

Carabid assemblages along a land use gradient in a Carpathian Mountain landscape

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Abstract. Agricultural land use intensification and deforestation are between the most significant drivers of biodiversity loss of terrestrial systems. However, if used in small scale and extensive way (as in traditionally used farmlands), land use may create a heterogeneous landscape that maintains high biodiversity. Here we evaluate the effect of traditional land use on carabid beetle communities in Eastern Carpathians, Romania. Three sampling areas were selected along a gradient of mountain landscape within the boundaries of the Olt river and mountain zone from Eastern Carpathian region: (i) forests (natural deciduous and pine plantation), (ii) semi natural habitats (willow and clearcut), and (iii) extensively used agricultural areas (apple orchard and cropland). We found that carabid communities react to landscape change induced by land use, the highest species diversity was found in clearcut and willow, whereas arable land contained the highest number of individuals and most of the common species regarded as "habitat specialists" were not associated with a specific "habitat patch". The landscape heterogeneity created by traditional land management result in species rich carabid communities.

Key words: traditional land use, habitat, diversity, population density, conservation.

Introduction

Land use change, including deforestation and intensification of agriculture, are actually considered the major drivers of biodiversity and ecosystem functions loss worldwide (Sala et al. 2000, Coll & Bolger 2007). Biodiversity of human fragmented landscapes lies in more or less isolated patches with seminatural vegetation. Preserving biodiversity in these remnants is actually a major concern in conservation biology. The persistence of species and populations in these fragments highly depends on the local population size (that is usually positively correlated with the patch size -as the metapopulation theory predicts (Hanski 1998), the connectivity with other patches and the ability of the organism to cross the space between patches (i.e. the matrix) (Tischendorf & Fahrig 2000, 2001). Loss of connectivity and decrease of habitat (patch) size will result in a decrease of local populations, an increase of extinction risk and an exposure to various stochastic and deterministic factors (Keller & Largiadèr 2003, Jordán et al. 2007, Balog et al. 2008, Okyar et al. 2009, Knorn et al. 2012), finally causing local extinction. Depending on the trophic position of the organism, population extinction may have a series of (often cascading) consequences on the ecosystem structure, chang-

ing it. As a reaction for massive deforestation, often afforestation/ reforestation occurs, especially to stop soil erosion, restore lost forest habitats or to increase timber production. These activities may not always be beneficial for native species and communities because non-native trees do not represent a habitat for them (Magura et al. 2008, Coll & Bolger 2007). Moreover, the agri-environmental schemes that aim to reverse the impact of intensive agriculture on biodiversity, may not work (Kleijn et al. 2001, Rosenthal 2010). Carabid beetles are suitable as a model group for studying the community level impact of land use changes because: (i) They are generalist predators and good indicators of ecological changes during forest succession (Niemelä et al. 1993) and homogenization of habitats (Koivula et al. 2002, Magura et al. 2004), (ii) They are easily trapped and are regularly present in high number of individuals and species rich communities (suggesting their importance in ecosystem function) (Brumwell et al. 1998). (iii) Finally, they are taxonomically well known. Several previous studies demonstrated that carabid communities change remarkably after afforestation and in the monocultures, with more abundant/increased habitat generalist and forest generalist carabid species (Bird et al. 2000, Werner & Raffa 2000, Elek et al. 2001). Previous studies

(e.g. Magura et al. 2000) demonstrated that management measures that encourage recolonization by native deciduous plants and the consequent accumulation of leaf litter, significantly contribute to the maintenance of carabid species richness and diversity even in non-native plantations (Norway spruce) 30 years after management. The aim of the present study is to explore the structure of carabid communities in a human-modified mountain landscape. The human impact on this landscape consists on plantation of species that are not characteristic for that elevation, deforestation and agricultural management. Moreover, natural and seminatural landscape elements are also present (such as willow with grassland and native deciduous forests). The specific objectives of our research are: (i) to test if carabid community structure is sensitive to land use gradient; (ii) to explore the effect of land use on the species richness and abundance of carabids.

Material and methods

Site characterization and sampling design

Three sampling areas were selected along a gradient of mountain landscape within the boundaries of the Olt river and mountain zone from Eastern Carpathian region. Sites were situated at a maximum distance of 500 m from each other, representing a gradient of the following land use categories: (i) forests, represented by mature natural deciduous mixed (oak and beech) forest with deficient herbaceous stratum and *Asperula odorata* in sunny patches. The pine (*Pinus silvestris* and *P. nigra*) forest (8 ha) was in continuation of cleared portion. The herbaceous stratum was rich in species (*Dryopteris filix-mas*, *Hepatica transilvanica*, *Pulmonaria rubra*, *Asarum europaeum*). (ii) semi-natural open habitats, represented by a willow near the Olt River, and a 10-year-old clearcut in the vicinity of the deciduous forest, and finally (iii) extensively used agricultural areas represented by apple orchard and actively used cropland (patches of potato, cereals and fodder-plants in an approximately yearly rotation of crops). In our study, annual wheat was planted. The willow and clearcut were sparsely dotted by shrubs and trees, the dominant vegetation being represented by natural weed and grass. Samples were collected throughout two years. Ten covered pitfall traps (300 cm³ in size, 8 cm in diameter, half-filled with ethylene glycol 30% solution) were placed in each land use types in transects from the margin of land use towards the centre at 5 m intervals. Samples were collected monthly from May to September. All ground beetles were sorted and identified up to species level.

Data analyses

The correlation between the species richness and the number of individuals was assessed with Pearson correla-

tion. Analysis of Variance and Factorial Analysis of Variance in General Linear Models (GLM) was used to test the effects of two grouping factors (study period and land use) on the carabid species richness and number of individuals. For this analysis, the dependent variables (species richness and number of individuals) were log-transformed to meet the assumption of GLM. To assess the significance of the differences between individual groups, Tukey test was used as Post Hoc. The Shannon-Weiner (H') and the log series Fisher alpha ($\hat{\alpha}$) diversity index were applied to measure biodiversity. The alpha diversity index is considered to be superior to commonly used indices due to its low sensitivity to sample size and its high discriminating ability (Shah et al. 2003). The maximum likelihood estimate $\hat{\alpha}$ can be divided from:

$$S = \hat{\alpha} \log(1 + N/\hat{\alpha}) \quad (1)$$

where S = number of species in the sample, and N = number of individuals in the sample.

The forming similarity of ground beetles communities were studied with "Principal Coordinate Analyse" (PCoA) methods and the Jaccard and Horn indices were calculated. The Jaccard index is used to compare the species composition of two communities using binary dates and registers only the presence and the absence of the species. These results can be derived from:

$$S_a = a / b + c - a \quad (2)$$

where: S_a = similarity Jaccard coefficient, a = the species number in both samples, b = the species number in sample b, c = the species number in sample c. If S_a = 0, the samples are completely differed from each-other, if S_a = 1, the samples are completely similar.

The Horn index is used to compare the dominant structure of the communities, considering the relative abundance of species. Horn can be derived from:

$$R_o = \frac{\sum (X_{ij} + X_{ik}) \log(X_{ij} + X_{ik}) - \sum X_{ij} \log X_{ij} - \sum X_{ik} \log X_{ik}}{(N_j + N_k) \log(N_j + N_k) - N_j \log N_j - N_k \log N_k} \quad (3)$$

where: R_o = Horn similarity index in samples j and k, X_{ij}, X_{ik} = the number of individuals of i species in samples j and k, N_j = $\sum X_{ij}$ = the total individuals in sample j, N_k = $\sum X_{ik}$ = The total individuals in sample k.

We computed Horn and Horn log₁₀ indices. Horn log₁₀ was used to reduce the importance of the dominant species and emphasize the importance of subdominant species.

Characteristic species of the urban, suburban and rural areas were identified by the IndVal (Indicator Value) procedure (Dufrene & Legendre 1997). This method identifies quantitatively the characteristic species of the studied habitat types, and generates a significance value (p-value) for the strength of association using a randomized computerized resampling technique. The IndVal of a species is expressed as a product of the specificity and fidelity measures. It receives its maximum (100) when all individuals of a species are found in a single type of sites (high specificity) and when the species occurs at all sites of that type (high fidelity) (Dufrene & Legendre 1997). The characteristic species is defined as the most representative species of each habitat type, found mostly in that habitat and present in the majority of sites belonging to

that habitat. This proved to be a useful method to identify the characteristic carabid species in several habitats (Elek et al. 2001, Magura et al. 2000).

Results

2891 individuals belonging to 100 species were captured. We found a highly significant effect of both land use and seasonality on the species richness and the number of individuals. 46% of variation in species richness and 62% of the number of individuals can be accounted for the factorial model. Table 1 shows the significance test for each term of the model. The species richness varied between the habitats, forest species were completely missing from willow, orchards and arable land, while the number of generalist species was significantly higher in these habitats and low in forests. Open habitat species were also underrepresented in forests (Fig. 1). The species abundance pre-

sented similar shape, however for open habitat species we have not observed significant differences between habitats (Fig. 2). The Shannon and Fisher α diversity values were highest for clearcut and willow and lowest for arable land (Table 2).

Arable land contained higher number of species than the two forest types and the orchard also contained the highest number of individuals (Table 2). The PCoA ordination based on the forming structure revealed the dissimilarity between habitats, carabid assemblages showed gradual changes from open toward agricultural lands and the Jaccard index of similarity indicated a clear distinction between forests, semi natural open and agricultural lands respectively (Fig. 3). This was confirmed by computing the forming structure (Horn log10) and forming dominance (Horn) of the species. However the subdominant and dominant species structure in clearcut shows noticeable similarity with forests (Fig. 4). The species charac-

Table 1. The effect of each term on species richness and number of individuals in Factorial ANOVA.

Source	SS	df	MS	F	P
Species richness					
R ² = 0.466					
Intercept	108.471	1	108.471	4.288.525	<0.001
Period (month)	0.642	4	0.160	6.344	<0.001
Land use	4.063	5	0.813	32.131	<0.001
Period * Land use	1.247	20	0.062	2.466	0.001
Error	6.829	270	0.025		
Number of individ.					
R ² = 0.62					
Intercept	191.570	1	191.570	3.148.346	<0.001
Period (month)	2.072	4	0.518	8.514	<0.001
Land use	19.430	5	3.886	63.864	<0.001
Period * Land use	5.461	20	0.273	4.487	<0.001
Error	16.429	270	0.061		

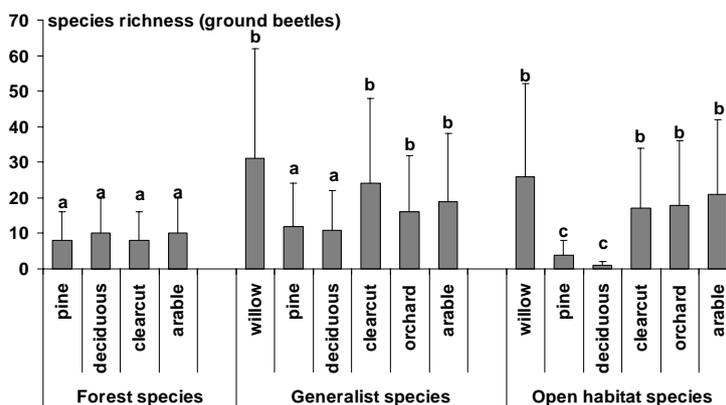


Figure 1. The species richness of carabid assemblages along the Carpathian natural-rural gradient (ANOVA). Different letter p < 0.05.

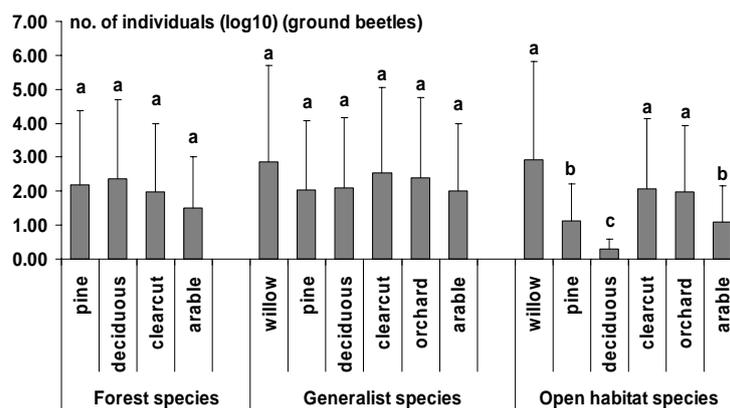


Figure 2. The activity-density of carabid assemblages along the Carpathian natural-rural gradient (ANOVA). Different letter $p < 0.05$

Table 2. The dominance and diversity of the ground beetles assemblages along the studied natural-rural gradient.

Ground beetles	willow	pine	deciduous	clearcut	orchard	arable
Individuals	858	154	195	214	186	1284
Species	55	21	22	45	29	32
Shannon index (H')	2.948	2.425	2.504	3.01	2.676	1.503
Fisher alpha (log 10)	1.118	0.818	0.804	1.240	0.984	0.774

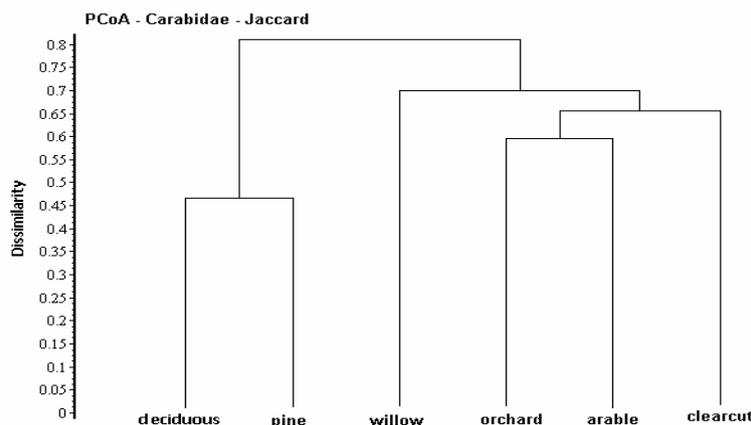


Figure 3. Cluster analysis of the carabid assemblages along the Carpathian natural-rural gradient at site level using the Jaccard index of similarity and the group average fusion algorithm.

ter power for the studied areas indicates the habitat preference of the species. We identified quantitative character species by the IndVal procedure for the compared areas. Altogether three groups of species were distinguished by habitat affinity: open habitat species, found mostly in willow and grassland, and forest species either recorded in

forest patches of semi natural open habitats and in orchard. The third group includes the habitat generalists; well represented in all land use types (Table 3). Three open habitat species (*Chlaenius nitidulus*, *Elaphrus aureus*, *Pterostichus anthracinus*), were significantly more represented in clearcut than in other land use types.

Discussion

The results of this study can be summarized as follows: (i) carabid communities react to landscape change induced by land use, and (ii) clearcut and willow had the highest diversity of carabids from all land use types from our study area and (iii) some species show no association with a specific "habitat patch". Changes in carabid communities according to land use (type and intensity) were already demonstrated by a number of studies. These studies suggest that agricultural intensification is

reflected in the changes of the structure of carabid beetle communities (these becoming poorer in species), and increase of permanent landscape structures, like hedgerows network in the agricultural landscapes, will increase the species richness, especially by adding specialist species (e.g. de la Pena et al. 2003, Burel et al. 2004, Batáry et al. 2008, Madjdzadeh & Mehrparvar 2009, Macovei 2011).

Our study suggests that extensive land management (small scale clearcuts and agriculture) may not have negative impact on carabid communities; these landscape elements having moderate

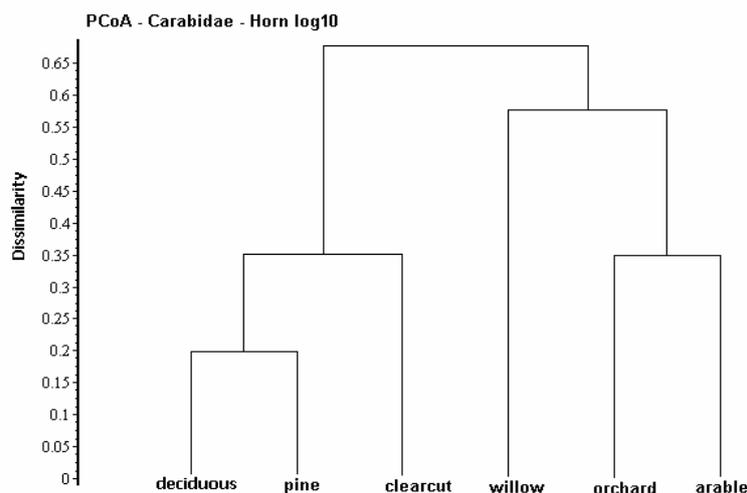


Figure 4. Cluster analysis of the carabid assemblages along the Carpathian natural-rural gradient at site level using the Horn log10 (forming structure) index of similarity and the group average fusion algorithm.

Table 3. Species character power for the studied areas, and the habitat preference of the dominant ground beetles species. The IndVal column shows the species character value for the corresponding clustering level. Notations: G - Generalist species, F - Forest species, and O - Open-habitat species, ns - not significant; * - $p < 0.05$.

Ground beetles	Habitat	IndVal	<i>p</i>	Forest	Semi natural open habitats	Agricultural rural habitats
<i>Chlaenius nitidulus</i>	O	18.0	*	0/0	48.5/19.4	0/0
<i>Elaphrus aureus</i>	O	20.0	*	0/0	50/20	0/0
<i>Poecilus versicolor</i>	O	14.0	ns	28.3/17	47/18.8	2/0.8
<i>Pterostichus anthracinus</i>	O	56.0	*	0/0	48/19.2	0/0
<i>Abax parallelus</i>	F	76.6	ns	49/12.2	43/10.7	24.5/12.2
<i>Molops piceus</i>	F	61.6	ns	49.5/9.9	42/8.4	3/0.6
<i>Pterostichus oblongopunctatus</i>	F	58.3	ns	50/2	29/7.2	5/1.2
<i>Bembidion tetracolum</i>	G	12.8	ns	31.3/6.2	50/14.29	0/0
<i>Carabus arvensis</i>	G	51.4	ns	31/5.1	49.5/16.5	42/16.8
<i>Carabus violaceus</i>	G	72.8	ns	30.6/4.3	49/9.8	47/15.7
<i>Harpalus rufipes</i>	G	77.1	ns	29.6/9.8	48.5/48.5	50/14.3
<i>Pterostichus melanarius</i>	G	40.0	ns	28/14	48/8.0	45.5/30.3
<i>Bembidion tetracolum</i>	G	12.8	ns	31.3/6.2	47.5/23.7	0/0

to high species diversity (clear cut) and high number of individuals (arable land) (Table 2) compared to other land use types. Moreover, three common open habitat species were exclusively found in clearcuts (*Chlaenius nitidulus*, *Elaphrus aureus* and *Pterostichus anthracinus*). Arable land had higher species richness than forests and the orchard, but still the lowest diversity index. This is due to the high number of individuals captured here (Table 2). The landscape effects on the distribution of organisms were demonstrated by many studies (e.g. Thies & Tscharnke 1999, Waldhardt 2003, reviewed by Hartel et al. 2008, Fischer et al. 2012). The possible explanation of the pattern found by us may lie in landscape structure around clearcut and arable land, that consists of small, closely situated patches, where the natural-seminatural habitats are still well represented (grasslands, willow, forest) and may serve as source of individuals and species. The large number of individuals of arable lands suggests that they represent proper habitats for quickly colonizing species (*Harpalus rufipes*, *Carabus violaceus*, *Pterostichus melanarius*, *Carabus arvensis*) that appear in high number after perturbation. Based on our results, we assume that landscape elements where the vegetation is towards the last successional stage (i.e. forest) negatively affect the species richness of carabid communities. We found that at least three common carabid species were significantly associated with open areas (clearcuts). At least these species are likely to disappear if the vegetation succession develops toward late stages (i.e. forest succession). We have no information regarding the temporal change of community structure of carabids in the traditionally managed arable land from our study area, in relation with land abandonment and vegetation succession. However, in this study we select land uses that represent a gradient, capturing all successional stages of existing land uses (and successional stages, excepting wetlands) in the landscape: arable lands, clearcuts with early successional vegetation, willows with mesophytic grasslands and two forest types. Our results suggest that land abandonment may result in carabid species loss and change of species composition because abandonment leads to vegetation succession. Traditional land use that maintain open habitats (such are low intensity grazing, skythcing, small scale arable lands) may represent a perturbing factor that may result in an increase of abundance and

species at landscape scale, most probably because of the creation and maintenance of high (and dynamic) spatial heterogeneity (Waldhardt 2003) and landscape connectivity (Tischendorf & Fahrig 2000, 2001, Fischer et al. 2012).

In classical landscape ecology models, landscape elements that positively influence the occurrence-distribution of the focal organism are regarded as 'habitat', otherwise they are considered "matrix" (i.e. non-habitat) (Mazerolle & Villard 1999, Fischer & Lindenmayer 2004, Gallé 2008, Korenko et al. 2011, Ladányi et al. 2011). Ten out of 13 common carabid species in our study were not associated with a specific land use type and four out of seven species regarded as open habitat or forest specialists were well represented in at least two habitat types (Table 2). Giving ecological attributes to species according to the preferred habitat type (i.e. open-, forested habitat specialists) may not work in all species (especially in the case of so called "forest specialists") and possibly the landscape structure may influence the found patterns. These results suggest that the habitat-matrix character of this landscape is not obvious for some carabid species (see also Driscoll 2005), possibly because the traditional land management maintain optimal environmental conditions for forest related species. Similar results were reported for other animal groups. For example, Cook et al. (2004) found that small mammals (voles - *Microtus* sp.) may have home ranges that include many patches and the intervening space (i.e. matrix). Similarly, Tubelis et al. (2004) found that birds may extend their home ranges from native vegetation to plantation matrix in surroundings. These studies suggest that the patch-matrix approach may lead to serious misestimating of habitat use in some species and landscapes (see also Price et al. 2009 for birds).

In conclusion, carabid beetle communities reflected land use patterns in the traditionally managed landscape studied by us. We suggest that species rich carabid communities may indicate high spatial heterogeneity and the small scale, low impact farming, typical of traditional land use. More effort should be allocated to explore the relationship between the land use and biodiversity in Eastern European countries. This is because, since these countries recently joined the European Union and they are developing, it is highly likely that changes in land use (i.e. agricultural land use intensification under the Common Agricultural Pol-

icy, infrastructural and urbanistic development) will occur in short to middle term. Recent studies demonstrated that massive biodiversity reduction occurs at the early stages of land use intensification (Kleijn et al. 2009). Agri-environmental schemes may not be efficient in halting-reversing biodiversity loss caused by intensive land use (Kleijn et al. 2001, 2007), therefore more environmentally friendly practices should be maintained to halt biodiversity loss in these landscapes.

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