THE USEFUL PLANTS OF TAMBOPATA, PERU: II. ADDITIONAL HYPOTHESIS TESTING IN QUANTITATIVE ETHNOBOTANY[1]

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Phillips, Oliver *(Department of Biology, Washington University, One Brooking's Drive, Campus Box 1137, St. Louis, MO 63130-4899, U.S.A.)* and **Alwyn H. Gentry** *(Missouri Botanical Garden, Box 299, St. Louis, MO 63166-0299, U.S.A.).* THE USEFUL PLANTS OF TAMBOPATA, PERU: II. ADDITIONAL HYPOTHESIS TESTING IN QUANTITATIVE ETHNOBOTANY. *Economic Botany 47(1): 33–43. 1993. We present results of applying a simple technique to statistically test several hypotheses in ethnobotany, using plant use data from non-indigenous people in southeast Peru. Hypotheses tested concern: (1) the power of eight different variables as predictors of a plant's use value; (2) comparisons of ethnobotanical knowledge among informants; and (3) the relationship between informant age and knowledge of plant uses. Each class of hypothesis is evaluated with respect to all uses, and classes (1) and (3) are evaluated for each of the following subsidiary use categories: construction, edible, commerce, medicine, and technology. We found that the family to which a plant belongs explains a large part of the variance in species' use values. Each of the other factors analyzed (growth-form, density, frequency, mean and maximum diameter, mean and maximum growth rate) is also significantly predictive of use values. Age significantly predicts informant knowledge of (1) all uses, and (2) of medicinal uses. Plant medicinal lore is particularly vulnerable to acculturation.*

Las plantas útiles de Tambopata, Perú: II. Hipótesis adicionales en etnobotánica cuantitativa. *Presentamos los resultados de la aplicación de una simple técnica cuantitativa, descrita anteriormente, para probar estadísticamente algunas hipótesis etnobotánicas. Usamos datos de los usos de plantas por los mestizos del Sur-Este del Perú. Las hipótesis que nos conciernen están relacionadas con: (1) el poder de ocho factores diferentes para pronosticar la utilidad de plantas; (2) el nivel del conocimiento etnobotánico entre informantes; y (3) la influencia de la edad del informante para pronosticar la varianza en el conocimiento de usos de plantas. Se evalua cada hipótesis con respecto a todos los usos, y se evalua las hipótesis (1) y (3) para cada una de la categorias de uso: construcción, comestibles, comerciales, medicinales, y tecnológicos. Concluimos que la familia a la cual pertenece una planta afecta el valor de su utilidad, y explica en parte la varianza de los valores de utilidad. Cada uno de los otros factores analizados (forma de crecimiento, densidad, frecuencia, diámetro promedio y máximo, tasa de crecimiento promedio y máximo) también pronostican significativamente los valores de utilidad. La edad es un buen pronosticador del conocimiento de todos usos, y de usos medicinales. Sin embargo, informantes de edades similares pueden tener niveles de conocimiento muy diferentes. El conocimiento de plantas medicinales es más suceptible a la aculturacción que el conocimiento de las otras categorias de uso.*

Key Words: hypothesis tests; statistics; prediction; diameter; density; trees; lianas; age.

In this, our second paper to present statistical tests of ethnobotanical hypotheses, we use the data-processing technique developed in Phillips and Gentry (1993), to test three more general kinds of hypotheses that are of interest to ethnobotanists. Firstly, we investigate the contribution of eight different ecological, growth-form, and floristic factors in predicting plant usefulness. Secondly, we compare informants' degree of knowledge of forest plant uses; and thirdly, we explore the relationship between informant age and knowledge of plant uses. In this paper and the previous one, our unifying aim is to try to show how quantitative methods of collecting and processing ethnobotanical data might be in-

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tegrated with the essential scientific process of hypothesis-testing (Popper 1963). By adopting an explicitly quantitative and statistical approach, and using these techniques to test and generate a wide range of hypotheses, we believe that ethnobotanists can make a major contribution to the development of the science.

METHODS

DATA COLLECTION

The statistical tests presented here use data from our study of plant uses among mestizos (people of mixed origin) in the Zona Reservada Tambopata and the environs, in the southeastern Peruvian department of Madre de Dios. Our ethnobotanical data collection and analysis methodologies are described in detail in Phillips and Gentry (1993).

Ecological data collected as part of the botanical inventory, by AG, OP and co-workers between 1983 and 1991, are used here. Tree and liana size data were gathered by measuring the stem diameters of more than 3500 woody stems ≥10 cm diameter at breast height (=d.b.h.), of nearly 600 species, in seven one-hectare inventory plots. The maximum diameter of each "folk-species" (see Phillips and Gentry, 1993) was assumed to be that of the largest stem within the plots, except where larger individuals were encountered outside the plots. Growth rates were calculated arithmetically; i.e., simply as the difference in diameter between the second and first measurements of each stem, divided by the number of months elapsed between measurements. In order to increase sample sizes for the growth rate calculations, recruitment, or new entries, into the plots in 1991, were assumed to have been 9.5 cm d.b.h. at the initial measuring period.

HYPOTHESIS TESTS

Ecology, Physiognomy, and Phylogeny

H_0 *1* = *species' use values are random with respect to their density, averaged across seven forest types.*

H_0 *2* = *species' use values are random with respect to their frequency at the one-hectare scale.*

H_0 *3* = *species' use values are random with respect to their average/maximum stem diameter.*

H_0 *4* = *species' use values are random with respect to their average/maximum growth rate.*

H_0 *5* = *species' use values are random with respect to their growth-form.*

H_0 *6* = *species' use values are random with respect to their family.*

Ethnobotanists have sometimes made assertions about the relationship between a plant's utility and a number of ecological and physiognomic parameters, beside the more obvious taxonomic variable of familial classification. For example, it is sometimes stated that more abundant or accessible plants are more useful (e.g., Johns, Kokwaro, and Kimanani 1990; Paz y Miño et al. 1991), or that vines should be especially important medicinally because they may have relatively high concentrations of bio-active secondary compounds (Gentry 1992, n.d.; Hegarty, Hegarty, and Gentry 1991; Phillips 1991). These assertions are worth investigating. For example, their refutation or support would shed light on theoretical debate about possible influences of environmental factors on cultures, or on potential "pre-screening" indicators that could guide pharmacognosy. Although a few quantitative tests of these intuitive assertions have been done previously (Adu-Tutu et al. 1979; Moerman 1979, 1991; Paz y Miño et al. 1991), to our knowledge this is the first analysis to statistically examine the ability of several simultaneous factors to predict the importance of a species.

With regression and Analysis of Variance (ANOVA) techniques, we use our data to investigate statistically several null hypotheses derived from such intuitive assertions, and to evaluate the contribution of each factor to determining "folk-species" use values (Phillips and Gentry 1993). (We use folk-species use values, as opposed to botanical species use values, because our definition of folk-species is closer to mestizo concepts of their plant environment.)

Table 1 summarizes the results of simple regression and one-way ANOVA analyses. Surprisingly, every one of the eight variables tested has some value in predicting a species' use value, and all but one of the 48 possible predictor/response variable relationships are positive. Moreover, the null hypotheses listed above are rejected at the 5% level for no less than 24 of the possible combinations. Thus, a woody species being any one of: a tree, having a high population

TABLE 1. PREDICTIVE POWER OF TAXONOMIC, PHYSIOGNOMIC, AND ECOLOGICAL TRAITS IN EXPLAINING VARIANCE IN SPECIES' USE VALUES.*

	Family[1]	Habit[2]	Log (Density)[2]	Log (Frequency)[2]	Log (mean d.b.h.)[3]	Log (max. d.b.h.)[4]	Log (mean growth rate)[3]	Log (max. growth rate)[3]
UV, (all uses)	0.466 ***	0.090 ***	0.069 ***	0.047 ***	0.051 **	0.084 ***	0.017	0.031 **
UV, (construction)	0.422 ***	0.070 ***	0.039 ***	0.032 **	0.000	0.021 *	0.005	0.012
UV, (edible)	0.578 ***	0.010 s	0.026 **	0.023 **	0.009	0.002	0.001	0.003
UV, (commerce)	0.350 ***	0.037 ***	0.002	0.001	0.079 **	0.061 ***	0.031 *	0.006
UV, (medicinal)	0.220 **	0.002	0.003	0.005	0.005	0.009	0.016	0.005
UV, (technology)	0.208 **	0.000	0.016 *	0.010 s	0.013	0.048 ***	0.002	0.016 s

* The predictor variables are listed by column, the response variables by row. R-squared values are for one-way analysis of variance for categorical variables (Family, Habit), and log-linear regression for quantitative variables (density, frequency, mean d.b.h., max. d.b.h., mean growth rate, max. growth rate). With just one exception, the relationship between the indicator and response variables is positive; this is partly explained by multicollinearity among some predictor variables (see text).

[1] N = 272 folk-species (families with <3 folk-species dropped).

[2] N = 312 folk-species of trees and lianas with ≥10 cm d.b.h. stems.

[3] N = 143 folk-species (folk-species with <5 individual stems measured were dropped). Stem diameters were measured for each species at time-intervals of four to eight years.

[4] N = 277 folk-species (includes conspecifics measured outside the inventory plots, when larger stems were found).

density, being frequent, being large, or fast growing, significantly increases the chances of it being useful.

These results need be interpreted with care, since establishing the existence of a relationship between two variables does not prove that they are causatively linked. In fact, several of the predictor variables are collinear with others. ("Collinearity" means that there is a strong relationship between some of the predictor variables. Thus, regression equations that use variables that are collinear with one another may be excessively sensitive to small changes in the data. One result of this is to make it less likely that effects of any given magnitude will be statistically significant.)

In order to gain greater insight into the meaning of the data, we performed several kinds of multifactorial analyses. Using stepwise multiple-regression and correlation matrices, three variables—frequency at the one-hectare scale, mean d.b.h., and maximum growth rate—were identified as being collinear with other, more strongly predictive variables, and so were dropped from the subsequent analyses. For each category of use value, each possible combination of the remaining five categorical and quantitative variables, including all possible second-order interaction variables, was then tested with ANOVA and multiple regression, to determine the most predictive equations.

The most predictive equations, with the non-significant variables dropped, are shown in Tables 2–7. Aside from the family, the significant factors in predicting a woody plant's usefulness simultaneously with other factors are: (1) habit (four out of six equations), (2) maximum d.b.h. (three equations), and (3) density (one equation). The r^2 values for the first four equations are remarkably high, showing that the total, construction, edible, or commercial usefulness of any unidentified woody plant is surprisingly predictable from knowledge of just two or three attributes of the plant.

There are several possible, common-sense, explanations as to why more abundant plants are more useful to mestizos. One hypothesis is simply that because the most common taxa in the forest are those which are most frequently encountered, people have had more opportunities to experiment and learn uses for these plants (the origin of the pattern). Moreover, the more accessible a species is, the more likely that once culturally learnt (whether independently, or through inter-cultural contact) such uses will persist (the maintenance of the pattern). This is a variant of the ecological "apparency" hypothesis

TABLE 2. LIST OF THE MOST PREDICTIVE MULTIFACTORIAL EQUATIONS IN PREDICTING USE VALUES (ALL USES).

UV_s (All Uses):
n = 268, $r^2 = 0.581$, F = 9.50***

(Highest r^2 for the best predictive equation that does not include the plant's family = 0.215, F = 7.03***.)

UV_s = −0.88* + 0.40 ln(max. d.b.h.)***
− 0.74(if liana)***
+ 1.53(if Annonaceae)***
+ 6.33(if Arecaceae)***
+ 1.69(if Bignoniaceae)s
+ 2.83(if Burseraceae)**
+ 1.87(if Fab: Caesalpinoid)s
+ 1.65(if Fab: Papilionoid)s
+ 4.35(if Lauraceae)***
+ 2.33(if Lecythidaceae)*
+ 2.53(if Meliaceae)*
+ 1.80(if Moraceae)s
+ 2.41(if Myristicaceae)*
+ 1.76(if Sapotaceae)s
+ 2.10(if Sapindaceae)*

Units for Tables 2–7:
d.b.h. = diameter at breast height (cm).
density = number of stems ≥10 cm d.b.h. per hectare.
*** = $P < 0.001$, ** = $P < 0.01$, * = $P < 0.05$, s = $P < 0.10$; where P = the probability of accepting the null hypothesis that the factor contributes no additional predictive power to the equation.

TABLE 3. LIST OF THE MOST PREDICTIVE MULTIFACTORIAL EQUATIONS IN PREDICTING USE VALUES (CONSTRUCTION USES ONLY).

UV_s (Construction Uses):
n = 268, $r^2 = 0.466$, F = 5.98***

(Highest r^2 for the best predictive equation that does not include the plant's family: $r^2 = 0.132$, F = 3.90***.)

UV_s = −0.06 + 0.08 ln(density)**
− 0.46(if liana)***
+ 4.30(if Annonaceae)***
+ 1.93(if Apocynaceae)s
+ 2.73(if Arecaceae)**
+ 2.43(if Bignoniaceae)*
+ 2.17(if Burseraceae)*
+ 2.46(if Caryocaraceae)*
+ 2.35(if Chrysobalanaceae)*
+ 1.94(if Euphorbiaceae)s
+ 3.15(if Fab: Caesalpinoid)**
+ 1.82(if Fab: Mimosoid)s
+ 2.27(if Fab: Papilionoid)*
+ 5.01(if Lauraceae)***
+ 1.99(if Lecythidaceae)*
+ 2.21(if Malpighiaceae)*
+ 3.97(if Meliaceae)***
+ 2.67(if Myristicaceae)**
+ 2.22(if Sapindaceae)*

first elaborated more than fifteen years ago (see Feeny 1976, and Phillips 1991:428). Although it is difficult to see how this hypothesis could be directly tested by ethnobotanists in its entirety, specific predictions of the hypothesis are certainly testable. For example a prediction of the maintenance half of the hypothesis might be: "given a specific structure needed to construct a house (e.g., a pole or a beam), builders are more likely to choose common species than rare ones, all other things being equal" (see also Adu-Tutu et al. 1979:323; Turner 1988). Clearly, a prerequisite for such a test would be independent evaluation of the builders' preferences for species, if mechanical attributes, such as durability and ease of working the wood, were the only factors influencing their choice.

A converse explanation for this pattern is that the vegetation was consciously manipulated in the past, probably by indigenous people, to favor useful plants (cf. Balée 1989), and that such patterns of relative abundance of species persist today. There are at least three reasons for considering this an unlikely explanation in the context of mestizo people of the lower Tambopata River. Firstly, native people were severely affected by the traumatic impact of the rubber boom in the first years of the twentieth century, after which

TABLE 4. LIST OF THE MOST PREDICTIVE MULTIFACTORIAL EQUATIONS IN PREDICTING USE VALUES (COMMERCIAL USES ONLY).

UV_s (Commercial Uses):
n = 268, $r^2 = 0.431$, F = 5.19***

(Highest r^2 for the best predictive equation that does not include the plant's family: $r^2 = 0.105$, F = 3.02**.)

UV_s = −0.47* + 0.16 ln(max. d.b.h.)***
− 0.18(if liana)*
+ 2.21(if Annonaceae)*
+ 2.11(if Burseraceae)*
+ 3.70(if Lauraceae)***
+ 1.75(if Meliaceae)s
+ 2.34(if Sapindaceae)*

TABLE 5. LIST OF THE MOST PREDICTIVE MULTIFACTORIAL EQUATIONS IN PREDICTING USE VALUES (EDIBLE USES ONLY).

UV_S (Edible Uses):
n = 268, $r^2 = 0.581$, F = 9.82***

(Highest r^2 for the best predictive equation that does not include the plant's family: $r^2 = 0.053$, F = 1.43.)

UV_s = 0.25 − 0.20(if liana)***
+ 6.02(if Arecaceae)***
+ 1.95(if Moraceae)s
+ 2.20(if Sapotaceae)*

TABLE 6. LIST OF THE MOST PREDICTIVE MULTIFACTORIAL EQUATIONS IN PREDICTING USE VALUES (TECHNOLOGICAL USES ONLY).

UV_S (Technological Uses):
n = 268, $r^2 = 0.215$, F = 1.94**

(Highest r^2 for the best predictive equation that does not include the plant's family: $r^2 = 0.073$, F = 2.02*.)

UV_s = −0.09 + 0.04 ln(max. d.b.h.)*
+ 3.05(if Burseraceae)**
+ 2.86(if Lecythidaceae)**

most of Madre de Dios appears to have been lightly populated until very recently, making extensive vegetation management quite unlikely. Secondly, our data on the population structures of useful palm species (e.g., *Iriartea deltoidea* R.&P., *Euterpe precatoria* Mart.) in the ZRT plots strongly indicate that they are currently replacing themselves in situ, without contemporary anthropogenic help. And finally, our plot inventory data show that most Tambopata forest-types are extremely dynamic, with annual mortality and recruitment rates of stems ≥10 cm d.b.h. averaging more than 2%, and stand half-lives of only 25–40 years (Phillips, Gentry, and Vásquez, unpublished data). Therefore, few individual plants that might have been planted or favored by people eighty years ago could be expected to be alive now. For these reasons, we surmise that any historical vegetation manipulation has probably had a relatively minor influence on the present-day composition of the area's forests. In fact, it is likely that the modern practice of cutting trees for building materials, and sometimes for fruit, has had the opposite effect of actually weakening the correlation between species abundance and importance.

It is not evident why larger species should be more technologically useful than smaller species (Table 6). Quite possibly, like the relative usefulness of many common species, the answer may be an effect of their greater "apparency" than smaller plants. The pattern of larger species being more useful commercially (Table 4) is likely a consequence of the fact that trees must be a minimum of about 40 cm d.b.h. to be worth felling for planks, and selling sawn-timber is the single most important commercial use for mestizos.

Irrespective of the ultimate cause of the correlations between density/frequency, size, and usefulness, simply demonstrating the existence of these relationships has potential applications. We predict, for example, that given two species with equal use value for a given use, the less apparent species is likely to be the more "intrinsically" useful. This suggests that ethnobotanists could gain extra insights by paying careful attention to ecological parameters when collecting plant use data, especially if their ultimate aim is to evaluate the relative efficacy of plants for specific, medicinal uses.

The demonstration that lianas are much less useful to mestizos than trees is surprising, in light of speculation to the contrary published by ourselves and others that lianas may be especially useful, especially medicinally. This statistical result suggests that the ethnobotanical significance of tropical lianas might have been overstated. However, we hypothesize that our results are more likely to reflect past acculturation, since it is likely that knowledge of specific liana uses will be among the first to vanish as acculturation proceeds. Certainly, botanists find lianas difficult to recognize in the field from the ground, and mes-

TABLE 7. LIST OF THE MOST PREDICTIVE MULTIFACTORIAL EQUATIONS IN PREDICTING USE VALUES (MEDICINAL USES ONLY).

UV_S (Medicinal Uses):
n = 268, $r^2 = 0.238$, F = 2.22***

(Highest r^2 for the best predictive equation that does not include the plant's family: $r^2 = 0.065$, F = 1.77s.)

UV_s = −0.16 + 0.05 ln(max. d.b.h.)*
+ 1.74(if Arecaceae)s
+ 1.91(if Myristicaceae)s

tizos might be expected to have similar problems in discriminating between species. This is borne out by our data—among the diverse large lianas of Bignoniaceae, for example, a few general-purpose names predominate (notably huangana huasca = "white-lipped peccary liana," used only for temporary cordage). Perhaps only less acculturated peoples, such as the Achuar Jívaro, who have diverse specific medicinal uses for at least ten bignoniaceous liana genera (Lewis, Elvin-Lewis, and Gnerre 1987), retain the motivation and perceptual precision needed to differentiate among many liana taxa. Our data-processing technique for estimating use values makes the hypothesis that mestizos have already lost knowledge of specific kinds of uses, or of specific plant life-forms, theoretically testable since use values can be compared between ethnic groups.

In spite of all the other significant trends identified above, it is clear that a plant's family is the single most important factor in determining its usefulness. Incorporating the plants' families in the ANOVA equation has the effect of increasing its r^2 several-fold, compared to the most predictive equation possible without accounting for family (Table 2). Plant family is more important for determining edibility than it is for determining any other category of use (Table 1), and edibility is only very weakly predicted by the ecological and physiognomic factors (Table 5). This may reflect the wide distribution of knowledge of edible plants amongst informants (see *Comparisons of Informants* below), overcoming any possible masking effect of ecological and growth-form "apparency" factors.

Comparisons of Informants

H_0 *1* = *two informants have an equivalent level of knowledge (for each pairwise comparison).*

H_0 *2* = *informant knowledge is not related to informant age (for each broad use category, and for all uses).*

In addition to testing hypotheses about the relative utility of taxa and contributing factors, our technique for calculating species' use values also allows the testing of several kinds of hypotheses about informant knowledge. We applied statistical techniques to make (a) comparisons of informant knowledge, and (b) to explore variation in plant use knowledge with informant age.

We tended to have data for more useful species from more informants than for the less useful species. Moreover, the extra informants tended to be slightly less knowledgeable than those who gave information on more species. Therefore, simply averaging each informant's UV_{is} estimate would artificially raise the values for less knowledgeable informants. To avoid this problem, we calculated a standardized "Relative Use Value" (RUV_i) for each informant, by the method:

$$RUV_i = \frac{\sum \frac{UV_{is}}{UV_s}}{n_i}$$

where n_i equals, for each informant, the number of folk-species with data from two or more other informants. Because the standardization normalizes with respect to UV_s, it clearly violates the statistical assumption that results from one informant's responses do not influence the results from others. However, the number of informants is sufficient that each individual case is not unduly influential, so that our conclusions should remain valid. (In the regression equations of RUV_i on informant age, the largest Cook's D influence statistic is only 0.252; whereas a value of greater than 1 is generally a cause for concern.)

In Table 8 we compare the RUV_i of each of the 11 informants for whom we had an n_i of more than 15. For each informant, each UV_{is}/UV_s value represents one observation in the Kruskall-Wallis tests. The null hypothesis H_0 *1* is rejected at the 5% level for 25 out of 55 possible pairwise comparisons (as opposed to just $5/100 \times 55 = 2.75$ significant comparisons expected by chance alone). The highly-significant nature of some of the comparisons (e.g., the 35 year-old and 29 year-old) is indicative of how knowledge of the forest varies enormously even between informants of similar age. If such extreme heterogeneity is typical of tropical forest peoples, the clear implication is that ethnobotanists and anthropologists need to work with a large and representative sample of informants if their conclusions about the distribution of ethnobotanical knowledge in the local population as a whole are to be valid (cf. Padoch and de Jong 1992). On the other hand, if the specific aim is to elucidate as rapidly and efficiently as possible which species are useful, and why, this heterogeneity underscores the importance of trying to select knowledgeable informants.

TABLE 8. RELATIVE KNOWLEDGE OF ELEVEN INFORMANTS.

(Read downwards for each informant in each pairwise comparison; shaded squares signify that the column informant's relative knowledge is greater than the row informant's, for 136 folk-species[1] of trees and lianas compared.)

	5	27	28	29	33	35	45	53	54	55	67
5	XXXXX XXXXX	0.7	4.9 *	0.1	4.1 *	16.5 ***	3.7 s	5.5 *	0.0	7.4 **	12.1 ***
27	0.7	XXXXX XXXXX	2.8 s	0.8	2.0	17.1 ***	1.8	3.5 s	0.5	5.2 *	11.3 ***
28	4.9 *	2.8 s	XXXXX XXXXX	7.7 **	0.1	7.3 **	0.3	0.2	4.3 *	1.0	2.5
29	0.1	0.8	7.7 **	XXXXX XXXXX	5.4 *	32.3 ***	6.6 *	6.6 *	0.1	9.6 **	23.2 ***
33	4.1 *	2.0	0.1	5.4 *	XXXXX XXXXX	6.5 *	0.0	0.0	3.5 s	1.3	2.4
35	16.5 ***	17.1 ***	7.3 **	32.3 ***	6.5 *	XXXXX XXXXX	13.9 ***	6.5 *	14.6 ***	0.5	2.1
45	3.7 s	1.8	0.3	6.6 *	0.0	13.9 ***	XXXXX XXXXX	0.1	3.3 s	1.9	6.3 *
53	5.5 *	3.5 s	0.2	6.6 *	0.0	6.5 *	0.1	XXXXX XXXXX	3.6 s	1.3	2.2
54	0.0	0.5	4.3 *	0.1	3.5 s	14.6 ***	3.3 s	3.6 s	XXXXX XXXXX	6.4 *	10.4 **
55	7.4 *	5.2 *	1.0	9.6 **	1.3	0.5	1.9	1.3	6.4 *	XXXXX XXXXX	0.0
67	12.1 ***	11.3 ***	2.5	23.2 ***	2.4	2.1	6.3 *	2.2	10.4 **	0.0	XXXXX XXXXX

All values are chi-squared values for each pairwise comparison.

Significance levels for the chi-squared values: *** = $P < 0.001$, ** = $P < 0.01$, * = $P < 0.05$, s = $P < 0.10$; all pairwise tests are Kruskall-Wallis non-parametric comparisons. (*P*-values are identical for the Wilcoxon rank sum and the Mann-Whitney U tests for pairwise comparisons.) Note that these are *P*-values for individual pairwise comparisons. The true *P*-values for the most significant column or cell would be subject to a Bonferroni correction.

Most informants' ages are approximate. Only informants who gave information on >15 species are compared here.

[1] See Phillips and Gentry (1993) for our definition of a "folk-species."

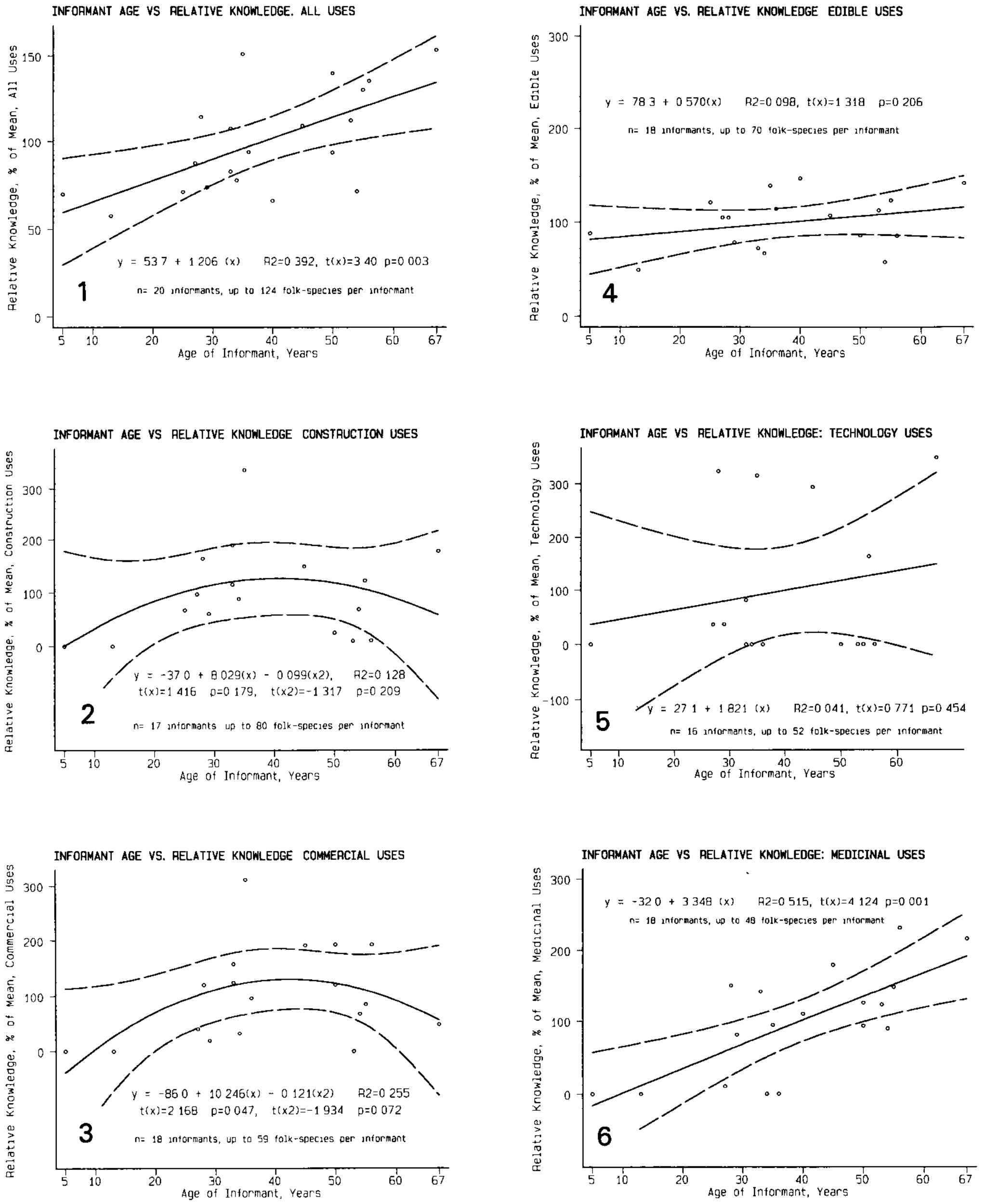


Fig. 1-6. Relative knowledge of informant vs. informant age. **Fig. 1.** All uses. **Fig. 2.** Construction uses. **Fig. 3.** Commercial uses. **Fig. 4.** Edible uses. **Fig. 5.** Technology uses. **Fig. 6.** Medicinal uses.

This demonstration of the importance of closely tying one's choice of methodology to the particular focus of an ethnobotanical study has some notable corollaries. For example, it underlines the value of stating the researchers' reasons for working with a particular set of informants. Equally, it suggests that investigators should attempt to predict how their results might have differed had they worked with informants of different ages, sex, or occupation.

In Fig. 1 to 6, we plot Relative Knowledge (= $RUV_i \times 100\%$) against informant age for different categories of plant use. The null hypothesis H_0 *2* is rejected at the 5% level only for informant knowledge of all uses and of medicinal uses (Fig. 1 and 6), although most of the regression lines have a positive gradient. For most of the variables, however, age does not explain much of the variance in relative informant knowledge, and our data are inadequate to conclusively test the hypothesis.

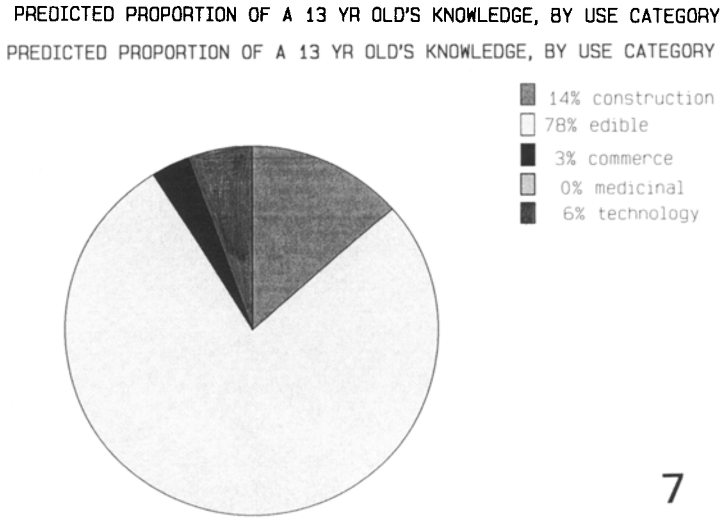
The results apparently reflect the importance of each category of use in each person's life. For example, construction and commercial uses (Fig. 2 and 3) are most important for men aged between 30 and 50, when most build houses for their family, or sell heavy forest products (mostly sawn timber, canoes, or fruits and nuts) to supplement agricultural income. This may account for the polynomial relationship between age and relative knowledge of both the construction and the commerce use categories.

The contrast in the edible and medicinal patterns is especially interesting (Fig. 4 and 6). Knowledge of edible uses increases only slowly (and non-significantly) with age, and age alone explains only 10% of the variance in relative knowledge of edibles. Apparently then, most young adults and even children already know much of what is edible. By contrast, young people have a negligible knowledge of medicinal plants, and age explains over 50% of the variance in relative knowledge of medicinals. Two, non-exclusive and testable hypotheses could explain the contrast: (1) knowledge of edible plants is much easier to learn than knowledge of medicinal plants, i.e., the contrast is a function of the relative rate of transfer of knowledge from old to young; and (2) the population is progressively losing its medicinal plant knowledge, i.e., the contrast results from acculturation. In fact, both explanations are supported by anecdotal observations. Thus, we have seen children enthusiastically eating fruits from several species that they said they had never seen before (parents the world over can attest to the fact that children are prone to "popping things in their mouths"!), suggesting that much learning of what is edible is simply by trial-and-error. In contrast, the preparation and use of most medicines is a longer and more complex process than preparing plant products for eating, and undoubtedly takes longer to learn. We have also been present at a few occasions where older mestizo or indigenous Ese-eja men and women actually heard of new medicinal plant uses from each other (cf. Lewis and Elvin-Lewis 1991), showing that the learning of medicinal plants can be a life-long process. Unfortunately, there is also strong evidence to support the hypothesis of acculturation: younger mestizo men are apparently less motivated to learn about plant medicine than older men and women. We suggest that simply establishing the existence of a uniquely steep increase in medicinal plant knowledge with age proves that ethnomedical knowledge is uniquely vulnerable to acculturation, regardless of whether acculturation is actually taking place now. This is powerful evidence for the importance of doing as much medical ethnobotany as possible, as soon as possible.

The pie-charts (Fig. 7, 8, and 9) compare the mean distribution of knowledge between use categories at ages 13, 40, and 67, and exemplify how quantitative techniques can aid the interpretation of ethnobotanical data. Thus, the extreme divergence between charts in the predicted proportion of knowledge in each use category, illustrates the value of working with informants of different ages. If we had worked only with the oldest informants (Fig. 9) we would have (erroneously) concluded that medicinal uses are the biggest contribution to the forest's value for mestizos. Similarly, working only with young and middle-aged adult men (Fig. 7 and 8) would have led us to overestimate the importance of commerce in timber to the local people.

Conclusions

We have shown here that, among mestizos in southeast Peru, woody plant species' usefulness is partly predictable from knowledge of any one of: plant family, growth-form, density, frequency, mean and maximum diameter, and mean and maximum growth rate. Informants of similar age can have very different levels of knowledge about the uses of forest plants. Notwithstanding this, informant age does predict, in part, informant knowledge. Not only do informants of different ages have predictably different levels of knowledge, but the kind of ethnobotanical knowledge they have is also markedly different. Thus, considerable knowledge about edible wild plants is gained early on in life, whilst informants' awareness of construction and commercial uses of the forest appears to peak when they are between 30 and 50 years old. Medicinal plant knowledge is largely confined to older people. Hence, medicinal plant lore is clearly the most vulnerable kind of knowledge to acculturation, and should be a main focus of attempts to both record indigenous



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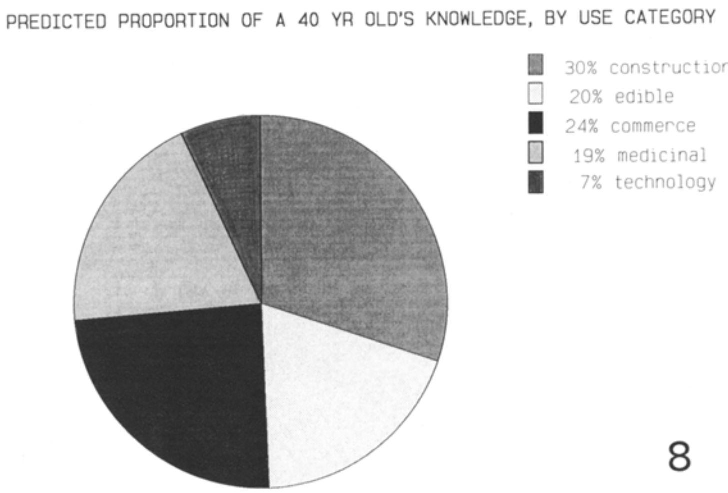

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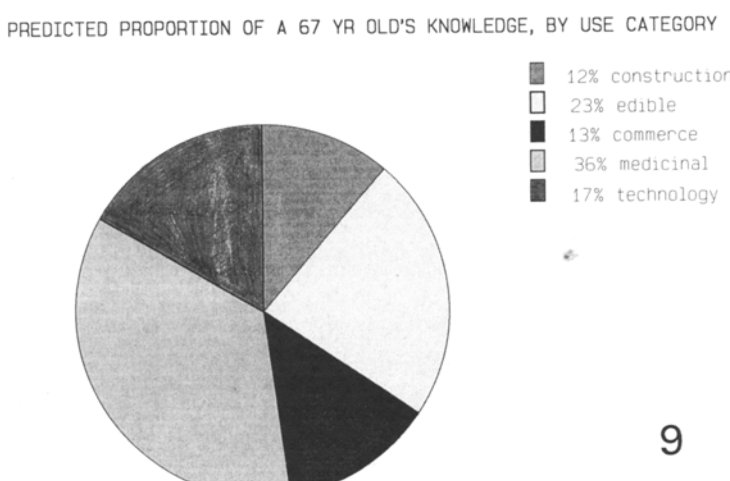

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Fig. 7-9. Average distribution of knowledge between use categories at different ages. **Fig. 7.** 13 years. **Fig. 8.** 40 years. **Fig. 9.** 67 years.

knowledge, and to encourage knowledge and pride in traditional cultural values.

Other kinds of ethnobotanical hypotheses could also be explored, using as a basis the same technique for calculating use values. The myriad possibilities include: (1) the hypothesis that terra firma forests are especially useful and therefore especially worthy of conservation action (Prance et al. 1987); (2) the long-running controversy between utilitarian/adaptationist and intellectualist positions about the nature of folk plant taxonomies (cf. Berlin 1990; Berlin, Breedlove, and Raven 1974; Hays 1982; Hunn 1982; Balée and Daly 1990); or (3) the likelihood that knowledge of certain environments, use classes, and plant life-forms, is unequally partitioned between men and women.

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