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BIODIAGNOSTIC EVALUATION OF EPIGEIC SPIDER COMMUNITIES

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Abstract
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The explanatory power of the various characteristics of spider communities for the indication of the degree of deterioration of the sites examined is assessed. The index of diversity, as a simple diagnostic index, does not suit to this purpose. A suitable simple diagnostic indicator of the degree of deterioration of sites is the percentage abundance of specimens of expansive species.

Introduction

Communities of diverse organisms have been used as bioindicators of the environmental status. A number of characteristics has also been employed for the description of the structure of these communities. For instance, communities of invertebrates have been characterized by the following parameters: number of species, number of specimens, index of richness, individual dominance of species, species sequence according to dominance, structure of dominance (which can be expressed via the index of dominance), index of diversity (Shannon's, Simpson's), evenness index, trophic structure, indicative species selected by means of multivariate analysis, and discriminant analysis. The following are regarded as useful for obtaining information on the status of environment: abundance of species of different zoogeographic proliferation, of species of different zonal, biotopic, soil, and biological demands, species of different degrees of rareness or different degrees of endangerment (Bioindikation, 1980). These characteristics of the communities under investigation are usually compared with those of other communities — from control sites, from sites at different distances from pollution sources, or from observations made in different years.

The gamut of characteristics used and comparison of communities from areas of different kind helps us to recognize the principles of action of various factors on the landscape. Of course, if communities from areas heavily affected by the activity of man are compared with those from control, totally unstressed areas, some differences are found practically always in the various characteristics. It will be clear that for a practical utilization of the results of bioindication in landscape ecology, several most sensitive characteristics with a large amplitude should be selected for use and data of these selected characteristics should be collected from a wide area and their normals should be established. The degree of deterioration of areas of interest then could be evaluated in absolute values, without having to resort to a comparison with some reference values. This would actually be a gradual transition from bioindication to biodiagnostics.

Material

A collection of 36 samples of spider communities was used for the main analysis. The collection contained all published data of spider communities in Bohemia and Moravia, available unpublished data — mostly work of students at the Faculty of Natural Sciences, Charles University, and samplings by the author. The main collection is compared with four mixed samples (No. 37—40) which are sums of material from several sites and serve as representatives of wider territories. All samples are from localities of non-forest nature. All material was obtained by the pitfall trapping method. For comparing this method with other sampling methods, nine other samples of communities were used in addition (No. 41—49).

The characteristics of the samples, along with the pertinent references, can be found in Růžička (1986). The numbering of samples in the present paper relates to that in the paper cited as follows:
1-1, 2—2A, 3-2B, 4-4A, 5-4B, 6-4C, 7-4D, 8-4E, 9-4F, 10-4G, 11-4H, 12-4J-58, 13-4J-60, 15-4J-62, 16-5A, 17-6A, 18-7A, 20-9, 21-10A, 22-10B, 23-11A, 25-11B, 26-13, 27-14-61, 28-14-62, 29-15-59, 30-15-60, 31-17, 33-18B, 34-18A, 35-19, 36-20, 37-3, 38-8, 39-12, 40-16, 42-23B, 44-26, 46-24.

The following nine samples have not been included in the previous paper:

19. Kopeč. State nature reserve. 1973 (5 traps): 51 species, 291 specimens (Buchar, 1976).
24. Třeboň. Waterlogged culture meadow in the "Mokré louky" complex. 1977 (5 traps): 40 species, 2453 specimens (Růžička, 1981).
32. Kyje. A sugar beet field. 1956 (2 traps): 8 species, 490 specimens (Miller, 1972).
41. Brná. Protected landscape region České stredohoří. Valley slope above Brná village near Ústí nad Labem. Hand-picking (1978): 19 species, 51 specimens (Buchar et al., 1979).
43. Záměský Borek. State nature reserve. Deciduous woods with hornbeam, ash-tree, bird cherry-tree. Hand-picking (1973): 35 species, 82 specimens (Buchar, 1977).

45. Borek. Oak coppice planted about 12 years before in a non-afforested area. Meadow species still prevailing in the herb layer. Shrub beating (1972): 63 species, 914 specimens (Bílek, 1973).
47. Chlum. A modified, poorer variant oak-hornbeam forests in an extensively agriculturally managed area. Shrub beating (1972): 46 species, 315 specimens (Bílek, 1973).
48. Lužany (Můstek, Kvilda). Sum of material from three culture meadows. Sweeping (1958-62): 88 species, 2141 specimens (Buchar, 1968).
49. Pohořelice. A lucerne field. Sweeping (1965): 24 species, 363 specimens (Miller, 1972).

Method

Several characteristics of the community structures were used and related to the site deterioration. The characteristics fall into two major groups:

A — Characteristics derived from data of the number of species and number of specimens in the community, irrespective of the properties of the species:

1. Index of species richness, d:

$$d = (S - 1)/\ln N.$$

2. Index of dominance, c:

$$c = \sum_i (N_i/N)^2 = \sum_i D_i^2.$$

3. Information index of diversity, H:

$$H = -\sum_i (N_i/N) \log_2 (N_i/N) = -\sum_i D_i \log_2 D_i.$$

4. Evenness index, E:

$$E = H/\log_2 S.$$

Here S is the number of species in the sample, N is the number of specimens in the sample, N_i is the number of specimens of the i-th species and D_i is the percentage abundance of the i-th species.

B — Characteristics calculated from the percentage abundances of species of given properties in the community:

5. Percentage abundance of specimens of species of different frequency, F.

Based on a revision of all material concerning spiders in Bohemia, Buchar (1972) divided species collected in Bohemia until 31. 12. 1970 into three frequency classes: class 1 — species collected in more than 50 specimens; class 2 — species collected in 20 – 50 specimens; class 3 — species collected in less than 20 specimens. This division is sort of objective classification of abundance. The percentage abundances of specimens of species in class 1 is expressed.

6. Percentage abundance of specimens of species of different degrees of abundance, h:

Miller (1971) classes species in eight categories according to their abundance: 1 — very rarely, 2 — rather rarely, 3 — rarely, 4 — very scarcely, 5 — scarcely, not abundantly, 6 — abundantly, 7 — rather abundantly, 8 — very abundantly. The percentage abundance of specimens in expressed in terms of this scale.

a) very abundant species — h_8,

b) combined very abundant and rather abundant species — $h_{8,7}$,
c) combined very abundant, rather abundant and abundant species — $h_{8,7,6}$.
7. Index of abundance, K.

The above three characteristics express the percentage abundance of species of the highest categories. The index of abundance is the average category of abundance,

$$K = \sum_k (N_k k)/N,$$

where k is the number of category of abundance (see above), N_k is the number of specimens of species in category k, and N is the total number of specimens.
8. Percentage abundance of specimens of expansive species, E_{sp}.

In the classification of relictness of occurrence (Buchar, 1972, 1983), species are classed in three categories: E — expansive species, i.e. species capable of forming populations on artificially deforested sites; R II — relicts of 2nd rank, i.e. species living in culture forests and other wood formations; R I — relicts of 1st rank, i.e. species living both on relict sites corresponding to past types of climate and in original and natural forests, hence woods corresponding to the present climate.

Now, from the point of view of site deterioration, we divide all samples into three separate groups according to the territory:

Group I: protected territories, i.e. state nature reserves and unmanaged parts of protected landscape areas;
Group II: territories not belonging to Groups I and III;
Group III: managed territories (meadows and fields).

Each sample were assigned the nine characteristics described. For each characteristics, the samples were arranged in the increasing (c, F, h, K, E_{sp}) or decreasing (d, H, E) order.

If some of the characteristics reflected fully the degree of deterioration of the site, the arrangement of samples according to its increasing or decreasing value should also correspond to the Group I-II-III order. Since usually this is not the case, we evaluated the order (or disorder) in the sample arrangement in terms of the total number of inversions (I), i.e., the number of pairs of samples where a sample of a higher group precedes one of a lower group, irrespective of the mutual sample distance in the sequence. Inversions occur if samples of Group II precede samples of Group I and samples of Group III precede samples of Groups I and II. (For instance, for characteristics h_8 (Fig. 1): in the sequence, sample No. 21 is before four samples of Group I; samples No. 23 and 20 are before two samples of Group I; and sample No. 22 is before one sample of Group II and two samples of Group I. I = 4 + 2 + 2 + 1 + 2 = 11.)

Results

The sample arrangement in sequences of increasing or decreasing values of the various characteristics is shown in Fig. 1. These sequences generally follow the territorial group order, many exceptions, however, occur. Some of the most notable deviations of the characteristics from values usual in the particular territory group are explainable.

In the protected territory group, samples No. 2, 3, and 6 exhibit exceptional characteristics. Samples No. 2 and 3 are from peat bogs, where the species variety is confined by the specific natural conditions. On either locality, always one species predominates markedly (2 — *Pardosa hyperborea*, 3 — *P. sphagnicola*). Sample No. 6 is from a dry grass stand where a species, viz. *P. bifasciata*, also prevails.

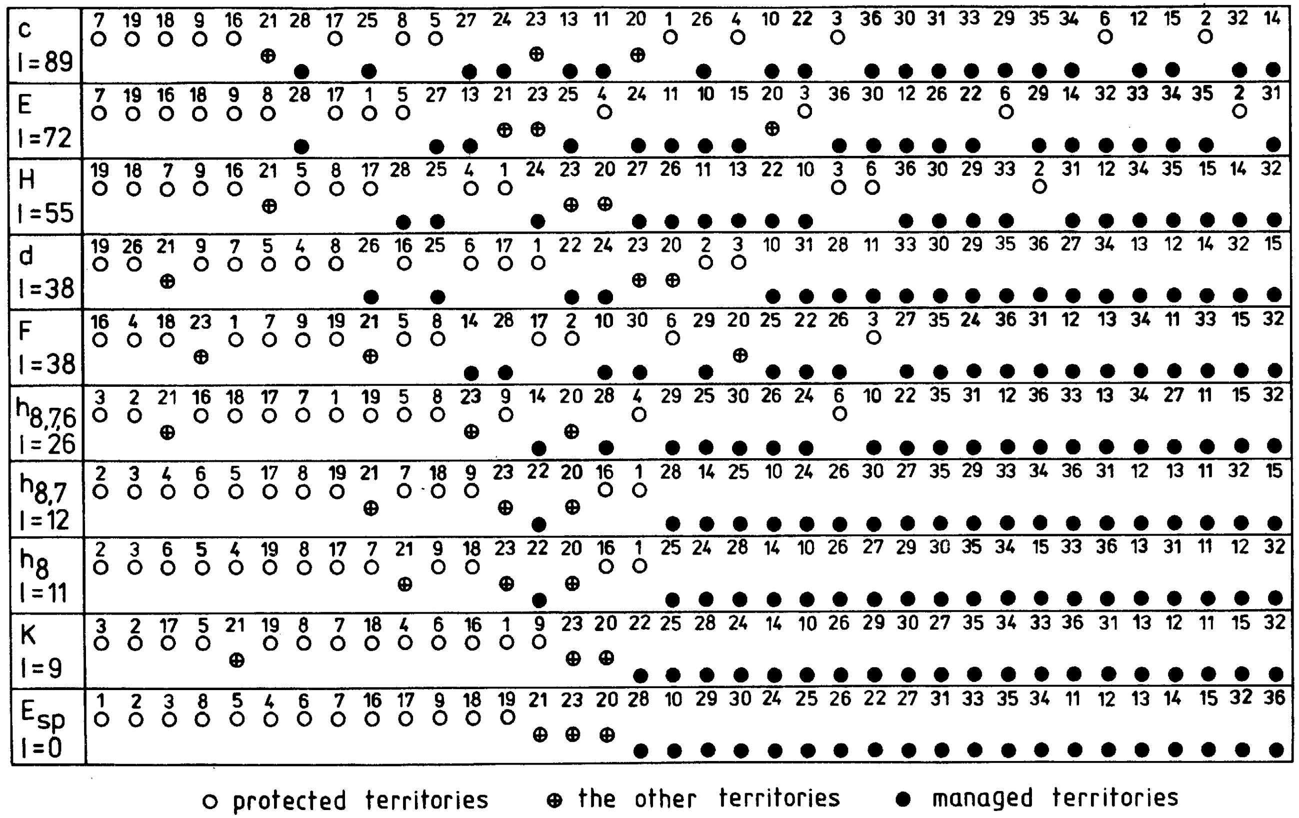

Fig. 1. The sample arrangement in sequences of increasing or decreasing values of the various characteristics.

In Group II, sample No. 21 is exceptional. This sample is from a herb stand near a fishpond where a variety of species occur and which, moreover, comprises two somewhat different microsites.

In the group of managed territories, unusual characteristics are found for samples No. 25 and 28. Here there are several leading species of approximately the same frequency (25 — *Oedothorax retusus, Pardosa prativaga, P. palustris*; 28 — *Centromerita bioclor, Oedothorax apicatus, Erigone dentipalpis*).

The remaining disorder is hard to account for.

In the scale of territories affected by the activity of man, the one limit is state nature reserves, the other, fields or freshly heaped dumps. In nature reserves, the remainders of communities that have adapted to their environment in long ages and which are only slightly stressed by the activity of man are protected. Ploughed fields and freshly heaped dumps, on the other hand, are territories standing quite at the beginning of their successive evolution, without a vegetation cover and heavily devastated by the activity of man.

Should some characteristics of the community serve as a bioindicator of the degree of deterioration, it would have to be able to clearly distinguish at least between these two poles. If these extremes are not discriminated safely, an extensive commentary is necessary for the interpretation of the characteristic aiming to explain why this characteristic fails to reflect the status in a straightforward manner, and any quantification of the characteristics would be useless.

The index of diversity is in a rather poor agreement with the classification of the samples in the three territory groups. Index I is about 38 – 89. It can be said globally that the diversity of communities is mostly reduced by the activity of man; it has, however, various components such as the species diversity or evenness, and its value is determined by many factors (distinctness of natural conditions, degree of successive evolution, degree of deterioration). In fact, the diversity can be different even under identical abiotic conditions of the environment because of differences in the biotic factors (effect of predators). The diversity is also affected by the size structure of the community. The evenness, for instance, can be increased owing to the fact that the leading species of the various size groups attain roughly the same frequency of occurrence (Růžička, 1985b); this is the case, e.g., with samples No. 25 and 28. It is imperative that samples for diversity calculations be taken from a homogeneous section of the locality.

The diversity value is calculated from the number of species and number of specimens in the community solely, irrespective of the properties of the species present. So it contains minimal information on the species in the community. The index of diversity does not suit well as a simple biodiagnostic indicator of site deterioration.

The characteristics derived from the abundances of the various groups of species in the community agree with the sample arrangement according to three territory groups considerably better than the index of diversity. Index I attains values of 0—38. These characteristics go more to the point, involving a great deal of our knowledge of the autecology of the various species.

The index of average abundance, *K*, appears to suit best to the assessment of the abundance of species. Should only the percentage abundances of the most abundant species be compared, we would find that the very abundant or the very abundant and rather abundant species, representing 13—22 % of all species in Czechoslovakia, are preferred.

The sample arrangement is best consistent with the percentage abundances of specimens of expansive species. The samples divide into the three groups with respect to the territory deterioration without any exception.

Discussion

Mixed samples

For the calculation of the indices of diversity it is prerequisite that the samples be collected from an absolutely homogeneous site. This requirement actually poses a problem. Natural sites often comprise a variety of microsites of different nature. And mixed samples representing the fauna of a larger area are unamenable to diversity evaluation at all. This effect is most apparent in the species diversity index. The first three in the decreasing sequence are mixed samples No. 38, 37, 40. The mixed sample from fields, No. 40, exhibits a higher species diversity than any sample from the protected territories.

On the other hand, when evaluating the percentage abundances of species of different categories of abundance (or relictness), mixed samples can be evaluated together with samples from individual sites. Material collected over a territory on gravel shores of a brook, in grass stands in a valley, and on rock precipes can be added together. If the territory has been unaffected by the activity of man, all sites will display similarly high percentage abundances of specimens of rare (relict) species.

For the calculation of the percentage abundances, the period of the season of year when the material was collected is also irrelevant (the samples usually comprise material collected over the whole year). This, however, is questionable if the diversity is to be calculated.

Abundance and relictness of occurrence

The degree of site deterioration can be assessed via the percentage abundances of specimens of expansive species. The division of species as *r*- and *K*-strategic could apparently serve this purpose as well. Since, however, these categorizations are only rarely elaborated for the animal group and territory of interest, they are replaced by the categorization of the abundance of species. Occasionally, the abundance of species that were found on few sites only (species with a low constancy) is also followed.

Constancy

By species constancy is meant the percentage fraction of sites where this species was found. Experience with this quantity is not unique. In forest communities of carabids, Lesniak (1980) observed an appreciable decrease in the abundance of the number of species with a low constancy even at a low contamination level. On the other hand, making use of this characteristics for comparing spider communities in mown and unmown wetland stands, Koponen (1979) found no substantial difference between them.

The explanatory power of the category of percentage abundance of species with a low constancy is limited due to a significant factor. The assembly of species that occur on a small fraction of sites only, includes two components in different ratios. The first is what we refer to as relicts of 1st rank, hence, species whose centre of occurrence is on the most original sites. On meadows, for instance, this component would include the rare wetland species of *Bathyphantes pullatus*. The other component is relicts of 2nd rank and expansive species that the localities examined do not suit to because of their light, humidity, etc., demands, irrespective of the degree of anthropogenic stress. On meadows, this component would include, e.g., the species of *Xysticus kochi*, individual specimens of which can get there at random from shrubs of forest edges. The occurrence of this expansive species in the material from pitfall trapping in meadows is fortuitous and is irrelevant for the bioindication of the degree of anthropogenic stress of the locality followed.

For this reason, the use of the constancy value for the bioindication of the degree of site deterioration is questionable, particularly for small site sets. If a marsh is compared with a field, we find species on the field that do not occur on the marsh; this, however, does not imply uniqueness of the field cultures.

Abundance

In the categorization by abundance, the species are divided into categories according to the frequency at which they are found. The categories are expressed in words (very abundantly, scarcely, rather rarely, etc.) in a numerical scale. The categorization can rely on the researcher's individual assessment or on numerical evaluation of an ample collection of material. In either case the evaluation can be biassed by the researcher's personal experience, by preferring some particular method of sampling, some territory, or some biotope.

Any classification of abundance holds reliably only for that territory for which it has been worked out. In the various parts of its area, a species can exhibit quite different properties. For instance, species that are very abundant in forests of northern countries can live in Czechoslovakia only very rarely on mountain peat-bogs. And expansive species are abundant in cultural landscape only; in wide areas of undisturbed nature such as Siberian taiga, expansive species will generally be among the rare ones.

Some species can be locally abundant and globally rare. For example, species living on peat-bogs only will be looked upon as rare if regarded as part of the fauna of Czechoslovakia; this, however, is a consequence of the fact that peat-bogs themselves are rare in this country. Within the communities of peat bogs solely, these species are abundant.

Kult's (1971) classification of the abundance of carabids relies on a comparative evaluation of ample material from the whole territory of Bohemia. The categories of his eight-membered scale are exactly determined by the numbers of revised specimens. This brings about another unexpected difficulty. Large--size species never occur in so high amounts as small-size species, and therefore they cannot be labelled as very abundant. Thus the categorization also depends on the species size.

Buchar's (1972) division of spider species into frequency classes, also elaborated based on an extensive treatment of ample material from the whole of Bohemia, is not very suitable for our purposes; because of various errors it is biassed more than the classification by Miller (1971), worked out "subjectively" based on the knowledge of species ecology.

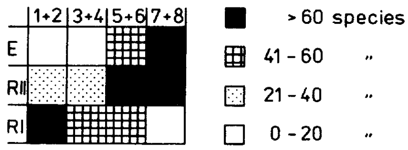

Fig. 2. Comparison of the classification of relictness of occurrence of spider species (Buchar, 1972, 1983) with the classification of their abundance (Miller, 1971).

A comparison of the classification of relictness of occurrence of spider species (Buchar, 1972, 1983) with the classification of their abundance (Miller, 1971) is shown in Fig. 2. A vast majority of the expansive species is among the abundant ones. Relicts of 2nd rank are distributed more evenly over the abundance scale, the majority, however, again belongs to abundant species. These species are peculiar to the still widely occurring and rather uniform forest ecosystems. A vast majority of relicts of 1st rank are rare species. Some of the relicts of 1st rank are denoted as more abundant; actually, however, they are only locally abundant in biotopes of some less frequent types.

In spite of these theoretical difficulties, the classification of abundance can be used in the practice with success. Problems in the classification usually concern less abundant species, which do not affect the total result significantly.

Relictness of occurrence of species

The classification of relictness of species occurrence is also usable reliably only for territories for which it has been devised.

Sampling methods

The sampling methods are also of importance when assessing the structure of communities. For spiders, pitfall trapping, hand-picking, beating of trees and shrubs, and sweeping of herb stands are feasible sampling methods. The structure of samples with respect to the relictness of species occurrence is shown in Fig. 3. The samples were collected on a locality using different sampling methods.

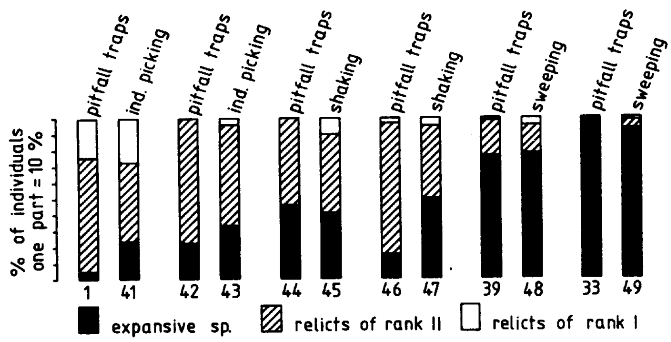

Fig. 3. The structure of samples with respect to the relictness of species occurrence. The samples were collected on one locality using different sampling methods. 1, 41 — Brná in protected landscape region České středohoří, valley slope; 42, 43 — state nature reserve Zámělský Borek, deciduous woods; 44, 45 — Borek, oak coppice; 46, 47 — Chlum, deciduous woods; 39, 48 — Lužany, meadows; 33, 49 — Pohořelice, lucerne field.

Hand-picking led to a slightly higher abundance of relicts of 1st rank as compared with pitfall trapping. This can be explained in terms of what Buchar (1977) says, namely, that "once a group of skilled and experienced pickers concentrate on a site, they ultimately find more of "rare" species than of common ones".

The results of sampling by pitfall trapping and by beating in a twelve-year-old oak coppice are nearly identical. In a grown-up forest, beating provided 34 % more specimens of expansive species than pitfall trapping.

Quantitative data for a comparison of the material obtained by sweeping and by pitfall trapping are only available from managed meadows and from a lucerne field. On these sites the structure of the material practically does not differ; expansive species predominate. Buchar (1977), however, found that on unmown natural grass of the alpine zone of the Giant Mountains and Bohemian Forest, where the fraction of expansive species in the ground layer is low, the generally prolific expansive species of *Linyphia pusilla*, *Meioneta rurestris*, and others prevail in the herb layer.

The material collected in the herb (or shrub or tree) layer has a structure of relictness of species occurrence different from that of the material collected in the ground layer. In natural localities unaffected by the activity of man, where there is a low fraction of specimens of expansive species in the ground layer, this fraction is rather high in the herb layer. The species from the herb layer occasionally exhibit strong dependences on the specific conditions of the ground; fewer relicts of 1st rank are present. Of epigeic spiders in Bohemia, 40 % species belong to relicts of 1st rank, whereas for nonepigeic spiders this fraction is as low as 17 %. On sites strongly affected by the activity of man the results obtained by the various methods do not differ substantially, specimens of expansive species prevailing in both layers.

The structure of relictness of occurrence of species in the herb and tree layers does not present a suitable criterion for the site characterization (Buchar, 1967, Bílek, 1973). Generally, only pitfall trapping is recommendable for sampling aimed at the study of the structure of relictness of species occurrence in arachnocenoses.

Conclusions

Two groups of characteristics of spider communities were compared in relation to the degree of site deterioration: A — characteristics calculated from data of the number of species and number of specimens in the community, and B — characteristics calculated from the percentage abundances of species possessing some particular properties in the community.

The index of diversity, calculated from data of the number of species and number of specimens in sample, was found dependent on many factors of the abiotic and biotic environment. This quantity is suitable for studies of more general nature, for examining the succession trends, for the recognition of the principles of changes in the communities. It does not suit, however, as a simple diagnostic indicator of the degree of deterioration.

The characteristics calculated from the abundances of species of different properties include some of our knowledge of the ecological demands of the species. It turns out that the degree of site deterioration is well indicated by the simple characteristics of the percentage abundances of specimens of species of individual categories in a categorization of relictness of species occurrence.

This characteristic has been found sufficiently sensitive for bioindication purposes (Růžička, 1986). The state of areas of interest may be evaluated in absolute values without having to resort to a comparison with some reference values. In protected territories the percentage abundance of specimens of expansive species does not exceed 45 %, the percentage abundance of specimens of relict of Ist and IInd rank is higher than 40 %. In managed areas is percentage abundance of specimens of expansive species higher than 85 %. This classification also suits very well to the assessment of the relation between the specimen abundances and abundances of species of the various categories in the community (Růžička, 1985a).

From these facts it follows that our knowledge of the autecology of the various species can be of assistance when the influence of man on its environments is evaluated making use of our investigation of animal communities. It would be desirable that specialists and experts in well-examined species-rich group of animals should sum up all their knowledge of the ecological demands of the species and evaluate the species in terms of the relictness of occurrence. In this manner, our knowledge, which is very rich in some respects and has accumulated over long period of time owing to the pain-staking efforts of whole generations of collectors, could be vastly exploited for the evaluation of our environment.

Translated by P. Adámek

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Růžička V.: **Biodiagnostické hodnocení epigeických společenstev pavouků.**

Autor posuzoval vypovídací možnosti různých charakteristik společenstev pavouků ve vztahu ke stupni deteriorizace zkoumaných stanovišť. Indexy diverzity se jako jednoduchý diagnostický ukazatel stupně deteriorizace stanovišť nehodí. Vhodným jednoduchým diagnostickým ukazatelem stupně deteriorizace stanovišť je procentuální zastoupení počtu exemplářů expanzivních druhů.

Ружичка В.: **Биодиагностическая оценка наземных сообществ пауков.**

Автор дискутирует возможности использования разных характеристик сообществ пауков в отношении к нарушению изучаемых экосистем. Индексы разнообразия негодится для оценки степени нарушения экосистем. Подходящим простым диагностическим показателем является процентуальное присутствие количества экземляров экспанзивных видов.

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