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Analytical Methods and Cultural Interpretations of Archaeological Plant Remains

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4

Selecting Quantitative Measurements in Paleoethnobotany

Virginia S. Popper

Introduction

Paleoethnobotanists learn little about human interaction with the plant world from raw plant-remains data. Cultural and noncultural factors bias the types and numbers of remains we recover from archaeological sites. Consequently, taxa frequencies alone do not directly reflect the human-plant interaction, and paleoethobotanists have developed methods of interpreting the frequencies. Ideally, paleoethnobotanists first define how taxa frequencies can answer research questions. We posit meanings to taxa frequencies through models, hypotheses, and assumptions (nonnumerical criteria). Then we derive from these nonnumerical criteria the types, numbers, distributions, and associations of taxa (i.e., the patterning) that we expect to find in the archaeobotanical data. In general, we use quantitative measurements to describe the patterning found in the data and to distinguish the patterning defined by our research questions from other sources of patterning.

This paper presents the determinants for selecting quantitative measurements. It discusses the sources of patterning in archaeobotanical data and four methods of quantifying these data: absolute counts, ubiquity, ranking, and diversity. Miller (chapter 5) discusses a fifth method, ratios, and Pearsall (chapter 8) provides examples of the ubiquity (presence) and ratio (frequency) methods. These three papers show that no one method of quantifying archaeobotanical remains is appropriate or even useful for

every paleoethnobotanical analysis. Quantitative measurements differ in their assumptions about archaeobotanical data and in the information that they provide about such data. The measurements we select will depend on our research questions and the quality of our data. To select the appropriate measurement, we must understand the possible sources of patterning in our data and the patterning we want to measure with our data. The more carefully and systematically we collect, process, and identify archaeobotanical samples, the more choices we have in selecting an appropriate quantitative measurement.

Sources of Patterning in Archaeobotanical Remains

Paleoethnobotanists must identify the many sources of patterning in a collection of plant remains to interpret the collection accurately. The sources of patterning are cumulative, beginning with human exploitation of plants and continuing through the paleoethnobotanist's recording of taxon frequencies. Figure 4.1 depicts the sequence of factors that may affect the types and frequencies of plant remains in a collection.

Patterning in the collection begins with people's beliefs about plants. Beliefs determine people's behavior toward the plant world (Ford 1979:290, 320-23). For example, beliefs prescribe how a plant is used or where it is planted. Plant remains vary depending on how people used, processed, stored, and prepared the plants and disposed of their by-products (Dennell 1976, 1978; Hillman 1984; Jones 1984). The remains form the underlying patterning from which we try to reconstruct the role of the plants. Two examples follow which illustrate how the same taxon can leave differently patterned remains. In the first example, one taxon is put to two uses; in the second example, the same crop is deposited at different stages of processing.

First, making chicha beer from maize will leave remains different from those resulting from toasting maize popcorn. To make chicha, kernels are soaked until they sprout and then are added to water, along with some chewed kernels, to ferment. To make popcorn, maize kernels are toasted whole in a pot or griddle over a fire. The broken-down chicha maize kernels are unlikely to be burned or dropped in a fire and therefore will probably leave no remains. In contrast, some popcorn kernels will probably burn, be discarded, and survive as remains.

The second example comes from Hillman's (1984:1-13) detailed description of traditional cereal processing in Turkey. Table 4.1 summarizes his data on two of the many stages in the processing of glume wheats (emmer, spelt, and einkorn) in areas with wet summers. Processing begins with harvesting and ends with cooking the prime grains. The wheat is stored

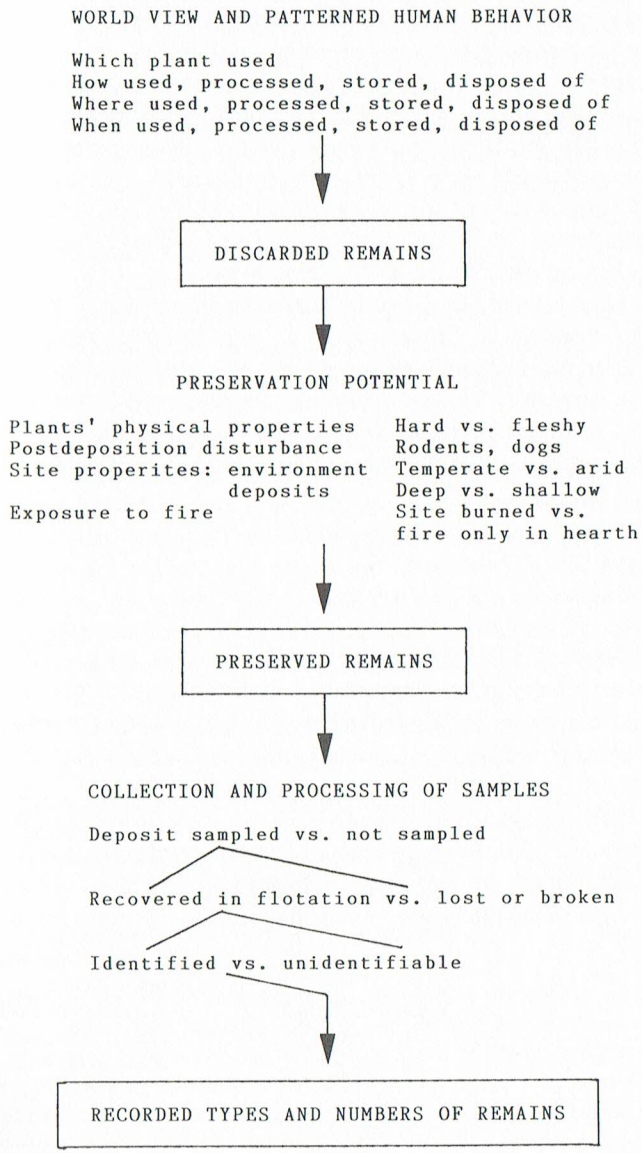

Figure 4.1. Cumulative stages of patterning of archaeobotanical data.

as spikelets before the second (coarse) and third (fine) sievings, which occur daily as grain is used. The coarse sieving removes some of the larger by-products from the prime grain. The fine sieving catches the prime grain and removes the smaller cleanings, including small grains, small weed seeds, and heavy bits of chaff. The cleanings from both sievings are usually thrown into the fire, at least in winter when hearth fires are common (Hillman 1981:155). The third column of table 4.1 shows "those components which, when exposed to fire, are small enough and dense enough to drop into the ashes and be charred rather than being burned to ash" (Hillman 1984:11). The charred remains from the coarse and fine sievings differ greatly, but both evidence the same crop and its processing.

After plant remains have been discarded or deposited, the vagaries of preservation introduce further patterning into assemblages of plant remains. Some plant parts are preserved better than others. Dense nutshells and seeds with much-resistant cellulose are preserved better than fleshy fruits with less-resistant sugars and starches (Dimbleby 1967:95; Munson, Parmalee, and Yarnell 1971; Carbone and Keel 1985:5-6). Many softer and

Table 4.1. Second and third sieving of glume wheats

Activity	By-Product	Likely Charred Remains
Coarse Sieving [a]	Unbroken spikelets	Some intact spikelets
	Straw nodes	Few culm nodes
	Large weed seeds	Few "weeds smaller than spikelets"
Fine Sieving [b]	Tail grain	Some tail grain
	Small weed seeds	Many "weeds smaller than prime grain"
	Heavy bits of chaff	Some spikelet forks
		Many glume bases
		Many rachis internode segments

[a] Prime grain passes through
[b] Prime grain retained
Source: Hillman 1984: fig. 5, table 1.

some harder plant parts may be eaten or chewed by insects, rodents, and dogs (Gasser and Adams 1981). Plants favored by these scavengers will be underrepresented in the assemblage. Environmental conditions at a site (soil type, temperature, moisture) affect preservation by allowing or inhibiting the activity of microorganisms (Carbone and Keel 1985:11-15). Remains from waterlogged sites and arid sites resist decay because many microorganisms cannot tolerate the lack of oxygen and water, respectively. Although extremely high or low temperatures, acidic soils, and toxic metal and salt compounds also inhibit microbial activity, in most sites environmental conditions allow decay, and only carbonized plant remains are likely to be preserved (Butzer 1982:114-17, fig. 7-16). The elemental carbon of carbonized remains does not support microbial activity. But erosion, root growth, and plowing can destroy carbonized remains. Sites with deep deposits or structures best protect carbonized remains from erosion and decay.

The cause of carbonization also influences frequencies and distributions of taxa. As Hillman (1981:139) notes: "On most well-drained sites . . . plant materials are preserved only by the chance of exposure to fire, and, even then, only when heating is relatively gentle (200-400 degrees C) or, if temperatures are higher, when they are smothered in the ashes (i.e., deprived of oxygen while heated) such that they are preserved intact by charring rather than being burned away altogether to mineral ash." A house that burns down, burying plant remains in situ, will provide a more complete record of its plant contents at the time of the burning than an abandoned, unburned house in which only plants exposed to a hearth fire are preserved. Hally (1981) shows that frequencies of plant remains in three houses at the Little Egypt site differed in part because two of the houses burned down before abandonment. Only the burned houses contained abundant remains of pokeweed, squash, persimmon, and honey locust (i.e., taxa not usually exposed to fire during processing or at disposal). About the different interpretive value of plant remains from burned and unburned structures, Hally (1981:738) states:

> The most important advantage inherent in carbonized botanical material from unburned structures is that its accumulation will generally be the result of accidents that are repeated with some degree of frequency and regularity through time. Such samples, therefore, will be little affected by short-term fluctuations in the availability of plant species or the frequency of particular processing activities.

Hally's data provide two views of plant use at the Little Egypt site. Differences in the cause of carbonization explain some of the patterning in the remains.

Further patterning can result from strategies for collecting, processing, and analyzing archaeobotanical remains. As discussed in the Introduction, archaeologists use a variety of sampling strategies to select deposits of plant remains for analysis. Too small or too few collected samples can misrepresent the types, frequencies, and distribution of plant remains at a site. Wagner (chapter 2) explains how different flotation and screening procedures for processing soil samples can influence the patterning of remains. For example, screening deposits with 0.25-in. mesh loses the many seeds and plant remains smaller than 0.25 inch. In analyzing plant remains, our proficiency at identification affects plant frequencies. Identifying remains only to family or genus may obscure patterning of the constituent species. If we cannot distinguish one species used commonly as a food from another used infrequently as a medicine, we lose information about the latter. We also chose in our analysis to measure remains by count, weight, or volume. Which units of measurement most accurately reflect the quantities of tiny seeds, nutshell fragments, and charcoal? As Miller (chapter 5) explains, the best measurement depends on the type of plant remains. Finally, by grouping samples for analysis (discussed in more detail below) we change patterning if we combine samples from different populations.

The sources of patterning in archaeobotanical data are many. Uncritically applying quantitative measurements to interpret patterning can lead to erroneous conclusions. Paleoethnobotanists must consider the cumulative sources of patterning in their data to isolate the underlying patterning that supports or refutes the hypotheses developed from their research questions.

Research Questions

The complexity of the patterns we seek in our data will vary according to our research questions. For example, a basic question in the interpretation of plant remains is how the plants were used. To distinguish possible uses, we draw predictions (from ethnographic models and other data about plant use and processing) about how use affects, among other things, the part of the plant that would be deposited. Two different uses may lead to disposition in different contexts or with different sets of plants. In the first case we look for patterns relating one taxon to its context (fig. 4.2a), and in the second case patterns relating one taxon to the assemblage of taxa in a sample (Fig. 4.2b).

Another question is the relative importance of plants in the economy. To evaluate relative importance, we begin again with nonnumerical criteria. We make an assumption about what we mean by importance. Do we

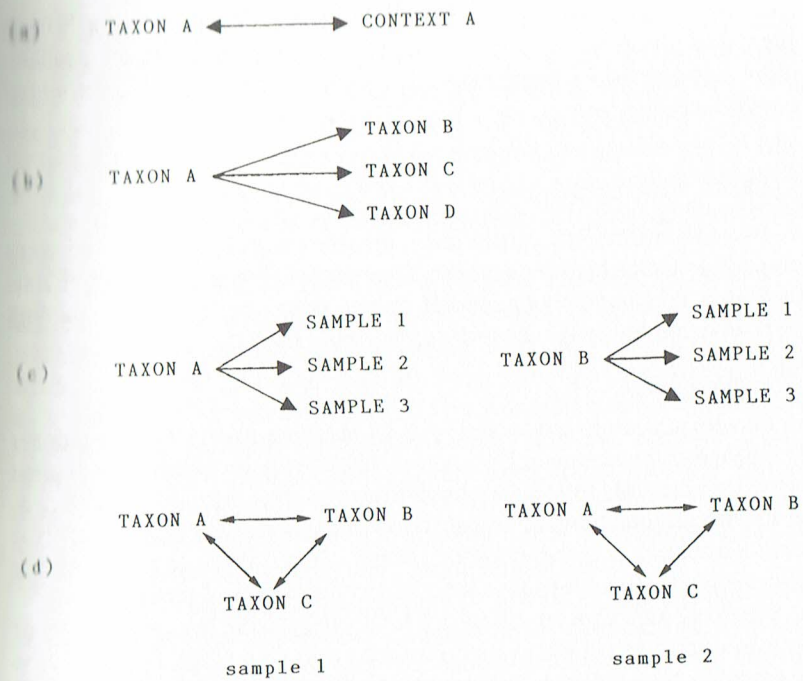

Figure 4.2. The complexity of the patterns sought in archaeological data depends on the complexity of research questions.

evaluate the importance of food sources by the quantity of particular food sources, by their nutritional contribution to the diet, or by the time and labor required to procure them? Can we compare food and nonfood resources? Whatever the criterion we use to define importance, we translate it into an expected numerical relationship between taxa. Depending on the criterion, we may look for patterns which compare the significance of different taxa in a group of samples (fig. 4.2c), or for patterns which compare the relationships among taxa in a group of samples (fig. 4.2d).

Different research questions lead us to look for different patterns of data and to look at different scales of patterns. As research questions become more complex, spanning different time periods or sites, our analysis

includes a greater variety of samples. Quantitative measurements differ in their ability to handle such complexity. Of course no quantitative measurement can correct for inaccurate nonnumerical criteria used to set up our predicted patterns.

Types of Measurements

No one method of quantitative measurement is suitable for every research question or every analysis. The summary below of the assumptions and biases of a number of quantitative methods suggests ways of deciding when one method might be more appropriate than the others.

Absolute Counts

Quantifying archaeobotanical data by absolute counts (the raw number of each taxon in each sample) assumes that the absolute frequency of plant remains accurately reflects prehistoric human-plant interaction. However, as the discussion above shows, absolute frequencies may reflect preservation, sampling, or various other factors. Thus, absolute counts rarely provide an adequate measurement for archaeobotanical remains.

The problem with absolute counts is illustrated by an example of quantifying charcoal excavated from a hearth. One could argue that the charcoal directly reflects the amounts of different taxa of firewood burned in the hearth. But some woods burn more completely than others, and some fracture more easily than others (Smart and Hoffman, chapter 10). In addition, clearly the significance of oak is different in one sample, where it comprises 100 fragments out of 1,000, from in another, where it comprises 100 fragments out of 150. Moreover, if the first group of charcoal was extracted from a 5-liter soil sample and the second from a 1-liter soil sample, the difference is even greater. A 5-liter soil sample must have 500 pieces of oak charcoal to be equivalent to the 100 pieces from the 1-liter sample. At the very least, the absolute counts must be standardized (converting them into ratios) to account for differences in sample size (see Miller, chapter 5) or differences in sample abundance (Scarry 1986:214). Paleoethnobotanists frequently use these standardized counts in further quantitative and statistical analyses.

Ubiquity

A common method for quantifying archaeobotanical data is ubiquity or presence analysis (Godwin 1956; Willcox 1974; Hubbard 1975, 1976, 1980). This method disregards the absolute count of a taxon (it assumes that the absolute counts of any particular taxon are too influenced by the degree of preservation to be meaningful) and instead looks at the number of

samples in which the taxon appears within a group of samples. Each taxon is scored present or absent in each sample. The taxon is considered present whether the sample contains 1 remain of the taxon or 100, thereby giving the same weight to 1 or 100. The frequency score of a taxon is the number of samples in which the taxon is present expressed as a percentage of the total number of samples in the group. For example, maize recovered in 8 of 10 samples receives a score of 80%. Chili pepper in 6 of those 10 samples receives a score of 60%.

An important characteristic of ubiquity is that the score of one taxon does not affect the score of another, and thus the scores of different taxa can be evaluated independently. Hubbard (1980:53) cautions that a single frequency score has significance only in comparison with other scores of the same taxon, and that ubiquity analysis "is intrinsically comparative and not absolute so that, while presence values can be compared within taxa, they probably cannot be used to compare the absolute importance of different taxa directly (e.g., emmer (wheat) at 70% P might be five times as important as hulled barley at 70% P)." But ubiquity scores of different taxa can provide information on the relative importance of taxa.

The primary methodological assumption in ubiquity analysis is that all samples in a group are independent. In addition, each sample must have two or more taxa. Two examples show that where sampling and recording are inadequate for assessing the homogeneity of deposits or the differences of context, it may be difficult to fulfill the assumption of independent samples and to insure that the data are appropriate for answering the research question. Table 4.2 shows how ubiquity scores will change if one sample (sample 1 in table 4.2) is mistakenly treated as two independent samples or analytical units (samples 1a and 1b in table 4.2). Because the presence of a taxon in each analytical unit receives equal weight, mistakenly splitting one sample into two analytical units inflates the frequency scores of the taxa in those analytical units. This could happen if one inadvertently takes two samples from one archaeological deposit and treats them as independent analytical units; or one might intentionally take two samples but then inadvertently score them as independent samples instead of averaging or combining them in an appropriate fashion. Clearly, mistakes alter the frequency scores less significantly when a group contains many samples.

Hubbard (1980:64) provides a second example from Çayönü, showing that similar problems arise if independent samples are mistakenly grouped. Hubbard's (1975: fig.3) initial ubiquity analysis grouped samples chronologically and showed a shift in high scores from cereals to pulses (lentils, peas, and *Vicia ervilia*). Hubbard (1975:203) concluded that plant use at the site changed over time. However, when Hubbard (1980:64) reanalyzed the data, grouping samples by location at the site, other patterns appeared. The

Table 4.2. Ubiquity and independent samples

Taxon	Sample No. [a]				Sample No. [a]				
	1	2	3	4	1a	1b	2	3	4
A	X				X	X			
B	X		X	X	X	X		X	X
C		X	X				X	X	
D	X			X			X		X
Frequency Score (%)									
A	25				40				
B	75				80				
C	50				40				
D	50				40				

Note: This table presents two versions of the same data to illustrate the two techniques.
[a] X indicates taxon present.

highest ubiquity of pulses came from a locality with no wheat. Wheat and pistachio ubiquity appeared correlated. (If the pistachios were used to flavor the grain this may represent a stage of food preparation.) The evidence suggests that the differences in ubiquity scores at Çayönü, more accurately reflect the differences in activities at different localities at the site. Hubbard's chronological grouping of the samples mistakenly assumed that each group represented the full range of plant use at Çayönü, at that time period. His regrouping by locality suggests that differences in plant processing in the different localities better account for the patterning in this small group of samples. The sample of plant remains was inadequate for answering questions about changing plant use over time.

Another methodological problem that can skew frequency scores is having too few samples, which inflates frequency scores. For example, in a group of four samples the minimum presence of a taxon is 25%, while in a group of twenty samples the minimum presence is 5%. Comparing scores from the two groups can be misleading. Similarly, "a taxon whose 'real' presence is 10% cannot be properly assessed with less than 10 samples" (Hubbard 1976:160). Having few samples more severely skews frequency scores of rare taxa, so with few samples rare taxa should be excluded from analyses or interpreted with caution.

In interpreting ubiquity scores, it is important to make explicit the relationship between the ubiquity scores and the information we seek. For instance, Minnis (1985:104,106) clearly explains his use of ubiquity:

> Making the assumption that charred remains are primarily the result of accidents, then ubiquity tends to measure the number of accidents, which is more closely related to the degree of utilization than is tabulation. Thus, I will assume that a change in the number of samples in which a taxon is present is an imprecise but useful measure of the relative change in the use of that resource.

Hubbard (1975:198; 1980) similarly uses ubiquity to examine crop introduction and use in Europe and the Near East over the past 10,000 years. Ubiquity analysis allows him to combine data from many sites, collected with different excavation and sampling strategies, to compare the use and spread of 11 crops within and between seven geographic areas. (Hubbard [1980] points out the possible sources of error with such data.) The broad view afforded by analyzing such a large data base suggests many interesting patterns and trends. For example, by correlating patterns of crop use with climate, Hubbard (1976:165; 1980) suggests that through time cultural preferences replaced ecological differences as the best explanation for many of these patterns.

In a second example of ubiquity analysis, Hastorf (1983) argues that ubiquity scores can measure crop production and land use of the prehistoric Wanka ethnic group. By using a smaller and more carefully controlled data base, she can draw more specific conclusions than Hubbard. Hastorf uses the standard error of the difference in proportions to test for the significance of trends across time and space and by context. For example, Hastorf (1983:256-59) tests for differences in use and processing of domesticated plants by examining the relationship between the frequencies of the domesticates and different contexts. Finding no significant patterns introduced by different processing, storage, or disposal methods, she concludes that all of the contexts represent the same group of activities. Consequently, she combines the frequencies of these remains from all contexts to test for

trends in crop production and land use. Another method for testing the significance of trends is Spearman's coefficient of rank-order correlation (Minnis 1985:106).

In sum, ubiquity analysis is useful, within limitations, for showing general trends when one has little control over the sources of patterning in one's data. By measuring the frequency of occurrence instead of abundance, it reduces but does not eliminate the effects of differences in preservation and sampling. At the same time, however, ubiquity can obscure cultural patterns of plant use where the frequency of use remains the same, but abundance changes (Scarry 1986:193). The results of ubiquity analysis are highly dependent on the grouping of samples and to some extent on the number of samples.

Ranking

Ranking aims to measure plant frequencies more precisely than ubiquity analysis by estimating and adjusting for noncultural sources of patterning. Ranking translates the absolute counts of the data into an ordinal scale. We define a ranking scheme, and for each taxon we separately determine a scale of abundance which sets the frequency required to fall within each rank. To choose the criteria for determining a scale of abundance for each taxon, we select the most important noncultural sources of patterning in the data for which we want to control. We set the scale to neutralize the biases introduced by these sources of patterning.

In a simple hypothetical example, to confirm differences in status between households, we predict that high-status households in highland Peru predominantly ate maize, while low-status households ate quinoa (*Chenopodium quinoa*) and potatoes. We assume that differences in quantities of these taxa between household kitchen middens reflect differences in diet. To test this prediction, we assess differences in the relative quantities of these taxa while controlling for the patterning that variability in preservation and seed production introduce into the data. We establish the scale of abundance based on the expected preservation potential of each taxon under a particular set of conditions and the expected seed production under a particular set of environmental conditions. Using these two criteria, we can define three ranks for quinoa, maize, and potato (table 4.3). Quinoa plants produce a large number of small seeds, which are dense and are preserved well. Therefore, in this example, 501 and 1,000 quinoa seeds per sample have equal significance. Maize plants produce many kernels. The kernels are starchy and are preserved moderately well. Potato plants produce a few large starchy tubers, which are rarely preserved in archaeological sites.

Table 4.3. Scales of abundance [a] for quinoa, maize, and potato

	Rank		
	1	2	3
Quinoa	1-50	51-500	501+
Maize	1-10	11-25	26+
Potato	1-2	3-5	6+

[a] Counts are the number of quinoa seeds, maize kernels, or potato tubers per 5-liter flotation sample.

Using these ranks, we look for differences in the abundance of these taxa in kitchen middens of three households. Independent criteria identify household 3 as high status. The plant remains confirm the predicted association between status and diet. Households 1 and 2 have more quinoa and potato and Household 3 has more maize (table 4.4). These differences are clearer when we look at the ranks instead of the absolute counts.

Table 4.4. Quinoa, maize, and potato counts

	Households		
	1	2	3
	Counts		
Quinoa	700(3)	70(2)	40(1)
Maize	24(2)	9(1)	30(3)
Potato	6(3)	3(2)	1(1)

Note: Counts show number of quinoa seeds, maize kernels, or potato tubers per 5-liter flotation sample. Numbers in parentheses are ranks.

The assumptions we must satisfy to apply ranking depend on the criteria used to create each taxon's scale of abundance. In this example, we assume first that the preservation conditions are the same for every sample. We cannot apply the same scale of abundance to maize from a dry rock shelter, where uncarbonized kernels are preserved, as to maize from a shallow open-air site with poor preservation. Because preservation conditions differ between contexts at the same site, the ranking method increases in accuracy if we only compare samples from the same context.

Second, we assume a relative weighting of seed production to establish the scales of abundance. This assumption is worthwhile only with a large number of remains in each sample and high counts of individual taxa. In this example (table 4.3), 100 and 400 quinoa seeds per sample are of equal significance, while 600 seeds are of greater significance. If no sample contains more than 10 quinoa seeds, this scale is useless. In addition, because of quinoa's high seed production, we should not divide 0 to 10 seeds into several ranks. Ranking this small range of data will probably introduce errors into our results rather than control for variation in seed production. Consequently ranking is not suitable.

In sum, ranking might be useful for evaluating the abundance of plant remains at a site that has consistently excellent preservation of plant remains and high counts of taxa in each sample. If these criteria limit us to applying ranking only to samples from one context at one site, we are limited in the types of questions we can answer with ranking. Ranking is advantageous because it allows taxa to be evaluated independently. But the subjective weighting of taxa frequencies to determine their scales of abundance increases the potential for introducing errors into the results. In many cases the complication and potential for error with ranking will exceed ranking's potential for measuring plant frequencies more precisely.

Diversity

A diversity measurement summarizes data to describe the composition of a plant assemblage. Of the several methods for measuring diversity, this paper uses the Shannon-Weaver information index as an example. This measurement incorporates the total number of taxa in an assemblage and the relative abundance of each taxon to express the certainty of predicting the identity of a randomly selected plant remain (Yellen 1977:107-8; Pearsall 1983:130). If there are many taxa evenly distributed in the assemblage, the certainty of predicting the identity of the selected plant is low and the index indicates high diversity. If the taxa are few and unevenly distributed, the index indicates low diversity. Pielou (1977:292) cautions that "since diversity depends on two independent properties of a collection ambiguity is inevitable; thus a collection with few species and high evenness could

have the same diversity as another collection with many species and low evenness."

Pearsall (1983:130-31) introduced the use of the Shannon-Weaver index to paleoethnobotany. She analyzed an assemblage of plant remains from Pachamachay, a multioccupation site in Peru, to distinguish remains of a specialized or temporary occupation from those of a base camp of sedentary hunter-gatherers. Pearsall's results showed partial agreement between the diversity index and independent measurements of intensity of occupation. Six of the eight phases showed constant, increasing, or decreasing diversity that corresponded to similar trends in intensity of occupation. Two phases with predicted low intensity of occupation (a sporadic hunting camp and a ceramic workshop) produced moderately high diversity indices. Pearsall (1983:134) suggests that low abundance of plant remains in these two phases probably skewed the results. Caddell (1983) and Scarry (1986) use the Shannon-Weaver index to examine variability in maize populations based on cob row number.

Pearsall (1983:137) used the following formula to calculate the Shannon-Weaver index. (Although her formula calls for natural logarithms, her example results are based on common logarithms. One converts to the other using a constant. Pearsall's [pers. com.] recalculation of her example using natural logarithms shows that the natural log curve parallels the common log curve in its shifts and supports the same conclusions.)

$$H = - \text{Sum}(N_j/N) \log (N_j/N)$$

where N = total number of seeds in the phase

N_j = total number of seeds of taxon j in the phase

A hypothetical example (table 4.5) points out some of the difficulties of the Shannon-Weaver index. The example looks at the diversity indices of plant remains from three excavated levels. Table 4.5 presents the counts (N_j) of five taxa in each level, totaling (N) 200 remains. The maximum possible diversity index in this example is .70, indicating even distribution ($N_j = 40$) of all five taxa.

The information derived from this analysis is necessarily general. The diversity index in level 1, close to the maximum, shows high diversity, while the lower index values in levels 2 and 3 show lower diversity. There is no simple statistic for measuring the significance of this difference in values. In addition, as Pearsall points out, the diversity index combines all frequency data from one period or level in one index, thus losing information on constituent data. Two samples with the same diversity measure may

Table 4.5. Example of diversity measurement

	Level 1	Level 2	Level 3
Lima beans	40	12	50
Avocado	37	10	0
Squash	29	140	70
Maize	50	15	0
Prickly pear	44	23	80
Total (N)	200	200	200
Diversity index (H)	.68	.44	.46

contain different taxa (Yellen 1977:108), and in this example, low diversity in level 2 comes from uneven distribution, while equally low diversity in level 3 comes from few taxa. Thus, this diversity measurement may be useful for looking for generalized (diverse) versus specialized (not diverse) plant assemblages, but gives only the broadest trends. We must look to the data themselves to understand the nature of the specialization. We may find that differences in seed production and preservation potential among taxa have influenced the measurement, thereby obscuring its cultural meaning. If prickly pear seeds, ranging from 0 to 1,000 per sample, are in the same index as avocado seeds, ranging from 0 to 20 seeds per sample, an automatic bias exists toward uneven distribution of the taxa and low diversity.

An advantage of the diversity measurement is that it is easy to calculate and provides a simple value. However, with more specific predictions about how, for instance, a permanent agricultural settlement's plant remains will differ from those of a temporary harvesting camp (e.g., differences in types, quantities, and contexts of remains) we could use other quantitative

measurements which would provide more specific information. Finally, the Shannon-Weaver index requires high counts for each taxon, limiting its applicability to archaeobotanical data. Pearsall (1983:130) believes that counts under 10 could lead to inaccurate results. If, as occasionally happens, we must combine samples (possibly from different contexts) to reach counts over 10, we must be careful to group samples from the same population (a problem already discussed in terms of ubiquity measurement).

Conclusion

This paper shows that we cannot draw direct conclusions about human-plant interactions from the frequency of taxa alone. The patterns in the data derive from cultural and noncultural factors. Our research questions, models, and assumptions define the patterns we seek in our data and suggest meanings for these patterns of plant remains. But we must also account for other sources of patterning in the data. Quantitative measurements assist us in these tasks. With the increasing complexity of the research questions we address to archaeobotanical data, the importance of selecting an appropriate quantitative measurement also increases.

Examples of different quantitative measurements point out the strengths and weaknesses of each method. The different methods treat the data with different degrees of specificity, require different conditions, and provide different information. As the measurements move away from absolute frequencies, we lose information on abundance. But more specific measurements, such as absolute counts and ranking, require greater control over preservation and context than ubiquity. Ratios (see Miller, chapter 5) also treat the data with greater specificity than ubiquity analysis. When our patterns involve well-controlled data (e.g., comparing taxa between the same type of context at one site) we may want a more specific measurement. Even with the same collection, other research questions that involve comparing samples from diverse contexts may call for more general measurements.

When choosing between alternative measurements, we also consider the conditions they require. Ubiquity is less reliable (especially for measuring the frequency of rare taxa) when there are few samples in a group. Ranking requires high counts of taxa. All paleoethnobotanical analyses require careful grouping of samples for accurate results. This is particularly important in ubiquity analysis, because grouping samples is an integral part of the calculation. Miller (chapter 5) discusses the issues involved in averaging values.

In the information they give, ranking and ubiquity allow us to evaluate taxa independently. This does not hold true for ratios that standardize data

by comparing the quantity of one taxon or category of remains to that of another taxon or category (see Miller, chapter 5). Diversity measurements are useful for summarizing groups of data but tell us nothing about individual taxa. The same cautionary note applies to the interpretation of all quantitative measurements. We must be explicit about how the values we receive from our measurements provide the information we need to answer our research questions.

This paper illustrates that one cannot generalize about the suitability of a particular quantitative method. Some methods may be better suited in general to some research questions, but the best method in any specific instance depends also on the condition of the archaeobotanical data. To choose a suitable method, we need to consider both the question and the data condition. Specific examples from this paper and this volume provide guidelines for the selection of quantitative measurements. Paleoethnobotanical analyses often include several methods of quantification and may benefit from comparing the results of different methods.

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