J. Ethnobiol. 1 (1): 182-192 May 1981

ASPECTS OF DETERIORATION OF PLANT REMAINS IN ARCHAEOLOGICAL SITES: THE WALPI ARCHAEOLOGICAL PROJECT

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ABSTRACT.—Walpi is a Hopi village which has been occupied continually since the 1690s. Accurate dating of proveniences has been attained through tree-ring data, ceramic seriation, early maps of the village, Euro-American remains, photographs, and informant data. In addition to building, fill, and abandonment dates, the number of years a deposit has been exposed to the natural elements is frequently known. With a data base ranging from the present to 3 centuries in the past, one can evaluate the factors causing the deterioration and disturbance of archaeological data; a complex set of processes which are as yet poorly understood.

In order to partially rectify this situation, experiments were set up in controlled environments to determine the effects of differential exposure to the elements on deterioration of plant species. These experiments over a period of one year have revealed a noticeable reduction in mass of seeds within 5 different genera. In addition, over 35,000 plant remains from Walpi were analyzed in relation to 26 attributes describing the condition of the specimens in an attempt to diachronically qualify differential preservation of archaeobotanical remains. Emphasis here is placed on the effects of carbonization and rodent and insect activity. The data indicate that vast quantities of plant remains may be lost to foraging rodents and insects. The paucity of carbonized remains at Walpi suggests that what is preserved in carbonized form in most open sites can give a skewed picture of plant use.

INTRODUCTION

Archaeologists and other specialists have been concerned with the representativeness of the archaeological record and processes of deterioration for almost 2 decades. Most attempts to evaluate deterioration have concentrated on inorganic remains in archaeological sites (Ascher 1962, 1968; Kleindienst and Watson 1956; Lee 1968; Schiffer 1976). Those who have addressed the process of deterioration of organic remains have thus far restricted themselves to the study of bone loss and preservation (e.g., Behrensmeyer 1975; Gifford 1978; Issac 1967). This paper considers deterioration of plant remains in archaeological sites and partially evaluates loss by 2 experimental studies, and by an examination of the conditions, and kinds, of plant remains at Walpi, a Hopi pueblo continuously occupied since A.D. 1690. The processes of deterioration are complex and multi-faceted. Here, some preliminary findings are presented which should aid in our overall understanding of deterioration of plant remains in archaeological sites.

The Walpi data are excellent, in that preservation of uncharred plant remains is generally good. Many colors are retained on the remains, and soft parts such as corn husks 250 years old look no different from those which are about 25 years old. In addition, the proveniences of these remains are well dated by tree-ring analysis, ceramic seriation, early maps, Euro-American manufactured remains, photographs, and informant data. Given the ability to date proveniences, some within 20 year spans, and the wide range of plant remains (over 37,000 were analyzed in relation to 26 attributes describing their condition), we are in a position to evaluate some factors causing the deterioration and disturbance of archaeobotanical data. These factors are some of the components of a complex set of processes which are as yet poorly understood.

METHODS

Two independent experiments were made under laboratory conditions to: 1) examine the effects of differential exposure to the elements on the seeds of 5 plant genera commonly found at Walpi, and 2) examine preferential eating habits of mice on 5 of the more common seed genera at Walpi. Analysis of the Walpi archaeobotanical record suggested that rodent and insect activity had a profound effect on the plant remains. In this report, some of that effect is measured in a qualitative and quantitative manner.

An initial concern was to measure the differences in plant remains which had been exposed to the elements for varying amounts of time. In this case, seed count and species condition information in 3 rooms at Walpi was viewed in relation to exposure to the open air for 10, 35, and 65 year intervals. The second look at the Walpi plant data concentrated on a synchronic assessment of the state of preservation of some of the analyzed plant remains at the pueblo.

DISCUSSION

Some effects of differential exposure to the elements.—Experiments on deterioration of Hopi corn, pumpkin seeds, pinyon nuts, red, white, and kidney beans, and sunflower seeds were initiated in December, 1977, and completed in November, 1978. The purpose of these experiments was to test the effects of moisture, temperature, moisture and temperature periodicity, and acidity on seed preservation. To study these effects 10 50-seed samples were selected, weighed, and placed in clear jars. One sample was sealed and kept as a control. The other samples were effected by one or more variables. Some were kept inside and either saturated with moisture at regular intervals; alternately saturated for 3 months and then kept dry for 3 months; or saturated with a slight (pH ca. 5.5) acid solution. These same variables (plus a constantly dry sample) were also placed outdoors to test the effects of temperature variation. These variables are listed for each sample in Table 1.

The loss of mass for each sample is listed in Table 2. The average loss was 7.8%. If this rate of the original mass were lost each year, the entire seed assemblage would be lost in only 13 years. This accelerated loss of mass is not often the case and probably was not occurring at Walpi. Within the experimental seed samples, however, there is considerable variation in loss of mass both between samples and between seed types.

Looking at the seeds individually, one notes that the 3 bean types have lost an average of almost 12% of their mass, while the other 4 seeds have lost only 4.8% of their mass.

The implications of the archaeological record are apparent. Given any environmental condition tested here, beans will be lost more rapidly. Beans have a thin, fragile seed coat which breaks rapidly leaving the interior immediately susceptible to external factors. When

TABLE 1.—*Variable states for each numbered sample.*

SAMPLE	VARIABLE STATES
3	Control sample. Sealed with lid.
4	No water added, placed outside.
5	Saturated with water monthly, placed outside.
6	One half water necessary for saturation is added monthly, placed outside.
7	Water added monthly 3 months, dry 3 months, kept inside.
8	Water less than saturation is added, kept inside.
9	Acidic water less than saturation is added, kept inside.
10	Water added monthly for 3 months, dry 3 months, placed outside.
11	Water less than saturation is added, kept outside.
12	Saturated with water monthly, kept inside.

TABLE 2.—*Per cent weight loss for each seed.*

SAMPLE NO.	CORN	PUMPKIN	PINYON NUT SHELLS	KIDNEY	RED	WHITE	SUNFLOWER	MEAN SAMPLE
3	0	0	0	0	0	0	0	0
4	*2.2	2.6	2.4	1.3	0	0	0	1.4
5	*2.1	*1.3	2.3	15.1	21.3	19.8	4.3	9.5
6	*0	*0	2.3	4.1	8.7	9.0	5.0	†5.8
7	5.8	3.8	5.1	7.0	8.6	13.5	5.1	7.0
8	5.8	5.3	2.3	9.3	10.5	15.2	1.2	6.9
9	3.7	1.3	4.8	8.5	11.8	12.4	1.3	6.3
10	5.6	11.4	6.5	9.6	7.9	9.0	2.8	7.5
11	3.9	2.6	6.7	6.6	8.9	9.3	2.5	5.8
12	16.3	5.7	11.4	18.5	40.7	35.2	13.2	20.1
‡MEAN SEED	5.7	4.7	4.9	8.9	13.3	13.7	3.9	7.8

*Eaten by mice 5 months into project.
†Excluding corn and pumpkin.
‡Excluding control sample.

the seed coat breaks, the bean splits into its 2 cotyledons also making deterioration easier. This process can be accelerated by seed germination, with the seedlings soon dying. Beans are also prone to attack by microbial organisms (e.g., Jansen 1979). All 3 bean types supported thriving bacteria and mold communities within 2 months after the experiment began. These communities were most active in moist conditions where the temperature was stable or where water was available to saturation. Dr. Jack States, a mycologist at Northern Arizona University, identified the microbs and noted that there was significant variation in kind and amount of destruction between the bean types. The white beans kept in a stable environment (sample 8) were intact, but had some cracking and disintergration on the seed coat. Oozes of bacteria and some crystal formations were causing the destruction. The kidney and red beans which were kept outside in a fluctuating environment (sample 11; Fig. 1) were often split open with both the cotyledons and seed coats partially decayed. There was a moderate amount of bacteria on these beans, but they were mostly covered with the mold *Paecilomyces* and small amounts of *Fusarium*. States further commented that *Paecilomyces* is common in Arizona and flourishes on habitats that are alternately wet and dry. Given time, the molds would probably destroy the beans in their entirity.

Microbial deterioration of plant remains is commonplace (Jansen 1979). In essence, microbs survive because they "spoil" food that would otherwise be used by man or other animals. Bacteria and molds are most effective on soft or fleshy foods. The tough seed coats or cases or the other seeds used in the experiment evidently provided more protection from attacks by mold and bacteria. It is evident that beans are susceptible to complete microbial destruction. This may explain why beans are relatively rare at Walpi (Gasser 1980) and why they are also rare in most Anasazi sites (Gasser 1981). Beans, however, are not the only foods which would be destroyed by microbs. Corn kernels, squash meat, greens, tubers, and fleshy fruits are also very susceptible to similar destruction.

FIG. 1.—Red beans from Sample 11 with *Paecilomyces* mold.

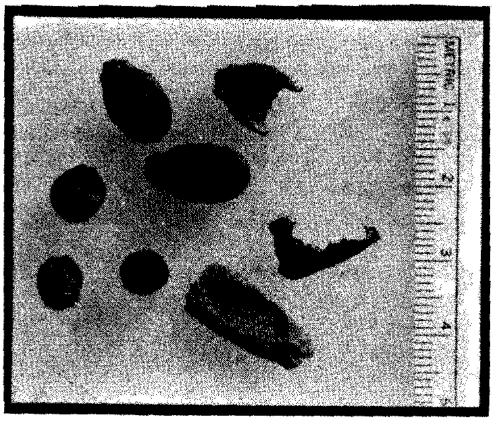

FIG. 2.—Rodent gnawed watermelon, bottle-gourd, and juniper seeds from Walpi.

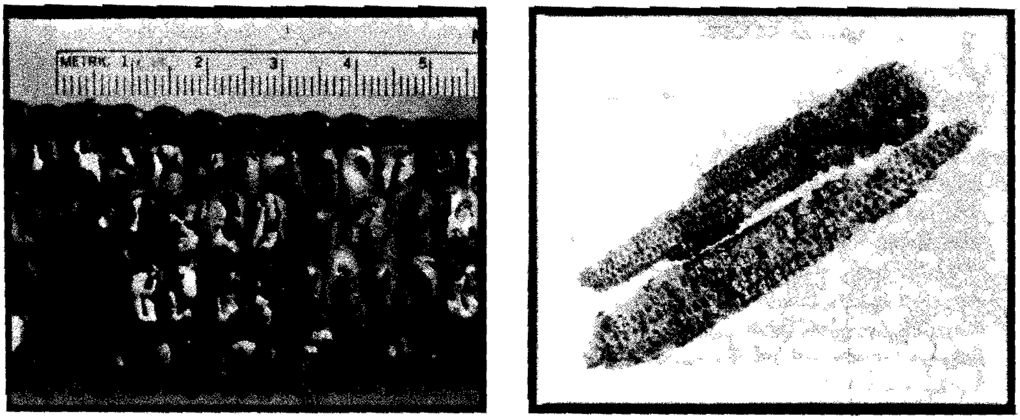

FIG. 3a, b.—Corn from Walpi damaged by larva of Dermestid beetles.

Analysis of the experimental data by sample also reveals systematic differences. The sample (#2) kept dry but subjected to temperature change varied only minutely. Samples 6 and 11 were the next least subject to loss of mass. Both were characterized by having less water added than the other specimens and by being outside and subject to temperature fluctuation. The outside sample most susceptible to loss of mass was the one saturated each month. Saturation is defined as the seeds being immersed in water for 8 hours and the excess water poured off. Thus, the seeds absorbed as much water as they could contain.

Weight loss of samples maintained at a constant temperature with only moderate water added was very slight. However, for the saturated sample the effects were dramatic. The combination of stable temperature and abundant water promoted healthy colonies of mold (Fig. 1) in all seeds and resulted in an average 20% loss in mass(Table 2). Even excluding the beans, the loss of mass was 11.6%.

A comparison of samples 8 and 9 reveals the effects of acid on deterioration. Overall, the seeds with slight acid solution lost 0.6% less mass than those without acid. Apparently, the acid slightly inhibited the growth of mold and bacteria. However, a marked change in color was noted in the corn kernels subjected to acid. The blue corn kernel turned a bright red color which penetrated the seed coat to the interior of the seed.

In summary, assuming an abundance of oxygen at all times, moisture is the most important factor causing deterioration of seeds. If moisture is abundant, a stable

TABLE 3.—*Species condition breakdown in 3 rooms at Walpi.*

	ROOM 168 **piki house** **fill date 1920-1965**		**ROOM 83** **storage room** **fill date 1930-1950**		**ROOM 187** **storage room** **fill date 1880-1920**	
CONDITION	**#**	**%**	**#**	**%**	**#**	**%**
unaltered, whole	38	18	133	31	74	10
rodent-insect gnawed	104	48	70	16	65	9
slightly degraded	17	8	50	12	150	21
fragments > 50%	22	10	60	14	204	28
fragments < 50%	10	5	51	12	38	5
split at suture	25	12	65	15	125	17
charred or partially charred	1	+	1	+	62	9
Total	217	101%	430	100%	718	99%

temperature also promotes deterioration. However, if moisture is present, but not abundant, the effect of temperature appears to be minimal. Over the course of a year a fluctuating temperature may impede deterioration during the winter by slowing the growth of mold and bacteria. The amount of loss during stable mid year temperatures with alternate periods of wetting from summer rains and drying might cause rapid disintegration. If the soil is slightly acidic, this will slow deterioration by impeding the growth of bacteria and mold.

The second examination of deterioration brought about by exposure to the elements was drawn from the Walpi archaeobotanical record. The time differences in species counts and their conditions in 3 rooms at the pueblo were measured. These rooms are, 1) Room 168, a piki house whose fill was deposited between 1920-1965, and has been exposed to the elements for 10 years, 2) Room 83, a storage room whose fill was deposited between 1930-1950, and has been exposed 25-35 years, and 3) Room 187, also a storage room whose fill was deposited much earlier, between 1880-1920. The fill in room 187 has been exposed for approximately 65 years.

The first test of this data base involved comparing plant counts by genera in each of the 3 rooms. Hypothetically, one would expect that the room exposed for the longest duration would contain the least plant remains. Such was not the case. This study produced results (Table 3) which indicated an inverse relationship, where more plant remains were in the room exposed for 65 years. This does not seem plausible, and an alternative needs to be examined. For instance, actual counts may be misleading as numbers may reflect the cultural bias of differential discard. Thus, more trash may have been discarded in Room 187 than in the other 2 rooms.

A more viable test of these data was to examine the condition of the specimens in each of the 3 rooms. A plant artifact's condition of preservation is more independent of the cultural experience than its numerical frequency. We are interested here in many of the non-cultural effects such as rodent and insect gnawing and other degradation of plant remains in sites.

Table 3 details the results of this examination of the state of preservation of the remains in each of the 3 rooms. These data indicate only a few relationships one would expect of remains which had differing lengths of exposure to the elements. For example, an assemblage of plant remains should continue to degrade with length of exposure. Seeds and other plant parts which were slightly degraded, fragmented less than 50%, split at suture, or charred or partially charred, occurred with greater frequencies as the length of exposure increased. This implies a steady and rather constant rate of degradation. In some examples this was not always the case. Unaltered remains and fragments greater than 50% were less common in the rooms exposed for 10 and 65 years than they were in the room exposed for 25-35 years. This might be the result of sampling error or the effect of unaccounted factors, but it does indicate that there is not a direct relationship, where organic remains throughout a pueblo disintegrate at an even rate.

Rodent and Insect Activity.—Another significant fact that appeared as a result of this study was that rodent and insect gnawing apparently decreased as the length of exposure increased. Rodent and insect gnawing occured on 48% of all the seeds in the room exposed for only 10 years, on 16% in the room exposed for 25-35 years, and 9% in the room exposed for 65 years. These data suggest that rodents initially gnaw and consume large amounts of plants soon after they are discarded, and may continue to do so until there is a more desirable nearby food supply. Rodents bias the record extensively. The data on Table 3 indicate that as much as 50% of some discarded organic trash is partially consumed by rodents.

Some seeds are probably consumed in their entirety by rodents and insects; others seem to be gnawed or cracked only enough to gain access to the soft portion of the seed encased in its shell. Figure 2 illustrates watermelon seeds from Walpi and reveals partial gnawing. A laboratory produced example of rodent gnawing on watermelon seeds was obtained at the beginning of the Walpi botanical analysis and enabled identification of some rodent gnawing on archaeological seeds. For this study, rodent gnawing was determined by the presence of incisor-sized impressions on a beveled surface of the seed or seed coat, such as that illustrated with the watermelon, bottle-gourd, and juniper seeds in Fig. 2. When some of this seed damage might be attributed to insects as well, the combined category of rodent-insect gnawing was used.

Insect gnawing was only reported when corn was damaged as illustrated in Figure 3 which shows corn kernels on cobs which have been infested with the larva of dermestid beetles. The cobs with dermestid infested kernels shown here was unaltered when Adams excavated them from Room 121 2 years ago. Dermestid larva accompanied the remains back to the Museum, and did this amount of damage in the intervening period. The larva of this beetle enter the kernel at its anterior end and consume the soft starchy interior, often leaving only the pericarp behind. The thin pericarp would probably disintegrate leaving no remains of the kernels.

Rodents and insects seem to prefer different foods, each taking its toll in differentially degrading and destroying plants in sites. The next analysis examined the presence of rodent and insect damage on all seeds in all of the sampled proveniences at Walpi (Table 4). Table 4 indicates those species affected by rodent and insect activity, the species total seed count in the sample, and the number and percent of which were either rodent or insect gnawed. In some cases it was impossible to identify the gnawer, hence the category rodent-insect gnawed. Table 4 indicates that 42% of all of the corn at Walpi, excepting shucked cobs, husks, and other non-kernel parts, were damaged by insect activity. Insects or rodents damaged over half of the bottle-gourd seeds, and often did much damage to other seeds of the Cucurbitaceae. Rodents damaged over half of the more than 24,000 watermelon seeds investigated by this analysis. Rodents (or insects) also damaged 75% of the juniper seeds. Rodent gnawing was also evident on many stones of fruits such as cherries, plums, and apricots. Peach pits, which were abundant at Walpi, seem to have been avoided by the rodent predators.

An analysis of 11 rodent nests and one rodent cache (Table 5) is helpful in determining preferred rodent foods. Table 5 indicates that 75% of these rodent contexts contained watermelon seeds and half or more contained sunflower, unidentifiable squash, and melon seeds. Corn was found in only 2 of the 12 contexts, beans in only one. In general, the nests contained few seeds, and the small seed counts in them may not be good indicators of a place to find preferred foods. A rodent cache (e.g., Lockard and Lockard 1971:221) in Room 112 at Walpi was much more revealing of the species preferred by rodents. The cache was in a small subfloor depression. It contained 1468 seeds of 15 genera, many of which were rodent gnawed, and a large amount of rodent feces. Almost half of the seeds in this cache were

TABLE 4.—*Tablulation of rodent and insect gnawed plant parts at Walpi.*

SPECIES	TOTAL COUNT	# INSECT GNAWED	% INSECT GNAWED	# RODENT GNAWED	% RODENT GNAWED	# RODENT-INSECT GNAWED	% RODENT-INSECT GNAWED
Bottle-Gourd seeds	462					240	52
Watermelon seeds	24,746			13,738	56		
Melon seeds	1,155					25	2
Maxima squash, banana type seeds	138					96	70
Maxima squash, S. American type seeds	23					6	26
Maxima squash seeds	9						
Pepo squash seeds	55					3	5
Mixta squash seeds	926					59	6
Unknown type A squash seed	9			1	11		
Not identifiable squash seeds	22					3	11
Beans	509					3	+
Corn cobs with kernels	46	41	89				
Cob fragments with kernels	10	3	30				
Corn kernels	1,692	642	38				
Peach pits	2,960			1	+		
Plum pits	23			2	9		
Apricot pits	43			11	26		
Cherry pits	9			5	56		
Almond hull	4			1	25		
Juniper seeds	700			523	75		
Pinyon testa	1,954			93	5		

watermelon, almost a third were corn kernels. The only other significant species were melon and striped cushaw squash seeds.

The data in Tables 4 and 5 are indicators of foods which rodents prefer when foraging on Hopi trash deposits. The last experiment undertaken involved a more direct test of rodent seed preference. Live mice were fed some seeds which were commonly found at Walpi to determine which were preferred over others. Four domesticated mice were purchased from the pet store and 2 domestic house mice (*Mus musculus*), a species which occurs at Walpi, were trapped and separated into 3 cages and fed 25 g each of various seeds. The results of this experiment are portrayed in Table 6. It is clear from this evidence that given a choice of 5 species which included blue flour corn, honeydew melon seeds, Mammoth Russian sunflower achenes, Halloween field pumpkin seeds, or white, common, kidney, or tepary beans, the "average" mouse preferred the corn. In the 2 experiments with the domesticated mice, they consumed over 40% of the available corn within 2 days, practically ignoring other species, and ate all of the 25 g of corn within 5 days. Once the corn started to diminish significantly, the mice turned to sunflower and melon seeds. They chewed the seeds from the margin, never splitting them along the suture to extract the soft interior as might be expected. The white beans and pumpkin seeds suffered no significant weight loss. After 3 days a few of the beans and pumpkin seeds were slighty chewed by the mice, resulting in nothing beyond slight damage to the seed. The experiment with the house mice also showed that after 3 days they, too, avoided the beans and selected the melon, corn, and sunflower seeds in nearly equal amounts.

TABLE 5.—*Breakdown of seed counts in one rodent cache and 11 nests at Walpi.*

	NESTS													
SPECIES	**FS107**	**FS207**	**FS59**	**FS289**	**FS113**	**FS164**	**FS154**	**FS139**	**FS182**	**FS223**	**FS216**	**FS204**	# of occurrence	% of occurrence
CUCURBITACEAE:														
Watermelon	665	1	1	1	4	35	1	4	no seeds	1			9	75
Melon	159		1	6		12	4				3	3	7	58
Bottle-Gourd	1					1							2	17
Mixta Squash	135						1						2	17
Pepo Squash	19											1	2	17
Squash				10	3	18		1		1	1		6	50
CORN	432										123		2	17
BEANS				1									1	8
OTHER DOMESTICATES:														
Cotton	5		1			1				13			4	33
Wheat	1												1	8
Peach	1			1									2	17
Sunflower	15		1	1	2	1					1		6	50
WILD SPECIES:														
Skunk Bush	1				1								2	17
Rice Grass	19			2	4	1	3						5	42
Prickly Pear	10												1	8
Pinyon	4			1		1				1	1		5	42
Ground Cherry					3								1	8
Amaranth											1		1	8
Goosefoot							1	1		2			3	25
Sunflower					1								1	8
Unknown	1												1	8
TOTALS	1468	1	4	23	18	73	10	6	0	18	130	4		

TABLE 6.—*Seed weight loss due to consumption by mice at 48, 72, and 120 hour intervals.*

EXPERIMENT #1	**at 48 hours seed weight**	**% loss**	**at 120 hours seed weight**	**% loss**
2 domestic mice with free water				
25 g flour corn	11	56	0	100
25 g melon	23	8	18	28
25 g sunflower	24	4	20	20
25 g pepo squash	25	0	25	0
25 g white beans	25	0	25	0
EXPERIMENT #2				
2 domestic mice with free water				
25 g flour corn	15	40	0	100
25 g melon	22	12	16	36
25 g sunflower	24	4	24	4
25 g pepo squash	25	0	24	4
25 g white beans	25	0	25	0
EXPERIMENT #3	**at 72 hours seed weight**	**% loss**		
2 house mice without free water				
25 g flour corn	23	6		
25 g melon	22	12		
25 g sunflower	23	6		
25 g kidney bean	25	0		
25 g tepary bean	25	0		

Other researchers have experimented with feeding native rodent species (*Perognathus* spp. and *Dipodomys* spp.) domesticated seeds, but did so for entirely different purposes than pursued here (Mares and Williams 1977; Lockard and Lockard 1971; Rosenzweig and Sterner 1970). These studies found that native rodents would accept all types of seeds presented, but might specialize in small or medium-sized varieties if resources were especially abundant (Mares and Williams 1977:1188; Rosenzweig and Sterner 1970:223). Lockard and Lockard (1971:219) found, in addition, that if specialization occurred, it generally favored seeds high in carbohydrates, oils, proteins, and species with a thin seed coat. Human trash deposits provide abundant nearby resources, and might encourage specialization in rodent foraging behavior. It is worth noting, too, that even in areas of abundant seed resources, there is not enough seed selection involved to prevent a number of rodent species from coexisting in the same environment (Rosenzweig and Sterner 1970: 222-223). Hence, an abundant habitat such as a trash midden could support a number of species of rodents.

These ecological studies recorded some information that appears to contradict findings reached here. For instance, Lockard and Lockard (1971:220) found that *Dipodomys deserti*, a kangaroo rat, preferred pinto beans and most other available species to sunflower seeds. Here, *Mus musculus* and its domesticated white relative, avoided beans entirely when other foods were available. Both Lockard and Lockard (1971:222) and Mares and Williams (1977:1188) found that *Perognathus* and *Dipodomys* preferred wheat over most species including sunflowers and corn. Rosenzweig and Sterner (1970:219) also found that pumpkin and squash seeds were preferred over sunflowers. Seed type preferences vary, undoubtedly, by rodent species and plant species availability. The critical factor is not really what species are preferred by foraging rodents, but that rodents might consume any type of seed in a trash deposit, and that consumption will favor some species over others.

CONCLUSION

Despite the fact that many of these Old World plants are not found in many Southwestern archaeological sites, these data on the condition of the Walpi plant remains, some of the effects of differential exposure, and preferred rodent foods, should be useful in assessing plant remains in other sites regardless of their location on the globe. Elements affecting differential exposure, and foraging rodents are universals that can be projected into the past and across spatial boundaries with some accuracy. The concept is, of course, uniformitarianism. We have performed a few experiments, have studied the condition of almost 40,000 plant remains, and can conclude that what is recovered by the archaeologist is a skewed picture of actual plant use. Corn kernels are quickly destroyed by insects and rodents, and most probably do not survive over 10 years in an unprotected room or midden. Beans are often destroyed by mold and bacteria during fluctuating moist and dry conditions, but do not seem to be affected by most rodents or insects. Some of the Cucurbitaceae are heavily foraged upon by rodents, others to a lesser extent. What is found in most archaeological sites is almost certainly a distorted image of past use. The present status of our knowledge can be refined, however. Hopefully, these experiments have pointed out the need for more experimental work. Only when this is done, will we proceed to a level of interpretation of archeobotanical data which is beyond guess work.

As a postscript, it is important to note that less than one percent of the plant remains from Walpi were carbonized, and what was charred did not accurately represent the entire assemblage. Archaeobotanists frequently have to rely on carbonized remains as indicators of plant use in the past (Minnis 1978: 362; 1981; Gasser 1981: 18-26) and it is evident that most carbonized remains represent a very skewed picture. Unfortunately, in most open sites all that remains to be excavated are charred plant macrofossils and pollen.

ACKNOWLEDGMENTS

We are grateful for assistance from biologists Jim Reichman, George Ruffner, and Jack States.

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