Journal of Classification 19:131-159 (2002)
DOI: 10.1007/s00357-001-0036-8

The Relation between Folk and Scientific Classifications of Plants and Animals

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Abstract: Methods are developed for decomposing agreement between classifications into two components: inclusiveness, or the extent to which groups in one classification strictly include groups in the other; and consistency, or the extent to which one classification subdivides the same groups that the other does. The methods are used to compare folk classifications with scientific classifications of plants and animals. Folk generics, which constitute the most salient taxonomic rank in folk classifications, are about as inclusive as scientific genera and definitely more inclusive than scientific species. Consistency between the classifications is substantial and independent of rank across the ranks of species, genus, and family.

Keywords: Measures of agreement; Taxonomic rank; Ethnobiological classification; Speciation; Signal detection theory.

This research was supported by grants from the UCLA Academic Senate. I thank Phipps Arabie, Joe Felsenstein, Thomas D. Wickens, and two anonymous referees for valuable comments on the manuscript. The folk classifications are available from the UCLA Institute for Social Science Research Data Archive at: www.sscnet.ucla.edu/issr/da/animalsplants.exe.

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1. Introduction

Field biologists working in remote parts of the world have long noted that the local folk classifications of animals and plants are generally consistent with their own scientific classifications of the same organisms (Matthews 1886; Davis and Richards 1934; Wyman and Harris 1941, p. 9; Mayr 1963, p. 17; Diamond 1966). Anthropologists have come to the same conclusion based on their own fieldwork (Conklin 1954, pp. 160-167; Berlin 1973; 1992, Ch. 1.2). The observed consistency between independent taxonomic systems implies that the classifications are not arbitrary cultural artifacts but instead are determined to some extent by biological realities or cognitive universals. Malt (1995) has recently summarized the psychological implications of these results.

More detailed interpretations have focused on particular taxonomic ranks. In biology, the emphasis has been on scientific species, because species are usually defined in terms of biological factors while groups at higher ranks are relegated to human judgment. In particular, the consistency of scientific species with folk classifications has been cited as evidence for theories of speciation that predict well-marked boundaries between species. According to Mayr's (1963, Ch. 16) theory of allopatric speciation, for instance, a species can split into two only when populations become isolated geographically; thus, Mayr suggested that folk classifications will include mostly distinct species because the human inhabitants of a local area are unlikely to encounter both parts of a species that is in the process of splitting. Alternatively, the punctuated equilibrium theory of Eldredge and Gould (1972) holds that new species split relatively rapidly from ancestral species and change little thereafter; thus, Gould (1979) inferred that at any given time such as the present, few species will be in the process of splitting and the rest will be distinct both to scientists and to folk. These theories, like other theories of speciation, do not invoke any biological processes to determine boundaries between genera, families, or groups at higher ranks; consequently, the theories imply that consistency between classifications will be greatest at the rank of scientific species.

The left panel in Figure 1 illustrates the situation predicted by such theories. The figure shows a simplified morphospace whose two dimensions stand for the many dimensions that characterize real organisms and are visible to human classifiers. Each point gives the centroid of a particular population of organisms. Populations in the same species are surrounded by a solid line; species in the same genus are surrounded by a dotted line. In the left panel, species boundaries are obvious because populations in the same species are all much closer together than are populations in different

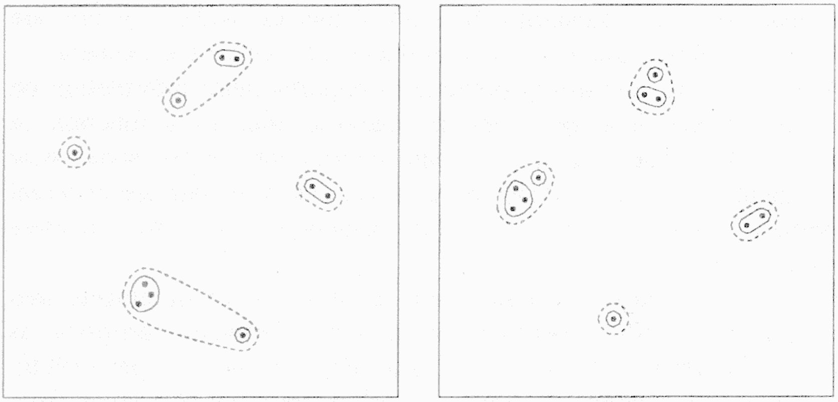

Figure 1. Hypothetical morphospaces with populations (dots) within species (solid lines) and genera (dotted lines), where species are more (left panel) or less (right panel) distinct than genera.

species, reflecting the predicted rarity of intermediate degrees of divergence; but genus boundaries are more arbitrary because distances between species are continuously distributed.

In anthropology, most research has been directed to the folk ranks of life form, generic, and specific. As examples in the American English folk classification of plants, *tree* is a life form, *pine* is a generic, and *white pine* is a specific. In nonindustrial societies, the generic rank is usually the basic level as defined by Rosch, Mervis, Gray, Johnson, and Boyes-Braem (1976). In industrial societies, where most people have little first-hand knowledge of plants and animals, the life form may be the basic level instead (Dougherty 1978), but even U. S. undergraduates prefer to use the generic rank for implicational inferences (Atran 1998). Both Berlin (1992, Ch. 2.3) and Atran (1998) attribute the salience of folk generics to the distinctiveness of the corresponding groups of organisms. There has been some ambiguity about which scientific rank corresponds most closely to the folk generic rank. In his early review of the consistency between folk and scientific classifications, Berlin (1973) suggested that folk generics correspond closely to scientific species; but after additional data became available, he later concluded (Berlin 1992, p. 64) that folk generics correspond most closely to scientific genera. The latest anthropological data therefore suggest that consistency between classifications will be greatest at the rank of scientific genus.

The right panel in Figure 1 illustrates the situation suggested by these data. The right panel is similar to the left except for the distribution of distances between points. In the right panel, genus boundaries are more obvious than species boundaries because distances within genera are continuously distributed and much shorter than distances between genera.

A test of these contrasting predictions requires more information on the relation between folk and scientific classifications as a function of taxonomic rank. The search for such information raises some new methodological problems, however, because the available data are different in important respects from the data generally used to compare classifications.

At any given rank, a classification partitions a set of objects into subsets called taxa. Most measures of agreement between partitions, as reviewed by Hubert and Arabie (1985) and Milligan and Cooper (1986), require counting the number of objects in each intersection of a taxon from one partition with a taxon from the other. In biological classifications, the objects classified are individual organisms or specimens. Studies of folk classifications, however, do not typically report the numbers of organisms or specimens included; and such numbers even when available reflect the inevitable vagaries of observation and collection rather than a statistical sampling plan. Instead, most publications list the folk taxa along with the scientific taxa that intersect them. Such data indicate only whether each intersection is empty or nonempty, which is not enough information for any of the standard measures of agreement.

The natural units of analysis for the available data are taxa rather than individual objects. Taxa in fact serve as units of analysis in a large body of research on consensus classification, reviewed by Rohlf (1982), Day (1986), Wilkinson (1994), and Nixon and Carpenter (1996). Given two or more classifications of the same objects, a consensus classification can be defined to include only those taxa that are consistent in some well-defined sense with all or most of the given classifications. Agreement between the given classifications can then be measured by a consensus index that depends upon the taxa in the consensus classification, relative to a normalization factor that accounts for the size of the classifications. Although most consensus indices depend upon the numbers of objects within taxa, Rohlf (1982) identified a few indices based on unweighted counts of taxa themselves, but even these indices rely on a normalization factor based on the total number of objects. Consensus indices would therefore have to be modified to depend entirely on numbers of taxa rather than numbers of objects, before being used to compare folk and scientific classifications.

Taxa (in particular, folk taxa) also serve as units of analysis in the descriptive statistics typically reported by anthropologists to summarize their data. Rather than calculating a single overall measure of agreement, most

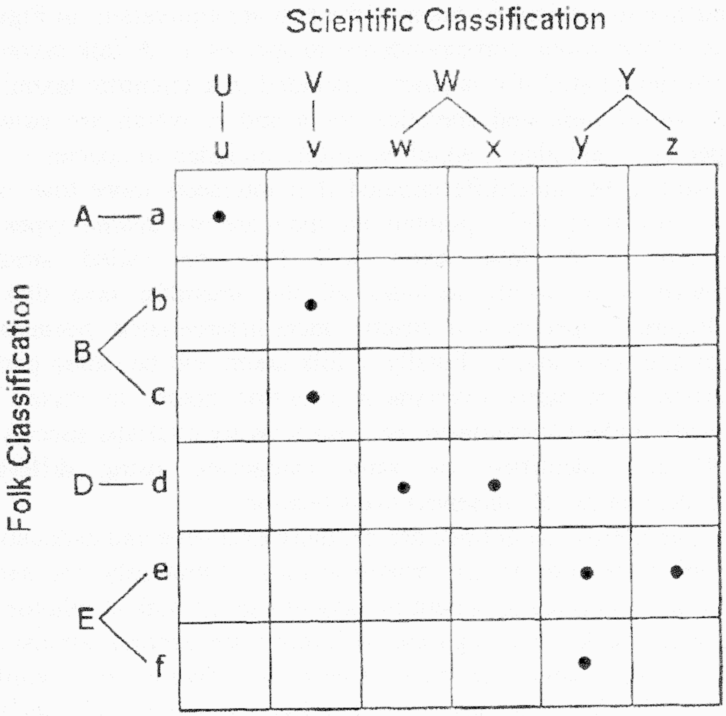

Figure 2. Relation between hypothetical folk and scientific classifications of the same objects. Rows are folk specifics, classified within generics at the left. Columns are scientific species, classified within genera at the top. The intersection of a specific and a species is nonempty if and only if the corresponding cell contains a dot.

anthropologists starting with Berlin (1973) have categorized folk taxa of a given rank according to how they are related to scientific taxa of a given rank. To illustrate the possible relations, Figure 2 depicts hypothetical folk and scientific classifications of the same set of objects. The folk classification contains the four generics *A*, *B*, *D*, and *E*, and the six specifics *a-f*; the scientific classification contains the four genera *U*, *V*, *W*, and *Y*, and the six species *u-z*. Each cell in the grid represents the intersection of a folk specific and a scientific species; the intersection is nonempty if and only if the cell contains a dot. The figure thus represents the information that is typically available in published comparisons of folk and scientific classifications.

Berlin's (1973) terminology is here first stated in general form for folk taxa in relation to scientific taxa, and then illustrated in Figure 2 for folk specifics in relation to scientific species. A folk taxon is said to be in one-to-one correspondence to a scientific taxon if the two are equivalent; in Figure 2, specific *a* is in one-to-one correspondence to species *u*. A folk taxon is said to be overdifferentiated if it is strictly included in a scientific taxon; in Figure 2, the overdifferentiated specifics are *b* and *c*, which are strictly included in species *v*, and also *f*, which is strictly included in species *y*. A folk taxon is said to be underdifferentiated if it intersects more than one scientific taxon. As Hunn (1975) pointed out, there are two distinct types of underdifferentiation. A folk taxon will here be called strictly underdifferentiated if it strictly includes all the scientific taxa that it intersects; in Figure 2, specific *d* is strictly underdifferentiated, because it strictly includes species *w* and *x*. Finally, a folk taxon will be called partly underdifferentiated if it partly overlaps a scientific taxon; in Figure 2, specific *e* is partly underdifferentiated, because it partly overlaps species *y*. Nelson (1979) also identified the same categories, using different terminology, in the context of consensus classification.

The four categories just defined are mutually exclusive and exhaustive for any folk rank in relation to any scientific rank. Obviously, the same categories can also be defined for scientific taxa of a given rank in relation to folk taxa of a given rank. Although the definitions are general, almost all published comparisons categorize folk generics in relation to scientific species. In most folk classifications, more than half the generics are one-to-one, suggesting substantial consistency between folk and scientific classifications. Also, more folk generics are underdifferentiated than overdifferentiated, suggesting that folk generics are more inclusive than scientific species.

Despite their face validity, the usual summary measures are not necessarily the best. Comparisons between numbers of overdifferentiated and underdifferentiated taxa can sometimes produce ambiguous inferences about inclusiveness. Several alternative measures of inclusiveness are discussed below, all of which avoid ambiguity and one of which also leads to convenient statistical tests. The proportion of one-to-one folk taxa depends not only upon consistency but also upon inclusiveness; for instance, the proportion of one-to-one folk generics would probably be increased if folk generics were about as inclusive as scientific species rather than more inclusive. Hunn (1975) addressed this problem by proposing a measure of consistency that counts one-to-one correspondence at any scientific rank rather than specifying a single rank. Berlin (1990) suggested a different approach by considering whether the distinctiveness of taxa is consistent between classifications. The present paper follows Berlin's approach to derive a method that assesses consistency at a particular rank and corrects for differences in inclusiveness.

In short, the present methods allow the partitions induced by taxonomic ranks in different classifications to be compared with respect to two distinct properties: inclusiveness and consistency. With the aid of these methods, folk specifics and generics are compared to scientific species, genera, and families. The available data relating folk to scientific classifications are introduced first; then the method for measuring inclusiveness is described and applied to the data; and finally the method for measuring consistency is described and applied to the same data.

2. Data

An attempt has been made to collect all the published folk biological classifications (including doctoral dissertations) that satisfy the following four conditions. First, the classification includes most of the plants or animals named in a particular culture. Second, scientific names are given for the organisms included in most of the folk taxa. Third, the ranks of folk specific and generic are explicitly distinguished, even if not necessarily given those names, by the authors who compiled the classification. Classifications are not included if taxonomic rank can only be inferred from nomenclature, because nomenclatural rules are known to have exceptions in folk classifications (Berlin 1992, Ch. 3.4). Fourth, synonymous names are distinguished from names of folk taxa that intersect the same scientific taxa but do not refer to the same organisms. Examples of this distinction can be found in the Tzeltal classification of plants. The Tzeltal names *winik te'* and *chamel te'* are interchangeably applied to the same plants, which are classified scientifically as *Garrya laurifolia* (Berlin, Breedlove, and Raven 1974, pp. 169-170); the two synonymous Tzeltal names are therefore counted as a single (one-to-one) generic. The Tzeltal names *bohch*, *tsu*, and *ch'ahko'*, however, refer to different shape varieties of the gourd *Lagenaria siceraria* (Berlin *et al.* 1974, pp. 423-424), and are therefore counted as three distinct (overdifferentiated) generics.

Certain common ambiguities in the data are resolved according to the following conventions. Questioned scientific taxa are always accepted. Folk taxa with no scientific identification are included in the counts of total folk taxa, but not in the analyses relating folk to scientific taxa. Folk taxa with incomplete scientific identification are included only in the analyses involving the scientific ranks to which they are identified. For instance, in the Tzeltal classification of plants, the generic *met chih* is identified as *Agave* sp. (Berlin *et al.* 1974, pp. 419-420); *met chih* is therefore included in the analyses involving genera, families, and orders, but not species. In some descriptions of folk classifications, scientific taxa that are clear or obvious examples of a given folk taxon (the basic, focal, or prototypical range of the taxon) are distinguished from scientific taxa that are merely closer to the given folk taxon than to any other (the extended range); in such cases, only the basic range is included here. For instance, in the Tzeltal classification of plants, the basic range of the generic *'alcash ch'ish* is *Jacquinia aurantiaca* and its extended range also includes *Croton guatemalensis* (Berlin *et al.* 1974, pp. 171, 174); this generic is identified as *Jacquinia aurantiaca* in the present analyses.

Table 1 lists the folk classifications along with their sources and descriptive characteristics. There are 21 classifications of plants and only seven of animals; classifications of both plants of animals are available for six cultures, plants alone for 15, and animals alone for one. Classifications are grouped according to the organisms classified: first plants, then animals. Within each group, classifications are subgrouped according to the mode of subsistence in the culture: first small-scale agriculture or (in the case of the Hong Kong boat people) commercial fishing, then hunting and gathering or (in the case of the Saami) reindeer herding. For convenience, the subgroups are henceforth called agricultural and nonagricultural, respectively. Within each subgroup, classifications are listed in order of the total number of generics contained; this number appears in the next to last column. The last column gives the mean number of specifics per generic; generics not subdivided into specifics are counted as having a single specific although folk classifications do not explicitly distinguish specifics from generics in such cases.

Brown (1985) studied the relation between mode of subsistence and folk taxonomy in a larger sample of cultures, but he had to infer taxonomy from nomenclature in most cases. He found more generics and more specifics per generic in agricultural than in nonagricultural classifications, and he concluded that when societies adopt agriculture, their folk biological classifications become larger and more complex. Berlin (1992, Ch. 2.7) repeated Brown's study in a smaller sample of more completely described classifications, and confirmed Brown's results for classifications of plants but found no clear differences in the small sample of classifications of animals. The classifications in the present sample are about as completely described as those in Berlin's, and the results are the same. Agricultural classifications of plants contain significantly more generics and more specifics per generic than do nonagricultural classifications of plants, $t(19)$ = 3.68 and 3.83, respectively. (A significance criterion of .05 is used in all tests.) No such differences are evident in the classifications of animals, which are too few in number to test statistically whether they differ from classifications of plants in the effect of agriculture.

Table 1.
Folk Classifications

Classification	Reference	FG	FS/FG
Plants, Agricultural Societies			
1. Hanunóo (Philippines)	Conklin (1954)	887	1.84
2. Tobelo (Indonesia)	Taylor (1990)	656	1.45
3. Tzotzil (Mexico)	Breedlove & Laughlin (1993)	649	1.64
4. Tzeltal (Mexico)	Berlin, Breedlove, & Raven (1974)	470	1.36
5. Ka'apor (Brazil)	Balée (1994)	453	1.36
6. K'ekchi' (Mexico)	Wilson (1972)	435	1.37
7. Mixe (Mexico)	Martin (1996)	415	1.70
8. Chinantec (Mexico)	Martin (1996)	386	1.58
9. Ndumba (New Guinea)	Hays (1974)	378	1.79
10. Bunaq (Indonesia)	Friedberg (1990)	339	1.86
11. Quechua (Peru)	Brunel (1975)	280	1.34
12. Navajo (U. S.)	Wyman and Harris (1941)	238	1.25
13. Bellona (Polynesia)	Christiansen (1975)	218	1.73
14. Rangi (Tanzania)	Kesby (1986)	141	1.00
Plants, Nonagricultural Societies			
15. Seri (Mexico)	Felger and Moser (1985)	303	1.39
16. Anindilyakwa (Australia)	Waddy (1988)	196	1.03
17. Bella Coola (Canada)	Turner (1973, 1974)	110	1.00
18. Gitksan (Canada)	Johnson (1999)	91	1.00
19. Witsuwit'en (Canada)	Johnson-Gottesfeld & Hargus (1998)	83	1.05
20. Montagnais (Canada)	Clément (1990)	81	1.25
21. Saami (Norway)	Anderson (1978)	72	1.11
Animals, Agricultural Societies			
22. Tobelo (Indonesia)	Taylor (1990)	418	1.39
23. Tzeltal (Mexico)	Hunn (1977)	335	1.33
24. Rangi (Tanzania)	Kesby (1986)	221	1.05
25. Hong Kong boat people	Anderson (1972)	196	1.64
Animals, Nonagricultural Societies			
26. Anindilyakwa (Australia)	Waddy (1988)	412	1.00
27. Saami (Norway)	Anderson (1978)	160	1.19
28. Montagnais (Canada)	Clément (1995)	131	1.61

Abbreviations: FS, folk specifics; FG, folk generis

3. Inclusiveness

Figure 2 provides an example of the sort of ambiguity that can occur when inclusiveness is inferred from the relative numbers of overdifferentiated and underdifferentiated taxa. Compared to scientific species, three folk specifics (*b*, *c*, and *f*) are overdifferentiated and two (*d* and *e*) are underdifferentiated, suggesting that specifics are less inclusive than species. Compared to specifics, however, three species (*w*, *x*, and *z*) are overdifferentiated and two (*v* and *y*) are underdifferentiated, suggesting that species are less inclusive than specifics. This anomaly is explained by the fact that overdifferentiated taxa tend to subdivide the world more finely than do underdifferentiated taxa, and are therefore likely to be more numerous. The same sort of ambiguity is widespread in real classifications too, occurring in 34 of the 168 comparisons among two folk ranks and three scientific ranks in the 28 classifications in Table 1.

The problem is caused by comparing the numbers of overdifferentiated and underdifferentiated taxa in the same partition (folk or scientific), and can be avoided by instead comparing the numbers of folk and scientific taxa in the same category (overdifferentiated or underdifferentiated). For example, in Figure 2, the overdifferentiated category contains three specifics (*b*, *c*, and *f*) and three species (*w*, *x*, and *z*), while the underdifferentiated category contains two specifics (*d* and *e*) and two species (*v* and *y*). Both comparisons are consistent with the obvious symmetry of the figure, although as alternative indicators of inclusiveness, the two comparisons do not always give precisely the same results in real classifications. The advantage of both comparisons is that they treat the two classifications exactly alike; thus, the results are not biased either way by the definitions of the categories.

A third comparison of the same sort can be based on the category of strictly underdifferentiated taxa. In Figure 2, this category contains one specific (*d*) and one species (*v*), again confirming the symmetry of the figure. This comparison has the additional advantage of leading to statistical tests. Let two partitions be given, one induced by a folk classification at a given rank and the other induced by a scientific classification at a given rank. By definition, each strictly underdifferentiated taxon in one partition corresponds to a set of two or more overdifferentiated taxa in the other. In Figure 2, *d* corresponds to (*w* and *x*), and *v* corresponds to (*b* and *c*). Consequently, each strictly underdifferentiated taxon, along with the corresponding set of overdifferentiated taxa in the other partition, can be treated as an independent sampling unit; under the null hypothesis, random assignment determines which partition contains the strictly underdifferentiated taxon rather than the overdifferentiated taxa. A sign test can therefore be used to determine whether one partition is significantly more or less inclusive than the other. The proportion of the strictly underdifferentiated taxa in both partitions that are members of particular partition can be used to measure the inclusiveness of that partition relative to the other. In Figure 2, this proportion is obviously 0.5 for specifics and species. A χ^2 test of heterogeneity of proportions can be used to test whether two or more folk classifications differ significantly in their inclusiveness relative to scientific classifications.

Comparisons of overdifferentiated taxa, or of all underdifferentiated taxa, do not lead to analogous statistical tests, because the members of these categories are not independent sampling units. Overdifferentiated taxa are not independent because if two overdifferentiated taxa are both included in the same underdifferentiated taxon, then they must both be members of the same partition. In Figure 2, *b* and *c* must be members of the same partition because both are included in *v*. Partly underdifferentiated taxa are not independent either, because such a taxon in one partition must by definition partly overlap at least one taxon in the other partition, which in turn must also be partly underdifferentiated. The relevant examples in Figure 2 are *e* and *y*. Inferences about inclusiveness will therefore be based on strictly underdifferentiated taxa.

Table 2 gives the inclusiveness of folk taxa relative to scientific taxa. The six columns refer to the six possible comparisons of folk specifics and generics to scientific species, genera, and families. Each column gives the percentage of strictly underdifferentiated folk taxa relative to all strictly underdifferentiated taxa. Percentages significantly above 50% by a sign test are followed by + and indicate that folk taxa are more inclusive than scientific taxa; percentages significantly below 50% are followed by – and indicate that folk taxa are less inclusive. The last line gives the total numbers of significant differences in each direction.

The summary in the last line of the table confirms Berlin's (1992, p. 64) suggestion that folk generics are approximately as inclusive as scientific genera and definitely more inclusive than scientific species. Similarly, folk specifics are about as inclusive as species and definitely less inclusive than genera.

An obvious feature of the data is the high variability among classifications even within the four subgroups defined according to the organisms classified (plants or animals) and the mode of subsistence in the culture (agricultural or nonagricultural). For instance, among the agricultural classifications of plants, folk generics range from being about as inclusive as scientific species (Ndumba, Rangi) to being significantly more

Table 2.
Percentage of All Strictly Underdifferentiated Taxa that are in Folk Classification

Classification	FS-SS	FG-SS	FS-SG	FG-SG	FS-SF	FG-SF
Plants, Agr.						
1. Hanunóo	10–	67+	2–	24–	0–	0–
2. Tobelo	27–	76+	11–	39	0–	6–
3. Tzotzil	73+	95+	14–	54	2–	13–
4. Tzeltal	78+	95+	18–	36–	4–	6–
5. Ka'apor	80+	97+	17–	32–	5–	6–
6. K'ekchi'	27–	91+	6–	30–	0–	3–
7. Mixe	30–	94+	9–	40	0–	0–
8. Chinantec	44	84+	15–	53	0–	0–
9. Ndumba	4–	57	0–	18	0–	0
10. Bunaq	35–	95+	8–	65+	2–	11–
11. Quechua	25–	89+	7–	24–	0–	3–
12. Navajo	85+	97+	37	79	18	17
13. Bellona	26–	80+	10–	23–	2–	3–
14. Rangi	25	25	8–	8–	5–	5–
Plants, Nonagr.						
15. Seri	45	73+	14–	46	0–	10–
16. Anindilyakwa	94+	94+	67	68+	19–	19–
17. Bella Coola	100+	100+	23	23	0–	0–
18. Gitksan	93+	93+	39	39	15–	15–
19. Witsuwit'en	60	67	27	33	6–	12–
20. Montagnais	80	100+	31	56	0–	11–
21. Saami	93+	93+	44	62	0–	0–
Animals, Agr.						
22. Tobelo	63	90+	31–	66	5–	21–
23. Tzeltal	88+	100+	45	75+	19–	33–
24. Rangi	92+	93+	53	60	14–	18–
25. Hong Kong	56	86+	8–	37	0–	4–
Animals, Nonagr.						
26. Anindilyakwa	97+	97+	86+	87+	42	43
27. Saami	85+	87+	44	58	21–	29–
28. Montagnais	94+	98+	43	91+	18–	60
Totals: +, –	13, 8	25, 0	1, 16	5, 7	0, 26	0, 24

Abbreviations: FS, folk specifics; FG, folk generics; SS, scientific species; SG, scientific genera; SF, scientific families; +, significantly above 50%; –, significantly below 50%.

inclusive than scientific genera (Bunaq). In general, the range of variation for a given folk rank is about equal to the range from one scientific rank to the next. Table 3 gives the results of χ^2 tests for differences between classifications within each of the four subgroups, for specifics and generics compared to species and genera. Comparisons involving scientific families are not tested because low expected frequencies invalidate the χ^2 approximation. The first four columns are arranged as in Table 2, and the fifth column gives the degrees of freedom; the first row for each subgroup gives the results of the tests for differences among the percentages in Table 2. There are significant differences among classifications in all but two of the 16 comparisons.

There is also a difference between agricultural and nonagricultural classifications of plants, which distinguishes between previously published explanations for the larger number of specifics per generic in agricultural classifications. Brown (1986) suggested that when societies adopt agriculture, they tend to expand generics to form more inclusive generics containing larger numbers of specifics. Relative to scientific classifications, therefore, generics should be more inclusive in agricultural than in nonagricultural classifications, while specifics should be about equally inclusive. Berlin (1986; 1992, Ch.7.2) proposed instead that societies adopting agriculture tend to split specifics within generics to produce larger numbers of less inclusive specifics. Consequently, specifics should be less inclusive in agricultural than in nonagricultural classifications, while generics should be about equally inclusive. The data favor Berlin's explanation. Specifics are significantly less inclusive in agricultural classifications, compared to scientific species, $t(19) = 3.45$, and genera, $t(19) = 4.37$, although a floor effect eliminates the difference compared to families, $t(19) = 1.06$. Generics do not differ in inclusiveness, compared to species, $t(19) = 0.80$, genera, $t(19) = 1.08$, or families, $t(19) = 1.60$. The baseline provided by scientific classifications shows that the adoption of agriculture is associated with a proliferation of folk specifics within generics and negligible change in the generics themselves.

In contrast to the classifications of plants, the few classifications of animals show no clear relation between inclusiveness and mode of subsistence. This null result is to be expected given the apparent absence of an effect of agriculture on the total number of generics or the number of specifics per generic in the same small set of classifications.

In the six cultures with recorded classifications of both plants and animals, there is a tendency for folk taxa to be relatively less inclusive for plants than for animals. The difference is significant for specifics and generics compared to families, $t(5) = 5.50$ and 4.95, respectively, and

Table 3.
χ^2 Values for Differences Among Classifications Within Subgroups

Subgroup	Property	FS-SS	FG-SS	FS-SG	FG-SG	df
Plants, Agr.	Incl.	336.93*	114.18*	60.07*	62.42*	13
	d'	57.90*	47.64*	9.90	9.60	
Plants, Nonagr.	Incl.	50.60*	20.74*	28.46*	11.90	6
	d'	8.02	14.37*	2.62	1.89	
Animals, Agr.	Incl.	14.74*	7.81	19.12*	9.56*	3
	d'	0.80	0.84	2.16	2.51	
Animals, Nonagr.	Incl.	6.37*	7.10*	33.67*	17.01*	2
	d'	13.26*	3.36	0.20	0.29	

$^*p<.05$.
Abbreviations: FS, folk specifics; FG, folk generics; SS, scientific species; SG, scientific genera; incl., inclusiveness.

Compared to genera, $t(5) = 3.35$ and 3.51, respectively, but not compared to species, $t(5) = 1.85$ and 1.21, respectively.

4. Consistency

In his study of distinctive taxa in scientific and folk classifications, Berlin (1990) suggested that a scientific species is likely to be distinctive if it is the only local representative of its genus. He then examined the Jívaro folk generics of mammals, birds, and fish that intersect scientific genera with only one local species; most of them proved to be one-to-one, and all the rest were strictly underdifferentiated. In other words, scientific genera with only one species were never divided between different folk generics. Berlin (1992, p. 87) reported similar results in two other folk classifications of birds as well. Berlin's findings suggest that if scientific and folk classifications are consistent, then scientific genera with only one species are less likely to be divided between different folk generics that are scientific genera with two or more species. This prediction can obviously be generalized to any rank: if the classifications are consistent, then scientific taxa of a given rank with only one subtaxon of the next lower rank are less likely to be divided between different folk taxa of a given rank that are scientific taxa with two or more subtaxa. Note that the prediction does not require the folk classification to subdivide the scientific taxa into the same parts that the scientific classification does. Instead, the prediction is that the likelihood of any subdivision between folk taxa depends upon whether the scientific taxa are subdivided.

These concepts are illustrated in Figure 2 for scientific genera divided into scientific species and folk specifics. Genus *U* has one species and is not divided between folk specifics, but genus *V* has one species and is divided between specifics *b* and *c*. Genus *W* has two species and is not divided between specifics, but genus *Y* has two species and is divided between specifics *e* and *f*. The prediction is that in real classifications, taxa like *V* are less common relative to taxa like *U* than are taxa like *Y* relative to taxa like *W*.

Unlike the measures of inclusiveness described in the previous section, the present approach to consistency does not treat the folk and scientific classifications alike. Instead, the scientific classification is the standard against which the folk classification is compared. It is of course formally possible to interchange the roles of the scientific and folk classifications in the analysis, although that possibility is not pursued here. The choice of the scientific classification as the standard does not assume that the scientific classification is entirely veridical, but only that it is closer to reality than the folk classification is.

Comparison of consistency across ranks introduces one potential complication. It is reasonable to expect that if folk and scientific classifications are consistent, scientific taxa with more than two subtaxa are more likely to be divided between folk taxa than are scientific taxa with exactly two subtaxa, because the former offer more distinctions for folk classifiers to notice. This difference in fact occurs in most of the classifications studied here. Also, the distribution of number of subtaxa per taxon depends upon rank in many classifications (Holman 1992). In particular, the portions of scientific classifications that intersect folk classifications tend to contain fewer species per genus than genera per family or families per order. The conjunction of these two factors can artificially depress inferred consistency at the rank of species compared to the ranks of genus and family. The problem is solved by not counting scientific taxa with more than two subtaxa. Consequently, consistency is inferred from the proportion of scientific taxa with exactly two subtaxa that are divided between folk taxa, in relation to the proportion of scientific taxa with exactly one subtaxon that are so divided. For convenience, these proportions are henceforth called p_2 and p_1, respectively. In Figure 2, for instance, p_2 and p_1 are both equal to 0.5 for genera divided into species and specifics.

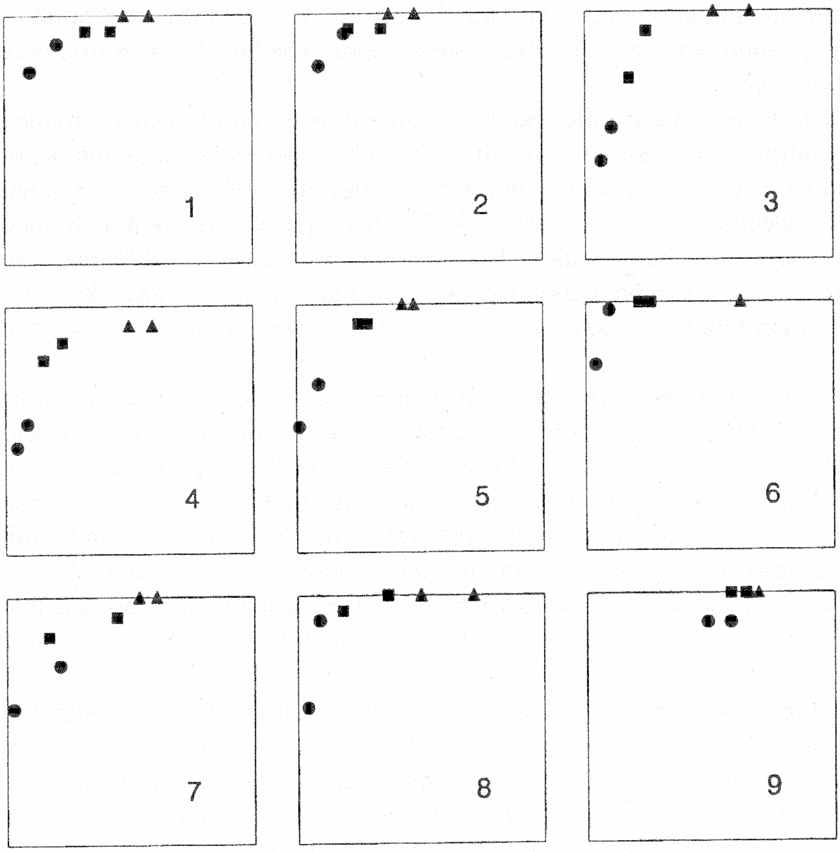

Figure 3a. Consistency of folk and scientific classifications of plants in agricultural societies. Each graph plots p_2, the proportion of scientific taxa with two subtaxa that are divided between folk taxa, against p_1, the proportion of scientific taxa with one subtaxon that are so divided, for scientific species within genera (circles), genera within families (squares), and families within orders (triangles), divided between folk specifics (upper right points) and generics (lower left points). Graphs are numbered according to the order of the classifications in Table 1. Vertical axes show p_2, horizontal axes show p_1, and both axes run from 0 to 1.

Each graph in Figure 3 plots p_2 against p_1 for a single folk classification compared with a scientific classification; the numbers in the graphs are the numbers by which the classifications are listed in Table 1. In all the graphs, the vertical axis shows p_2, the horizontal axis shows p_1, and both axes run from 0 to 1. Circles, squares, and triangles denote the scientific ranks of species within genera, genera within families, and families within orders, respectively. At each scientific rank, the upper right point

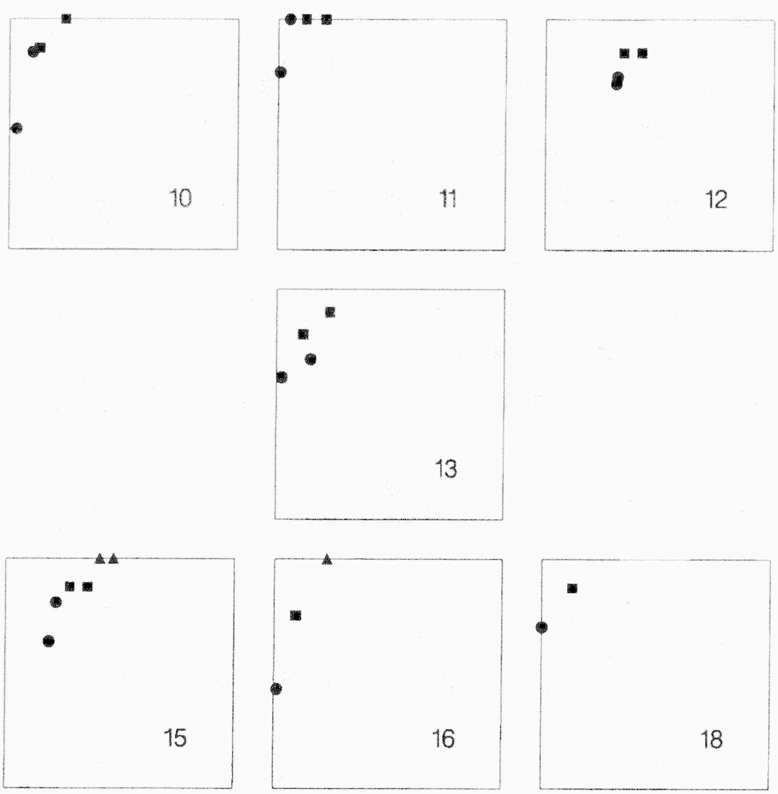

Figure 3b. Consistency of folk and scientific classifications of plants in agricultural (top two rows) and nonagricultural (bottom row) societies. Each graph plots p_2, the proportion of scientific taxa with two subtaxa that are divided between folk taxa, against p_1, the proportion of scientific taxa with one subtaxon that are so divided, for scientific species within genera (circles), genera within families (squares), and families within orders (triangles), divided between folk specifics (upper right points) and generics (lower left points). Graphs are numbered according to the order of the classifications in Table 1. Vertical axes show p_2, horizontal axes show p_1, and both axes run from 0 to 1.

Refers to folk specifics, and the lower left point refers to folk generics. These two points are closer together if the mean number of specifics per generic is lower, until they merge as the mean approaches 1. Points are omitted from the graphs if they are based on fewer than ten scientific taxa for either p_1 or p_2. Each graph can contain as many as six points, but some contain fewer because of insufficient taxa or merged points, and a few classifications lack graphs because there are no points based on enough taxa.

All the points in all the graphs are above the main diagonal, meaning that scientific taxa with two subtaxa are more likely be divided between folk taxa than are scientific taxa with only one subtaxon The difference is

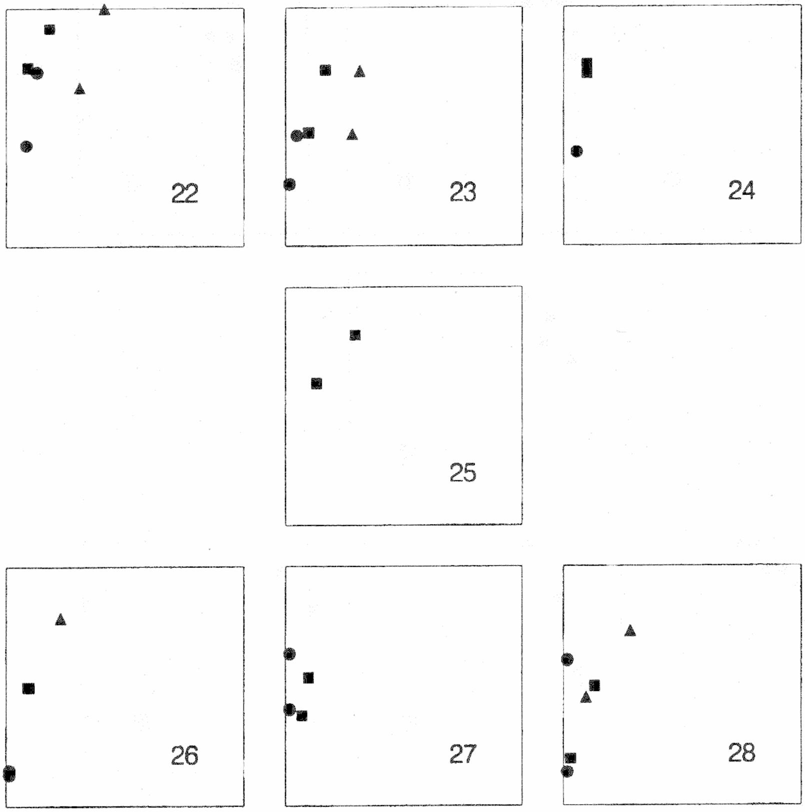

Figure 3c. Consistency of folk and scientific classifications of animals in agricultural (top two rows) and nonagricultural (bottom row) societies. Each graph plots p_2, the proportion of scientific taxa with two subtaxa that are divided between folk taxa, against p_1, the proportion of scientific taxa with one subtaxon that are so divided, for scientific species within genera (circles), genera within families (squares), and families within orders (triangles), divided between folk specifics (upper right points) and generics (lower left points). Graphs are numbered according to the order of the classifications in Table 1. Vertical axes show p_2, horizontal axes show p_1, and both axes run from 0 to 1.

Significant, $\chi^2(1) \geq 5.31$, in all comparisons of species within genera and genera within families, including those with too few taxa to appear in the graphs. In the comparisons of families within orders, which are based on the fewest taxa, the difference is again significant, $\chi^2(1) \geq 3.95$, in all but three cases: specifics and generics in the Navajo classification of plants, and generics in the Tzeltal classification of animals, $\chi^2(1) \leq 3.77$. The present evidence for consistency between classifications thus confirms the findings of Berlin (1990; 1992, p. 87) and extends them across three scientific ranks and two folk ranks in a larger sample of classifications.

To compare the degree of consistency between classifications at different taxonomic ranks, it is necessary to distinguish the effects of consistency from those of inclusiveness. As a folk classification becomes less inclusive relative to a scientific classification, more scientific taxa will be divided between folk taxa, and both p_1 and p_2 will increase. If the classifications at different taxonomic ranks differ only in inclusiveness and not in consistency, then all the points in the graph are predicted to lie on a single monotonic nondecreasing curve. For the two folk ranks at each scientific rank, monotonicity holds by necessity: because specifics are subsets of generics, any scientific taxon that is divided between different generics must also be divided between specifics, but not conversely. In the hypothetical data of Figure 2, for instance, p_1 and p_2 both increase from 0 for generics to 0.5 for specifics. The present method therefore does not test for differences in consistency at different folk ranks. There is no logical requirement of monotonicity, however, across different scientific ranks; thus, monotonicity can be checked empirically to test for differences in consistency among scientific ranks. In the real data of Figure 3, the points in most of the graphs are monotonic across scientific ranks, particularly in the classifications of plants. The prevalence of monotonicity in the data suggests that the degree of consistency between folk and scientific classifications is independent of scientific rank across the ranks of species within genera, genera within families, and families within orders.

The graphs in Figure 3 are analogous to ROC (Receiver Operating Characteristic) graphs in signal detection theory (Green and Swets 1966, Ch. 2.2; MacMillan and Creelman 1991, p. 14). On each trial of a detection experiment, an observer is presented with one of two stimuli (signal or noise) and instructed to respond "yes" to signal and "no" to noise. An ROC graph plots the proportion of yes responses on signal trials, which is analogous to p_2, against the proportion of yes responses on noise trials, which is analogous to p_1. If the observer can discriminate signal from noise, then the proportion of yes responses will be higher to signal than to noise, and the corresponding point will be above the main diagonal in the ROC graph. If the stimuli are held constant, then increases (or decreases) in response bias toward yes will increase (or decrease) both proportions, and the points will all lie on a single monotonic ROC curve. Discrimination between stimuli in signal detection theory is thus analogous to consistency between classifications in the present context, and response bias is analogous to inclusiveness. Signal detection theory leads to a convenient descriptive measure of discriminability, d', which is defined as follows in the present notation:

$$d' = z(p_2) - z(p_1),$$

where z is the inverse of the cumulative standard normal distribution. In most studies of empirical ROC curves, the inverse normal transformation keeps the difference between the transformed proportions approximately constant at most points on a single ROC curve; the difference, d', thus depends mainly on discriminability rather than on response bias. In the present context, d' measures the extent to which the folk classification subdivides the same taxa that the scientific classification does.

Table 4 gives d' for each of the four possible combinations of folk specifics and generics with scientific species and genera. Two accommodations are made for the fact that d' is not defined if p_1 is 0 or p_2 is 1. First, scientific families within orders are not included in Table 4 because p_2 for families is 1 in many cases, as seen in Figure 3. Second, 0.5 is added to each raw frequency used in calculating p_1 and p_2; this adjustment eliminates proportions of 0 or 1 and is recommended for its statistical properties by Hautus (1995) and Hautus and Lee (1998).

All the 112 d' values in the table are positive, as expected from Figure 3. Differences among classifications can be assessed by a χ^2 test for differences among a set of d' values, which Marascuilo (1970) derived from earlier results of Gourevitch and Galanter (1967). Table 3 gives (after the tests on inclusiveness already discussed) the results of this test for differences in d' among the classifications in each of the four subgroups for each of the four combinations of folk and scientific ranks. There are only four significant differences, all involving scientific species; the tests for species are more powerful because they use genera as the sampling unit, whereas the tests for genera use families, which are less numerous. Differences between classifications are not as prominent for consistency as for inclusiveness.

The same test is not applicable to differences among taxonomic ranks. Taxa of different rank in the same classification cannot be treated as independent sampling units, because taxa at the lower rank are subsets of taxa at the higher rank. Instead, a bootstrap test (Efron and Gong 1983) was performed on each classification, using scientific families as the sampling unit. Each bootstrap sample was constructed by sampling scientific families from the classification, with replacement, until the bootstrap sample contained as many families (including repeats) as the original classification. In each of 10,000 such samples, values of d' were calculated and compared between scientific ranks at each folk rank. The proportion of samples in which d' was greater for species than for genera was calculated for each folk rank in each classification. Figure 4 plots the frequency distribution of these proportions in the 56 comparisons produced by two folk ranks in 28 classifications. The null hypothesis predicts a uniform distribution, while

Table 4.
Discrimination (d')

Classification	FS-SS	FG-SS	FS-SG	FG-SG
Plants, Agr.				
1. Hanunóo	1.96	1.98	1.52	1.79
2. Tobelo	2.19	2.09	1.77	2.15
3. Tzotzil	1.32	1.25	2.00	1.50
4. Tzeltal	1.41	1.49	1.74	1.76
5. Ka'apor	1.80	2.30	1.79	1.90
6. K'ekchi'	3.00	2.38	2.70	2.84
7. Mixe	1.35	1.99	1.43	1.88
8. Chinantec	2.51	1.82	2.22	2.24
9. Ndumba	0.88	1.12	1.62	1.78
10. Bunaq	2.29	1.88	2.56	2.14
11. Quechua	3.70	3.00	2.66	3.00
12. Navajo	1.13	1.07	1.16	1.36
13. Bellona	1.49	2.18	1.81	1.90
14. Rangi	2.85	2.85	2.49	2.49
Plants, Nonagr.				
15. Seri	1.60	1.20	1.40	1.62
16. Anindilyakwa	2.03	2.03	1.92	1.92
17. Bella Coola	2.37	2.37	2.04	2.04
18. Gitksan	2.85	2.85	1.81	1.81
19. Witsuwit'en	2.03	2.03	2.71	2.71
20. Montagnais	3.17	2.93	1.70	2.12
21. Saami	1.40	1.40	2.06	2.22
Animals, Agr.				
22. Tobelo	1.71	1.17	2.09	1.91
23. Tzeltal	1.58	1.52	1.55	1.20
24. Rangi	1.31	1.31	1.93	1.81
25. Hong Kong	1.65	1.10	1.31	1.33
Animals, Nonagr.				
26. Anindilyakwa	1.16	1.07	1.28	1.32
27. Saami	2.39	1.84	1.36	1.17
28. Montagnais	2.35	1.07	1.10	1.05

Abbreviations: FS, folk specifics; FG, folk generics;
SS, scientific species; SG, scientific genera.

significant differences in d' between species and genera would produce high frequencies in the lowest (0 - 0.1) and highest (0.9 - 1) intervals. The data support the null hypothesis. As suggested by Figure 3, consistency between folk and scientific classifications is independent of scientific rank.

Consistency is also independent of agriculture. There are no significant differences in *d'* between agricultural and nonagricultural classifications of plants for any of the four combinations of folk and scientific ranks, $t(19) \leq 0.62$. Not surprisingly, no differences are apparent in the classifications of animals either. Brown (1985) and Berlin (1992, Ch. 7.2) both agree that the increased number of specifics per generic in agricultural classifications of plants is a result of farmers' greater attention to botanical detail, but evidently this attention does not make their classifications any more consistent with science. Possibly the additional generics that are also present in agricultural classifications are relatively difficult taxonomically, thus counteracting the effect of greater attention. To test this hypothesis, a generic can be defined as taxonomically difficult if it intersects at least one scientific taxon that is not identified to the species level; an example is the previously mentioned Tzeltal generic *met chih*, which is identified as *Agave* sp. (Berlin *et al.* 1974, pp. 419-420). The mean percentage of such generics in agricultural and nonagricultural classifications of plants is 35% and 9%, respectively. The difference is significant, $t(19) = 3.14$, suggesting greater taxonomic difficulty, for scientists as well as folk, in the agricultural classifications.

In the six cultures with classifications of both plants and animals, there may be a tendency toward greater consistency for plants than for animals. The difference is significant for *d'* based on generics and genera, $t(5) = 5.42$, but not for specifics and genera, generics and species, or specifics and species, $t(5) = 2.46$, 2.21, and 1.17, respectively. The overall mean *d'* is 2.02 for the 21 classifications of plants and 1.49 for the seven classifications of animals.

5. Discussion

The present results extend previous evidence for consistency between independent classifications by measuring consistency at individual taxonomic ranks and then showing that consistency extends across a range of ranks. Folk classifications can distinguish between one scientific species and two even when they are in the same genus. They can also distinguish, equally well, between genera in the same family and between families in the same order. The latter findings are not consistent with either of the predictions illustrated in Figure 1. In the left panel, *d'* is predicted to be higher for species within genera than for genera within families, because boundaries between species are more obvious than boundaries between genera. In the right panel, however, *d'* is predicted to be higher for genera

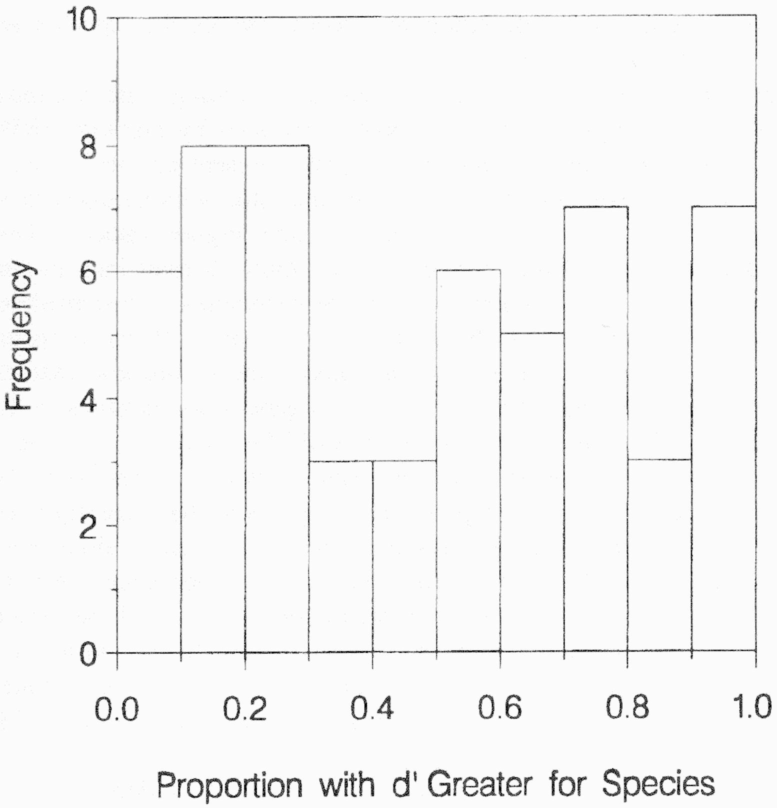

Figure 4. Frequency histogram of proportions of bootstrap samples with higher *d'* for scientific species than genera; the unit of analysis is a single folk rank (specific or generic) in a single folk classification.

than for species, because boundaries between genera are the more obvious. To predict the observed invariance of *d'*, the pattern in the figure would have to look the same at the different levels of magnification corresponding to the different taxonomic ranks. Characterization of the class of such patterns that can also be generated by phylogenetic trees remains a question for future research.

Any application of the present results to biology requires the assumption that consistency between folk and scientific classifications reflects biological properties of organisms as well as cognitive properties of classifiers. Mayr (1963, p. 17) and Gould (1979) relied on this assumption in citing the consistency of folk taxa with scientific species as support for their prediction that most of the species living in a given area are biologically distinct. By the same assumption, the present evidence for invariance of consistency across taxonomic ranks implies that species are biologically no more distinct than are genera or families.

Assuming that the present results are relevant to biology, the two most prominent biological explanations were both introduced by Darwin (1859, Ch. 4). First, Darwin suggested that species just represent an interval on a continuous scale of remoteness from a common ancestor, which ranges from varieties through species to genera, families, and higher ranks. This hypothesis does not predict that species are any more distinct than higher taxa. Second, Darwin also pointed out that the extinction of intermediate forms would increase the distinctness of the survivors. Because forms intermediate between higher taxa have had more time to become extinct, their extinction might increase the distinctness of genera and families to the same level predicted for species by the theories of Mayr and of Gould. In a more quantitative vein, the relation between extinction rates and the distribution of times since the divergence of living species has recently been explored by Nee, Holmes, May, and Harvey (1994); the results, along with the appropriate assumptions about the relation of divergence time to distinctness, might lead to quantitative predictions that could be tested against the present findings. In any case, consistency with folk classifications can be added to the set of properties that are self-similar across a range of ranks in scientific classifications (Van Valen 1973; Burlando 1990, 1993).

Given that consistency between classifications is independent of taxonomic rank, the salience of folk generics cannot be explained by any superior distinctness possessed by the corresponding groups of organisms. Culture and experience are known to influence whether the generic rank is the basic level in folk classifications (Dougherty 1978); but these factors do not appear to determine the preferential use of generics for implicational inferences (Atran 1998). Although Atran explained the latter result by an assumed greater discriminability of generics to our evolutionary forbears, that assumption is not necessary to his argument. In the environment in which human beings evolved, implicational inferences may be more successful at the generic rank than at the other ranks, even with discriminability held constant. This explanation does not specify, nor do the present data determine, whether the difference in implicational inferences is biologically or cognitively based.

The inclusiveness of folk taxa appears to be multiply determined. A high degree of cultural influence can be inferred from the effect of agriculture on the inclusiveness of specifics, but generics are impervious to that particular factor. Even generics show substantial variation in inclusiveness among classifications. Culture is not the only factor that could contribute to such variation. Because folk taxa are less discrete than scientific taxa, the compiler of a folk classification must exercise judgment in deciding which scientific taxa intersect each folk taxon; compilers undoubtedly differ in their criteria for deciding how far to extend the basic ranges of folk taxa and how to treat disagreement among informants. Another source of variation is the scientific classification itself, which exists in various alternative versions prepared by taxonomic lumpers and splitters. Finally, there is the suggestion in the data that folk taxa are more inclusive in classifications of animals than plants; this possibility, like the possibility of lower consistency between classifications of animals than plants, must await the publication of more folk classifications of animals before much can be said about it.

The present results supplement the earlier findings of Brown (1985, 1986) and Berlin (1986; 1992, Ch. 7.2) to produce a coherent account of the relation between agriculture and folk classifications of plants. Farmers tend to split previously undivided generics into several specifics, and farmers also incorporate into their classifications additional generics that were previously too difficult taxonomically. Both these differences may be a result of farmers' greater attention to botanical detail, as suggested by both Brown and Berlin. As Berlin has emphasized, however, the differences may also reflect the reduced circumstances of present-day nonagricultural societies, most of which are confined to areas of low biological diversity and are subject to acculturation by more powerful neighbors.

Although both folk and scientific classifications include taxonomic ranks higher than those studied here, an attempt to extend the investigation to higher ranks would run into problems. First, as rank increases, the number of taxa decreases, resulting in small samples, inaccuracy in estimating proportions, and low power in statistical tests. Second, in folk classifications, the membership of generics in higher taxa can be ambiguous, in the sense that informants can disagree about whether a generic belongs in a higher taxon; membership can also be incomplete, in the sense that some specifics or organisms within a generic can be members of a higher taxon while others are not. Such situations would introduce ambiguities and inconsistencies into the measures and tests used here. Other methods will probably have to be developed to study the relation between folk and scientific classifications at higher ranks.

Compared to the methods typically used for comparing classifications, the present methods offer two advantages: the ability to provide separate measures of inclusiveness and consistency rather than one overall measure of agreement, and the lack of reliance on information about the number of objects in each taxon. The present methods also incur the disadvantage of requiring large classifications with dozens or hundreds of taxa, while other methods can be applied to classifications of any size. Because classifications with few taxa and unknown numbers of objects provide little information for comparison, some sort of tradeoff appears inevitable between number of taxa and number of objects within taxa, but such a tradeoff might be able to preserve the advantage of separate measures of inclusiveness and consistency. For instance, the present methods might be adapted to small classifications with known numbers of objects by weighting each taxon by the number of objects contained in it. A similar adaptation might be used at the higher ranks of large classifications, with higher taxa weighted by the numbers of subtaxa at a given lower rank.

Further progress might also be possible in the direction of consensus indices. Given that Nelson (1979) has provided consensus interpretations for the four categories of relative differentiation defined by Berlin (1973) and Hunn (1975), a new consensus index might be constructed as a function of the numbers of taxa in these categories. Developing the index itself would probably be less difficult than accumulating the background of theoretical and empirical understanding that is by now taken for granted in signal detection theory. A new index would therefore be most justified if it captured aspects of agreement not already summarized by d', or if it could be used in situations where d' could not.

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