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# MULTIVARIATE ANALYSIS OF COMPOSITIONAL CHANGES IN COMMUNITIES OF EPHEMEROPTERA (INSECTA) IN THE LABE BASIN, CZECHOSLOVAKIA - A COMPARISON OF METHODS

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**Abstract.** The mayfly communities of 150 localities of brooks, rivers, lakes and ponds from the Labe basin were quantitatively sampled in the two research periods (1950-65, 1970-85). Besides classical saprobiological methods, the following methods of multivariate analysis were applied to evaluate qualitative and quantitative changes in community composition: detrended correspondence analysis (DCA), agglomerative hierarchical classification, and divisive hierarchical classification (TWINSPAN). Two designs were applied; in the first one, the samples from each period were analyzed separately to determine factors responsible for community differentiation in each period. In the second design, all the samples were pooled and the changes in membership in clusters, or shifts of localities in ordination space, were interpreted as signs of community changes.

The ordination results reflect the saprobiological indicator values of species. The classification by TWINSPAN provides informative results for subsequent construction of transition matrices.

## Introduction

The mayflies (Ephemeroptera) represent one of the important groups of freshwater insects and their communities sensitively reflect the state of environment as well as the whole ecosystem. Moreover, many species of mayflies can be used as biological indicators of water quality, especially in lotic-erosive habitats and biotopes. However, the more effective use of these freshwater insects (and other aquatic insects in general) for indicator purposes is hindered by: (i) lack of long-term distributional data from large areas and (ii) problems with selection of appropriate methods to evaluate their distributional and quantitative changes.

The objective of this paper is to compare results from different methods of multivariate analysis of data from an extensive survey of mayfly communities with results obtained by means of some classical, saprobiological methods and procedures.

## Material and Methods

During two phases (1950-1965 and 1970-1985) of an intensive faunistic survey of aquatic insects in the Labe basin in Czechoslovakia over 400,000 specimens of mayfly larvae of 75 species have been collected. The material was sampled by the usual quantitative collecting methods, including the 'kitching' technique, benthometry, and drift nets; the collection is deposited in the Institute of Entomology, Czechoslovak Academy of Sciences, České Budějovice. To evaluate the qualitative and quantitative changes, communities of 150 localities, evenly distributed within the whole basin area (about 45,000 km $^2$), were selected. These included all types of aquatic biotopes (brooks, streams, rivers, ponds, lakes, pools etc.), as seen in Fig. 1 at all altitudes (11 localities up to 200 m a.s.l.; 201 - 500 m: 80, 501 - 700 m: 38, above 750 m: 21) and in all saprobiological classes. All the localities selected were sampled in all seasonal aspects (4 times a year), in most of the cases monthly during both research periods (for details see Landa and Soldán 1988). The compositional data were first evaluated by classical saprobiological methods (see Landa and Soldán 1988) as follows:

(1) Assignment to saprobiological classes with a determination of saprobity for every locality during the respective period. The saprobiological classes were defined according to Czechoslovak National Standard No. 830532. Localities investigated were classified into 4 classes, as follows: x (xenosaprobity, water of the best quality); o (oligosaprobity); bmes (beta-mesosaprobity); and ames (alpha-mesosaprobity, water of a very low quality). Details on the determination of resulting saprobity of individual localities on the basis of mayfly larvae are given in Zelinka and Marvan (1961), Jacob and Braasch (1976), Russev (1979), and Landa and Soldán (1988).

(2) Classification of water quality according to the saprobial index of Pantle-Buck which is correlated with oxygen content classes (see Czechoslovak National Standards No. 830602). Localities with saprobial index to

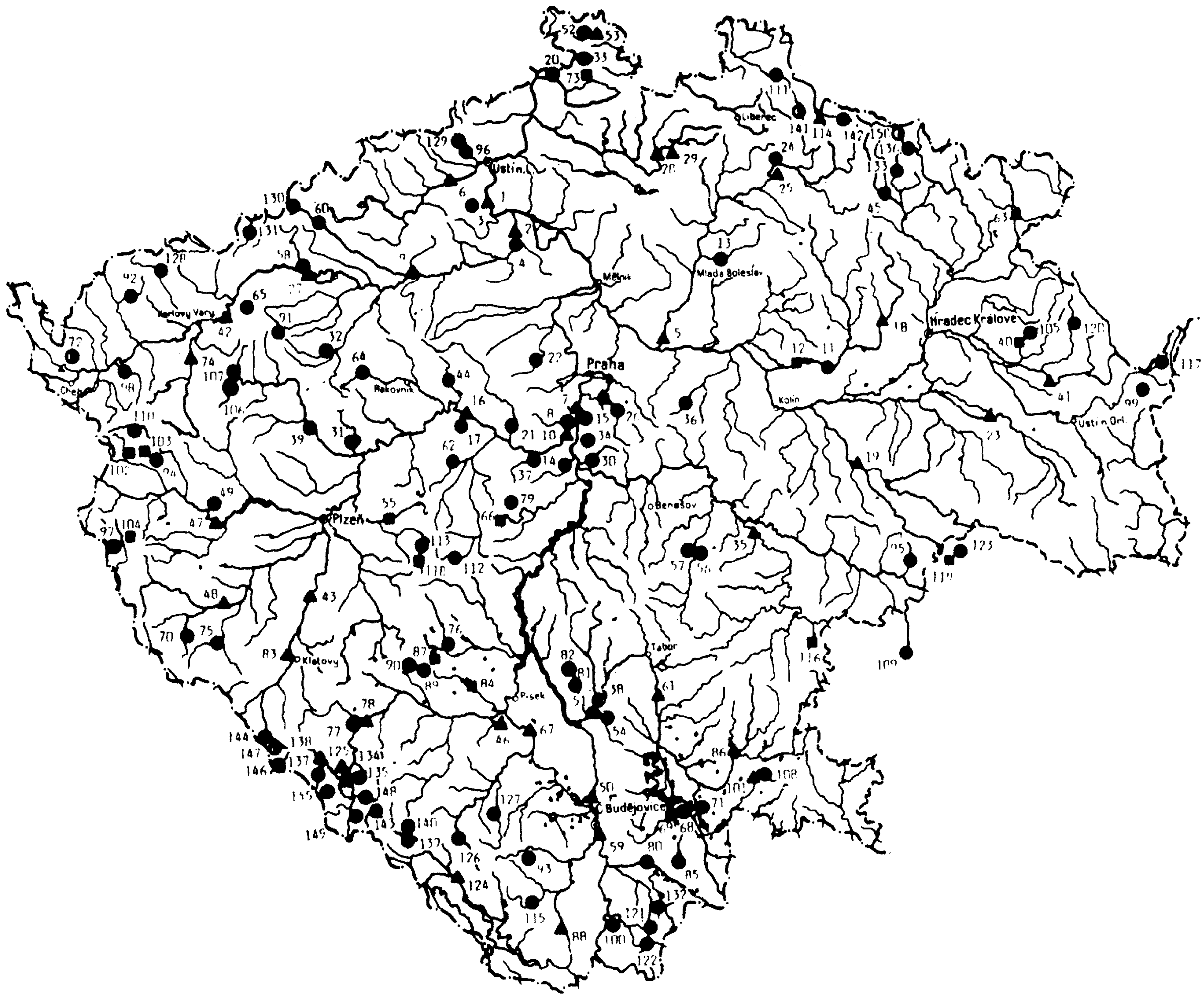


**Fig. 1. Localities investigated in the Labe basin, Czechoslovakia according to the type of aquatic biotope (triangle - potamon, circle - rhithron, quadrate - stagnant waters, mostly ponds).**

1.00 are considered to have a very high water quality. Saprobial index from 1.01-1.50 indicates slightly polluted water, from 1.51-2.00 moderately polluted water and higher than 2.01 considerable pollution at least for several months a year. The rationale of these methods is similar to community analysis based on indicator values (Ellenberg 1974) and on the weighted averages method of direct gradient analysis (Whittakker 1973). The indicator values of particular species are assessed according to the subjective experiences of the researcher.

The data were subjected to several methods of multivariate analysis: (i) Agglomerative, hierarchical classification by the average linkage method. The dissimilarity between individual localities was measured as a standardized Euclidean distance (Orlóci 1978 - chord distance). (ii) Divisive hierarchic classification by TWINSPAN (two-way indicator species analysis, Hill 1979a). In this procedure each division has indicator species characteristic for each side of dichotomy. (iii) An ordination by detrended correspondence analysis (DCA, program DECORANA, Hill 1979b). The DCA provides alternative ordinations of localities and species.

We have used two designs of analysis to detect the general trends in community composition: (a) Comparison of dendrograms structure based on samples from the first and second research periods. This approach was applied in the case of both classifications. (b) Changing membership of particular localities in the clusters, or their shifts in ordination space, where the set of samples from both periods is analyzed jointly. This approach was applied in the case of TWINSPAN and DCA.

Results of the TWINSPAN classification of all samples were subsequently used for construction of transition matrices (Lepš *et al.* 1988). The transition probabilities were estimated in the ordinary way, *i.e.* the probability of transition from class i to class j was estimated as the ratio of the number of transitions from i to j to the number of localities in state i in the first

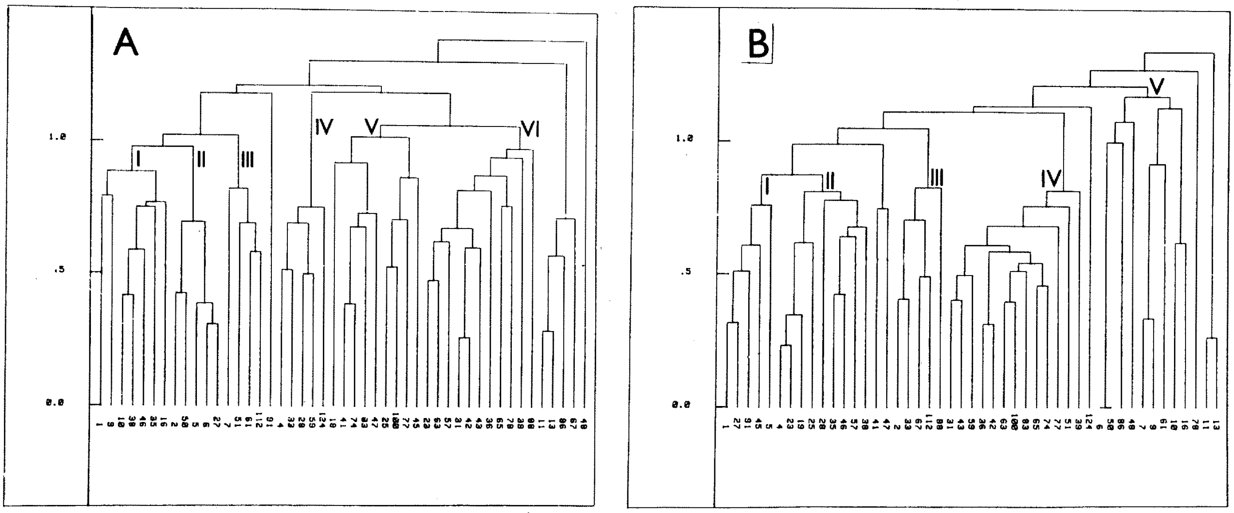


Fig. 2. Average linkage classification of localities of potamon. Dissimilarity measure: standardized Euclidean distance. A: first research period 1950-1965 (POTAM-1). B: second research period 1970-1985 (POTAM-2).

period.

In some cases the more homogeneous subsets of localities such as potamon, rhitron were subjected to analysis. We labelled the subsets by the period, *e.g.* POTAM-1 the subset of localities of potamon in the first research period.

## Results

Classical methods (Landa 1984, Landa and Soldán 1988) revealed that 105 of 150 localities are the beta-mesosaprobe class in the second research period. Twenty localities shifted to lower water quality category, mostly from o to bmes or from x to o or bmes. At 44 localities considerable increase of saprobial index was observed. The species diversity (Shannon-Weaver index) decreased at more than half of the localities.

(i) *Agglomerative hierarchic classification of localities*

Classification was performed on localities of rhithron (lotic-erosive biotopes), potamon (lotic-deposital biotopes) and of standing water separately. Since the dendrograms of the localities of pools, ponds and lakes do not show substantial changes in the quantitative and qualitative presentation of species in the two research periods, we shall concentrate on the running water localities (rhithron and potamon) only.

*Potamon* (Fig. 2). The localities of small, heavily polluted lowland rivers are separated at the highest level of dissimilarity (11, 13, 86, 67 and 48 in POTAM-1 and 11 and 13 in POTAM-2). Further hierarchical levels show the separation of two large clusters in POTAM-1, each subdivided further into three subclusters. The first of the large clusters consists of the following groups:

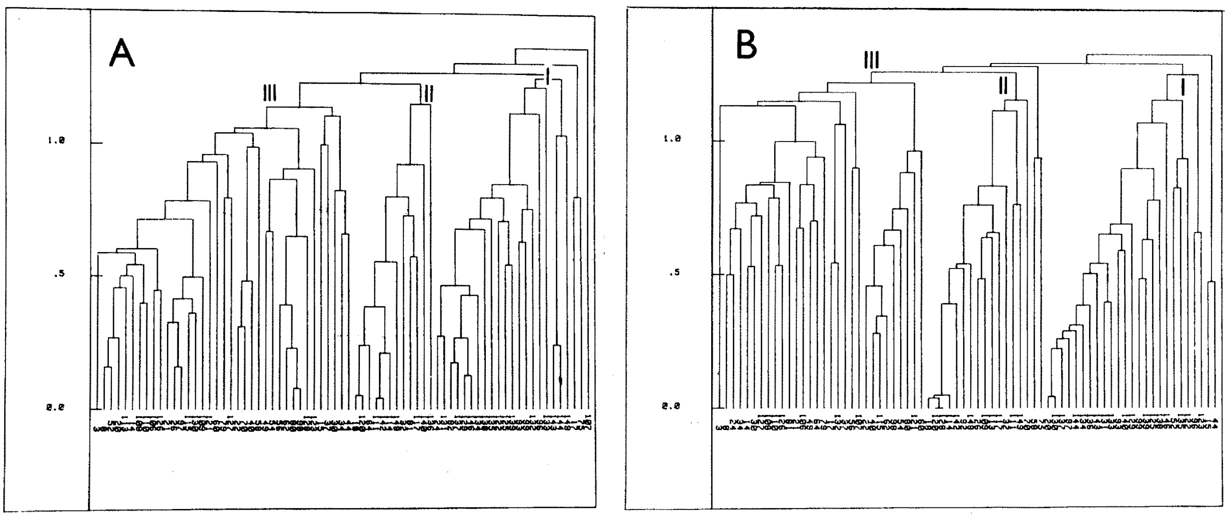


Fig. 3. Average linkage classification of localities of rhithron. Dissimilarity measure - standardized Euclidean distance. A: first research period 1950-1965 (RHITHRO-1). B: second research period 1970-1985 (RHITHRO-2).

I - large lowland rivers with relatively high species diversity and good water quality (localities 1, 9, 10, 38, 46, 35, 16); II - large lowland rivers with low water quality and low species diversity (2, 50, 5, 6, 27); III - smaller rivers, mainly of highlands, with low water quality (7, 51, 61, 112). The second of large clusters comprises the following groups: IV - smaller rivers of various altitudes with very low water quality inhabited by several resistant species only (4, 33, 28, 59, 124); V - predominantly higher altitude localities with high species diversity and high water quality (*e.g.* 83, 100, 77, 45); VI - predominantly smaller rivers with low water quality, and few localities (88, 78, 39), exhibiting high diversity and high water quality.

In the classification of POTAM-2 (Fig. 2b), the localities with extremely polluted water are separated first, (78, 11, 13), then a very heterogeneous group (V), containing considerably polluted rivers (6, 50, 86, 48, 10, 16), and low species diversity, even in localities showing high water quality (7, 9, 61). At other hierarchical levels, four principal clusters are differentiated: I - mainly large lowland rivers with lower species diversity and lower water quality (1, 27, 91, 45, 5); II - a heterogeneous group of smaller lowland polluted rivers (4, 23, 19, 25) and highland rivers with high water quality and high diversity; III - strongly polluted rivers of various sizes and at altitudes; IV - large cluster of polluted rivers of low species diversity (*e.g.* 31, 43, 59, 36, 42) and rivers of high diversity and high water quality (*e.g.* 39, 51, 77, 74, 65).

Whereas the dendrogram structure of POTAM-1 and POTAM-2 differ considerably, the dendrogam structures of rhithron show much smaller differences (Fig. 3). In both RHITHRO-1 and RHITHRO-2, the cluster separated at the highest level of dissimilarity comprised mostly the same mountain localities with lower species diversity and stenotopic species, and very high water quality (137, 144, 134, 143, 131, 93, 129, 99, 146, 122 and 96). The clusters separated at lower dissimilarity levels, exhibit the same phenomenon - mostly localities at lower altitudes with good water quality and high species diversity (eurytopic species as well) are included (*e.g.* 111, 32, 117, 148, 142, 114, 120, 18). The remaining cluster (III) represents mostly streams and brooks heavily polluted, but having varying species diversity (in both classifications).

(ii) *Divisive hierarchic classification (TWINSPAN)*

In the first research period (Fig. 4), lotic and lenitic biotops are separated first (division I) based on three common indicator species. Further division of 128 lotic localities separates mountain localities with highest water quality (indicator *Baetis alpinus*) from a group of localities on lower altitudes with varying water quality. The first group (31 localities) is eparated (division IV) into localities of crenon and mountain lakes with indicator species *Leptophlebia vespertina* (144, 147, 150) and into subgroups (division IX) with indicator *Siphlonurus lacustris* (mountain streams and reservoirs with very low density - 111, 141, 149) and with indicator species of the genus *Baetis* (29, 114, 142, division XVIII and XXXVII). The group indicators *B. vernus* and *B. alpinus* are characteristic for large mountain streams division XXXVIII) and less diversified streams of epirhithron (121, 122, 24, 52, 97, 130, 135) and others (division XXXIX).

The group of 97 localities (with 6 indicator species) is divided into a subgroup with localities, mostly potamon, and another mostly rhithron with indicator species of lotic erosive and lotic deposital preference. The localities of rhithron comprise mostly submontane and montane sites with lower diversity but very high water quality (indicator species *B. alpinus* and the *Heptageniidae* - divisions X, XX, and XXXI) and localities of brooks and streams of highlands with very high diversity but lower water quality (division XXXXII), including springs of lower altitudes (15, 44, 31) and a group of larger rivers of highlands, showing increasing pollution (18, 26, 32, 51, 54, 58 - division XXXXIV).

The group of 35 localities with predominantly potamon biotopes (division XI) comprises 8 localities of polluted zone, having indicator species *Leptophlebia marginata* and *Baetis vernus* (69, 103, 71, 80) and groups of strongly polluted lowland brooks and rivers (4, 22, 33 - divisions XXIII, XXXXVI). From the group of 27 potamon sites (division XI), localities of large lowland rivers with smaller species diversity are separated by indicator species *Heptagenia flava (e.g.* 1, 2, 28, 59) from localities with strong pollution (11, 91 - division XXXXV). This large group consists of 2 subgroups (division XXXXIV) of rivers of lowlands and highlands with extremely high diversity (*e.g.* 5, 9, 10, 16, 27) and of wetlands with low diversity and poor water quality (*e.g.* 6, 7, 8, 40). Within localities with stagnant water (division III) the oligotrophic ponds and lakes (87, 89, 90, 104, 119) and eutrophic ponds with lower species diversity (*e.g.* 12, 82, 95) are separated.

The classification of the second research period is rather different (Fig. 5). At first (division I) mountain streams and lakes are separated. These include sites with very high water quality, indicated by *Baetis alpinus* and *Ameletus inopinatus*. The group classification is similar to that of the first research period, but a new indicator species, *Rhithrogena hybrida*, is detected.

Ponds, lakes and lotic biotopes (division III) are characterized by higher numbers of indicator species (including, among others, *Baetis fuscatus, Centroptilum luteolum, Ephemera danica*). Within the group of sites with stagnant water (23 localities) some localities are shifted to the group of eutrophic sites (*e.g.* 53, 66, 73, 84 - divisions XVI and XXXIII) and some indicator species drop out *(e.g. Leptophlebia marginata* and *Caenis*

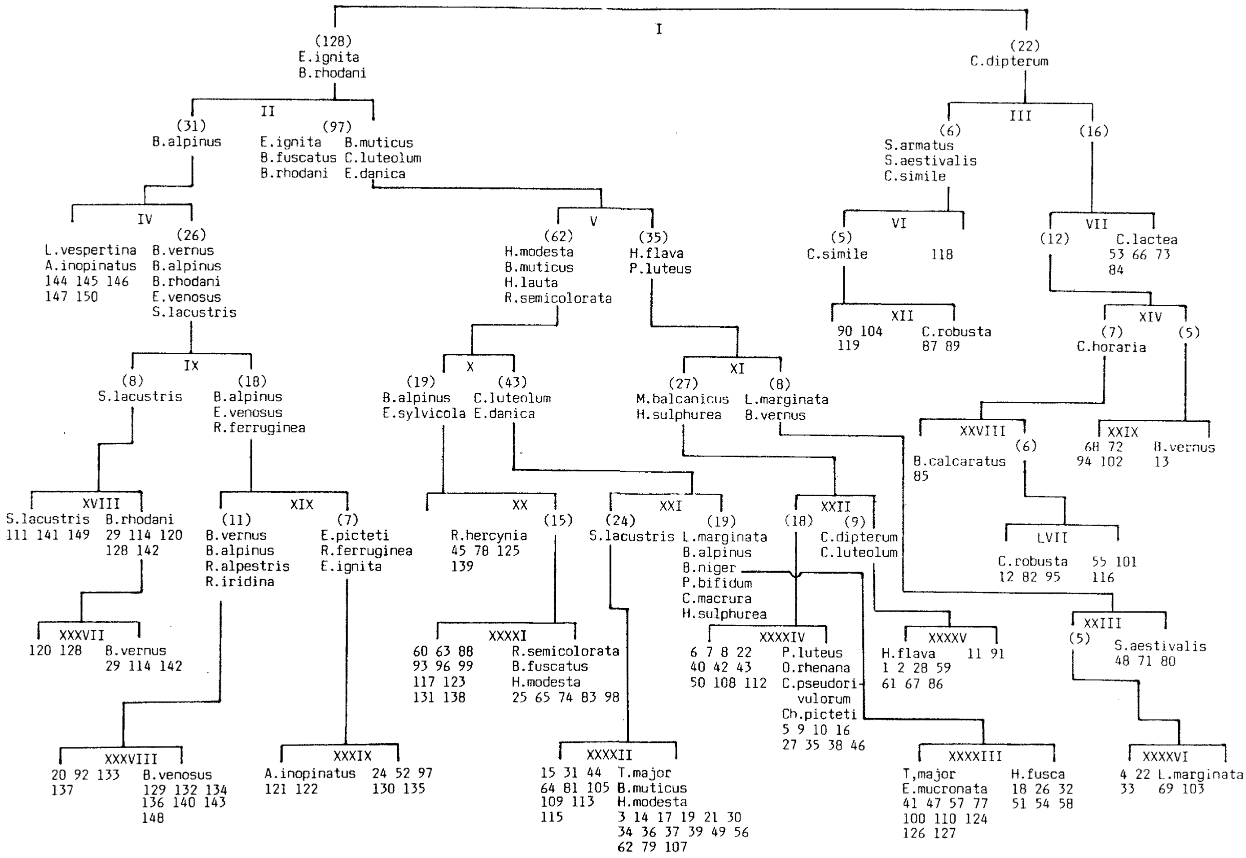


**Fig. 4. Divisive hierarchical classification (TWINSPAN) of all localities, first research period. Each division is labeled by indicator species.**

*lactea)*.

The group of 101 localities with running waters on lowlands and highlands is subdivided in a similar manner: 81 localities of predominantly rhithron and 20 localities of potamon. Indicator species of higher site quality (*e.g. Habrophlebia lauta* and *Rhithrogena semicolorata* - division V) are eliminated. Sites of the potamon group have moderate water pollution and high species diversity.

Within the same group (division XXI) two groups of localities are isolated: large rivers with extreme species diversity, slightly polluted water (10, 16, 38) and indicator species *Procloeon bifidum* and multitude of localities (division XXXXIII) with considerably polluted water. The group of 81 predominantly rhithron localities divides (division XI) into a subgroup with mostly running water which in turn is divided into subgroups of small brooks of the so called 'roach' zone (small lowland brooks with relatively warm water) and streams with very low diversity (*e.g.* 48, 90, 110). Of these, 17 localities are extremely polluted in lowlands and highlands (*e.g.* 14, 17, 19, 21, 23, 34) and 20 localities (indicator species *Baetis fuscatus, Centroptilum luteolum* and *Baetis niger*) include smaller rivers and streams with relatively good water quality (division XXXXV).

Localities where *Baetis alpinus* occur (division XI) number 26 and have 6 stenotopic indicator species; the species diversity is low but the water is clean (*e.g.* 3, 25, 45, 60, 134, 140). The division (XXXXVII) based on eurytopic indicator species *Ephemerella ignita, B. rhodani* and *B. vernus* is confusing and do not separate extremely polluted waters (4, 33) from localities with better water quality but low diversity (120, 128).

The TWINSPAN classification of combined samples from the two research periods (Fig. 9) was subsequently used for construction of transition matrices. For this purpose, the six groups were decided to represent an ecologically interpretable structure:

Group 1 - Localities with highest water quality (no pollution); there are mostly montane streams at high altitudes (900 to 1000 m a.s.l.).

Group 2 - Localities with a high water quality, such as the montane and submontane lakes and pools; some acidification is detectable, particularly at altitudes above 750 m a.s.l. in the mountains.

Group 3 - Localities with good water quality; these are mostly submontane streams, brooks and smaller rivers at altitudes of 500-750 m a.s.l., with highest species diversity and only local sources of pollution.

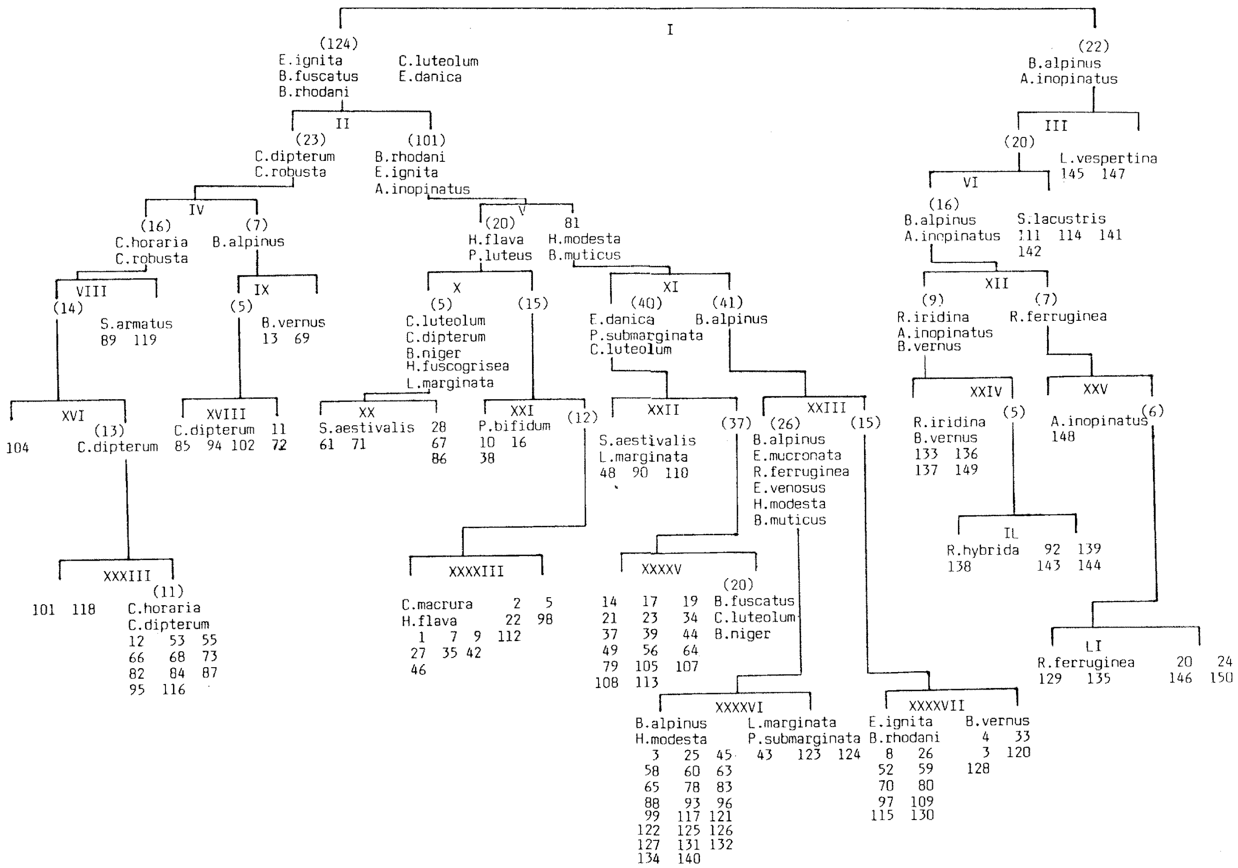


**Fig. 5. Divisive hierarchical classification (TWINSPAN) of all localities, second research period. Each division is labeled by indicator species.**

Group 4 - Localities of poor water quality; these are exposed to continuous significant pollution; included are foothill and lowland brooks and streams, and canals, some slightly eutrophic, and all with low species diversity, and mostly with species of wide ecological range and tolerance to pollution.

Group 5 - Localities with moderately polluted water (mostly cumulative pollution), including large lowland rivers at altitudes up to 250-300 m a.s.l.; these show relatively high species diversity, mostly stenotopic riverine species with disjunctive distribution.

Group 6 - Considerably polluted and mostly eutrophic lowland and foothill lakes and fish-ponds, inhabited by species that tolerate temporal or permanent anoxia.

### (iii) *Ordination*

DCA ordination was applied to combined samples from the two research periods. At first, all the samples were subjected to ordination. The first two axes distinguished the particular types sufficiently (Fig. 6, A-rhithron, B-potamon, C-other localitis, D-stagnant water). However, the shifts of particular localities in the ordination space are difficult to interpret. The most pronounced shifts occur in the rhitron group. However, it should be noted that the length of the shift is negatively correlated with species diversity. Interesting to note that since the score of locality is a weighted average of scores of its constituent species, even the extinction of a single species caused a pronounced shift of the localities with extremely low species diversity. Contrasting to this are the localities of rhithron which have higher species diversity and show only slight shifts. Importantly, the shifts are not unidirectional. Even when examining the more homogeneous subsets of localities (*e.g.* potamon, Fig. 7), it is difficult to find any regularity. It appears that heterogeneity in data set, affected by environmental variables, particularly temperature, affected by environmental variables, particularly temperature, effectively masks the compositional changes caused by water pollution.

The ordination of species reveals the ecological significance of the first axis (*e.g.* 30 - *Ecdyonurus picteti*, 45 - *Rhithrogena hercynia*, 46 - *R. hybrida*, 7 - *Baetis alpinus*, indicating highest water quality). The width of ecological range increases (and the indicator value of species decreases) with the increasing score on the first axis; species of medium indicator value include, *e.g.*, 44 - *Rhithrogena germanica*, 15 - *Baetis scambus*, 68 - *Paraleptophlebia cincta*, 24 - *Ecdyonurus affinis*, 71 -

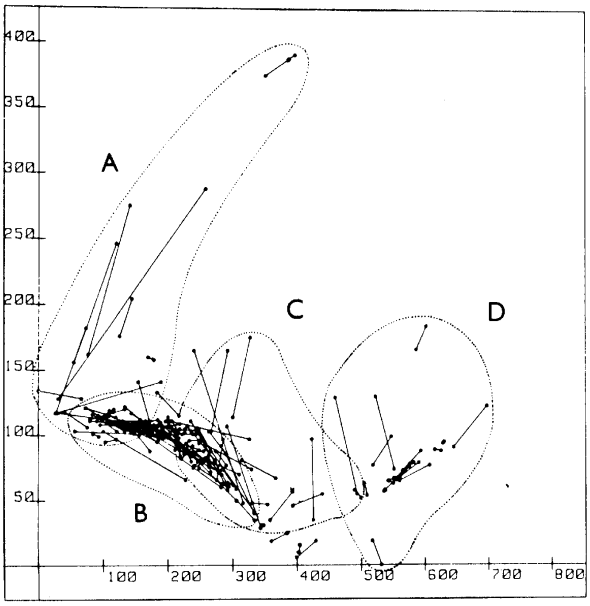


**Fig. 6. Ordination of localities (combined samples from both periods). A: rhithron. B: potamon. C: other localities. D: stagnant waters. The solid lines connect the earlier and the present state.**

*Ephoron virgo*, 74 - *Ephemera vulgata* and others; eurytopic ubiquist species with wide ecological range and limited bioindicator value include, *e.g.*, 16 - *Baetis vernus*, 21 - *Procloeon bifidum*, 38 - *Heptagenia flava*, 40 - *Heptagenia sulphurea* and others. Species with extremely wide ecological range inhabit mostly stagnant water, show the highest score on the first axis, *e.g.*, 19 - *Cloeon dipterum*, 20 - *C. simile*, 55 - *Caenis horaria*, 61 - *Caenis robusta*.

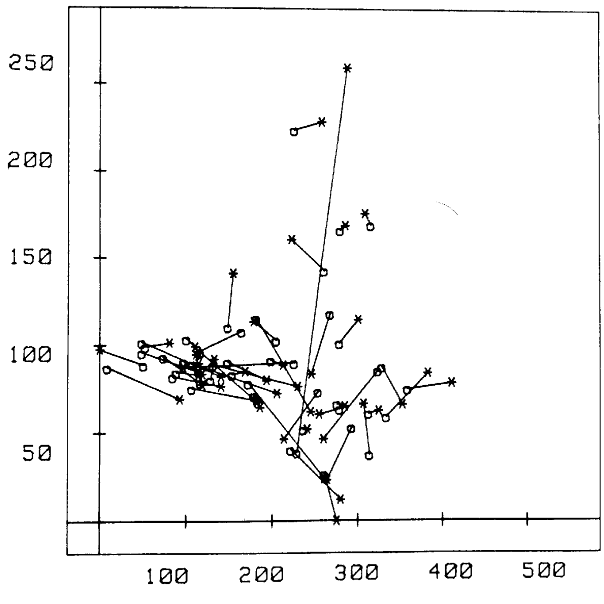


**Fig. 7. Ordination of localities of potamon (combined samples from both research periods). o - first period, * second period.**

The second ordination axis is positively correlated with elevation optimum of the species. Stenotopic montane species have very high scores, *e.g.*, 1 - *Ameletus inopinatus*, 67 - *Leptophlebia vespertina*, 48 - *Rhitrogena loyolaea*. The highland and lowland species with scarce occurrence mostly have low scores on the second axis, *e.g.*, 39 - *Heptagenia fuscogrisea*, 54 - *Brachycercus harrisella*, 9 - *Baetis calcaratus*.

The results of TWINSPAN were used for construction of the transition matrix in Table 1 (details are given in Lepš *et al.* 1988). To the six classes obtained from TWINSPAN, the 7th was added including localities where mayflies were not present. The 'dead waters' class was considered to be an absorbing state. The transitions are not strictly unidirectional, yet, they reflect clearly a tendency towards water deterioration.

**Table 1. Transition matrix for mayfly communities constructed from the output of TWINSPAN (Fig. 9).**

| To \ From | 1 | 2 | 3 | 4 | 5 | 6 | localities without mayflies |
|---|---|---|---|---|---|---|---|
| 1 | .77 | 0 | .06 | 0 | 0 | 0 | 0 |
| 2 | 0 | .60 | 0 | 0 | .05 | .05 | 0 |
| 3 | .14 | 0 | .82 | .04 | .05 | 0 | 0 |
| 4 | .06 | .20 | .06 | .90 | .05 | 0 | 0 |
| 5 | 0 | 0 | .06 | .02 | .75 | 0 | 0 |
| 6 | 0 | .20 | 0 | 0 | .05 | .95 | 0 |
| localities without mayflies | .03 | 0 | 0 | .04 | .05 | 0 | 1.0 |

## Discussion and conclusions

Three methods of multivariate analysis were compared with respect to their usefulness for detecting directional changes in community composition. It was found that the interpretation of agglomerative hierarchical classification is difficult and always needs reference back to the data. Particularly when classifying a large number of cases, the dendrograms are difficult to comprehend. The resulting groups are, however, usually interpretable. The comparisons of results from two research periods indicate the simplification of structure in the second research period.

Useful information come to light about environmental changes at the localities through divisive hierarchic classification (TWINSPAN). This classification produced well defined groups. The dendrograms, even with as many as 50 divisions could be quickly referenced, as a consequence of indicator species. By comparing the classifications for the two research periods, changes of environmental conditions are characterized by changes in grouping and in indicator species. Most cases, indicator species are changed from stenotopic to eurytopic. The indicator species extracted in the analyses

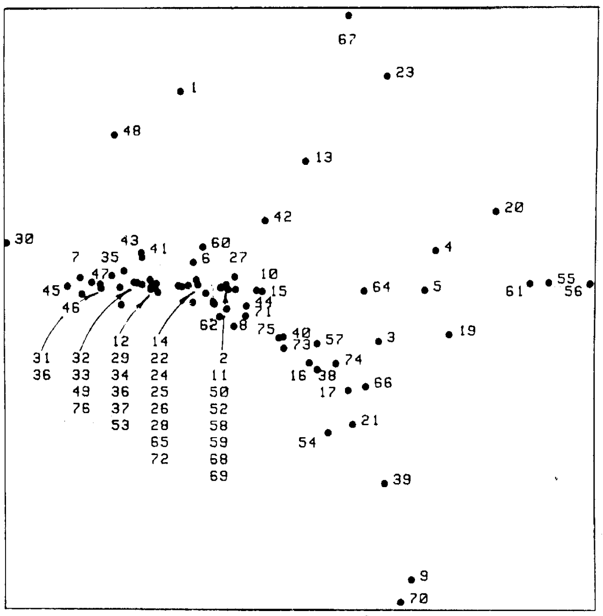


**Fig. 8. Ordination of species. 1 - *Ameletus inopinatus*, 2 - *Metreletus balcanicus*, 3 - *Siphlonurus aestivalis*, 4 - *S. alternatus*, 5 - *S. armatus*, 6 - *S. lacustris*, 7 - *Baetis alpinus*, 8 - *B. buceratus*, 9 - *B. calcaratus*, 10 - *B. fuscatus*, 11 - *B. lutheri*, 12 - *B. muticus*, 13 - *B. niger*, 14 - *B. rhodani*, 15 - *B. scambus*, 16 - *B. vernus*, 17 - *Centroptilum luteolum*, 18 - *C. pennulatum*, 19 - *Cloeon dipterum*, 20 - *C. simile*, 21 - *Procloeon bifidum*, 22 - *Oligoneuriella rhenana*, 23 - *Arhroplea congener*, 24 - *Ecdyonurus affinis*, 25 - *E. aurantiacus*, 26 - *E. dispar*, 27 - *E. forcipula*, 28 - *E. insignis*, 29 - *E. lateralis*, 30 - *E. picteti*, 31 - *E. quadrilineatus*, 32 - *E. subalpinus*, 33 - *E. submontanus*, 34 - *E. torrentis*, 35 - *E. venosus*, 36 - *Epeorus sylvicola*, 37 - *Heptagenia coerulans*, 38 - *H. flava*, 39 - *H. fuscogrisea*, 40 - *H. sulphurea*, 41 - *Rhithrogena alpestris*, 42 - *R. diaphana*, 43 - *R. ferruginea*, 44 - *R. germanica*, 45 - *R. hercynia*, 46 - *R. hybrida*, 47 - *R. iridina*, 48 - *R. loyolaea*, 49 - *R. semicolorata*, 50 - *Ephemerella ignita*, 51 - *E. mucronata*, 52 - *E. notata*, 53 - *Torleya major*, 54 - *Brachycercus harrisella*, 55 - *Caenis horaria*, 56 - *C. lactea*, 57 - *C. luctosa*, 58 - *C. macrura*, 59 - *C. pseudorivulorum*, 60 - *C. rivulorum*, 61 - *C. robusta*, 62 - *Choroterpes picteti*, 63 - *Habroleptoides modesta*, 64 - *Habrophlebia fusca*, 65 - *H. lauta*, 66 - *Leptophlebia marginata*, 67 - *L. vespertina*, 68 - *Paraleptophlebia cincta*, 69 - *P. submarginata*, 70 - *P. werneri*, 71 - *Ephoron virgo*, 72 - *Ephemera danica*, 73 - *E. lineata*, 74 - *E. vulgata*, 75 - *Potamanthus luteus*.**

reflect true qualitative and quantitative changes of locality, avoiding the danger of overestimating the change, which is usually the case with global indicators. The method is sensitive even to such obscure factors as acidification pressure, water treatment or stream bed regulation.

A further attractive property of the method is the meaningful first or second division in environmental terms. This enables a proper definition of terminal groups (see Figs. 4, 5). Furthermore, the divisive algorithm enabled effective corroboration of the data set - notwithstanding a total of 300 samples from the two research periods. The classification provided a basis for subsequent construction of a transition matrix, modelling the changes in mayfly communities (Lepš *et al.* 1989).

The DCA ordination was able to distinguish particular types of water habitats (potamon, rhithron, standing waters). However, the data set proved to be too heterogeneous to enable the ordination to show changes in particular localities. Caution is urged when interpreting the length of 'shifts' in ordination space. They are negatively correlated with the species diversity of particular localities - extinction of a single species in extremely species poor localities causes long shifts which need not be caused by considerable changes of environmental conditions. On the other hand, ordination of species can be easily interpreted from the bioindication point of view, even represesnting certain quantification of formerly rather intuitive evaluations of 'indicator value' in individual mayfly species. This conspicuous correlation is undoubtedly worth of our further attention.

When comparing the results of multivariate analysis with those of standard saprobiological methods for determination of resulting saprobity and saprobial index (Czechoslovak National Standard No. 830532) some advantages of multivariate analysis become apparent: (i) saprobiological methods, especially determination of resulting saprobity, are very rough, practically not distinguishing within the same saprobiological category. The same localities are easily classified and grouped by multivariate analysis (except for ordination); (ii) saprobiological methods do not describe relationships among localities investigated which often reflect the way of changing environmental condition; (iii) methods of multivariate analysis can distinguish often even between local source and cumulative pollution and are able to separate polluted localities with azonal communities and/or secondary enrichment of species diversity; (iv) methods of multivariate analysis can signify also factors, causing changes of environmental conditions other than pollution (*e.g.*, acidification, drainage, sedimentation); (v) methods of multivariate analysis better reflect really long-term changes containing effects of environmental factors for many years. However, certain weakness of methods of multivariate analysis is the relativity of locality evaluation; this is contrasted to classical methods. Each group is meaningful in the context of the data set under study only. Even the quantification of the range of environmental conditions suitable for particular group is very difficult. Remarkable concordance was achieved between saprobiological characteristics of individual species according to Czechoslovak National Standards and the ordination of species.

To conclude, we found methods of multivariate ana-

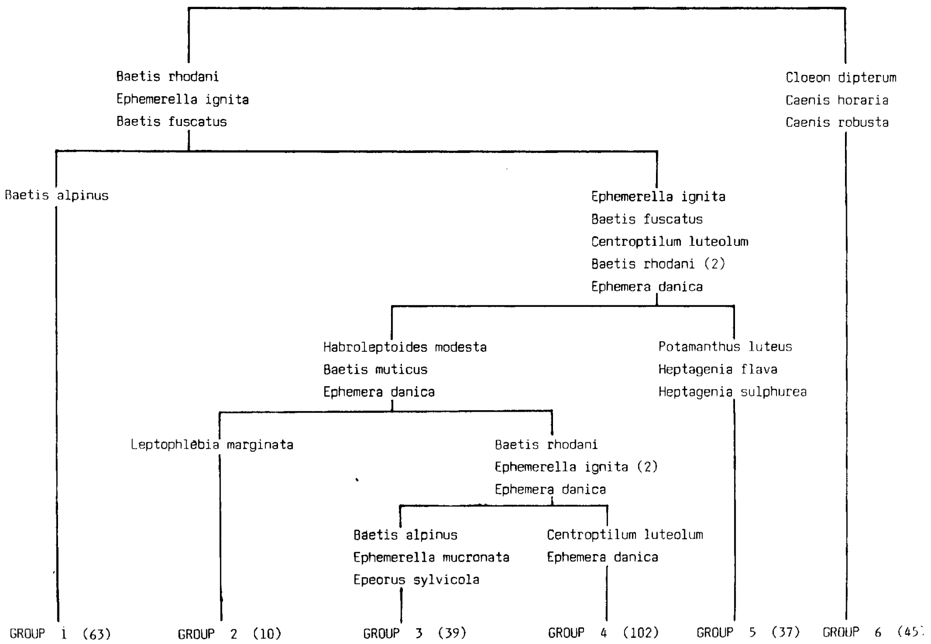


**Fig. 9. Divisive hierarchical classification (TWINPSAN) of all samples from both periods to groups suitable for subsequent construction of transition matrix.**

lysis advantageous for evaluation of data obtained by the above described method of collecting mayfly larvae, yielding much more information than simple comparison of resulting saprobity and saprobial index. Of these methods, divisive hierarchic classification (TWINSPAN) seems to provide the most suitable results being detailed and easily interpretable reflecting large set of environmental factors causing changes of aquatic biotopes and their Ehpemeroptera communities.

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