Connectivity metrics affect Lepidopteran species richness on alpine sites of the High Sudetes Mts.

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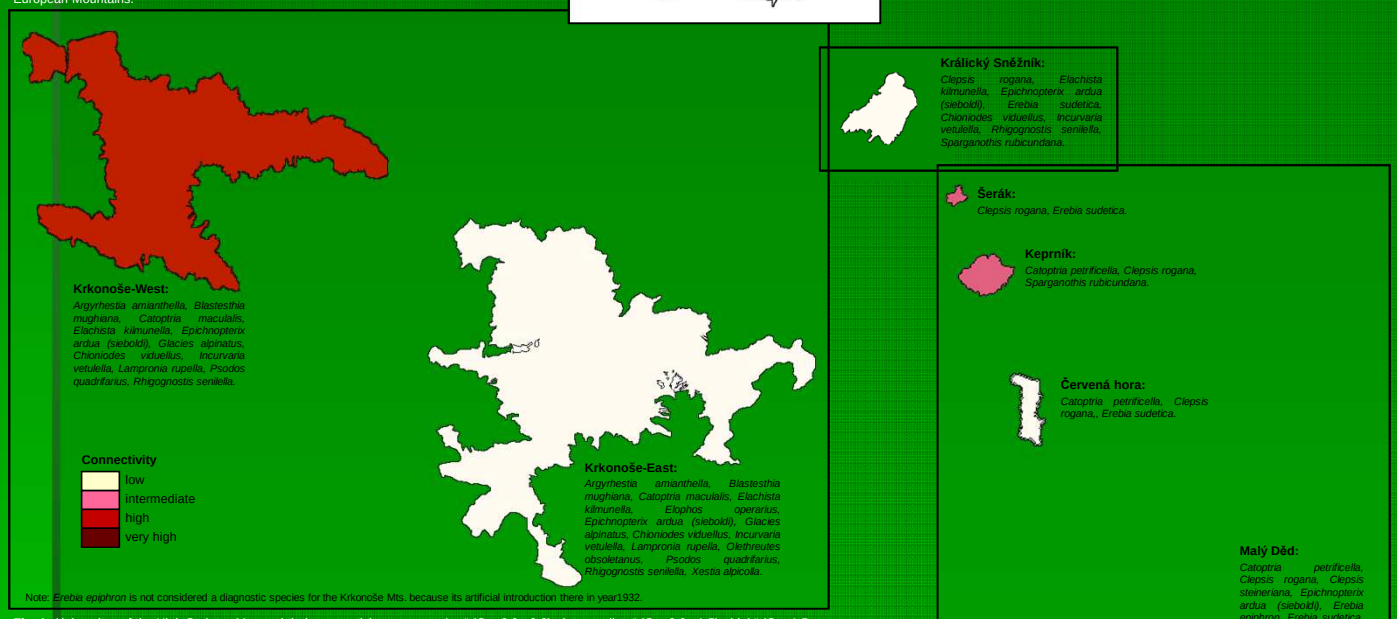
Introduction

Richness of Lepidoptera species was studied on 10 alpine sites of the High Sudetes Mts.: Krkonoše-West (Kotel Mt. – 1435 m), Krkonoše-East (Sněžka – 1602 m), Králický Sněžník (1424 m), Šerák (1351 m), Keprník (1423 m), Červená hora (1337 m), Malý Děd (1355 m), Mravenečník-Vřesník (1343 m), Praděd (1491 m) and Vysoká hole (1464 m); the last 7 alpine sites are parts of the Hrubý Jeseník Mts.

A list of Lepidoptera species was compiled for each alpine site including only "diagnostic species", i.e., species with an exclusive affinity for alpine habitats or generally unlikely to be found below the timberline (Patočka and Kulfan 2009). From an eco-zoogeographical point of view (sensu Krampl 1992) it means species with euboreal, boreo-alpine, arctic-alpine and subalpine types of distribution with disjunctive and very narrow dispersal ranges within Central European Mountains.

Materials and Methods

The simplest method for analyzing the patch area effect on biodiversity is the Species-Area Relationships model which was used to identify "hot spots" among alpine sites in the High Sudetes Mts. in order to aim protection measures at the most valuable parts of this mountain range. Next, we tested connectivity (*Si*) by the mean of Incidence Function Model to determine the effect of isolation. Canonical analysis and permutational multivariate analysis of variance using distance matrix was conducted to test which factor (area, distance or connectivity) significantly influence dissimilarity in species composition between alpine sites.



Note: *Erebia epiphron* is not considered a diagnostic species for the Krkonoše Mts. because its artificial introduction there in year1932.

Fig. 1. Alpine sites of the High Sudetes Mts. and their connectivity measure: „low" (S_i = 0,0 - 0,6); „intermediate" (S_i = 0,6 - 1,5); „high" (S_i = 1,5 - 8,0); very high" S_i = 8,0 - 13,5) with Lepidoptera diagnostic species occuring on individual alpine sites.

Connectivity measure

Connectivity/isolation of each alpine site was estimated using the incidence function model which count with species presence or absence on studied patches. This model takes into account all patch areas and the nearest distances from the focal patch to every similar patch within a specific buffer zone:

$$S_i = A_i^c \sum_{j \neq i} \exp\left(-\alpha d_{ij}\right) A_j^b$$

where Si is the connectivity of patch i, dij is the nearest distance between patches i and j (all distances were measured from edge-to-edge of treeless summits), parameters b and c represent emigration and immigration rates, and parameter α is scaling the effect of distance to migration (1/α is the average migration distance) We derived this parameter from the mean dispersal distances of the studied species which mostly ranged between 0.5 to 1.5 km (α = 1.5).

Alpine site	Nr. of species	Area (ha)	S_i
Králický Sněžník	8	89.6	0.00
Mravenečník-Vřesník	4	46.7	0.13
Krkonoše-East	3	65.7	0.52
Červená hora	2	21.9	1.16
Šerák	3	80.1	1.49
Keprník	14	3212.6	1.84
Krkonoše-West	11	2116.1	1.92
Malý Děd	7	55.0	**4.94**
Vysoká hole	10	678.5	**8.00**
Praděd	12	142.5	**13.26**

Table 1. Number of species, area and connectivity value (*Si*) of 10 alpine sites in the High Sudetes Mts; highest connectivity rate is marked in red.

Species-area relationship

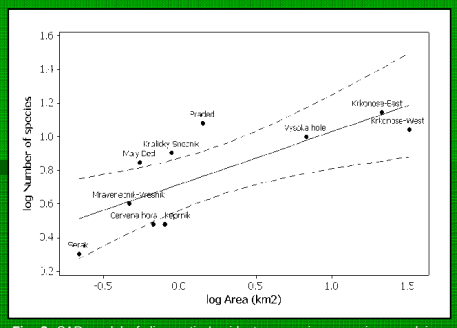


Fig. 2. SAR model of diagnostic Lepidoptera species occurring on alpine sites in the High Sudetes Mts. Regression function is log S = 0.717 + 0.312 log A (continuous line) and 95% confidence intervals are displayed (dashed lines); R2 = 59.1% , p = 0.009.

Canonical analysis

Canonical analysis was used to test similarities in species composition of the studied alpine sites. The first canonical axis explains 63% of the variation and is correlated with area and distance. The second canonical axis explains 19% of the variation and represents the connectivity gradient. The variance explained by individual factors was calculated using a Monte Carlo test and all included factors had significant effect (area: p = 0.003, distance: p = 0.002, connectivity: p = 0.032).

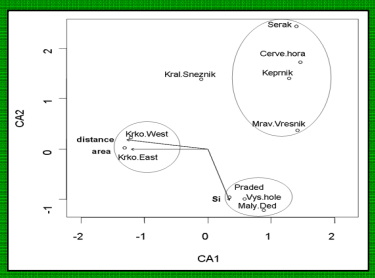


Fig. 3. CA ordination graph distinguishes groups of alpine sites according to species composition and shows the effect of geographic factors – area (A), the nearest distance (d), connectivity (*Si*) – on species richness.

Conclusion

Alpine sites are generally ranked among habitats threatened by climatic change. Recent predictions suggest that with a temperature rise indigenous alpine species could become endangered or even extinct as a result of the loss of alpine areas by forest encroachment, habitat fragmentation, invasion by introduced species and direct climatic effects. Therefore, alpine ecosystems are a conservation priority.

We have shown that all geographic factors, area, the nearest distance and connectivity (involving both, area and the nearest distance between sites), are important predictors of species richness and composition. Our study highlights the alpine "hotspots" of the High Sudetes Mts., e.g. Maly Ded, Praded and Vysoka hole, as a conservation priority. However, any decline in the area and a consequent decrease in the connectivity of all studied alpine sites may have negative impacts on the species living here.

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