

Brown bear activity in traditional wood-pastures in Southern Transylvania, Romania

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Abstract: During the past century, habitat fragmentation and increased human impacts have reduced populations of large carnivores throughout the world. Although bears have been extirpated from human-dominated landscape in most parts of Europe, they still occur in multi-use cultural landscapes in Southern Transylvania, Romania. Wood-pastures—grazed permanent grasslands with scattered or clumped trees and shrubs—are important elements of these cultural landscapes and provide habitat for a wide range of species. However, wood-pastures are under threat from land-use change, including intensified agricultural use and land abandonment. In 2012 we assessed the level of activity of brown bears (*Ursus arctos*) and environmental factors influencing bear activity in 54 wood-pastures in Southern Transylvania. As an index of bear activity, we measured the proportion of anthills that were destroyed by bears. The variables were combined in 3 groups (anthropogenic effects, local variables, and landscape context) to test which group most strongly influenced bear activity. Bear activity was found in 47 (87%) wood-pastures. Bear activity was best explained by variables describing the landscape context, with proximity to the Carpathian Mountains, terrain ruggedness, and amount of surrounding woody vegetation positively related to bear activity. Local variables (distance to forest edge and anthill density) had no effect, and surprisingly, variables related to anthropogenic features (distance to major roads, distance to villages) were positively related to bear activity (albeit weakly). Most of the wood-pastures in Southern Transylvania were used by bears for foraging on ant larvae. For the conservation of brown bears in Southern Transylvania, it is important to maintain large areas of forest but also consider cultural landscape elements such as wood-pastures. To conserve European wood-pastures, we suggest they be explicitly considered in national nature conservation policies and in major European Union (EU) policies such as the EU Habitats Directive.

Key words: agroforestry, cultural landscapes, Eastern Europe, European brown bear, silvopastoralism, *Ursus arctos*, wood-pastures

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Introduction

Habitat fragmentation and increased human impact have reduced populations of large carnivores throughout the world (Breitenmoser 1998, Woodroffe 2000). The brown bear (*Ursus arctos*) is Europe's largest carnivore, but has been displaced from human-dominated landscapes in most parts of

Europe (Swenson et al. 1995, Zedrosser et al. 2011, Kopatz et al. 2012). Most remaining populations are confined to mountainous regions and heavily depend on major conservation efforts (Swenson et al. 2000, Zedrosser et al. 2001). Thus, the need to protect the brown bear in Europe remains a priority (Zedrosser et al. 2011, Krofel et al. 2012), even though the species has been listed in Annex II and Annex IV of the European Union (EU) Habitats Directive (92/43/

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Fig. 1. Typical wood-pasture in Southern Transylvania, Romania, where we assessed the level of activity of brown bears (*Ursus arctos*) and environmental factors influencing bear activity during summer 2012.

EEC) since 1992. Although bear populations are now increasing in some areas (Zedrosser et al. 2011), agricultural intensification and habitat fragmentation, resource extraction, road development, recreation development, and urban expansion still threaten Europe's remaining bear populations (Swenson et al. 1995, Breitenmoser 1998, Zedrosser et al. 2001).

Romania has the largest national brown bear population in Europe (excluding Russia; Chestin 1999, Spassov and Spiridonov 1999), estimated by the International Union for Conservation of Nature, to be stable at approximately 6,000 individuals (Huber 2007). In Transylvania, bears occur not only in large forest patches, but also in multi-use cultural landscapes. However, potential landscape changes such as intensified agriculture, deforestation, and planned new highways could negatively affect Transylvania's bear population (Swenson et al. 2000, Ministry of Agriculture, Forestry and Rural Development and the Ministry of Environment and Water Management [MAPDR and MMGA] 2005).

Changes in land use also pose a major threat in multi-use cultural landscapes such as the traditional grazing systems of wood-pastures (Plieninger 2005, Bergmeier et al. 2010). Wood-pastures are grazed permanent grasslands with scattered trees and shrubs or with groups of trees and shrubs, and important elements of cultural landscapes in Europe (Bergmeier et al. 2010). Wood-pastures are used by a wide range of species, including many threatened species (Tucker and Evans 1997, Wegener 1998, Olea

and San Miguel-Ayanz 2006, Bergmeier et al. 2010, Dorresteijn et al. 2013). Plants, invertebrates, and birds are the most commonly studied species in wood-pastures but, apart from some publications mentioning use of the Spanish *dehesas* by Iberian lynx (*Lynx pardinus*; Olea and San Miguel-Ayanz 2006, Bergmeier et al. 2010), relatively little is known about the use of wood-pastures by large carnivores. To our knowledge, this is the first ecological study focusing on the use of wood-pastures by large carnivores.

Wood-pastures in Southern Transylvania (Fig. 1) are generally open, with a density of approximately 8 trees/ha (Hartel et al. 2013). Some wood-pastures are surrounded by forest, while others are situated within open pastures or, more rarely, arable fields. Wood-pastures in Southern Transylvania are mainly grazed by sheep, cattle, and sometimes goats and buffalos in moving herds. The main tree species are oak (*Quercus* spp.) and beech (*Fagus sylvatica*), but also fruit trees such as wild pear (*Pyrus silvestris*) and hornbeam (*Carpinus betulus*). Characteristic shrub species are hawthorn (*Crataegus monogyna*), blackthorn (*Prunus spinosa*), blackberry (*Rubus* spp.) and dog rose (*Rosa canina*; Hartel et al. 2013). Most of these trees provide potential food sources (mast and fruits) for brown bears.

Anthills are also typical elements of wood-pastures, and the larvae within these provide an important source of protein for brown bears in spring (Swenson et al. 1999). The most common ant

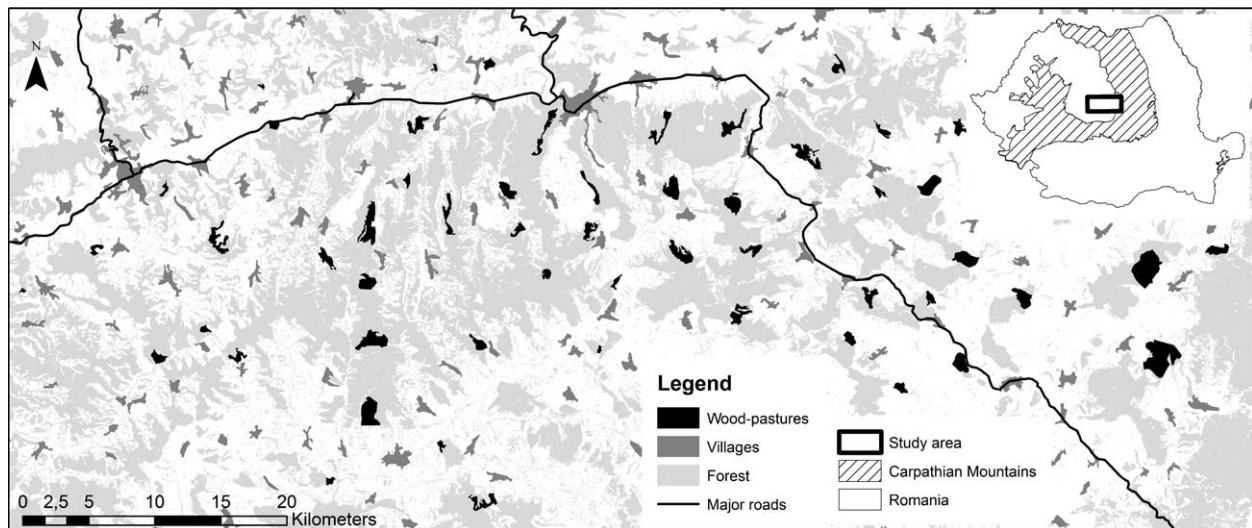


Fig. 2. Study area where we assessed the level of activity of brown bears (*Ursus arctos*) and environmental factors influencing bear activity during summer 2012 in Southern Transylvania; figure shows Romania, the Carpathian Mountains, forest areas, villages, major roads, and locations of the 54 wood-pasture sites.

species in grasslands (such as the wood-pastures in Southern Transylvania) include yellow meadow ants (*Lasius flavus*), black garden ants (*L. niger*), *L. paralienus*, and pavement ants (*Tetramorium* cf. *caespitum*; B. Markó and K. Erős, Babes-Bolyai University, Cluj-Napoca, Romania, unpublished data). Three of these (*L. flavus*, *L. niger*, and *T. cf. caespitum*) are probably consumed by bears, based on the abundance of nests in the field, the abundance of individuals in the nests, and the amount of larvae and pupae (B. Markó, personal communication).

Wood-pastures in Southern Transylvania thus contain several useful elements for brown bears: (1) their heterogeneous character provides a wide variety of food sources including ant larvae in spring, fruits and berries in the summer, and hard mast during autumn; (2) groups of trees or shrubs provide immediate refuge for bears (Swenson et al. 2000); and (3) they are used extensively by grazing livestock in moving herds (Hartel et al. 2013), meaning that pastures are not fenced and are accessible for bears.

To date, it is largely unknown which environmental variables explain bear activity in cultural landscapes such as wood-pastures, and at which scales these variables are important. To fill this knowledge gap, we investigated bear activity in wood-pastures in Southern Transylvania. We aimed to ascertain (1) whether, and to what extent, wood-pastures were used by brown bears; and (2) which

environmental variables, and at which scale, could explain bear activity in wood-pastures.

Methods

Study area and site selection

We conducted the study in Southern Transylvania, Romania. Southern Transylvania is a plateau surrounded by the Carpathian Mountains. We investigated bear activity in 54 wood-pastures around the town of Sighisoara (Fig. 2). The study area was chosen because of the widespread occurrence of wood-pastures and available information about them (Hartel and Moga 2010).

We defined wood-pastures as pastures with scattered trees and shrubs, or with groups of trees and shrubs (Bergmeier et al. 2010). To locate wood-pastures, we used published literature (Hartel and Moga 2010) as well as CORINE pasture distribution data (CORINE land-cover; European Environmental Agency [EEA] 2006) and satellite images of the area (Google Earth). We selected wood-pastures with a broad gradient in percentage surrounding forest cover. Within each wood-pasture, we established 2–6 transects, depending on the size of the wood-pasture (<30 ha = 2 transects; 30–80 ha = 3 transects; 80–130 ha = 4 transects; 130–180 ha = 5 transects; >180 ha = 6 transects). At each site, we placed one transect 7 m from, and parallel to, the forest edge and one in the center of the pasture.

Additional transects were placed randomly via Geographic Information System and were typically separated by several hundred meters. Each transect was 400 m long and 6 m wide.

To quantify bear activity, we documented the proportion of anthills disturbed by foraging activity (i.e., we counted all destroyed and intact anthills in each transect). This method was developed and successfully used by the *Mammal Conservation Workgroup of the "Milvus Group" Bird and Nature Protection Association* for monitoring bear activity in Transylvania (http://milvus.ro/Mammal_Conservation). In each transect, we noted the coordinates in longitude and latitude using a Global Positioning System at 100-m intervals, and recorded the number of intact anthills (diam >25 cm, ht >15 cm) and destroyed anthills in the previous 100-m segment. All surveys were conducted from 1 May to 24 June 2012.

Environmental variables

Bears are known to react to both human activity (e.g., Clevenger et al. 1992, Nellemann et al. 2007, May et al. 2008) and environmental conditions (Slobodyan 1974, Swenson et al. 2000), and we assumed based on their large range size (Preatoni et al. 2005) that they are sensitive to multiple spatial scales. Therefore, to investigate which combination of variables best explained bear activity in wood-pastures, we grouped our explanatory variables as follows: (1) anthropogenic variables (AV), (2) local variables (LV), and (3) variables describing the (broader) landscape context (LC). Each of the variables was calculated based on the midpoints of each 100-m segment.

We used anthropogenic variables to describe disturbance, measured as the shortest distance to village limits and major roads (using CORINE land-cover data from 2006 [EEA 2006]), based on each midpoint. For local variables, we estimated the proportion of woody vegetation cover within a 300-m-radius circle and measured the distance to forest edge (using CORINE forest data from 2006 [EEA 2006]), as a proxy for distance to shelter, from each segment's middle point. We also accounted for possible effects of the total number of anthills/100 m by including them as a local variable, because bears might be more attracted to pastures with more anthills. Finally, landscape-context variables included woody vegetation cover and terrain ruggedness within a 3-km radius around each segment's midpoint, as well as distance to the Carpathian

Mountains, measured from each segment's midpoint to the edge of the Carpathian Mountains. Both woody vegetation cover and ruggedness may be important with respect to the availability of sheltering habitat and a wider variety of food for bears. Woody vegetation and distance to the Carpathian Mountains may be important for connectivity to a larger (source) population and to dens at the higher altitudes. We derived woody vegetation from a supervised classification of the monochromatic channels of SPOT 5 data (©CNES 2007; Distribution Spot Image SA, Toulouse, France) using a support vector machine algorithm (Knorn et al. 2009). We calculated terrain ruggedness as the standard deviation of the elevation (Advanced Spaceborne Thermal Emission and Reflection Radiometer [ASTER] Global Digital Elevation Model Version 2 [GDEM V2]; Land Processes Distribution Active Archive Center, Sioux Falls, South Dakota, USA).

Modeling bear activity

As an index of bear activity, we quantified the proportion of destroyed anthills relative to the total number of anthills in each 100-m segment of each transect. The resulting data structure therefore was nested, with 4 segments/transect, and several transects per site (i.e., pasture). Thus, we modeled activity at the transect level to simplify the structure of random effects to 2 nested levels (transect/site). We used a binomial error distribution for the response data. All statistical analyses were implemented in the R environment (R Development Core Team 2013), and generalized linear mixed models were fitted using the package "lme4" (Bates et al. 2014).

To account for the nested data structure, we initially included site as a random intercept in the model, while in a second model we accounted for potential changes in activity over time by including Julian date as a random slope. Using both date and site as random factors at the same time was not meaningful because they were redundant, meaning each site was sampled on a specific date. Because site explained a greater amount of variance and arrived at more parsimonious models based on initial Akaike Information Criterion (AIC) comparisons, we used the model that included site only as a random intercept.

Distance to forest and anthill density were strongly skewed; therefore, we log-transformed these variables before modeling. Furthermore, we standardized all

Table 1. Summary of candidate models influencing brown bear activity in wood-pastures, Southern Transylvania, Romania, in 2012, including the maximized log-likelihood (Log(L)), number of estimable parameters (K), AIC_c , difference in AIC_c compared with the model with the lowest AIC_c (Δ_i), and Akaike weights (w_i). Also shown are the marginal and conditional R^2 values for all models. (AV = anthropogenic variables, LV = local variables, LC = landscape context).

Model	Log(L)	K	AIC_c	Δ_i	w_i	Marginal R^2	Conditional R^2
AV + LC	-1,778.81	7	3,571.77	0.00	0.66	0.125	0.695
AV + LV + LC	-1,777.46	9	3,573.16	1.39	0.33	0.117	0.686
LC	-1,785.53	5	3,581.15	9.38	0.01	0.179	0.754
LV + LC	-1,784.27	9	3,582.68	10.90	0.00	0.167	0.743
AV + LV	-1,801.77	6	3,615.64	43.87	0.00	0.017	0.451
AV	-1,804.16	4	3,616.36	44.60	0.00	0.014	0.446
LV	-1,811.37	4	3,630.78	59.00	0.00	0.003	0.429
Null model	-1,813.90	2	3,631.81	60.04	0.00		

predictors by subtracting their mean and dividing by their standard deviation to make the estimates comparable. Because of a strong correlation between distance to forest edge and woody vegetation within a 300-m-radius circle (Spearman rank correlation; $r = -0.68$), we removed woody vegetation from the group of local variables.

We used an information theoretic approach for model selection to identify models that best explained bear activity (Burnham and Anderson 2002). We constructed 7 alternative candidate models, which considered all possible combinations of the 3 groups of variables (AV, LV, LC). We used the R package AICmodavg (Mazerolle 2012) to rank the candidate models, based on AIC_c values to account for small-sample bias (Burnham and Anderson 2002). The AIC_c values of the best models were compared with the AIC_c values of the null model (which only included the random effects). Marginal and conditional R^2 values were calculated following the procedure outlined by Nakagawa and Schielzeth (2013), using the package arm (Gelman et al. 2013).

Results

The size of wood-pastures ranged from approximately 11 ha to 475 ha, but most were 30–130 ha (<30 ha, $n = 8$; 30–80 ha, $n = 19$; 80–130 ha, $n = 15$; 130–180 ha, $n = 6$; >180 ha, $n = 6$). We surveyed 199 transects, with a mean of 3.6 transects/wood-pasture. Anthills were found in all pastures; only 1 of the transects and 21 of the 100-m segments contained no anthills.

We detected destroyed anthills in 87% of wood-pastures and in 42% of transects. We found 29,236 total anthills, including 1,771 destroyed anthills (6%). Within a given 100-m segment, we recorded

up to 300 anthills, and up to 127 destroyed anthills (mean total no./100 m ≈ 37 ; mean destroyed/100 m ≈ 2).

Mean distance to nearest village was 2 km (range = approx. 150 m to approx. 5 km). The distance to the major roads averaged 35 km (120 m to 100 km). The average distance to the Carpathian Mountains was 30 km (11–64 km) and average distance to forest edge was 0.2 km (7 m to 1.8 km). The woody vegetation cover within 3,000 m averaged 44% (7–84%). Terrain ruggedness averaged 57 m (32–105 m).

All models including explanatory variables performed better than the null model (Table 1). The best supported model ($w_i = 0.66$) included anthropogenic variables (AV) and landscape context variables (LC). Despite the low difference in AIC values (<2) between the best supported and the second-ranked model, we selected the most parsimonious one (i.e., containing AV and LC), because the contribution of the third group of variables (local variables; LV) was unlikely to contribute meaningful explanatory power to the model (Anderson and Burnham 2002, Arnold 2010), given the low estimates of the local variables (Table 2). The marginal (i.e., only explaining the fixed effects) R^2 value for the top model was low, but the conditional R^2 value (explaining the random and fixed effects) was 70% (Table 1).

Landscape context was the most important variable group related to bear activity. Within this group, the distance to the Carpathians Mountains had the strongest effect. Bear activity increased with decreasing distance to the mountains. Also terrain ruggedness and percentage of woody vegetation cover in the surrounding area were positively related to bear activity in wood-pastures (Table 2). Bear activity was slightly correlated with the anthropogenic

Table 2. Best-supported model describing which variables explained bear activity in wood-pastures, Southern Transylvania, Romania, in 2012. The table shows the model coefficients (and SEs) that were included in the best ranked models. Also shown is the second-ranked model to highlight the low estimates for both variables of the group “local variables” (AV = anthropogenic variables, LV = local variables, LC = landscape context).

Model	Model terms							
	Intercept	Distance to villages (km)	Distance to roads (km)	% woody vegetation within 3 km	Terrain ruggedness within 3 km	Distance to mountains (km)	Distance to forest edge (km)	Anthill density (no./0.06 ha)
AV + LC	3.67 ± 0.33	-0.26 ± 0.07	-0.05 ± 0.06	0.29 ± 0.10	0.74 ± 0.11	-0.90 ± 0.30		
AV + LC + LV	3.72 ± 0.34	-0.26 ± 0.07	-0.05 ± 0.6	0.30 ± 0.10	0.72 ± 0.11	-0.82 ± 0.30	-0.02 ± 0.03	-0.14 ± 0.09

variables: we found higher bear activity in wood-pastures that were closer to villages, but almost no relationship between bear activity and proximity to roads.

Discussion

Our findings show that most of our studied wood-pastures in Southern Transylvania were used by brown bears, confirming the relevance of non-forest habitats (Slobodyan 1974, Swenson et al. 2000). In the following, we reflect on the survey method used, the variables related to bear activity, and potential conservation implications arising from our work.

Survey method

Ants are a well-known food resource for bears (Swenson et al. 1999), and several previous studies have used destroyed anthills as a sign for the presence of bear activity (e.g., Munro et al. 2006, Ciarniello et al. 2007). Using the proportion of destroyed anthills to total anthills turned out to be a pragmatic, but apparently useful, index of bear activity in our study, despite the unequal distribution of anthills across wood-pastures. Ideally, we would have compared our activity estimation with some other measure of bear activity known to be reliable. No such validation was possible during the study period; however, a similar study in 2012 in the same study area also used destroyed anthills as an index for bear activity and generated ecologically consistent results (I. Dorresteijn et al., Leuphana University, Lueneburg, Germany, unpublished data). Studies on the foraging behavior of bears have shown that bears often target ants during spring when numbers of pupae increase (Noyce et al. 1997, Swenson et al. 1999). Because of the harsh winter of 2011–2012, ant larvae were available later in the season than expected, and bear foraging activity increased rapidly a few weeks after we started our

surveys. Additionally, it is plausible that activity may increase over time because we considered anthills during a period of 2 months. Both of these issues could result in a positive effect of time on observable foraging activity; however, such effects were corrected for by including site (and thus implicitly survey date) into our model as a random intercept. We did not take into account potential selection by bears for different ant species, but we acknowledge that this may occur and warrants additional research.

Variables influencing bear activity in wood-pastures

Bear activity in wood pastures was primarily driven by environmental variables at the landscape level and to a lesser extent by anthropogenic variables. The importance of the landscape variables is consistent with previous studies, which also identified mountainous regions (Posillico et al. 2004), as well as rugged and forested areas, as being preferred by bears for shelter, denning sites, and food (Clevenger et al. 1992, Preatoni et al. 2005, Nellesmann et al. 2007, May et al. 2008). The relative lack of importance of local variables was surprising because we hypothesized that distance to the forest edge could be an important element of escape cover (Swenson et al. 2000) and expected higher bear activity closer to forests. However, the relatively small size and complex shape of many of the studied wood-pastures may have ensured that the forest edge was generally within close proximity. Alternatively, the structurally rich wood-pastures could have provided adequate shelter. Anthill density also did not appear to influence bear activity; fewer anthills than were available in our study area are potentially still sufficient in number to attract bears.

Bear occurrence has been shown to be negatively affected by human presence (Clevenger et al. 1992, Preatoni et al. 2005, Nellesmann et al. 2007, May et al. 2008). However, bear activity in our study was

slightly positively associated with the anthropogenic variables we measured. This unexpected finding may be explained by most villages in Southern Transylvania being small and characterized by low human density (approx. 34 inhabitants/km²; Arion et al. 2011). Elsewhere in Europe, bears inhabit areas with human densities up to 80 people/km² (Linnell et al. 2001). In Scandinavia, female brown bears avoided human activity, but used human-dominated landscapes for foraging when human density was low, especially at night (Martin et al. 2010). Such temporal niche partitioning between humans and bears may also occur in Southern Transylvania. Major roads were generally several kilometers from the wood-pastures we studied, which may explain their lack of influence on bear activity.

Conservation and management implications

Although bears typically require large, relatively undisturbed areas, we showed that they also use wood-pastures within the cultural landscapes of Southern Transylvania. This is likely because they represent a source of protein (ants), which is critically important in the otherwise mainly vegetarian diet of the brown bear in temperate latitudes (Bojarska and Selva 2012). Wood-pastures likely provide fruits and hard mast as food sources for brown bears in summer and autumn, but our investigations were confined to the spring season when ants and their larvae were most abundant and sought after by bears.

Wood-pastures in Southern Transylvania face several threats. Land abandonment leads to forest succession, which will eventually displace species linked to the semi-open character of wood-pastures, including fruit trees and invertebrates such as the grassland ant species (both food sources for bears). On the other hand, intensified agricultural use, including clearing of tree cover or fertilization, will destroy the semi-open and semi-natural character of the wood-pastures, which is also a threat to animal and plant species (Manning et al. 2006). Additional threats to wood-pastures are illegal burning in spring, which often leads to the destruction of trees, and legal and illegal cutting of trees. These factors, in combination with occasional overgrazing and clearing the pastures of shrubs as part of the requirements for EU agricultural subsidies, leads to a lack of regeneration (Hartel et al. 2013). Within Europe, some types of wood-pastures (such as the *dehesas* in Spain and the fennoscandian wooded pastures in

Scandinavia) are protected under the EU Habitats Directive, but there is no consistent conservation approach across Europe (Bergmeier et al. 2010). A loss of Transylvania's wood-pastures could mean the loss of some food sources for bears, but also the loss of a buffer between forest patches and villages, which could increase conflicts between people and bears. The protection and management of wood-pastures in Southern Transylvania thus could make a positive contribution to bear conservation.

Finally, a critical aspect of bear conservation in Southern Transylvania is the maintenance of a network of large and well-connected forest patches. Southern Transylvania has approximately 30% forest cover, which offers several potential corridors to nearby mountains and source populations. We did not observe a negative effect of roads on bear use of wood-pastures. However, other studies have shown the negative impact of highways, and newly planned major highways could negatively impact bear activity by causing habitat fragmentation (Kaczensky et al. 2003, Karamanlidis et al. 2011). Further research is needed on the importance of connectivity of forest patches to the mountains and how it may be affected by improvements and/or alterations to the local road network.

Zedrosser et al. (2011) suggested that bear conservation in Europe should not be restricted to only wild and remote areas, because few such areas remain (Linnell et al. 2005), and because other landscape elements can provide useful complementary conservation opportunities. Our findings suggest this is the case for our study area, where bears also use wood-pastures within multi-use cultural landscapes.

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