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Numerical methods of biodiversity studies and the problems of the protection of nature

Abstract. Numerical methods of faunistical research make possible estimation of species diversity and analysis of taxocoene structure. This enables a new approach to the problems of species diversity protection. The most important issue is the preservation of endangered and vulnerable species. They are an integral part of the normal and developed structure of communities, where they can occur as both recedent and dominant species.

Key words: species diversity, taxocoene structure, endangered and vulnerable species

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INTRODUCTION

Contemporary studies of plant and animal species diversity are closely related to the issue of the protection of endangered species. However, the current approach to species protection differs fundamentally from previous methods. Classical species protection revolves chiefly around the problems of population dynamics, while biodiversity conservation is mainly concerned with assessing a situation in nature where a multi-species community exists. Evaluation of these complicated systems has to be based on mathematical analysis of the faunal material collected. Three issues are crucial in this respect: the number of species in the habitat, the value of species diversity and the structure of community.

ESTIMATING THE NUMBER OF SPECIES

The number of species inhabiting a given area depends on the species capacity of the habitats, which, in turn, results from the dynamic processes of species migration and elimination (Fig. 1). Determination of the species capacity of the habitat under study is fundamental to properly performing an analysis of species diversity. The crude number of species (*S*), calculated empirically from the samples, provides only an approximation of the number of species inhabiting a given area. The parameter is related to the skill of the explorer, the size of sampling material, sampling techniques etc. Those factors are difficult to estimate. In order to calculate the number of species (*S**) inhabiting a given area, the empirical material must be subjected to more thorough analysis.

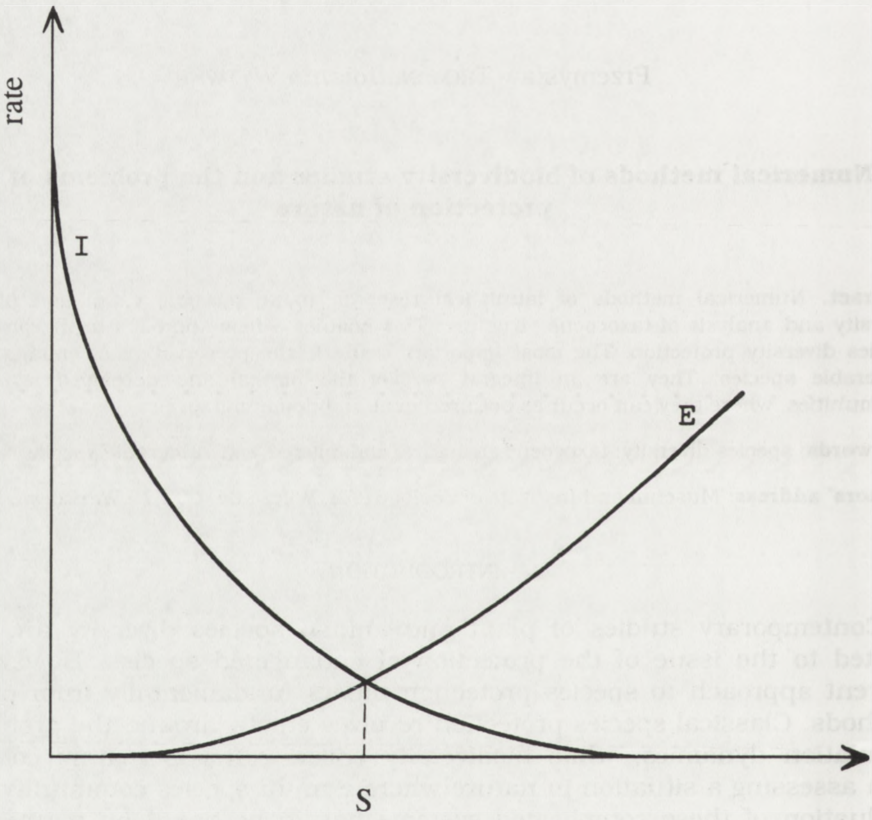

Fig. 1. The number of species inhabiting a given area as the point of balance between the rate of immigration and elimination of species (according MACARTHUR and WILSON 1967).

The first method draws on the relationship between the number of species and the size of sampling material. The relationship is expressed by one of three functions (Arrhenius', Romell's and Kylin's) known as the "species-area" curves (BALOGH 1958). A fit between empirical data and the theoretical functions enables estimation of sampling efficiency. If there is an overlap with Kylin's asymptotic curve, one can determine the number of species that can potentially inhabit a given area (*S**) (Fig. 2).

The second method for the estimation of species capacity of a given habitat takes into account the structural properties of the community and its similarity to statistical distributions. If the empirical data concerning the distribution of individuals into species overlap with the lognormal or negative binomial distributions, it is possible to determine the number of species theoretically forming the community.

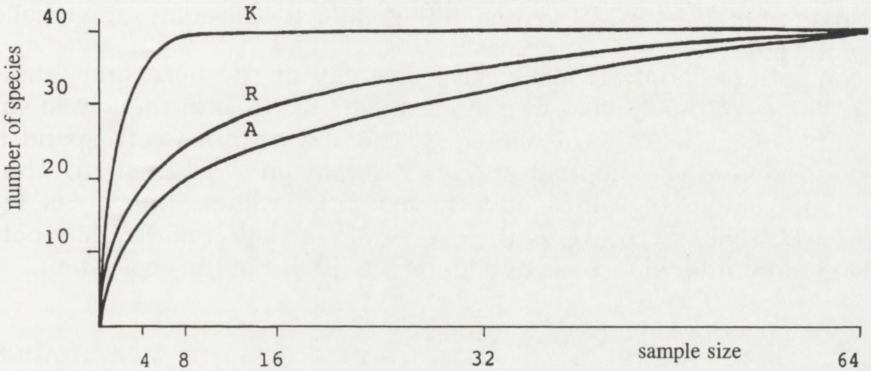

Fig. 2. Different types of "species-area" curves: A – Arrhenius', R – Romell's, K – Kylin's curve (according BALOGH 1958).

Comparing the empirical number of species (*S*) and that calculated using statistical methods (*S**) allows to evaluate sampling efficiency objectively as well as perform further analyses of community structure with a view to assessing species diversity.

ESTIMATING SPECIES DIVERSITY

Species diversity can be estimated on the basis of diversity indices which take into account both the number of species in a community and the abundance proportions of the species.

Among the many measures of species diversity, the following two, stemming from the theory of information, can be applied most broadly:

1) Shannon and Weaver's index:

$$H' = \sum_{i=1}^{S^*} p_i \log p_i$$

2) Simpson's index:

$$I = \sum_{i=1}^{S^*} p_i^2$$

where p_i is the proportion of individuals belonging to *i*th species between S^* species

Both indices are hardly affected by sample size and usually have low variances, thus satisfying the criteria for statistically useful methods.

Species diversity is the smallest where the community comprises only one species. It is the greatest when each species in the community is represented by an equal number of individuals. The values of Shannon's index corresponding to the two extremes are to be found between $0 \geq H' \geq \log S^{*}$. When Simpson's index is used, in turn, the extreme values (the minimum and maximum) are found interval of $1 \geq I \geq 1/S$, so that the greater the diversity, the smaller the value of the index.

In comparative analyses of species diversity of the flora and fauna, the extreme values of this indices (the highest values of H' and the lowest value of I) can function as a plane of reference. The above values correspond to the highest possible (i.e. potential) species diversity in a given area. The ratio between the empirical values and the potential values, known as Pielou's index ($J = H'/Hmax$), represents the degree of realization of diversity potential in a given habitat, area or even developmental phase of the ecosystem.

THE STRUCTURE OF THE TAXOCOENE AND SPECIES DIVERSITY CONSERVATION

Analysis of species abundance distribution within the taxocoene is the most reliable representation of the numerical relations between the species and their place in the community. This, in turn, generates significant input for consideration of the regularities governing dominance patterns in communities. Such analyses are of much greater value than the single parameter – the index of diversity.

The ranking of species in order of diminishing abundance provides a basis for dominance analyses in ecology. In floristical and faunistical studies it may facilitate evaluation of species for biodiversity protection. A comparison of the two ways of analysis indicates a different focus of interest in the two branches of biology. Ecology considers community structures from the standpoint of domination of species. The most abundant species play the major role in the community, while rare forms do not influence the results of elementary analyses. The centre of interest for conservationists is the complete opposite of the above. High species diversity hinges on the "tail" of the distribution, that is species of the lowest abundance.

The differences can be pinpointed by comparing the categories of species distinguished by ecologists and conservationists (Fig. 3). The border between the two approaches is seen in category 3 – what ecologists call influential species, faunists and florists consider rare forms. Ecology is most interested in the first two categories, whereas faunistical and floristical studies are centred rather on the last two.

For an ecologist, vulnerable species are the forms which are eliminated from the community when the habitat is degraded, the degree of its patchiness reduced and the structure simplified. Such phenomena often result from exploitation of the ecosystem for economic purposes.

Endangered species are neglected in ecological studies. Such forms are found at the distant end of the species abundance "distribution tail" and they occure in few ecosystems only. Their preservation is essential to retaining species diversity in the landscape. What is more, they often participate in the processes of community reconstruction and appear for a short time in the succession series.

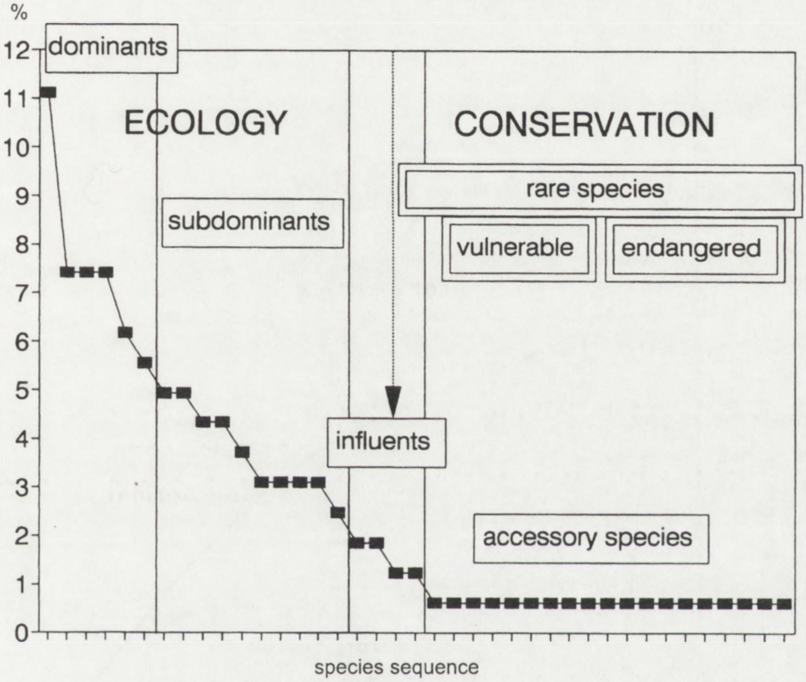

Fig. 3. Domination structure of community species as the focus of interest of ecologists and conservationists.

The final stage in the studies of community structure is the selection of a mathematical model and adjusting it to describe the species abundance distribution (Fig. 4). This depends not only on the determination of the distribution parameters, which are actually an attribute of the distribution, but do not express any "biological" meaning for most models. Research experience shows that communities corresponding to certain mathematical distributions possess certain specific features. The geometrical series, for instance, is considered to occur in habitats inhabited by a low number of species, often characteristic of an early stage of succession (WHITTAKER 1972). The logarithmic series, with a small number of high-frequency species and a large percentage of rare species, may describe a community in a habitat subject to regular influxes of new species that use up the resources equally or are influenced by one or just a few factors (MAY 1975). The lognormal distribution, in turn, is thought to be indicate mature communities whose present structures have been shaped in the course of their evolution by a number of different patterns of resource distribution (MAY 1981). A collection of such conclusions aimed at broadening the knowledge of the structural patterns of communities will be particularly valuable for species diversity protection.

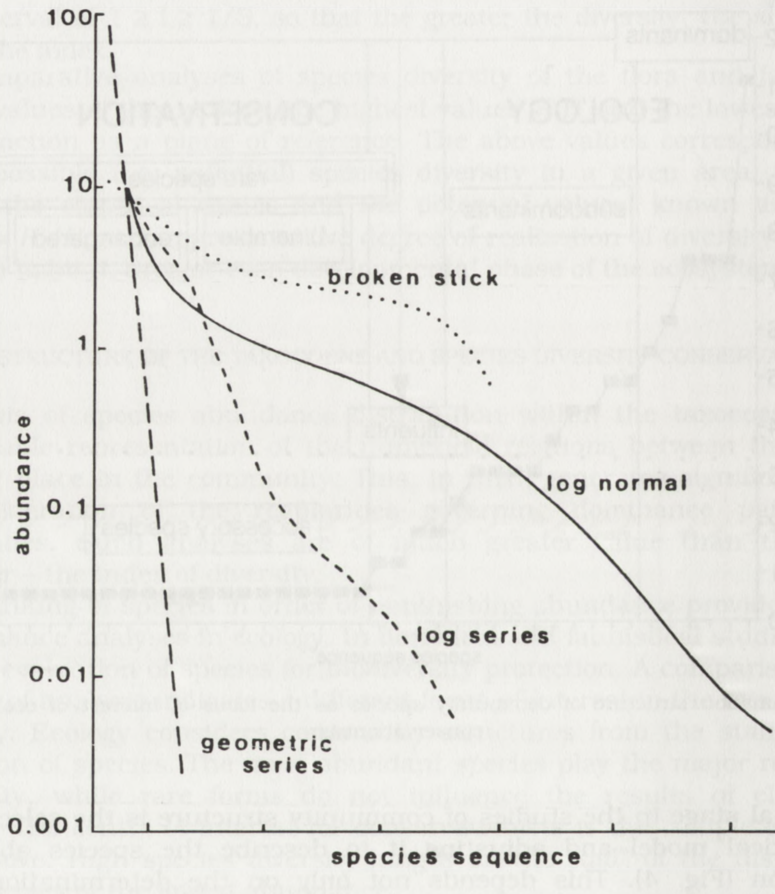

Fig. 4. Rank abundance plots illustrating the typical shape of four species abundance models: geometric series, logarithmic series, lognormal distribution and broken-stick model according to WHITTAKER 1970, after MAGURRAN 1988).

DISCUSSION

Numerous examples of disturbances, caused most often by man's economic activity, suggest an unfavourable effect on species diversity in communities.

For this reason, diversity is regarded as an index of ecosystem wellbeing and its measures used as ecological indicators (MAGURRAN 1988).

The relationships, however, are not clear enough. An ecosystem disturbance may induce multi-directional changes in the community as some species are affected adversely while others may thrive under new conditions. As for biocenoses subject to strong anthropogenic pressure, examples of a reduction in species diversity in comparison with natural habitats have been observed together with cases where a rise in biodiversity occurred, for instance, due to an increase in habitat patchiness. Such phenomena have been recorded e.g. in suburban areas, where a rise in the number of species is seen for birds, mammals and certain invertebrates (GARBARCZYK & PISARSKA 1990). Most often, however, the process leads to faunal "unification", i.e. to the formation of "universalised" communities comprising mainly widely distributed eurytopes, with steno- and oligotopes declining (PISARSKI & KULESZA 1982). An increase in species richness or other biodiversity indicators may thus not always be the desired outcome of environmental protection schemes.

Protection of the environment should rather be aimed at preserving community structures found in natural climax ecosystems. In such communities apart from the one or few species which are much more abundant than others, there is often also a well-preserved "tail" of rare forms that are, nevertheless, "well-rooted" in the structure. On the other hand, when the habitat is changed, some abundant, and therefore dominant species, particularly steno- or oligotopes, may become endangered and be excluded from the community, even from the "tail" of rare forms.

In the most "natural" communities, diversity is far from the highest possible value. The latter actually corresponds to a state of natural chaos and is a fiction convenient for making comparisons.

The postulate of biodiversity conservation may be understood in different ways:

1. Preservation of unique and vulnerable species. According to the traditional view on environmental protection, the task is in most cases difficult to accomplish unless a group of related species is considered as a whole.

2. Achieving a high degree of diversity. Statistically such a state is never attained in nature, particularly in stable climax communities.

3. Preservation of a normal well-developed community structure including species from all categories. This objective seems worthy of further investigation and putting into practice.

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STRESZCZENIE

[Tytuł: Numeryczne metody badań nad bioróżnorodnością a problemy ochrony przyrody]

Zastosowanie metod ilościowych w badaniach nad strukturą taksocenów daje podstawy dla nowego ujęcia zagadnień ochrony różnorodności gatunkowej flory i fauny. Podstawowe metody tych analiz to: estymacja liczby gatunków zgrupowania, różnorodności gatunkowej oraz matematyczne przybliżenie struktury taksocenów. Uzyskane dane pozwalają nie tylko na ocenę zagrożenia poszczególnych gatunków ale i stanu badanego taksocenu w danych warunkach przyrodniczych. W zrozumieniu tych kwestii ważną rolę odgrywa poznanie struktur zgrupowań właściwych dla ekosystemów naturalnych, gdzie obecności gatunków wrażliwych i zagrożonych nie zawsze towarzyszy wysoka różnorodność gatunkowa.