Scree habitat as ecological refuge: A case study on the Carpathian endemic species *Platynus glacialis* and *Pterostichus pilosus wellensii* (Coleoptera, Carabidae) in their first case of co-occurrence in the rock debris

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**Abstract.** In the actual context of global climatic and environmental changes, two endemic species for the Carpathians – *Platynus glacialis* Reitter, 1877 and *Pterostichus pilosus wellensii* (Drapiez, 1819), previously localized in and characteristic for two different mountain habitats (rocky areas in alpine to subalpine zone, respectively high altitude mountain forests), were found cohabiting, in large numbers, in the scree of subalpine zone. The bibliographical sources compiled with our field records revealed that both species have disjunct distributions. The effect of environmental variables (temperature, relative humidity and depth) on their populations was tested in this new type of habitat, where these two species were found coexisting. The statistical analysis of data gathered during a two years period, indicated that each species uses the scree habitat in different way, mainly depending on the exterior temperature variations, emphasizing the ecological importance of this habitat for species conservation. A distribution map of both species is given.

**Key words:** *Platynus glacialis*, *Pterostichus pilosus wellensii*, Carpathian endemic species, scree habitat, covariance, ecological refuge, Romania.

**Introduction**

Nowadays, due to global changes, many species seem to respond to the changes in their habitat conditions by modifying their latitudinal and altitudinal distribution as a compensation of these disturbances (Drees et al. 2011) and by adapting themselves to new habitats which preserve more properly their major environment requirements.

*Platynus glacialis* Reitter, 1877 and *Pterostichus pilosus wellensii* (Drapiez, 1819) are two endemic species of Carabidae, highly representative for the Carpathian fauna of Coleoptera (Holdhaus & Deubel 1910, Csiki 1946, Müller-Motzfeld 2004). Up to present, each species was known as characteristic for different habitat types. *Pl. glacialis* was known as a cryophilic, strictly localised species, recorded in rocky environments of the alpine and subalpine zones (Ganglbauer 1892, Holdhaus & Deubel 1910, Csiki 1946, Müller-Motzfeld 2004). *Pt. pilosus wellensii* was known as a representative soil (edaphic) species for the subalpine zone with shrubs of *Pinus mugo* and *Vaccinium* and downwards the spruce forest zone and that of mixed forests (Varvara 2005, Nitzu et al., 2008, Nitzu et al. 2014), being sporadically recorded in subalpine pastures (Merkl 2008).

During the 2008–2009 period, in the frame of a throughout study on the fauna of scree habitats of the “Piatra Craiului” National Park, both species were sampled in large number of individuals at 0.5 m and 0.75 m depth in the scree habitat of “Marele Grohotiș” (1579 m altitude) in the subalpine zone. These predator species were identified as co-dominant in the previously mentioned habitat (Nitzu et al. 2014).

In theory, the maximum number of coexisting species is given by the limiting factors and resources (Armstrong & McGehee 1980), although, quoting Tilman (2007) ‘high diversity of coexisting competitors can result from spatial heterogeneity, temporal variability, spatial structure and interactions between competition and colonization, and trophic complexity’. According to the Lotka-Volterra competition model, two species can stably coexist at equilibrium when each inhibits itself more than it inhibits the other species (Tilman 2007).

Taking into consideration that both *Pt. pilosus wellensii* and *Pl. glacialis* belong to the same ecological functional type (predators), the aim was to observe whether, in this unique case of co-occurrence in scree habitat, these species directly interact with each other, or use the same habitat (as resource) without any direct interaction.

I tested whether i) a positive or negative association between species can be identified; ii) the seasonal and annual variations of species abundance strongly suggests a direct species interaction (i.e. trophic interaction, facilitation or compe-
tition), or not; iii) the use of the same habitat (as resource) can be correlated with the variation of some environmental factors (depth, relative humidity, temperature); iv) the variation in the abundance of the two species represents their response to the same or to different environmental factors.

Material and methods

Study area

The National Reserve “Piatra Craiului”, the unique site where both species were recorded in the same habitat, is located in the Southern Carpathians and is considered one of the most important karst areas in Romania. The scree habitat of “Marele Grohotiș” (MG) in Piatra Craiului is a semi-mobile scree situated in the subalpine zone at 1571 m altitude (45° 30’ 34” N; 25° 11’ 35” E); its lower part is bordered by spruce forest.

Species distribution


Species abundance sampling

Fauna was collected monthly, from April to October in 2008, and from April to November in 2009. As already presented in detail in a recent article on scree habitats (Nitzu et al., 2014), the samples were taken at two depths: 0.5 m and 0.75 m. This made a total of 29 assemblages (2 depths × 2 years × 6 months = 24; 2 depths × 1 year × 2 months = 4; 1 depth × 1 year × 1 month × 1 habitat type = 1).

Fauna was sampled using pitfall traps. A pitfall trap (80 × 100 mm), half filled with ethylene glycol as a preservative solution (70%) was placed vertically in each hole. Each pitfall trap was protected by a perforated PVC pipe to prevent gravel falling into the trap and to provide access for the specimens. The upper end of the PVC pipes was closed with a plastic lid and covered with the initial conservative solution (70%).

Measurement of environmental variables

Temperature (T - °C) and relative humidity (Rh - %) values were measured using a humidity/Log R thermohygrometer “Digi-Sense” Cole Palmer. T and Rh were measured at the surface (hereafter Tsurf and Rhsurf) and at 0.5 m and 0.75 m depth from the surface. Both T and Rh had similar values at 0.5 and 0.75 m depth and were highly correlated (Nitzu et al. 2014). Therefore, the means of the temperature and humidity values taken at 0.5 and 0.75 m were used as a measure of in-depth temperature and in-depth relative humidity (hereafter Tint and Rhint).

Data analysis

Species’ association (based on presence/absence) and species’ covariation (based on species abundance) were both tested statistically.

Species’ association was tested by computing variance ratio, chi-square test, and indices for species association (Ochiai, Dice, Jaccard nonprobabilistic association indices) (SPSS/PC, Ludwig & Reynolds 1988). To avoid biased chi-square values, resulting from low cell expectations (Zar 1984), the chi-square Yates’s correction was computed.

To test the species covariation, the normality of the bivariate distributions of data was tested first, using the R-mode correlation coefficient for species affinity: Spearman rank correlation (Mann-Whitney test 1993), resulting in a total of 21 sample units (N) (29 – 8).

Canonical correspondence analysis (CCA) on species abundances (in 21 sample units) was used to investigate their associations with environmental variables (Ter Braak & Verdonschot 1995; Legendre & Legendre 1998). The previously mentioned selection procedure was applied with Monte Carlo simulations (199 permutations) to constrain the final model to include only the environment variables significant at p < 0.05. CCA was carried out using the vegan package in R version 1.81 (R Development Core Team 2003).

Results

Species distribution

The numbers in brackets, following the names of sites, represent the site number according to the distribution map (Fig. 1).

*Platynus glacialis* Reitter, 1877 (P. Craiului (1); Cernogora (1); Negoiu (2); Căraș (3); Brașov-Postăvarul (4); Făgăraș (6); Piatra Mare (7); Serbota (8) (all: Petri 1912); Făgăraș, 15.V.1985, leg. Nitzu E.; Bucegi, 5.VI.1984, leg. Nitzu E.; P. Craiului at Padina Lâncii (9), 1.V. 2009 in mixed forest (spruce and beech), 1600 m alt., leg. Nae A.; P. Craiului at Valea Seacă, 1.V.2009 in mixed forest, 1000 m alt., leg. Nae A.; Piatra Craiului at Marele Grohotiș (1600 m alt), 2008-2009, in scree habitat, leg. Nae A.; Piatra Craiului at Cerdacul Stanciului (1610 m alt), 2008-2009, leg. Nae A.

*Pterostichus pilosus wellensii* (Drapiez, 1819): Făgăraș (6); Retezat (10) (both, Petri 1912); Bucegi (5) (Ionescu & Bogoeescu 1941, Ienișteia 1948; 15.V. 1985, leg. Nitzu E.); Pietrosul Rodnei (11) (at 2005
Carpathian endemic Carabidae inhabiting screes

m, 1795 m, 1413 m, 1269 m alt.) (Nitzu et al. 2008); Giumalău (12) (Nitzu & Olenici 2009); Piatra Craiului (Nitzu et al. 2014); Slătioara (13) (Varvara 2005); Maramureș Mountains at: Borșa (14); Fântâna Stanchi (15) (1600 m alt, in alpine pasture, 26.VII.2007); Mt. Cearcău, Valea Vinisor; Poienile de sub Munți (16); Valea Izei (17); Munții Lăpuș; Rodna Mt. at Valea Cimpoieș (11) (all: Merkl 2008); Tocaria; Certina; Grohot; Vaserului Valley (beech forst) (16) (all: Nitzu 2007); Negoiu (2), 4.VII.1933 leg. M.AI. Ieniștea; Sgliver Peak (18), 13.VII.1933 leg. M.AI. Ieniștea.

Spatial-temporal variances of species abundance in Marele Grohoti (Piatra Craiului Massif)

During the 2008–2009 sampling period, a total of 208 individuals of Platynus glacialis and 127 individuals of Pterostichus pilosus were collected at MG.

The monthly variation in the abundance of both species during the two years at MG (the unique site where both species occurred in large number of specimens) is presented in Fig. 2. The monthly variation of the abundance has its peak in June, for both species, in both years, but inversely proportional as amplitude between years. For June, the abundance of both species, on years and depth, is presented in Fig. 3.

The monthly variations of internal and external temperature (ºC) and relative humidity (%) are presented in Fig. 4. For June, when the abundance of both species was highest, the external temperature and relative humidity values differ between 2008 (27 ºC ext / 45% RH ext) and 2009 (18 ºC ext / 59% RH ext), whereas the internal temperature and relative humidity values were relatively constant (10 ºC – 15 ºC and 85 % – 95 %) during the sampling period in both years.

Due to the fact that two species may exhibit a strong positive association with regard to their joint occurrence in the sample unit, yet may have a strong negative covariation (Ludwig & Reynolds 1988), both species association (based on presence/absence) and species covariation (based on species abundance) were statistically tested.

The chi-square test of species association (the theoretical chi-square value for 1 degree of freedom (df) at the 5% probability level) indicates a negative association between species. Chi-square computed value was 7.875 > 3.84, meaning that the null hypothesis is rejected (the co-occurrence of both species is not independent). The computed values of association indices were low (below 0.5) (Table 1).

To assess the covariation in abundance between species, the Anderson-Darling test for normality (p>0.05) was performed as a first step. The obtained p values were p = 0.057 for Pt. pilosus and p = 0.0031 for Pl. glacialis. As far as the test for normality shows that bivariate distributions are not normal, the nonparametric coefficient – the Spearman rank correlation was computed. The null hypothesis was that the species abundances are uncorrelated. For Spearman’s correlation, the obtained value of rs (0.385) did not exceed the critical value of rs and the null hypothesis was
Table 1. Interspecific association indices and test statistics between *Pt. pilosus* and *Pt. glacialis* in the scree habitat from Marele Grohotiș.

<table>
<thead>
<tr>
<th>Species pair</th>
<th>Association (+ or -)</th>
<th>Chi-square</th>
<th>Yates’s correction</th>
<th>Ochiai</th>
<th>Dice</th>
<th>Jaccard</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Pt. pilosus</em> / <em>Pt. glacialis</em></td>
<td>-</td>
<td>7.875</td>
<td>49.219</td>
<td>0.354</td>
<td>0.333</td>
<td>0.200</td>
</tr>
</tbody>
</table>

Figure 3. The variation of species abundance in June, on years and sampling depth.

accepted, thus, the species abundances are uncorrelated (Table 2).

In multivariate analysis (canonical correspondence analysis), the abundance of species was significantly related to exterior and interior temperature and depth, as indicated by the Monte-Carlo test (Table 3).

The association of these significant environmental variables and species abundance (direct gradient analysis focus scaling on inter-species distances) was depicted in the CCA ordination plot (Fig. 5). The two eigenvalues were 0.437 (for axis I) and 0.048 (for axis II). The first axis explained 90.1 % of the total variance for species data. In Fig. 5, the species are shown by points, and the environment variables are shown as vectors, arrowheads indicating the direction in which
the value of environmental variable increases (Lepš & Šmilauer 1999). Species plotted close to the vectors have a strong relationship with them. All environmental variables were significantly correlated with the first axis. The abundance of *Pt. pilosus* in the scree habitat at MG was strongly correlated with the internal temperature (T_{int}) whereas the abundance of *Pl. glacialis* in the same habitat was correlated with depth and exterior temperature (T_{ext}).

**Discussion**

Literature data shows that both species display a disjunct distribution in the Carpathians (Fig. 1), the most probable cause being their habitat fragmentation. In Piatra Craiului Massif, both species occurred in a new type of habitat – the scree habitat at Marele Grohotiș in the subalpine zone. The inversely proportional variations of species abundance in June between the years 2008 and 2009 at 0.5 m and 0.75 m scree depth (Figs. 2–3) suggested a possible direct interaction between the two species, suspected at first as a competition between these predator species. The statistical test of species association suggested a negative association between them. In theory, the negative association between two species occurs in cases of competition, avoidance, mutualism or predation (Schluter 1984). In this case, both species being predators, only the first two mentioned ecological relationships were worth to be taken into consideration. The statistical tests of the covariation showed that
their variations of abundance in the scree habitat were uncorrelated, meaning that there is no competition between the two species. Combined statistical analysis of environmental factors and monthly variation of species abundance in two consecutive years indicated that the two species are using the same habitat in different weather conditions and prefer different depths (Fig. 5). The cryophilic species *P. glacialis* populated the empty spaces inside the scree habitat, in large number of individuals in warm periods, when the exterior temperature increased, preferring also the depth of 0.75 m. On the contrary, *P. pilosus wellensis* populated the scree in large number of individuals in the year 2009 when the exterior temperature in aestival season was lower than in 2008, preferring depth of 0.5 m and showing a strong positive correlation with internal temperature.

Brole & Keplin (2005) stated that ‘Mountain ecosystems belong to the most endangered ecosystems in the world. Especially, the treeline ecotone acts as an indicator for environmental change’. The importance of gravels as preferential habitat for numerous invertebrate species, including glacial relicts and endemic species, has been emphasized by Christian (1987), Ržička (2000), Ržička et al. (2012). In line with the previously quoted studies, in the specific conditions of the Carpathians, other two endemic species: *Pt. pilosus wellensis* and *Pl. glacialis* were found populating the scree habitat situated in sub-alpine zone, at the upper limit of the spruce forests. The two species inhabit this new environment in different conditions related to the seasonal variations of some environmental factors (temperature, depth), without establishing competitive relationships among themselves.

In the actual circumstances of habitat fragmentation for these Carpathian species, the scree habitat proved to play an important role in their life cycle, especially in the context of the global climatic changes (Mann et al. 2008, Fenoglio et al. 2010). Therefore, for a better protection of invertebrate species, more effort must be paid in future studies and conservation activities targeting scree habitats as potential ecological refuge in mountains.

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