Species richness, abundance and diversity of beetles (Coleoptera) in relation to ecological succession

By

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ABSTRACT: Beetles (Coleoptera) were collected by pitfall trapping near Budapest (Hungary), in three stages of dolomitic succession from April to October in 1988. Species richness and abundance were greatest in the mature stage, in sessile-turkey oak forest. The diversity and equitability values were greatest in the medium stage, in dolomitic steppe meadow. The open dolomitic grassland was the poorest habitat. The similarity was high between the two grass-dwelling communities, but low between the forest and each of the grass-dwelling communities. The changes of diversity and equitability did not support the general theory of ecological succession.

INTRODUCTION

Succession theory has always played a central role in ecology from the beginning of the twentieth century (Clements 1916, Gleason 1926, Margalef 1968, Odum 1969, Horn 1976, Connell and Slayter 1977, MacMahon 1980). This theory gives general trends in community development, providing an important tool for the prediction of environmental changes (Pest and Christensen 1980). The latter has a significant role in nature conservation.

The majority of succession projects dealt with plant communities (Gallé 1985). There are some further studies on birds, e.g. Shugart and James 1973, Helle and Fuller 1988, Moskát and Székely 1989, but papers on insects are rather scarce. There are only a few papers about the succession of beetles, namely about phytophagous (Brown and Hyman 1986) and aquatic species (Nilsson 1984).

We studied species richness, species abundance and diversity of ground-dwelling beetle communities of different successional stages of a rocky vegetation in Hungary.

STUDY AREA

The study area is located on the Kutya hill in the Budai Mountains (Northern Hungary). The area lies 30 km from Budapest in NW direction (47° 35' N, 18° 90’ E). The basic rock is Triassic dolomite. There are rendzina in patches covered by grass vegetation, and brown soil in forested areas. We selected three study sites to represent different levels of the successional series:
I. Open dolomitic grassland ('open habitat'). (Jascula leucocephala- Festucetum pallens). This is the first stage of dolomite succession after the lichen-moss communities (Jakub 1981). Festucetum pallens and Jascula leucocephala are the dominant and characteristic plant species. The rock/grass ratio is about the same.

II. Dolomitic steppe meadow ('steppe habitat'). (Chrysopogono-Caricetum humile). There are several steppe plant species in this phase, where Carex humile and Chrysopogon gryllos are the dominant and characteristic species. This plant community is almost closed, the rock/grass ratio is about 5/95.

III. Seselis-turkey oak forest ('forest habitat'). (Quercus petraea-cerris). This forest type is mainly composed of Quercus cerris and Q. petraea. The presence of Fraxinus ornus is also pronounced. The trees are too high (10-15 m), because of the shallow soil.

METHODS

For sampling we used altogether 324 pitfall traps, 108 for each of the 3 vegetation phases. Plastic jars were used with a mouth diameter of 9 cm. The traps contained ethylene-glycol. The project lasted for about six months, from 7th of April to 31st of October, 1988. We visited the traps in every fortnight, altogether fourteen times, and mean values of the 14 visits were used. Only beetle data were analyzed.

We compared the beetle communities connected with the three different plant communities with the help of community structure parameters, like species richness, species abundance and species-abundance distributions. The Sorensen index was applied to measure the similarity between the habitat:

\[ C = 2 \times \frac{A \times B}{A + B}, \]

where \( A \) = number of species caught on site A,
\( B \) = number of species caught on site B,
\( J \) = number of joint occurrences.

If \( C = 1 \), then the two communities are identical, if \( C = 0 \), then totally different (Southwood 1978).

The Shannon-Weaver's diversity index was evaluated in relation to different beetle communities. The diversity index is:

\[ H = \sum p(i) \ln p(i), \]

where \( p(i) \) is the proportion of individuals in the \( i \)-th species (Southwood 1978).

Equitability was calculated according to the formula:

\[ J = H / \ln S, \]

where \( S \) is the number of species present.

We applied agglomerative cluster analysis based on 154 species, which were collected more than one time. Squared Euclidean distance and single linkage grouping strategy was chosen. Multiple stepwise regression was also applied for the Coleoptera data. These statistical analyses were carried out by the SPSS/PC+ statistical program package (Norusis 1986).

RESULTS

32 families, 139 genera and 231 species are represented by a total number of 21,827 captured specimens. We recorded 13,952 individuals belonging to 153 species in the 'forest habitat', 7,562 individuals of 129 species in the 'steppe-habitat', and 2,325 individuals of 56 species in the 'open habitat'.

The species-abundance distributions of the three beetle communities are shown in Fig. 1. On double logarithmic scale these curves show linear relationships, but their slopes are different (Table 1).

Fig. 1. Species-abundance distribution of beetles in three stages of successional series. A: Open dolomitic grassland; B: Dolomitic steppe meadow; C: Seselis-turkey oak forest. (\( s \) is the number of species, \( n \) is the number of individuals per species).
The values of the Sorensen index indicate high similarity between the beetles of the 'forest habitat' and the 'open habitat', and low similarities between the beetles of the 'forest habitat' and the other two phases (Table 2).

Table 1. The slopes of regression lines fitted to the double logarithmic curves of the species-abundance distributions. [P(F) significance of explained variance, slope: slope of the fitted lines, se: standard error of the slope, p: significance of regression lines]

<table>
<thead>
<tr>
<th>Species-combination</th>
<th>P(F)</th>
<th>Slope</th>
<th>Se</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sessile-turkey oak forest</td>
<td>0.0000</td>
<td>-1.388</td>
<td>0.1067</td>
<td>0.0000</td>
</tr>
<tr>
<td>Dolomitic steppe meadow</td>
<td>0.0000</td>
<td>-1.286</td>
<td>0.1269</td>
<td>0.0000</td>
</tr>
<tr>
<td>Dolomitic grassland</td>
<td>0.0000</td>
<td>-1.245</td>
<td>0.1999</td>
<td>0.0000</td>
</tr>
</tbody>
</table>

Between the 'forest habitat' and the 'steppe habitat' the mean diversity values for the fourteen samples are similar (two-tailed t-test, DF=14, t=1.39, n.s.), but the value of the 'open habitat' is much smaller than both the values of the 'forest habitat' and 'steppe habitat' (t=3.08, p<0.01; t=4.13, p<0.001, respectively (Table 3). Equitability shows an opposite similarity due to the small diversity values. There is a significant difference in only one case, namely, between the species of the 'steppe habitait' and 'open habitat' (t=2.53, p<0.05) (Table 3).

Table 2. Values of similarity between the three stages of the successional series, based on the Sorensen index

<table>
<thead>
<tr>
<th>Species-combination</th>
<th>Sorensen index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sessile-turkey oak forest</td>
<td>0.3758</td>
</tr>
<tr>
<td>Dolomitic steppe meadow</td>
<td>0.3465</td>
</tr>
<tr>
<td>Dolomitic grassland</td>
<td>0.4756</td>
</tr>
</tbody>
</table>

The mean number of species is similar between the 'forest habitat' and the 'steppe habitat' (t=1.35, n.s.), just like the abundance (t=1.80, n.s.). The beetle community living in the 'open habitat' highly differs from that of the 'forest habitat' in the case of species richness (t=4.99, p<0.001) and abundance (t=3.84, p<0.001) (Table 3). The relationships are similar between the 'open habitat' and 'steppe habitat' too (species richness: t=4.61, p<0.001; abundance: t=2.70, p<0.05).

Table 3. Structure parameters of beetle communities associated with the three vegetation stages. (N=14, standard deviation in brackets)

<table>
<thead>
<tr>
<th>Species richness</th>
<th>Abundance</th>
<th>Diversity</th>
<th>Equitability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open dolomitic grassland</td>
<td>8.71 (7.36)</td>
<td>1.54 (1.23)</td>
<td>0.49 (0.85)</td>
</tr>
<tr>
<td>Dolomitic steppe meadow</td>
<td>26.6 (12.3)</td>
<td>5.00 (4.64)</td>
<td>2.00 (0.36)</td>
</tr>
<tr>
<td>Sessile-turkey oak forest</td>
<td>34.5 (27.9)</td>
<td>9.19 (7.35)</td>
<td>1.78 (0.47)</td>
</tr>
</tbody>
</table>

According to the results of the cluster analyses (Fig. 2) we can separate the three beetle communities into two main groups, namely, to the forest- and to the grassland-dwelling beetles.
Fig. 2. The diagram of three stages of succession, based on the squared dean distance. Steppe: Open dolomite grassland; Steppe: Dolomite steppe meadow; Forest: Sessile-turkey oak forest.

Discussion

The succession of plants living on dolomite is well known (Jakubs 1963) and this community (I.), which becomes more and more closed during the successional process. The next stage is the dolomite steppe meadow phase (II.), which forms a vegetation. In the present study the forest is the climax community, the end of the ecological succession process (sessile-turkey oak forest (III.).)

The two grassy communities of these successional stages are much more similar to each other than the forest community to any of them. The presence of the beetles is represented by differences between the community structure parameters of these vegetation phases, depending evidently on the methods applied.

The number of species, species abundances and the diversity values are then compared with these differences. The ‘open habitat’ differs from the ‘steppe habitat’ and the ‘steppe habitat’ from the forest habitat. The open habitat consists of a great portion of bare rocks, while the other two sites are covered by soil and unbroken vegetation. The high similarity occurred between beetles of the ‘forest habitat’ and the ‘steppe habitat’ in the case of the ‘open habitat’. The latter was high in the case of the ‘steppe habitat’ and the ‘open habitat’.

The ‘open habitat’, which is at the beginning of the ecological succession, contains only a few species and individuals of plants and beetles, and the dolomite steppe meadow having developed from the open dolomite grassland. These two stages contain a lot of common species of plants (Jakubs 1981) and Coleoptera. This plant community is almost closed, therefore, its diversity and abundance are greater than those of the previous stage. Due to the increasing value of cover and diversity of plant community, the diversity value of beetle communities also increased in the case of ground-dwelling species (Busby 1986) and the aquatic ones (Hilsenroth 1984). Belye et al. (1985) found that the number of beetles and their diversity increase during the whole arthropod community. Brown and Rymann (1986) found such a trend only in the early stages of succession in pithyphagous beetles. The sessile-turkey oak forest is the mature stage having developed from the grassy communities after a long period of time. The long time and the stages between the steppe and forest phases are the reasons for the small portion of common species, though the species numbers and abundances are similar to that of the Coleoptera community of the steppe meadow.

The classical theory of succession (Margalef 1968, Odum 1969, Price 1985) gives predictions to the changes of a lot of ecological characteristics, for example the species richness, abundance, and diversity. These features are supposed to increase during succession. None of the studies on arthropods also support these results (Belye et al. 1985, Hilsenroth 1984, Mandux et al. 1986). Our results showed some deviations from these expected changes in the case of diversity, and equitability (Table 6). The lower values of diversity, and equitability in the mature community are due to the extreme abundance of a few species: Geotrupes versicolor, Carabus convarius and Micronus vasculus.

Table 6. Expected changes of community structure parameters during the ecological succession based on the general theory, and the observed changes in the case of beetles.

<table>
<thead>
<tr>
<th>Successional stages</th>
<th>Expected</th>
<th>Observed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Developmental</td>
<td>Nature</td>
</tr>
<tr>
<td>Species richness</td>
<td>low</td>
<td>high</td>
</tr>
<tr>
<td>Abundance</td>
<td>low</td>
<td>high</td>
</tr>
<tr>
<td>Diversity</td>
<td>low</td>
<td>high</td>
</tr>
<tr>
<td>Equitability</td>
<td>low</td>
<td>high</td>
</tr>
</tbody>
</table>

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REFERENCES


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