# Some observations on morphometric analyses of *Antennaria* (Asteraceae: Inuleae): Reply[1]

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There are many types of problems in systematics that can be analyzed by multivariate methods and even for a given problem different researchers may not agree on which method is best or most appropriate.

In my opinion, principal components analysis was an appropriate method for my morphometric analysis of *Antennaria* (Bayer 1987). I am not prepared to argue whether this was the most appropriate method or not, but I will say that my results cannot be dismissed as easily as Chmielewski and Chinnappa would apparently desire. Principal components analysis (PCA) is one of the most, if not the most, widely used multivariate technique in ecology and systematics (James and McCulloch 1990).

All of the arguments that Chmielewski and Chinnappa present rely on statements expressing the opinions of various authors. They have not provided empirical data to establish that my analysis is inappropriate. Rather their reanalysis repeats my earlier systematic conclusion with respect to this group. They argue that I should not have used PCA because groups were selected a priori. Some a priori knowledge of groups must necessarily be present when conducting a morphometric analysis, for example, for an analysis of *Antennaria* section *Alpinae*, one would not measure specimens of section *Carpaticae*. I selected roughly equal numbers of specimens that I thought represented morphologically discrete taxa. I was looking for morphological gaps among the groups. In my opinion, PCA is not inappropriate for this type of analysis and my investigation cannot be dispelled solely on the basis of opinion that canonical analysis would have been a better treatment for these data.

Most data sets using morphological data have some missing data. For example, mature achenes may not be present for measurement on a plant specimen, or if they are, then corollas may have already been shed. It is often difficult to obtain specimens that have complete data for all characters. Some species of *Antennaria* that I used in my analysis are quite rare, e.g., *A. aromatica* (discovered and named in 1984), and it was necessary to use most available specimens. These specimens will tend to have more missing features because one does not have the luxury of selecting complete specimens. NT-SYS (Rohlf 1987) does allow the use of missing data in its calculation of PCA. The presence of some missing data does not invalidate the analysis. Chmielewski and Chinnappa have not provided any empirical support that demonstrates missing values affected the outcome of my analysis.

The question of number of characters to be used in a phenetic study is an important one. I have used 38 (Bayer 1987), including both quantitative and qualitative characters, in my analysis. Ideally as many characters as possible should be used in a morphometric analysis because this stabilizes the values of the similarity coefficients. Sneath and Sokal (1973) have suggested 60 as a minimum number, although this is not always possible. I have used as many characters as possible. By contrast, Chmielewski and Chinnappa have used only 15–17 characters in their later study (Chmielewski et al. 1990*b*) of the same groups of *Antennaria* in which I measured 38 characters. All the data in my analyses were standardized prior to analysis so "problems associated with units of measurement" were overcome. All my qualitative characters were ordered.

Leaf pubescence is really a continuous quantitative character (Sneath and Sokal 1973). Such characters are best treated by dividing them into a small number of discrete intervals, each representing one character state. I have divided leaf pubescence into such intervals ranging from glabrous to canescent. Leaf standards of pubescence were used for comparison with each individual OTU. In my scale canescent had approximately twice as many hairs per unit area as tomentose. Glabrous–villous had approximately one-tenth the hairs as canescent, villous about two-tenths, and so forth. This character was definitely not weighted as claimed by Chmielewski and Chinnappa. Chmielewski and Chinnappa claim that pubescence types "frequently cause problems. . ." because their genetic basis is unknown. I would point out the genetic basis of most, if not all, of the characters used in most morphometric analyses are usually unknown. I hope they are not advocating use of only those characters for which the genetic basis is known, as this would nullify most of the morphometric studies that have been done to date, including theirs.

Dioecious taxa can present problems because staminate and pistillate flowers are produced on separate individuals. In 1978, when I began my first phenetic study of *Antennaria*, I determined through phenetic studies (R. J. Bayer, unpublished data) that there is virtually no dimorphism between the genders with respect to vegetative characters. Chmielewski and Chinnappa's statements that staminate plants are smaller than pistillate is very misleading (I presume this refers to the height of the flowering stem, not to nonreproductive characters). Chmielewski and Chinnappa have not provided any empirical data demonstrating sexual dimorphism for vegetative characters. In many *Antennaria* species the pistillate flowering stem continues to elongate after pollination, presumably to provide for better dispersal of the wind-borne achenes. Consequently, the staminate plants of many species of *Antennaria* are smaller, referring to their height. This is a synapomorphous feature of specialized species of *Antennaria*, and is certainly not characteristic of all *Antennaria* (Bayer 1990), because many species have genders that are the same height at maturity. However, difference in gender height is characteristic of all species under consideration with regard to this matter. Since there are no differences with respect to vegetative characters, it is possible to treat the plants as one would monoecious taxa.

An OTU (operational taxonomic unit) does not necessarily have to be an individual, but can be a population, species, genus, family, etc. OTUs can be an average representing a taxon at any rank (Sneath and Sokal 1973). In this case, my OTUs are not individuals, but exemplars of populations. My choice of OTU does not invalidate my analysis. In many

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studies dealing with higher taxa, averages of several individual taxa are employed as OTUs to stand as the higher taxon (Sneath and Sokal 1973). I presume that Chmielewski and Chinnappa would classify these as "hypothetical OTUs" as well. Since they "do not accept the hypothetical OTU as a valid entity of analysis," I suspect they would also consider most of the studies of higher taxa as invalid as well.

I consider all the concerns expressed by Chmielewski and Chinnappa against my phenetic analysis to be unfounded. Their lack of supporting empirical data contrasts with my own recent reanalyses that show the supposed problems to be inconsequential. I must therefore stand by all my previous morphometric analyses and the systematic conclusions drawn from them.

Finally, Chmielewski and Chinnappa admit that their own subsequent analysis (Chmielewski et al. 1990*a*, 1990*b*) of the taxa studied earlier by myself (Bayer 1987) showed that the taxa are "morphologically distinct and recognizable". Therefore, I construe one purpose of their commentary and comments made in some of their other recent publications (Chmielewski and Chinnappa 1988; Chmielewski et al. 1990*a*, 1990*b*) to be an unstated justification for reanalysis of my work (e.g., Bayer 1985*a*, 1985*b*).

I regret that this rebuttal must point out their failure to do more than express unfounded opinions and thus imply that they have stepped beyond normally accepted boundaries of scientific debate.

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