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Importance Indices in Ethnobotany

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Research Methods

Abstract

Measuring the "importance" of plants and vegetation to people is a central concern in quantitative ethnobotany. A common tool to quantify otherwise qualitative data in the biological and social sciences is an index. Relative cultural importance (RCI) indices such as the "use values" developed by Prance *et al*. (1987) and Phillips and Gentry (1993a, 1993b) are applied in ethnobotany to calculate a value per folk or biological plant taxon. These approaches can provide data amenable to hypothesis-testing, statistical validation, and comparative analysis. The use of RCI indices is a growing trend in ethnobotanical research, yet there have been few attempts to compile or standardize divergent methods. In this review, we compare RCI indices in four broad categories and present a step-by-step guide to some specific methods. Important background topics are addressed, including ethnographic methods, use categorization, sampling, and statistical analysis. We are concerned here only with "value" as a non-monetary concept. The aspiring and veteran researcher alike should find this paper a useful guide to the development and application of RCI indices.

Introduction

The scientific rigor of ethnobotanical research has increased dramatically in the past two decades due to the adoption of quantitative methods (Phillips 1996). By and large, ethnobotanists have recognized and responded to the need for research based upon hallmarks of the scientific method, including testable hypotheses, reproducible methods, and statistical measures of variation. A primary challenge in this quantitative trend is how to produce values that are reliable and comparable measures of less tangible qualitative data. Borrowing from the social sciences and ecology, considerable advances have been made through the development and application of relative cultural importance (RCI)[1] indices that produce numerical scales or values per plant taxon (Alexiades & Sheldon 1996, Kvist *et al*. 1995, Lykke *et al*. 2004, Martin 2004, Phillips & Gentry 1993a, 1993b, Phillips *et al*. 1994, Phillips 1996, Prance *et al*. 1987, Reyes-García *et al*. 2006a, Turner 1988).

The application of RCI indices in ethnobotany began during the late 1980s. Boom (1990) determined the percentage of plants used by Panare indigenous informants within a 1 hectare forest plot in Venezuela. His research was an important starting point for quantitative inter-cultural comparisons of plant knowledge. Recognizing that not all uses are equal, Prance *et al*. (1987), applied weighted indices of 1.0 for "important" uses and 0.5 for "minor" uses. This approach was aimed at capturing relative degrees of "importance", but did not address informant variation. Gentry and Phillip's (1993a, 1993b) publication on RCI "use values" was a watershed event in quantitative ethnobotany. These last authors evaluated variation among informants based upon use-citation frequencies, considering each as a statistical "event."

Since the methods of Prance *et al*. (1987) and Phillips and Gentry (1993a, 1993b) were introduced, the number

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and type of RCI applications and formulas have steadily increased (Byg & Balslev 2001, Chazdon 1999, Gómez-Beloz 2002, Heinrich *et al*. 1998, Kremen *et al*. 1998, Kristensen & Balslev 2003, Kvist *et al*. 1995, Lykke *et al*. 2004, Quinlan *et al*. 2002, Reyes-García *et al*. 2006b, Rossato *et al*. 1999, Silva *et al*. 2006). With diverse applications and keen interest among researchers, RCI indices are set to remain as key research tools in ethnobotany. Therefore, we believe it essential that ethnobotanists are well-informed about RCI methodologies and strive to develop or maintain competency in their application.

Researchers interested in RCI indices are presently confronted by a disorderly array of RCI models in the literature. The most recent comprehensive review of RCI indices was published more than ten years ago (Phillips 1996). With the aim of mitigating this situation, we compile and compare RCI indices within four broad categories and present a step-by-step guide to some specific methods. Important background issues are discussed, including ethnographic methods, use categorization, sampling, and statistical analysis. Our overall goal is to assist researchers in comparing RCI indices and choosing (or developing) the most effective methods for specific questions and field research situations[2].

This article is submitted in response to calls by the editor of this publication for clear explanations of current methods in ethnobotany to be made available to a larger audience (McClatchey 2006). We also explore competency levels for use of this method as recommended by Bridges and Lau (2006).

Methods

On October 20, 2006, we conducted a search using Google Scholar (Google 2006) with the search terms "Ethnobotany" and "Use Value". The search returned 125 results. Our literature review was limited to articles that address RCI indices on a per-taxon basis (folk or biological). We disregarded results that only casually mention use values (or any of the other RCI indices) or that referred to the monetary valuation of extracted resources. We included additional articles that were cited by authors in our search results that were clearly relevant to our discussion of RCI indices. For each reviewed paper we recorded the purpose of the study, the hypothesis being tested, the form of the RCI index applied, ethnographic methods employed, and the sample size of informants. The remainder of this article is a discussion and analysis of the various index methods found in the search results.

Results

We recorded 12 specific RCI methods and classified these into 4 major categories following Phillips (1996) and Kvist *et al*. (1995). Among the 12 methods, we did not provide all RCI formula variants; these can be found in the referenced literature. Informant sample sizes ranged from 1 to 174 informants. RCI index methods were applied to a wide range of research questions and data analyses. Formulas for the broad RCI-categories noted in the literature search are presented in Table 5 and an overview of their relative merits is presented in Table 2. A step-by-step description of the application of the "use value", a popular RCI index developed by Phillips and Gentry (1993a), is presented in the appendix.

Discussion

Relative Cultural Importance (RCI) indices are quantitative measures designed to transform the complex, multidimensional concept of "importance" into standardized and comparable numerical scales or values. Per-taxon plant use citation data from ethnographic plant interviews is applied to RCI formulas (Table 5) to derive values. The number of people interviewed can range from one to hundreds, depending upon the research design and the logistical and cultural limitations of fieldwork. Before comparing the various RCI indices by category, we discuss some pertinent RCI topics here, including ethnography, use-categories, sampling, and statistical methods and tests.

Ethnographic Data

The numbers and statistics used in quantitative ethnobotany may look impressive, but are meaningless if not based upon reliable ethnographic data. A variety of ethnographic methods, mostly from the social sciences, have been used effectively to collect data amenable to RCI analyses (Bernard 2002, Martin 2004). More than one method is often necessary to address research questions and environments.

An essential activity associated with ethnobotanical interviews is collection of plant voucher specimens. Vernacular names and biological species names differ and local names change over time. Scientific names also change due to taxonomic revision. The use of herbarium specimens ensures that future researchers and others can verify results and make useful comparisons (Alexiades 1996).

Practical ethnographic methods are presented here with statistical issues covered in the sample size and statistical analysis sections below.

- <u>Interview documentation</u>. It is critical that each interview, questionnaire or other such "event" is recorded in a systematic way. Pre-prepared data sheets, robust field books, and PDAs or laptops are standard interview equipment. A small notebook and a digital voice recorder (with permission from the research participants) are also useful tools.

- Open and semi-structured interviews are guided by an outline of questions or hypotheses, but the researcher remains open to unforeseen avenues of informative discourse. This may be facilitated by house interviews with plant specimens and plant artifacts or a "walk-in-the-woods" (Phillips & Gentry 1993a). The minimum data required in plant use interviews involves three deceptively simple questions: "Do you know this plant?", "Do you know a name for this plant (and if so, what is it)?" and "Do you use this plant (and if so, how do you use it)?."

- Freelisting is a method that documents all (or many) of the plants or uses that a research participant can cite at a given time (Quinlan 2002).

- Participant observation and direct observation are additional methods for reducing researcher subjectivity and intrusiveness, establishing rapport, and matching the statements of research participants with their actions (Kremen *et al*. 1998, Prance *et al*. 1987, Reyes-García *et al*. 2006a).

- Surveys, questionnaires, and checklists allow only limited responses about plant uses, often using a fixed list of local plant names developed from preliminary research. These techniques are often applied when time in the field is limited (Gómez-Beloz 2002).

- Additional analytical methods include pile-sorting, preference ranking, and triadic and paired comparisons (Bernard 2002, Martin 2004). Structured methods are more amenable to statistical analysis than open-ended approaches.

- Interview prompts. To ensure that the interviewee and interviewer are talking about the same organism and to jog interviewee memory, it is useful to provide live plants, voucher specimens, pictures, or cards in interviews.

Use categories

Many RCI indices pool the specific uses cited by informants into "use-categories" (Gausset 2004). The number of categories and sub-categories is potentially endless, but common broad titles include: "construction", "food", "medicine", "technology", "firewood" and "other". Standardized categorization facilitates compilation, comparison and efficient presentation of data sets. Plants are frequently cited for uses that differ only slightly (e.g. wood for house beams and wood for posts). Such plants would receive exaggerated "outlier" RCI scores if data were not broken down into use-categories.

An inherent danger of researcher-defined use-categories (Prance *et al*. 1987) is that subjective "hair-splitting" may be required. Gausset (2004) provides an informative example of the complexity of data categorization. Suppose that a tree is cited as useful for both economic income and for honey collection. If honey were found to be an important source of income in a given community, the two cited uses would lack independence. The choice to merge or separate the uses in categories subjectively raises or lowers an RCI index.

In recent years, informant-defined "folk" use-categories (and value scales) are presented more often (McClatchey *et al*. 2006). Informant-defined categories provide another dimension to the data and improve reproducibility by reducing researcher bias. However, the idiosyncratic nature of folk categories reduces options for comparison with other studies. A solution would be to include and compare results with both researcher- and informant-defined categories.

RCI Sample Size

Informant sample size in much ethnobotanical work appears to be either subjective or based loosely upon limitations of field time. A basic rule-of-thumb is that greater than 35 independent, random samples are required if robust, parametric statistics are to be applied.

Some ethnobotanists have experimented with quantitative ecological methods to determine the appropriate sample size (Balick 1996, Balslev 2003, Lozada *et al*. 2006). Accumulation curves (a.k.a. collector's curves) and richness estimators are used to describe the total sampling effort (species found per unit of sampling effort) and to estimate expected species richness if sampling were to continue indefinitely (Colwell 2005). A suite of estimation formulas are available to extrapolate the total number of species given a number of samples (Colwell 2005).

Balick (1996) addressed the question of sample size systematically by applying the concept of accumulation curves. His "multiple-use" curves compared the cumulative number of uses identified by informants to interview frequency. Balick found that the cumulative number of uses for the tree species, *Vitex gaumeri* Greenm., reached asymptote after only 16 interviews. However, for another species, *Bursera simaruba* (L.) Sarg., 141 interviews were insufficient to reach asymptote. Kristensen and Balslev (2003) applied species richness estimators for plants used by the Gourounsi of Burkina Faso. After thirty interviews, 61%-81% of useful species in five use-categories had been identified.

Estimation tools could be used by ethnobotanists to determine if informant sample size is sufficient (Balick 1996, Lozada *et al*. 2006), to predict the total number of useful species based upon interview samples, and to estimate the total number of distinct uses for each species. Improvement in ethnobotanical estimation methods would facilitate greater comparability between studies such as may be accomplished with free software like EstimateS (Chao & Shen 2003, Colwell 2005). Additional work is needed to understand how closely ethnobotanical knowledge might conform to the assumptions of these models.

Statistical Analysis

A statistical approach to generalist knowledge in a study community requires random (not haphazard or opportunistic) selection of participants and sufficient sample size (Martin 2004, Romney 1999). Participants should be interviewed in isolation from others in the community to satisfy the requirement of statistical independence. In other cases, specialized knowledge of a few "key informants" (Martin 2004) or elders is sought and low sample size will likely preclude robust statistical analysis. In general, research conditions are sub-optimal (bearing little resemblance to assumptions of research proposals) and trade-offs usually must be made between statistically robust data and what is logistically or culturally feasible.

Once interviews have been completed and RCI indices have been calculated, data with sufficient sampling will be amenable to statistical analysis and the testing of hypotheses. Species are often ranked by RCI values and any two species can be compared for significant differences (Phillips & Gentry 1993a). RCI values can also be used to compare and test hypotheses concerning the "importance" of vegetation zones, plant families, or growth forms (Albuquerque *et al*. 2005, Chazdon 1999, Hammer & Harper 2006, Kvist *et al*. 1995, Johnston 1998, Phillips *et al*. 1994).

Statistics are sometimes applied to RCI data to reveal predictive relationships between plant characteristics and how they are used (Hoft *et al*. 1999). Phillips and Gentry (1993b) examined the factors of plant frequency, density, stem diameter, growth rate and growth form with regression and analysis of variance (ANOVA). They found significant, predictable use-value patterns for all tested plant characters. These authors also introduced the Family Use Value (FUV) to distinguish plant families that have more uses than would be expected by random chance.

Multivariate techniques such as principle components analysis (PCA) and discriminate function analysis are used to determine complex relationships among variables. Lykke *et al*. (2004) and Hoft *et al*. (1999) applied PCA analysis to find links between specific demographic groups and use-value trends. Similarly, Nolan and Robbins (1999) used multiple correlation and regression analysis to look for relationships between useful plant frequencies and socioeconomic factors. They found a strong positive relationship between the number of medicinal plant citations and residence distance away from urban centers in the Ozarks.

Free internet software is available for a wide variety of statistical tests. PAST (Hammer & Harper 2006) is a fairly comprehensive suite of statistical tools. Metasig (Estabrook 2003) tests the null hypothesis that patterns of plant use can be explained by random processes.

RCI indices by category

In this analysis, we use terminology adopted by Phillips (1996) to describe various RCI indices. Phillips defined three broad method categories including: "uses totaled", "subjective allocation" and "informant consensus". Kvist *et al*. (1995) gave different names to the same categories, including "researcher-tally", "researcher-score" and "informant-tally", respectively. Kvist *et al*. used "tally" for methods that indiscriminately count every use cited, and "score" for methods that sort uses into pre-determined hierarchical categories. "Informant score" is a fourth tally method that refers to consensus based RCI values using entirely informant-generated scores.

1. Uses Totaled/Researcher Tally (Boom 1990, Paz Y Mino *et al*. 1995)

The uses totaled methods are among the earliest in quantitative ethnobotany. Citations of use (and non-use) are recorded for all plant species within a limited area or encountered during general plant walks and interviews with community informants. The uses are recorded and may be assigned to use-categories. The number of uses are summed and ranked (Table 1a). To remove the bias associated with many similar uses for a taxon (i.e. a plant used in construction of two types of structure) the index may be "category-limited". In this case (Table 1b), a score of 1 is entered for each use-category with at least one cited use, but the total number of specific uses is ignored.

The uses totaled method does not distinguish relative degrees of importance for different uses; the most "important" taxon is simply that with the most use-citations. The percent of useful plants and a breakdown of plant uses within specific use categories are provided. Because the method requires the least amount of data collection (a list of species and associated uses), less field time is required than with other methods. In fact, the uses totaled method could be based only upon literature review.

In terms of statistical relevance and hypothesis testing, the uses totaled method is the least effective. It lacks an explicit method and "importance" scores are sensitive to sampling intensity. Intra-cultural variability cannot be assessed because data is not recorded per-respondent or informant. Furthermore, this method ignores the dynamics of cultural importance, such as distinctions between current and historical use, frequency of use, and relative degrees (rankings) of importance.

Table 1. Example of "Uses Totaled" RCI methodology. Uses recorded in 4 categories for species 1 through 4, with a) all specific uses recorded and b) only binary data on categories recorded (multiple specific uses within the same category ignored).

a) Uses Totaled (Researcher-Tally) Specific Uses					
	Construction	Food	Medicine	Other	Total
Species 1	0	4	6	4	14
Species 2	0	0	3	4	7
Species 3	6	0	3	0	9
Species 4	0	0	2	0	2
b) Uses Totaled (Researcher-Tally) Category Limited					
	Construction	Food	Medicine	Other	Total
Species 1	0	1	1	1	3
Species 2	0	0	1	1	2
Species 3	1	0	1	1	2
Species 4	0	0	1	0	1

2. Subjective Allocation/Researcher Score (Pinẽdo-Vasquez *et al*. 1990, Prance *et al*. 1987, Stoffle *et al*. 1990, Turner 1988)

This group of methods adds the allocation of a score or rank to the same set of data that would be obtained by the "uses totaled" method. The researcher distinguishes between major and minor uses by assigning a weighted score in each use category for each taxon (Table 2), ideally based upon substantial knowledge and experience. Using a similar approach to Boom (1990), Prance *et al*. (1987) determined the percent of useful plants per hectare within pre-established use categories for different cultural groups in Amazonia. His group assigned weighted values of 0.5 for a minor use and 1 for a major use. Anderson (2001) modified this approach by incorporating informant perspectives on weighted use-values.

The Cultural Significance Index (CSI), an anthropological approach presented by Turner (1988) and modified by Stoffle *et al*. (1990) and Silva *et al*. (2006), calculates importance through researcher-determined weighted ranking of multiple factors (See Table 5). Turner assigned scores on a five-point scale to the variables of quality and intensity of use, and assigned a score of 2, 1, or 0.5 for the exclusivity or preference of use. To reduce the subjectivity of this approach, Silva *et al*. (2006) revised the CSI with a two-point scale for the variables of species management (2=managed, 1= not managed), preferred (2= preferred for a given use, 1= not the preferred species for a given use) and use frequency (2=species effectively used for a given use, 1=species rarely cited for a given use). They also incorporated a consensus method called a correction factor to reduce the sensitivity of this method to sampling intensity (Table 3). The ethnographic, qualitative approach of the CSI method requires considerable experience and rapport with a cultural group for meaningful results.

Subjective allocation methods can save time in the field and provide a more refined dataset than the "uses totaled" method. However, these methods introduce researcher bias because degrees of importance and categories are based solely upon researcher assessment. Furthermore, as with other methods in this category, informant responses are not independently recorded, thus eliminating the opportunity for analysis of informant variability.

3. Informant Consensus/Informant Tally (Phillips & Gentry 1993a, 1993b)

Phillips and Gentry's use value method (1993a) was inspired initially by the work of researchers (see Adu-Tutu *et*

Table 2. Example of "Subjective Allocation" RCI methodology. Similar to Table 1b above except that the researcher has generated a score (1 for a major use and 0.5 for a minor use) for each species within each category of use.

Use-Value (Subjective Allocation)					
	Construction	Food	Medicine	Other	Total
Species 1	0	0.5	1	0.5	2
Species 2	0	0	0.5	0.5	1
Species 3	1	0	1	0	2
Species 4	0	0	1	0	1

Table 3. Example of "Cultural Significance Index (CSI)" RCI methodology (as revised by Silva *et al*. 2006). The researcher begins by collecting interview data on each taxon and assigning weights to variables (i, e, c) for specific uses (SU) (see text). A correction factor (CF), the number of informant citations for a given taxon divided by the number of informant citations for the most cited taxon, is multiplied by the sum of (i*e*c) for each specific use to arrive at the CSI value.

Cultural Significance Index (as revised by Silva *et al*., 2006)								
	# informant citations		SU 1	SU 2	SU 3	Sum (i*e*c)	CF	CSI
Species 1	2	Management (i)	1	1	1			
		Preference (e)	1	2	1			
		Frequency (c)	1	2	2			
		(i*e*c)	1	4	2	7	0.4	2.8
Species 2	4	Management (i)	2	2	2			
		Preference (e)	2	2	1			
		Frequency (c)	2	2	2			
		(i*e*c)	8	8	4	20	0.8	16
Species 3	1	Management (i)	2	2	2			
		Preference (e)	2	2	2			
		Frequency (c)	1	1	2			
		(i*e*c)	4	2	8	14	0.2	3.4
Species 4	5	Management (i)	1	1				
		Preference (e)	1	2				
		Frequency (c)	2	2				
		(i*e*c)	2	4		6	1	6

al. 1979, Friedman *et al*. 1986, Johns *et al*. 1990, Trotter & Logan 1986) interested in consensus as a bias-reducing method in ethnobotany (Phillips 1996). Informant consensus methods require substantially more data to be collected than those previously discussed. Each plant citation is recorded separately and referred to as an "event" and the same plant and same informant may participate in many "events". Initial data collection is simply a count and use citations are not ranked. The use citations are summed for each informant and divided by the total number of "events". The final species use values are calculated as the sum of the species use values for each informant divided by the total number of informants interviewed about a given species (See Table 5 and the Appendix).

The informant consensus method has had more influence over the past 13 years than any other RCI index. Many researchers have applied or adapted the Phillips and Gentry approach (see Ankli *et al*. 1999, Byg & Balslev 2001, Gazzaneo *et al*. 2005, Gómez-Beloz 2002, Heinrich *et al*. 1998, Kremen *et al*. 1998, Kvist *et al*. 1995, Lykke *et al*. 2004, Reyes-García *et al*. 2005, Rossato *et al*. 1999, La Torre-Cuadros & Islebe 2003, Young 2005) (See Tables 5 and 6). However some limitations of the use value method have been noted:

- It does not distinguish degrees of importance and analyzes only the average number of cited uses. Thus, a rarely used plant with two cited uses would be more "important" than a very popular plant with only one use (Kvist *et al*. 1995).
- An open-ended tally (no maximum) artificially inflates use values for plants with multiple single-category uses (Kvist *et al*. 1995).
- It does not distinguish between cited and observed uses.
- "The results say more about the structure of people's knowledge than they do about the importance of plants *per se*." (Wong 2000)

Other consensus methods include:

1. The Fidelity Level, (Friedman *et al*. 1986) that calculates a ratio between the number of informants who cite

Table 4. Example of “Informant Consensus” RCI methodology. This table shows the results of interviews with 2 informants concerning 4 plant species. Each informant was interviewed twice (Events 1 & 2). Each specific use is tallied, although specific uses may be grouped in use categories. For each species, the total uses cited by an informant is summed and divided by the number of events to arrive at the UVis (use value of the species for a single informant). The average of all the UVis for a species is the UVs (total use value of the species for all informants). See the Appendix for a step-by-step example of this method.

Use Value (Phillips & Gentry 1993)											
	Informant 1					Informant 2					UV_s
	Constr.	Food	Med.	Other	Total	Constr.	Food	Med.	Other	Total	
Species 1											
Event 1	0	2	6	2	10	0	2	3	3	8	
Event 2	0	2	0	0	2	0	2	3	2	7	
UV_{is}	0	2	3	1	6	0	2	3	2.5	7.5	6.75
Species 2											
Event 1	0	0	0	0	0	0	0	3	3	6	
Event 2	0	0	0	0	0	0	0	2	2	4	
UV_{is}	0	0	0	0	0	0	0	2.5	2.5	5	2.5
Species 3											
Event 1	4	0	3	0	7	0	0	0	0	0	
Event 2	3	0	0	0	3	0	0	0	0	0	
UV_{is}	3.5	0	1.5	0	5	0	0	0	0	0	2.5
Species 4											
Event 1	0	0	2	0	2	0	0	0	0	0	
Event 2	0	0	2	0	2	0	0	0	0	0	
UV_{is}	0	0	2	0	2	0	0	0	0	0	1

the use of a species for the same major purpose and the total number of informants who mentioned any use for the species.

2. The Overall Use Value (Gomez-Beloz 2002) that considers the number of plant parts used from each species.

3. The Salience Value (Quinlan *et al*. 2002) that infers importance based on the order and frequency that a species is mentioned by informants in freelisting exercises.

4. Cultural, Practical, and Economic Value (Reyes-García *et al*. 2006) that uses consensus methods to distinguish between actual and potential or past uses and also takes economic valuation into consideration. The overall score is a composite value.

Each of the above methods attempts to capture importance in a different way, but share the assumption that citation frequency is an indicator of importance. It is important to remember that actual uses and cited uses are unlikely to yield the same importance value. Actual use can be influenced by seasonality, resource scarcity, age, sex, traditions, management practices, knowledge loss, and cultural degradation. In the author’s experience, many informants freely mix use citations from the present and past, the obscure and popular, and from personal knowledge and hearsay. Consensus methods do not directly capture plant perceptions or preferences, and, with the exception of the Cultural, Practical, and Economic Value method, they do not distinguish between actual and potential uses.

4. Informant Consensus/Informant Score

Since the earliest efforts at quantitative ethnobotany, researchers have acknowledged that cultural informants are best able to determine relative cultural importance. According to Turner (1988), “Ideally, evaluations of cultural significance should be done by native peoples themselves living within a traditional culture.” Four methods that emphasize the judgment of informants rather than researchers in classifying the importance of uses are given below.

1) The Informant Score Method (Kvist *et al*. 1995, Lykke *et al*. 2004) is similar to the Use values of Phillips and Gentry but with an informant generated score similar to the score assigned by Prance *et al*. (1987).

2) The Choice Value Method (Kremen *et al*. 1998) considers cohorts of substitute products to measure relative preference for specific uses.

3) The Importance Value (Byg & Balslev 2001) measures the proportion of informants who regard a species as most important.

4) Rapid Informant Rank (Lawrence *et al*. 2005) asks informants to list and rank the 10 most important species harvested from the forest over the past 10 years.

Formulas of all the methods discussed are presented in Table 5 and a comparison of applications is provided in Table 6.

Table 5. Formulas for calculating Relative Cultural Importance (RCI) indices.

Relative Cultural Importance (RCI) index		
Data Source	**Formula**	**Calculation/Explanation**
1) Uses Totaled (Researcher-Tally)		
	$= \sum Uses_{Species\ (i)}$	A simple sum of all known uses for each species. The uses can be categorized by utility, plant taxon or vegetation type.
2) Subjective Allocation (Researcher-Score)		
Use Value (Prance *et al*. 1987)	$UV_S = \sum_{i}^{n} Value_{UseCategory(i)}$	The species Use Value is a sum of the researcher-generated scores for each of its uses. "Major" uses are scored 1 while "minor" uses are scored 0.5. Uses refer to use-categories (such as construction or food), not specific uses.
Index of Cultural Significance (Turner 1988)	$ICS = \sum_{i=1}^{n} (q * i * e)$	For each species, scores for all uses cited (from 1 to n uses) are added together. The score for each use is determined from the multiplied scores derived from three ordinal scales of significance. q = quality of use [critical resource (5) to little noticed (0)]. i = intensity of use [high (5), low (0)]. e = exclusivity of use: [substitutions available?, (2)-(1)-(0.5)]
Ethnic Index of Cultural Significance (Lajones & Lemas 2001, Stoffle 1990)	$EICS = \sum_{i=1}^{n} (p / u * i * e * c)$	Modified from Turner (1988) to be less subjective. Calculated as the sum of the total number of uses and/or plant parts used for a specific purpose (p/u) multiplied by: i = intensity of use [same as Turner 1988) e = exclusivity of use [preferred by at least one informant (2), not mentioned as preferred (1)]. c = contemporary usage [contemporary (2) or not (1)]
Cultural Significance Index (Silva *et al*. 2006)	$CSI = \sum_{i=1}^{n} (i * e * c) * CF$	Designed to combine elements from former indices with consensus methodology and binary use classes to reduce subjectivity. i = species mgmt [non-managed (1) or managed (2)] e = Use Preference [not preferred (1) or preferred (2)] c = Use Frequency [rarely used (1) or used frequently (2)] CF = Correction factor [number of citations for a given species divided by the number of citations for the most-mentioned species].
3) Informant Consensus (Informant Tally)		
Corrected Fidelity Level (Rank Order Priority) (Friedman 1986)	$FL = I_p / I_u * 100\%$ $ROP = FL * RPL$	The FL quantifies the importance of a species for a given purpose. Ip = number of informants who cited the species for the particular use. Iu = Total number of informants that mentioned the plant for any use. RPL or Relative Popularity Level is a number between 0-1.

Use Values (Phillips & Gentry 1993a) (See Table 6 and Appendix)		
Species Use-Value for one informant	$UV_{is} = (\sum U_{is})/(n_{is})$	U_{is} = number of uses mentioned for species s by informant i and n_{is} = the number of 'events' in which informant i cites a use for species s. Tally the number of plant uses mentioned for a given species (all uses equal) and divide by the number of 'events' (all use citations over time of the study for a species by one informant).
Species Use Value (For one species across all informants)	$UV_s = (\sum UV_{is})/(n_i)$	n_i = total number of informants interviewed for species s. Sum the informant use values for a species and divide by the total number of informants
Family Use Value	$FUV = \sum UVs/(n_s)$	n_s = total number of species within a given family Sum the use values for all the species within a given family and divide by n_s.
Relative Use Value	$RUV_i = \sum (UV_{is} / UV_s) / n_i$	n_i = the number of study species with data from two or more other informants. This gives a standardized measure of how many plant uses an informant knows relative to the average knowledge among all informants.
Overall Use Value (and Plant Part Value) (Gómez-Beloz 2003)		
Reported Use Value	$RU = \sum_{i}^{n} Species_i$	The total number of uses reported for each plant. This is the same value as UV_{is} (Phillips *et al.* 1993) except that the number of species citation 'events' per informant is always one (interviews were not repeated).
Reported Use Value (per plant part)	$RU_{PlantPart}$	The number of uses cited for each plant part (e.g. outer bark, inner bark, root, leaf, flower, fruit).
Plant Part Value	$PPV = \sum RU_{(plantpart)} / \sum RU$	The ratio between the total reported uses for each plant part and the total number of reported uses for a given plant.
Specific Reported Use	SU	The number of times a specific use is reported by the informant (used for partitioning the data into use categories).
Intra-specific Use Value	$IUV = \sum SU_{(plantpart)} / RU_{(plantpart)}$	The ratio of the number of specific uses and reported uses for a given plant part.
Overall Use Value	$OUV = PPV * IUV$	Allows for ranking and comparison of uses within a group of plants. May be calculated in various ways.
Cultural Practical and Economic Value (Reyes-García *et al.* 2006)		
Cultural Value Index	$CV_e = Uc_e * Ic_e * \sum IUc_e$	where e = ethnospecies (voucher specimens did not match up with herbarium botanical species so were referred to as ethnospecies) Uc_e = number of uses reported (through free listing) for an ethnospecies divided by the total number of use categories (6). Ic_e = Number of participants who listed a species as useful divided by total number of participants. ΣIUc_e = Number of participants who mentioned each use (category) for the ethnospecies divided by the total number of participants.

Practical Value Index	$PV_e = Up_e * Ip_e * DUp_e$	Up_e = number of uses (out of 6) reported (through scan observations) for an ethnospecies divided by the total number of use categories (6). Ip_e = Number of times an ethnospecies was brought to the household for use divided by the total number of participants in scan observations. DUp_e = an assignment of duration of use for each item brought to the household. In this case "scan observation" methodology was employed to determine the species "practical value". Randomly selected subjects were asked about the plants they brought home within a 24 hour period.
Economic Value Index	$EV_e = Oe_e * Pe_e$	Oe_e = number of times an ethnospecies was brought to a household. Pe_e = Price of the ethnospecies based on market price or time taken to obtain the species multiplied by the average daily wage.
Total Value Index	$V_e = CV_e + PV_e + EV_e$	All three values are summed to determine the composite value of the ethnospecies.
4) Informant Consensus (Informant Score)		
Informant Score Method (Kvist *et al*. 1995)	$IS_s = (\sum IS_{is})/(n_i)$	Informants assess importance of species as a 0.5 (usable but suboptimal), 1 (suitable) or 1.5 (near-optimal) in each of five categories (Table 5). These are summed to get a score in the range 0-7.5, for each event, then the average score of repeated events (IS_{is}) is calculated and the average use-value across all informants.
Choice Value (Kremen *et al*. 1998)	$CV_{species\ 1} = P_{cs} / S_c$	P_{cs} = percent of informants that cited Species 1 for substitution category a divided by S_c which is the total number of species mentioned for the substitution category a by all informants. Choice values are ranked from 0-100 with 100 indicating complete preference and/or fewer alternatives.
Importance Value (Byg & Balslev 2001)	$IV_s = n_{is} / n$	n_{is} = number of informants who consider species s most important, n = total number of informants. Informant score method (rather than consensus): measures the proportion of informants who regard a species as most important. Values range from 0 to 1.
Rapid Informant Rank (Lawrence *et al*. 2005)	$RIR_{Taxon} = \frac{1}{2}(\sum \frac{T_m}{n_m} + \sum \frac{T_f}{n_f})$	Each informant lists in order of importance the 10 most important taxa harvested over the past 10 years. The rank is coverted to a score (i.e. Rank of 1 becomes a score or 10). T_m = The sum of scores given a species by the men. n_m = the number of male respondents. T_f = The sum of scores given a species by the women. n_f = the number of female respondents.

Table 6. Comparison of RCI indexing methods for various criteria. [Notes: 1. Use lists generated by informants. 2. Researcher assigns score. 3. Yes, except for assignment of uses to categories. 4. Yes,if specific uses are further classified. 5. No, only the overall most important species recorded. 6. Yes, only between groups. The per informant value is not calculated. 7. Yes, only between groups. Only the most important species per informant is recorded. 8. Yes, plants are ranked as cohorts of substitution products. 9. Yes, by combining interviews and observations. 10. Species are not scored. 11. Researcher scores 1 for major use and 0.5 for minor use. 12. Researcher scores 1 or 2 for each cited use. 13. Species are not scored by informants. 14. Rank is inferred from citation frequency and position. 15. Informant scores each species as 0, 0.5 or 1.0 for each use. 16. Informant scores “most preferred.” 17. Informant states most important species overall. 18. Informant ranks the top 10 species used.]

Criteria	Uses Total	Subjective Allocation (Researcher Score)		Informant Consensus (Informant Tally)					Informant Consensus (Informant Score)			
	Uses Totaled Research Tally	Use-Value (Prance *et al*. 1987)	Cultural Significance Index (Revised) (Silva *et al*. 2006)	Fidelity Level (Friedman 1986)	Use Value (Phillips & Gentry 1993)	Overall Use Value (Gomez-Beloz 2002)	Salience Value (Quinlan *et al*. 2002)	Cultural, Practical, and Economic Value (Reyes-García *et al*. 2006)	Informant Score Method (Kvist *et al*. 1995)	Choice Value Method (Kremen *et al*. 1998)	Importance Value (Byg & Balslev, 2001)	Rapid Informant Rank (Lawrence *et al*. 2005)
Methods explicit?	NO	NO	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Values objective	YES[1]	NO[2]	NO[2]	YES	YES[3]	YES[3]	YES	YES[3]	YES[3]	YES[3]	YES	YES[3]
Methods sensitive to sampling intensity	YES	YES	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Data values generated	Discrete Ratio Scale	Discrete Ordinal Scale	Continuous	Continuous	Continuous	Continuous	Continuous	Continuous	Continuous	Continuous	Continuous	Continuous
Data collection & analysis time	LOW	LOW	MOD	MOD	HIGH	HIGH	MOD	HIGH	HIGH	MOD	MOD	MOD
Habitat/area statistical analysis possible?	YES	YES	YES	NO	YES	YES	NO	NO	YES	NO	NO	NO
Statitistical analysis of use categories possible?	YES	YES	YES[4]	YES	YES	YES	YES	YES	YES	YES	NO[5]	YES

Criteria	Uses Total	Subjective Allocation (Researcher Score)		Informant Consensus (Informant Tally)					Informant Consensus (Informant Score)			
	Uses Totaled Research Tally	Use-Value (Prance *et al*. 1987)	Cultural Significance Index (Revised) (Silva *et al*. 2006)	Fidelity Level (Friedman 1986)	Use Value (Phillips & Gentry 1993)	Overall Use Value (Gomez-Beloz 2002)	Salience Value (Quinlan *et al*. 2002)	Cultural, Practical, and Economic Value (Reyes-García *et al*. 2006)	Informant Score Method (Kvist *et al*. 1995)	Choice Value Method (Kremen *et al*. 1998)	Importance Value (Byg & Balslev, 2001)	Rapid Informant Rank (Lawrence *et al*. 2005)
Statistical analysis of informants possible?	NO	NO	NO	YES[6]	YES	YES	YES[6]	YES[6]	YES	YES[6]	YES[7]	YES[6]
Considers resource substitution	NO	NO	YES	NO	NO	NO	NO	NO	NO	YES[8]	NO	NO
Distinguishes between actual and potential uses	NO	NO	NO	NO	NO	NO	NO	YES[9]	NO	NO	NO	NO
Use values calculated for specific plant parts?	NO	NO	NO	NO	NO	YES	NO	NO	NO	NO	NO	NO
Considers order and freq. of species citations?	NO	NO	NO	NO	NO	NO	YES	NO	NO	NO	NO	NO
Uses emic-based score to rank useful species?	NO[10]	NO[11]	NO[12]	NO[13]	NO[13]	NO[13]	NO[14]	NO[13]	YES[15]	YES[16]	YES[17]	YES[18]

[Notes: 1. Use lists generated by informants. 2. Researcher assigns score. 3. Yes, except for assignment of uses to categories. 4. Yes,if specific uses are further classified. 5. No, only the overall most important species recorded. 6. Yes, only between groups. The per informant value is not calculated. 7. Yes, only between groups. Only the most important species per informant is recorded. 8. Yes, plants are ranked as cohorts of substitution products. 9. Yes, by combining interviews and observations. 10. Species are not scored. 11. Researcher scores 1 for major use and 0.5 for minor use. 12. Researcher scores 1 or 2 for each cited use. 13. Species are not scored by informants. 14. Rank is inferred from citation frequency and position. 15. Informant scores each species as 0, 0.5 or 1.0 for each use. 16. Informant scores “most preferred.” 17. Informant states most important species overall. 18. Informant ranks the top 10 species used.]

Conclusion

To effectively use RCI indices as a tool in quantitative ethnobotany, researchers should familiarize themselves with basic ethnographic methods and research design, including sample-size considerations and statistical tools. As research hypotheses and proposals are developed, study and practice with RCI indices is essential to determine the methods most appropriate for the questions being considered.

The RCI-proficient researcher can create a complete mock-up of the data to be recorded in spreadsheet or statistical software and is able to routinely check data for sample size considerations. He or she may employ multiple data gathering methods to record different dimensions of data (such as potential and actual use). The researcher with an expert understanding of RCI indices methods may combine or split apart methods employed previously and develop new approaches as appropriate. A good understanding of advanced statistical concepts is required to reach or maintain this level. Ethnobotanists should aim to be at least proficient with RCI indexing methods because of their growing importance in the field of ethnobotany and because the skills developed in the process have widespread applications.

Quantifying a complex, multi-dimensional concept such as “importance” is a formidable task. In this review, we have attempted to sort out and compare the bewildering array of RCI indices that have grown like wildflowers cross-fertilized by the social and biological sciences. As we have shown, even the most “objective” use-value methods are subjective, especially in the assignment of plant use categories. Despite the challenges, RCI indexing methods have significantly improved the precision and scientific validity of ethnobotanical research in less than 15 years. Recent authors have brought fresh perspectives, and it is apparent that RCI indices will continue to be vital in ethnobotanical research and conservation applications.

We believe that the novice and expert researcher alike should find this review useful for learning about the past and recent trends in the development of RCI indices and in the design and analysis of their own research. We recommend that ethnobotanists who choose to use RCI indices carefully select the method that will most appropriately address the hypothesis they are testing.

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Foot Notes

1. In the interest of consistent terminology, we borrow the term “relative cultural importance” (RCI) from Turner (1998) as an all-inclusive term for the indices discussed in this paper. We evaluate only those indices that address relative cultural importance per biological species, morpho-species, or folk taxa.

2. Researchers should be careful that the desire to become more “quantitative” does not lead to uncritical adoption of quantitative methods. Quantification can provide “proof” for validation of essentially qualitative evidence (Platt 1964), but is not an end in itself.

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Appendix 1. Step-by-step description for calculating Phillips and Gentry Use Values - Informant Consensus Method (Presentation adapted from Phillips and Gentry, 1993a)

Step 1 – Collect data on specific uses per plant for individual research participant

Collect raw data from individual research participants (informants) on research species (Linnaean or folk taxa). Tally and total the number of specific uses cited by a given participant for the same species during separate interview 'events'. In Table 2.1, the specific uses cited by research participant number # 1 during 3 events for a forest tree, *Pouteria cuspidata* (A. DC.) Baehni, are shown in the column headings. The research participant cited many more uses during Event 2 than during Event 1 or 3.

Step 2 – Calculate UV_{is} per plant for individual research participant

Using formula 1, calculate UVis values for each plant species, based on the raw data collected in Step 1. The number of times a specific use is mentioned is averaged by the number of events. In Table 2.2 the number of uses cited by participant # 1 for *P. cuspidata* are totaled and divided by three events. The use of P. cuspidata as a fertility medicine is the most consistently cited specific use (3 citations/3 event-days).

Step 3 –Group categorized UV_{is} data for all research participants

Make a summary table that pools results from all research participants for a given species. Table 2.3 shows the *P. cuspidata* UV_{is} for six participants within pre-established general use categories (emic or etic). Values for specific uses grouped in the same general use-class are summed. For example, the UV_{is} for the two different medicinal uses from Table 2.2 (0.333 and 1) are summed and placed under the Med heading in Table 2.3 as 1.333. The two uses of wood, poles and planks, (0.333 and 0.333) in Table 2.2 are summed as 0.667 in Table 2.3 under the Con heading.

Step 4 – Calculate categorized UV_s for all research participants

Using Formula 2, calculate per species UV_s by summing UV_{is} from all research participants and dividing by the total number of research participants. In Table 2.4, P. cuspidata has an overall use value of 2.333 and medicine and edible fruits are the top two important use categories for the species.

Step 5 – Compare categorized UV_s for all study plants

Assemble a table listing all plant species and respective UV_s data for comparative analysis (assuming the number of participants is sufficient for a statistical approach). In Table 2.5, differences between species are clearly indicated for total UV_s and by use class. It is no surprise that the two palm species on the list have the highest use values overall as ethnobotanical importance for palms has been noted in many studies. The vine genus, *Bauhinia*, shows the lowest use value overall, yet is highest among all the species for medicinal purposes. *Pouteria cuspidata* has a moderate use value overall and does not score high for any single use class. The Lauraceae and Lecythidaceae species score higher than other plant species in construction and edibility (Brazil nuts) classes, respectively.

Formula 1: $UV_{is} = (\Sigma U_{is})/(n_{is})$
where U_{is} = number of uses mentioned for species s by research participant i and n_{is} = the number of 'events' in which research participant i cites a use for species s.

Formula 2: $UV_s = (\Sigma_i UV_{is})/(n_s)$
where n_s = total number of participants interviewed for species s.

Table 2.1. Fieldbook data recording the number of specific uses cited by research participant #1 for *Pouteria cuspida* (A. DC.) Baehni during three interview 'events' (an event = all citations on one day for one species).

Research Participant #1 - *Pouteria cuspidata* (A. DC.) Baehni (Sapotaceae)								
Specific Uses	Total	Poles*	Planks*	Edible Fruit*	Botfly Med*	Fertility Med*	Arrow head*	Ritual Lvs*
Event 1	1	0	0	0	0	1	0	0
Event 2	5	1	1	1	1	1	0	1
Event 3	1	0	0	0	0	1	0	0

Table 2.2. Fieldbook data calculating UV$_{is}$ based on research participant #1 citations for *Pouteria cuspida* (A. DC.) Baehni.

Research Participant #1 - *Pouteria cuspidata* (A. DC.) Baehni (Sapotaceae)								
Specific Uses	Total	Poles*	Planks*	Edible Fruit*	Botfly Med*	Fertility Med*	Arrow head*	Ritual Lvs*
Event 1	1	0	0	0	0	1	0	0
Event 2	5	1	1	1	1	1	0	1
Event 3	1	0	0	0	0	1	0	0
Total Uses	7	1	1	1	1	3	0	1
UV$_{is}$	2.333	0.333	0.333	0.333	0.333	1	0	0.333

*Specific Uses: Poles – branches/saplings for house support; Planks – cut wood for building newer-style houses; Edible Fruit – fruit pulp eaten; Botfly Med – sticky, white exudate used to suffocate botfly larvae parasites; Fertility Med – Bark peeled and boiled with other plants to make medicine for increasing fertility in women; Tech – twigs used to make arrow heads; Ritual – leafy branches used in shamanistic ceremonies to invoke spirits.

Table 2.3. *Pouteria cuspidata* (A. DC.) Baehni UV$_{is}$ for all research participants arranged by general use category.

All participants - *Pouteria cuspidata* (Sapotaceae)						
Participants	Total	Con†	Edi†	Med†	Tec†	Rit†
1	2.666	0.667	0.333	1.333	0	0.333
2	4	1	1	1	1	0
3	0.333	0	0.333	0	0	0
4	0	0	0	0	0	0
5	4	1	.667	1.333	1	0
6	3	0	1	1	0	1

Table 2.4. *Pouteria cuspidata* (A. DC.) Baehni UV$_{s}$ for all research participants arranged by general use category.

Pouteria cuspidata (A. DC.) Baehni (Sapotaceae)						
Participants	Total	Con†	Edi†	Med†	Tec†	Rit†
1	2.666	0.667	0.333	1.333	0	0.333
2	4	1	1	1	1	0
3	0.333	0	0.333	0	0	0
4	0	0	0	0	0	0
5	4	1	.667	1.333	1	0
6	3	0	1	1	0	1
Total/# Partic.	13.999/6	2.667/6	3.333/6	4.666/6	2/6	1.333/6
UV$_{s}$	2.333	0.444	0.555	0.777	0.3333	0.222

†Use Classes: Con - house construction; Edi - edible plant parts; Med – medicines; Tec – technology including plants used to make material implements for subsistence livelihoods and plants used in technological processes such as fermentation; Rit – ceremonies, rituals, invocations, or healings that involve magico-spiritual elements not physically evident.

Table 2.5. UV_s by general use category for plant species.

Family	UV_s (n = 6)					
Species	Total	Con†	Edi†	Med†	Tec†	Rit†
Arecaceae						
Euterpe oleracea Mart.	3.333	1	1	0.333	0.667	0.333
Arecaceae						
Maximiliana maripa (Aubl.) Drude	3.667	.667	1.333	0.333	1	0.333
Fabaceae						
Bauhinia sp.	1.677	0	0	1.333	0	0.333
Lauraceae						
Ocotea splendens (Meisn.) Baill.	2.333	1.333	0	0.677	0.333	0
Lecythidaceae						
Bertholletia excelsa Bonpl.	2.677	0	1.677	1	0	0.333
Sapotaceae						
Pouteria cuspidata (A. DC.) Baehni	2.333	0.444	0.555	0.777	0.333	0.222

†Use Classes: Con - house construction; Edi - edible plant parts; Med – medicines; Tec – technology including plants used to make material implements for subsistence livelihoods and plants used in technological processes such as fermentation; Rit – ceremonies, rituals, invocations, or healings that involve magico-spiritual elements not physically evident.