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Qualitative Studies in Angiosperm Taxonomy VI. Potentilla VI I. Pedicularis

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Qualitative Studies in Angiosperm Taxonomy VI. *Potentilla* VII. *Pedicularis*[1]

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Abstract. A type of quantitative approach is applied to the description of variation within and between mass collections of two angiosprem genera in the central Rocky Mountains. No taxonomic status changes are suggested. These studies are preliminary and suggest a means of approaching a more objective taxonomy.

Certain quantitative or quasi-quantitative methods have been applied to the taxonomic descriptions of individuals and taxa for many years. Only recently, however, have attempts been made to develop completely numerical (arithmetic or statistical) methods for the objective definition and classification of taxa. These quantitative approaches have now been attempted in many areas, mostly zoological. Some of the recent studies in botanical fields are those by Sneath (1961), Rogers and Tanimoto (1961), and Soria and Heiser (1961), on bacteria, *Manihot*, and *Solanum*, respectively. Some of those in zoological areas are those of Ginsberg (1938, 1954) on fish, Michener and Sokal (1961) on insects, and Hudson *et al.* (1959) on birds.

These approaches are designed to cope with our increasing ability to accumulate large quantities of a variety of kinds of data. There appears to be increasing realization by some investigators that it may be

possible to replace our "intuitive" decisions by more logical devices. The present paper, one of a series[3], is an attempt to illustrate a numerical approach which may establish angiosperm taxonomy, on subgeneric levels, upon a more operational (repeatable) basis. The methods used in the descriptive analyses here described have been developed with the aid of many students. These techniques have been described and justified in detail in other papers (see Russell 1961a, 1961b, especially).

Prior to presenting a detailed outline of the methods of measurement and analysis, it is necessary to discuss two of the criteria or principles followed in the studies. First, the data are not deliberately weighted according to any set of biological criteria. The two criteria or sets of criteria most used today in organismic taxonomy for the weighting of data are "evolutionary relationships" and "genetic relationships". In our studies we were

[1] This research was supported in large part by grants from the National Science Foundation.

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unable to measure or define these relationships quantitatively; as a matter of fact we were unable to observe them directly. We dealt only with differences, choosing as many as we could analyze without the use of computer facilities. Though so-called "similarity" indices may be derived from our data, we have instead developed a technique for generating "difference" indices.

Second, we refer to the groups of individuals studied as "mass collections" or "samples", not as "population samples". The term "population" ordinarily connotes a breeding unit or deme, and we were unable to recognize the limits of such demes in the field. Indeed, the actual existence of breeding populations in nature has rarely been demonstrated. In the laboratory, and then only with extremely constant and careful observation, may one be justified in the use of the concept of an inter-breeding population. Like the species concept (or category) the deme concept is a hypothetical model which is difficult, if not actually impossible to demonstrate in an operational manner. Our approach to our "samples" has been to carefully define both the physical area of sampling and the method of sampling in each case. In this paper we are able to give only a summary of our sampling data. Duplicated copies of the complete sampling data and all the measurement and scales may be obtained from the author on request.

General Procedure

Our policy was to study as many plants from as many locations for as many differing characteristics as possible. We considered that measurements on living or freshly picked plants were most desirable; all those referred to in the two studies reported upon here were made on freshly collected specimens. All specimens were later pressed and are stored in my private herbarium.

Before actual measurements were begun the plants under study were carefully observed in the field, and all morphological characteristics showing measurable inter-plant differences were listed. From this preliminary list, approximately 25 properties were chosen, these being the ones that differed most obviously from plant to plant. Next, collections were made in areas where the particular plants could be found; these were primarily in the vicinity of Gothic, Gunnison County, Colorado. The studies here reported upon were made during the summer of 1961, while I was an instructor at the Rocky Mountain Biological Laboratory.

Particular measurements or scores were obtained for the plants of each mass collection, as indicated below. Next the

[3] Other papers prepared in this series are Russell, 1961b, Russell and Crosswhite in press, Russell and Clark in press, Russell and Kalil in press, and Russell in press, a)

ranges of the measurements of each character for each collection were plotted and compared between collections. From these ranges an index was prepared for purposes of totaling the differences and comparing each collection with each of the others. The method of indexing, at this stage, differed in the two studies, as will be pointed out. Basically it consisted in using characteristics common to two collections, where the range could be separated into two portions, one with over half the measurements of one collection and the other portion with more than half the plants of the second collection. A value of O was given to portions of ranges characteristic of one of the collections, chosen arbitrarily, and a value of 2 to the other. This method of totalling differences was originally devised by Anderson (1936) and has been widely used in studies of presumed hybridization.

After scoring is completed for the plants of the collections being compared, the values are totaled so that each plant is represented by a total score or index. The value of this index will vary from O to 2X the number of characteristics used. The distributions of the index scores are next plotted for each of the collections and may then be compared to determine the total difference in the characteristics used between the two collections. These may be used for the comparison of two distribution ranges or curves. In our studies we have devised a rough, arithmetical method, which we believe more adequately describes each curve in relation to the other. Two descriptions are made, one for each of the two index distributions. Four properties of each curve, each a consequence of the other curve, are described (Figure 1).

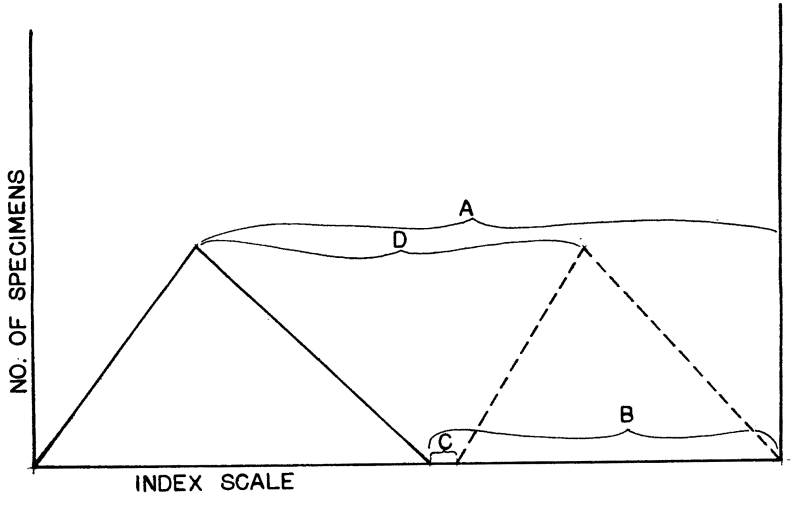

Figure 1. A pair of distribution curves, indicating the four percentage measurements made. See text for further explanation.

They are:

1. Percentage of the portion of the total scale (common to the two collections) from the mode of one range to the scale extreme characteristic of the other collection.
2. Percentage of the scale not covered by the collection distribution.
3. Percentage of the scale not occupied by either distribution (plus value) or occupied by both (minus value).
4. Percentage of the scale between the modes of the two collections.

The four percentage figures thus obtained (for each collection) may then be added to obtain a single figure we have called the "total difference index". These final indices may be arranged in matrices when all possible collection pair comparisons have been completed. Any particular collection may be numerically defined with reference to the other collections by its total difference indices. In the concluding portion of this paper we will consider possibilities for further taxonomic uses of these matrices.

VI. Morphological Variation in Potentilla (Rosaceae)

Potentilla, the genus of Cinquefoils (Rose Family), has approximately 300 species (Willis, 1948), of which a considerable number are found in the Rocky Mountains. Kearney and Peebles (1960), list 22 for Arizona, Munz (1959) lists 29 for California, and Harrington (1954), describes 27 in Colorado. Although some of these species seem to be morphologically distinct and nonvariant, others are extremely variable. One such variable species is *Potentilla pulcherrima Lehm.* In the immediate area of Gothic, Colorado, plants which key out to this species are very abundant on open slopes. Many specimens fit the keys and descriptions imperfectly, due to considerable morphological diversity. A student, Mr. Jon Reiskind[4], chose to investigate and describe the extent of this diversity during the summer of 1961. The purpose of his study was to describe the nature of several of the local stands of this *Potentilla* in a way which would enable quantitative comparison of them with similar studies in other genera which exhibited more or less morphological diversity. His studies were preliminary and will be continued and expanded in the future by the author of this paper and other students.

In making his collections and choosing measurable differences he followed the general procedure described in the introductory part of this paper. He obtained four samples in the neighborhood of the Laboratory. Brief descriptions of the areas of collection follow.

Collection 61A—One mile south of Gothic, 8 miles north of Crested Butte, Gunnison County, Colorado. J. Reis-

kind, July 9, 1961. Open, sandy, dry gradual north-facing slope just south of bridge over Copper Creek. Elev. 9300'.

Collection 61B—One mile north of Gothic, Colorado. Between dirt road (to Emerald Lake) and East River on 10°, west-facing slope. Open, sandy, relatively damp habitat with some willows near base of slope. J. Reiskind July 13, 1961. Elev. 9700'.

Collection 61C—South slope of Belleview Mountain on open, relatively barren, steep talus slope. Seven miles north of Gothic. Elevation between 11,000 and 11,500 feet. July 14, 1961. J. Reiskind.

Collection 61D—On laboratory grounds, Gothic, Colorado. Open, rocky 30° south-facing slope between the Mammalogy Laboratory and a dirt road at the base of the slope. July 18, 1961. J. Reiskind. Elev. 9500'.

The characteristics measured or scored, after a careful examination of plants from these and other areas, were as follows:

1. Number of flowering stalks.
2. Number of basal leaves (arising from rootstock).
3. Height (to closest centimeter) of tallest flowering stalk.
4. Number of internodes on this stalk from base to inflorescience.
5. Length of the first internode at the base of this stalk.
6. Amount of pubescence, scored as O-none, 1-slight, 2-medium, and 3-heavy.
   a. On stalk.
   b. On largest basal leaf
7. Color of spot at base of petal. O-no orange, 1-small or faint orange tinge, 2-medium orange pigmentation.
8. Number of leaflets of largest basal leaf.
9. Number of lobes in right half of largest leaflet, not counting the tip of the leaflet as a lobe.
10. Length of largest leaflet.
11. Breadth of largest leaflet.
12. Breadth betwen sinuses of leaflet at widest part.
13. Length of petiole of largest leaf.
14. Diameter of largest open flower.
15. Length of a petal of this flower.
16. Breadth of this petal.
17. Number of sepals for this flower.
18. Stem color: p-green, 1-slightly red, 2-medium red, 3-dark red.
19. Diameter of flower stalk 10 cm. from the rootstock.

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20. Length of second internode above rootstock.

Ratios computed from above raw measurements:

10/13, 11/10, 10/9, 16/15, 3/5, 12/11.

Each of the six possible comparisons was made among the four collections by setting up separate scales for comparison. These were based, in each case, on characteristics in which the collections being compared differed. Characteristics in which the samples appeared virtually identical were not used. *Table 1* is the scale used in the comparison between collection 61 C and collection 61D; in this instance the collections were found to differ in 14 of the measured characteristics and 3 of the computed ratios, so that any particular plant might have an index value varying between O and 34. Actual extremes found in this comparison were from 2 through 30.

Table 1. Scale prepared for the comparison between collections 61-C and 61-D of *Potentilla*. See text for explanation of characters, represented here by numbers.

	Ranges	
Character	61-C (value 0)	61-D (value 2)
2	4-7	0-3
3	16-42.0	42.1-81.0
4	2-3	4-5
5	12-77	78-175
7	0	1-2
8	5-6	7-9
9	4-9	10-17
10	20-45	46-82
11	11-16	17-29
12	4-10	11-19
13	25-113	114-245
18	2-3	0-1
19	1-2	2.5-4
20	5-20	21-32
Ratios		
11/10	.386-.583	.253-.385
10/9	4.56-8.00	3.07-4.55
12/11	.250-.6105	.611-.765

The distributions of index scores for the two collections are plotted on the same graph in *Figure 2*. These distributions were described, using the four criteria listed earlier in this paper, with the following formulae being obtained:

C – 43/71/-11/57 - D

D – 50/86/-11/57 – C

Adding these we obtain the following "total difference indices":

C – 160 – D

D – 182 – C

This procedure was followed for each of the six possible comparisons, and the twelve resultant indices are plotted in *Table 2* in the form of a full matrix. Some methods for illustrating and

utilizing these indices will be discussed in the concluding remarks of this paper. They represent an attempt to operationally

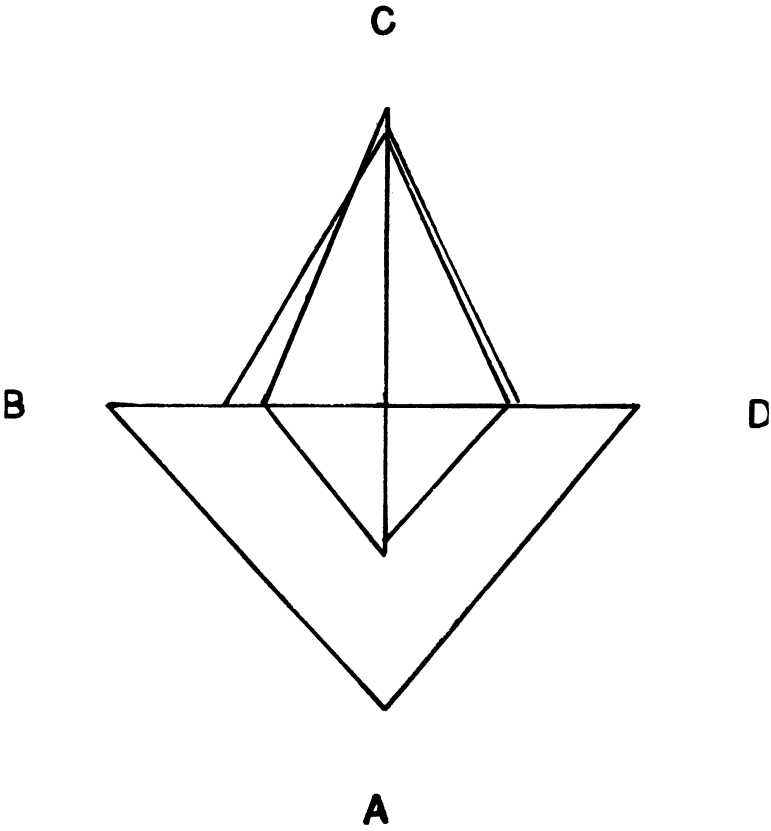

Figure 2. Matrix of total difference indices plotted for *Potentilla*.

(sensu modern physics – see Bridgman, 1936) and numerically define the "total morphological nature" of each sample with respect to the others with which it has been compared.

Table 2. Matrix of total difference indices for *Potentilla* collections.

	A	B	C	D
A	x	104	177	84
B	88	x	174	80
C	192	174	x	160
D	95	76	182	x

VII. *Morphological Variation in Pedicularis* (*Scrophulariaceae*)

Pedicularis (Louseworts, Figwort Family) is a large genus, consisting of about 275 species (Willis, 1948), most varied in eastern Asia and South America. Relatively few species are found in western United States. There are said to be 5 in Arizona (Kearney and Peebles, 1960), 10 in California (Munz, 1959),

and 9 in Colorado (Harrington, 1954). In the immediate area about Gothic, Colorado, where the collections to be reported upon were made, three kinds of *Pedicularis* are rather frequent and offer little difficulty in identification; i. e. there is apparently no marked overlap in characteristics used in taxonomic keys. In the present study, made by Miss Linda Carr[5], five collections were made, two of *Pedicularis paysoniana* Pennell (A-1 and A-2), two of *P. racemosa* Dougl. (B-1 and B-2), and one of *P. grayi* A. Nels (C-1). The habitats and locations for each sample may be summarized as follows:

Collection A—1—¼ mile south of Gothic, 9 miles north of Crested Butte, Gunnison County, Colorado. L. Carr, July 5, 1961. Along roadside ditch in shade of shrubby willows and associated with umbellifers. Soil moist to wet. Elev. 9500′.

Collection B—1—3 miles north of Gothic Colorado. L. Carr, July 12, 1961. Meadow in spruce-fir forest area along border. Growing with *P. racemosa*. Soil sandy. Elev. 9700′.

Collection B—1—3 miles north of Gothic Colorado. L. Carr, July 19, 1961. Location same as Collection A—2.

Collection B—2—Fremont Pass, Colorado, L. Carr, July 25, 1961. Open areas in spruce-fir forest. Elev. 10,500′.

Collection C—1—¼ mile north of Gothic, Colorado. L. Carr, July 19, 1961. Roadside bank, shaded by aspens. Small dense colony. Elev. 9600′.

The characteristics chosen for measurement or scoring on all plants were as follows:

1. Length of the calyx of the largest open flower.
2. Length of the longest calyx tooth of this flower.
3. Length of the corolla of this flower.
4. Length of the galea of this flower.
5. Shape of the galea of this flower (arbitrary scale, values 1 through 3).
6. Color of this flower corolla (arbitrary scale, values 1 through 3).
7. Pubescence of the inflorescence (arbitrary scale, value 0 through 4).
8. Length of the inflorescence.
9. Total height of the tallest flowering stalk.
10. Number of leaves of this flowering stalk.
11. Length of the lowest internode of this flower stalk.
12. Length of the second internode from the base.
13. Length of the third internode from the base.
14. Length of the fourth internode from the base.

[5] Department of Zoology, Butler University, Indianapolis, Ind.

15. a. Length of the lowermost leaf on the flower stalk.
b. Breadth of this leaf.
16. Length of the petiole of this leaf.
Ratios computed:
15a/15b, 9/11 1/2 3/4, 9/10, 9/8.

Plants of each of the five collections were measured and ranges of the measurements plotted. In comparing the total differences of the collections, a procedure was followed that differs somewhat from that used for *Potentilla*. In the present study the measurements were combined for the two samples of *Pedicularis paysoniana* (A-1 and A-2) and for the two samples of *P. racemosa* (B-1 and B-2). Then three scales for comparison were set up: between A and B, between A and C, and between B and C. The scale for the comparison between A collections and the collection C-1 is given in *Table 3*.

Table 3. Scale prepared for the comparisons between *Pedicularis* collections A and C. See text for explanation of characters represented here by numbers.

Character	Ranges A (value 0)	C (value 2)
1	4.5-11.9	12.0-19.4
3	10.5-24.8	24.9-34.5
4	5-9	10-30
6	2	3
7	4-	1-3
8	25-184	185-424
9	214-787	788-1034
10	3.5-8.4	8.5-20.9
13	43.5-141.4	1.5-43.4
14	.5-46.6	46.7-154.4
15	42.5-215.6	215.7-475.4
16	4.5-98.9	99.0-193.4
Ratios		
15a/15b	0.5-1.7	1.8-4.3
9/11	4.5-18.5	18.6-117.2
1/2	.5-1.9	2.0-3.4
3/4	3.0-4.4	1.5-2.9
9/10	91.9-145.4	11.5-91.8
9/8	4.6-11.5	1.6-4.5

After the collections had been indexed, separately for each comparison, ranges of the index values were prepared and compared, using the four criteria previously described. As an example the percentages obtained for the comparisons between B and C were:

B–1 – 100/82/55/100 – C–1
C–1 – 100/70/55/100 – B–1
B–2 – 97/70/42/97 – C–1
C–1 – 100/70/42/97 – B–2

When these are added the following "total difference indices" are obtained:

B–1 – 337 – C–1
C–1 – 325 – B–1
B–2 – 306 – C–1
C–1 – 309 – B–2

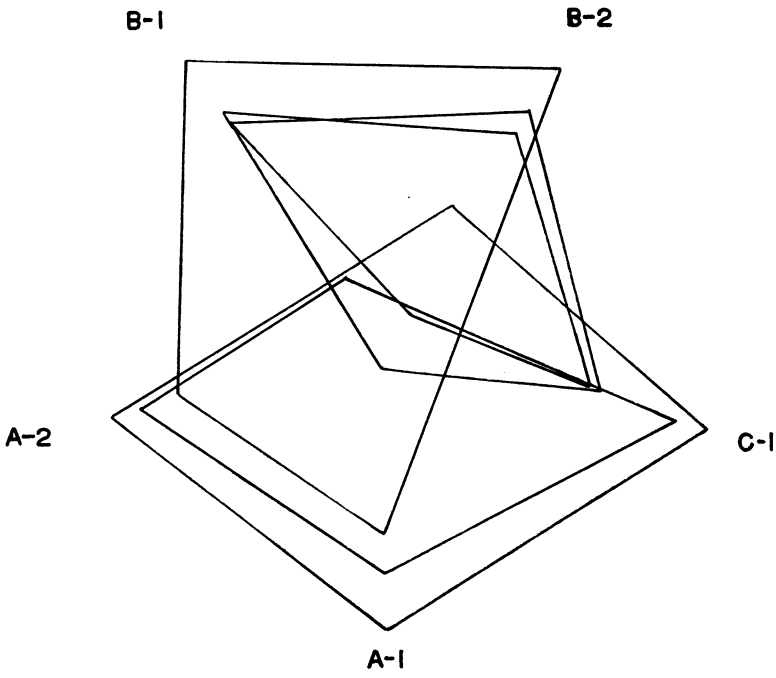

Figure 3. Matrix of total difference indices plotted for *Pedicularis*.

The matrix prepared from results of all possible comparisons is given in *Table 4.*

Table 4. Matrix table of total difference indices for *Pedicularis* collections.

	A-1	A-2	B-1	B-2	C-1
A-1	x	-21	261	232	213
A-2	43	x	254	258	226
B-1	299	280	x	140	337
B-2	242	258	60	x	306
C-1	206	213	325	309	x

Discussion

The total difference indices presented in the matrices for each study may be illustrated in several ways. Two methods are utilized here. They point up the overall differences among the samples and between the total variation patterns in the samples of the two genera studied. In Figures 2 and 3 the total difference indices were plotted on polar coordinate graph paper. Each radius represents the possible 400% scale of comparison for one of the collections. The inclosed polygons have been prepared by con-

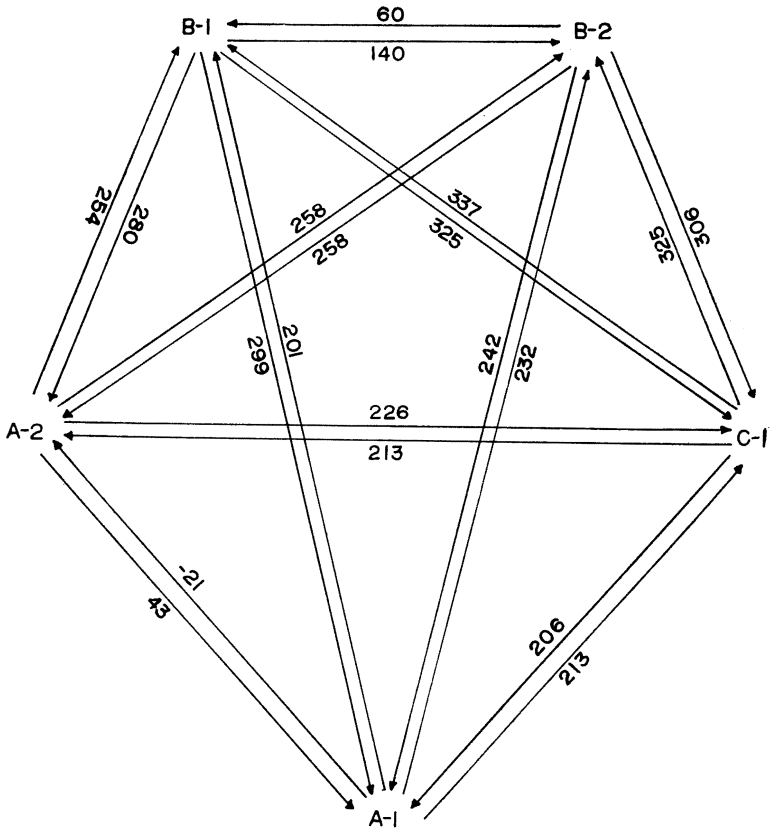

Figure 4. Matrix of total difference indices plotted for *Pedicularis*.

necting the points between each of the possible comparisons with other collections and are "open" facing the collection they describe. We may note that in *Potentilla* three of the collections have very similar patterns, while the fourth, obtained at a considerably higher elevation, differs markedly from the other three. In *Pedicularis* three patterns (A, B, and C collections) are distinguishable. Another method of illustration of the index data is shown in Figure 4, where the indices for and "from" each collection are shown in two dimensions. Obviously this is inadequate to reveal all the mathematical relations, for we would require four linear dimensions for this. The matrices represent a multi-dimensional way of defining particular collections.

I can, at present, suggest no way of treating these data taxonomically to obtain "species" or "subspecies" definitions. Although a number of possibilities exist, I feel that, until more such comparisons are available, it would be unwise to attempt to fit the data into old, poorly defined, taxonomic models (such as the

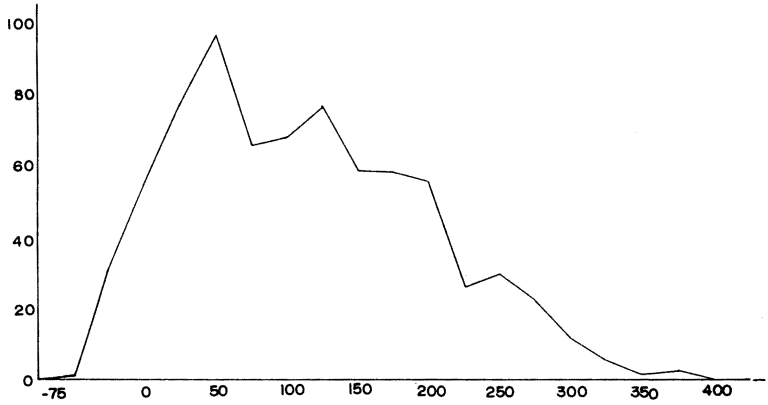

Figure 5. Distribution of the total difference indices obtained in 744 comparisons in various angiosperm genera.

species concept) or to attempt the construction of new, more logical models. The 32 total difference indices obtained in the present studies have been added to those my students and I have obtained in other studies and, in Figure 5, all these (744) are plotted. There appears to be little suggestion of natural taxonomic categories in nature from this distribution, but the sample is still minute, and the addition of more comparisons may reveal these categories (Russell, in press, b). If it does, we may use their boundaries; if it does not, the application of proper mathematical criteria would be appropriate.

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Notes on Iowa Diatoms I. An Interesting Collection from a Moss-Lichen Habitat[1]

JOHN D. DODD[2] AND EUGENE F. STOERMER[2]

Abstract. A diatom flora associated with a lichen (*Collema* sp.) and various mosses on a sandstone outcrop in Boone County, Iowa, is analyzed. Species rated "common in collection", are *Melosira roseana* Rabh., *Pinnularia lata* Breb., *Navicula gibbula* Cleve, *Navicula mutica* Kutz., *N. mutica*, var. *Cohnii* (Hilse) Grun., *Navicula contenta* var. *biceps* Arnott, *Achnanthes* (*Achnanthidium*) *coarctata* Breb., and *Hantzschia amphioxys* (Ehr.) Grun. Less common species are *Hantzschia amphioxys var. major* Grun., *Caloneis bacillum* (Grun.) Meresch, *Neidium knuthii*, var. *heilprinensis* Foged, *Navicula mutica* var. nivalis (Ehr.) Hustedt, and *Navicula fritschii* Lund. The occurrence of several isolated valves of *Hantzschia* possessing numerous spines is noted.

In 1960, a project entitled, "Ecology of Diatoms in Hardwater Habitats", was initiated under the general supervision of the senior author. This project has three phases: 1. An investigation of the diatoms of Lake Okoboji, Iowa, involving a comparison of the modern flora with the fossil flora found in post glacial sediments.

2. An investigation of the diatoms of the Des Moines River involving possible correllations between species composition and various environmental factors.

3. An investigation of the diatoms occurring in farm ponds with

[1] The project of which this investigation is a part receives support from the National Institutes of Health, Division of Water Supply and Pollution Control.
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