited activity Grand Gulch sites do not show this relationship with deep soil pinyon-juniper. This is what would be expected if not all limited activity sites agricultural and also indicates that our results are not due to some unspecified generalized adaptation to the pinyon-juniper zone by the Basketmaker II. This overall pattern is to be expected of rainfall agriculturalists, and shows strong similairites with the later agricultural people who occupied Cedar Mesa, and agrees with the abundant remains of maize found in Basketmaker II contexts, on Cedar Mesa and elsewhere.
Of almost equal interest to the overall pattern are those exceptions to the pattern, the residuals. Evaluated first are the residuals seen in Figure IX-3, those habitation quadrats with low amounts of pinyon-juniper coverage, say less than 30%. It is quite possible for a habitation site to be located in quadrat with low percentages of dense pinyon-juniper and still be located near dense pinyon-juniper, say when the site is located on the edge of a dense area which barely extends into the quadrat. In addition, we have described other possible farming strategies, slick rock rainfall collecting, sheet wash farming, flood water farming and extreme rainfall storage farming. All of these are possible minor farming strategies that should be checked against the residuals.

The first habitation quadrat with less than 30% dense pinyon-juniper on Figure IX-3 is Bullet 18. Sagebrush covers 73% of its surface while dense pinyon-juniper covers 27% of this quadrat, which is located in a deep soil area on the divide which forms the north boundary of the Bullet drainage. This sort of deep soil divide area with abundant sagebrush is one of the areas that appears to be ideal for rainfall farming, so the presence of a habitation site here is as expected. In fact abundant areas of dense pinyon-juniper are found adjacent to this relatively high elevation (1940 m (6360 ft)) quadrat. This residual, then, is explained by the presence of sagebrush, which in this situation appears to be
indicative of arable soils. Sagebrush was set aside earlier because it occurs in a variety of circumstances, many of which appear not to be arable, and which are difficult to objectively discriminate between. Sagebrush and the relationship between sagebrush and agriculture with continue to cause problems in interpretations as is demonstrated in Chapters X and XI.

Hardscrabble 14 is also an outlier, containing very similar amount of pinyon-juniper (29%) and sagebrush (74%) as Bullet 18. This quadrat is at a lower elevation (1840m, 6040 ft), and neither the trees or sagebrush are as thick or as large as they are in Bullet 18. It is unlikely that straight rainfall farming would be successful here. The occurrence of both Basketmaker III and Pueblo components, both interpretations as habitation sites, intermixed with the Grand Gulch component, certainly suggests that agriculture was possible here. No obvious important, unusual wild plant resources are available here. Two of the alternative farming practices do appear possible, that of extreme water storage and mesa top flood water farming. There are some small sand dunes present along the edges of the pinyon-juniper within the quadrat and more extensive ones within 750 meters. None of these are very large and none of them are obvious large moisture collection areas. While the use of these small sand dunes for farming does not appear to be very practical, it is difficult to dismiss this possibility out of hand.
Matson, Lipe and Haase (Jun. 90) IX-11

There is also a large shallow wash adjacent to the sites which is not cut by an arroyo today. It is possible, perhaps even likely, that this wash in the sagebrush flats was used for mesa top flood water farming. The presence of the two other period sites certainly suggests some kind of successful farming was possible here.

Of the remaining three residual quadrats, only Hardscrabble 5 has arable soil immediately adjacent. This very low elevation quadrat (1710 m, 5605 ft) is located next to a canyon head (and a spring) with shallow soil pinyon-juniper (27%), bare rock and Blackbrush being the abundant coverage types. Some large dune areas of large sand dunes are located immediately to the south of the quadrat, as well as some smaller ones inside. The area has the largest sand dunes noted during the survey on Cedar Mesa, and appear to have moisture collection areas from some of the neighboring slickrock. Of all the quadrats surveyed, this one has the circumstances best suited for extreme water storage, or sand dune farming.

The remaining two quadrats share with Hardscrabble 5, the trait of being adjacent to canyons, or canyon heads. West John’s 17 is also located at a low elevation (1884 m, 6180 ft) next to a canyon head entrenchment with Blackbrush and shallow soil pinyon-juniper being the most common plant community types. The Blackbrush community can be taken as indicating that rainfall farming is not possible and no other
Matson, Lipe and Haase (Jun. 90) IX-12 obvious arable possibilities are adjacent. West John's 21 is located on a point between two canyon heads with shallow soil pinyon-juniper being the most abundant cover (37%). This quadrat is located at a higher elevation than the previous two (1960 m, 6426 ft) so rainfall agriculture should be possible given the proper soil and some deep soil pinyon-juniper does begin some 300 meters to the east of the quadrat.

These last three quadrats share the characteristics of being located on shallow soils adjacent to a canyon, which is also shared by Hardscrabble 5. They do not fit the general arable land model indicated above, and instead, fit our earlier "canyon rim" model which will be further discussed later in this chapter.

Turning to the elevation residuals, we find that like the amount of dense pinyon-juniper coverage, we have residuals only on the low site (Figure IX-1). Unlike the coverage case, this is due not to a one sided model, as one would expect high elevation residuals, but due to the distribution of the data with a sudden stop at about 2040 m (6700 ft) and a long tail at lower elevations.

If we consider the tail on Figure IX-1 to begin at 1880 m (6170 ft), just six meters below the first quartile, we have seven residual quadrats. Two of these have already been discussed, Hardscrabble 5 and 14, and nothing more need be said here. The other five quadrats are all found in the
Matson, Lipe and Haase (Jun. 90) IX-13
North Road drainage.

We have previously pointed out that the effects of the
SW-NE exposure trend which occurs on Cedar Mesa, as well as
in most other northern hemisphere temperate situations
(Pianka 1974:44-5). The northeast exposures are wetter,
colder, and therefore, equivalent to higher elevation than
neutral exposures, while southwestern exposures tend to be
warmer and drier than neutral exposures and, thus, equivalent
to lower elevations. Due to the spine of the mesa, quadrats
in Hardscrabble tend to have southwestern exposures and
quadrats in North Road, northeastern exposures. Thus these
low elevation North Road quadrats are equivalent
environmentally to Hardscrabble and West John's quadrats well
in excess of 1830 m (6000 ft). The lowest quadrat (North
Road 8) also has some sand dune areas within 400 meters.
Since dense pinyon-juniper usually only occurs in high
elevation, deep soil areas, it is of some interest that not
one of the five North Road quadrats are in the residual class
of the pinyon-juniper coverage, while both the non-North Road
quadrats are. While we were attempting to use elevation as a
proxy measure for effective moisture, the North Road quadrats
because of their exposure are mis-measured according to this
measure. In the final analysis, these five "residual" North
Road quadrats are examples of problems with the proxy
measure, not of habitation quadrats not fitting the general
Grand Gulch pattern.
Matson, Lipe and Haase (Jun. 90) IX-14

The true elevation residuals are thus the three "rim" quadrats (West John's 21, 17, and Hardscrabble 5) and the slightly, but not too, anomalous Hardscrabble 14, all of which were previously discussed as residuals in terms of pinyon-juniper coverage. By most measures, the most anomalous one is Hardscrabble 5, which is in a far dryer setting than the rest, although it is amidst some dune fields. It is of some interest that the single Grand Gulch habitation site in this quadrat (H 5-3) is located immediately adjacent to a dune area.

Several other ideas about Grand Gulch settlement patterns can be explored using the same variables. If rainfall agriculture is the dominant subsistence activity, not only ought habitation sites to be closely tied to arable land but also most quadrats with Grand Gulch limited activity sites would be related to agricultural activities and share the same environmental parameters. On the other hand, as we expect, if hunting and gathering contributed significantly to the subsistence, a broader range of environments would be predicted for limited activity quadrats, including some environments that would be completely unfit for agriculture.

Inspection of Figure IX-1 does show that the elevation range of the 21 quadrats that have limited activity sites but no habitation sites present does appear to be broader than that of the 32 habitation quadrats. Even though the sample size of the limited activity quadrats is smaller, it includes
Matson, Lipe and Haase (Jun. 90) IX-15 elevations both higher and lower than the habitation quadrats. Further, the interquartile range for the limited activity quadrats is 162 m (530 ft) compared to 107 m (350 ft) for the habitation quadrats. We may conclude from inspection that the postulated greater range does exist. It is quite another thing, however, to demonstrate this statistically. If we set up another pair of tables comparing dispersions, as we did in Table IX-2, we find the pattern seen in Table IX-3, with Table IX-3a being insignificant and Table IX-3b being significant at the 0.02 level. Unfortunately the major source of the chi-square value is in the right most cell, which is not indicating more dispersion for the limited activity quadrats, but instead a higher elevation for the Habitation quadrats.

In fact, the Limited Activity quadrats have a mean elevation of 1888 m (6195 ft) compared to 1926 m (6318 ft) for the Habitation quadrats which is significant at .10 (this unit normal deviate is 1.391, .10 is 1.282) according to the Wilcoxon test. So, overall, Limited Activity quadrats are located at slightly lower elevations in spite of being located both higher and lower than Habitation quadrats. Both having a greater dispersion and being located, generally lower, are in accord with the idea that many of the limited activity sites are not associated with agriculture and make up an important aspect of the Grand Gulch adaptation.

The pinyon-juniper coverage shows even larger differences
between the two different classes of quadrats. Figure IX-3 illustrates the two distributions and the interquartile range of the Limited Activity quadrats are over twice that of the Habitation quadrats. In fact, the entire interquartile range of the Habitation quadrats fits inside the third quartile of the Limited Activity quadrats. There is absolutely no doubt about a broader dispersion here.

To summary this comparison of Limited Activity and Habitation quadrats, the Limited Activity quadrats have broader dispersions in both elevation and pinyon-juniper coverage variables, and centered at lower values. Many of the limited activity sites are located in situations with no agricultural potential. This pattern is in accord with the idea that many of the limited activity sites are not related to agricultural activities.

Inspection of Figure IX-1 also indicates that our sample has incorporated the full range or "niche" of the Grand Gulch adaptation as the site density falls off both at high and low elevations. This is not the case with most of the later occupations.

<Alternative Approach>

Another way of examining the distribution of Basketmaker sites on Cedar Mesa is not variable by variable, but to look at the overall patterning. The problem with this approach is to decide which variables to use. We have developed an
Matson, Lipe and Haase (Jun. 90) IX-17 approach which partially resolves this issue, a kind of operational use of Hutchinson's niche space described in Chapter 1.

In effect, we are interested in characterizing the range of environment in which Basketmaker II population could exist indefinitely. This is analogous to one concept of "niche" as used in ecology. Determining which variables actually compose a niche is a subject of some argument. One approach is that of Hutchinson(1957) in which the niche is visualized an n-dimensional hypervolume space whose axes are determined by independent environmental factors. The boundaries of such a niche "space" would correspond to the environmental limits of the Basketmaker II adaptation.

Since its planning stages, the Cedar Mesa Project has been orientated around the use of Hutchinson's niche space model (Lipe and Matson 1971a: Lipe and Matson 1971b). As orginally defined by Hutchinson and reviewed in Chapter I,(see also Pianka 1974) the fundamental niche model expresses the relationship between a species (in our example, a population) and its environment. This concept describes a niche space in terms of environmental variables with the range of values on a variable that allows an organism to survive indefinitely, determining the length of that axis. The number and nature of the axes or variables are left undefined, but the model specifies rectangular coordinates which assumes that they are uncorrelated or
Matson, Lipe and Haase (Jun. 90) IX-18 independent. There would be little point in having much of the niche space defined by a number of different measurements of the same environmental factor as could be the case if the variables were highly correlated. Even environmentally independent variables may be correlated in a niche space as in the case of amount of water needed and temperature for most mammals.

As stated earlier, the niche space does not refer to an actual physical volume or physical space. That is, the actual geographical location of the niche space on the ground will be at points where the variables making up the hypervolume have values within the specified limits. These points might make up a single large area, or might be scattered spots depending on the nature of the environment and the niche space. While Hutchinson’s formulation is in set theoretical terms, this model can easily be conceptualized in terms of gradients (Hudson 1969:Fig. 1). In the gradient version, the probability of finding a surviving organism decreases as one goes toward extreme values but that no sharp boundary exists. It would be expected that many variables would be likely to show this sort of cline (Hutchinson 1957:416; Hudson 1969:368). This minor revision has greater realism and is more in accord with our implementation.

In the original discussion of Hutchinson’s niche concept, the two classes being considered were environmental variables
Matson, Lipe and Haase (Jun. 90) IX-19
and a species. For our use, the "Human species" is an
inappropriate subject and we refer instead to a group of
people having a similar way of life and adaptation, or an
archaeological culture. In such a usage, as recognized by
Hudson, the limits of a hypervolume would be dependent on the
implementation of cultural knowlege, as well as physical
limitations (Hudson 1969:367). In Hudson's example, referred
to earlier, commercial grain farming in the Great Plains
became feasible with the development of railroads.

The introduction brings us to our other orientating
concept, that of the Complex Adaptive System model, briefly
reviewed here (Buckley 1967,1968, Wood and Matson 1973, and
Brooks (1973). The Complex Adaptive Model is one of an open
system allowing for the importation of energy and information
and one that focusses attention on the interactions of
environment and socio-cultural systems (Buckley 1967:50).

In any adaptive system, a source of variety in terms of
responses and forms of organization is needed to cope with
variations in the environment and to serve as a pool of
potential adaptations. Along with such a source, a selective
mechanism is needed to select from the varieties produced and
yet another mechanism is needed to propogate the successful
varieties (Wood and Matson 1973:678; Buckley 1967:63).

The successful cultural variants must have a component of
environmental "mapping"; that is, the variants must be able
to continue within the ongoing environmental constraints, as
Matson, Lipe and Haase (Jun. 90) IX-20
well as to be able to respond successfully to short or long
term environmental changes. The environmental "mapping" of
a complex adaptive system would be the cultural factor in the
human application of the Hutchinson niche space hypervolume.
The extent on any dimension would be dependent on the
"organization" or "cultural practices" of a society and the
physical environment, as the given dimension must exist in
the environment before it can exist in the niche space.

The locus of change in a complex adaptive system is not
localized, but could be external or internal to the
socio-cultural system in question. Thus changes in niche
space might be the result of environmental changes, such as a
switch to hunting and gathering initiated by a shortening of
growing seasons which made maize growing unreliable as
suggested by Longacre (1970a) or be internally initiated
such as a change initiated by the development of water
control systems. In other situations it can be difficult to
describe the origin as inside or outside, even though the
cause is clear, such as in Hudson's (1969) railroad and Great
Plains agriculture.

The niche space then, can be conceived as a product of
the enviroment and the "mapping" of the complex adaptive
system model. To use these concepts we are forced to rely on
material remains of past activities, or prehistoric sites of
some sort. These sites, however, can be expected to be
located in respect to the activities taking place on them
Matson, Lipe and Haase (Jun. 90) IX-21 (Hill and Plog 1971) and reflect the niche space and the mapping.

<Development of a Hypevolume Niche Space>

Initially we thought that the environmental variables recorded on each site during survey and collection could be used to develop a hypervolume. These variables were recorded in the belief that the environmental gradients that exist today on Cedar Mesa also existed in the prehistoric past. For instance, if a certain Basketmaker II site today exists in a location that is dryer than another Basketmaker II site, it probably also existed in a relatively dryer location when occupied prehistorically, regardless of the actual vegetation present at that time.

Since the Anasazi were dependent upon maize agriculture dimensions of the environment that are correlated with arable soil and precipitation would be appropriate starting places and measurements of present day vegetations is one way to approach this. Other nonagricultural plant and animal resources should also be correlated with specific plant communities. Initial attempts (Matson 1974a) used presence-absence tabulations of vegetable classes present at each site. In spite of some initial success this approach had the drawback of not specifying the conditions where human habitation was absence.

An alternative approach used here, was to use the percentage of vegetation cover within each of the 76
Matson, Lipe and Haase (Jun. 90) IX-22 quadrats, as defined by Haase (1983a). This measure has the advantages that areas without sites are also included, as well as areas adjacent to, but not at sites. The main potential disadvantage is in the relative few plant community classes. By calculating a city block unstandardized distance matrix between individual survey quadrats, we should have a measure of how similar the quadrats are in terms of plant communities, and amount of bare rock. This matrix can then be scaled to find the minimum number of independent dimensions accounting for differences between quadrats. These dimensions should be interpretable in terms of environmental factors and, ideally, quadrats with any particular kind of sites should be limited to only certain parts of the environmental spectrum of Cedar Mesa.

This approach to "operationalizing" the n-dimensional hypervolume was developed at the same time, but independent of, similar attempts in biology. Green (1971) used multiple discriminant analysis to discern the differences between the niche spaces of 10 bivalve species and developed five dimensions, four of which were interpretable. Miracle (1974) used principal components analysis to define the niche structure in fresh water zooplankton. She was able to interpret three of the components, which accounted for 85% of the variance, and find a number of differences between niches. Makarewicz and Likens(1975) used a different approach with zooplankton, defining the niche in terms of
Matson, Lipe and Haase (Jun. 90) IX-23

depth of feeding, season of feeding, and nature of food. All of these approaches demonstrate the utility of the niche space model in nontheoretical situations, although our approach is closest to those of Green and Miracle.

<Results of Scaling>

Figure IX-4 shows the 76 quadrats as plotted on the first two dimensions, forming a pattern resembling an upside-down horseshoe. Such patterns can often be interpreted as lineal arrangements or clines, such as a temporal cline in pottery seriation, as we did earlier. In this case the cline begins on the left side of the plot and goes from three quadrats covered with sagebrush and grasses (Hardscrabble 1, 12 and 9) to two quadrats covered with sagebrush and some deep-soil pinon-juniper (Bullet 14, North Road 10) at the top central part of the curve. The downward leg of the curve apparently results from decreasing precipitation and increasing amounts of bare or exposed bedrock. First, the amount of area covered by shallow soil pinon-juniper increases, then slickrock and tree covered talus, along with decreasing amounts of shallow soil pinon-juniper, with the result that the bottom-most quadrat, Hardscrabble 11, is 71% covered by slickrock and tree covered talus.

One can also interpret this plot as a three pole graph with sagebrush at the lower left, deep soil pinon-juniper at the top, and bare rock at the bottom right. Together, the first two dimensions account for 65.5% of the squared
Matson, Lipe and Haase (Jun. 90) IX-24 distance from the centroid. In addition to the obvious gradient from left to bottom right of deep to shallow soil, effective moisture is also involved. The quadrats at the top of the plot are the ones in the most moist environments. The three factors contributing to moisture we have discussed before are that of exposure, elevation and position on the north-south axis of the mesa. The ten quadrats highest on the vertical dimension have a median elevation of 1930m (6,333 ft) compared with 1804m (5,920 ft) for the ten bottom most. The north/south trend is seen in that only seven of the 40 quadrats from the three northern drainages are below the midline on this figure.

The trend from deep soil vegetation, such as dense pinon-juniper to increasing amounts of shallow soil vegetation and bare rock is also correlated with distance from quadrat to canyon rim. When comparing distance from canyons for the ten quadrats at the bottom right of Figure IX-4 with the ten quadrats at the bottom left of the figure the results are as expected. Using an arbitrary depth of 50m (160 ft) to define an entrenched canyon, we measured from the center of each quadrat to the nearest such canyon. The ten quadrats at the lower right have a lower quartile of 90m, a median of 255 m and an upper quartile of 560m, compared to 690, 1120 and 1300 meters, respectively of the 10 quadrats at the lower left hand side of the plot. According to the Wilcoxon two sample test this difference is significant at
the .001 level. While this is a very strong relationship, it is not perfect, as quadrat Hardscrabble 12 of the deep soil group is only 180 meters from a canyon rim, and one quadrat from each of the two groups are 660 meters from the nearest canyon (Hardscrabble 10 and Bullet 19). The general trend, however, is clear; deep soil areas are found away from canyon rims while rocky shallow soils areas are generally adjacent to rims.

The first two dimensions not only account for most of the interpoint distances but also agree with the postulated two most important environmental factors, edaphic soil depth and effective precipitation. Precipitation increases both with elevation and along a northward mesa top trend. These two general environmental factors are two of the most important for maize agriculture as well, as pointed out in Chapter VIII. Some problems still exist, however. The most apparent one is the multiple locational nature of sagebrush. As noted above sagebrush grows in the deepest soils at the highest elevations of Cedar Mesa, in the shallow mesa top valleys in the middle elevations, and generally replaces pinon-juniper on moderately deep soils at lower elevations of the plateau. Bullet 18 is an example of the first location(elevation 1940m), while Hardscrabble 14 is an example of the last, located at an elevation(1840m) where deep soil pinon-juniper is being replaced by sagebrush, yet these two quadrats are located adjacent to each other on Figure IX-4. So changes in
Matson, Lipe and Haase (Jun. 90) IX-26
the nature and meaning of the 11 coverage classes are not
necessarily reflected in this scaling, particularly when only
a few cover classes are present--but the sagebrush problem
also was present in the earlier presence-absence trial
(Matson 1974a).

Because the environmental interpretation of the first
two dimensions are well in accord with <a priori> ideas about
Cedar Mesa's environment, we can tentatively evaluate the
niche space at this point. As predicted it is evident that
the majority (25/32) of the quadrats containing Basketmaker
II habitations are found above the midline in Figure IX-4,
located in deep soil pinon-juniper. Only three quadrats with
habitations (Hardscrabble 5, West John's 17 and 21) are
located any distance below the midline. These are the same
three residual found before, all located in portions of the
niche space adjacent to canyon rims. Figure IX-4, then,
provides a visual summary of the settlement location of
Basketmaker II Grand Gulch Phase habitation sites, complete
with the same exceptions noted previously in the variable by
variable analysis.

The next two dimensions are less important and together
contribute only 23.6% of the squared distance from the
centroid (Figure IX-5). There is a large clump of quadrats in
the center of the plot, surrounded by a few outlyers. In
situations such as this, it is usually best to look just at
the outlyers for interpretations. The outlyers at the very
Matson, Lipe and Haase (Jun. 90) IX-27

top of Figure IX-5 have abundant slickrock and tree covered
talus slopes, but lack the shallow soil pinon-juniper usually
found in such situations. Quadrats at the bottom of the plot
contain shallow soil pinon-juniper and mixed
sagebrush/blackbrush community. The latter plant community
is generally found on shallow soils, and tends to be a lower
elevation replacement for pinon-juniper. The lowest five
quadrats in Figure IX-5 have a median elevation of 1873 m
(6,145 ft) while two in this group (Hardscrabble 2 and 10)
are found below 1800 m (5,900 ft). At even lower elevations,
this mixed plant community is replaced by stands of pure
blackbrush. Quadrats dominated by this community are found
on the left side of Figure IX-5, spread out along dimension 4.
Within these quadrats pinon-juniper trees no longer grow on
talus and are replaced by blackbrush on this landform as
well. These quadrats are all very low in elevation, with
none above 1770m (5,800 ft).

By examining the center cluster of the quadrats, it can
be seen that the group of West John’s 12, 2, North Road 10,
and Bullet 14 are covered with deep soil pinon-juniper, while
shallow soil pinon-juniper increases toward the right. In
effect, quadrats with deep soil pinon-juniper are found at
the center of the cluster, while percentages of this plant
community type diminish with distance from the cluster. Most
quadrats located away from the center of the cluster are
found in the dryer Hardscrabble and West John’s drainages.
In terms of niche space, we would expect habitation sites to be concentrated in the central cluster of quadrats, and that is what is seen on Figure IX-5, with the exception, once again, of West John's 17.

The last two dimensions, five and six, contribute only 11% of the squared distance from the centroid, contribute little interpretable information and are not illustrated. All the quadrats distant from the center are low elevation, with the fifth dimension again contrasting pure blackbrush communities with those of mixed sagebrush and blackbrush. The last dimension may contrast low elevation sand dune quadrats with those that are covered with low elevation talus and, possibly, grass.

To summarize the interpretation of the "hypothetical" niche space for Basketmaker II habitations as implemented through percent of vegetable cover within each quadrat, the most important dimensions are soil depth and precipitation. These factors can be seen to interact in the first two dimensions. The next two, less important factors, deal with some aspect of less effective moisture, with all "heavily weighted" quadrats being ones of low elevation from the Hardscrabble and West John's drainages. In terms of "realized" niche space, quadrats with habitation sites are confined to higher elevation areas with deep soils and pinon-juniper trees, with the three recurring exceptions found near canyon rims.
From the analysis of variance approach discussed earlier, it would be expected that quadrats which have limited activity, but no habitation sites present, would occupy a less restricted niche space than habitation quadrats. Figure IX-6, which illustrates the first two dimensions with these two classes of quadrats indicated, demonstrates that this is indeed the case. Particularly noticeable is the concentration of limited activity sites in rocky, lower lying quadrats close to canyon rims, and their absence in deep soil heavily forested areas. Limited actively sites occur in drier rocky areas where habitation sites, except for the "rim" subgroup, do not. Neither kind of site is found in the deep soil areas in low elevation contexts (lower left on Figure IX-6).

Figure IX-7 shows the third and fourth dimension of the niche with the quadrats that contained only limited activity sites indicated. As anticipated, distribution of these sites is much broader than that of contemporary habitations.

Quadrats with only limited activity sites have a niche hypervolume, not only larger than the habitation quadrats, but also one of different dimensions. Comparatively, limited activity sites are found in lower elevations and rocky, rim environments, away from deep soil areas. Thus we find them located well out on dimensions three and four where habitation quadrats are essentially absent.
One of our original basic expectations was that Basketmaker II base camps would be located to provide access to both canyon and mesa top (Lipe and Matson 1971a:36). If we equate our habitation site class with the 1971 base camps all we need to test this idea is a measure indicating rim location to test this idea. We used the definition of canyon described earlier and the center of the quadrat to get distance measures. This definition of canyons is far from perfect, in particular in that high mesa top areas where some canyons seem to start but then spread out and walls decrease to less than 50 m, but should give an approximate measure.

Figure IX-8 is a box-and-dot plot of quadrats and shows that the median distance for habitation quadrats is 540 meters; for all other 530 meters. The Wilcoxon test indicates there is not a significant difference with the rank sum indicating, if anything, that the habitation quadrats are farther than expected from the canyons.

Comparing quadrats with habitation sites with those that have only limited activity sites (Figure IX-8) results in the finding that limited activity sites are closer to canyons (median of 385 m) than habitation quadrats, significant at the .10 level (Wilcoxon test). Limited activity quadrats are also significantly closer to the rims than those quadrats without any Basketmaker II sites (Figure IX-8). Empty
Matson, Lipe and Haase (Jun. 90) IX-31 quadrats have a median distance of 660 m which is also significant at the .10 level according to the Wilcoxon test. Quadrats with any kind of Grand Gulch phase sites have smaller median distances (430 m) than the rest of the quadrats (660 m) but the rank sum is not significant.

All of these results are in accord with the pattern seen in the niche space analysis and the initial analysis of variance approach. Unfortunately it is not in accord with the results reported earlier (Matson and Lipe 1975; Matson 1974b: Matson and Lipe 1978) as confirming our initial idea that habitation sites are located close to the rims.

Our first confirmation of the pattern was based on the Bullet drainage which showed both in terms of artifacts per quadrat and sites per quadrat that the "rim" quadrats had more Basketmaker material than the divide quadrats. We interpreted these results as supporting the rim hypothesis. We reran these tests using our finalized counts and classifications. We used a judgemental decision as to whether a quadrat was divide or rim in nature. Only nine quadrats were defined as rim quadrats according to this impressionistic criteria, while 12 were classed as divides. This might suggest that increased distance to rim is correlated with increased elevation and that is what is shown in Figure IX-9.

Using artifact totals per quadrat and the Wilcoxon test, the difference between the two samples is just significant at
Matson, Lipe and Haase (Jun. 90) IX-32
.10 (.10 significant rank sum is 80, this rank sum is 80).
Using number of Basketmaker II sites per quadrat the
difference is also significant at .10 (This rank sum 77.5).
In both case, the difference appears to be the presence of
more empty quadrats in the divide group of quadrats. So even
with revised data and different measures of rim and divide,
the previously reported pattern is confirmed. If we use our
more objective measure of distance to the m canyon and using
1000 meters as a cutoff distance between rim and divide
quadrats, neither site nor artifact totals are significant
but both trends, however, are in the direction postulated by
our original hypothesis.

One of the "false" canyons mentioned above, that start in
the high mesa area and then spreads out, is located just to
the south of a trio of quadrats, Bullet 8,10, and 21, that
was densely occupied during the Grand Gulch phase. These
facts make the definition of canyons critical to the results,
and in both the present impressionistic and more objective
distance measures, the "false" canyon was not considered a
canyon, although it was earlier and this accounts for the
higher significant figures reported earlier. The rationale
used to eliminate this "canyon" was that it was not connected
to a main canyon nor was there any canyon bottom alluvium to
farm.

The reason for the Bullet pattern to run counter to the
overall trend in Basketmaker II settlement pattern is that
Matson, Lipe and Haase (Jun. 90) IX-33 increases in distance to canyon is correlated with increasing elevation. The median distance to canyon in the Bullet drainage is 1180 meters, over twice that expected overall, with six of the seven quadrats that are over 2500 meters from a canyon are from the Bullet drainage. Thus "divide" quadrats include the upper elevation truncation of the Basketmaker II settlement pattern discussed above. Even within this portion of the "niche" though, there is not a strong trend for <habitation> sites to be located towards the rim, as the measures used to demonstrate the counter trend did not include type of site.

In short, our original idea about base camps(Habitations) being usually located on the rim areas to have access to both canyon bottom and mesa top is clearly falsified. Habitation sites are occasionally located near rims, but these are clearly a minority, a residual class. On the other hand, quadrats with only limited activity sites are located in rim situations. Not only are limited activity sites located to canyons than expected, but the hypervolume pattern analysis indicates they tend to be located in shallow soil and slickrock areas. Previous interpretations of some of these limited activity sites as "base camps" may have also previously confused things. In particular, sites such as the three in Hardscrabble 11, immediately adjacent to a canyon, were classified as "multiuse" by Camilli (1975), which we previously took to mean "base camps", are now classed as
Matson, Lipe and Haase (Jun. 90) IX-34 non-habitation campsites. Only a few such instances are needed to result in a different interpretations to the settlement pattern.

A further misleading aspect has to do with the interpretation of the nature of "site furniture." Previously, we had shown (Matson 1974b; Matson and Lipe 1978) that there was a correlation between shallow soils and percentage of core tools and deep soils and the percentage of flake tools. Since, as everyone knows, core tools are associated with base camps, we interpreted this relationship as further confirmation of base camps being located on rims. Actually, of course, the relationship is that limited activity sites have a greater proportion of core and groundstone tools than habitation sites as reported in Chapter V, so the current interpretation of this relationship is directly opposite to our earlier statements. We will show, however, in Chapter XI, that of the three occupations, the Grand Gulch Habitations are the closest to the canyon rims.

<Site Class Locations>

<Limited Activity Sites (Groups 0 and 1)>

The most ephemeral Basketmaker II site class is that of Group 0, small limited activity sites, those sites with less than 12 lithic tools recovered. With such a small sample of tools, it is difficult to make functional judgements, as such
Matson, Lipe and Haase (Jun. 90) IX-35
a site could have been used intensively once or for short
durations several times. It is likely that both situations
occur within this group. Of some interest is the fact that
no quadrat had only a Group 0 site present; there were always
other kinds of Grand Gulch sites also present. Half of the
six quadrats that had Group 1 sites present, but not Groups
2, 3 or 4, also had Group 0 sites present. Only seven of the
17 quadrats that had campsites, but not Groups 1, 3, or 4 had
Group 0 sites present and nine of the 23 quadrats with
habitations present but not Groups 1, 2, or 4 had Group 0
sites present. We had previously argued that small limited
activity sites (Group 0) were most similar to the larger
limited activity sites (Group 1) and this association
suggests a similar locational pattern. Certainly, Group 0
sites are not intensively used sites of long duration. Based
on similarity of site facilities, tools, debitage and
associations, we will now consider these two groups together,
as limited activity sites.

In general, as we argued before, we expect hunting to be
an important activity in this class. This is based on the
observation that projectile points and bifacially
resharpening flakes have their highest abundance in this
class. It may be that denticulates, which also have their
highest abundance in this class of sites, are also related to
hunting and butchering. Limited activity sites are occupied
for only short durations and have very few site facilities
Matson, Lipe and Haase (Jun. 90) IX-36
with ash and sandstone slab hearths being the only features
occurring in any frequency, and these are usually absent.

If limited activity sites do have a strong hunting
emphasis, we would not expect them to be confined to the same
narrow band of elevation and environment as habitation sites.
At the same time, these sites might be expected to be
present in the agricultural area. As pointed out earlier,
Bye (1981) and Ford (1984) have argued that one of the
benefits of maize agriculture is that current and abandoned
fields have a much higher production of both large and small
game animals than the undisturbed climax situation. Thus,
agriculture may increase the amount of game available at the
same time it behooves the farmer to keep the numbers of game
down to protect his crops. One would, however, not expect
hunting camps to be maintained near habitations or that game
would have their peak abundance near habitations. Day trips
to fields near habitations would be carried out without the
development of separate hunting sites. Overhunting would
also be expected to occur in the areas adjacent to the
habitation sites, at least for larger game. Even in the
absence of habitations and farming plots, present and past,
the pinyon-juniper areas would be expected to be some of the
better hunting areas on Cedar Mesa. It is difficult to
predict which effects would dominate, whether hunting sites
(and thus limited activity sites) would be concentrated in
the pinon-juniper zone or not. In general, the initial
Matson, Lipe and Haase (Jun. 90) IX-37 statement of broader range, including the habitation zone, appears to be the most appropriate.

One might also expect that at least one other environment to be exploited in addition to the pinon-juniper community. This is the relatively low lying areas in West John’s and Hardscrabble that are the only areas today on Cedar Mesa with significant amounts of grass, areas generally higher in elevation than the extensive blackbrush belt, but lower than the sagebrush. If grazing is important to game animals, there are the only present areas with extensive grass, and so might be expected to have higher amounts of game than elsewhere.

The probability of site facilities and the length of duration of occupation of hunting camps might both be expected to increase with increasing distance from habitation sites. In other words, staging "campsites" might exist for hunting in areas far from the "habitation" belt. These hunting related sites would turn up as campsites or Group 2 sites if this process was carried far enough.

If hunting takes place over a broader environmental range (in a large niche space) than agriculture and our limited activity sites are mainly hunting sites, we would expect that limited activity sites would be distributed over a broader range and have a lower central tendency in terms of elevation than habitation sites. The lower elevation would be expected because habitation sites are concentrated in the higher
Matson, Lipe and Haase (Jun. 90) IX-38 elevations. Thus we might expect the average elevation of limited activity sites to be the same as the overall 76 quadrats.

Comparing the elevation of the 20 quadrats that had only limited activity site present with the 56 other quadrats (See Figure IX-1) with the Wilcoxon test results in no significant difference at the .10 level. The population parameters are (L.A.S. versus 56 others) means—1884 m (6184 ft)—1911 m (6272 ft), first quartile—1786 m (5860 ft)—1840 m (6040 ft), medians 1892 m (6213 ft)—1934 m (6348 ft), third quartile—1977 m (6490 ft)—1992 m (6540 ft). This finding indicates that limited activity sites are spread throughout the elevational range of the quadrats—if anything with a lower central tendency and a broader range than expected.

If the limited activity quadrats have elevations not significantly different from all other quadrats, we would expect them to be significantly lower in elevation than habitation quadrats, given the tendency for habitation quadrats to be concentrated in the higher elevations. Figure IX-1 does appear to demonstrate this. Grouping the 11 quadrats that had both habitation sites and limited activity sites into both classes, the Wilcoxon test indicates that the difference is significant at the .10 level (this unit normal deviate, 1.439, .10, 1.282) in spite of the overlapping quadrats. Not only is the elevation of the limited activity quadrats lower than that of the habitation quadrats, but the
Matson, Lipe and Haase (Jun. 90) IX-39
interquartile range is also wider, 192m (630 ft) compared to
110 m (360 ft). In fact, 19 of the 32 habitation sites fit
within the "midbreadth" (interquartile range) of the limited
activity quadrats, in spite of the lower elevation of the
limited activity sites. Conversely, only six of the 20
limited activity quadrats fall within the midbreadth of the
habitation quadrats. Relative to habitation sites, limited
activity sites show both a broader elevational distribution
and an tendency to occur at lower elevations.

While deep soil pinon-juniper is a good measure of arable
land, it is not necessarily a good measure of game
productivity. Therefore, one might expect a weaker
association with deep soil pinon-juniper for limited activity
sites than for habitation sites. One might particularly
expect this in light of the grassland distribution discussed
above. On the other hand we stated in 1971 (Lipe and Matson
1971a) that all Basketmaker II sites are strongly associated
with pinon-juniper. If this is the case we might expect a
similar distribution of dense pinon-juniper in both
habitation and limited activity quadrats. The values are
shown in Figure IX-3. According to the Wilcoxon test, the
difference in percent coverage of the 20 limited activity
quadrats and the 32 habitation quadrats is not significant
(or even close to significant). The population parameters
are (limited activity--habitation) mean-59.5%--67.8%, first
quartile-23%--50%, median-76%--73%, third quartile 91%--88%. 
Matson, Lipe and Haase (Jun. 90) IX-40
While there is no significant difference in central
tendencies between the two site classes, there is a
noticeable difference in dispersion with the limited activity
quadrats having an interquartile range of .68 compared to
only .38 of the habitation quadrats. The midbreadth of the
limited activity quadrats would include 25 of the 32
habitation quadrats(Figure IX-3), but the midbreadth of the
habitation quadrats would include only six of the 19 limited
activity quadrats.

The overall mean percent of the 76 quadrats covered by
deep soil pinon-juniper is 53.75%, considerably lower than
that measured on limited activity activity quadrats. Since
the amount of deep soil pinon-juniper coverage on habitation
quadrats was found to be significant from the overall at the
.005 level, and since limited activity and habitation
coverage are not significantly different, we can safely
assume that the limited activity quadrats are also
significantly different from the overall coverage, at least
at the .10 level.

What these results indicate is that limited activity
quadrats are associated with dense pinyon-juniper, as
postulated in 1971, but not with high elevations. The
elevations associated with limited activity sites are both
lower than those associated with habitation sites and spread
out through a greater range. This distribution is in
accord with the idea that they are related to hunting and are
Matson, Lipe and Haase (Jun. 90) IX-41
not limited to the agricultural band or tightly associated
with habitation sites. At the same time the close
association with pinon-juniper shows that most limited
activity sites are located there--the central tendency is the
same as for habitation sites--but the range shows a broad
dispersion, much broader than for habitation sites.

If the limited activity quadrats include hunting as a
major activity, then these sites ought also to possess the
"overview" attribute. This was orginally defined by
Judge(1973) in terms of ability to see into areas which might
have game. Pokotylo (1978,1981a) was able to show that
overview was an important factor on hunting camps in the
Upper Hat Creek Valley of British Columbia. If overlook is
also a factor for limited activity sites during Grand Gulch
times, they ought to be located in areas of shallow soil
pinon-juniper, since almost all high areas with an overview
on Cedar Mesa have thin soils at their edges. So if one is
located in a place to over look a canyon, or a sagebrush or
grassy area, the chances are that one will be on an area of
thin soil.

A good comparative group would be the habitation quadrats
since we have found that both quadrat classes select for deep
soil pinon-juniper areas. So our hypothesis is redefined as,
compared to habitation sites, limited activity sites will be
found in quadrats with more shallow soil pinon-juniper as the
result of selecting for overview locations. The comparative
Matson, Lipe and Haase (Jun. 90) IX-42 parameters are (limited activity--habitation) mean, 10.65%--7.1%, first quartile 1%--0%, median 8%--.5%, third quartile 18%--20%, and the two distributions are significant at the .05 level, according to the Wilcoxon test (this unit normal deviate, 1.765, .05 normal deviate is 1.645). Limited activity quadrats, then, do have significantly more shallow soil pinon-juniper cover than do habitation quadrats.

Other factors might account for the increase in shallow soil pinon-juniper. Closeness to canyon rims might also have the same effect and was checked using the distance to 50m measure developed above. The population parameters are (limited activity--habitation) mean 668m--1044m, first quartile 230m--230m, median 320m--590m, third quartile 950m--1900m and according to the Wilcoxon test are not significant at the .10 level (this unit normal deviate .916, .10 normal deviate is 1.282). Since a quadrat has to be relatively close to a canyon rim for this factor to become important, the identity of the first quartiles indicates that this factor is not responsible for the difference in amount of shallow soil. The difference in third quartile suggests that habitation quadrats are sometimes located very far from canyon rims, while limited activity sites are not, a pattern noted earlier with other variables. In conclusion the overview attribute appears to be a reasonable explanation, and a possible factor in selecting limited activity site locations.
Thus far the hypothesis tested indicate that limited activity quadrats and sites are associated with deep soil pinon-juniper, but in lower elevations and with more shallow soil than habitation quadrats. The limited activity quadrats show a greater dispersion than habitation quadrats in both elevation and percent covered by deep soil pinon-juniper. All these are in accord with a non-agricultural function involved in limited activity sites, in particular hunting, as suggested earlier on the basis of tools found in this site class. On the other hand, habitation sites have a greater dispersion with respect to canyon rims than limited activity sites, suggesting that limited activity sites are more focussed on canyon rims than habitation sites. Let us turn briefly to the hypervolume model to see if this pattern is confirmed there.

<Hypervolume>

Figure IX-10 is the first two dimensions of the niche space hypervolume coed for the limited activity quadrats, which again includes all quadrats that have limited activity sites, whether or not habitation sites are also present. Notice that all but one (West John's 13) are located on the descending right leg of the horseshoe. This illustrates the concentration of limited activity sites away from the deep soil sagebrush areas with 18 of the 19 quadrats being in deep soil pinon-juniper environments to more shallow soil areas of
Matson, Lipe and Haase (Jun. 90) IX-44
pinon-juniper and slickrock. While only 31% of the total 76
quadrats are below the midline, nine of the 19 limited
activity quadrats are. This pattern visually confirms the
results of the hypothesis testing and also gives one an idea
of the interaction between variables.

Figure IX-11 shows the third and fourth dimensions, coded
as Figure IX-10. Limited activity quadrats are found in the
extension to the bottom and are relatively absent on the top.
The lower part of the third dimension we interpret as one of
mixed blackbrush-sagebrush community, so these figures show
limited activity quadrats extending into lower and rockier
settings and into lower deeper soil settings than habitation
sites.

Limited activity quadrats thus fall into the pattern
expected of hunting sites, but might also fit other
functional patterns. We suggested a possible additional
aspect was that the low lying grassy areas might also be
selected by hunters. To see if this was the case we examined
those quadrats that have large grassy areas nearby and that
have pinon-juniper present. We found eight such quadrats in
the Hardscrabble drainage and six in West John’s for a total
of 14. Six of these have limited activity sites present.
Remembering that only 20 of 76 quadrats have only limited
activity sites (Groups 0 or 1) present, this is higher than
expected by chance which indicates that limited activity
sites are as common in this setting as they are anywhere.
Matson, Lipe and Haase (Jun. 90) IX-45
These same fourteen quadrats have eight of the total 36 total campsites present, a bit more than expected. On the other hand, only four of the 52 habitation sites are located in these 14 quadrats, only a third of the expected. So this area is one that is well utilized during the Grand Gulch phase, although not for residential purposes. This use is in accord with the hunting function of limited activity sites, although not exclusive to hunting and we will suggest alternative uses of this region below.

<Campsites (Group2)>

The campsites show more evidence of residential use than the limited activity sites, but less than the amount seen on habitation sites. Sandstone slab hearths and cists are common, as well as ash hearths. Compared to limited activity sites, there are less projectile points in this group, and site more frequently have core and groundstone tools present--the residential site furniture group--although these make up a lower proportion of the total assemblage. Because of the more residential nature of this site type, it is difficult to discern other functions in terms of artifact profiles, since most tools found on these sites can be related to the residential aspects. We will attempt to test four different ideas.

In our discussion of the limited activity sites, we pointed out that hunting in areas some distance from habitation sites might not result in limited activity sites,
Matson, Lipe and Haase (Jun. 90) IX-46 but campsites. Campsites would result because if one is going to travel a long way, one might as well be gone sometime, and if this is so, set up a relatively complete campsite. Such a site would act as a staging point, perhaps with subsidiary hunting sites of the limited activity nature around it, or perhaps not. Figure IX-12 illustrates this idea in a diagrammatic style. One would expect such campsites to be located at some distance from the habitation "zone", in areas that would be productive for hunting and thus have very little groundstone tools. Such sites might be reoccupied fairly frequently, giving rise to site facilities (hearth, cists?) and site furniture.

Residential activities would also take place where procurement activities occur regularly because resources are abundant and predictable. If we imagine that hunting campsites exist because of a small single sex group going a long distance from the habitation zone for some time, we can think of a larger multi-sex and multi-age group going a relatively shorter distance, but for a relatively longer time, would also result in a campsite. Even if such an area was but a few miles from one's habitation, if entire family groups are going to go there regularly for some days, setting up a campsite may make economic sense. Of course, the further away from a habitation such an area is, the more likely a campsite will be established.

We can suggest three plant procurement systems that might
Matson, Lipe and Haase (Jun. 90) IX-47 result in such camps. Indian rice grass is an important staple and at Cedar Mesa grows best in low lying areas, especially so in some of the low lying dune areas in Hardscrabble and West John's. These are significantly lower than the habitation "zone", particularly in Hardscrabble. Areas with dense reliable Indian rice grass might thus also be expected to have campsites present.

A second procurement system would be the previously discussed extreme water storage agricultural strategy. This, too, would take place in low lying areas quite distant from most habitations. Here, there would be an even closer relationship with dunes, as it would be among the dunes that the fields would be planted. Haase(1983) has argued that such agricultural field stations would show more residential activities than most others because they are located far from habitation sites. In addition, since labor in in the most demand around harvest time, it is argued that cists for temporary storage would be found in this situation with the maize and other crops to be transported back to the habitation sites at ones leisure after the harvest season.

Both these types of vegetable processing sites have similar settlement pattern implications, particularly since cists might also be expected in rich Indian rice grass areas. While closeness to substantial sand dunes, which are more critical for agriculture, may offer a way of separating them, for now we will consider the settlement pattern expectations
Matson, Lipe and Haase (Jun. 90) IX-48 as identical.

A third important procurement system is pinyon nut harvesting. Due to the ubiquitous nature of pinyon trees on the higher portions of Cedar Mesa, it is difficult to see how to develop settlement implications for this, particularly since arable fields, or at least habitations are also concentrated in the pinyon-juniper. The tools expected to be found on pinyon camps vary, as if the cones are collected but not processed, groundstone is not necessarily present. Other than a concentration on the higher elevations, there is little in terms of expectations. On all plant processing sites, one might expect some groundstone and little in the way of projectile points.

Campsites might also come into being at agricultural field stations in the pinyon-juniper that are located some distance from habitations. These would be very difficult to distinguish from pinyon processing campsites and would have settlement pattern implications similar to habitation sites. We will return to the question of agricultural field stations in more detail later when we deal with sites as the unit of analysis rather than quadrats.

While a number of different activities possibly related to campsites with a number of different settlement implications can be proposed, what can be stated about overall expectations? Because several proposed activities take place at lower elevations than the concentrated
Matson, Lipe and Haase (Jun. 90) IX-49 pinyon-juniper zone, we can predict a lower elevation overall than the habitation quadrats, as well as a broader range. Further, since some activities are related to pinyon-juniper areas and others are not, we can expect a much broader range of deep soil pinyon-juniper coverage than habitation sites, as well as a lower central tendency.

If campsites have more evidence of residential activity than limited activity sites, we would expect campsites to be lower in elevation than limited activity sites on the basis that campsites are the results of stays more distant from the habitations. If campsites are occupied for long durations than limited activity sites and occupied in the same seasons, we might expect campsites to be located closer to permanent water than limited activity sites.

The presence of some pinyon-juniper trees is a given. Almost all Cedar Mesa sites are located around pinyon-juniper trees probably because of factors of shade, building materials and firewood. This constant association supports the inference that edaphic factors control the boundaries of most plant communities and that such climatic change that has occurred in the last 1800 years has not been enough to override these factors.

Turning to the specific hypotheses, we find (Figure IX-1) the 27 quadrats with campsites present do have a significant lower elevation than habitation sites (this unit normal deviate 2.176, .025 probability has a normal deviate of 1.96
Matson, Lipe and Haase (Jun. 90) IX-50 and .01 one of 2.33. The population parameters (campsite quadrats—habitation quadrats) are mean 1873m(6145 ft)—1926m(6319 ft), first quartile 1790m (5880 ft)—1884m(6180 ft), median 1887m (6190 ft)—1948m(6390 ft), third quartile 1957m (6418 ft)—1993m (6540 ft). The interquartile range of the campsite quadrats is 164m compared with 110m for habitation quadrats. Even though the campsite midbreadth is broad, only 13 of the 32 habitation quadrats fall within it because of the habitation quadrats higher elevations.

According to the Wilcoxon test there is not significance difference between the amounts of dense pinyon-juniper coverage found on campsite and habitation quadrats (this unit normal deviate .882, probability of .19 unit normal deviate .878). As is seen on Figure IX-3, there is, however, quite a difference in range. For campsite quadrats, the interquartile range is 18—94%, for habitation quadrats, 50—87%. If we test to see how many of the 32 habitation quadrats fall within the interquartile range of the campsite quadrats, we find 26. This gives a chi-square of 12.50, highly significant (d.f. of 1, probability of .01, chi-square is 6.35). If we check to see how many of the campsite quadrats fall within the habitation interquartile range, we find that only six do, resulting in a chi-square of 8.32. So while the pinyon-juniper coverage central tendency for the campsites quadrats does not appear to differ from the
Matson, Lipe and Haase (Jun. 90) IX-51
habitats (although it is in the predicted directions), the
dispersion is, as predicted, much greater.

Examining the elevation differences between limited
activity sites and campsites, we do not find a significant
difference according to the Wilcoxon test. In fact, the unit
normal deviate is only .323, one that would occur by chance
26% of the time and it is in the direction of the limited
activity sites being <lower> than campsites. Inspection of
Figure IX-13 shows no apparent differences in dispersion with
near equal distributions in every way.

A similar comparison of distance to nearest permanent
water source has a number of problems with it. First,
springs that exist today may not have existed in the past and
vice versa. This problem is particularly so in the canyons
that today have had their alluvium cut-out. Today water is
generally available in these arroyos, but was it when the
alluvium was intact? Description of other areas in the
southwest before arroyo cutting took place in the late
nineteenth century indicates that the canyons may well have
had water sources previously. Usually, though, these lower
canyon water sources are not the ones closest to the mesa top
and so do not figure in most of these measurements. Another
problem is that while we have a good knowledge of present
day water sources within the five drainages, we do not from
neighboring drainage areas. Thus we can usually be fairly
certain about the distance to the nearest water source within
Matson, Lipe and Haase (Jun. 90) IX-52

the drainage but not about water sources in neighboring
drainages. Many quadrats on the edges of the five drainages
may be closer to unknown water sources in adjacent areas than
to the known ones within the drainages.

When the Wilcoxon test is used to compare the distances
to the nearest known water sources for all quadrats with
campsites versus all quadrats with limited activity sites
(eight quadrats had both) a unit normal deviate of 1.108
results, which is not significant at .10 (unit normal deviate
of 1.281, approximate probability of 1.108 is about .14).
All of the eight quadrats that had both classes of sites
present had distance to water at or below the joint median.
The population parameters (campsite--limited activity
quadrats) mean 530m--668m, first quartile 250m--300m, median
350m--650m, third quartile 800m--1100m. Notice that the
interquartile range of the campsites quadrats is only 550m
compared to 800m for the limited activity quadrats. If we
rerun this test to compare those quadrats that have campsites
with those that have limited activity sites but <no>
campsites, we find a unit normal deviate of 2.237 significant
at .015 (.015 deviate is 2.17) with sample sizes of 12 and
27. We can conclude then, that quadrats with campsites do
appear to be closer to known water sources than quadrats with
limited activity sites--or at least significantly closer to
water than quadrats with limited activity sites and no
campsites.
Matson, Lipe and Haase (Jun. 90) IX-53

Turning away from the univariate analysis of variance approach, let us inspect the patterns seen in the niche space hypervolume. Dimensions 1 and 2 (Figure IX-14) plot campsites over much of the distribution, supporting the percent coverage of dense pinyon-juniper test. Campsites range almost as far as habitation sites to the deep soil sagebrush end of the continuum, yet are also abundant at the other end in low elevations with substantial bare rock coverage. Neither here, nor in the elevation test is a shift to bare rock or low elevation compared with the limited activity sites that would explain nearness to water on that basis.

Figure IX-15 diagrams dimensions 3 and 4 with campsite quadrats indicated and demonstrates a wide-spread distribution. While campsite quadrats are not as confined to the center cluster as habitation quadrats, a larger proportion may be there than is the case for limited activity quadrats. Campsite quadrats are also found in the most extreme locations, including West John's 15, the most extreme of all. In sum, the hypervolume pattern, supports the results of the analysis of variance but adds little new, showing the campsite quadrats have a very wide-spread distribution, distinguished in terms of central tendency only in closeness to water. This conclusion may change as we turn to possible functions.

We have suggested separate functions of hunting and vegetable food processing, possibly separable on the basis of
Matson, Lipe and Haase (Jun. 90) IX-54 artifact assemblages. Within vegetable food processing we have suggested four possible activities, which occur in pairs that are indistinguishable in terms of locations and expected artifacts, that is, between Indian rice grass and sand dune agriculture procurement systems on the one hand, or between pinyon nut campsites and pinyon-juniper agricultural camps.

First we inspected all campsites to see if projectile points and fragments or groundstone was present on the basis that hunting would result in projectile points and that seed processing would result in groundstone. If both were present, the site was considered to fit both categories (Actually groundstone is a better indicator of vegetable food processing given other uses of projectile points and their greater portability). If neither groundstone or projectile points were present, the site was placed into a question mark category. Quadrats were then classified as to which class the campsites found within belonged. The result of this procedure were 14 quadrats classified as "hunting", eight as "vegetable processing" and 10 as questionable. Five of the quadrats were classed as both hunting and vegetable food processing.

Hunting quadrats would be expected to show a broader dispersion both in terms of deep soil pinyon-juniper and elevation than vegetable food processing quadrats. The low elevation sand dune areas are still on top of the mesa, and in some cases, not far from deep soil pinyon-juniper, while
Matson, Lipe and Haase (Jun. 90) IX-55 mountain sheep might be expected to be hunted from even lower elevations and more distant from the habitation zone. Because of this factor we might also expect the central tendency to be lower for hunting campsites as well.

Table IX-4 gives the parameters for these two variables, while Figures IX-16 and 17 show the actual data points. Notice that the central tendencies are reversed from our predictions with "hunting" quadrats being located at higher elevations and having more pinyon-juniper coverage than the vegetable processing ones, but not significantly so in either case.

Figure IX-17 seems to show a greater difference between the two subclasses, with hunting seemingly being both more concentrated in the dense pinyon-juniper and having a wider dispersion. Figure IX-16 does not seem to show as much difference, but when it is recognized that the three lowest quadrats in the vegetable class are also classed as hunting and that the highest three in the hunting group, are hunting only, we can observe the same kind of differences we see on Figure IX-16. The very lowest elevation quadrat is West John's 15, located off the mesa, far from any habitation site, with four sites and six components present, numerous projectile points and fragments, yet no groundstone. This quadrat must be an example of the very low elevation, distant, hunting-staging camps— that was expected and indicative of the elevation range of hunting campsites.
Matson, Lipe and Haase (Jun. 90) IX-56

We discussed above the concentration of Limited Activity Sites and Campsites around the lower elevation grassy areas, suggesting at that time a possible hunting function. According to the present distributional information, we might expect, instead, a vegetable food function, either of Indian rice grass or sand dune agriculture. The concentration of Basketmaker II sites in this area shows an emphasis very different from succeeding times and not one of habitation. One of the seven quadrats in this area that had a campsite was placed into the questionable class (no groundstone or projectile points), four in the both hunting and vegetable class and two in the vegetable only class. Six of the eight campsites classed as vegetable food processing thus are found in this environment. The other two (North Road 1 and 6) are found in moderate elevations with abundant deep soil pinyon-juniper halfway down the North Road drainage.

In conclusion, this low lying grassy area appears to be the focus of our vegetable food processing campsites, whether for Indian rice grass or sand dune agriculture is not clear at this point. Hunting campsites, or at least sites so classed, appear to have a much wider distribution and include (at least in the joint hunting-vegetable class) this area as well. They are found in much lower situations as well in higher elevations with higher concentrations of pinyon-juniper. Pinon nut processing sites with groundstone are essentially absent from this sample, as only one
Matson, Lipe and Haase (Jun. 90) IX-57
"vegetable" quadrat has more than 61% of it covered by dense
pinyon-juniper and that one also has projectile points present
(see Figure IX-13). The tests run so far are mute on the idea
of pinyon-juniper agricultural campsites, except that if this
hypothetical site type includes groundstone, it is absent.

<SITES AS UNITS OF ANALYSIS>

There are a number of problems in using quadrats as the
unit of analysis. First, quadrats yield relatively good
measures of association with other variables but do not give
good estimates of on site variables such as exposure.
Second, a single quadrat may have two or more kinds of sites
present, leading to problems in classifying the quadrat.
After all, we are fundamentally interested in sites, as
locations of human activities, not quadrats, except that
quadrats are an indirect way of obtaining this information.
Because of these limitations it is easy to come to the end of
productive hypothesis testing using quadrats, in spite of
there superior probabilistic properties, and we have reached
that point here.

The use of sites as units of analysis do have a number of
apparent advantages. One is that there are a lot more Grand
Gulch sites than quadrats, 130, compared to 76. We can also
calculate more exact distances to water and on site variables
and so forth. Unfortunately, we cannot treat our sample of
Matson, Lipe and Haase (Jun. 90) IX-58 sites as if it were random. Our sample is the 76 quadrats. The probability of the site sample deviating from a random sample increases with increasing clustering of sites. Since sites within a quadrat will tend to be alike, the "real" sample size will be closer to the number of quadrats than sites in this case. If more than one example of a site kind never occurred in any single quadrat, this problem would not exist (Of course, there would also be no sample size advantage in using sites as units either). If sites rarely occur as multiples within quadrats, it is probably safe to use the site sample as if it were a random sample. Unfortunately, several Grand Gulch site types, particularly the limited activity site class and habitation sites, do have a clustered distribution and so cannot be safely assumed to be random samples. In other situations, site classes that do not have such a clustered distribution and probably can safely be assumed to approximate a random sample.

In other situations one must use a more judgemental approach. One can still quantify observations and use statistical tests, but the results need to be treated as nominal rather than as true probabilities.

With these <caveats> in mind, let us turn to ideas involving onsite variables. Perhaps the key aspect of any settlement pattern approach is the description of residential activities. For the Grand Gulch phase, we have been able to show that habitation sites, as defined by our "functional
variability" analysis, are concentrated in one environmental portion of Cedar Mesa. Two important questions still unresolved about habitation sites, however, are the identification of season of occupation, and whether we can assume all had pithouse present. Let us first see if we can usefully treat our sample of habitation sites as a random sample.

Figure IX-18 is the histogram of quadrats by Grand Gulch habitation sites and shows that 44 quadrats have zero, and that 12 have two or more. The number of quadrats with two or more suggests that we can not treat our sample of habitation sites as a random sample, although we assume it is a representative one. Figure IX-19 graphs the number of habitation sites found in each class of quadrat and shows that 33 habitation dwellings are found in quadrats with other habitations, while only 20 are found by themselves. The mean number of habitation sites is .697 and the standard deviation is 1.185, well above the mean indicating a very clustered distribution. (A "random" distribution, the Poisson, has its mean equal to its standard deviation, distributions with smaller standard deviations than means are more evenly spaced than random, and ones with higher standard deviations are more clustered). We will examine the meaning of this clustering later.

Another observation is that almost half (26 out of 53) of the habitation dwellings are found in the Bullet
Matson, Lipe and Haase (Jun. 90) IX-60

drainage. Only two are found in Upper Grand Gulch, three in
Hardscrabble, ten in North Road and 12 in West John’s.

These figures suggest that they are found at about the rate
of one per quadrat in the two richest quadrats (Bullet and
North Road) and much less than that in the highest (Upper
Grand Gulch) and almost absent in the lowest (Hardscrabble
and parts of West John’s) drainages. While this merely
repeats the earlier information, we can use the quadrats that
have multi-habitation sites as indicating the areas of most
dense occupation. We might expect both the elevation range
and dense pinyon-juniper coverage of these quadrats to be
less than that of all habitation quadrats. The elevation has
a first quartile of 1847m (6060 ft), a median of 1948m (6390
ft) and 1949m (6595 ft), a distribution with the same central
tendency but a wider interquartile range than the
distribution of all 32 habitation quadrats. We do find
differences, however, with percent covered by dense
pinyon-juniper, with a lower quartile of 72%, a median of 84%
and an upper quartile of 93%, a higher cental tendency and a
smaller inter quartile range than all 32 quadrats (Median of
84%--73% and interquartiles of 21%--37%.

If we revert, momentarily to quadrats as the unit of
analysis, we find that this difference is significant at the
.025 level (This rank sum 141, .025 probability rank sum is
147), indicating that quadrats with two or more habitation
sites have significantly more deep soil pinyon-juniper than
Matson, Lipe and Haase (Jun. 90) IX-61
those with only one, as well as a tighter dispersion. Since
habitation sites are usually found in areas with dense
pinyon-juniper, it is not surprising that ones chances of
finding two in a quadrat increases with the amount of
coverage of deep soil pinyon-juniper.

It is easy to generalize from this finding that the
amount of Grand Gulch material is directly related to amount
of deep soil pinyon-juniper. For the Grand Gulch Phase as a
whole there is a significant relationship using the Spearman
rank order correlation coefficient of +.228, significant at
the .05 level, but is too weak to indicate much. The
(corresponding product moment coefficient was only +.110 and
is not significant at the .05 level (this assumes normal
distributions, which is clearly not met). This weak
relationship does not support the idea that the differences
observed between the two habitation quadrat classes (quadrats
with one, and those with more than one habitation sites) can
be attributed to a general increase in density of Basketmaker
II sites with increase in percentage of coverage of dense
pinyon-juniper.

If habitation sites occur in a clustered fashion and are
confined to a special environmental setting within a narrow
elevation band, how can we be certain they are substantial
year-around occupied sites? Our argument about their
location agreeing with our expectations for arable soil might
lead to the alternative idea that our habitations include, or
Matson, Lipe and Haase (Jun. 90) IX-62 are mostly, summertime sites associated with agriculture and that the rest of the year is spent elsewhere.

Haase (1983a) has argued, as we will report more fully in the Pueblo settlement pattern section, that a year-around dwelling in this climate would be focused on reducing winter effects since that is the time when shelter is most needed. In winter, a house exposure to the south or southwest will maximize the heat from the winter sun. Thus, habitation sites occupied on a year-around basis, or only in winter, should demonstrate a concentration of southerly or southwesterly exposures.

The physiographic forms which were filled out for every site and often for every feature, have an exposure category (we had no notion of Haase’s idea when the forms were filled out). It might seem an easy matter to simply tabulate these to determine site exposure; however, in practice, as with distance to permanent water, there were a number of problems involved. Many sites showed a number of exposures measured from different places and some were not given any. Where a possible or probable pithouse feature was recorded, it was usually possible to find an exposure for that specific point. Where no clear pithouse feature was recorded and several different exposures were given for a site, the situation could be unclear. Of the total 53 habitation sites (counting west John’s 13-1 as two sites, since the two pithouses present there had different exposures), 50 could be
Matson, Lipe and Haase (Jun. 90) IX-63 given definite exposures. Some of these 50 had exposures that ranged more widely than others and had their exposure classed in several of the 45 degree classes used.

The results of this tabulation are seen in Figure IX-20. Here a clear concentration on southern directions is seen with a secondary peak pointing to the west. This distribution supports the idea that occupation of habitation sites occurred during the winter.

We can use this exposure information to test if the habitation sites without clear indications of pithouses were summertime occupation sites. If they were, we would expect a different exposure than that found on the pithouse sites. Figure IX-21 graphs the result of the 21 probable pit structures and shows a very close similarity with the overall pattern, with the possible exception of the west direction. Figures IX-20 and 21 indicate that there is no seasonal difference between habitation sites with pit structures and those without. This finding supports considering the two subtypes of habitation sites as equivalent and suggests that the absence of features indentified as possible pithouses on half of the habitation sites has more to do with preservation, erosion, ground cover and varying ability to make correct inferences in the field than any real absence.

Comparing the results of the habitation site exposure with those of the 76 quadrats also points up some large differences. Figure IX-22 shows the exposures of the quadrats
Matson, Lipe and Haase (Jun. 90) IX-64 tabulated in a similar fashion where one quadrat may be tabulated in more than one direction. The southward emphasis found on habitation sites is not apparent here with the south, southwest, and west all being essentially equal, followed closely by the north. The western direction seen in the habitation sites might be due to the quadrat setting, as measurements of exposure on sites without identified pithouses might be expected to more closely reflect the overall trend of the land as compared to measuring the exposure of a specific feature. Since the measurements are all using magnetic north, the southern emphasis of the habitation sites has a true south-southwest direction, as would be expected for maximizing winter solar exposure.

We have argued in Chapter VIII that agricultural fields, at least deep soil rainfall fields, should show a northeast exposure. Field sites related to agricultural activities might also be expected to show a similar exposure. Additional thought suggests that overseeing the field for protection from animals or for hunting purposes, one might expect an opposite slope exposure, or southwest, if it is locally available. Haase (1983a and in Chapter XI on Pueblo settlement patterns) has demonstrated different exposures between field stations and habitation sites for later time periods.

For Grand Gulch Phase times, one might expect that the sites indicative of shortest duration, limited activity sites
would be those most likely to be field stations. This site
class, however, is found in many places improbable for
agricultural fields and earlier we presented evidence in
support of a hunting function. The latter idea is not
improbable for field stations as the field must be protected
and as Ford (1984) has pointed out, abandoned fields are
likely to be more productive of game than elsewhere.
Undoubtedly many, if not most, of the limited activity sites
are located in areas where agriculture can not be practised
and so must not be field stations.

We used two ways to try to separate limited activity
sites that could not be field stations. The first way was to
consider only those limited activity sites that fell within
the elevation interquartile range of the habitation quadrats.
The rationale for this procedure is the argument that the
densest agricultural activities should have taken place in
this zone and that this would eliminate the sites that were
clearly outside the agricultural zone. Some fourteen
limited activity sites fit this criteria, but unfortunately,
eight of them are from just two quadrats, West John’s 4 and
10, so this group, at least, should not be treated as if it
were a simple random sample. Plotting the exposures of these
14 sites resulted in Figure IX-24a, a very different pattern
from those produced by the 76 quadrats and habitation sites,
but quite different than what was expected. The
concentration on the southeast exposure indicates that a
Matson, Lipe and Haase (Jun. 90) IX-66
definite exposure was selected, but why southeast is not self
evident.

The second attempt to eliminate nonagricultural limited
activity sites was made through the use of percent deep soil
pinyon-juniper. In this case, all quadrats with more than
50% deep soil pinyon-juniper with limited activity sites were
considered. The 50% figure is the first quartile of the
habitation quadrats, but unlike elevation, there is no "tail"
at the higher percentages, so that the possibility of a
habitation site increases as the percentage of dense
pinyon-juniper increases without the fall off which occurs
with elevation. Here, 22 limited activity sites were found
in quadrats that had 50% or more of their area covered with
dense pinyon-juniper and 21 had discernable exposures. Only
one quadrat contributed four sites (West John's 4), so this
appears to be a better sample than the first one. The
results of tabulating the exposures are seen in Figure IX-24b,
again showing a southeastern emphasis, although this time
east is slightly more represent than south. North, as well,
is better represented. While this figure agrees with the
previous one, it too, is different than expected.

While coding the limited activity sites, it was noticed
that some of them were located on thin soils with no nearby
arable soils apparent. Such sites would have little chance
of being agricultural related. Only nine of the 14 limited
activity sites controlled by elevation had our best deep soil
Matson, Lipe and Haase (Jun. 90) IX-67 indicator, sagebrush, present. The five that did not have sagebrush present also did not have any other deep soil indicators. Some of these sites, then, were located on thin nonarable soils. The eastern trend in exposure is in accord with the expectation for field stations, but the expected northern trend is not present. While habitation site exposure is as predicted and supports the inferred function of that site class, the exposure of this class does not. The limited activity sites used undoubtedly include sites that are not field stations. The southeastern-eastern exposure may be indicative of field stations, perhaps located on slightly different exposures than expected. It is likely that this distribution does include field stations as well as other sites, used for different purposes, including hunting game.

<Campsites (Group 2)>

Two separate ideas about Campsites can be tested by onsite information. Since Campsites are apparently the site class with the second longest duration, we expect them to have specific exposures for residential ease. We have, however, suggested at least two functions for these sites and so need to make three tests, one as a group and for the two subclasses, separately.

Our main expectation is that since habitation sites are occupied during the winter the campsites will be occupied during the other seasons. Thus a less south-facing emphasis
Matson, Lipe and Haase (Jun. 90) IX-68 would be expected. Actually, a southward exposure, might be important in the spring and in the fall, so that if we do find a pattern similar to habitation sites, we can interpret this as indicative of fall and/or spring use. A pattern without the southern dominance would be indicative of summer use.

The pattern found using all campsites is different from any illustrated up to now (Figure IX-25). Two concentrations are apparent, both to the north and the south, with more emphasis on the southern direction. The emphasis on the north is greater than expected or that seen in the previous figures. This trend might be indicative that this site class includes field stations. If this is so then, the "vegetable" class of campsites should show this exposure. On the other hand, most wild vegetable foods would be harvested in late summer, so this direction would be expected for wild food processing as well.

If we define "vegetable" processing sites as before, those with groundstone, we find the rose diagram seen in Figure IX-26. While only a few sites are involved, the patterns seen here is reminiscent of that found for limited activity sites. Perhaps this is the exposure for sites involved in agricultural field stations, as this pattern has now recurred three times on separate test of sites that most likely included field stations. One can visualize a situation where sites are located opposite agricultural
Matson, Lipe and Haase (Jun. 90) IX-69 fields on east facing draws (Figure IX-27), and having this orientation. The fields themselves would have a northeast exposure while the field station would be in a good observation location adjacent to the field and have the reoccurring southeast exposure.

The much larger "hunting" campsite class has a magnetic northern exposure. This could be indicative of summertime occupation or even a "field station" purpose. Obviously, at this point we are unable to rigorously test ideas related to exposure with this site class. What we have demonstrated is that different patterns of exposure exist for Campsites than for the other kinds of sites and for the two subtypes of Campsites.

One idea developed by Haase (1983a, 1983b) while working on Cedar Mesa Pueblo components is that within a given limited activity site class the further from a known habitation the more site facilities that will be present. This idea has already been briefly discussed when hunting sites were analyzed. The idea is that as the further one gets from a habitation site, the more time is spent in transit so that if one is a considerable distance away, one will invest in site facilities rather than commuting regularly or camping for some time at a site without site facilities.

If this idea is valid, we would expect campsites with abundant features to be located at lower elevations and at
Matson, Lipe and Haase (Jun. 90) IX-70 distances further from known habitations than those campsites with less facilities. If we consider slab lined features, either hearths or cists, and limestone concentrations as facilities, we find that the number of facilities on campsites ranges from zero to four. If we eliminate multicomponent sites and the previously discussed special case of West John’s 15, the low elevation hunting camp quadrat, we end up with 28 sites. Six of these have no features, nine have one, 12 have two and a single site (North Road 10-4) has four. We grouped these campsites into three classes, those with no facilities, those with one and those with two or more. The appropriate non parametric test to use is the Kruskal-Wallis oneway analysis of variance which is the Wilcoxon two sample test generalized to the three or more sample situation (Bradley 1968).

If we use elevation as a measure of closeness to habitation sites, with the idea that high elevation campsites will be close to habitation sites and have fewer facilities than those at lower elevation, we find a non-significant chi-square of .709 with two degrees of freedom. Recognizing that this sample of sites is not a good approximation of a random sample this value should be considered nominal. Instead of 28 independent samples, we have only 22 quadrats represented here. Five quadrats are represented by more than one site, four by two and one by three. These multiple site quadrats do seem to be relatively well spread out through the
three facility classes so that there is not obvious gross clustering. While not as nice as a distribution one would like, this sample is not obviously biased by over representation from a few quadrats. In spite of the absence of a nominal significance, sites with more features are located at slightly lower elevations than those with lesser numbers of features, as the average rank of elevation decreases with increasing numbers of facilities. For sites with no facilities, the average rank is 16.5, for one feature, 14.17, and for two or more features 13.81.

A more direct test of Haase’s idea would be to use the distance to the nearest contemporary habitation site. This distance could only be calculated exactly if we had a complete survey and exact dates. We might expect, though, that since the Grand Gulch Phase is short and since areas with large numbers of habitation sites should be represented in the survey quadrats, that the measure of nearest known habitation site would be correlated to the desired exact calculation.

A quick look at the number of campsites within a habitation quadrat also suggests that this measure might be worth exploring further. Two of the six campsites without features are found in habitation quadrats, five of the nine with one facility, and only four of the 13 with two or more features. When we run the Kruskal-Wallis test as before, however, using distance to nearest known habitation site, we
Matson, Lipe and Haase (Jun. 90) IX-72 obtain a non-significant chi-square value, this time of .987. If we collapse the two smaller classes together and use the Wilcoxon test, a rank sum of 172.5 results, not significant at the .10 level (rank sum of .10 probability is 159). These findings suggest that there is a tendency for campsites with larger numbers of features to be located further from habitation sites than those with fewer facilities, but a trend that could be due to chance.

Some of the campsites are probably mis-classified habitation sites, which does not help this comparison. We would expect such sites, if they exist, to tend toward large numbers of features, and given the strong tendencies of habitation sites to cluster in space, such "campsites" might be expected to be located in quadrats with habitation sites, as are a majority of identified sites. Because of this factor and the problems associated with sampling, one could argue that the "real" trend is stronger than the one observed. On the other hand, some of the "campsites" located near habitation may be summertime dwellings. If so, this might explain the northern exposure concentration found on campsites. Such sites, if they exist, would be really part of the main dwelling/habitation complex and again interfere with a good test of Haase's principle.

<Campsite Summary>

Campsites exhibit variability in location. The main commonality in artifact composition appears to result from an
Matson, Lipe and Haase (Jun. 90) IX-73
intermediate duration of occupation. The only tight
environmental association was with nearness to permanent
water sources. This amount of duration could develop in a
number of ways, via the location of particularly reliable and
dense resources or through an interaction of resource
reliability and denseness with distance from habitation.
Given the apparent complexity observed in this class, a
number of such factors was probably involved. In particular,
we find long distance hunting camps, as exemplified by West
John’s 15 and a relatively low elevation concentration of
"vegetable processing" campsites in West John’s and
Hardscrabble drainages. Two alternative reasons for this
last group may exist, Indian rice grass seed gathering or
sand dune extreme water storage agriculture.

Not only does this low lying area have a larger
percentage of campsites than expected, but a large proportion
of the campsites have millingstones. Of the eight campsites
with possible cists, four are located in this area. There is
no doubt that this is a special area which provided reliable
and abundant vegetable resources which resulted in the
campsites found in the archaeological record.

Campsites in other locations may be related to other
hunting areas, or rainfall agriculture in areas located some
distance from the main habitation, or pinyon nut collecting.
All three of these activities have similar locational
expectations, deep soil pinyon-juniper, and so cannot be
Matson, Lipe and Haase (Jun. 90) IX-74 easily distinguished at this scale of analysis.

<Distribution of Habitation Sites>

We pointed out above that the ratio to the mean indicated that this was clustered distribution on the basis that if it was random the variance would be equal to the mean (Poisson distribution). Here we go a step further and demonstrate that the fit with the Poisson distribution is not good, particularly in comparison with that of the negative binomial, a clustered distribution.

Table IX-5 shows the calculated Poisson distribution (Johnson and Kotz 1969) compared with that observed. Notice that impressionistically the fit is not that good with an underestimate of both the 0 and 1 classes and also of the high categories. If we collapse the last three categories, we can calculate the Pearsonian chi-square, which in this situation is known to overestimate the goodness-of-fit and so is used here as a comparative measure with a nominal rather than a\accurate probability.

Table IX-6 shows the corresponding fit with the negative binomial distribution (Bliss 1953, Wood 1971). The negative binomial has two parameters, one $M$, as in the Poisson, is estimated by the mean of the sample. The other one, an exponent, referred to here (following Bliss and Wood) as $k$, can be estimated in a number of ways. The simplest is the use of the moment estimate, but this does not always give a precise estimate. In this case by reference to a chart
Matson, Lipe and Haase (Jun. 90) IX-75
(Johnson and Kotz 1969:133) it appears to be about 95% efficient as compared to the usually most efficient estimator, the maximum likelihood method. So the moment estimate appears to be suitable in this case.

The calculated values in Table IX-6 show a good fit with the observed distribution, fitting well throughout the range, unlike the Poisson. Note that the calculated chi-square is also much less. The lesser number of degrees of freedom do not refer to a different collapsing procedure, as that was followed as before, but to the fact that the two parameters in the negative binomial reduces the degrees of freedom. In fact the last collapsed cell (quadrats with 3 or more) has a higher expected value for the negative binomial than for the Poisson, and thus the chi-square should be a better goodness-of-fit for the negative binomial. In all Table IX-6 illustrates a very credible fit.

Discrete probability statistics, such as these, are often sensitive to quadrat size effects. Since we are dealing with a quadrat sample rather than a contiguous block survey, we are limited in what other quadrat sizes can be tried, but we can divide each quadrat into quarters and check to see if the relative fit remains the same. Tables IX-7 and IX-8 illustrate the results. At this quadrat size as well, the negative binomial distribution gives the superior fit. In this case the moment estimator of k is not as efficient as before, but the previously mentioned chart still gives it an efficiency
Matson, Lipe and Haase (Jun. 90) IX-76 of over 90%, good enough for our purposes. In order to use the chi-square with more than zero degrees of freedom, four cells had to be used and the fourth cell has a value of only 1.134. Usually the use of too small expected values results in inflated chi-square values, not exactly the problem here.

The results of the second quadrat size agrees with the first, that the habitation sites occur in a clustered fashion, in good agreement with the negative binomial distribution. Since 60% of the habitation sites were found in quadrats with other habitation sites and since we do not know about other nearby habitation sites outside quadrat boundaries, we can be relatively certain that at least 80% of the habitation sites occur in close proximity (200-400 meters?) to other habitations.

In principle, at least, the finding of good agreement between a recognized statistical distribution and a sampled distribution should enable one to calculated intervals for the mean. This is readily done if one has a Poisson distribution (Johnson and Kotx 1969:97), but not as easily done with the negative binomial. At this point, we wish only to point out this possibility.

<Grand Gulch Villages>

Most Grand Gulch habitation sites occur in quadrats that have at least one other Grand Gulch habitation site, as we described in the last section. In the Cedar Mesa sample, habitation sites clearly occur in clusters, with isolated
habitation sites being in the minority. There are three obvious, but not necessarily mutually exclusive explanations of this clustering. It could be that one habitation site per quadrat occurs at any given time and that the apparent clustering is due to serial use of a series of pithouses, with each house being abandoned before the next one is occupied. On the other hand, multiple habitation sites per quadrat could be the result of each pithouse site having an associated summer habitation site so that the actual clustering of housepit sites is much less than that of habitation sites. Finally, the clustering may be the result of contemporaneous occupation of pithouses--villages.

The exposure of the Grand Gulch habitation sites is relatively constant, as pointed out earlier, so all habitation sites were probably occupied during the same season whether pithouses were evident or not. Further, a number of quadrats have two or more features interpreted as pithouses. In fact, we have recorded five such quadrats with up to three such features tentatively indentified. So in many cases, pithouses are found together in quadrats, so not all habitation sites associations are summer-winter pairs. These two observations make unlikely the second idea of separate summer and winter habitations "causing" the clustering of habitation sites.

The possible explanation for the clustered habitation sites now is reduced to whether habitation sites are occupied
Matson, Lipe and Haase (Jun. 90) IX-78 sequentially or not. K. Dohm (1981) argued that the Grand Gulch sites were villages, in part because the sites within a quadrat always appeared to be very similar to each other. If sites were occupied serially, we would expect more differences. Further, if the habitation sites were serially occupied, it is difficult to see why one would build nearby, but not rebuild the structure. Many of these sites appear to be at a distance of 50 to 100 metres apart, a distance which would not give easy access to different resources, either arable land or to a new source of firewood. So continuous occupation with short distance moves does not appear to be very likely.

Another kind of serial occupation is reoccupation after a period of abandonment when the resources renew themselves. Given the short (maximum is circa 200 years) duration of the Grand Gulch phase and the long time it takes for pinyon-juniper woodland to mature after being destroyed, it is possible that it would take the entire Basketmaker II period before the first fields would recover. These factors make it very unlikely that reoccupation is responsible for the clustered nature of the Grand Gulch habitation sites.

Serial continuous use is not as convincingly rejected, but in the absence of some additional information or idea is difficult to support. Why move a habitation such a short distance? If these structures were short time winter villages that were remade each year, such an interpretation
Matson, Lipe and Haase (Jun. 90) IX-79 might be tenable. In comparison with such onetime winter dwellings as were made by the southern Paiutes in the same environment, these are much more substantial dwellings with typically well developed middens to the south and hearth and cist features to the north of the dwellings. Many of these features show evidence of modifications, reuse, and are filled with refuse. Such extensive facilities and their reuse argue for a longer duration of use, although quite possibly only that of a few years.

We know that elsewhere at Talus village (Morris and Burgh 1954) and during the Los Pinos Phase in the Navajo Reservoir area (Eddy 1961) that Basketmaker II people were living in villages. In the more recent work at Black Mesa (Smiley 1984), villages are also found, although these may be slightly earlier than the Cedar Mesa Grand Gulch Phase. The simplest and most direct explanation for the clustering of Grand Gulch habitation sites on Cedar Mesa is that villages existed here as well, although in a more dispersed fashion.

The maximum cluster located during the survey on Cedar Mesa is the 11 habitation sites found on the contiguous Bullet quadrats 8,10,21. Such a cluster would be very difficult to generate serially given the short duration of the Grand Gulch phase. On the other had, there is not necessity for all sites in a cluster to be occupied at any given time so that this number of 11 may be larger than the number of dwellings occupied at any one point in time.
We have answered a number of basic questions about the Grand Gulch phase, the age of it, the duration, the way of life, the kinds of sites, and basic questions about settlement patterns—the location of the various sites kinds, their numbers and their clustering into villages. A final basic question is how many people lived on Cedar Mesa in Grand Gulch times. We will cover the various assumptions in some detail here, as the same logic is used in calculating the Mossbacks and Pueblo populations.

A first question has to do with the total number of Grand Gulch dwellings on Cedar Mesa. Once we estimate this figure, we can derive a population figure by estimating the duration of the phase, the number of people per house, and what turns out to be the least known variable, the duration of use for each dwelling. If we argue, as we have, that each habitation site has one house, except for West John’s 13, which we know has two, we find a total of 53 Grand Gulch houses. Because of the clustered nature of the habitation sites, it is very difficult to derive any sort of confidence interval for overall estimates based on this point value. If we are able to assume some clustered distribution such as the negative binomial, it might be possible to do so. Some empirical estimate via jackknife or bootstrap methods might also be possible. In the absence of these confidence intervals, let us use the point value to estimate the sum total number of
Matson, Lipe and Haase (Jun. 90) IX-81 houses on Cedar Mesa and return to the reliability problem later.

Since we initially sampled the drainages at a 20% rate, and then within drainages at a 7% rate, we have an approximate 1.4 (actually 1.45%) overall rate. Let us call it a 2% rate to be conservative for now. Thus our sample would be one-fiftieth of the total houses on Cedar Mesa, a total of 2650 Grand Gulch habitation sites.

Earlier, we have summarized the duration of the Grand Gulch phase as being at the maximum 200 years, but most likely less than that, possibly as short as 100 years. If we use 150 years as an estimated duration, we will probably not be too far off the mark. Even if the duration is somewhat longer than this, we are assuming during these calculations a constant population, while undoubtedly initially and towards the end of the occupation, it was not constant, so this is probably a safe estimate. If a house, on the average, was occupied by a family of five (a conservative number as we will explain below), we obtain the population estimates seen in Figure IX-28, given an estimate on how long a house was used, on the average. If we take the total number of dwellings (2650) we have a figure that is the result of the average duration of uselife and the length of the Grand Gulch Phase. If a house was occupied for an average of 10 years, we would divide the 2650 dwelling figure by fifteen (150 year phase duration divided by uselife) which gives us the average total
Matson, Lipe and Haase (Jun. 90) IX-82 number of dwellings that were occupied at any one time, 176.6 in this case. Multiplying this by the average number of people per dwelling (5) gives us an estimate of 883 (5 x 176.6). Using a house-life estimate of five years gives us a population estimate of 442 people. It is likely that these two population figures give a reasonable range of population for Grand Gulch Phase.

Figure IX-28 is based on estimates for all parameters except for house-life, which is left variable. This arrangement was based on the observation that we had, or could derive reasonable estimates for all parameters except for the house-life variable. Its uncertainty is an order of magnitude greater than the other parameters and the value given it are not based on material that has a clear relationship with the uselife. While a house may not have lasted five years, at a minimum, it probably lasted very close to that, given the arguments presented in the preceding village section. It is possible that such a house lasted longer than 10 years but a figure of 15 years would be an outside limit. Using these kinds of values for house-life population sizes of a few hundred and possibly as much as a thousand are obtained for Cedar Mesa. This figure may seem large, so let us examine some assumptions that would reduce it.

We have previously discussed the observation that not all habitation sites had features identified as pit structure
Matson, Lipe and Haase (Jun. 90) IX-83

habitations. Let us examine the possibility that we may have substantially overestimated the number of dwellings by assuming that all "habitation" sites had dwellings. We have excavated some three quadrat sites that were thought to have Grand Gulch pithouses present and found pithouses in all three. So we can be certain that obvious surface features identified as pithouses are correctly identified. Some ten of the 52 habitation sites have these very clear surface evidences. Since there were two such structures in West John's, we can be definite that there are at least 11 such structures in the quadrats surveyed.

In many other cases too much erosion or other disturbance has occurred to identify whatever structural remains were there originally with any certainty. In addition, in some situations trees and sand dunes covered up likely areas on sites, so that features could not be identified. Because of these two reoccurring factors, we can estimate that only half of the Grand Gulch dwellings would exist today in the condition that there would be enough erosion to expose them for identification but not too much to make them uninterpretable. This argument would lead us to expect only 26 of the 52 habitation sites would have recognizable pithouse features. In addition to the 11 definite identifications, another 11 were tentatively identified as pithouses, given a total of 22 dwellings, very close to the above figure. So the number of identified dwellings is close
Matson, Lipe and Haase (Jun. 90) IX-84 to what one might expect if all 52 habitation sites had dwellings present originally.

A more conservative procedure would be to base the population estimate on the number of tentatively identified dwellings. In this case one assumes that the number of dwellings not identified (too buried or too eroded) is partially offset by the number of dwellings misidentified. By the use of this procedure we come to the conclusion that at least half of the habitation sites have dwellings present and use the figure of 26 dwellings for our estimate, as seen in Figure IX-29, again varying the population estimate according to the house-life. We judge this procedure underestimates the number of dwellings and fails to take into account the vagaries in identifying features, the erosional and other physical processes, as well as the analysis of functional variability and exposure. It is, however, a possibility.

Another possible factor causing overestimation is the area actually sampled. We may have sampled a higher proportion of the densest Grand Gulch occupation area than our overall sampling rate indicates. Certainly Bullet appears to be the center of Grand Gulch habitation. If Bullet and North Road together are the most concentrated area of Grand Gulch habitation, by how much is our 2% figure apt to be an overestimate? An absolute limit would be 7% instead of 2% which is the sampling rate of the drainages and assumes
Matson, Lipe and Haase (Jun. 90) IX-85
that no Grand Gulch habitation sites fall outside those two
drainages.

We also know that the high elevation areas in West John’s
have substantial Grand Gulch populations. In fact, the two
richest Grand Gulch habitation quadrats are from West John’s;
in terms of habitation sites West John’s 19 and in terms of
artifacts and tools, West John’s 13. So the dense Grand
Gulch occupation extends at least to there. If we include
this area as dense Grand Gulch habitation, the possible
maximal overestimate is reduced from 7 to 3.5% (compared with
2%). Further, we know that Grand Gulch sites exist to the
north of Bullet drainage. We found two habitation sites in
Upper Grand Gulch; Lipe’s 1969-1970 excavation and survey was
also located just north of Bullet. Adding this area to the
Bullet and North Road "optimal" habitation area would bring
the possible over-estimate down to something like 3% rather
than 2%. While a possible overestimate of some 50% might
appear to be serious, in light of the larger uncertainties in
house-life, it is not.

In contrast with these factors which may indicate that
our population figures are overestimates, there are three
which indicate that our population figures are
underestimates. First the family-dwelling estimate of five.
Hill(1970c:76) reviews Pueblo data as to average number of
people per household and finds values that range from a low
of five to a high of seven or eight. He concludes that a
Matson, Lipe and Haase (Jun. 90) IX-86 value of six or 6.1 is the most appropriate. So higher, but not lower, figures appear to be justifiable from Pueblo ethnography.

Houses can be rebuilt rather than abandoned. While this may be possible to determine through excavation, it is not via survey. If houses were rebuilt once or twice before being abandoned relatively long house-lifes and higher population estimates would result.

Finally, the Cedar Mesa overall sampling rate is about 1.45% not 2%. Changing the figures to represent this would also increase population estimates. In view of the joint concentration of Grand Gulch habitation sites and our sampled drainages in the center of the mesa, to actually implement this step would appear to be a mistake.

In conclusion, there is a lot of guess work involved in developing population estimates and one can massage the survey data to develop lower or higher estimates. In view of the unknowns involved in estimating the length of time a dwelling was used before it was abandoned, uncertainties of other variables do not appear to be very important. We can safely conclude that the population was not less than 200 during Basketmaker II times. This is the approximate value obtained using an expected dwelling life of five years and assuming that only half of the "habitation" sites have dwellings. The latter assumption is almost certainly too conservative. On the upper end, a figure of around 1350 can
Matson, Lipe and Haase (Jun. 90) IX-87
be generated assuming all habitation sites have dwellings and
a very long(to us) house-life of 15 years. The range of
440-880 results from applying our best judgement to
house-life and the number of dwellings per habitation site.
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**Chapter IX, Grand Gulch Settlement Patterns**

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IX-28  Grand Gulch Population on Cedar Mesa; Population by Pithouse House Life; Assuming all Habitation sites have Pithouses Present
IX-29  Grand Gulch Population on Cedar Mesa; Population by Pithouse House Life; Assuming only Pithouses Identified in the Field Exist
ALL QUADRATS  (n=76)

HABITATION QUADRATS  (n=32)

NON-HABITATION QUADRATS  (n=21)

Figure IX-1
Figure IX-2

Total tools per quadrant
ALL QUADRATS  \((n=76)\)

HABITATION QUADRATS  \((n=32)\)

NON-HABITATION QUADRATS  \((n=21)\)

CAMPISODE QUADRATS  \((n=27)\)

LIMITED ACTIVITY QUADRATS  \((n=20)\)

\[\begin{array}{cccccc}
0 & 20 & 40 & 60 & 80 & 100 \\
\end{array}\]

\text{deep}  \hspace{1cm} \text{soil}  \hspace{1cm} \text{pinyon-juniper}

Figure IX.3
Quadrats with BM II Habitation Sites

Figure IX-5
- Quadrats with BM II Habitation Sites
- Quadrats with only BM II L.A. Sites

Figure IX-6
Quadrats with only BM II L.A. Sites

Figure IX-7
ALL QUADRATS  (n = 76)

HABITATION QUADRATS  (n = 32)

LIMITED ACTIVITY QUADRATS  (n = 20)

QUADRATS WITHOUT B.M. II SITES  (n = 24)

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<tr>
<th>0</th>
<th>250</th>
<th>500</th>
<th>1000</th>
<th>2000</th>
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<td>distance in meters to nearest 50 m canyon</td>
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Figure IX-8
Figure IX-9

- quadrat with BM habitation site
- quadrat with BM non-habitation site
- empty quadrat
Quadrats with Groups O and I L.A. Sites

Figure IX-10
Quadrats with Groups 1 and 2 L.A. Sites

Figure IX-11
Group 0-1 hunting sites

Group 2 hunting sites

Figure IX-12
"VEGETABLE" GROUP 2 QUADRATS (n=8)

"HUNTING" GROUP 2 QUADRATS (n=14)
"VEGETABLE" GROUP 2 QUADRATS

"HUNTING" GROUP 2 QUADRATS

0  20  40  60  80  100

% deep soil pinyon-juniper

Figure IX-17

*= mean
a) "vegetable" campsites

b) "hunting" campsites

Figure IX-26
fields (northeast exposure) and field stations (southeast exposure) located on east facing draws

Figure IX-27
Figure IX-28

Figure IX-29
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<td>ALL (N=76)</td>
<td>1609-2073</td>
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<tr>
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<td>(6040-6525)</td>
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<td></td>
<td>(5605-6640)</td>
<td>(6180-6540)</td>
</tr>
<tr>
<td>WITH NON-HABITATION SITES</td>
<td>1609-2073</td>
<td>1795-1961</td>
</tr>
<tr>
<td>(N=21)</td>
<td>(5280-6800)</td>
<td>(5890-6435)</td>
</tr>
<tr>
<td>LIMITED ACTIVITY (GROUPS 0 and 1) (N=20)</td>
<td>1709-2055</td>
<td>1786-1978</td>
</tr>
<tr>
<td></td>
<td>(5605-6740)</td>
<td>(5860-6490)</td>
</tr>
<tr>
<td>CAMPSITE (GROUP 2) (N=27)</td>
<td>1609-2073</td>
<td>1792-1956</td>
</tr>
<tr>
<td></td>
<td>(5280-6800)</td>
<td>(5880-6418)</td>
</tr>
<tr>
<td>ALL QUADRATS WITHOUT HABITATIONS (N=44)</td>
<td>1609-2073</td>
<td>1795-1989</td>
</tr>
<tr>
<td></td>
<td>(5280-6800)</td>
<td>(5890-6525)</td>
</tr>
</tbody>
</table>
# TABLE IX-2

DIFFERENCES IN DISPERSIONS OF ELEVATION  
BETWEEN HABITATION AND NONHABITATION  
QUADRATS (BASKETMAKER II)

a) Habitation Quartiles

<table>
<thead>
<tr>
<th>Elevation</th>
<th>Observed</th>
<th>Expected</th>
<th>Observed</th>
<th>Expected</th>
</tr>
</thead>
<tbody>
<tr>
<td>1887 m</td>
<td>21</td>
<td>11</td>
<td>13</td>
<td>21</td>
</tr>
<tr>
<td>(6190 ft)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1993 m</td>
<td>10</td>
<td>11</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(6540 ft)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Nonhabitation Quadrats  
Chi Square = 12.32  
with 2 d.f., signif. at .01

b) Nonhabitation "Quintiles" (20%)

<table>
<thead>
<tr>
<th>Elevation</th>
<th>Observed</th>
<th>Expected</th>
<th>Observed</th>
<th>Expected</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 1742 m</td>
<td>1</td>
<td>6</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>(5715 ft)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>More than 2030 m</td>
<td>0</td>
<td></td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>(6660 ft)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Chi Square = 10.167  
i d.f., signif. at .01
TABLE IX-3

DIFFERENCES IN DISPERSIONS OF ELEVATION BETWEEN LIMITED ACTIVITY AND HABITATION QUADRATS. (BASKETMAKER II)

a) **HABITATION QUARTILES**

<table>
<thead>
<tr>
<th>LIMITED ACTIVITY QUADRATS (n=21)</th>
<th>1887 m (6190 ft.)</th>
<th>1993 m (6540 ft.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>observed</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>expected</td>
<td>5</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5</td>
</tr>
</tbody>
</table>

Chi square = 4.364
with 2 d.f. not significant at the .05 level

b) **NON-HABITATION QUARTILES**

<table>
<thead>
<tr>
<th>HABITATION QUADRATS (n=32)</th>
<th>1796 m (5890 ft.)</th>
<th>1962 m (6435 ft.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>observed</td>
<td>4</td>
<td>14</td>
</tr>
<tr>
<td>expected</td>
<td>8</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td></td>
<td>14</td>
</tr>
<tr>
<td></td>
<td></td>
<td>8</td>
</tr>
</tbody>
</table>

Chi square = 6.75
with 2 d.f. significant at the .05 level
### TABLE IX-4

ELEVATION AND PERCENT DENSE PINYON-JUNIPER COVERAGE FOR "HUNTING" AND "VEGETABLE FOOD PROCESSING" CAMPsite Quadrats.

#### ELEVATION

<table>
<thead>
<tr>
<th></th>
<th>RANGE</th>
<th>INTERQUARTILE RANGE</th>
<th>MEDIAN</th>
<th>MEAN</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;HUNTING&quot;</td>
<td>1610 - 1997m (5280-6550 ft.)</td>
<td>1793 - 1950m (5880-6395 ft.)</td>
<td>1894m (6213 ft.)</td>
<td>1862m (6108 ft.)</td>
</tr>
<tr>
<td>(n=14)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&quot;VEGETABLE&quot;</td>
<td>1741 - 1950m (5710-6395 ft.)</td>
<td>1769 - 1920m (5803-6298 ft.)</td>
<td>1849m (6065 ft.)</td>
<td>1846m (6054 ft.)</td>
</tr>
<tr>
<td>(n=8)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### PERCENT DENSE PINYON-JUNIPER COVERAGE

<table>
<thead>
<tr>
<th></th>
<th>RANGE</th>
<th>INTERQUARTILE RANGE</th>
<th>MEDIAN</th>
<th>MEAN</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;HUNTING&quot;</td>
<td>0 - 99%</td>
<td>16 - 88%</td>
<td>51%</td>
<td>51.1%</td>
</tr>
<tr>
<td>(n=14)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&quot;VEGETABLE&quot;</td>
<td>0 - 99%</td>
<td>18 - 55%</td>
<td>40%</td>
<td>40.5%</td>
</tr>
<tr>
<td>(n=8)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
TABLE IX-5
FIT OF POISSON DISTRIBUTION WITH HABITATION
QUADRAT DISTRIBUTION
(400 Meter Quadrats)

<table>
<thead>
<tr>
<th>Class</th>
<th>Observed</th>
<th>Poisson</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>44</td>
<td>37.84</td>
</tr>
<tr>
<td>1</td>
<td>20</td>
<td>26.39</td>
</tr>
<tr>
<td>2</td>
<td>8</td>
<td>9.20</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>2.14</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>.373</td>
</tr>
<tr>
<td>≥ 5</td>
<td>2</td>
<td>.0588</td>
</tr>
</tbody>
</table>

 Lambda=.6974  
 Variance=1.184
chi square=3.4998  
d.f.=2

TABLE IX-6
FIT OF NEGATIVE BINOMIAL DISTRIBUTION WITH
HABITATION QUADRAT DISTRIBUTION
(400 Meter Quadrats)

<table>
<thead>
<tr>
<th>Class</th>
<th>Observed</th>
<th>Negative Binomial</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>44</td>
<td>44.79</td>
</tr>
<tr>
<td>1</td>
<td>20</td>
<td>18.38</td>
</tr>
<tr>
<td>2</td>
<td>8</td>
<td>7.55</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>3.106</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>1.277</td>
</tr>
<tr>
<td>≥ 5</td>
<td>2</td>
<td>.897</td>
</tr>
</tbody>
</table>

 Mean=.6974  
 Variance=1.185
chi square=.494  
d.f.=1
k (by moments)=.9979  
\(\sim\) prob.=.45
TABLE IX-7
FIT OF POISSON DISTRIBUTION WITH ARTIFICIAL
200 METER QUADRATS (HABITATION SITES)

<table>
<thead>
<tr>
<th>Class</th>
<th>Observed</th>
<th>Poisson</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>260</td>
<td>255.36</td>
</tr>
<tr>
<td>1</td>
<td>36</td>
<td>44.52</td>
</tr>
<tr>
<td>2</td>
<td>7</td>
<td>3.88</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>.2255</td>
</tr>
</tbody>
</table>

Lambda=.1743
chi square=5.254
d.f.=1
\sim prob.=.05

TABLE IX-8
FIT OF NEGATIVE BINOMIAL DISTRIBUTION WITH ARTIFICIAL
200 METER QUADRATS (HABITATION SITES)

<table>
<thead>
<tr>
<th>Class</th>
<th>Observed</th>
<th>Negative Binomial</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>260</td>
<td>259.38</td>
</tr>
<tr>
<td>1</td>
<td>36</td>
<td>37.590</td>
</tr>
<tr>
<td>2</td>
<td>7</td>
<td>5.896</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>1.134</td>
</tr>
</tbody>
</table>

Mean=.1743
chi square=.2913
d.f.=1
k (by moments)=.858759
\sim prob.=.60