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EVALUATING THE STABILITY OF SUBSISTENCE STRATEGIES BY USE OF PALEOETHNOBOTANICAL DATA

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ABSTRACT.–Two analyses of archaeological plant remains are presented to illustrate how ethnobotanical data can be applied to the problem of determining stability of subsistence strategies through time. An analysis of charred wood from the Real Alto and Rio Perdido sites in coastal Ecuador revels changes in firewood collection strategies which correlate to changes in settlement patterns and land use in the area. An analysis of seed and wood remains from the Pachamachay site, Peru, explores the utility of four quantitative approaches. Patterns of change in occurence of plant taxa are pinpointed within the overall pattern of stability of plant utilization strategies in the puna zone.

INTRODUCTION

Over the past few years, paleoethnobotanists have made an increasing effort to apply their data to questions of cultural process: the evolution of early nutritional systems, cultivation strategies, long term stability of subsistence strategies, and the process of agricultural intensification, among other current research problems in archaeology. Richard Ford (1979), in a recent review of paeloethnobotany in North America, details the evolution of this trend, and the emergence of anthropological ethnobotany. This paper demonstrates the application of ethnobotanical data to the problem of determining the stability of subsistence strategies through time. Two cases will be presented: analyses of charred wood from the Real Alto site, coastal Ecuador (Pearsall 1979), and of charred seeds from the Pachamachay site, Department of Junin, Peru (Pearsall 1980). In each case, ethnobotanical data are available from a series of carbon 14 dated phases, distinguished by ceramic or lithic style. Data independent of the botanical remains exist on subsistence and overall adaptation allowing comparisons between conclusions reached from each set of data. Using several quantitative approaches, it will be demonstrated that even in a case of poor preservation of plant remains valuable insight can be gained by a diachronic examination of paleoethnobotanical data.

Several recent papers (Asch and Asch 1975; Asch, *et al.* 1979; Dennell 1976; Minnis 1981) have emphasized caution in the interpretation of archaeological seed assemblages. The lack of direct correlation between raw seed counts or percentages and dietary importance of the plant is well understood by most ethnobotanists, who routinely include in their analyses cautions about the bias produced by differential preservation of botanical materials archaeologically. A variety of quantitative means have been applied to ethnobotanical data in an attempt to circumvent this problem. No overall review of these measures has been made. No such assessment is attempted herein, rather it is hoped that comment can be generated on this topic by the presentation of the Real Alto and Pachamachay data in several different quantitative formats.

REAL ALTO CHARRED WOOD ANALYSIS

The Real Alto site, excavated under the direction of Donald W. Lathrap, is a 300 x 400 m oval village located on the Rio Verde in southwestern Ecuador. It was occupied by peoples of the Valdivia and Machalilla ceramic traditions. The Valdivia tradition belongs to the early Formative phase of coastal Ecuador (Meggers 1966:34-42). Earliest

Valdivia ceramics, Valdivia I, appear at Real Alto at 3545 B.C. (Damp 1979). The entire sequence, Valdivia I-VIII, is present at the site, but for purposes of this analysis, phases VII and VIII were combined as late Valdivia, terminating at about 1500 B.C. The Machalilla phase, the middle Formative of coastal Ecuador, dates approximately 1500-1000 B.C. The Machalilla samples used in this analysis come from a second site, Rio Perdido (OGCh-20), a multiple component site located near Real Alto and excvated by Ronald D. Lippi. Lippi (1980) proposes a hiatus of several hundred years between the abandonment of Real Alto and the beginning of the Machalilla occupation at Rio Perdido.

The research problem investigated in the full ethnobotanical analysis of plant remains from Real Alto and Rio Perdido was the nature of the subsistence strategy of the Valdivia and Machalilla peoples living in the study area from 3500-1000 B.C., including an investigation of the role of agriculture, the presence of specific crops, such as maize and root crops, and the pattern of firewood and other wild plant utilization (Pearsall 1979). Evidence of maize agriculture, beginning in the earliest Valdivia period, was obtained through phytolith analysis (Pearsall 1978; 1979). Cultivation of a member of the Cannaceae, probably *achira (Canna edulis)*, is also suggested by the phytolith data. Charred fragments of *Canavalia* beans, identified by Lawrence Kaplan (Damp *et al.* 1980) as probably domesticated *C. plagiosperma,* also date from earliest Valdivia times onward. A model of Valdivia and Machalilla subsistence developed from the Real Alto study includes not only agriculture, but wild plant gathering, terrestrial hunting, fishing, and collecting of molluscs from mangrove swamps (Pearsall 1979: 186-189).

Charred wood fragments were the only well preserved macroremains recovered in any quantity from the sites. Samples of 20-30 pieces greater than 2.0 mm could be identified from many flotation samples by comparison to modern wood from the region.

Because there was no evidence for structural fire in the areas excavated at Real Alto and Rio Perdido (e.g., no charred posts, no evidence of roofing or wall collapse due to fire), all charred wood could be assumed to be the result of deliberate burning. Small pieces of charred wood were found in concentrations, suggesting cooking areas, and spread in household debris. Stone-constructed hearths were not found at the sites. This situation implies that all charred wood can be considered functionally comparable (also see Miller, 1980). Further, it can be argued that wood charred by deliberate burning is the *one* type of ethnobotanical remain where the archaeological patterning directly translates to a pattern of human behavior (Fig. 1). The charring of wood reflects its function: as a fuel to be burned. By contrast, the charring of most other botanical remains is not the result of its function, but is accidental. Of course, before percentage

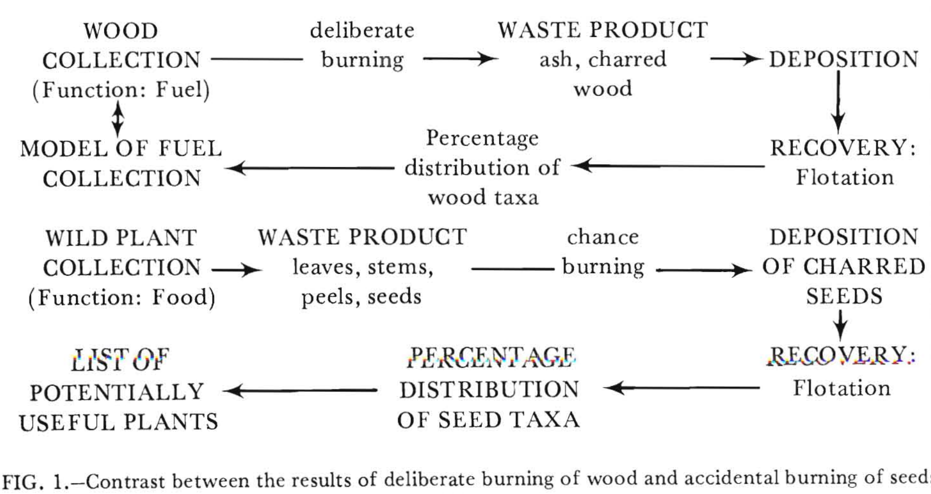

FIG. 1.—Contrast between the results of deliberate burning of wood and accidental burning of seeds in the interpretation of archaeological plant assemblages.

distributions of wood species can be translated into firewood preferences, different fracturing properties, hardness, and ashing properties of the woods, to correct for over- and under-representation in the archaeological record, must be considered. With more experimental work in this direction the potential exists for controlling for these biases, whereas there is little possibility to correct the accidents of seed preservation.

Turning now to the Real Alto analysis, Fig. 2 shows the major vegetation zones of southwestern Ecuador as reconstructed for the early Formative. This reconstruction assumes that the climate during the Valdivia and Machalilla periods (3500-1000 B.C.) was similar to the present day climate of southwestern Ecuador, and controlled by the same patterns of wind and currents which operate today. A critical evaluation of climatic reconstruction curves proposed by Hough (1953), Fairbridge (1961, 1962), McDougle (1967), Sarma (1974) and Byrd (1976) revealed neither convincing evidence for climatic change during the 3500-1000 B.C. period nor evidence that conditions were different from today (Pearsall 1979: 55-79). The description of the floristic communities is based on observations in the area made August 1974 through August 1975, interviews with long-time residents concerning recent man-induced changes, and on the published works of Acosta-Solis (1961, 1968, 1969) and Svenson (1946). Familiarity with two forest communities is necessary for the wood analysis, the xerophytic forest, a dry open formation dominated by leguminous trees, and the seasonally deciduous forest, a denser formation of two stories requiring more abundant and regular rainfall. Both are considered climatic climax vegetation types (Richards 1972:321). The open grassland appearance of much of this area today is secondary grassland formation, caused by man-made disturbance (Pearsall 1979). Both the xerophytic forest and the deciduous forest formations have been modified in composition in modern times because of intensive exploitation,

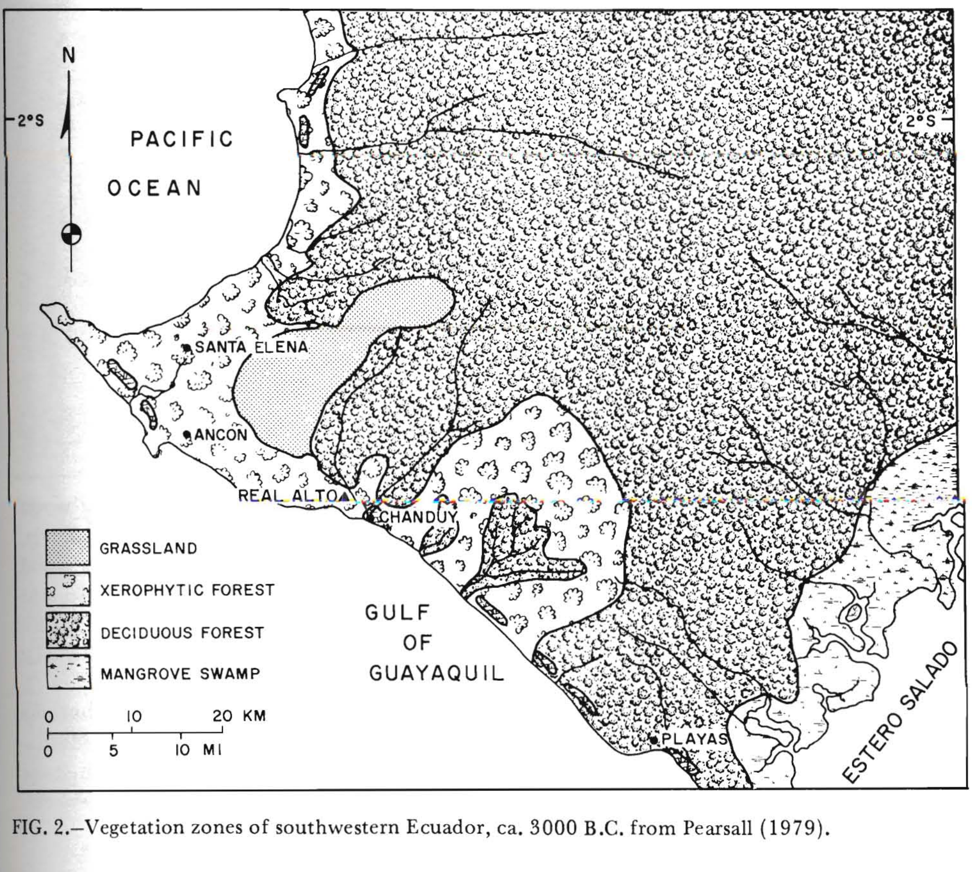

FIG. 2.—Vegetation zones of southwestern Ecuador, ca. 3000 B.C. from Pearsall (1979).

particularly cutting of trees and shrubs, and pulling of dead stumps of previously cut trees, for making *carbôn* (locally produced charcoal). The Real Alto and Rio Perdido sites are located near the boundary of the two forest zones.

Seventeen archaeological wood types were defined in this analysis (Table 1).[1] Five of these could be identified securely to species. The other 12 types were either less securely identified, not present in the comparative collection of 75 species, or were similar to more than one species. Types A, C, F, G, I, and J were not similar to any taxon in the collection, and so could not be assigned to habitat. Type H is assigned to the xerophytic forest because it is probably *Maytenus octogona* (L Her.) D.C. Because the archaeological specimens are so few, and minute, this identification is tentative. Type B resembles two taxa: *Triplaris guayaquilensis* H.B.K. and *Tecoma gandichandi* D.C., both native to the deciduous forest. Type D resembles four genera occurring in either deciduous or evergreen forest formations: *Ocotea* sp., *Guazuma ulmifolia* Lamark, *Vitex gigantea* H.B.K., and *Bombax ruizii* Schum. Type E is similar to *Muntingia calabura* L. and two unidentified taxa, all collected in the deciduous forest. Type K is similar to *Dodonaea* sp., a woody vine collected in the deciduous forest of Chongon. This identification is tentative, however, because of the small sizes of the pieces. Because the final unidentified wood type (the soft, grainy type) resembles numerous taxa in the comparative collection, notably many of the large deciduous and evergreen forest trees, it was assigned to the deciduous forest for purposes of this analysis.

TABLE 1.—*Archaeological wood taxa identified at Real Alto and Rio Perdido and their assigned habitats.*

Xerophytic Forest	Deciduous Forest	Unknown Habitat
Prosopis juliflora (S.W.) D.C.	*Stercula corrugata* Little	Type A
Acacia macracantha H. & B.	*Tabebuia chrysantha* (Jacq.) Nicholson	Type C
Pithecellobium dulce (Roscb.) Benth.		Type F
	Type B	Type G
Type H	Type D	Type I
	Type E	Type J
	Type K	
	Soft, grainy Type	

Chi-square analysis of the charcoal data was performed to determine if the 17 wood taxa were randomly distributed among the eight time periods (Valdivia I-VI, late Valdivia, and Machalilla). For this analysis, all taxa and time periods were used, and the wood types having totals less than 10 observations (types G, H, I, J, and K) were combined into the "Other" category. The categories and analysis matrix appears in Table 2. A Chi-square value of 1,416.4 (d.f. = 84) indicates a highly significant difference ($p \ll 0.01$); therefore, the taxa did not appear to be randomly distributed among time periods.

Chi-square analysis was also performed to determine if non-random distributions existed within wood type categories or within time periods. This showed that the Machalilla period accounted for most of the lack of randomness between periods, and the taxa *Prosopis juliflora, Acacia macracantha, Stercula corrugata,* and Types B and E between taxa.

TABLE 2.—Chi square test of wood taxa and time periods. Taxa abbreviations: *Prosopis juliflora* (P.j), *Acacia macracantha* (A.m), *Stercula corrugata* (S.c), *Tabebuia chrysantha* (T.c), and *Pithecellobium dulce* (P.d).

		P.j	A.m	S.c	T.c	P.d	A	B	C	D	E	F	S	Other	Row T.	Row Chi	Sign. Lev.
Val I	Ob.	131	62	0	1	0	7	3	1	0	15	5	1	4	230	55.54	0.001
	Ex.	95.55	56.44	20.56	1.51	2.72	6.45	13.51	4.23	1.31	13.51	5.04	6.85	2.32			
Val II	Ob.	152	29	8	0	5	5	2	6	5	14	20	9	1	256	109.57	0.001
	Ex.	106.35	62.82	22.89	1.68	3.03	7.18	15.03	4.71	1.46	15.03	5.61	7.63	2.58			
Val III	Ob.	455	271	5	3	8	37	44	21	6	76	15	48	7	996	116.00	0.001
	Ex.	413.76	244.42	89.04	6.55	11.78	27.93	58.49	18.33	5.67	58.49	21.82	29.68	10.04			
Val IV	Ob.	25	17	0	0	0	1	1	1	2	4	1	0	0	52	21.26	0.05
	Ex.	21.60	12.76	4.65	0.34	0.62	1.46	3.05	0.96	0.30	3.05	1.14	1.55	0.52			
Val V	Ob.	10	24	1	0	0	1	0	0	0	2	0	0	1	39	32.85	0.01
	Ex.	16.20	9.57	3.49	0.26	0.46	1.09	2.29	0.72	0.22	2.29	0.85	1.16	0.39			
Val VI	Ob.	71	111	1	0	5	10	5	3	0	15	3	2	7	233	102.56	0.001
	Ex.	96.79	57.18	20.83	1.53	2.76	6.53	13.68	4.29	1.33	13.68	5.11	6.94	2.35			
Late Val	Ob.	55	0	2	0	0	0	0	0	0	2	0	5	0	64	64.65	0.001
	Ex.	26.59	15.71	5.72	0.42	0.76	1.79	3.76	1.18	0.36	3.76	1.40	1.91	0.65			
Mach	Ob.	49	46	187	11	9	3	79	10	0	6	6	3	3	412	914.02	0.001
	Ex.	171.16	101.10	36.83	2.71	4.87	11.55	24.19	7.58	2.35	24.19	9.03	12.28	4.15			
Col. Tot.		948	560	204	15	27	64	134	42	13	134	50	68	23	2282	1416.45	
Column Chi		164.19	141.21	749.56	31.72	12.37	13.77	160.16	6.27	23.99	20.44	43.21	34.81	14.75		1416.45	
Sign. Lev.		0.001	0.001	0.001	0.001	0.10	0.10	0.001	0.70	0.01	0.01	0.001	0.001	0.05			

Overall Chi Square= 1416.45, with 84 degrees of freedom, significant at the less than 0.0001 level

This conclusion was drawn by comparing the observed (Ob.) and expected (Ex.) values for the matrix points in the row or column where high Chi square values occurred. For example, much of the deviation from chance giving the high Chi square value for the Machalilla row (914.02), occurs in the P.j, A.m, and S.c points (compare observed and expected values for these taxa).

Fig. 3, showing the percentage distribution of these tax, allows the direction and magnitude of the changes to be seen more easily. Two trends in these data are noteworthy: the replacement of the leguminous tree taxa *(Prosopis* and *Acacia* summed) by taxa of the moister deciduous forest formation *(Stercula* and Type B summed); and the replacement within the leguminous taxa of *Prosopis* by *Acacia.*

Throughout the Valdivia period, wood utilization centered around the leguminous trees of the xerophytic forest. This formation lay to the seaward side of the Real Alto site, providing a close source of firewood. *Prosopis,* the mesquite of the American Southwest, is a highly resinous, hot burning fuel, with a heating value/unit of wood volume 1.4 times that of other woods (Wiley and Manviller 1976:48-51). *Acacia* produces a light brown gum and is very dense. The dead wood from these common, low growing trees is easily collected, a task of children today. The larger deciduous forest trees are very scantily represented in the Valivia samples. The percentages of leguminous taxa may be inflated because of their dense, durable nature. On the other hand, these woods also burn very hot and completely, which might tend in turn to reduce their preservation.

From Valdivia I to VI, a gradual replacement of *Prosopis* by *Acacia* occurs at Real Alto. The late Valdivia samples show a reversal of this tendency, but this may be the

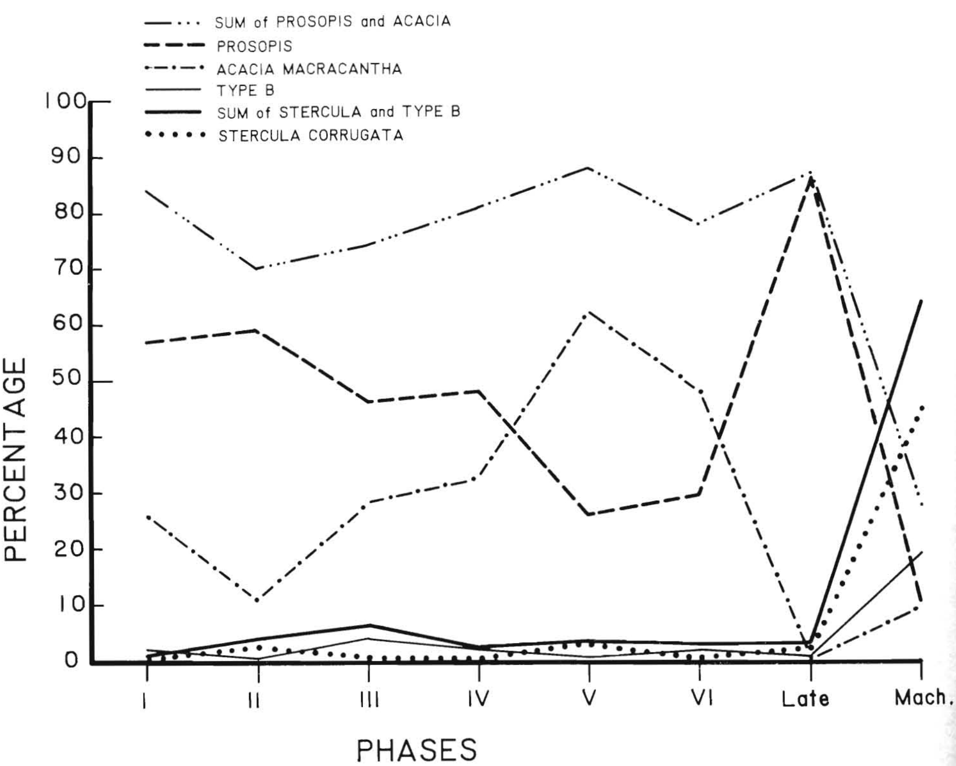

FIGURE 3.–*Percentage distribution of wood taxa, by phase, at the Real Alto and Rio Perdido sites.*

result of small sample size (three features). The replacement of *Prosopis* by *Acacia* could be interpreted as the decreasing availability of the preferred fuel being made up by a less preferred, but similar taxon. Collection pressure would have decreased the availability of *Prosopis*. It can be hypothesized that the Valdivia wood pattern presented here is an example of the maintenance of a traditional fuel system based on collection in the xerophytic forest in the face of declining availability of the best fuel.

In the Machalilla period, striking changes occur. Leguminous tree taxa fall to 23% while 64% of the charred wood belongs to two taxa, *Stercula corrugata* and Type B. *Stercula corrugata* and Type B are both native to deciduous forest. The magnitude of this change suggests that a shift in basic fuel collection strategy has occurred. This hypothesis is supported by other archaeological data, which show in the Machalilla period a spreading of population from a centralized site to small sites along the river course (Zeidler 1977). Localized collecting in the gallery deciduous forest, replacing wide ranging collection in the xerophytic forest, may be the explanation for the shift in the recovered wood remains.

To summarize, this analysis of charred wood from the Real Alto and Rio Perdido sites brings up several points of general interest:

1. A site with poor preservation, i.e., nothing but charred wood, can still yield interesting data on human interaction with the environment.
2. Because patterns in archaeological charcoal closely correspond, though not in exact numbers, to the pattern of use of the resources, the relationship of one taxon to another represents cultural selection.
3. Interpretation of charred wood data, analyzed first to demonstrate areas of statistical differences and then to show the direction and pattern of these changes, can generate hypotheses to be tested against other archeological data and further excavation. In this case it was hypothesized that during the Valdivia period a conservative strategy of collection of hot burning leguminous tree wood from the open xerophytic forest was maintained by substitution of taxa in the face of declining availability of the main taxon. At the end of this period, a change in basic collection strategy occurred, with collection in the deciduous forest replacing the earlier pattern. There is no evidence to support the idea that the deciduous forest expanded in extent during Machalilla times and was therefore more frequently used for firewood collection. Evidence from deep sea cores (Hough 1953; Pearsall 1979; 51-64) suggests that, if anything, the climate during the Machalilla period was slightly cooler and drier than during the Valdivia sequence. Even if it were wetter, there is scarcely time to hypothesize a major vegetation shift. What did shift during the transition from Late Valdivia to Machalilla was the settlement pattern. The greater occurrence of wood from the deciduous forest may represent the burning of scrap wood collected during clearing of the gallery forest for agricultural purposes. The spreading out of the population along the Rio Verde may have necessitated more use of land in the high alluvium area. This need, combined with a decline in the availability of the hot burning leguminous wood through millenia of exploitation, caused the shift in firewood selection.

Finally, it is important to keep in mind, in any ethnobotanical analysis, the sources of error which may affect conclusions drawn from the data. In this study, it was not possible to obtain equally large counts of charred wood for each of the time periods. As is shown in Table 2, the Valdivia IV, V, and Late Valdivia periods had low wood counts. This may have affected the pattern of distribution of charcoal observed in the analysis. Another potential source of error, discussed above, is differential preservation of wood taxa based on their relative hardness.

ANALYSIS OF SEED DATA FROM PACHAMACHAY

The Pachamachay site, excavated by John W. Rick, is a small rock shelter located at just above 4,000 m in the Junin puna of Peru. The Junin puna is an open, rolling grassland with a variety of native plant and animal resources capable of supporting long-term human occupation (Rick 1980:11-28; Pearsall 1980). Occupation at the Pachamachay site is dated by radiocarbon determination from 10,000 B.C. until about A.D. 200 (Rick 1980:64-69). Rick (1980:316-326) defined five preceramic phases (Phases 1-5), with three ceramic phases (Phases 6, 7, and Late), occuring after the preceramic occupation. A model of sedentary, year-round hunter-gatherer occupation of the Junin puna, based on exploitation of camellids, especially vicuna *(Vicugna vicugna),* and of plant and other animal resources, is proposed for the preceramic (Rick 1980:25-28).

Water flotation was used to recover botanical remains from all strata at the site. Only charred remains were preserved. The sheltered location of the site favored charred seed preservation, giving seed counts almost equal to wood counts. Twenty-one taxa of seeds were identified (Table 3), shown here grouped by the zone in which they occur in highest concentration. In general, the dry puna grassland, dominated by bunch grasses (e.g., *Festuca dolichophylla, Calamagrostis recta)* and scattered rosette plants, is the most extensive zone. Where ground moisture levels are higher (lake shores, edges of small streams, depressions) polster-forming taxa (e.g., *Plantago rigida; Distichia muscoides)* and distinct moist area herbaceous taxa occur. Rock outcrops, scattered over the puna, provide a favorable environment for rosettes, tuber-producing species, and small, hardy shrubs (e.g., *Ephedra americana, Margyricarpus strictus).* A number of weedy species occur in disturbed habitats in the zone.

TABLE 3.—*Archaeological seed taxa identified at Pachamachay.*

HABITAT TYPE			
Dry Puna Grassland	Disturbed	Moist (Lakeside)	Rocky
Calamagrostis	*Amaranthus*	*Luzula*	Compositae
Festuca	*Chenopodium*	*Polygonum*	*Euphorbia*
Stipa	*Lepidium*-type Brassicaceae	*Ranunculus*	Leguminosae (other)
Gramineae (other)		*Scirpus*	*Lupinus*
		Sisyrinchium	*Malvastrum*
		Umbelliferae	*Opuntia floccosa* Salm.-Dyck.
			Oxalis
			Plantago

Previous presentation of the ethnobotanical data (Pearsall 1980) relied solely on subjective interpretation to conclude that the constancy of occurrence of taxa through time indicated a stable, puna based collecting strategy virtually unchanged for 10 millenia. These data will be re-examined here, applying several quantitative measures, to better test these conclusions. As discussed above, raw counts or percentages of different seed taxa occurring during a phase or within an individual sample give no direct indication of the relative importance of each taxon. As Asch and Asch (1975) have discussed, however, if context of preservation can be assumed as constant, comparing the variation in occurrence of different plants between assemblages can indicate change in their utilization relative to one another. Can context of preservation be assumed as constant for the eight phases of occupation at Pachamachay? Several factors enter into this evaluation. First, because cave deposits were periodically wet throughout their depth, preservation of dried botanical materials did not occur. Only seeds charred by chance and wood charred as fuel or by accidental burning were preserved. This is a constant. Second, the number of seeds and wood fragments recovered in equal-sized samples from each phase was not constant.[2] Samples from Phases 1-4 have lower quantities of seeds and wood fragments than those from Phases 5 and 6. Phase 7 samples have much higher counts than other samples. Third, cave function, as reconstructed by Rick (1980:293-326), changes to some degree over the period of use of the site. Rick proposes light, sporadic occupation of Pachamachay during Phase 1. Relatively continuous occupation of the shelter began in Phase 2. After an interval of sporadic but intensive use (late Phase 2–early Phase 3), the cave was used as a sedentary base camp until late Phase 5. During Phase 6 and 7 use of Pachamachay as a hunting camp of herders occupying open air lakeshore settlements is suggested, while in the early part of the late ceramic period the cave was used as a ceramic workshop, as indicated by the presence of characteristic clay mixing pits. Taking all these factors into consideration, context of preservation of botanical remains was probably most constant during Phases 1-5, before the cave began to be utilized for activities not involving the whole social unit. Although Phase 1 was a period of less intensive use of the cave, recovery of remains was equal to, or better than, some later phases. Following the discussion of the quantitative analyses applied to the Pachamachay ethnobotanical data, the impact on the results of possible changes in preservation factors in the later phases will be discussed.

The data will be discussed using the following measures: 1) intensity of occupation, measured by the total count of wood in each phase; 2) the percentage distribution of selected seed taxa through time, with intensity held constant by dividing seed count by wood count, 3) species richness or diversity, as measured by the Shannon-Weaver formula and 4) calculation of standard scores, or the number of standard deviation units each taxon varies away from the mean.[3] After first presenting a series of charts showing the results of each approach, these will be compared and conflicts and correlations resulting from their use discussed.

Intensity of Occupation. It has been proposed by several researchers (Asch and Asch 1975; Johannessen 1981a, b), that the total amount of charcoal resulting from deliberate burning can serve as a measure of the intensity of use of an occupation area. An occupation containing a much higher amount of charcoal under conditions of similar preservation and sampling is interpreted as having more intensive cooking or other hearth activity. Fig. 4 shows the charred wood counts through time at Pachamachay. These data were obtained by counting all charred wood fragments greater than 2.0 mm from four flotation samples of equal volume from each phase. It should be noted that length of each phase did not correlate with the amount of charred wood recovered per sample.[4] There are several points of interest in this figure. First, there is a high constancy in the intensity measure for the first four phases of the preceramic, a period of almost 8,000 years. Second, the late preceramic (Phase 5) and the earliest ceramic period (Phase 6) show an increase in occurrence of charred wood relative to the earlier phases, and are similar to each other. Third, Phase 7, the middle ceramic period, shows a marked deviation from the early pattern, with a much higher occurrence of charred wood. In the late ceramic phase, the intensity measure declines, but remains high relative to the earliest six phases.

Percentage Distribution of Selected Seed Taxa. Several authors (Asch and Asch 1975; Johannessen 1981a, b) measure the percentage occurrence of taxa within an assemblage relative to wood count, rather than total seed count. This serves to hold intensity of occupation constant, so that the occurrence of the seed taxa can be compared between assemblages. Fig. 5 shows seed/wood ratios for eight seed taxa considered food resources, and the Gramineae, considered here to represent thatch or fuel resources. With intensity of occupation held constant, several interesting patterns emerge. First, *Opuntia* declines in overall abundance through time. Decline occurs between Phases 1-3 and between

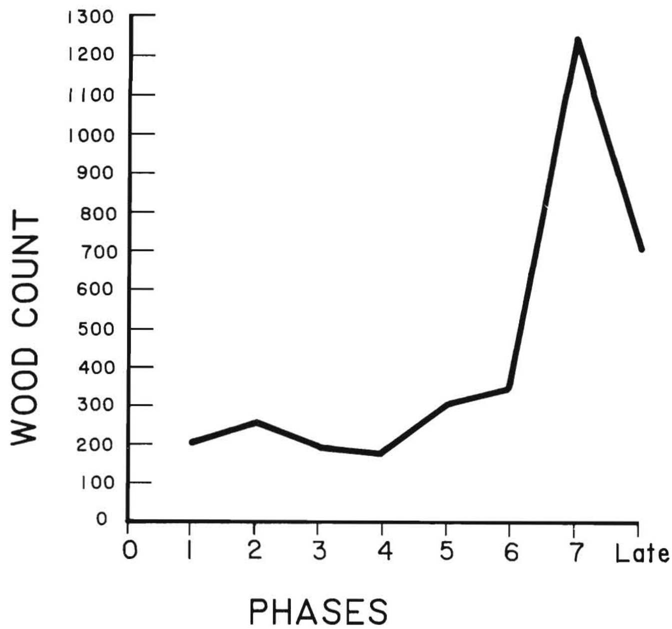

FIG. 4.—Intensity of occupation, by phase, at Pachamachay

Phases 5-7, with a sharp resurgence in Phase 4, the middle preceramic. *Chenopodium* increases from Phases 1-3, while *Lupinus,* other legumes, and lakeside plants, *Scirpus, Sisyrinchium,* and *Luzula* stay fairly constant in Phases 1-3. Second, *Amaranthus, Chenopodium,* lakeside plants, and legumes all reach their greatest relative abundance in either Phases 5 or 6, the late preceramic and early ceramic phases. Third, all seed taxa considered food resources decline in Phase 7. By contrast, the grasses (black), declining from Phases 1-4, increase through Phase 7, reaching their highest peak there. These parameters are difficult to depict graphically because of the wide range of variability present.

Species Richness or Diversity. Species diversity is a measure that takes into account both the total number of species or taxa present in a population, and the abundance of each species (Pielou 1969:221-235). High diversity results when a large number of species are evenly distributed, i.e., when it would be difficult to predict what a randomly selected item would be. Low diversity results when the number of species present is low, or when abundance of each is highly variable. Since ethnobotanical data deal both in numbers of species and counts of each, combining these into one index, diversity, may be useful. Yellen (1977) used the Shannon-Weaver information index (Shannon and Weaver 1949) as a diversity measure, and demonstrated that a !Kung base camp had a higher diversity index than a specialized activity area. In the !Kung study, each kind of debris encountered in an abandoned campsite (porcupine bones, nut-cracking stones, etc.) was equated to an individual species. The amount of each kind of debris was then equal to the abundance of that species (Yellen 1977:101-108). It is important to note that the Shannon-Weaver index is a poor measure when abundance of species is low (Pielou 1969:231-233). In the Pachamachay data, even with 4 samples per period combined, many seed counts were less than 10. Rather than artificially lump species to raise counts, the Shannon Weaver index is presented uncorrected here as an example of this approach (Fig. 6). Phases 1-3 show marked constancy of diversity. The index rises somewhat in Phase 4. The highest diversity is achieved in Phase 5, the late preceramic. The earliest ceramic

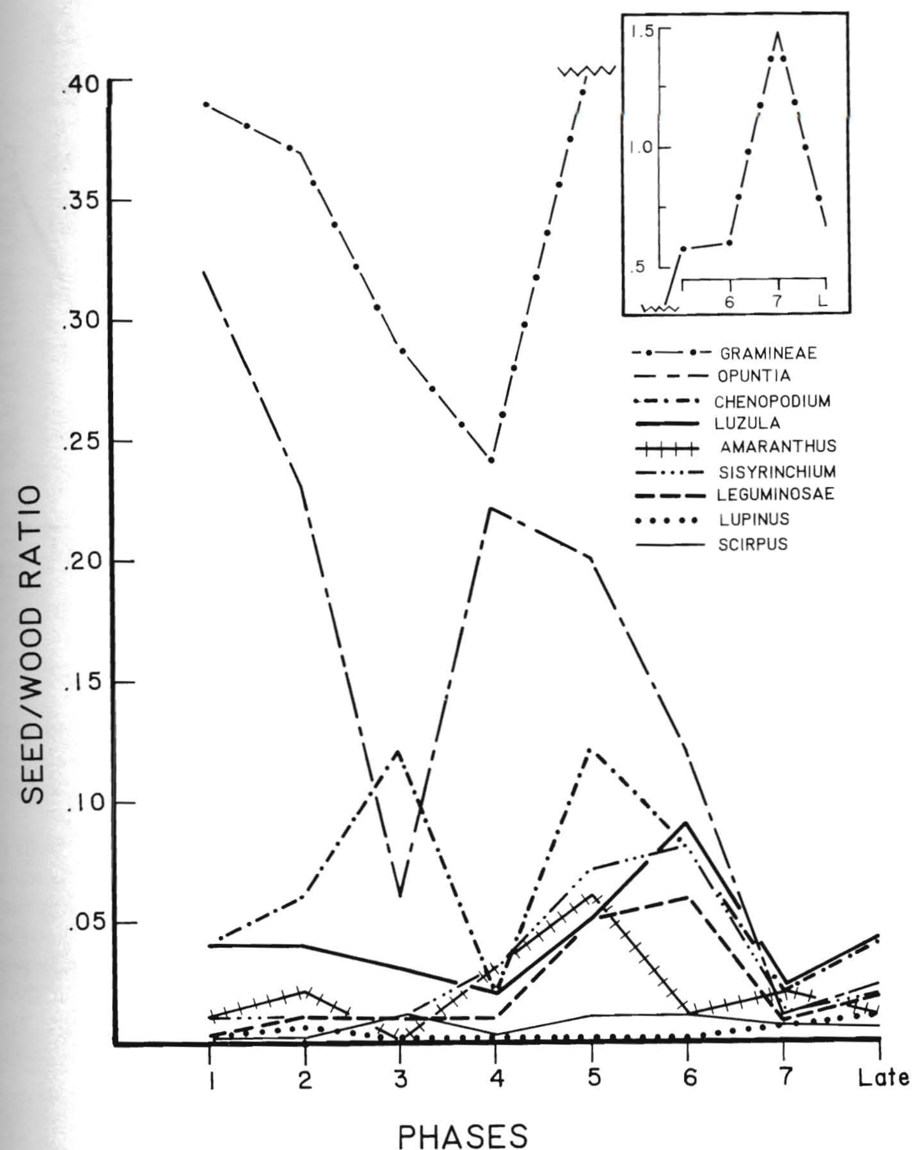

FIG. 5.—Percentage distribution of seed taxa, by phase, at Pachamachay with intensity of occupation held constant.

phase, Phase 6, has a diversity index similar to Phase 5. There is a dramatic drop in diversity in Phase 7. Inspection of the Phase 7 data reveal that very high counts of grass seeds, i.e., a lack of evenness in the data, account for the low diversity index for this period. Diversity goes back up to earlier levels in the late ceramic phase.

Standard Scores. Another attempt to convert raw seed counts to a more useable form was made by converting the data to standard scores, or the number of standard deviation units each taxon varied away from the mean. This procedure involved finding the mean count of each species through time, calculating the standard deviation of each species, and then calculating for each occurrence of each species the number of standard deviation

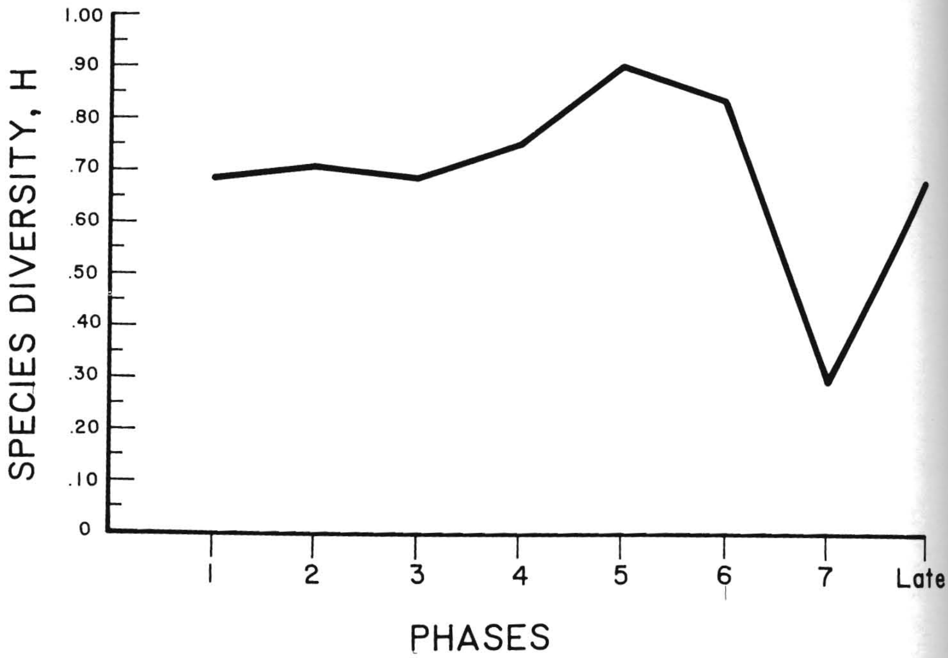

FIG. 6.—Species richness or diversity, by phase, for Pachamachay seed taxa.

units, or Z, of each count away from the mean (Blalock 1972:80-101). These standard scores can then be examined as data points instead of the raw counts. This reduces the impact of absolute quantities, and evens out insignificant differences. Similarities in the direction of changes obscured by different absolute counts can be more easily seen.

Fig. 7 shows the standard scores of all taxa possibly used for food except *Oxalis* (1 seed). Again, for the purposes of this analysis, it is assumed that most grass seeds represent accidental burning of thatch, or inclusion of seeds in camellid dung used as fuel. Except for *Opuntia* cactus, and possibly *Chenopodium*, all taxa show a similarity in variation during the first 4 preceramic phases. All occur below the mean and vary relatively little in their standard score from phase to phase. Similarly, most taxa occur above the mean in the later half of the sequence. Variation is no longer even, however. Two clusters of high positive deviation occur in Phases 5 and 6. All taxa except *Amaranthus* then decline in Phase 7. The late ceramic phase is very variable.

Looking at the fuel or thatch plants (Fig. 8), there is little variation in occurrence of these taxa in Phases 1-4. This pattern continues into Phase 5, with the exception of a sharp positive rise in standard score for Compositae and *Stipa*. In Phase 6, all scores except *Calamagrostis* approach the mean. Phase 7 shows a cluster of high positive scores. While the potential food plants showed peaks of high positive standard scores in Phases 5 and 6, late preceramic and early ceramic, most fuel or thatch taxa clustered highly positive in Phase 7. Both groups of plants exhibited little variation in standard scores during Phases 1-4. The exception to this was *Opuntia*, which deviated from all other species, occurring above the mean early in the occupation and below the mean during later phases.

To summarize, these four quantitative approaches to the Pachamachay seed data suggest the following:

1. There was agreement in all measures employed for a high degree of constancy during preceramic Phases 1, 2, 3, and 4, or from 10,000-2200 B.C. It is hypothesized that a longterm, stable strategy of utilization of local puna resources existed. The relative

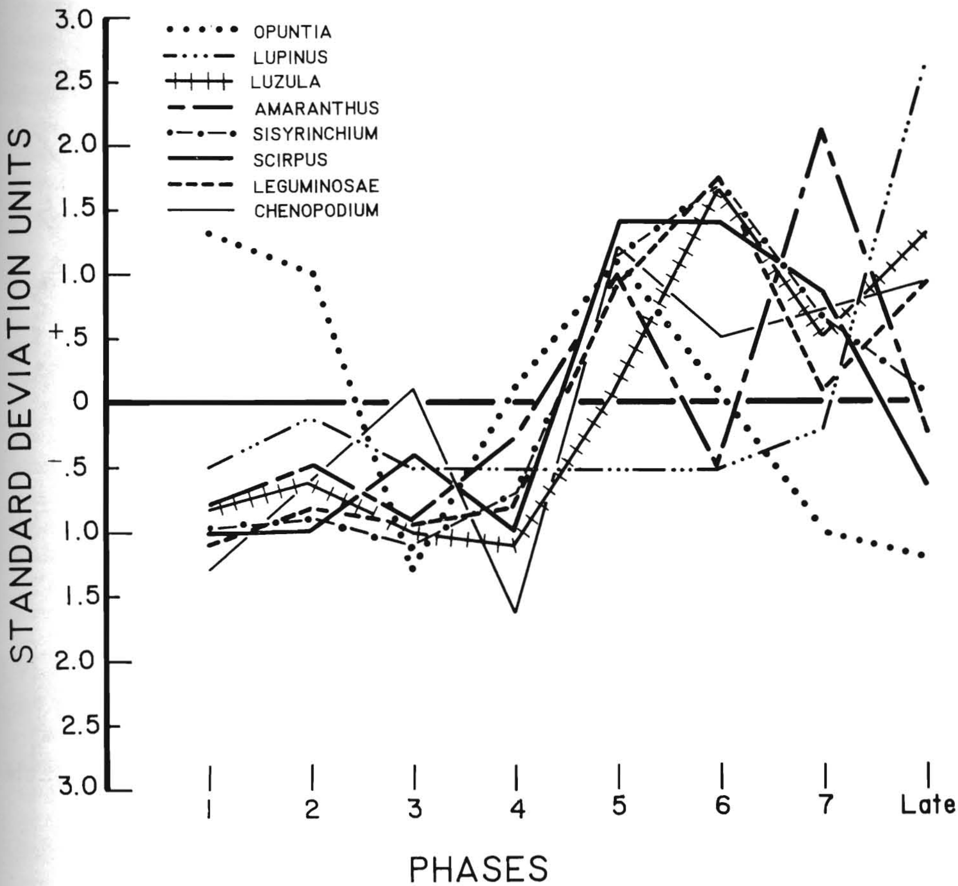

FIG. 7.—Occurrence of taxa with edible seed, by phase, at Pachamachay, expressed as the number of standard deviation units from the mean.

importance of each taxon is difficult to conclude, but the variation in *Opuntia,* running contrary to most other taxa, suggests a declining role for this wild food.

2. All measures indicate a change in direction in the late preceramic period, (Phase 5) and similarity between Phase 5 and Phase 6, the earliest ceramic phase. The occurrence of most foods, measured by standard score or percentage occurrence, peak in either Phase 5 or 6, or are high in both. There is increased variability in seed occurrence as a whole.

3. Phase 7 is also marked by abrupt changes in most of the measures. A dramatic drop in species diversity occurs, corresponding to low occurrences of edible plants and the high occurrence of fuel and thatch plants. Even with the caution that low abundance counts were used to calculate this measure, a change in the function of the site seems to be indicated. The rise in the amount of charred wood present in Phase 7 suggests a function related to increased burning.

How do these results correlate with the non-botanical data from Pachamachay? Intensity of occupation of the cave and the nature of that occupation changed over the period of use of the site (Rick 1980:293-326). Intensity was low in Phase 1, followed by intense occupation in Phase 2. After a decrease of intensity at the end of Phase 2—early Phase 3, intensity of occupation rose again until a final decline from late Phase 5 onward.

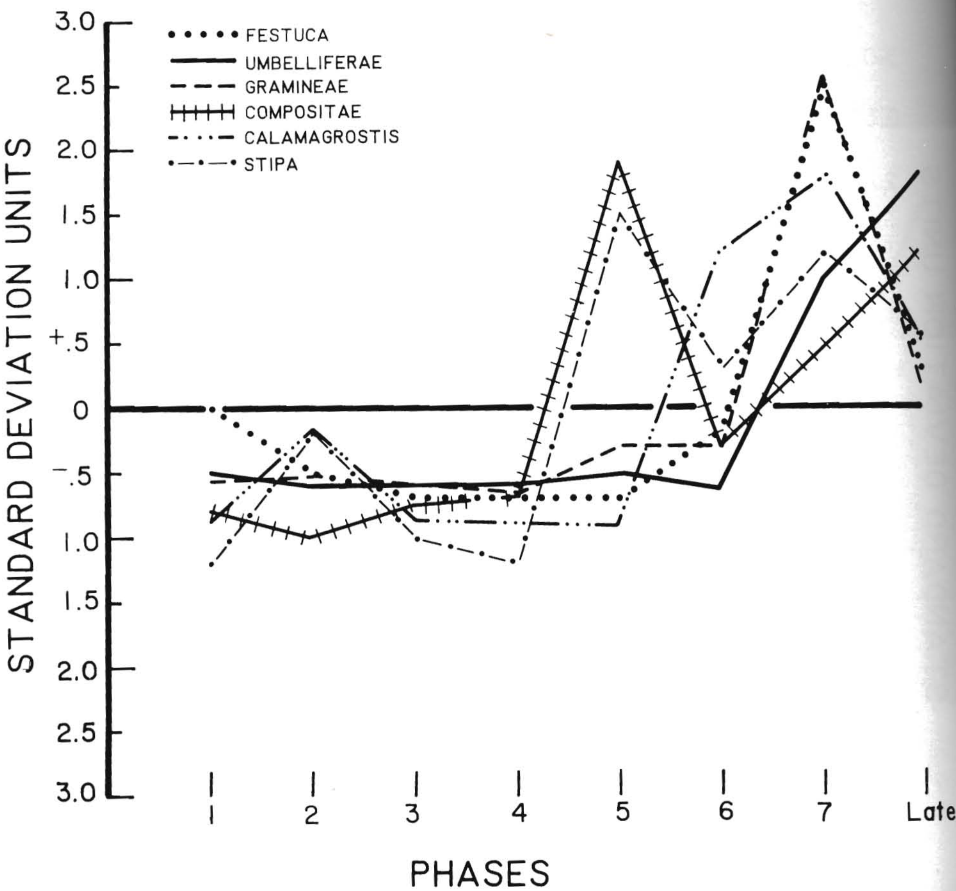

FIG. 8.—Occurrence of fuel and thatch taxa, by phase, at Pachamachay, expressed as the number of standard deviation units from the mean.

As a measure of intensity of occupation, wood count per phase (Fig. 4) does not reflect this pattern. The lower intensity of Phase 1 is not detected, intensity does not rise appreciatively from Phase 2 to Phase 5, nor decline in the later phases. The species diversity measure (Fig. 6) correlates better with Rick's data on intensity of occupation, showing increases in Phases 4 and 5, and declines in Phases 6 and 7. Phase 1 is not distinguished from the other phases, however. If low abundance could be corrected for, this measure may have considerable potential for distinguishing the botanical remains of a base camp from those of a temporary or special activity camp.

The occurrence through time of individual taxa as measured by standard score or percentage occurrence, show patterns which do not parallel the data on intensity of occupation at Pachamachay. The basic assemblage of subsistence plants changes little from Phases 1-4, even with increasingly intense occupation. This finding supports the conclusions of the initial study (Pearsall 1980), that a stable, puna-based collecting strategy was in operation through the millenia at the site. The transitional nature of Phases 5 and 6, obscured in this analysis somewhat because of lumping of levels, is expressed by increasing variability and high occurrence of some edible taxa. It seems clear that change or lack of change in the occurrence of specific taxa is dependent on other factors than intensity of occupation.

Because the "hard" archaeological data suggest changes in the nature of human use of the cave during Phases 6, 7, and the Late Ceramic Period, conditions leading to the charring and preservation of seeds and wood also could have changed. For example, if the hunting parties occupying the shelter during Phases 6 and 7 were small, and spent little time actually in the cave, the remains of their camp fires or cooking fires might have been covered over before the next occupation, giving better preservation of remains than when the cave was used on a daily basis. This might be part of the explanation for the higher quantities of wood and seeds in samples of the later phases (see Note 2). Occurrence of individual seed types could also be affected by such factors.

CONCLUSIONS

An attempt has been made to apply ethnobotanical data to the problem of determining the stability of subsistence strategies through time. The two cases discussed had well dated and analyzed "hard" archaeological data which could be used to evaluate the hypotheses generated from the perishable botanical data. Several different quantitative measures of seed occurrence could also be tested. Both the Real Alto charred wood analysis and the Pachamachay seed analysis illustrate the potential of these data in giving valuable insight into subsistence patterning through time. The application of archaeological plant data to questions of cultural process is an exciting direction for paleoethnobotany, and one with great potential.

To take full advantage of this potential, however, ways must be found to analyze ethnobotanical data to minimize the vagaries of preservation. The quantitative measures applied in this study attempt this, with varying success. Of the measures applied in the Pachamachay seed analysis, using standard scores to replace counts or percentages as data points seems to have considerable potential for indicating direction and magnitude of changes, while minimizing the impact of absolute quantities. This technique also allows clear graphic presentation of results. Use of a species diversity measure, such as the Shannon-Weaver information index, minimizes the impact of any particular set of data by combining all data from one time period into one index. Of course, information on the behavior of the constituent data sets is also lost. It is argued that use of percentage occurrences in wood analysis, or absolute counts, if sample sizes can be held constant, can give direct information on cultural selection of wood (see Fig. 1). Over or under-representation of specific taxa due to differential burning characteristics could be corrected by experimental work.

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LITERATURE CITED

ACOSTA-SOLIS, MISAEL. 1961. Los bosques del Ecuador y sus productos. Editorial Ecuador, Quito, Ecuador.

________. 1968. Las Divisiones fitogeográficas y las formaciones geobotánicas del Ecuador. Editorial Casa de la Cultura, Quito, Ecuador.

________. 1969. Glumifloras del Ecuador. Instituto Ecuatoriano de Ciencias Naturales, No. 71, Quito, Ecuador.

ASCH, DAVID L., KENNETH B. FARNSWORTH, and NANCY B. ASCH. 1979. Woodland subsistence and settlement in west central Illinois. Pp. 80-85, *in* Hopewell archaeology (D.S. Brose and N'omi Greber, eds.), Midcont. J. Archaeol. Spec. Pap. 3, Kent State Univ. Press, Kent State, Ohio.

ASCH, NANCY BUCK and DAVID L. ASCH. 1975. Appendix V. Plant remains from the Zimmerman site - grid A. A quantitative

LITERATURE CITED (continued)

perspective. Pp. 116-120, *in* The Zimmerman site: further excavations at the Grand Village of Kaskakia. Margaret Kimball Brown. Illinois State Mus., Springfield, Rep. Invest., No. 32.

BLALOCK, HUBERT M., JR. 1972. Social statistics. Second edition (1960). McGraw-Hill, New York.

BYRD, KATHLEEN MARY. 1976. Changing animal utilization patterns and their implications: southwest Ecuador (6500 B.C. - A.D. 1400). Unpubl. Ph.D. dissert. (Anthr.), Univ. of Florida, Gainesville.

DAMP, JONATHAN EDWARD. 1979. Better homes and gardens: the life and death of the early Valdivia community. Unpubl. Ph.D. dissert. (Archaeol.), Univ. Calgary., Calgary, Canada.

———, DEBORAH M. PEARSALL and LAWRENCE T. KAPLAN. 1981. Beans for Valdivia. Science 212:811-812.

DENNELL, R.W. 1976. The economic importance of plant resources represented on archaeological sites. J. Archaeol. Sci. 3(3): 229-249.

FAIRBRIDGE, RHODES W. 1961. Eustatic changes in sea level. Pp. 99-185, *in* Physics and chemistry of the earth, Vol. 4, (L.H. Ahrens, F. Press, K. Rankania and S.K. Runcorn, eds.), Pergamon Press, New York.

———. 1962. World sea level and climate changes. Quaternaria (Roma) 6:111-134.

FORD, RICHARD I. 1979. Paleoethnobotany in American archaeology. Pp. 286-336, *in* Advances in archaeological method and theory. Vol. 2, (Michael B. Schiffer, ed.). Academic Press, New York.

HOUGH, JACK L. 1953. Pleistocene climatic record in a Pacific Ocean core sample. J. Geol. 61:252-262.

JOHANNESSEN, SISSEL. 1981a. Appendix A: Plant remains from the Sandy Ridge farm site (11-S-660). Pp. 18-23, *in* Final report on archaeological investigations at the Sandy Ridge farm site (11-S-660). FAI-270 Archaeological Mitigation Project Report, No. 20. Univ. Illinois, Urbana.

———. 1981b. Floral resources and remains. Pp. 120-130, *in* The Dryoff-Levin site: A Late Archaic occupation in the American Bottom. Thomas E. Emerson. FAI-270 Archaeological Mitigation Project Report, No. 24., Univ. Illinois, Urbana.

LIPPI, RONALD. D. 1980. The Machalilla phase from an inland perspective. Paper presented at the 8th Annual Midwest Conference on Andean and Amazonian Archaeology and Ethnohistory. Madison, Wisconsin. Unpubl. Ms. deposited with the author.

McDOUGLE, EUGENE J. 1967. Water use and settlements in the changing environments of the southern Ecuadorian coast. Unpubl. Master's essay, (Anthr.). Columbia Univ., New York.

MEGGERS, BETTY J. 1966. Ecuador. Praeger, New York.

MILLER, NAOMI F. 1980. Paleoethnobotanical studies at Malyan: the use of wood as fuel. Paper presented at the 45th Annual Meeting of the Society for American Archaeology, Philadelphia. Unpubl. Ms. deposited with the author.

MINNIS, PAUL E. 1981. Seeds in archaeological sites: sources and some interpretive problems. Amer. Antiq. 46(1):143-152.

PEARSALL, DEBORAH M. 1978. Phytolith analysis of archeological soils: evidence for maize cultivation in Formative Ecuador. Science 199:177-178.

———. 1979. The application of ethnobotanical techniques to the problem of subsistence in the Ecuadorian Formative. Ph.D. dissert. (Anthr.), Univ. Illinois. Univ. Microfilm, Ann Arbor, Michigan.

———. 1980. Pachamachay ethnobotanical report: plant utilization at a hunting base camp. Pp. 191-231, chapter 9 *in* Prehistoric hunters of the High Andes. John W. Rick. Academic Press, New York.

PIELOU, E.C.* 1969. An introduction to mathematical ecology. John Wiley and Sons, New York.

RICHARDS, P.W. 1972. The tropical rain forest: an ecological study. Fourth edition (1952). Cambridge Univ. Press, Cambridge.

RICK, JOHN W. 1980. Prehistoric hunters of the High Andes. Academic Press, New York.

SARMA, A.V.N. 1974. Holocene paleoecology of south coastal Ecuador. Proc. Amer. Philos. Soc. 118(1):93-134.

SHANNON, C.E. and W. WEAVER. 1949. The mathematical theory of communication. Univ. Illinois Press, Urbana.

SVENSON, H.K. 1946. The vegetation of the coast of Ecuador and Peru and its relation to the Galapagos Islands. Amer. J. Bot. 33:394-498.

WILEY, A.T. and F.G. MANWILLER. 1976. Market potential of mesquite as fuel. For. Prod. J. 26(9):48-51.

YELLEN, JOHN E. 1977. Archaeological approaches to the present: models for re-

LITERATURE CITED (continued)

constructing the past. Academic Press, New York.

ZEIDLER, JAMES A. 1977. Early Formative settlement in the Chanduy Valley, southwest Ecuador. Paper presented at the 42nd Annual Meeting of the Society for American Archaeology, New Orleans. Unpubl. Ms. deposited with the author.

NOTES

[1]Charred wood was identified from both flotation samples and carbon samples (samples collected during excavation). In samples where charred wood was abundant, a minimum of 20 pieces were selected at random for identification. For samples with little wood present, all pieces roughly 2 mm or larger were identified. Number of samples examined per phase: I 10; II 10: III 28; IV 9; V 2; VI 9; Late 5; Mach. 4. Total wood count: 2282 pieces.

[2]Four general level flotation samples per phase were used for this analysis. Counts of identified seeds and all charred wood fragments were as follows:

	Seeds	Wood		Seeds	Wood
Phase 1	196	199	Phase 5	433	302
Phase 2	211	253	Phase 6	434	332
Phase 3	112	196	Phase 7	2046	1227
Phase 4	117	182	Late	719	711

Total seeds: 4268; total wood: 3402

[3]Measures employed in this analysis were calculated as follows: *Intensity of Occupation:* Total count of charred wood, summed by phase. *Percentage Distribution of Seed Taxa, Intensity of Occupation held Constant:* Seed count of each taxon, summed by phase, divided by total wood count, summed by phase.

Species Richness or Diversity: The Shannon-Weaver Information Index for finite populations (H) was calculated for each phase.

$$H = -\Sigma \left(\frac{N_j}{N}\right) \ln \left(\frac{N_j}{N}\right)$$

N: total number of seeds in the phase

In: natural log

N_j: total number of seeds of taxon$_j$ in the phase

Taking the Phase 1 calculation as an example: N = 196 seeds, 12 taxa. The product $\left(\frac{N_j}{N}\right) \ln \left(\frac{N_j}{N}\right)$ was calculated for each seed taxon.

For example, *Opuntia*: $\frac{64}{196} \ln \frac{64}{196} = -0.16$

H equals the negative sum of the 12 products, or 0.69.

Standard Deviation Units, Z (Standard Scores)

$$Z = \frac{x-\bar{x}}{s}$$

$\bar{x}$; occurrence of a seed taxon in a phase

x: mean occurrence of a taxon in all phases

s: standard deviation of a taxon from the mean

The standard score, Z, was calculated for each taxon in each phase, and used as a datum point on the graphs.

[4]To insure that the amount of wood present per phase was not just a function of the length of each phase, wood counts were graphed versus length of phases, in years. No correlation was found. For example, Phases 1, 3, and 4, which have almost equal wood counts (199, 196, and 182 pieces, respectively) vary in estimated length from 3000 to 800 years.