

# Orthopteran assemblages as indicators of grassland naturalness in Hungary

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## Abstract

Grasslands are among the most threatened habitats on Earth, as large areas have been transformed into agricultural lands. Therefore, the registration of the state of grassland remnants is of crucial importance for conservation. An easy way to survey or monitor a habitat is to choose adequate indicator taxa. North American studies showed that grasshopper communities are good indicators of disturbance. We tested this observation for Hungarian steppes. The orthopteran assemblages of three steppe patches in the Buda Hills (Hungary) were sampled. One site was newly abandoned arable land, the second was a secondary meadow with large mammal grazing pressure, the third was a strictly protected seminatural steppe meadow. Our study in Hungarian steppe remnants supports earlier findings that orthopterans are good indicators for disturbance and naturalness. We found that density was highest on the most disturbed site, while species richness and diversity indices were greatest on the seminatural site. We argue that the use of simple statistical tests ( $\chi^2$  and rank correlation analysis) may be favoured in inventories or monitoring programs instead of complicated multivariate analysis (e.g., detrended correspondence analysis). The rank correlation analysis on the species abundance/site matrices proved to be the most effective tool in finding differences and similarities between orthopteran communities. Published by Elsevier Science B.V.

*Keywords:* Human disturbance; Orthopteran communities; Indication; Hungary

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## 1. Introduction

The emerging field of conservation biology is a response of the scientific community to the rapid collapse of biological integrity and to the decrease of biodiversity (Meffe and Carroll, 1994). One of the most important tasks is to identify and to follow the changes of biota in space and time to prevent degra-

ation and further loss of biodiversity. This includes the survey and comparison of different sites and the development of monitoring programs. In fact, there are more and more such programs, addressing different species, communities, habitats or geographic areas (e.g., Goldsmith, 1991; Spellerberg, 1991; Stohlgren et al., 1995). The design of a survey or of a monitoring program is a multistep procedure, including the identification of aims, the selection of indicators, the selection of managed and control areas, and the designation of sampling scheme. One

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of the most crucial steps in the design is to select appropriate indicators, attributes and statistical analyses. The following criteria were suggested for indicators of temporal changes by several authors (Noss, 1990; Goldsmith, 1991; Spellerberg, 1991; Pearson, 1994): the indicator should be (1) sensitive to changes, (2) widely distributed, (3) easily and cost-effectively measurable, collectable, and identifiable (stable taxonomy), (4) able to differentiate between natural and anthropogenic variations, (5) relevant to ecological phenomena, and (6) economically important. These criteria are valid not only for monitoring programs, but for many programs addressing environmental questions. A simple comparison of two or more sites with different disturbance levels may also require such indicators. We argue, that orthopteran assemblages are good indicators, because, first, the structure of communities are sensitive to environmental changes. Many studies have demonstrated correlations between plant communities and orthopteran communities (e.g., Otte, 1976; Kemp et al., 1990; Quinn et al., 1991). Second, the orthopterans are present in almost every grassland and rangeland habitat. Third, there is a simple sampling method, sweep-netting, which can be standardised to obtain relative abundance data. The identification is relatively easy, partly due to the low number of species, and their taxonomic stability. There are only 115 orthopteran species in Hungary, contrasting with the ca. 10,000 Coleoptera or 3260 Lepidoptera species. Fourth, orthopterans have a key role in grassland ecosystems, because they constitute the major proportion of arthropod biomass (Shure and Phillips, 1991). Fifth, they are economically relevant as extremely abundant herbivore pests during outbreaks (although it is very rare event in Hungary).

The role of orthopterans as indicators is important for nature conservation, because they are good indicators of grasslands, and natural grasslands are rapidly disappearing. The naturalness of Western European grasslands is strongly decreasing; most of them are intensively managed (Firbank et al., 1994). Fielding and Brusven (1993a) showed that almost two-thirds of the variation in grasshopper species composition could be caused by the vegetation variables that are controlled by human activities. These results indicate the strong relationship between human disturbances and orthopteran assemblages. The

natural steppe habitats, which cover large areas in Asia, are very rare in Europe, and populations of the related animal species are decreasing. For example, there are several orthopteran species living in the steppe remnants of Hungary, which are listed in the IUNC Red List of Threatened Animals (Groombridge, 1993). The predatory bush cricket (*Saga pedo*) is categorised as vulnerable, *Stenobothrus eurasius*, a relict taxon in the Carpathian Basin, as a rare species, and *Onconotus servillei*, as an endangered taxon. The latter species is now probably extinct.

There were several studies investigating the ecology of invertebrates of steppe meadows in Hungary (e.g., Báldi, 1990; Báldi and Ádám, 1991; Kisbenedek, 1991; Waliczky, 1991; Fuisz and Moskát, 1992), including grasshoppers (Nagy, 1991; Kisbenedek, 1992; Kisbenedek and Báldi, 1994, 1995). However, from a nature conservation point of view, several important questions remained unanswered. A basic problem is the evaluation of orthopteran assemblages as indicators of naturalness and disturbances. Fielding and Brusven (1993a,b) showed that grasshopper species composition differed among disturbance categories on several scales in North American rangelands. Parmenter et al. (1991) found that several community structure parameters of orthopterans were sensitive and indicated more disturbance on revegetated surface coal mines than at undisturbed sites. The use of orthopterans as indicators of naturalness and human disturbances in Central Europe require the testing of their indicative power in this region, as well.

The aim of the present study is to test the ability of orthopteran assemblages to indicate different levels of human disturbances, namely to compare the orthopteran assemblages of three sites differing markedly in their naturalness. Our hypothesis was that the more natural steppe patch is most specious, as suggested by Fielding and Brusven (1993a). However, we did not focus merely on the relation of the orthopteran assemblages and disturbance for scientific reasons, but we investigated the possibilities of orthopterans to be included into monitoring or inventory programs. Although our study was conducted on a local spatial scale, we will argue that the study of orthopteran communities should be involved even into large scale programs. The analysis of Fielding

and Brusven (1993a,b) were clear and correct, however such multivariate techniques as DCA (detrended correspondence analysis) may be too complicated for use in a program conducted mainly by nonscientific staff. We, therefore, evaluated some simple comparative indices and tests, and we aimed to select the best (i.e., most sensitive, informative, and simple) analysis and statistics for investigations of naturalness and disturbances.

## 2. Study area and methods

The study area is located near Kutya Hill and Meszes Hill, in the Buda Hills, Hungary (47°35'N, 18°90'E). The highest point is 558 m a.s.l. The annual precipitation is 617 mm, the mean temperature in July is 19.4°C. The basic rock of the hills was dolomite. We chose three large grassland sites and sampled the orthopteran assemblages (see detailed description below). The sites differed in their naturalness, i.e., in the level of human disturbance. Originally, the whole region was forested, except on very steep slopes. Therefore, our three sites were probably covered by forests, but were cut in historical times. Maps from 1911 and 1915 indicate that all the three sites were grasslands already at the beginning of the century. Thus, the original conditions of the sites were very similar. The grassland is a secondary habitat at the three sites, therefore we refer to the undisturbed grassland as seminatural, instead of natural. One of the sites was an abandoned arable land, the second was a mesofil meadow and the third was a strictly protected seminatural steppe meadow. The distance was < 1.5 km between them.

We estimated some ecological parameters to describe the sites: vertical and horizontal heterogeneity of vegetation, plant species composition, richness, and dominance relations. The parameters were assessed independently by two of us, then the values were averaged. Plant species composition, richness and dominance relations were assessed by us, then confirmed by two colleagues.

(1) The first site was a newly abandoned arable land (AAL), with tall grass (average height of the grasses was about 70 cm). The dominant plant species were *Calamagrostis epigeios*, *Brachypodium sylvaticum*, *Agropyron repens*, *Festuca pratensis* and *Verbascum* sp. The area was more than 40 ha. The

coverage of the ground was not complete, although the grass itself was dense; there was no vegetation layer on the ground. Both the vertical and horizontal heterogeneity of the vegetation was lower than on the other sites.

The second site was a meadow (MED). The vegetation was in two layers (average height of the first layer of the grass was about 20 cm, and the second layer of the grass 40–50 cm). The dominant plant species were *Carex humilis*, *Arrhenatherum elatius*, *Koeleria cristata*, *Poa angustifolia*, *Salvia nemorosa*, *Eryngium campestre* and *Cirsium vulgare*. The vegetation was more dense and the estimated plant species richness was higher than on the AAL. The area was about 9 ha. There were two main types of human induced disturbances: first, there was a game feeder on the meadow, therefore large mammal grazing pressure can be assumed. Second, the area is partly bordered by agricultural land.

The third site was a seminatural steppe meadow (SNSM), with low vegetation in two layers. The average height of the first grass layer was about 15–20 cm, and of the second about 35–40 cm. The size of the area was ca. 10 ha. The spatial heterogeneity is high, in the matrix of the steppe meadow there are some small patches of open or closed dolomitic grasslands. The dominant plant species were *Carex humilis*, *Festuca rupicola*, *Festuca valesiaca*, *Stipa capillata*, in the patches *Seseli leucospermum*, *Draba lasiocarpa*. The dolomite bedrock was often on the surface. The site is within a strictly protected part of the Buda Landscape Conservation Area.

Orthopteran assemblages were sampled using the sweep-netting method on previously marked 1-m wide transects. The collector walked along a straight line on the transect with standard speed. The number of sweeps were 142/50 m ( $sd = 17.5$ ,  $n = 20$ ). The total length of the transects was 200 m on the AAL and MED sites, and 310 m on the SNSM site. The sampling was carried out from ca. 11:00 h, only on warm days without strong wind and precipitation in mid-July 1992 and 1993. All the collected orthopteran imagoes (i.e., adult individuals) were identified. The material is stored at the Hungarian Natural History Museum, Budapest.

One aim of the study was to compare the efficiencies of some simple comparative tests to determine

which one is the most powerful in differentiating among the three orthopteran assemblages from the three sites. DCA (detrended correspondence analysis, Hill, 1979) was used as a reference to North Ameri-

can studies, where this multivariate technique is widely used in entomological analysis (e.g., Evans, 1988; Kemp et al., 1990; Quinn and Walgenbach, 1990; Quinn et al., 1991; Fielding and Brusven,

Table 1

List of Orthopteroidea species and their abundances given as number of individuals/habitat. The length of transects were 200 m for the AAL and MED, and 310 m for the SNSM habitats

Orthopteroidea species	1992			1993			Total
	AAL	MED	SNSM	AAL	MED	SNSM	
<b>Orthoptera</b>							
<b>Phaneropteridae</b>							
<i>Leptophyes albovittata</i>	0	4	2	13	6	3	28
<i>Phaneroptera falcata</i>	1	0	0	0	0	0	1
<b>Conocephalidae</b>							
<i>Conocephalus discolor</i>	2	0	0	0	0	0	2
<i>Conocephalus dorsalis</i>	0	0	0	4	0	0	4
<b>Tettigoniidae</b>							
<i>Decticus verrucivorus</i>	0	0	0	0	2	0	2
<i>Metrioptera (Bicolorana) bicolor</i>	1	1	2	4	1	1	10
<i>Pholidoptera fallax</i>	0	4	0	0	1	0	5
<i>Pholidoptera griseoaptera</i>	0	0	0	3	0	0	3
<i>Platycleis (Tessellana) vittata</i>	10	2	0	21	5	0	38
<i>Platycleis grisea</i>	0	0	1	0	0	4	5
<i>Tettigonia viridissima</i>	1	0	0	0	0	0	1
<b>Sagidae</b>							
<i>Saga pedo</i>	0	0	1	0	0	0	1
<b>Tetrigidae</b>							
<i>Tetrix tenuicornis</i>	0	1	0	0	0	0	1
<b>Acrididae</b>							
<i>Calliptamus italicus</i>	1	0	0	5	0	1	7
<i>Chorthippus (Glyptobothrus) apricarius</i>	1	0	0	11	9	0	21
<i>Chorthippus (Glyptobothrus) biguttulus</i>	0	0	2	0	0	0	2
<i>Chorthippus (Glyptobothrus) brunneus</i>	3	0	1	2	1	2	9
<i>Chorthippus (Glyptobothrus) mollis</i>	0	0	0	3	0	0	3
<i>Chorthippus (Glyptobothrus) vagans</i>	9	1	0	0	0	0	10
<i>Chorthippus albomarginatus</i>	36	0	1	12	0	0	49
<i>Chorthippus dorsatus</i>	0	2	0	0	3	2	7
<i>Chorthippus paralellus</i>	68	139	0	97	135	0	439
<i>Euchortippus declivus</i>	42	7	2	149	4	3	207
<i>Euchortippus pulvinatus</i>	5	0	0	2	0	0	7
<i>Euthystira brachyptera</i>	1	0	0	1	0	0	2
<i>Omocestus (Dirshius) haemorrhoidalis</i>	0	0	0	0	0	6	6
<i>Omocestus (Dirshius) petraeus</i>	0	0	0	0	0	1	1
<i>Omocestus ventralis</i>	0	0	4	0	0	3	7
<i>Stenobothrus crassipes</i>	0	3	31	0	7	21	62
<i>Stenobothrus lineatus</i>	0	0	13	0	0	15	28
<i>Stenobothrus nigromaculatus</i>	0	0	0	0	0	1	1
<b>Mantodea</b>							
<b>Mantidae</b>							
<i>Mantis religiosa</i>	1	0	4	3	1	1	10
Total:	182	164	64	330	175	64	979

AAL: abandoned arable land; MED: meadow; SNSM: seminatural steppe meadow.

1993a). First, we compared the most common community structure parameters, like species richness (number of species,  $S$ ), species richness following corrections for different sample sizes by the rarefaction method, abundance (number of imagoes), density of imagoes, Shannon–Wiener's  $H'$  diversity measure, Simpson's diversity measure and the most commonly used equitability measure ( $J = H'/\ln S$ ). Second, we also used two simple comparative analyses, the  $\chi^2$  test and a rank correlation (Kendall  $\tau$ -B) on the abundance of species by sampling date–site matrix. The SPSS/PC+ program package was applied for rank correlation analysis (Norusis, 1990).

### 3. Results

There were 979 imagoes of 32 orthopteran species (including the *Mantis religiosa*) collected during the study (Table 1). (We omitted the collected nymphs from the analysis because the problems of identification of species within some genus. The proportion of nymphs was 11%.) Indices referring to community structure of the two years were similar, the differences could be due to the larger number of individuals on AAL in 1993 (Table 2). The differences were mainly the consequence of the large number of *Euchortippus declivus*. The corrected species number was highest on the SNSM, which is in accordance with the expectations, but the observed species richness did not show the expected trend. The density was lowest on the SNSM and highest on the AAL. The Shannon–Wiener diversity measures were simi-

lar for the AAL and the SNSM in 1992, but it was largest for the SNSM in 1993. Similar differences can be found for the Simpson's measure. Put together, the diversity was greater for the SNSM than for the other sites. The equitability values were largest for the SNSM in both years, although in 1992 the difference was small.

The assemblages were compared directly, based on the distribution of individuals among species. The  $\chi^2$  statistics showed strong significant differences in almost all cases, except that the orthopteran assemblages of the two least disturbed grasslands (MED and SNSM) did not differ significantly between the two years (Table 3). However, this was not true for the most disturbed site (AAL), where there was significant differences between the communities of the two years. The rank correlation analysis supported this difference, since the largest (significant at the  $p < 0.1$  level) positive correlations were found for the same two cases (Table 4). Elsewhere negative correlations, or the lack of significant correlations were found. The most disturbed site (AAL) showed strong negative correlation with the natural site (SNSM) in all cases. There were low correlation coefficients between the MED and the other cases, except the between year correlation of this site. This showed an intermediate position for the MED, which is in accordance with the expectation.

The DCA of abundance data indicated that primary axis (axis 1) explained 72.5% of the sample variation (Fig. 1). The two years were put close together, except for the AAL. The SNSM was clearly

Table 2  
Community structure parameters of orthopteran assemblages at three sites of different naturalness in two years

	1992			1993		
	AAL	MED	SNSM	AAL	MED	SNSM
$S$	15	10	12	15	12	14
$S(E)$	9.6	6.9	12	10.4	8.4	14
$N$	182	164	64	330	175	64
$D(N/100\text{ m}^2)$	91.00	82.00	20.64	165.00	87.50	20.64
$H'$	1.7510	0.7299	1.7146	1.6742	1.0240	2.0728
Simpson	0.2346	0.7204	0.2773	0.2918	0.6001	0.1721
$J$	0.6466	0.3170	0.6900	0.6038	0.4121	0.7854

$S$ : number of species;  $S(E)$ : expected number of species, corrected for sample size by rarefaction;  $N$ : number of individuals;  $D$ : density of individuals;  $H'$ : Shannon–Wiener diversity index; Simpson: Simpson diversity index;  $J$ : equitability.

Table 3  
Comparison of orthopteran communities of the three study sites and two years by  $\chi^2$  statistics. The first value given is the  $\chi^2$  and the value inside the parentheses is the *df*; *p* is also given

	1992/AAL	1992/MED	1992/SNSM	1993/AAL	1993/MED	1993/SNSM
1992/AAL	1	126.492 (19) <i>p</i> < 0.001	219.510 (21) <i>p</i> < 0.001	99.868 (19) <i>p</i> < 0.001	137.487 (19) <i>p</i> < 0.001	217.425 (23) <i>p</i> < 0.001
1992/MED		1	196.843 (17) <i>p</i> < 0.001	185.356 (20) <i>p</i> < 0.001	20.827 (13) <i>p</i> < 0.1	188.679 (18) <i>p</i> < 0.001
1992/SNSM			1	332.669 (21) <i>p</i> < 0.001	185.395 (17) <i>p</i> < 0.001	21.875 (16) <i>p</i> < 0.1
1993/AAL				1	183.110 (19) <i>p</i> < 0.001	329.600 (23) <i>p</i> < 0.001
1993/MED					1	178.661 (18) <i>p</i> < 0.001
1993/SNSM						1

Table 4

Comparison of orthopteran communities of the three study sites and the two years by a nonparametric correlation analysis (Kendall  $\tau_B$ )

	1992/AAL	1992/MED	1992/SNSM	1993/AAL	1993/MED	1993/SNSM
1992/AAL	1	-0.0603 ( <i>p</i> = 0.3728)	-0.4148 ( <i>p</i> = 0.0100)	0.1375 ( <i>p</i> = 0.2180)	-0.1270 ( <i>p</i> = 0.2427)	-0.2124 ( <i>p</i> = 0.0790)
1992/MED		1	0.0941 ( <i>p</i> = 0.2735)	0.0589 ( <i>p</i> = 0.3698)	0.3294 ( <i>p</i> = 0.0627)	-0.2098 ( <i>p</i> = 0.1345)
1992/SNSM			1	-0.2952 ( <i>p</i> = 0.0444)	-0.2569 ( <i>p</i> = 0.0921)	0.2670 ( <i>p</i> = 0.0896)
1993/AAL				1	0.1147 ( <i>p</i> = 0.2585)	-0.3900 ( <i>p</i> = 0.0090)
1993/MED					1	-0.2337 ( <i>p</i> = 0.1042)
1993/SNSM						1

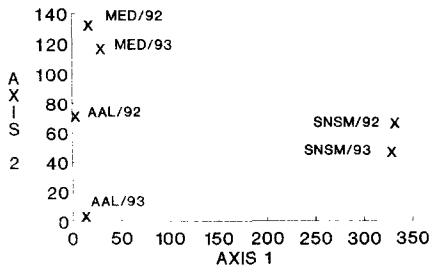


Fig. 1. DCA ordination of six samples (three sites and two years) and grasshopper species using abundance data (AAL: abandoned arable land; MED: meadow; SNSM: seminatural steppe meadow).

separated from the two other sites. These results show similar relations among the sites as the rank correlation analysis.

#### 4. Discussion

Several studies have related grasshopper community structure to plant communities (Otte, 1976; Evans, 1988; Kemp et al., 1990; Quinn et al., 1991; Fielding and Brusven, 1993a). We found that the distribution of orthopterans in 27 steppe patches of different sizes was not random (Kisbenedek and Báldi, 1994, 1995; Báldi and Kisbenedek, in prep). In these studies we demonstrated that both the area and the distance from source or continent had significant effects on species number. Although we have insufficient data on the vegetation, we also found that vegetation may influence the distribution of orthopterans, since there was a significant positive correlation between grass height and species number. However, grass height and elevation also correlated, therefore it should be interpreted only with great caution. The area of the three sites were different (AAL: > 40 ha, MED and SNSM: ca. 10 ha), however, these were the largest sites from the studied 27 patches (Kisbenedek and Báldi, 1994, 1995; Báldi and Kisbenedek, 1997). We supposed that the area had no significant effects on the orthopteran assemblages of the three study sites, because the species–area curve is not steep in the linear graph at these size classes. In addition, we found that the expected species richness is lowest on the AAL, which is the largest site. Therefore, if we take into consideration the effects of size, than the species richness will decrease more on AAL, and this further evidence our findings. Thus, we can omit the influ-

ence of size, and conclude that purely the disturbance regime of the three sites was different, which in turn, changed the vegetation.

We evaluated the potential of the orthopteran community structure parameters to indicate the naturalness of the three study sites. Fielding and Brusven (1993a) found that in North American rangelands the most disturbed sites had the highest grasshopper densities, and had the lowest species richness and diversity. Similar patterns were found by Parmenter et al. (1991): species richness, diversity and evenness measures were higher on undisturbed than on disturbed sites. Our analysis showed very similar patterns for density and diversity measures as the above cited North American studies. The larger abundance and density values on the more disturbed sites may be a consequence of the much larger vegetation volume on those grasslands, which may provide more foraging possibilities and more protection against predators. That is, the density is a good measure of naturalness of steppe patches (but see Van Horn, 1983). However, it may not be true for other habitats, like wet meadows. The diversity measures (Shannon–Wiener and Simpson) also reflect the expected pattern, but the large number of individuals in 1993 at the AAL partly confused the results, and did not separate the AAL and SNSM clearly, may be as a consequence of sample size differences. The two diversity indices showed smaller between-year variations for the AAL than for the other sites, which is not in accordance with the expectations (i.e., the AAL is the least stable habitat). However, the evenness measures partly showed the expected rank of the sites, where the SNSM was the one with the most equilibrated orthopteran community.

From a conservationist's point of view, not only community structure parameters are important when ranking sites for conservation, but the presence of individual species, as well. In our study, as expected, the 'best' site, a seminatural steppe patch, was the most specious. The vulnerable predatory bush cricket was present only at this site (Table 1 and personal observations from other years), which is a good representation of convergence in species- and community-level prioritization of sites.

We expected the orthopteran assemblages to be more stable on the undisturbed and intermediate sites (MED and SNSM), and the between-year variances

in community structure to be smaller than that of in the disturbed site (AAL). These expectations were suggested by Quinn et al. (1991) who attributed the between-year changes in community composition to vegetational characteristics. In our study, the SNSM had the most stable assemblage as indicated by the evenness measures,  $\chi^2$  and the rank correlation analysis. In contrast, the AAL, the most disturbed site had an erratic assemblage, which resulted in significantly different orthopteran assemblages in the two years. The instability of the newly abandoned arable land was further evidenced by a field visit in 1996, when we found no changes in the vegetation on the SNSM and MED, but the AAL was transformed to a MED like meadow. The MED had an intermediate position, which is in accordance with its disturbance status.

Which measures or statistics are the best for differentiating among the three sites? From the evaluated community structure parameters, the rarefied species number, density and partly the evenness measure seemed to be the best ones. The diversity indices also may provide good results, but they may be biased due to largely different sample sizes. Their use is only proposed if the sample sizes are similar. The comparison of assemblages based on the distribution of individuals among species showed the expected results in both the  $\chi^2$  and rank correlation analysis. The latter proved to be much more effective, because it can indicate not only similarities, like the  $\chi^2$  statistics, but differences, that is negative correlations, as well. Such information may be as important as the similarities. The multivariate technique of DCA showed very similar results to the rank correlation analysis, therefore it may be more simple to use only the latter method than to compile complicated data files for DCA. In our study the omission of DCA would not lead to any loss of information. The application of simple methods is important when a large scale program is designed, e.g., a country level monitoring program, when the staff may not be familiar with statistics, ecology of special taxa, and/or sites. In this case, information, like in Table 4, may suggest a relative conservation ranking of sites, without any required knowledge on the sites, vegetation or orthopteran ecology.

We suggest that orthopteran assemblages are good indicators of naturalness and disturbances in Hun-

gary. Both the North American and our results indicate that several simple community measures seem to be appropriate and useful for the comparison of different sites: density was greater on the disturbed sites while species richness (rarefied species number) and evenness index on the natural sites. We argue that rank correlation analysis is an effective tool in the comparison of sites, because it can indicate similarities and differences with statistical significance, and it gives similar information to those provided by the more complicated multivariate techniques.

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