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The environmental evaluation by synecological zooindication - a proposal of the method based on epigeic invertebrate communities[x]

Abstract: This paper presents an original methodological attempt at natural valorization based on the analysis of epigeic invertebrate communities. The essence of the method is in determining the proximity of the real community towards the standard one, the latter elaborated so that it is representative for the ecosystem of given type. The survey, the assessment of the natural value and the evaluation of the anthropopressure are all based on the test describing epigeic communities of invertebrates with the use of seven indices: I. Per cent share: (1) per cent share of characteristic - exclusive species F_3; and total of characteristic exclusive and choosing species F_3+F_2; (2) the index of community uniqueness S_c; (3) the index of community stability N_c; (4) the index of species diversity H'; (5) the index of community natural quality B_c; (6) the index of dynamic heterogeneity DHt; (7) the index of habitat species capacity P_c

Key words: natural valorization, zooindication, indices, method, epigeic communities, invertebrates

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INTRODUCTION

One of the most substantial tasks of the faunistical study is the assessment of the site's natural quality. The long-term study on staphylinid communities (ŁĘGOWSKI *et al.* 1995; SMOLEŃSKI 1995, 1997a, 1997b, 1999, 2000a, 2000b) has been the background for the new method on natural valorization. The objective of the present paper is to present the theoretical assumptions and the algorithm of valorization procedure as a standard for the assessment of natural quality of the environment, using the zooindicative method.

The valorization of the natural environment with the methods of zooindication is aimed at the assessment of:

1. Natural quality of the environment;

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2. Direction and dynamics of the natural environmental processes;
3. Direction, dynamics, and degree of anthropogenic deformation of the environment.

The valorization understood as outlined above needs an empirically determined reference or, in other words, the standardized description of natural communities characteristic of high natural value. This standard will serve for comparative purposes each time a new community is to be evaluated. The most substantial task of zooindication is, thus, to search for either natural or semi-natural areas characteristic of possibly high natural value and to describe the standard communities involved, together with calibration of the range of possible deformation.

The valorization method presented in this paper has been tested on staphylinids (*Coleoptera, Staphylinidae*) captured with the use of 250 Barber pitfall traps in *Empetro-nigri pinetum* associations of Mierzeja Łebska, Słowiński National Park. The collected material consisted of 5075 beetle specimens representing 123 species. The beetles were collected in five deflation basins and in one belt dune (SMOLEŃSKI 2001).

DESCRIPTION OF THE VALORIZATION METHOD

1. Valorization procedure

The accepted valorization procedure consists of the three stages:

A. The survey of live resources of the environment limited to the tested animal community.
B. The assessment of natural value of the live environmental resources on the basis of determining the degree of attraction of the habitat for the tested community of animals.
C. The assessment of anthropogenic effect based on the comparison of the tested animal community with the accepted standard of a natural community.

2. The test assessing epigeic communities of invertebrates

The inventory is actually a test describing the epigeic communities of arthropods. Seven determined zooindicative indices are included in the test. These are:

I. Per cent share:
   - of exclusively characteristic species F_3;
   - of the sum of exclusively characteristic species and choosing ones F_3+F_2;

II. Departure degree of given community from the standard system, as defined with the index S_c;

III. Resistance degree against deformation, as defined in terms of the index N_c;

IV. Species diversity, as determined by the index H'

V. Natural quality, defined in terms of the index B_c;

VI. Dynamic heterogeneity, determined by the index DHt;

VII. Habitat species capacity, as defined by the index P_c.

The numeric values of the indices obtained during the valorization procedure, after comparing them with the natural community standard (the later worked out for determined site conditions) allow for the valuation of the natural quality of the studied ecosystem as well as for the assessment of the anthropopressure to which it is subjected.

Each element of the test describes a specific feature of the community. The three first points treated together make it possible to say whether the real community may be assessed as stable and specific. Point four of the test considers the analysis of biological diversity with use of the Shannon-Weaner index of species diversity. This last mentioned index is commonly adopted for the assessment of the probability of random selection of a specific element of the community. The three last points assess (each from a different point of reference) the degree of attraction of the given ecosystem for the community present in it. The index of natural quality deals with the general structure of the community. The index of dynamic heterogeneity is based upon a single characteristic of the community: the spatial distribution of the community. The index of the site species capacity gives synthesized knowledge on the site preferences of particular populations – members of the community.

3. The assumptions of the valorization method

- The natural value of the community is assessed based on the numeric values of particular indices. The empirical-based knowledge is necessary, therefore, of the variability ranges within particular types of ecosystem.
- The anthropogenic change is subjected to assessment *via* comparing the real values of the indices with those standard numeric values for the natural communities. It is therefore necessary, to empirically determine the threshold index values for the natural communities in particular types of the ecosystem.
- The two last points of the test (the indices DHt and P_c) are based on the microsite heterogeneity of the ecosystem. It is therefore necessary to collect faunistic material fully representative of the actually occurring site.

DESCRIPTION OF THE ZOOINDICATION INDICES

1. Step one of the test assessing the epigeic communities of invertebrates: the assessment of the share of distinctive species

Each community may be described using the per cent share of characteristic exclusive species F_3 and the summary share of both exclusive characteristic and choosing species F_3+F_2.

Theoretical background

In the analysis of species fidelity towards a given type of ecosystem the species of the community are being ascribed to one of the four fidelity classes (SZUJECKI 1983). The classes themselves are as follows: the class of exclusively characteristic species (3), the class of choosing characteristic species (2), the class of accompanying species (1) and the class of alien species (0).

In the pine forest (SMOLEŃSKI 2000a, 2001), the species distinctive for the coniferous forest types belong to the highest class of fidelity: class 3. Those species loosely connected with forest ecosystems are classified as class 2 of fidelity. The eurytopic species belong to fidelity class 1, while the open area species, avoiding the forest environment, create the lowest fidelity class: class 0.

In the formula describing epigeic multispecies communities, no weight was given to the information of per cent share of distinctive species F_3 nor to the general share of characteristic species F_3+F_2. Such an attitude is justified by the fact that the fidelity classes division system uses the adaptive potential of living organisms. It means, in other words, that representatives of particular fidelity classes differ between themselves considering the size of realized ecological niches and, if so, they also differ in respect with their adaptive potential to the presently dominating type of landscape. In central Europe, it is the agricultural landscape that prevails at present, therefore considering the example of the coniferous environment in Poland's Lowland (the broad-leaved forest biome) the exclusive characteristic and choosing species are characteristic of poor adaptive potential towards the synanthropic environments prevailing in the landscape, they deserve equal value while analysing the communities.

As an example the ranges of particular indices may be given for the epigeic staphylinids of the coastal variety of pine forest (*Empetro-nigri Pinetum*) (SMOLEŃSKI 2001):

- F_3 may vary from 19% to 42%,
- F_3+F_2 may vary from 58% to 86%,
- while the standard (natural and stable) community of epigeic staphylinids of the coastal variety of pine forest is characteristic of the following values: $F_3 \geq 20\%$ and $F_3+F_2 \geq 60\%$;

2. Step two of the test assessing the epigeic communities of invertebrates: the assessment of the deformation degree of a community from the standard pattern – expressed in terms of the index of community uniqueness

$$S_c = \sqrt{\frac{\log F_3}{\log f_3}\left(\frac{\log F_{32}}{\log f_{32}}\right)^2} \qquad \text{(formula 1)}$$

where:

F – per cent share (specimen number) in the dominance structure of community:
   F_3 – of exclusive characteristic species,
   F_{32} – of the sum of characteristic species (exclusive + choosing ones),

f – minimum per cent share in the dominance structure of a natural and stable community, typical of the given type of ecosystem:
   f_3 – of exclusive characteristic species,
   f_{32} – of the sum of characteristic species (exclusive + choosing ones);

Theoretical background

Community uniqueness is the set of features allowing for discrimination of the community and accompanied by specific natural standards – repeatable and recognizable systems, frequently represented and important from either the scientific or economic point of view.

The relevance of the formula to natural science

An excellent descriptive feature of community uniqueness is the share of fidelity classes of particular species in the dominance structure and particularly so with respect to the portion of distinctive species (exclusive species). As a consequence, one may describe the uniqueness of a natural standard community in terms of distinctive species proportion, while the real communities' uniqueness may be measured by the index defining the degree of departure from the standard system. In order to achieve this, one needs to empirically determine the critical values of distinctive species share (F_3) as well as the share of all characteristic species (F_3+F_2). Critical values are such values below which the community is neither more stable nor unique. The values are empirically determined for each syntaxon and given type of ecosystem, following the example of selected natural systems. They are denoted with symbol f in formula 1, they have the symbol f_3 for the characteristic exclusive species while the appropriate symbol for the characteristic exclusive species and choosing species is f_{32}.

The index of community uniqueness assesses the relationships between the real and the critical shares of characteristic species (F_{32}) and distinctive species (F_3). The index' assumption is that the lacking share of the group of distinctive species (F_3) may be partly made up by the increased proportion of the remaining characteristic species (F_2) and *vice versa*. It determines the departure degree of the given community from the standard system. An important feature of the index is the fact of paying more weight to the share of distinctive species (F_3), that are unique (ascribed exclusively to the given type of ecosystem). Besides, the formula is so built that the index value always equals one ($S_c = 1$) each time that the real shares of distinctive species (F_3) and characteristic species (F_{32}) are equal the determined critical values (or, in other words always when $F_3 = f_3$ and $F_{32} = f_{32}$). Thus, the value of the index equal one discriminates between the unique and non-unique systems:

- $S_c \geq 1.0$ suggests unique and stable biocenoses,
- $S_c < 1.0$ suggests non-unique and labile biocenoses.

An example may be given here of the epigeic staphylinids of coastal pine forest (*Empetro-nigri Pinetum*) (SMOLEŃSKI 2001), with respective indices values $f_3 = 20\%$ and $f_{32} = 60\%$:

- S_c index value may range between 0.98 and 1.29;
- while the standard (both natural and stable) community of epigeic staphylinids of coastal pine forest are characteristic of $S_c \geq 1.0$.

Description of formula

This index is based on the proportion of real and critical shares of characteristic species (their sum) *versus* distinctive species. The product ensures considering the assumption that a given insufficient share in the group of distinctive species (F_3) may be made up to a degree by the increased portion of characteristic species (F_2) or opposite. It is why the operation of rooting has been applied, limiting the effect of the "lacking" portion of distinctive species. This operation effect is opposite to the operation of involution, the latter emphasizing the summary deficit of characteristic species. Logarithmic expression of variables is aimed at limiting the range of variability of the index and, thus, to facilitate the interpretation of the results.

3. step three of the test assessing the epigeic communities of invertebrates: the assessment of the resistance a community for deformation – expressed in terms of the index of community stability

$$N_c = \frac{F_{32} \log F_3}{f' \log(F_{10} + 1{,}1)} \quad \text{(formula 2)}$$

where:

F – per cent share (specimen number) in the dominance structure of community:

F_3 – of exclusive characteristic species,

F_{32} – of the sum of characteristic species (exclusive+choosing ones),

F_{10} – of the sum of accompanying and alien species,

f' – coefficient specific for given community in determined type of ecosystem;

Theoretical background

Stability is the ability of a system to adopt internal stimuli without change of its stable inner structure (MacArthur 1955). The inner structure of a system is subjected to a continuous process of genesis, following the ecological evolution. Because of the above fact, the steady state of ecological systems is a relative conception (Attiwill 1994, Bormann & Likens 1979, Delcourt & Delcourt 1991, Putman 1994, Shugart 1984, Spruegel 1991, Whittaker 1975). One may distinguish between three "faces" of stability: inertia, resilience and constancy - (Lewontin 1969, May 1972, 1976, Orians 1975, Pimm 1982, 1984).

1. The inertia type of stability. In stable systems, representing the advanced stages of succession, the complexity of biocenosis is so large that the system becomes closed for egzogenic elements, both alien and eurytopic.

2. The resilience type of stability. This represents systems able to adapt to the continuous functioning under the permanent external stress condition. Such ability is a derivative of accomodation ability to the changed environmental condition.

3. The constancy type of stability. In the strictly isolated systems their constancy is due to the physical barriers closing completely the strongly unique system.

The stable forest ecosystems in the lowland Europe are clearly resiliant, in exceptional cases they are also inertia type ecosystems but never – constancy ones.

The relevance of the formula to natural science

In order to assess the system's resistance against deformation there was accepted the index of species fidelity, under the assumption that slight shares of alien species (F_0) and eurytopic species (F_1) in the dominance structure of the community always indicate closed or inertial systems or isolated ones which means constancy communities *sensu* Orians (1975). It is because the presented index describes the proportion: share of characteristic species ($F_3 + F_2$) / share of remaining species ($F_1 + F_0$) in the dominance structure of community. The most remarkable peculiarity of the index is giving the highest weight to distinctive species (F_3). And this attitude is derivative of the fact that the portion of such species, conservative by their definition, and characteristic of significantly lower adaptive potential as compared with the category of remaining species, is determinant of saturation of the majority of the ecosystem's unique ecological niches. It is noteworthy that high values of the index suggest the following, depending on the actual type of system:

- non-isolated systems (e.g. forest systems) characteristic of high stability – its inertia,
- isolated (e.g. peatland) systems of high stability – its constancy.

The index has been based on the assumption that each multispecies community has to contain both exclusive characteristic species (F_3) and all characteristic species ($F_{32}=F_3+F_2$) in shares higher than the empirically determined critical values, in order to be stable. Based upon the foregoing, the value of the f' coefficient is determined, grounded on given syntaxon and ecosystem type so that the value of the N_c index be equal unity for the critical values $F_3 = f_3$ and $F_{32} = f_{32}$ (formula 2). Therefore, the stability index for the multispecies communities gives the following picture of habitat value:

- $N_c \geq 1,0$ – suggests stable biocenoses,
- $N_c < 1,0$ - suggests unstable biocenoses.

Considering the example of epigeic staphylinids of coastal pine forest (Smoleński 2001), given the value of the coefficient $f = 48,37$:

- N_c value may vary from 0.95 to 2.37;
- The standard (natural and stable) community of epigeic staphylinids of coastal pine forest is characteristic of values higher than $N_c \geq 1,0$.

Description of formula

The index has been based on the proportion between characteristic species (F_3+F_2) and the remaining species (F_1+F_0), as represented – *nota bene*- by the fixed coefficient f' in the dominance structure. Consequently, the actual value is dependent exclusively on the numerator. The final value of the numerator is, additionally, corrected by the share of exclusive characteristic species. The logarithmic expression applied results in clear flattening of the range of possible values, thus leading to reducing the role of distinctive species: they become merely a correction coefficient. Similar is the interpretation of the non-characteristic species after the logarithmic procedure applied in the denominator that also plays the role of a correction coefficient, of opposite character, however. The formula does not allow for the non-presence of characteristic exclusive class species (each specific habitat has distinctive elements – specific for the habitat only). On the other hand, it allows for the non-presence of associated and alien species. Therefore, in order to make the formula proper, it is necessary to add the constant *1,1* to the logarithmic variable in the denominator.

4. Step four of the test assessing the epigeic communities of invertebrates: the assessment of species diversity expressed in terms of the Shannon-Wiener index of species diversity

$$H' = -\sum_{i=1}^{S} p_i \log p_i \qquad \text{(formula 3)}$$

where:

p_i – the proportion of number of individuals (n_i) of *i-th* species to the number (N) of individuals of the entire community containing (S) species.

Theoretical background

Species diversity of the system is described as the joint result of the following two characteristics (PUTMAN 1994):

- species richness – that is the maximum number of species that may exist under one system without causing any disturbances of the system itself;
- equitability – distribution of individuals between particular species enabling proper (and specific) functioning of the system.

The relevance of the formula to natural science

The Shannon-Wiener index should be considered the least susceptible to the changing size of samples among the indices proposed by the relevant literature. Besides, this index is perhaps the most popular and commonly used for the assessment of species diversity: both botanists and zoologists use it frequently. It seems therefore to be the most adequate index for the comparative analyses of multispecies invertebrate communities.

Considering the example of epigeic staphylinid communities of the *Empetro-nigri Pinetum* forest type as outlined below (SMOLEŃSKI 2001) it is to state that:

- H' may vary from 3.2 to 4.7;
- while the standard (natural and stable) epigeic staphylinid communities of the *Empetro-nigri Pinetum* forest type is characteristic of the following range: $4{,}7 \geq H' \geq 3{,}6$.

Description of formula

The idea of the index has been taken from the theory of information. The index itself is a measure of random sampling of a determined individual belonging to a specified species of the community. The figure value of the index depends on two factors: the equitability of distribution between particular species' representatives and on the number of species within the community. The higher the Shannon-Wiener index values the higher the risk of not sampling individuals of given species or, in other words, the larger the species diversity of the community (TROJAN 1992).

5. Step five of the test assessing the epigeic communities of invertebrates: the assessment of natural quality expressed in terms of the index of community natural quality

$$B_c = \sqrt[4]{J' N_c D_k D_E} \qquad \text{(formula 4)}$$

where:

J' – index of evenness (formula 5),

N_c – index of community stability (formula 2),

D_k – per cent portion of species characterizing the food availability in the habitat in the dominance structure of the community,

D_E – per cent portion of species characterizing the value of the ecosystem for conservation of local forms.

The Pielou index of evenness J' *is:*

$$J' = \frac{H'}{H'_{max}} = \frac{H'}{\log_2 S} \qquad \text{(formula 5)}$$

where:
H' – index of species diversity (formula 3),
S – number of species in the community.

Theoretical background

Natural quality of a system is a set of the system's attributes describing its uniqueness, stability, the share of valuable local forms as well as the utilization of the potential capacity of ecological niches and the available food resources.

The two parameters: natural quality and species diversity, describe the overall natural value of a system.

The relevance of the formula to natural science

The index of natural value utilizes the three parameters:

- the use of potential ecological niches;
- stability;
- food availability;
- representation of local forms.

In this paper only those indices were utilized that are least susceptible to the effect of sample size:

- In order to describe the utilization degree of potential representatives of ecological niches in the ecosystem there was used the Pielou index of evenness J' (formula 5).
- To describe stability, the index of community stability has been used N_c (formula 2), showing in full the maturity degree of an ecosystem.
- In order to describe food availability (for the epigeic communities) there was used the share of detritophilous species D_k. This index characterises the availability of accumulated organic matter and the complexity of trophic nets in the ecosystem. A general conclusion may be derived that the higher the share of detritophilous species in the dominance structure of the community, the higher the deposits of easily available dead organic matter subjected to the fermentation processes in the habitat. Of course, also other groups may be used, depending on the actual syntaxon and coenotic level, such that would best describe the availability of accumulated organic matter in the ecosystem, in a particular case.
- In order to describe representation, there was used the share in the dominance structure of those species limited in their distribution to a single zoogeographical region (e.g. Europe) D_E, such that would fully characterise the ecosystem's value for the preservation of local forms. Depending on the actual degree of faunistical knowledge of particular taxocens one may introduce to the formula smaller zoogeographical areas.

The higher value of the index of natural quality B_c the richer in species is the community, more mature and stable, containing more valuable local forms and functioning under the condition of good food availability.

Considering the example of epigeic staphylinids of coastal pine forest it is to state that (Smoleński 2001):

- values of J' index may vary from 0.60 to 0.79;
- values of N_c may vary from 0.95 to 2.37;
- values of D_k (share of detritophilous species) may vary from 36% to 60%;

- values of D_E (share of European species) may vary from 15% to 42%;
- values of B_c may vary from 4.6 to 7.2;
- while the standard (natural and stable) epigeic staphylinid community of the coastal pine forest is characteristic by the B_c index values ranging from 5.2 to 7.2.

Description of formula

The index of natural quality is a root of fourth degree from the product of four elements. It is so constructed in order to obtain synthesized information on qualitative parameters of the community. And because the product contains four elements quite different by nature, that differ between themselves also in one order of magnitude, it was necessary to use the fourth degree root in order to obtain the complete formula.

6. Step six of the test assessing the epigeic communities of invertebrates: the assessment of the microsite differentiation degree as expressed using the indices of static heterogeneity and dynamic heterogeneity

The index of static heterogeneity *SHt:*

$$\mathrm{SHt} = 100\,(1 - \frac{S'}{S})[\%] \qquad \text{(formula 6)}$$

The index of dynamic heterogeneity *DHt:*

$$\mathrm{DHt} = \mathrm{I_{ds}}(1 - \frac{S'}{S}) \qquad \text{(formula 7)}$$

where:

S – real value of species number of the entire community,

S' – expected value of species number expressed as arithmetic (or weighed) means from all samples,

$I_{ds} = dV_d$ –coefficient of species richness diversity of the site,

d – real value of the index of species richness for the entire community (formula 8),

V_d –coefficient of variation of the index of species richness (the proportion: standard deviation/ expected value of the index, where expected value is the arithmetic or weighed means from all samples).

The Margalef index of species richness:

$$d = \frac{S-1}{\log N} \qquad \text{(formula 8)}$$

where:

S – species number in the community,

N – total number of individuals.

Theoretical background

The two proposed synthetic indices serve for the assessment of microsite heterogeneity diversity using the number of species and communities size. Both the heterogeneity indices have been constructed under assumptions taken from the relevant literature sources (Dias 1996, Eriksson 1996, Howe 1991, Kotliar & Wiens 1990, Pickett & Cadenasso 1995, Pulliam 1988, Pulliam & Danielson 1991, Watkinson & Sutherland 1995) and saying that: The heterogeneous habitat community (occupying a clearly differentiated site, with strong representatives of source and sink) should be characterised in particular microsites by high variability of species richness. Besides, it is important that the mean number of species should be, for given microsite, several times lower than the general mean value revealed. Low degree species variation diversity does not necessarily suggest habitat homogeneity, it does however describe given habitat as lacking the network: source - sink.

There can be present, thus, two types of habitat heterogeneity:

- Type one heterogeneity: only qualitative mosaic of community's species composition, without differentiating the biological capacity of microhabitats (despite the fact that different species are present in different microsites, the number of species is always comparable). In such a case, the indices of species diversity have very much similar values in the habitat under study. This heterogeneity is characterised by a small value of standard deviation considering the indices of Shannon, Pielou, Margalef, as well as the number of species. Such a type of microsite mosaic may be named "static heterogeneity".

- Type two heterogeneity: qualitative and quantitative mosaic of community species composition types, connected with the well-developed diversity in microsites biological capacity (with well-developed network between sink and source). Microsites differ between themselves strongly in the number of species and number of individuals. In such a case, the values of the indices of species diversity are differentiated within a single habitat under study. They are characterised by high value of standard deviation of the indices of Shannon, Pielou, Margalef and the species number. Such a microhabitat mosaic may be called "dynamic heterogeneity".

The relevance of the formula to natural science

Static heterogeneity is described by the index *SHt* that has been based on the relationship between the mean number of species from one microsite and the total number of species recorded in the entire habitat.

This index value provides information on the general microhabitat differentiation. The larger the diversity the higher the value of the index. The static heterogeneity depends on the actual size of the sample. The larger the sample the more reliable is the information obtained.

Dynamic heterogeneity is described by the index *DHt*, the latter contains the static heterogeneity supplemented with additional information on the shares of particular extreme microsites (the sources and sinks).

The coefficient of site species richness diversity I_{ds} informs of functioning of the system "source & sink" in the ecosystem.

In order to build up the index another index has been used: the Margalef index of species richness. The latter is very much sensitive to the size of sample and as such it gives best discrimination in the species capacity of microsites (especially distinctly it expresses differences in species number and individuals number between microsites).

An example may be given here of the epigeic staphylinids of the coastal pine forest type (SMOLEŃSKI 2001):

- *SHt* index value may vary from 53% to 65%;
- I_{ds} index values may vary from 1.3 to 4.7;

- *DHt* index may vary from 0.7 to 2.9;
- while the standard (natural and stable) community of the epigeic staphylinids of the coastal pine forest type is characterised by the values of the index *DHt* 1.4 and 2.9.

Description of formula

The index of static heterogeneity *SHt* presents the proportion of the mean value (arithmetic or weighed) of the number of species in a single microsite to the total number of species recorded in the entire habitat. This index has been constructed so that the higher microsite differentiation be expressed in terms of higher value of the index (therefore the proportion *S'/S* is subtracted from the unity). The index is presented in the per cent form, in order to allow an easier interpretation.

The index of dynamic heterogeneity *DHt* is the product of the index of static heterogeneity *SHt* and the coefficient of species richness diversity of the site I_{ds}.

The construction of the coefficient I_{ds} is based on the Margalef index of species richness (formula 8). The I_{ds} index is the product of the real value of the index of species richness as calculated for the entire community (*d*) and the coefficient of variation of index of species richness as calculated for the sites under analysis (V_d). The coefficient of variation of the index of species richness (V_d) is the proportion between the standard deviation (σ_d) and arithmetic (or weighed) means (*d'*) of the index of species richness as calculated based on all analysed microsites.

The index $I_{ds} = dV_d = \sigma_d \cdot d/d'$, may also be put as the proportion of the real value (*d*) calculated for the entire community and the arithmetic (or weighed) means, calculated on the base of analysed microsites (*d'*) and multiplied by the value of standard deviation as calculated for the analysed microsites (σ_d). As a result: $I_{ds} = \sigma_d$ than $d = d'$.

The coefficients of species richness diversity of the site I_{ds} presents, thanks to the incorporated coefficient of variability (V_d), the degree of differentiation of species number and individuals number between particular microsites. The I_{ds} coefficient is composed also of the real value of the index of species richness (*d*) supplying information of the site's species capacity (following the tendency: the higher the capacity the higher the value of the *d* index). Summing up, the coefficient I_{ds} supplies the information of the direct differences in the number of species and number of individuals between particular microsites; besides, it gives indirect information of the species capacity of the entire habitat.

7. Step seven of the test assessing the epigeic communities of invertebrates: the assessment of attractiveness of a site for given community as expressed in terms of the index of habitat species capacity

The value of P_c index may be determined after two conditions listed below have been fulfilled:

a. Extreme sites are selected for particular species with use of index c_s;
b. The degree of site diversity utilization by a species of the system is determined with use of the C_s' index.

7.a. Selecting extreme microsites – sources and sinks for particular species on the basis of the index of microsite preferences of a species c_s

$$c_s = \frac{I_{fd}}{I_{fd}(\max)} \qquad \text{(formula 9)}$$

where:

$I_{fd} = \sqrt{\frac{n_j^2}{N_j}}$ - coefficient of given species dominance for j-th sample j (in j-th microsite),

$I_{fd}(max)$ – the highest value of given species dominance coefficient as revealed considering all samples (R),

n_j – number of individuals of given species for j-th sample,

N_j – total number of individuals for j-th sample.

Theoretical background

In order to describe the spatial differentiation of population the PULLIAM "source-sink" theory (1988) was used.

The relevance of the formula to natural science

Microsite preferences are expressed in quantitative terms as an index considering dominance and population size. The c_s index determines the saturation degree of given microsite with particular species (as compared with the possibly highest saturation degree. When assessing the specific species' microsite preferences one should consider both the species' population size and its share in the dominance structure of the community. Using exclusively the number of individuals as the only criterion may lead to erroneous conclusions. In microsites characteristic of large species capacity, the size of a given species population may be very high but the actual share in the dominance structure of the community may be, at the same time, insignificantly small. Opposite cases may, also, appear - in poor sites a low number species may reach a high dominance position in the community. When determining microsite preferences it is important to have information touching the maximum occurrence of given species in a determined type of ecosystem. Such maximum value is a reference point for any comparisons and while ascribing given elements to the sources and sinks. Only having all the three characteristics together (population size, maximum dominance and real dominance of a species) allows for understanding the microsite preferences of a given species. Using the index of species' microsite preferences one may relate microsites to the network source & sink, for the species characteristic of abundant occurrence and high degree stability toward given habitat.

The values of the index of microsite preferences of species c_s range from 0 to 1.

Following the standard of normal distribution one may distinguish between the following three typical cases:

- $c_s > 0,85$ – the population should be placed in the source region of its distribution range;
- $0,85 \geq c_s \geq 0,15$ – the population is in the standard region of its distribution range;
- $c_s < 0,15$ – the population is at the area of sink.

Description of formula

The index of microsite preferences of a species is the proportion between the real value of dominance coefficient (determined for a specific microsite) and the highest revealed one as observed in a given ecosystem type. The highest revealed value of the dominance coefficient is empirically determined for a given ecosystem type based on the set of all analysed microsites.

The index of microsite preferences of a species reaches highest values in the microsites most attractive for given species (the sources) and it reaches lowest values in case of those unfavourable microsites (the sinks).

The coefficient of dominance contains two separate elements: the size of species population (number of individuals) and the share of the species in the dominance structure of the community: $I_{fd} = n \cdot n/N = n^2/N$. The square root of the product of two variables gives as a result one dependent variable $I_{fd} = n_j^2 / N_j$. Assuming one knows the actual values of the coefficient of dominance for all microsites, one may determine its maximum value $I_{fd}max$ that gives the basis for identification of the extreme microsites for given species.

7.b. The assessment of utilization of the system of actual site diversity as measured based on the index of site heterogeneity utilization by given species

$$C_s' = \frac{2\sum_{j=1}^{R} c_{sj}}{R} \text{ (formula 10)}$$

where:

c_{sj} – index of microsite preferences of a species for j-th sample - microsite (formula 9),

R – number of samples - microsites.

The relevance of the formula to natural science

After the information on the c_s index (formula 9) has been collected for all microsites, one may assess the degree of utilization of microsite diversity by given species of the system. In order to achieve this the index C_s' is to be used. This index, named the index of site heterogeneity, represents the actual degree of site saturation with the population of given species.

This attempt has been based on the following assumption: if a microsite mosaic occurs within the distribution area of a stable population then the area considered sinks for the species has to be at least equalised by the source areas. Given the above assumption meat, the model stable population is characterised by the normal distribution of microsite preferences for the entire biocenosis which means $C_s' = 2 \cdot 0,5 = 1$.

C_s' values in multispecies communities give the following habitat valorization:

- $C_s'>1$, the microsite mosaic favours given population in a more than average degree. The habitat is dominated by the sources of population distribution.
- $1 \geq C_s' \geq 0.3$, the population prefers the microsite mosaic in a more or less average degree. The sources are in balance with the sinks of population distribution.
- $C_s'<0.3$, the population does not prefer the microsite mosaic. The sinks of population distribution dominate the site.

Description of formula

The C_s' index is doubled arithmetic means of the c_s index (formula 9) as calculated for all microsites.

Assuming that he model stable population (the reference point) is characteristic of the normal distribution of microsite preferences for the whole of biocenosis the arithmetic means of the c_s index or

$$\frac{\sum_{j=1}^{R} c_{sj}}{R} \text{ is equal } 0.5$$

In order to have value "one" as the reference point for any comparisons, the arithmetic means of the c_s index was doubled, leading thus to the final form of the formula (formula 10).

7.c. The assessment of site attractiveness degree for given community, expressed in terms of the index of habitat species capacity

$$P_c = \frac{\sum_{i=1}^{S} C_{si}'}{\log S} \text{ (formula 11)}$$

where:

C_{si}' – index of site heterogeneity utilization by *i-th* species (formula 10),

S – number of species in community

The relevance of the formula to natural science

Having obtained relevant data on the index of site heterogeneity utilization C_s' (formula 10) for all species of the community one may attempt to assess the species capacity of the whole of the site. While doing this the substantial principle is to be followed: the larger the value of the C_s' index, the more attractive the habitat for given species; and, moreover: the higher the value of the P_c index (the sum of C_s' index values for all species) the more attractive the habitat for the entire community. The index of habitat species capacity P_c may be considered one of the indices describing species diversity. It evaluates the habitat through the utilization of microsites by particular species constituting the community. Using this index one may draw a conclusion as to the site attractiveness for the entire community. It can be stated, therefore, that when determining the efficiency of utilization of the potential species diversity of a site, one assesses indirectly the degree of site species capacity for the community of interest. The P_c index is not sensitive to the size of sample collected. Considering the forested ecosystems, it should be expected that the P_c value will be positively correlated with the fertility of the site. Having the standard values of species capacity of the whole site spectrum of forest ecosystems (of natural communities) available it will be possible to assess the actual degree of species diversity impoverishment of degraded and synanthropized habitats.

The actual value of the P_c index may vary, in the case of standard (natural and stable) communities of epigeic staphylinids of the coastal variety of pine forest type from 8.5 to 12.8 (SMOLEŃSKI 2001).

Description of formula

The index of habitat species capacity P_c is as a matter of fact the mean value of the C_s' index (formula 10) as calculated for all species of the community. The denominator of the logarithm reduces the effect of species number or in other words the number of C_s' indices summed up. It emphasizes, however, the differences between habitats considering the utilization degree of the potential species diversity of sites. It increases, consequently, the range of the potential value of the index, facilitating thus the interpretation of the results.

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STRESZCZENIE

[Tytuł: Waloryzacja przyrodnicza metodą zooindykacji synekologicznej. Propozycja metody wykorzystującej epigeiczne zgrupowania bezkręgowców]

Praca przedstawia oryginalną metodę waloryzacji przyrodniczej z zastosowaniem epigeicznych zgrupowań bezkręgowców. Wykorzystuje następujący algorytm waloryzacyjny:

1. Inwentaryzację żywych zasobów środowiska ograniczoną do wybranego zgrupowania zwierząt.

2. Oszacowanie wartości przyrodniczej żywych zasobów środowiska na podstawie określenia stopnia atrakcyjności środowiska dla danego zgrupowania.

3. Ocenę zmian antropogenicznych, degradujących środowisko, dokonaną na podstawie porównania rzeczywistej grupy zooindykacyjnej z przyjętym wzorcem zgrupowania naturalnego.

Zasadą proponowanej metody jest opisanie każdego badanego zgrupowania za pomocą testu złożonego z siedmiu wskaźników zooindykacyjnych. Uzyskane wartości liczbowe po porównaniu z (opracowanym dla danego typu ekosystemu) wzorcem zgrupowania naturalnego pozwalają na ocenę wartości przyrodniczej ekosystemu i wywieranej na niego antropopresji.

Test określa:

I. procentowy udział:
  - gatunków charakterystycznych wyłącznych F_3
  - łącznie gatunków charakterystycznych wyłącznych i wybierających F_3+F_2

II. stopień odkształcenia zgrupowania od układu wzorcowego, wyrażony wskaźnikiem S_c

III. stopień odporności na odkształcenia, wyrażony wskaźnikiem N_c

IV. ogólną różnorodność gatunkową, wyrażoną wskaźnikiem H'

V. jakość przyrodniczą, wyrażoną wskaźnikiem B_c
VI. heterogenność dynamiczną, wyrażoną wskaźnikiem *DHt*
VII. pojemność gatunkową siedliska, wyrażoną wskaźnikiem P_c

Każdy ze wskaźników opisuje odrębną charakterystykę zgrupowania. Trzy pierwsze punkty testu traktowane łącznie pozwalają ocenić, czy rzeczywiste zgrupowanie można uznać za stabilne i swoiste. Czwarty punkt dotyczy analizy różnorodności biologicznej z wykorzystaniem wskaźnika ogólnej różnorodności gatunkowej Shannona–Weanera. Jest on powszechnie stosowany do oceny prawdopodobieństwa wylosowania konkretnego elementu zgrupowania. Trzy następne oceniają (każdy z innego punktu odniesienia) atrakcyjność danego ekosystemu dla występującego w nim zgrupowania. Wskaźnik jakości przyrodniczej dotyczy ogólnej struktury zgrupowania. Wskaźnik heterogenności dynamicznej opiera się tylko na jednej charakterystyce struktury zgrupowania, mianowicie na jego przestrzennym rozmieszczeniu. Wskaźnik pojemności gatunkowej siedliska syntetyzuje wiedzę na temat preferencji siedliskowych poszczególnych populacji wchodzących w skład zgrupowania.