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CONCEPTS AND METHODS IN STUDIES MEASURING INDIVIDUAL ETHNOBOTANICAL KNOWLEDGE

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ABSTRACT.—We review 34 quantitative studies that have measured individual-level variations in ethnobotanical knowledge, analyzing how those studies have conceptualized and operationalized ethnobotanical knowledge. We found that this type of research is recent but growing, and is concentrated in indigenous peoples of developing countries. We also found that studies differ on how they conceptualize and measure individual ethnobotanical knowledge. As it is the case in other interdisciplinary research, the lack of conceptual consistency and comparable data limit the inferences that can be drawn from empirical analyses of ethnobotanical knowledge. Future research should 1) validate the consistency of measures of individual ethnobotanical knowledge; 2) analyze the reliability of data generated by the different methods developed so far; and 3) address the relationship between the various dimensions of ethnobotanical knowledge. Studies of individual ethnobotanical knowledge have the potential to contribute to a systematic understanding of humanity's most widespread and ancient form of knowledge.

Key words: ethnobotanical knowledge, intra-cultural variation, quantitative methods, folk knowledge.

RESUMEN.—En este artículo revisamos 34 estudios que han medido cuantitativamente el conocimiento etnobotánico individual, analizando cómo lo han medido y definido. Hallamos que este tipo de investigaciones es reciente pero creciente y que se concentra en poblaciones indígenas en países en desarrollo. También se observan diferencias a la hora de definir y medir el conocimiento etnobotánico individual. Como en otras investigaciones interdisciplinarias, la

falta de consistencia conceptual y de métodos que proporcionen datos comparables limita las conclusiones que podemos obtener de este tipo de investigación. Se necesita más investigación que 1) valide la consistencia de los métodos usados, 2) analice la fiabilidad de la información generada por los métodos usados hasta ahora, y 3) estudie la relación entre las distintas dimensiones del conocimiento etnobotánico. Los estudios sobre el conocimiento etnobotánico individual pueden ayudarnos a entender mejor la forma de conocimiento más antigua y común de la humanidad.

RÉSUMÉ.—Nous avons comparé 34 études quantitatives qui portent sur la mesure des variations individuelles en savoirs ethnobotanique. Notre analyse vise à comprendre comment ces études ont conceptualisé et rendu opérationnel le savoir ethnobotanique. Nous remarquons que ce type de recherche, quoique récent, prend de l'importance. Également, il prend davantage racine parmi les Premières Nations des pays en développement. De plus, les études diffèrent dans la façon de conceptualiser et de mesurer le savoir ethnobotanique individuel. À l'instar des autres recherches pluridisciplinaires, le manque de similitude conceptuelle et de données comparables réduisent la porté des conclusions que l'on peut tirer des analyses empiriques faites sur le savoir ethnobotanique. Les recherches ultérieures doivent 1) vérifier la rigueur des mesures sur le savoir ethnobotanique individuel, 2) évaluer la fiabilité des données générées par les différentes méthodes développées ce jour et 3) aborder les relations entre les diverses dimensions du savoir ethnobotanique. Les études portant sur le savoir ethnobotanique individuel possèdent un important potentiel pouvant aider à la compréhension de la plus ancienne forme de savoir issue de l'humanité, laquelle forme est également la plus répandue.

INTRODUCTION

A fundamental step in the development of research on ethnobiology in general and ethnobotany in particular has been the move from a descriptive to a more analytical and quantitative approach (Phillips 1996). Interest in quantitative ethnobiology has grown in the last two decades with the majority of research focusing on plants, remedies, animals, or ecosystems as units of analysis. This research has improved our understanding of the relative importance of the environment for cultural groups (Medin and Atran 1999). But until recently, quantitative research in ethnobiology did not pay much attention to people as units of analysis, thus we have a more limited understanding of the factors that predict individual-level variation in knowledge of the natural environment or of the benefits provided by this knowledge.

Previous quantitative studies aimed at measuring individual levels of ethnobotanical knowledge have focused on how knowledge varies by demographic (Boster 1986; Caniago and Siebert 1998), social (Benz et al. 2000; Sternberg et al. 2001; Zent 2001), and economic (Godoy et al. 1998; Guest 2002; Reyes-García et al. 2005) characteristics of subjects. However, this research has generated conflicting results. For example, some authors have provided evidence of a negative effect of acculturation and market integration on ethnobotanical knowledge (Benz et al. 2000; Caniago and Siebert 1998), while others have found persistence in ethnobotanical knowledge through time despite major economic

changes (Zarger and Stepp 2004). Still others have found that only certain aspects of market integration affect ethnobotanical knowledge (Godoy et al. 1998). Research on how ethnobotanical knowledge varies across demographic and social characteristics also shows contradictory results (e.g., Godoy et al. 2005).

A likely explanation for the inconsistency across findings may be that definitions and methods used to measure individual ethnobotanical knowledge vary across studies. For example, while some authors have proxied ethnobotanical knowledge by studying medicinal plants (Sternberg et al. 2001), others have centered on the many uses of wild plants (Reyes-García et al. 2005), and some authors have focused on crops (Boster 1986). Researchers have also used a variety of methods to measure individual ethnobotanical knowledge. Some authors have measured individual ethnobotanical knowledge by using results from transect surveys (Zarger and Stepp 2004) and specimen identification (Begossi 1996). Others have used cognitive methods (Atran et al. 2002; Boster 1986; Zent 2001), or objective tests (Godoy et al. 1998).

The differences in methods and concepts used in previous studies measuring individual ethnobotanical knowledge are mainly due to different theoretical goals of authors. But, to develop a theory about what drives the creation, loss, or persistence of ethnobotanical knowledge across cultures in the world, we need a methodology that allows us to quantify individual ethnobotanical knowledge in a consistent way. Such a methodology should allow comparability across studies, making it possible to draw generalizations about what it is that shapes ethnobotanical knowledge distribution. For that goal, empirical research on individual ethnobiological knowledge must overcome two major burdens: conceptual inconsistency and the lack of methodology that provides data comparable at cross-cultural level.

In this article we offer a review of quantitative studies that have measured individual-level variations in ethnobotanical knowledge. The article does not claim to provide a census of all the work that has been done in the topic, but rather aims at providing a good example of the methods used to measure individual ethnobotanical knowledge, the potential of those methods in quantitative ethnobiology, and the challenges ahead. We focus on ethnobotanical knowledge because ethnobotany is a popular field within ethnobiology, and we expected to find more articles in this topic than in others (e.g., ethnoentomology).

For the review presented in this paper, we conducted a bibliographic search to find articles that have used a formal method to measure individual variation in ethnobotanical knowledge. We restricted the search to studies that were: 1) quantitative; 2) published between 1986 and 2005; and 3) published in refereed journals, plus three articles published in an edited book (Heckler 2002; Hunn 2002; Zent 2001). We restricted the search to articles published in refereed journals because those are more easily available. Although the selection of articles might be biased (i.e., overestimating research published in English and research conducted at North American institutions), it provides some indication of the direction that the field is taking. We report on 34 studies with those characteristics (Table 1). The list of articles is certainly not exhaustive, but includes all the articles known to us that had studied variations in individual ethnobotanical knowledge and met the criteria mentioned above.

TABLE 1.—Sample of studies measuring individual ethnobotanical knowledge (1986–2005).

	[A]	[B]	[C]	[D]	[E]	[F]	[G]	[H]
#	Reference	Discipline	Population and geographic area	Sample	Domain	Dimension	Method to collect data	Method to analyze data
1	Boster 1986	Anthropology	Aguaruna*, Peru	79	Crops	Skills	Identification	Cultural consensus
2	Johns et al. 1990	Anthropology	Luo*, Kenya	45	Medicinal plants	Knowledge	Interview	Matching between informants
3	Figueiredo et al. 1993	Biology	Caiçaras*, Brazil	58	Useful plants	Knowledge	Interview	Number of plants reported
4	Phillips and Gentry 1993b	Biology	Mestizo, Peru	20	Useful plants	Knowledge	Interview	Matching between informants
5	Johns et al. 1994	Anthropology	Batemi*, Tanzania	22	Medicinal plants	Knowledge	Interview	Matching between informants
6	Joyal 1996	Biology	Farmers, Mexico	47	Useful plants	Knowledge	Questionnaire (Multiple-choice)	Matching ecological data
						Skills	Observation	Matching ecological data
7	Hynes et al. 1997	Biology	Farmers, Argentina	^	Useful plants	Knowledge	Interview	Number of plants reported
8	Caniago and Siebert 1998	Biology	Kalimantan*, Indonesia	32	Medicinal plants	Knowledge	Interview	Matching with experts
9	Godoy et al. 1998	Anthropology	Tawahka*, Honduras	80	Wild plants	Knowledge	Questionnaire (Multiple-choice)	Matching ecological data

TABLE 1.—Continued.

#	[A] Reference	[B] Discipline	[C] Population and geographic area	[D] Sample	[E] Domain	[F] Dimension	[G] Method to collect data	[H] Method to analyze data
10	Benz et al. 2000	Biology	Huastec* and mestizo, Mexico	259	Wild plants	Skills	Identification	Matching between informants
11	Hanazaki et al. 2000	Biology	Caiçaras*, Brazil	102	Useful plants	Knowledge	Interview	Number of plants reported
12	Byg and Balslev 2001	Biology	Betsimisaraka*, Madagascar	54	Useful plants	Knowledge	Interview	Matching between informants
						Skills	Observation	Matching ecological data
13	Prince et al. 2001	Anthropology	Luo*, Kenya	86	Medicinal plants	Knowledge	Interview	Number of plants reported
14	Sternberg et al. 2001	Psychology	Luo*, Kenya	85	Medicinal plants	Knowledge	Questionnaire (Multiple-choice)	Matching with experts
15	Zent 2001	Anthropology	Piaroa*, Venezuela	104	Wild plants	Knowledge	Interview	Cultural consensus
						Skills	Identification	Matching ecological data
16	Atran et al. 2002	Anthropology	Itza'*, Ladino & Q'eqchi', Guatemala	36	Wild plants	Knowledge	Questionnaire (Free listing)	Cultural consensus
17	De Albuquerque and Andrade 2002	Biology	Farmers, Brazil	30	Useful plants	Knowledge	Interview	Matching between informants

TABLE 1.—Continued.

#	[A] Reference	[B] Discipline	[C] Population and geographic area	[D] Sample	[E] Domain	[F] Dimension	[G] Method to collect data	[H] Method to analyze data
18	Geissler et al. 2002	Anthropology	Luo*, Kenya	7	Medicinal plants	Knowledge	Interview	Number of plants reported
19	Heckler 2002	Biology	Piaroa*, Venezuela	178	Useful plants	Knowledge	Interview	Matching between informants
						Skills	Identification	Matching between informants
20	Hunn 2002	Anthropology	Zapotec*, Mexico	6	Wild plants	Skills	Identification	Matching ecological data
21	Peroni and Hanazaki 2002	Biology	Agriculturalists, Brazil.	33	Crops	Knowledge	Questionnaire (Free listing)	Number of plants reported
						Skills	Observation	Diversity indices
22	Ross 2002	Anthropology	Lacandon*, Mexico	^	Wild plants	Knowledge	Questionnaire (Free listing)	Cultural consensus
23	Ticktin and Johns 2002	Biology	Chinanteco*, Mexico	18	Useful plants	Skills	Self-report	Matching ecological data
24	Kristensen and Lykke 2003	Biology	Gourounsi*, Burkina Faso	200	Useful plants	Knowledge	Questionnaire	Matching between informants
25	Reyes-García et al. 2003	Anthropology	Tsimane'*, Bolivia	511	Useful plants	Knowledge	Questionnaire (Multiple-choice)	Cultural consensus

TABLE 1.—Continued.

#	[A] Reference	[B] Discipline	[C] Population and geographic area	[D] Sample	[E] Domain	[F] Dimension	[G] Method to collect data	[H] Method to analyze data
26	Casagrande 2004	Anthropology	Tzeltal*, Mexico,	26	Useful plants	Knowledge	Interview	Cultural consensus
27	Ghimere et al. 2004	Biology	Agropastoralists, Nepal	120	Medicinal plants	Knowledge	Interview	Matching ecological data
						Skills	Identification	Matching ecological data
28	Ladio and Lozada 2004	Biology	Mapuche*, Argentina	57	Useful plants	Knowledge	Interview	Number of plants reported
						Skills	Self-report	Number of plants reported
29	Uma Shaanker et al. 2004	Biology	Soliga*, India	206	Useful plants	Knowledge	Interview	Matching ecological data
30	Vandebroek et al. 2004	Biology	Quechua* and Yuracare*, Bolivia	125	Medicinal plants	Knowledge	Interview	Number of plants reported
31	Zarger and Stepp 2004	Anthropology	Tzeltal*, Mexico	29	Wild plants	Skills	Identification	Matching ecological data
32	Reyes-García et al. 2005	Anthropology	Tsimane'*, Bolivia	150	Useful plants	Knowledge	Questionnaire (Multiple-choice)	Cultural consensus
33	Rocha 2005	Anthropology	Farmers, Peru	37	Crops	Knowledge	Questionnaire (Pile sorting)	Cultural consensus

TABLE 1.—Continued.

#	[A] Reference	[B] Discipline	[C] Population and geographic area	[D] Sample	[E] Domain	[F] Dimension	[G] Method to collect data	[H] Method to analyze data
34	Ross et al. 2005	Anthropology	Tzotzil*, Mexico	51	Wild plants	Knowledge	Questionnaire (Triad)	Cultural consensus

* Indigenous population
^ Exact sample size not reported.
[A] author and year of publication; [B] discipline of the lead author; [C] population and geographic area of the research; [D] sample size; [E] domain of knowledge addressed on the research; [F] type of knowledge collected; [G] method used to collect data; [H] method used for data analysis.

The remainder of the article is organized in five parts. First, we provide an overview of the development of quantitative ethnobiology, emphasizing the recent growth and geographical distribution of research measuring individual ethnobotanical knowledge. The second section addresses the complexity of the concept ''individual ethnobotanical knowledge'' by analyzing how the selected studies focus on different domains and dimensions of ethnobotanical knowledge. In the third section we review different methodological approaches to collect and analyze individual ethnobotanical knowledge. The fourth section offers suggestions that might bring researchers closer to the development of a common metric to measure individual-level variations in ethnobotanical knowledge. In the fifth section we conclude.

HISTORICAL BACKGROUND AND CURRENT STATUS

The content of the knowledge that human groups have of their local environment has attracted the interest of researchers since the beginning of the 19th century (see Berkes 1999 for a review). Initial studies focused on documenting the knowledge itself and how native peoples used to classify their environment (Berlin et al. 1966; Conklin 1954). By the 1990s, researchers adopted a more utilitarian approach and started to study how knowledge of the local environment contributed to human adaptation (Balee 1994). At that point, quantitative ethnobotany began flourishing (e.g., Alexiades and Sheldon 1996; Phillips and Gentry 1993a, 1993b; Phillips et al. 1994).

Most of the first studies on quantitative ethnobiology focused on the importance of plants, remedies, animals, and ecosystems for specific cultural groups. For example, Trotter (1981) analyzed a large sample of home remedies (focusing on the occurrence of folk remedies in the data) to determine the characteristics of the ethnopharmacological resources in use in Mexican-American communities. Ngokwey (1995) analyzed popular notions and practices concerning home remedies and pharmaceutical drugs in Feira (Brazil). In a cross-cultural study, Heinrich and colleagues (1998) examined the use of medicinal plants in five groups in Mexico to calculate the relative importance of a given medicinal plant within a culture. These papers focused on the relative importance of plants for different groups, but not on the variation on the ethnobotanical knowledge of informants.

The idea that there is individual variation in cultural knowledge is not new, but the quantitative measurement of individual variation of ethnobotanical knowledge is recent. As early as 1936, anthropologists pointed out the importance of systematic variation in cultural knowledge (for a review see D'Andrade 1987; Romney and Moore 1998), and since the 1960s the idea that culture is heterogeneous and that intra-cultural variation is patterned became popular in anthropology (Furbee and Benfer 1983; Mathews 1983; Sankoff 1971; Wallace 1961). The idea was first applied to the study of variations on biological knowledge during the 1970s (Ellen 1979; Gardner 1976; Hays 1976). Since then, the interest in understanding the patterns in which individual ethnobotanical knowledge is distributed within a cultural group has grown. For example, in Table 1 (Column [A]), we found one of such studies between 1986 and 1990, but

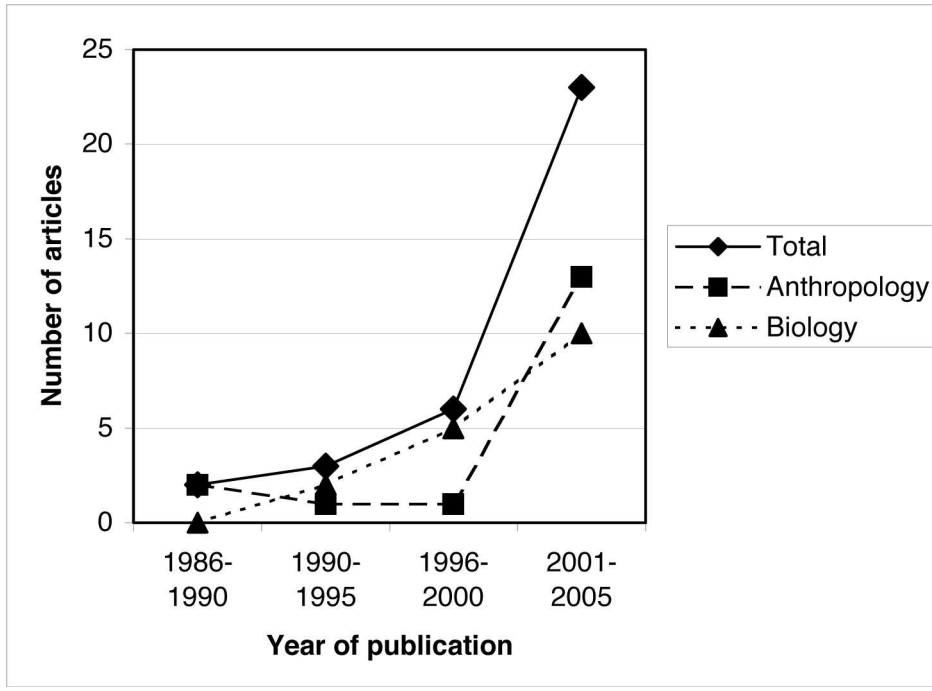

FIGURE 1.—Evolution of the number of studies measuring individual ethnobotanical knowledge (n = 34) (1986–2005). From Table 1.

we found 23 studies between 2001 and 2005. Using the publications in Table 1, we found a 9% yearly increase in the number of articles measuring individual ethnobotanical knowledge from 1986 until 2005, which shows a growing interest in the field.

Results from Table 1 (Column [B]) also show that interest in the topic comes mainly from anthropology and biology. From the 34 studies analyzed, the first authors of 50% of the articles (n = 19) were biologists. The first authors of 73% of the articles (n = 16) were anthropologists. Psychologists wrote one of the articles in Table 1. Relative to biologists, it appears that anthropologists have more recently started to use quantitative methods to measure individual ethnobotanical knowledge. Only 13% of the articles published by anthropologists appeared before 2000 (n = 2), whereas 47% of the articles published by biologists appeared before 2000 (n = 9) (Figure 1). Few studies combine the strengths of anthropology and biology.

Researchers have argued that ethnobotanical knowledge emerges from the interaction of a given culture or society with a local biophysical environment (Warren and Rajasekaran 1993). This implies that ethnobotanical knowledge is not restricted only to indigenous peoples nor only to developing countries. Indigenous groups possess ethnobotanical knowledge developed through generations of interactions with the local environment (Brookfield and Padoch 1994; Turner et al. 2000), but similar knowledge has been found among non-indigenous groups such as farmers (Barrera-Bassols and Toledo 2005; Pieroni et

TABLE 2.—Comparison of studies measuring individual ethnobotanical knowledge (n = 34), by the discipline of the lead author.

		Anthropology		Biology		Total	
		N	%	*N*	%	*N*	%
[C] Population	*Indigenous*[a]	14	41	10	29	25	74
	Non-indigenous[b]	1	3	6	18	7	21
	Both[c]	1	3	1	3	2	6
	Total	**16**	**47**	**17**	**50**	**34**	**100**
[E] Domain	*Medicinal*[a]	4	12	3	9	8	24
	Useful[b]	3	9	12	35	15	44
	Wild[c]	7	21	1	3	8	24
	Crop	2	6	1	3	3	9
	Total	**16**	**47**	**17**	**50**	**34**	**100**
[F] Dimension	*Knowledge*[a]	12	35	9	26	22	65
	Skills[b]	3	9	2	6	5	15
	Both[c]	1	3	6	18	7	21
	Total	**16**	**47**	**17**	**50**	**34**	**100**
[G] Method of data collection	*Interview*[a]	5	15	8	24	13	38
	Other[b]	10	29	5	15	16	47
	Both[c]	1	3	4	12	5	15
	Total	**16**	**47**	**17**	**50**	**34**	**100**
[H] Method of data analysis	*Consensus*[a]	9	26	6	18	15	44
	No-consensus[b]	5	15	9	26	15	44
	Both[c]	2	6	2	6	4	12
	Total	**16**	**47**	**17**	**50**	**34**	**100**

Note: To construct Table 2, we generated dummy variables for each of the columns in Table 1. For example, to analyze differences in the population studied (column [C]), we generated a dummy variable - *indigenous*- that took the value of one if the study was conducted among an indigenous population and zero otherwise.

al 2004). Researchers have also argued about the importance of ethnobotanical knowledge for rural people of industrialized countries (Agelet and Vallès 2001; Pieroni et al. 2004).

Despite those claims, most studies measuring individual ethnobotanical knowledge have been conducted among indigenous populations and mainly in Latin America. We found that researchers have given more attention to the measure of the ethnobotanical knowledge of indigenous peoples than to the knowledge of non-indigenous peoples (Table 1, column [C]). Seventy-four percent (n = 26) of the studies in Table 1 were conducted among indigenous populations and only 21% (n = 7) among non-indigenous populations (Table 2). We found that only two studies had a mixed sample comparing the ethnobotanical knowledge of indigenous and non-indigenous peoples inhabiting the same area.

We also found an uneven distribution of the geographical areas covered. The totality of the studies in our list were conducted in developing countries. Of the 34 studies examined, 70% took place in Latin America, 21% in Africa, and 9% in Asia. We did not find any study measuring individual ethnobotanical knowledge with European or North American populations. The uneven distribution across geographical areas can be explained by the effort of a few active research groups. For example, researchers and students from the University of Georgia and

researchers of a team led by Atran have conducted much of the research in Central America and Mexico, and a group of researchers led by Begossi carried out most of the research in Brazil. Thus, the concentration in the studied populations is even larger than it appears. The finding is surprising because studies on other aspects of European and North American ethnobotany and ethnobiology have been on the rise over the last two decades, including studies in Italy (Pieroni 2001), Austria (Vogl and Vogl-Lukasser 2004), Spain (Agelet et al 2000; Agelet and Valles 2001; Pardo de Santayana et al. 2005), the United States (Stoffle et al. 1999), and Canada (Berkes and Jolly 2002; Chipeniuk 1998; Olsson et al. 2004; Turner et al. 2000), to name some examples.

In sum, the list of publications in Table 1 suggests that research on individual ethnobotanical knowledge is recent but growing, mainly conducted by biologists and anthropologists, and concentrated in indigenous peoples of developing countries (especially Latin America).

CONCEPTUALIZING INDIVIDUAL ETHNOBOTANICAL KNOWLEDGE

The first major burden for empirical research on individual ethnobotanical knowledge is the lack of conceptual consistency. Providing an exact definition of ''individual ethnobotanical knowledge'' is beyond the scope of this paper, but in trying to synthesize methodological lessons from quantitative research on individual ethnobotanical knowledge we will mainly focus on 1) the many fields or domains included in the concept of ''ethnobotany;'' and 2) the several dimensions included in the concept of ''knowledge.'' Below we discuss the incidence of those two characteristics in empirical research on individual ethnobotanical knowledge.

Domains of Knowledge.—Plant knowledge can be gathered from undertaking several different pursuits such as harvest, medicinal collection, preparation for spiritual ceremonies, or maintenance of a household economy. Therefore, ethnobotanical knowledge spans many different sub-fields of knowledge, as it is reflected in the topics covered by articles listed in Table 1 (Column [E]). For example, some authors have proxied ethnobotanical knowledge by studying medicinal plants (Geissler et al. 2002; Sternberg et al. 2001). Others have centered in wild plant uses (Caniago and Siebert 1998; Reyes-García et al. 2005; Zent 2001), and some authors have only considered crops (Boster 1986; Rocha 2005). Out of the 34 studies of individual ethnobotanical knowledge listed in Table 1, we found eight in which authors studied all the wild plants known by an ethnic group, 15 that centered on useful wild plants, eight that centered only on medicinal plants, and three that focused on edible crops.

Differentiating between specific domains of knowledge is important for comparative purposes. For example, in his study on manioc varieties, Boster (1986) found that Aguaruna women in Peru knew more about manioc than men, but in their study of useful plants among the Tsimane', Reyes-García and colleagues (2005) found that men knew more about wild plants than women. Those results are not comparable because they refer to different domains of knowledge within ethnobotany (e.g., crops and wild plants).

Dimensions of Knowledge.—Researchers argue that local ecological knowledge, including ethnobotanical knowledge, is better understood as a complex system that might include a system of classification (Berlin 1992), a set of empirical observations about the local environment, a system of self-management that governs resource use (Ostrom 1990), and a set of beliefs about the environment (Berkes and Henley 1997). However, operationalizing this complexity in empirical research has proven difficult.

Empirical research has successfully differentiated between the theoretical and the practical dimensions of ethnobotanical knowledge. Theoretical or passive ethnobotanical knowledge refers to the intellectual ability, such as the ability to name plants, whereas practical ethnobotanical knowledge, or skills, refers to the practical dimension, such as the ability to put the knowledge into practice (Atran et al. 2004). For example, some people may know the potential uses of a plant, but they may not know how to use the plant. We found that 65% of the 34 studies (n = 22) measured theoretical ethnobotanical knowledge and only five (15%) measured practical ethnobotanical knowledge (Table 1, column [F]). The bias towards measuring the theoretical dimension might be partially related to the costs of assessing skills through observations and the potential errors associated with self-reports.

Only in eight studies did researchers measure both theoretical knowledge and practical skills of the same individuals, and in only three of them did researchers compare results across the two dimensions. Byg and Balslev (2001) carried out interviews on the knowledge and observations on the use of *Dypsis fibrosa* (Arecaceae) in Eastern Madagascar. They found no correlation between an individual's knowledge of plants, as elicited in surveys, and the actual extent of use of different plant resources by the same individual. Similarly, in a study among the Mapuche from northwestern Patagonia, Ladio and Lozada (2004) found that people knew significantly more about edible plants than actually consume those plants. These few case studies suggest that different dimensions of ethnobotanical knowledge might not be well captured with only a single measure.

Furthermore, research on the transmission of ethnobotanical knowledge suggests that most of the ethnobotanical nomenclature is acquired by adolescence (Hunn 2002; Reyes-García et al. 2005; Stross 1973; Zarger 2002), but the acquisition of practical skills is not always gained at the same time and, in some cases, begins during adulthood (Hewlett and Cavalli-Sforza 1986; Ohmagari and Berkes 1997). Thus differentiating between the theoretical and practical dimensions of ethnobotanical knowledge might be key in studies on the transmission of ethnobotanical knowledge.

Researchers have also argued that ethnobotanical knowledge also encompasses belief systems that may be instrumental in managing natural areas and institutional systems that allow groups to maintain sustainable uses of ecosystems (Berkes et al 2000; Byers et al. 2001; Toledo et al. 2003) and institutional systems that govern resource use (Ostrom 1990). Measuring those aspects at the individual level has proven challenging, as studies relating to individual-level religious or institutional values of local plants are uncommon.

MEASURING INDIVIDUAL ETHNOBOTANICAL KNOWLEDGE

The second major burden for empirical research on individual ethnobotanical knowledge is the lack of attention to the reliability and consistency of the various methods used. Methodological issues are becoming a growing concern for quantitative research in ethnobiology as they provide the key for a shift towards comparative and statistical research rather than single-case analyses. Below we use the articles of Table 1 to discuss three methodological issues related to the measurement of individual ethnobotanical knowledge: sampling strategy, methods used to collect data, and methods used to analyze data.

Sampling.—About ten years ago, Begossi (1996) conducted a literature review on the number of informants interviewed in ethnobotanical studies. She noticed that little effort had gone to obtain samples of more than 50 people. She also noted a paucity of studies reporting variability of ethnobotanical knowledge between people. The information in Table 1 suggests that researchers may have responded to Begossi's plea[1]. We found that the average study in our list had a sample size of 90 people (±99). Only two studies did not report the sample size (Table 1, Column [D]). Furthermore, we found that the average sample size of the studies has doubled between 1986–1995 and 1996–2005: from 45 (±25) people/study during 1986–1995, before Begossi's study, to 99 (±105) people/study after Begossi's study.

Researchers, however, have paid scarce attention to other issues when selecting the study samples. For example, previous studies suggest that ethnobotanical knowledge is distributed across age and sex groups (Begossi et al. 2002; Boster 1986; Caniago and Siebert 1998), or according to the length of residence in the community (Guest 2002; Nyhus et al. 2003), yet researchers have not always stratified their samples taking into account these variables. Considerations, other than a sufficient sampling size, should be added to the design of sampling strategies. Additionally, the field can benefit from studies targeted to specific groups. For example, studies with children might help us to understand better how ethnobotanical knowledge is acquired and accumulated.

Methods of Data Collection.—Researchers have used a variety of methods to collect data on individual ethnobotanical knowledge (Table 1, Column [G]). The selection of the method partially depends on whether the researcher assessed informants' theoretical knowledge or practical skills. For example, to measure theoretical knowledge, some authors have used cognitive methods such as free lists (Atran et al. 2002), but others have used objective botanical tests (Godoy et al. 1998). To measure practical knowledge, authors have used transect surveys (Zarger and Stepp 2004) and specimen identification (Begossi 1996), but also self-reports (Ticktin and Johns 2002).

To elicit information on the theoretical dimension of individual ethnobotanical knowledge, researchers have shown an almost equal preference for interviews (38%; $n = 13$) and formal, structured questionnaires (29%; $n = 10$). From the ten studies that used questionnaires to assess individual ethnobotanical

knowledge, five used multiple-choice questionnaires, three used free lists, one used pile sorts, and one used a triad tests (see Bernard 2004 for a description of those methods).

When eliciting information on theoretical knowledge, it may be enough to simply ask people about the domain of interest, whereas when assessing skills researchers can choose between self-reported evaluations of skills or actual observations. We found that researchers have preferred observations to self-reports to assess individuals' ethnobotanical skills. Of the 12 studies that measured individual ethnobotanical skills, in seven researchers asked informants to identify specimens (in the field, in vouchers, or in pictures) and in three they directly observed the informant's abilities using the skills. Only two of the studies that measure ethnobotanical skills did so by asking informants to self-report their abilities.

We have scarce evidence of the correspondence (or lack of correspondence) of data collected using such a diversity of methods. Few studies have exactly replicated methods used in previous research (but see Zarger and Stepp 2004 for a notable exception) or compared results across different methods (but see Reyes-García et al. 2004). As a consequence, results from different studies are difficult to compare. Different methods might capture different dimensions of ethnobotanical knowledge that do not necessarily overlap. This implies that researchers should either select the method of data collection to ensure that it captures the desired dimension, or they should include a variety of methods to get a comprehensive understanding of individual ethnobotanical knowledge.

Methods to Analyze Data.—When studying local ethnobotanical knowledge, researchers typically lack answers to the questions they pose. In contrast to a classroom instructor who asks questions but who also has an answer key, researchers who ask about local plants do not necessarily have an answer key to evaluate the correctness of the answers provided by informants. To overcome the problem, researchers have used three different methods to analyze individual ethnobotanical knowledge.

Most authors (52%; $n = 19$) have analyzed individual ethnobotanical knowledge by comparing informants' answers with the information provided by other informants in the same cultural group. Researchers have developed the idea that agreement between informants stands for cultural knowledge but have developed different metrics and indices to quantify agreement. One method known as ''informant consensus'' was initially developed by Friedman and colleagues (1986) and Trotter and Logan (1986) and was later adapted by other authors (Johns et al. 1990; Phillips and Gentry 1993b). The method of informant consensus states that the degree of agreement between informants' answers indicates the importance of a given use of a plant; in other words, a plant more frequently cited has a more important use than a plant less frequently cited. Three authors have used a variant of this method, i.e., evaluating individual's answers by comparing it with information collected from a group of local experts, not with the whole group. A more sophisticated approach known as cultural consensus analysis has come from Romney and colleagues (1986). Rather than rely on simply frequency of responses by informants, cultural consensus

analysis uses factor analysis to weight the responses of those informants who agree with each other more often. Using this approach, one can accurately determine the culturally ''correct'' answer if the assumptions of the technique are met. Conversely, it can also indicate lack of consensus in a particular domain and demonstrate large intra-cultural variation within ethnobiological knowledge.

In Table 1 we refer to the ''informant consensus'' method of data analysis as ''matching with other informants'' to avoid confusion with the term ''cultural consensus.''

A second group of authors (26%; $n = 9$) has checked informants' answers against ecological data collected during the same study or previously recorded in the literature. For example, researchers have asked textbook questions such as ''What is the color of a flower of a mahogany tree?'' and evaluated the informant's answer against the information provided by the scientific literature. The method works when evaluating how well people converge to the scientific standards, but it does not capture people's knowledge of local resources to provide goods and services deemed important by the culture. The method can also be problematic when scientific ecological data is not fully available in the area of study (Henfrey 2002).

The third group of authors (43%; $n = 8$) has evaluated informants' knowledge using indices used in ecology, such as Shannon's Index and Simpson's Index, which look at species richness and eveness as a measure of biological diversity. These measures were originally developed as a way to quantify information (Stepp 1999), and Begossi (1996) suggests using them in this manner to look at ethnobotanical knowledge. The method is limited in that it only allows for the analysis of local biological resources inventories, but it does not allow the analysis of other types of knowledge that are less easily quantified (e.g., relations between different species).

As is true with methods of data collection, few studies have addressed the reliability of results obtained by analyzing data in different ways.

FUTURE DIRECTIONS

In this section we offer four suggestions that might bring researchers closer to the development of a common metric to measure individual-level variations in ethnobotanical knowledge.

First, researchers should explore regions of the world (e.g., Europe) and types of populations (e.g., pastoralists) that have been less studied in previous research on individual variation of ethnobotanical knowledge. This type of research would benefit the general pool of distribution of ethnobotanical knowledge because those populations might show different patterns of distribution of ethnobotanical knowledge that can provide new insight in cross-cultural research. For example, researchers could study with formal methods the variation in distribution of ethnobotanical knowledge of farmers living in rural areas of developing countries. Previous research has shown that farmers can adopt modern, high-yielding agricultural techniques while maintaining local management practices (Bellon and Brush 1994). The study of individual-level variation in farmers' ethnobotanical knowledge might help

understand how modern and traditional practices can be merged. Similarly, research suggests that people who take up new occupations related to the environment might acquire new information (Guest 2002), which might help us understand how ethnobotanical knowledge is generated.

Second, future research should validate the consistency of quantitative measures of individual ethnobotanical knowledge previously used. A way of doing so is to collect individual measures of ethnobotanical knowledge twice from the same sample of subjects and evaluate within-subjects consistency of data for each method.

Third, future research should analyze the reliability of data generated by the different methods of data collection developed so far. Methods previously used to generate measures of individual ethnobotanical knowledge have rarely been tested for reliability, so we lack of a correspondence between data produced for each method. Exploring within-subject correlation of different measures would allow researchers to assess whether the measures are reliable, and which measures assess the same dimensions of knowledge.

Last, future research should also test hypotheses about the different dimensions that compose ethnobotanical knowledge. As we have seen, ethnobotanical knowledge encompasses various dimensions that might or not overlap with each other, such as (a) culturally defined theoretical ethnobotanical knowledge (e.g., naming local plants); (b) culturally defined theoretical ethnobotanical knowledge of interactions between plants and the environment (e.g., knowing which plant marks the beginning of the rainy season); (c) theoretical botanical knowledge (e.g., flowering period); (d) active or practical knowledge of plants and the environment (e.g., ability to identify plant species); and (e) culturally defined practical knowledge of uses of plants (e.g., knowing how to prepare a medicine from a plant). Future research should address the relationship between the various dimensions of ethnobotanical knowledge and their contribution to variance in levels of ethnobotanical knowledge. Researchers should also start considering how to measure individuals' beliefs that might be related to ethnobotanical knowledge.

Pursuing the lines of research suggested here should help to develop a multidimensional scale for measuring individual ethnobotanical knowledge. Advances in other fields or research, such as psychology, suggest that single dimension scales of complex phenomena have poor reliability (Power et al. 1999). To devise a measure of individual ethnobotanical knowledge that is both reliable and valid, a broad range of potentially independent domains covering all of the important aspects of ethnobotanical knowledge is necessary. Therefore, a comprehensive measure of ethnobotanical knowledge should include all the non-overlapping dimensions.

CONCLUSION

In sum, the last two decades have seen an increase in the number of studies measuring individual levels of ethnobotanical knowledge. Those studies differ in the concepts and the methods they have used to collect and analyze information. As is the case in other interdisciplinary research (Poteete and Ostrom 2004), the

lack of conceptual consistency and comparable data limit the inferences that can be drawn from empirical analyses of individual ethnobotanical knowledge, because they hinder comparability across studies. Case studies are extremely valuable, but without comparisons, it is likely that many conclusions from case studies are relevant primarily for the sample under consideration. In this paper we have tried to alert researchers about topics to keep in mind to enhance the accuracy, replicability, and comparability of their studies. If done well, individual level studies of ethnobotanical knowledge have the potential to contribute to a systematic understanding of humanity's most widespread and ancient form of knowledge.

NOTE

[1] In this article we have focused on studies that measure ethnobotanical knowledge of lay people, not on specialists (e.g., shamans, healers, etc.), since specialists tend to be limited in numbers within any given community.

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