Incidence or Frequency? Methodological issues in characterizing the medicinal flora of North America

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RÉSUMÉ

Dans cet article, nous comparons deux protocoles de régression linéaire pour l'étude des usages des plantes médicinales par les populations indigènes d'Amérique. Dans le premier protocole, la variable est le nombre d'espèces médicinales utilisées dans chaque famille botanique et, dans l'autre protocole, la variable est le nombre d'usages des différentes espèces de plantes dans chaque famille. On peut conclure que le dernier protocole est plus complexe et apporte peu d'information utile.

In several papers, I have used a method of regression residual analysis to attempt to make sense of the medicinal flora of Native North America (MOERMAN 1979, 1989, 1991). The method has also been used to compare the medicinal flora of North America with that of a region in North India (KAPUR *et al.*, 1992), and, in a preliminary fashion, to compare the medicinal flora with the food flora of North America (MOERMAN, n.d.). The essence of that method has been to do a regression analysis of the number of species per family *which are used medicinally* on the *total number of species* per family, then to rank families by the size of the residuals from regression. Families with large positive residuals are interpreted as having disproportionately large usage relative to the overall size of the family and are particularly medicinal families. By contrast, families with large negative residuals have comparatively few medicinal species. In North America, examples of the former are *Rosaceæ*, *Caprifoliaceæ* and *Lamiaceæ*; examples of the latter are *Poaceæ* and *Juncaceæ*. Why such a pattern should exist is not immediately obvious, and raises a number of interesting and challenging questions about the distribution of biologically active substances among the plants on the one hand and, on the other, about the nature of the processes by which people have learned about these useful species.

On a number of occasions, colleagues have commented that this method leaves something out. By using the *incidence* of a species rather than the *frequency* of its utilization, very rarely used taxa are given the same value as those which are very widely used. There is no doubt that there is a substantial variation in the usage of medicinal species in Native America. Table 1 shows the number of species with 1 through 5 uses in my catalog of the Medicinal Plants of Native America (hereafter MPNA) (MOERMAN 1986); there are 1344 species with 5 or fewer medicinal uses. By contrast, Table 2 shows the 5 most frequently used species; the five have 590 uses. Clearly, some taxa can be construed as frequently utilized while others can be considered exotics, used only very rarely.

Which is the better way to procede? I will examine this problem in two ways, conceptually and analytically.

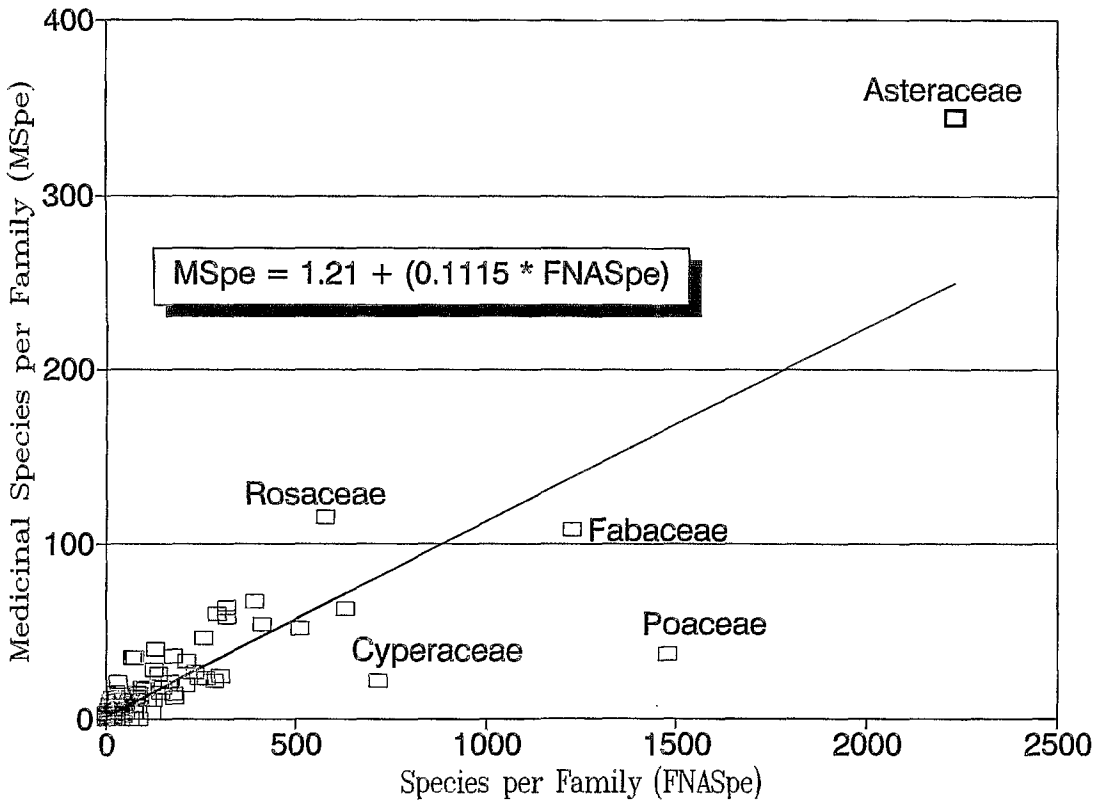
Table 1
Number of rarely used medicinal species

Uses	*Number of Species*
1	499
2	354
3	215
4	147
5	129
Sum	1344

CONCEPTUAL CONSIDERATIONS

On the one hand, ethnobotany is interested not so much in quantities as characteristics. That only one culture discovered a valuable medicinal plant and then kept the knowledge to itself does not diminish the potential interest of that species; indeed, there may be very interesting and useful species which have not yet been discovered at all. Moreover, some important species with

Figure 1
Regression of medicinal species on total species per family, for native North America.



In a regression analysis, one seeks to determine if there is a relationship between two (or more) variables which can be measured. Is there a relationship between shoe size and income? Between family size and annual movie attendance? Between the amount of fertilizer applied and the yield per acre? Between femur length and stature? Typically, an investigator has a sample of a few dozen data points. If there is some sort of linear relationship between the variables (as in the stature example) the data points, when graphed, will typically form a lens shaped cloud, rising from lower left to upper right. In a negative relationship (car weight and miles per gallon), the cloud will range from upper left to lower right. The closer the relationship between the two variables (the higher the "correlation" between them) the narrower will be the cloud.

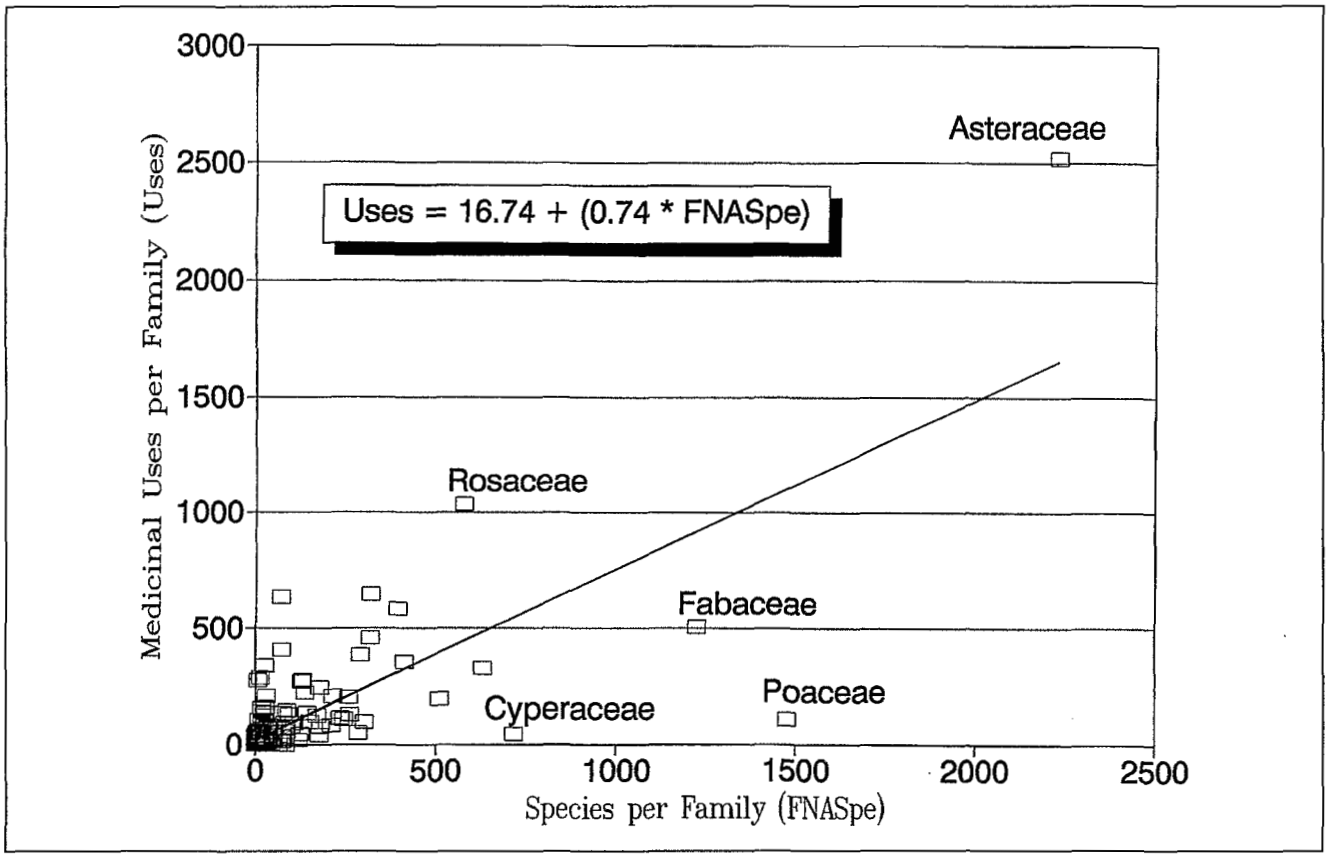
Like these typical cases, this regression analysis explores a relationship between two sets of numbers. What is the relationship between the size of a particular plant family (there are 232 in North America) and the number of those species which were used medicinally by native Americans? Each data point on the graph represents one pair of numbers. The total size of the family is plotted on the horizontal axis, and the number of medicinal species (the incidence) is on the vertical axis.

Typically, too, the investigator wants to learn about these relationships in order to make predictions: having found a fossil femur, the investigator wishes to predict what the overall stature of this individual might have been (or, what the yield might be if more fertilizer is used).

In the regressions here, there are some differences from the more normal situations. The medicinal plant data are, for all intents, a *census* of the data. It is unlikely that there are very many plants known to be used by native Americans which are not represented in the database. Therefore, there is little need for us to predict anything. The distance of a point from the regression line —the residual— is particularly important information showing that the particular plant family (or habit group, or life form) is used much more, or much less, than is typical for other similar categories. In this graph, we can see that *Asteraceæ* and *Rosaceæ*, lie well above the regression line, and are therefore families which have a disproportionately large use as sources of medicines. *Poaceæ*, *Cyperaceæ*, and *Fabaceæ* lie well below the line indicating that they are disproportionately small sources of medicines.

To calculate the residual value for each point in the regression, one calculates the "predicted value" according to the regression equation, then subtracts that from the "actual value. All these values are displayed in Table 5.

Figure 2
Regression of medicinal uses on total species per family, for native North America.



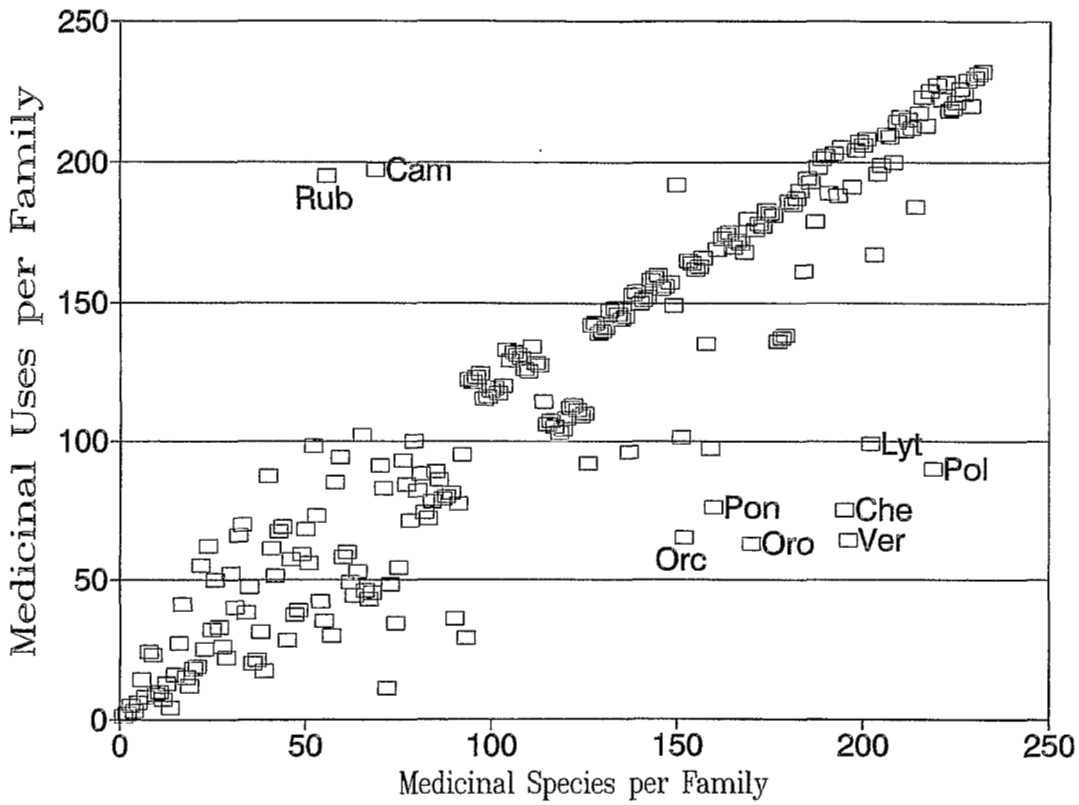
This regression analysis displays the relationship between the number of species per family and the number of times those species are utilized as medicines (the *frequency).* Although there are many differences of detail between this figure and Figure 1, the basic shapes of the two figures are the same. As in the previous case, *Asteraceæ* and *Rosaceæ* are well above the regression line (they have a disproportionately large share of uses) and *Poaceæ, Cyperaceæ* and *Fabaceæ* are well below the line (they have a disproportionately small share of uses). For all the data plotted in this graph, see Table 5.

very interesting characteristics might not be widely distributed on the continent, and so might not be widely available. A good example of that is *Taxus brevifolia*: found only in the old growth forests of the Pacific Northwest, it is unsurprising that the taxon is not used all over North America; that it has only 10 uses in MPNA does not make it uninteresting.[1]

In addition, considering frequency rather than incidence as a dependent variable adds a confounding character to an analysis of this sort. In particular, it means that the dependent and independent variables are of different sorts since the latter, the overall number of plants in the family, is a measure of incidence while the former is a frequency. Consider two families of the same size, each with 50 species. In family A, 20 species are used medicinally, each only once. In family B, only one species is used medicinally, but it is quite popular and is used by 20 different societies. If we are interested in determining which families are substantial contributers of medicinal species (in this case family A), clearly an incidence measure is more valuable than a frequency measure.

On the other hand, as already noted, it is clearly the case that there are many species which are of only the most marginal usage. By contrast, some taxa with quite restricted distributions are widely utilized nonetheless. Even though *Eriodictyon californicum* (*Fabaceæ*) Mountain balm or Yerba Santa, is found only along the west coast of the US, it has 54 uses by a dozen different tribes of the region. This is a particularly intriguing case since *Fabaceæ* is one of the families which has a fair number of medicinal species (108) but ends up with a substantial and negative residual in an incidence regression; hence it appears very low on the list of medicinal families, ranking 230 of

Figure 3
Residual ranking on two regression analyses



This graph compares the residual values from the two regression analyses. In each analysis, the 232 families are ranked by the size of their residual values (as shown in Tables 3 and 4). This graph plots each of those two rankings. If each of the 232 families ranked exactly the same on each regression, the points would form one straight line. Some points fall away from the line; several of those are marked with 3 letter abbreviations (*Rubiaceæ, Campanulaceæ, Verbenaceæ, Polemoniaceæ, Chenopodiaceæ, Orobanchaceæ, Lythraceæ, Orchidaceæ* and *Pontederiaceæ*). These are discussed in the text. It appears that there may be more variation in residual rankings for families ranked higher than those ranked lower on the two regressions; the families at the lower left portion of the graph seem to show more "scatter" than families at the upper-right. This may be worth closer examination.

Table 2
Utilization of commonly used species

Acorus calamus	148
Achillea millefolium	146
Artemisia tridentata	110
Mentha arvense	94
Prunus virginiana	92

232. Perhaps using incidence rather than frequency has obscured the particular medicinal character of this family.

Although the methodological problems seem to me serious, it is also clearly possible to argue that using incidence rather than frequency may obscure interesting and potentially important dimensions of the medicinal flora of a region. To test these issues, I will compare regression analyses using both approaches with the same set of data.

ANALYTICAL APPROACH

I proceeded to review the regression residual analysis of medicinal plants of native America previously reported and to compare that analysis to a similar analysis based on the frequency of medicinal uses. Figure 1 displays the regression

analysis of the number of medicinal species on total species by family (for complete details, see Moerman 1991). In the figure, families far above the regression line (*Asteraceæ, Rosaceæ*) are those with many medicinal species regardless of the size of the family. Those well below the regression line (*Poaceæ, Cyperaceæ, Fabaceæ*) are those with very few medicinal species regardless of the size of the family. In this case, a species is counted once regardless of how many times only utilization is not borne out. Indeed, overall, the outcome of the two regressions is very similar.

One way to compare the two regression analyses is to list families in terms of their residual values in the two regressions. Table 3 lists the top 10 and the bottom 10 families in terms of the residual on the regression of medicinal plants on total plants. *Asteraceæ* and *Rosaceæ* hold first and second place on both regression residual lists. Similarly, the lowest residual ranking

Table 3
Regression results ranked by medicinal species

	Total	*Medicinal Species*				*Medicinal Uses*			
Families	*Species*	*Actual*	*Predicted*	*Residual*	*Rank*	*Actual*	*Predicted*	*Residual*	*Rank*
Asteraceæ	2 231	345	250	95	1	2 522	1657	865	1
Rosaceæ	577	115	66	49	2	1 038	441	597	2
Lamiaceæ	320	64	37	27	3	645	252	393	4
Ranunculaceæ	294	60	34	26	4	384	233	151	14
Pinaceæ	71	35	9	26	5	635	69	566	3
Caprifoliaceæ	77	35	10	25	6	404	73	331	5
Salicaceæ	131	40	16	24	7	272	113	159	12
Liliaceæ	393	67	45	22	8	580	306	274	7
Apiaceæ	319	58	37	21	9	457	251	206	10
Corylaceæ	33	21	5	16	10	204	41	163	11
Acanthaceæ	65	0	8	–8	223	0	65	–65	216
Scrophulariaceæ	632	63	72	–9	224	324	481	–157	227
Hydrophyllaceæ	183	12	22	–10	225	77	151	–74	218
Boraginaceæ	304	25	35	–10	226	98	240	–142	226
Agavaceæ	86	0	11	–11	227	0	80	–80	220
Juncaceæ	123	4	15	–11	228	17	107	–90	222
Caryophyllaceæ	287	22	33	–11	229	48	228	–180	228
Fabaceæ	1 225	108	138	–30	230	503	917	414	230
Cyperaceæ	718	22	81	–59	231	43	545	–502	231
Poaceæ	1 477	37	166	–129	232	107	1102	–995	232

it may be used. The *Asteraceæ*, with 2231 species in North America, have 345 species which are utilized 2522 ways; in this analysis, we use the figure for utilization (345) not the figure for frequency (2522). We do this even though two *Asteraceae* species are used over 100 times each (*Achillea millefolium* L. is used 146 times; *Artemisia tridentata* is used 110 times) while 183 species are used 3 or fewer times.

Figure 2 shows the regression analysis of the number of uses of medicinal plants per family on the total species per family. In this case, for *Asteraceae* we use the figure for frequency (2522) not the figure for utilization (345); we do the same for all the other families in the analysis. Complete data for the analysis are shown in the Table 5. What is most striking about this graph is how much it resembles Figure 1. *Asteraceæ* and *Rosaceæ* maintain very nearly identical relative positions well above the regression line, and *Poaceæ, Cyperaceæ* and *Fabaceæ* maintain their respective positions well below the line. The proposition suggested above, that *Fabaceæ*'s role as a source of medicinal plants is minimized by considering on the frequency regression is 14 for the top ten on the utilization regression. The same is true at the other end of the list. The last three families on the utilization regression hold the same last three places on the frequency regression. And of the bottom ten on the utilization regression, the highest ranking on the frequency regression is position 216.

Table 4 shows the analogous information with the top 10 and bottom 10 families on the frequency regression, and the conclusions one can draw from an examination of this list is essentially the same as for Table 3; there are few differences in those lists. Two families bear mention from Table 4. *Araceæ* ranks higher on the frequency regression (8th) than on the utilization regression (24th). This is largely due to the widespread use of *Acorus calamus*, mentioned earlier. Similarly, *Araliaceæ* ranks 9th on the frequency regression but only 23rd on the utilization regression. This can be attributed to the widespread usage of three genera *Aralia, Panax* and *Oplopanax.*

The bottom portion of Table 4 shows a great deal of uniformity; the two sequences are nearly identical. The generally

Table 4
Regression results ranked by Medicinal Uses

Families	Total Species	Medicinal species				Medicinal uses			
		Actual	Predicted	Residual	Rank	Actual	Predicted	Residual	Rank
Asteraceæ	2 231	345	250	95	1	2 522	1 657	865	1
Rosaceæ	577	115	66	49	2	1 038	441	597	2
Pinaceæ	71	35	9	26	5	635	69	566	3
Lamiaceæ	320	64	37	27	3	645	252	393	4
Caprifoliaceæ	77	35	10	25	6	404	73	331	5
Cupressaceæ	27	15	4	11	14	334	37	297	6
Liliaceæ	393	67	45	22	8	580	306	274	7
Araceæ	16	8	3	5	24	286	28	258	8
Araliaceæ	10	8	2	6	23	272	24	248	9
Apiaceæ	319	58	37	21	9	457	251	206	10
Onagraceæ	247	23	29	–6	218	106	198	–92	223
Malvaceæ	213	19	25	–6	219	79	173	–94	224
Cactaceæ	180	14	21	–7	221	39	149	–110	225
Boraginaceæ	304	25	35	–10	226	98	240	–142	226
Scrophulariaceæ	632	63	72	–9	224	324	481	–157	227
Caryophyllaceæ	287	22	33	–11	229	48	228	–180	228
Brassicaceæ	510	52	58	–6	220	195	392	–197	229
Fabaceæ	1 225	108	138	–30	230	503	917	–414	230
Cyperaceæ	718	22	81	–59	231	43	545	–502	231
Poaceæ	1 477	37	166	–129	232	107	1 102	–995	232

few species from these families which are utilized medicinally are, in general, not broadly utilized.

While these two analyses show remarkably similar patterns, the cases of *Araceæ* and *Araliaceæ* suggest we look further for families with a few species accounting for most of substantial usage. Table 5 can be used for this search. It lists all 232 families of North American plants according to the *difference* between the ranking on the utilization regression and the ranking on the frequency regression. A family ranks high if it has a relatively low residual on the utilization regression but a relatively high residual on the frequency regression. These data are plotted on Figure 3. The families at the top of the list appear in the upper left on the graph; the families at the bottom appear on the lower right of the graph.

The first thing to notice is that, for the great majority of cases, the rankings on the two regressions are very much the same. Indeed, for 185 of 232 cases (80~), the two figures are within 10~ of one another. That is, in 185 cases, one ranking is within 23 points of the other, positively or negatively. On the graph, this can be seen in the apparent "line" from lower left to upper right indicating very nearly identical rankings on each regression; in the table, these cases range from *Caricaceæ* down to *Garryaceæ*.

Second, there are families which are obvious outliers. At the upper left hand corner of the graph (from the top of Table 4) are *Rubiaceæ* and *Campanulaceæ*. Although these families' regression rankings differ by 139 and 128 respectively, neither is really very remarkable.

- For *Rubiaceæ*, 15 of its 145 species are utilized 132 ways. About half of these uses are accounted for by *Mitchella repens* with 57. Several species of *Galium* account for most of the rest with 56.
- For *Campanulaceæ*, 11 of its 110 species are utilized 13 ways; the preponderance of these uses are accounted for by three species of the genus *Lobelia.*

These taxa, *Mitchella, Galium,* and *Lobelia,* generally account for the outlier position of these two families as they are fairly widely used species from moderately productive medicinal families.

Third, there are the outliers on the lower right hand corner of the graph (from the bottom of the list in Table 4). The last seven families on the list (marked with 3-character abbreviations on the figure) all have incidence residuals from –1 to +1, and are listed in the middle of the incidence residual ranking (from 63 to 90). They all have ample negative residuals on the frequency regression, from –19 to –78; they have fewer medicinal uses that one would expect. Their very average number of medicinal species are only rarely utilized.

DISCUSSION

What, then is to be gained from using frequency data rather than incidence data? The answer seems to be "very little". Generally speaking there is little new information gained by adding this level of analysis.

The basic impulse to use frequency data seems to follow from an intuitive proposition that says that if a medicinal plant is useful for one group of people, it will be useful for another, and hence is likely to be used by them. This is certainly true in some cases. But it is not true in all, or even in very many. In general, it seems that there are very many species with very few uses, not shared by other groups (see Table 1). In part this may reflect the local character of floral distributions (most species in North America have relatively restricted distributions). But this cannot be all of it as there are clear counterexamples. The Flora North America Preliminary Checklist (SHETLER and SKOG, 1978) includes a distribution key based on 17 North American regions. A rough measure of the breadth of distribution of a species is the number of these regions in which it is found. Overall, for 16,270 species listed in FNA, the average number of regions per species is 3.24 (suggesting that most species have fairly restricted distributions).

Five continental species —found in all 17 regions— are used medicinally by only one tribe; no other group found these taxa useful even though they were available in their region.[2] Fifty-three species found in 10 or more North American regions, generally covering more than half of the continent, have only one use in the database. Moreover, sometimes even a taxon which seems to have broad usage really does not.

Cypripedium spp. (Lady slipper), for example, is a widely distributed, continental genus of the orchid family which is distinctive and attractive. It is used medicinally 38 ways by native Americans; but 19 of these uses are by the Cherokee and 11 are by the Iroquois. The remaining uses are scattered among various Algonquian groups (Fox, Menominee, Ojibwa, Penobscot, etc.). There is no evidence that the genus has any significant usage in the South or West even though it occurs there and is a showy and interesting taxon with significant biochemical constituents (WILLARD 1991:196-7).

Essentially, what an incidence analysis shows us is that a few species have broad usage. But that can be determined simply by listing medicinal species in terms of their frequency of use. In general, it seems more productive to rely on incidence rather than frequency. Since it is easier to know *that* a taxon has been used than how *often* it is used, this seems a congenial conclusion.

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NOTES

1. *Taxus brevifolia* has been shown to contain a substance known as taxol which is highly active against certain otherwise refractory tumors, particularly of the ovaries. Taxol is currently undergoing extensive clinical trials in the United States.

2. The five are *Descurainia sophia, Melilotus officinalis, Polypogon monspeliensis, Sisymbrium altissimum* and *Thlaspi arvense.*

Table 5
Medicinal species and medicinal uses regressed on total species

Families	Total Species	Medicinal species				Medicinal uses				Rank Difference
		Actual	Predicted	Residual	Rank	Actual	Predicted	Residual	Rank	
Rubiaceæ	145	15	17	–2	195	132	123	9	56	139
Campanulaceæ	110	11	13	–2	197	92	98	–6	69	128
Balsaminaceæ	11	2	2	–0	87	52	25	27	40	47
Phytolaccaceæ	6	1	2	–1	98	35	21	14	52	46
Ophioglossaceæ	18	1	3	–2	192	11	30	–19	150	42
Papaveraceæ	89	12	11	1	62	145	82	63	24	38
Hamamelidaceæ	4	2	2	0	70	52	20	32	33	37
Sarraceniaceæ	9	1	2	–1	102	22	23	–1	65	37
Tiliaceæ	13	2	3	–1	94	30	26	4	59	35
Zygophyllaceæ	19	4	3	1	66	64	31	33	32	34
Lauraceæ	12	4	3	1	55	100	26	74	22	33
Moringaceæ	1	0	1	–1	133	0	17	–17	104	29
Proteaceæ	1	0	1	–1	122	0	17	–17	94	28
Tropæolaceæ	1	0	1	–1	123	0	17	–17	96	27
Scheuchzeriaceæ	1	0	1	–1	124	0	17	–17	97	27
Pæoniaceæ	2	1	1	–0	85	23	18	5	58	27
Punicaceæ	1	0	1	–1	132	0	17	–17	106	26
Rafflesiaceæ	1	0	1	–1	121	0	17	–17	95	26
Typhaceæ	4	2	2	0	69	41	20	21	44	25
Theophrastaceæ	1	0	1	–1	131	0	17	–17	107	24
Aristolochiaceæ	20	6	3	3	41	136	31	105	17	24
Begoniaceæ	1	0	1	–1	129	0	17	–17	105	24
Ulmaceæ	18	5	3	2	50	88	30	58	26	24
Saururaceæ	2	2	1	1	67	41	18	23	43	24
Caricaceæ	1	0	1	–1	134	0	17	–17	111	23
Elæocarpaceæ	1	0	1	–1	130	0	17	–17	108	22
Rutaceæ	37	7	5	2	52	82	44	38	30	22
Linaceæ	35	4	5	–1	100	31	42	–11	79	21
Nyssaceæ	4	1	2	–1	91	14	20	–6	70	21
Thymelæaceæ	5	2	2	0	73	31	20	11	53	20
Apocynaceæ	35	6	5	1	61	69	42	27	41	20
Platanaceæ	4	2	2	0	68	35	20	15	50	18
Podostemaceæ	1	0	1	–1	119	0	17	–17	101	18
Musaceæ	1	0	1	–1	118	0	17	–17	100	18
Adoxaceæ	1	0	1	–1	116	0	17	–17	99	17
Goodeniaceæ	1	0	1	–1	126	0	17	–17	109	17
Hæmodoraceæ	4	1	2	–1	93	9	20	–11	76	17
Parkeriaceæ	1	0	1	–1	115	0	17	–17	98	17
Sphenocleaceæ	1	0	1	–1	120	0	17	–17	103	17
Araceæ	16	8	3	5	24	286	28	258	8	16
Bixaceæ	1	0	1	–1	128	0	17	–17	112	16
Crossosomataceæ	3	0	2	–2	160	0	19	–19	145	15
Pedaliaceæ	2	0	1	–1	143	0	18	–18	128	15
Mayacaceæ	2	0	1	–1	148	0	18	–18	133	15
Lennoaceæ	2	0	1	–1	142	0	18	–18	127	15
Azollaceæ	3	0	2	–2	154	0	19	–19	139	15
Marantaceæ	3	0	2	–2	159	0	19	–19	144	15
Trapaceæ	1	0	1	–1	125	0	17	–17	110	15

Table 5 *(Continued)*
Medicinal species and medicinal uses regressed on total species

Families	Total Species	Medicinal species				Medicinal uses				Rank Difference
		Actual	Predicted	Residual	Rank	Actual	Predicted	Residual	Rank	
Casuarinaceæ	3	0	2	–2	153	0	19	–19	138	15
Salviniaceæ	1	0	1	–1	117	0	17	–17	102	15
Basellaceæ	3	0	2	–2	158	0	19	–19	143	15
Flacourtiaceæ	2	0	1	–1	147	0	18	–18	132	15
Araliaceæ	10	8	2	6	23	272	24	248	9	14
Aponogetonaceæ	1	0	1	–1	127	0	17	–17	113	14
Ebenaceæ	2	1	1	–0	83	12	18	–6	71	12
Vitaceæ	34	7	5	2	47	72	42	30	35	12
Limnanthaceæ	2	0	1	–1	146	0	18	–18	134	12
Hydrocharitaceæ	14	0	3	–3	202	0	27	–27	190	12
Lemnaceæ	14	0	3	–3	201	0	27	–27	189	12
Zannichelliaceæ	4	0	2	–2	165	0	20	–20	153	12
Annonaceæ	15	0	3	–3	203	0	28	–28	192	11
Anacardiaceæ	27	9	4	5	27	157	37	120	16	11
Krameriaceæ	5	0	2	–2	175	0	20	–20	164	11
Burmanniaceæ	5	0	2	–2	173	0	20	–20	162	11
Passifloraceæ	15	1	3	–2	180	7	28	–21	169	11
Juncaginaceæ	5	0	2	–2	174	0	20	–20	163	11
Sapotaceæ	16	0	3	–3	205	0	28	–28	194	11
Nymphæaceæ	16	4	3	1	57	47	28	19	46	11
Callitrichaceæ	12	0	3	–3	198	0	26	–26	188	10
Cyrillaceæ	4	0	2	–2	164	0	20	–20	154	10
Chrysobalanaceæ	2	0	1	–1	141	0	18	–18	131	10
Olacaceæ	3	0	2	–2	151	0	19	–19	141	1
Canellaceæ	2	0	1	–1	140	0	18	–18	130	10
Hippuridaceæ	3	0	2	–2	150	0	19	–19	140	10
Cochlospermaceæ	3	0	2	–2	152	0	19	–19	142	10
Myricaceæ	8	3	2	1	59	39	23	16	49	10
Butomaceæ	2	0	1	–1	139	0	18	–18	129	10
Burseraceæ	3	0	2	–2	156	0	19	–19	147	9
Cannaceæ	3	0	2	–2	157	0	19	–19	148	9
Illiciaceæ	2	0	1	–1	145	0	18	–18	136	9
Frankeniaceæ	3	0	2	–2	155	0	19	–19	146	9
Malpighiaceæ	10	0	2	–2	194	0	24	–24	185	9
Moraceæ	19	5	3	2	51	56	31	25	42	9
Simaroubaceæ	7	0	2	–2	183	0	22	–22	174	9
Ceratophyllaceæ	2	0	1	–1	144	0	18	–18	135	9
Menyanthaceæ	4	0	2	–2	166	0	20	–20	157	9
Celastraceæ	28	7	4	3	40	74	37	37	31	9
Resedaceæ	5	0	2	–2	169	0	20	–20	161	8
Cupressaceæ	27	15	4	11	14	334	37	297	6	8
Arecaceæ	17	0	3	–3	207	0	29	–29	199	8
Najadaceæ	7	0	2	–2	182	0	22	–22	175	7
Eriocaulaceæ	10	0	2	–2	193	0	24	–24	186	7
Agavaceæ	86	0	11	–11	227	0	80	–80	220	7
Elatinaceæ	9	0	2	–2	190	0	23	–23	183	7
Hydrophyllaceæ	183	12	22	–10	225	77	151	–74	218	7
Isoetaceæ	17	0	3	–3	208	0	29	–29	201	7

Table 5 *(Continued)*
Medicinal species and medicinal uses regressed on total species

Families	*Total Species*	*Medicinal species*				*Medicinal uses*				*Rank Difference*
		Actual	*Predicted*	*Residual*	*Rank*	*Actual*	*Predicted*	*Residual*	*Rank*	
Theaceæ	4	0	2	–2	163	0	20	–20	156	7
Urticaceæ	17	7	3	4	32	92	29	63	25	7
Polygalaceæ	47	6	6	–0	88	38	51	–13	81	7
Acanthaceæ	65	0	8	–8	223	0	65	–65	216	7
Myrsinaceæ	4	0	2	–2	162	0	20	–20	155	7
Clethraceæ	2	1	1	–0	84	7	18	–11	77	7
Selaginellaceæ	30	0	5	–5	216	0	39	–39	210	6
Buddlejaceæ	8	0	2	–2	186	0	23	–23	180	6
Molluginaceæ	5	0	2	–2	172	0	20	–20	166	6
Marsileaceæ	6	0	2	–2	178	0	21	–21	172	6
Juncaceæ	123	4	15	–11	228	17	107	–90	222	6
Loasaceæ	51	4	7	–3	204	25	54	–29	198	6
Plantaginaceæ	28	8	4	4	33	95	37	58	27	6
Aizoaceæ	17	0	3	–3	206	0	29	–29	200	6
Hymenophyllaceæ	7	0	2	–2	181	0	22	–22	176	5
Taxaceæ	5	3	2	1	56	35	20	15	51	5
Myrtaceæ	27	0	4	–4	214	0	37	–37	209	5
Tamaricaceæ	5	0	2	–2	170	0	20	–20	165	5
Bignoniaceæ	14	1	3	–2	176	6	27	–21	171	5
Styracaceæ	8	0	2	–2	187	0	23	–23	182	5
Piperaceæ	6	0	2	–2	177	0	21	–21	173	4
Schizæaceæ	5	0	2	–2	171	0	20	–20	167	4
Hypoxidaceæ	8	0	2	–2	185	0	23	–23	181	4
Lentibulariaceæ	21	0	4	–4	210	0	32	–32	206	4
Ephedraceæ	9	5	2	3	38	54	23	31	34	4
Meliaceæ	3	1	2	–1	89	3	19	–16	85	4
Zosteraceæ	46	2	6	4	215	4	51	–47	212	3
Taxodiaceæ	5	1	2	–1	95	3	20	–17	92	3
Amaryllidaceæ	37	2	5	–3	209	11	44	–33	207	2
Juglandaceæ	25	9	4	5	25	101	35	66	23	2
Pinaceæ	71	35	9	26	5	635	69	566	3	2
Amaranthaceæ	74	4	9	–5	217	12	71	–59	215	2
Staphyleaceæ	2	1	1	–0	82	6	18	–12	80	2
Euphorbiaceæ	264	23	31	–8	222	130	211	–81	221	1
Liliaceæ	393	67	45	22	8	580	306	274	7	1
Caryophyllaceæ	287	22	33	–11	229	48	228	–180	228	1
Cornaceæ	17	12	3	9	16	152	29	123	15	1
Caprifoliaceæ	77	35	10	25	6	404	73	331	5	1
Solanaceæ	129	28	16	12	13	269	112	157	13	0
Cyperaceæ	718	22	81	–59	231	43	545	–502	231	0
Turneraceæ	3	0	2	–2	149	0	19	–19	149	0
Asteraceæ	2231	345	250	95	1	2522	1657	865	1	0
Rosaceæ	577	115	66	49	2	1038	441	597	2	0
Crassulaceæ	85	7	11	–4	211	36	79	–43	211	0
Boraginaceæ	304	25	35	–10	226	98	240	–142	226	0
Pilulariaceæ	1	0	1	–1	114	0	17	–17	114	0
Poaceæ	1477	37	166	–129	232	107	1102	–995	232	0
Fabaceæ	1225	108	138	–30	230	503	917	–414	230	0

Table 5 *(Continued)*
Medicinal species and medicinal uses regressed on total species

Families	Total Species	Medicinal species				Medicinal uses				Rank Difference
		Actual	Predicted	Residual	Rank	Actual	Predicted	Residual	Rank	
Buxaceæ	2	1	1	–0	86	2	18	–16	86	0
Combretaceæ	5	0	2	–2	168	0	20	–20	168	0
Lamiaceæ	320	64	37	27	3	645	252	393	4	–1
Portulacaceæ	85	7	11	–4	212	27	79	–52	213	–1
Apiaceæ	319	58	37	21	9	457	251	206	10	–1
Aquifoliaceæ	17	4	3	1	60	31	29	2	61	–1
Corylaceæ	33	21	5	16	10	204	41	163	11	–1
Xyridaceæ	17	1	3	–2	189	2	29	–27	191	–2
Elæagnaceæ	8	3	2	1	58	26	23	3	60	–2
Rhamnaceæ	80	15	10	5	26	132	76	56	28	–2
Berberidaceæ	29	12	4	8	19	121	38	83	21	–2
Pyrolaceæ	27	12	4	8	18	132	37	95	20	–2
Scrophulariaceæ	632	63	72	–9	224	324	481	–157	227	–3
Fagaceæ	140	26	17	9	15	221	120	101	18	–3
Cactaceæ	180	14	21	–7	221	39	149	–110	225	–4
Convolvulaceæ	125	11	15	–4	213	43	109	–66	217	–4
Malvaceæ	213	19	25	–6	219	79	173	–94	224	–5
Onagraceæ	247	23	29	–6	218	106	198	–92	223	–5
Sterculiaceæ	17	1	3	–2	188	1	29	–28	193	–5
Salicaceæ	131	40	16	24	7	272	113	159	12	–5
Capparidaceæ	30	2	5	–3	199	7	39	–32	205	–6
Phrymaceæ	1	1	1	–0	78	2	17	–15	84	–6
Sapindaceæ	18	1	3	–2	191	1	30	–29	197	–6
Equisetaceæ	16	7	3	4	31	58	28	30	38	–7
Asclepiadaceæ	97	18	12	6	22	128	88	40	29	–7
Ericaceæ	180	36	21	15	12	245	149	96	19	–7
Menispermaceæ	5	2	2	0	71	9	20	–11	78	–7
Haloragaceæ	15	1	3	–2	179	3	28	–25	187	–8
Symplocaceæ	1	1	1	–0	79	1	17	–16	87	–8
Bromeliaceæ	20	1	3	–2	196	1	31	–30	204	–8
Fouquieriaceæ	1	1	1	–0	80	1	17	–16	88	–8
Cistaceæ	31	2	5	–3	200	4	40	–36	208	–8
Datiscaceæ	1	1	1	–0	81	1	17	–16	89	–8
Alismataceæ	24	4	4	0	74	21	34	–13	82	–8
Zingiberaceæ	1	0	1	–1	106	0	17	–17	115	–9
Myoporaceæ	1	0	1	–1	112	0	17	–17	121	–9
Iridaceæ	81	13	10	3	39	93	76	17	48	–9
Schisandraceæ	1	0	1	–1	113	0	17	–17	122	–9
Calyceraceæ	1	0	1	–1	107	0	17	–17	116	–9
Brassicaceæ	510	52	58	–6	220	195	392	–197	229	–9
Magnoliaceæ	9	5	2	3	37	41	23	18	47	–10
Ranunculaceæ	294	60	34	26	4	384	233	151	14	–10
Osmundaceæ	3	3	2	1	53	20	19	1	64	–11
Martyniaceæ	5	2	2	0	72	7	20	–13	83	–11
Hippocrateaceæ	1	0	1	–1	105	0	17	–17	117	–12
Valerianaceæ	30	7	5	2	42	49	39	10	54	–12
Bataceæ	1	0	1	–1	108	0	17	–17	120	–12
Achatocarpaceæ	1	0	1	–1	111	0	17	–17	123	–12

Table 5 *(Continued)*
Medicinal species and medicinal uses regressed on total species

Families	Total Species	Medicinal species				Medicinal uses				Rank Difference
		Actual	Predicted	Residual	Rank	Actual	Predicted	Residual	Rank	
Hippocastanaceæ	9	4	2	2	49	25	23	2	62	–13
Loganiaceæ	9	2	2	–0	77	6	23	–17	91	–14
Leitneriaceæ	1	0	1	–1	109	0	17	–17	124	–15
Stemonaceæ	1	0	1	–1	110	0	17	–17	125	–15
Cycadaceæ	1	0	1	–1	103	0	17	–17	118	–15
Rhizophoraceæ	1	0	1	–1	104	0	17	–17	119	–15
Polygonaceæ	413	54	47	7	21	350	320	30	37	–16
Aceraceæ	15	10	3	7	20	58	28	30	36	–16
Cucurbitaceæ	47	11	6	5	28	72	51	21	45	–17
Clusiaceæ	50	9	7	2	44	55	53	2	63	–19
Oleaceæ	50	10	7	3	35	63	53	10	55	–20
Oxalidaceæ	25	6	4	2	46	32	35	–3	66	–20
Calycanthaceæ	3	3	2	1	54	9	19	–10	75	–21
Polypodiaceæ	215	33	25	8	17	204	175	29	39	–22
Geraniaceæ	51	9	7	2	45	49	54	–5	68	–23
Garryaceæ	10	1	2	–1	135	4	24	–20	158	–23
Sparganiaceæ	12	1	3	–2	161	2	26	–24	184	–23
Santalaceæ	5	4	2	2	43	17	20	–3	67	–24
Lycopodiaceæ	17	5	3	2	48	20	29	–9	73	–25
Loranthaceæ	16	7	3	4	30	34	28	6	57	–27
Primulaceæ	79	8	10	–2	184	20	75	–55	214	–30
Diapensiaceæ	4	1	2	–1	92	2	20	–18	126	–34
Commelinaceæ	40	4	6	–2	167	16	46	–30	203	–36
Violaceæ	84	14	11	3	34	69	78	–9	74	–40
Dioscoreaceæ	5	1	2	–1	96	2	20	–18	137	–41
Dipsacaceæ	10	1	2	–1	137	2	24	–22	178	–41
Droseraceæ	10	1	2	–1	136	2	24	–22	177	–41
Melastomataceæ	10	1	2	–1	138	2	24	–22	179	–41
Plumbaginaceæ	9	1	2	–1	101	4	23	–19	151	–50
Gentianaceæ	89	14	11	3	36	65	82	–17	90	–54
Saxifragaceæ	260	46	30	16	11	200	208	–8	72	–61
Empetraceæ	6	1	2	–1	97	1	21	–20	159	–62
Nyctaginaceæ	103	17	13	4	29	75	92	–17	93	–64
Pontederiaceæ	9	2	2	–0	76	3	23	–20	160	–84
Orchidaceæ	171	21	20	1	65	123	142	–19	152	–87
Lythraceæ	25	3	4	–1	99	5	35	–30	202	–103
Orobanchaceæ	18	4	3	1	63	9	30	–21	170	–107
Chenopodiaceæ	151	18	18	–0	75	99	128	–29	195	–120
Polemoniaceæ	237	27	28	–1	90	113	191	–78	219	–129
Verbenaceæ	90	12	11	1	64	54	83	–29	196	–132