THE POLYGONAL GRAPH FOR SIMULTANEOUS PORTRAYAL OF SEVERAL VARIABLES IN POPULATION ANALYSIS

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Hutchinson (1936) described the polygonal graph as a means of portraying various related data. While he used this method to depict relationships in a few angiospermous families, no analytical use was made of the method. A later paper (1940) was restricted to the ecological applications of the technique, and the method of comparing climatic zones could well be adapted to the comparison of plant populations (figs. 4, 5, 6). The polygonal graph may serve also as a convenient and useful taxonomic technique in population analysis.

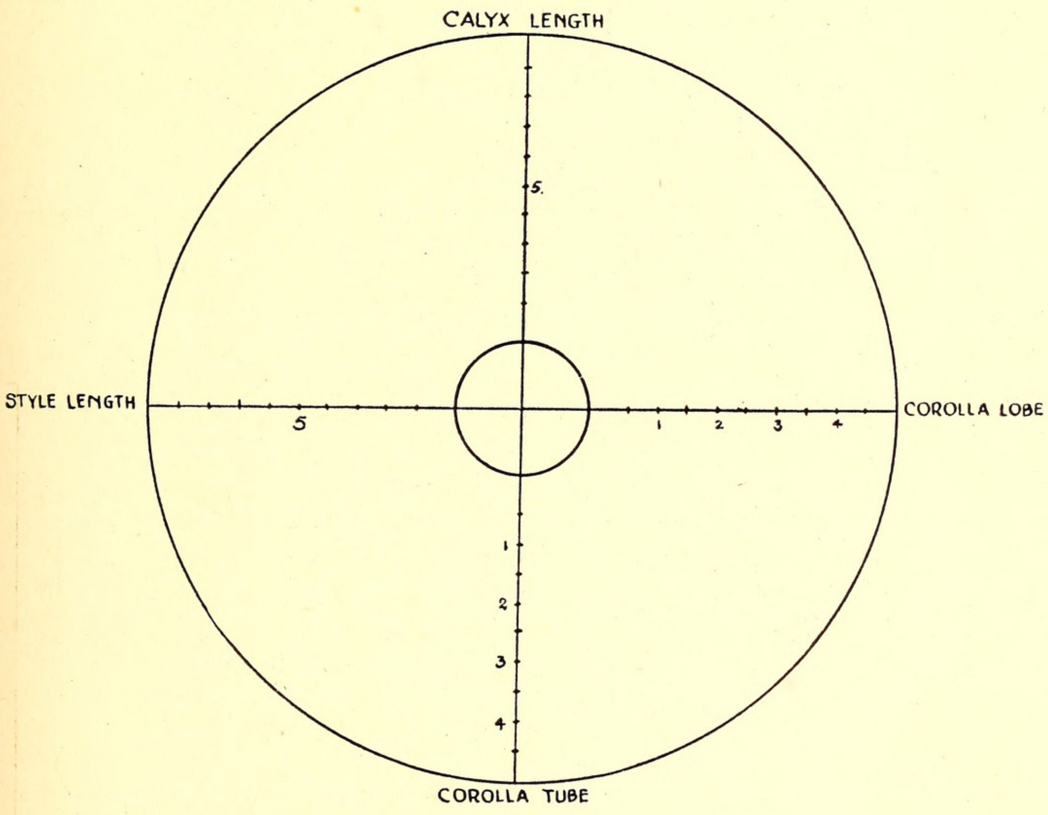

Fig. 1. A base for the polygonal graphing of four characters, using absolute measurements. The radii have been calibrated so that the expected range of variation covers most of each radius.

In population analysis, a taxonomist is generally concerned with determining whether a population contains two or more segregates or merely one variable entity. This may be determined by a fairly large series of two-dimensional graphs, such as curves, bar graphs, or scatter graphs, or by a single polygonal analysis.

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The advantage of polygonal graphing is that members of an entire population may be compared in a number of varying characters at a glance. The completed figure in a polygonal graph readily supplies the following data:

(a) the range of variation in any one of three to ten characters.
(b) the mean of any character.
(c) the occurrence of a bimodal distribution in any character.
(d) the correlation between any two of the characters plotted.
(e) the validity of a character in delimiting proposed segregates.

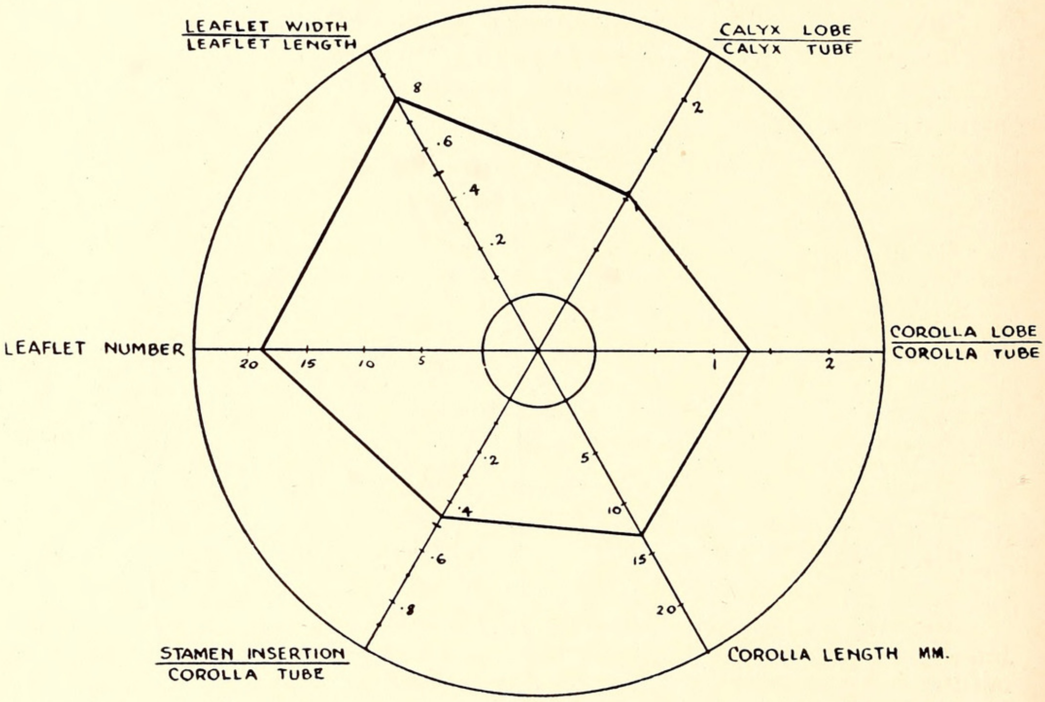

Fig. 2. A base for graphing six characters, some being absolute measurements, some being relative. The ratio leaflet width over leaflet length is an approximation of the more qualitative concept of leaflet shape. The single specimen plotted shows the following characters:
Calyx lobe subequalling the calyx tube.
Corolla lobe 1.3 times the corolla tube.
Corolla 13 mm. long.
Stamens inserted slightly below the middle of the corolla tube.
Leaflets 19.
Leaflets 0.8 as broad as long.

Basically the graph consists of a circle, with as many radii as there are characters to be compared (fig. 1). The characters, measured along each radius, are assigned absolute, relative, or arbitrary values. The characters possessed by each specimen are plotted along each radius, and the points so plotted are joined. Thus each specimen is represented by a polygon (fig. 2), and the entire population is represented by the polygons plotted on the same or similar bases.

The choice of characters is important, and normally those which are thought to possess "keying possibilities" are chosen. However, if many characters are used, separation of entities may be accomplished on one or more of the criteria utilized. In practise, using a circle 10 cm. or more in radius, fifty or more speci-

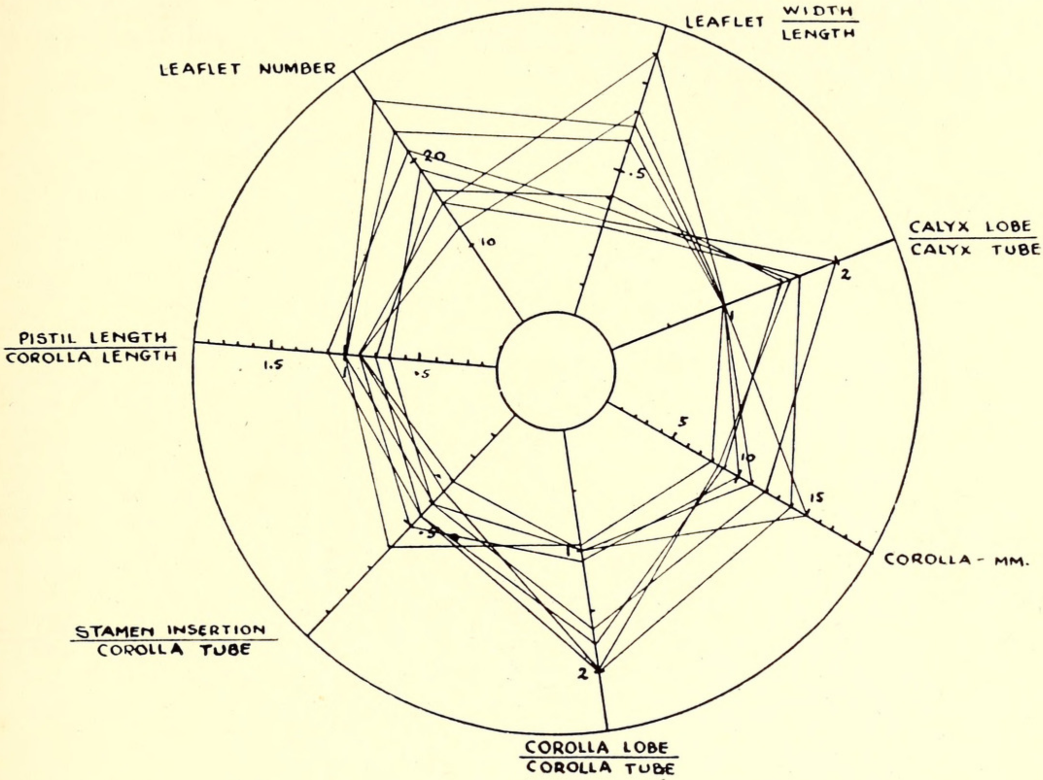

FIG. 3. A mixed population has been graphed for seven characters. In the interest of simplicity only eight specimens are shown. The presence of two entities is demonstrated by the bimodal distribution on three of the radii. The other radii show normal distributions.

If all radii showed a normal distribution, similar to that of $\frac{\text{stamen insertion}}{\text{corolla tube}}$, other characters of possible diagnostic value would be selected. If these all showed normal distributions, the conclusion could be drawn that the population consisted of one variable entity.

mens may be compared on one base sheet. In larger populations, the use of thin paper or tracing paper makes superposition of two or more sheets possible, provided of course, that the same base measurement is retained. In some problems, particularly those dealing with the correlation of color with other characters, it may be expedient to use appropriately colored pencils to form the polygons.

After plotting a few members of a population, random variability is commonly apparent on some of the radii representing the selected characters. In practise it has been found convenient to replace such characters with others, in order to test as many as possible for diagnostic value.

The completed figure will show a normal frequency distribution on any radius which represents a character which varies at random (fig. 3, corolla length, stamen insertion, pistil length). From such radii, the customary frequency curve may be constructed, if desired, by utilizing the number of specimens occurring in any desired interval.

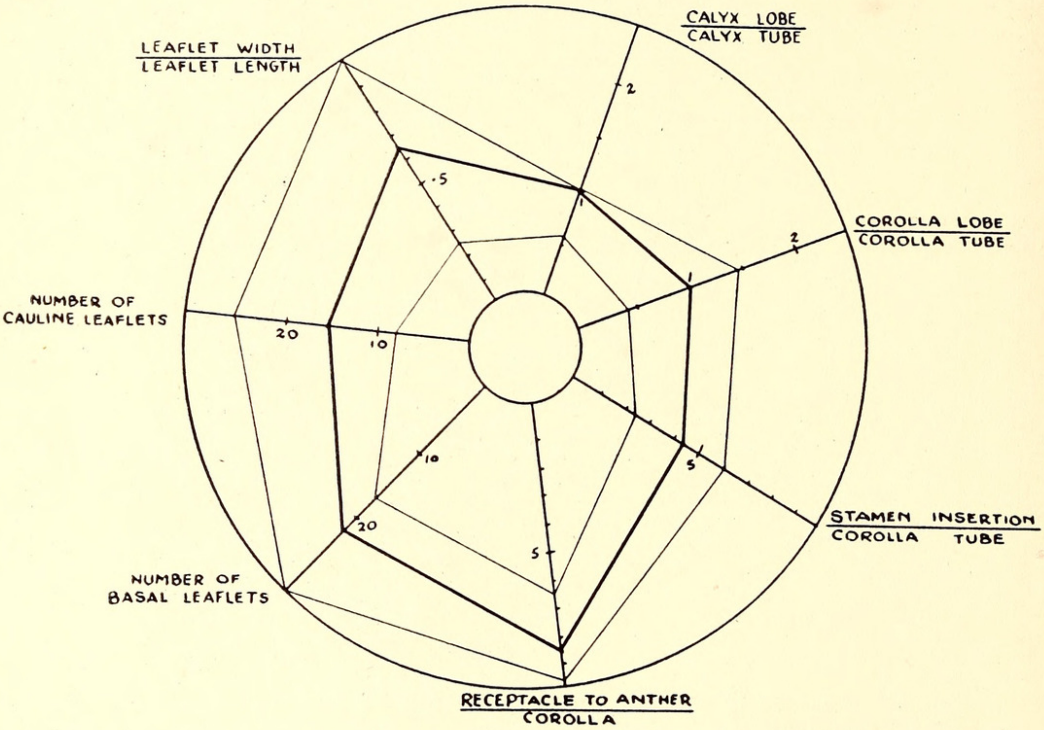

FIG. 4. A synopsis of a polygonal graph of a *Polemonium pulcherrimum* population from the Rocky Mountains of British Columbia and Montana. Compare the range of variation in each character in this population with the corresponding characters in the southern populations (figs. 5 and 6).

The occurrence of a bimodal distribution on any radius shows the presence of two entities, and if the distributions around each mode are mutually exclusive, the character would be valid for keying purposes. If several diagnostic characters have been graphed, the segregation into the two or more entities may be seen on the radius for each character (fig. 3, leaflet, calyx, and corolla proportions).

Positive correlation of characters is shown between adjacent radii by essentially parallel lines, as would be shown in figure 3, between calyx proportions and corolla proportions, were these two radii adjacent. Negative correlation is demonstrated in figure 3 between leaflet and calyx proportions, by the intersecting lines. The narrower leaflets show negative correlation with the short calyx lobes, or conversely, positive correlation with the long calyx lobes. The fact that this correlation is not 100 per cent is shown in the specimen with the longest calyx lobe proportion. To show 100 per cent correlation, this specimen should have a leaflet proportion value of less than 0.3.

Figures 4, 5, and 6 show the use of the polygonal graph for

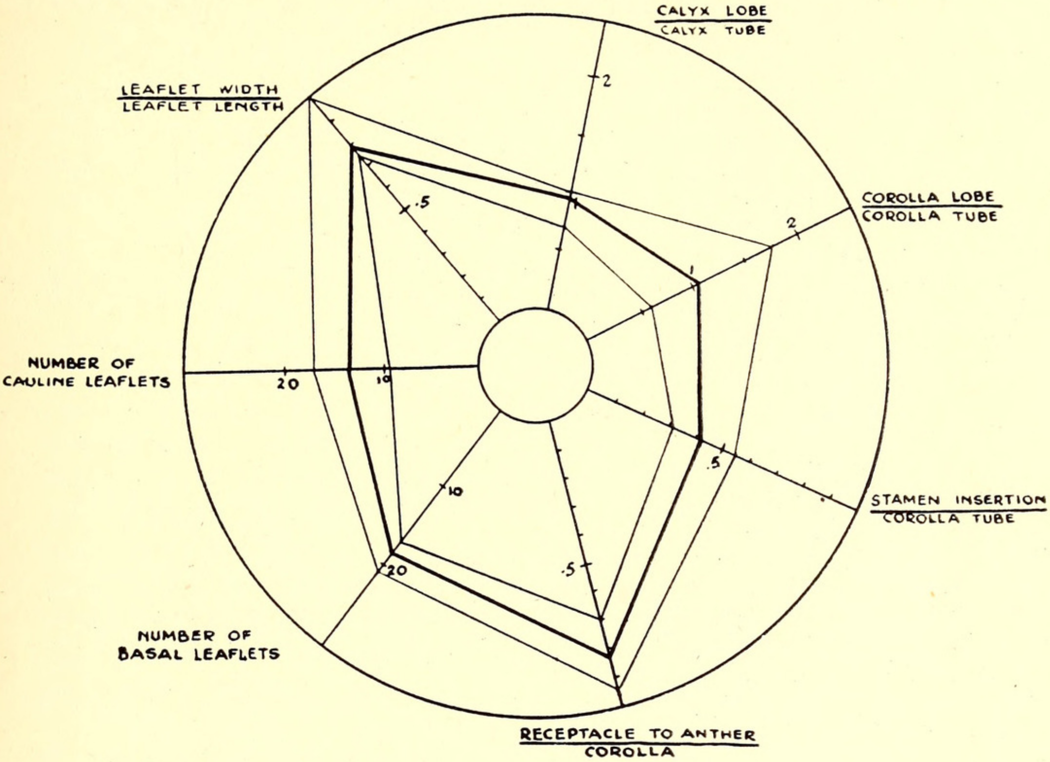

FIG. 5. A synopsis of a *Polemonium* population from the Sierra Nevada of California which appears to be, on the basis of the graphed characters as well as other characters that were selected, a less variable form of *Polemonium pulcherrimum.*

the simultaneous comparison of seven characters in three distinct populations. In each figure, only the minimum, mean (heavy line) and maximum for each character has been plotted. The similarity of polygon shape in figures 4 and 5 is evidence of close relationship, considered here to be conspecific. Conversely, the difference in shape between figures 4 and 6 was the basis for rejection of conspecific status for these two entities. A further point shown in these figures is the reduced variability in both the southern populations as compared with the northern population.

The figures will serve to illustrate the method used, as well as to show some of the results obtainable.

LITERATURE CITED

HUTCHINSON, A. H. 1936. "The polygonal presentation of polyphase phenomena." Trans. Roy. Soc. Can., Ser. 3, Sect. V, 30: 19–26.

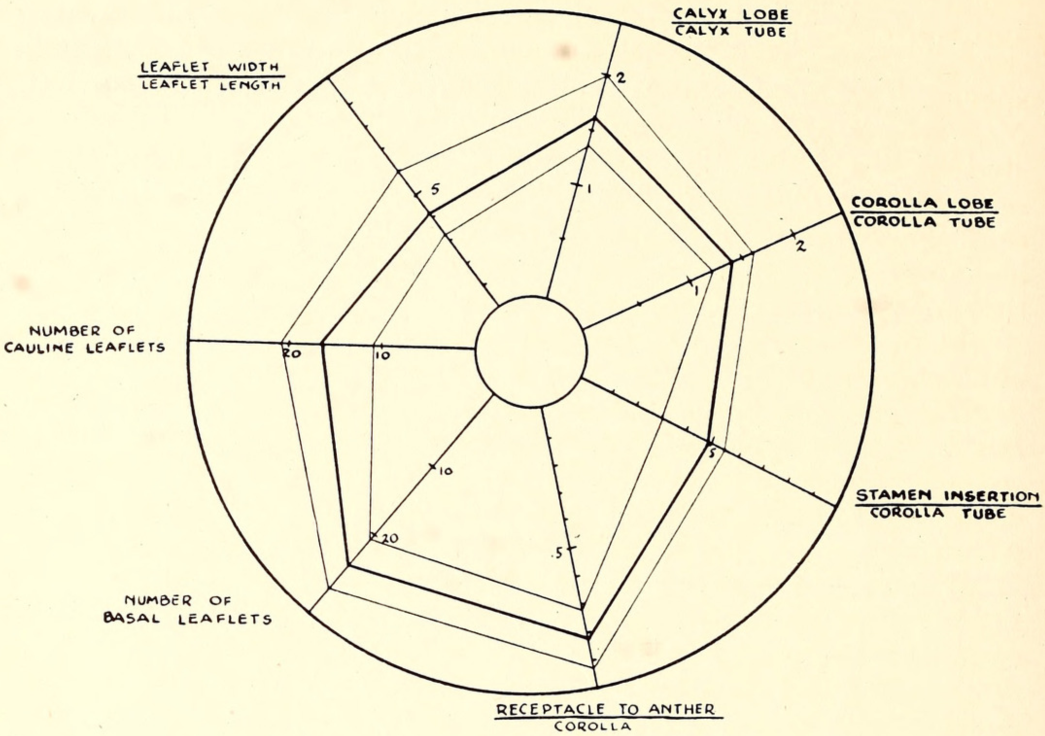

Fig. 6. A synopsis of another *Polemonium* population from the Sierra Nevada of California. The variation from *P. pulcherrimum* is evident in a number of respects in the mean (heavy line), but the calyx proportion appears to be most diagnostic.

————. 1940. Polygonal graphing of ecological data. Ecology 31: 475–487.

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MATURATION OF THE GAMETES AND FERTILIZATION IN NICOTIANA[1]

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Examination of megasporo- and megagametogenesis in a number of species of *Nicotiana* was undertaken with special reference to the extent to which details in the development of the female gametophyte might contribute evidence concerning species origins and relationships. The investigation was later extended to determination of the development, structure and behavior of the sperms. On this latter point no detailed reports have been published in the case of *Nicotiana* and relatively few references to megasporo- or megagametogenesis appear in the literature dealing with the genus.

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