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A contribution to the study of taxa differentiation in cestode taxonomy

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Abstract. A new approach for differentiating between different groups of individuals on the basis of statistical evaluation of pairs of attributes (each member belonging to different group) is proposed. The " polythetic divisive " classificatory method is employed. The methods discussed may prove helpful in establishing precise interspecific variations as also the variability amongst various higher taxa in cestode taxonomy thus contributing a support in the direction of revision attempts of future workers.

Keywords. Monothetic divisive classificatory system ; polythetic agglomerative classificatory system; polythetic divisive method ; attributes ; entities ; numerical taxonomy.

1. Introduction

In a traditional classificatory procedure the highest common factors present in one group and absent in another are looked for in working from lower levels to higher. A number of characters of individuals are usually considered in describing the taxa keeping their diagnostic significance in mind. Precisely the fidelity and constancy of attributes possessed by the organisms are considered for description of various taxa.

Basically two different approaches to classification have been applied presently in cestode taxonomy. These are the monothetic divisive and the polythetic agglomerative classificatory systems. In the former, consideration of one attribute after another in sequence is made for placing an individual in its suitable category of taxa, while in the latter the individuals are grouped on the basis of their overall similarity with respect to several attributes considered simultaneously. Since a polythetic approach involves more than one attribute which is usually desired, it is preferable to a monothetic approach of classification. At present if the approach is to be polythetic it is also to be agglomerative.

A third, "polythetic divisive" method of classification is introduced in this paper in the cestode systematics. With this as a basis, a procedure has been developed which leads to the ultimate, most frequent differentiation of individual attributes between different species. It may be expected to be useful when applied to classificatory studies of animals which are difficult to observe directly. It must, therefore, be studied initially by substantiating statistically their basic similarities or dissimilarities within different species groups. It is also hoped that the present method will help further elucidate the significance of taxometric studies in establishment of new taxa (also other than species) and in the much too needed revision attempts of various taxonomic categories in the field of cestode taxonomy.

2. Review of some methods in numerical taxonomy

The proposed method in taxometry has never been attempted by earlier workers in the field of cestode taxonomy. However, the Bray-Curtis (1957) measure for coefficient of dissimilarity has been applied in recent marine studies by Field (1969, 1970, 1971), Stephenson and Williams (1971) and Stephenson *et al* (1972).

Recent papers on classificatory devices include those of Macnaughton-Smith (1965), Good (1965), Kendall (1966), Lance and Williams (1967), Jardine and Sibson (1968, 1971a, b), Sibson (1971), Cormack, (1971) Williams *et al* (1971a, b), and Williams (1971, 1972).

Lance and Williams (1967) argued in favour of simplification of the data by ordination. However, this procedure may or may not lead to the recognition of groups within a series of sites or taxa. Williams (1971) illustrated a dichotomous key to classifications. His first choice fell between overlapping or nonexclusive and nonoverlapping or exclusive. In the former an entity may appear in more than one group. In general, taxonomists have not favoured such classificatory strategies.

For the taxonomist in particular, hierarchical classifications are attractive in that they are both traditional and have a parallel in evolutionary theory. Furthermore, hierarchical classifications bring organization to a body of knowledge and if science is defined in terms of organized knowledge they are the more "scientific" of the alternatives.

3. Materials and methods

Fortyseven proteocephalid worms belonging to genus *Gangesia* Woodland, 1924 were collected from twelve fishes, *Labeo rohita* from Etawah, U.P. (Species A) and twentyfive cestode parasites from fifteen *Mystus vittatus* from Mehamdabad, Gujarat (Species B), India.

The entire intestine including stomach was examined and the position of each cestode recorded. Worms were killed in water heated to approximately 80° C and fixed in Bouin's solution. Specimens were stained in haemalum; cleared in xylol and mounted in canada balsam for morphological studies. The material was fixed and embedded in paraffin to prepare paraffin blocks for studying histological details of parasites. The serial sections were cut at 0·006–0·008 mm and

Table 1. Measurements recorded for species '*A*' and '*B*'.

Attributes	Species *A*	Species *B*
Size	0·110 × 0·5–2·0 (59·5 × 1·25)	90–140 × 0·5–2·0 (120 × 1·5)
Scolex	0·234–0·5384 × 0·2574–0·534 (0·429 × 0·362)	0·175–0·426 × 0·35–0·56 (0·392 × 0·416)
Rostellum	0·1053–0·195 × 0·1024–0·234 (0·154 × 0·1911)	0·1154–0·261 × 0·1365–0·2613 (0·154 × 0·164)
Rostellar hooks :		
No.	26–36 (31)	33–66 (46)
Length	0·0194–0·0273 (0·0195)	0·0156–0·0292 (0·0195)
Suckers	0·0975–0·2145 × 0·0897–0·2184 (0·1195 × 0·1911)	0·175–0·396 × 0·1014–0·21 (0·199 × 0·198)
Neck	0·255–0·356 × 0·198–0·234 (0·293 × 0·205)	0·14–1·4 × 0·14–0·56 (0·56 × 0·241)
Proglottides:		
Total No.	80–250 (165)	90–150 (115)
Immature	0·042–0·14 × 0·210–0·49 (0·089 × 0·392)	0·042–0·56 × 0·112–0·84 (0·14 × 0·53)
Mature	0·420–1·82 × 0·074–0·42 (0·76 × 0·366)	0·14–2·38 × 0·112–2·38 (1·4 × 1·54)
Gravid	0·21–1·96 × 0·398–1·896 (0·995 × 0·855)	0·20–2·0 × 0·168–1·26 (1·68 × 0·89)
Genital Atrium:		
Deep	0·007–0·05 (0·021)	0·012–0·115 (0·112)
Wide	0·0112–0·048 (0·0255)	0·014–0·195 (0·099)
Testes:		
No.:		
Precirrus Pouch	14–80 (50)	9–30 (26)
Postcirrus Pouch	11–50 (40)	10–30 (28)
Aporal	26–210 (108)	20–80 (50)
Total	53–215 (130)	41–105 (90)
Size	0·0115–0·112 × 0·0195–0·098 (0·084 × 0·042)	0·011–0·14 × 0·01–0·14 (0·07 × 0·112)
Cirrus Pouch	0·0012–0·392 × 0·022–0·22 (0·294 × 0·214)	0·0105–0·42 × 0·009–0·16 (0·28 × 0·126)
Ovary	0·05–0·98 × 0·12–1·966 (0·42 × 0·308)	0·07–0·196 × 0·20–1·08 (0·099 × 0·89)
Vagina (dia.) :		
Copulatory part	0·0126–0·069 (0·021)	0·008–0·07 (0·035)
Conducting part	0·0129–0·0215 (0·013)	0·0019–0·014 (0·012)
Vitellaria	0·0022–0·0113 × 0·0053–0·0132 (0·0095 × 0·0112)	0·002–0·07 × 0·0025–0·042 (0·056 × 0·025)
Uterine diverticula:		
No.	9–20 (15)	13–30 (22)
Uterine Pores:		
No.	1–9 (5)	2–8 (5)
Eggs	0·0029–0·0195 × 0·003–0·0176 (0·0193 × 0·0158)	0·002–0·0195 × 0·004–0·21 (0·0114 × 0·112)

stained by double-staining method using haematoxylin and eosin stain. Camera lucida sketches were prepared.

After systematic tabulation of various morphometric observations of different organs of the collected parasites (table 1), methods of "Bray-Curtis (1957) measure" for estimating dissimilarities in various entities (species) was attempted for the first time in cestode taxonomy (Malhotra 1979). Similarly other mathematical expressions have been applied for calculating the coefficient of similarity, coefficient of divergence (CD) and mean character difference (MCD) (Dixit *et al* 1979).

The various formulae applied are—

Bray-Curtis (1957) formula for coefficient of dissimilarity (C.Dis)

$$\frac{\sum_{1}^{n} | X_{1j} - X_{2j} |}{\sum_{1}^{n} (X_{1j} + X_{2j})}. \qquad (1)$$

Coefficient of similarity (CS)

1-value for coefficient of dissimilarity. (2)

Klauber's (1940) formula for coefficient of divergence (CD)

$$CD = 2\frac{(\bar{m}_1 - \bar{m}_2)}{\bar{m}_1 + \bar{m}_2} \qquad (3)$$

Cain and Harrison (1958) formula for mean character difference (MCD)

$$MCD = \frac{1}{n} \sum_{1}^{n} \frac{| X_{1j} - X_{2j} |}{X_{max}} \qquad (4)$$

where n is the number of entities (species); X_{1j} and X_{2j} are the values of the jth attribute for any pair of entities (species); $\bar{m}_1$ and $\bar{m}_2$ are the mean values of a parameter in two populations, and X_{max} is the maximum value assumed by the attribute.

The coefficient of dissimilarity and MCD assume a value from zero (complete similarity) to unity (complete dissimilarity) while the values are different for CS i.e. zero (complete dissimilarity) to unity (complete similarity).

4. Application of new methods

The procedure to be illustrated for specific differentiation between various attributes may appear complicated but with little practice it can be gone through rapidly. It has the virtue of repeatability; given the same primary information, two workers will always arrive at the same groupings of individuals. This means that if several workers using similar specimens make studies in different localities and find different individuals there is some assurance that the differences are real and not the result of differences in judgement or emphasis.

Table 2. Coefficients calculated between species A and species B.

Attributes	Coefficient of similarity			Coefficient of dissimilarity			Coefficient of divergence			Mean character difference		
	L	W	No.	L	W	No.	L	W	No.	L	W	No.
Size	0·057	..	..	0·43	..	..	2·3	2·0000	..	0·63	0·85	..
Proglottides	..	..	0·5	..	..	0·4	..	..	2·1579	..	..	0·54
Immature progl.	0·942	0·3898	..	0·058	0·6102	..	2·5357	2·152	..	0·8125	0·719	..
Mature progl.	0·236	0·139	..	0·764	0·6617	..	2·6232	2·6691	..	0·7004	0·8884	..
Gravid progl.	0·562	0·452	..	0·4397	0·548	..	2·0069	2·2327	..	0·8964	0·8284	..
Suckers	0·0865	0·0537	..	0·9135	0·9417	..	2·7341	2·0053	..	0·7536	0·5532	..
Scolex	0·5995	0·5135	..	0·4005	0·4865	..	2·1248	2·06	..	0·5773	0·4465	..
Rostellum	0·6501	0·657	..	0·3491	0·3439	..	2·1123	2·0831	..	0·5089	0·521	..
Rostellar hooks	0·8506	..	0·871	0·1494	..	0·129	2·0000	..	2·200	0·62	..	0·38
Neck	..	..	..	..	..	..	2·4319	2·236	..	0·5918	0·451	..
Genital Atrium	0·364	0·433	..	0·646	0·567	..	..	2·344	2·558	0·9261	0·8474	..
Testes	0·605	0·334	0·551	0·395	0·666	0·449	2·0998	2·12	2·18	0·8951	0·8673	0·8767
Testes (Precirrus pouch)	..	..	0·3459	..	..	0·6541	..	..	..	..	..	..
Testes (Postcirrus pouch)	..	..	0·0109	..	..	0·0891	..	..	..	..	..	..
Aporal Testes	..	..	0·3323	..	..	0·6772	..	..	..	..	..	..
Cirrus Pouch	0·014	0·61	..	0·986	0·36	..	2·0454	2·25	2·1655	0·97	0·92	..
Ovary	0·186	0·9231	..	0·8148	0·0769	..	2·5895	2·309	..	0·7985	0·9602	..
Vagina:												
Copulatory part	..	0·316	..	..	0·684	..	..	2·014	..	..	0·8516	..
Conducting part	..	0·585	..	..	0·415	..	..	2·3710	..	..	0·6311	..
Vitellaria	0·363	0·622	..	0·637	0·378	..	2·6862	2·411	..	0·892	0·7664	..
Uterine diverticula	..	..	0·505	..	..	0·405	..	..	2·19	..	..	0·55
Uterine Pore	..	..	0·3	..	..	0·7	..	..	2·09	..	..	0·81
Eggs	0·431	0·48	..	0·569	0·52	..	..	2·103	..	0·8733	0·902	..
RANGE	0·014 to 0·942	0·0537 to 0·9231	0·0109 to 0·871	0·05 to 0·9135	0·0769 to 0·9417	0·0891 to 0·7	2·00 to 2·7341	2·0 to 2·6691	2·09 to 2·5585	0·5085 to 0·97	0·4465 to 0·9602	0·38 to 0·8767

The following points may be emphasized concerning application of the four formulae mentioned above for establishing variability in various individuals by way of an assessment of their individual attributes:

(*a*) Maximum available attributes (characters) are considered for evaluation.
(*b*) Not more than two groups of individuals are taken up for finding statistical variations at a time.
(*c*) Since in most of the taxonomic descriptions in the field of cestode taxonomy only the maximum and minimum ranges of measurements of each attribute are mentioned it would be more practical presently to apply these ranges fulfilling the requirements of (*b*) in Bray-Curtis measure of dissimilarity and the mean values, if available, in estimating mean character difference (the values of X_{1j} and X_{2j}) and coefficient of divergence.
(*d*) The evidence for affinity is significant at the 0·5 level for all the pairs of attributes within the groups for estimating coefficient of dissimilarity, CS and MCD, besides other important taxonomic relationships.
(*e*) Nothing definite presently, but a range of 2 to 3 may be predicted as significant for coefficient of divergence.

Hence by application of data available in table 1 on the lines suggested in (*a*) to (*c*) above, the results obtained for Species A vs B are presented in table 2.

Further, considering (*d*) and (*e*) it can be mentioned that the values thus obtained for each of the coefficients show a tendency of higher ranges in coefficients of dissimilarity, and divergence and individual character difference (mean) while studies reveal a lower range of coefficient of similarity in most of the attributes of taxonomic significance. This conclusively establishes such comparative differences amongst species marked A and B as to place them in different taxonomic categories subject to final fulfillment of (*d*).

4. Discussion

This paper presents a defined, repeatable method for grouping individuals of different species separately which may or may not be frequent components of each other's biological environment. Such a method enables comparison of groups found in different habitats or at different times or localities at variable altitudes. It may, however, be proposed that if taxometric evaluations are related to the size, activity, etc., of the organisms and the significance requirement (as illustrated in (*d*) and (*e*)) above is made stringent, the groups formed may have ecological unity in the sense of significant intragroup agreement on what constitutes a good or bad habitat. It seems reasonable, therefore, to consider them as natural assemblages, somewhat artificially delimited but nonetheless real.

Since the method employed for classification represents a polythetic divisive procedure in which maximum available attributes of individuals are considered and each pair of the attribute (each member belonging to different group) is weighed statistically one after the another and also at the same time, this represents a particularly appropriate method within which to examine interspecific relationships. The analytical procedures suggested for this examination have two purposes; the provision of a summary description of relationships and the suggestion of working hypothesis upon which to base further field and laboratory work. The use of methods employing individual attributes gives each species an equal voice in the analysis, removes many of the difficulties due to non-normality of distributions and makes it possible to determine the constancy of general trends. The methods proposed may open up a new line of action for the taxonomists intending to undertake revision work of various spread out taxonomic categories.

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