Conference Volume | 5th Symposium for Research in Protected Areas 10 to 12 June 2013, Mittersill | pages 177 - 183

The Carpathian Ecological Network GIS approach to detect the landscape permeability for particular umbrella species

Filippo Favilli, Elisa Ravazzoli, Christian Hoffmann, Thomas Streifeneder

Abstract

Large protected areas are fundamental for ecological processes to operate over spatial and temporal scales and for the survival of wildlife. Nevertheless, the increasing landscape fragmentation in Europe, due to the extension of human-related facilities, poses serious threats to the survival of biodiversity.

In this respect, BioREGIO Carpathians, an ETC European project, aims to face this issue studying biodiversity in the Carpathian area and introducing a GIS analysis to enhance ecological connectivity between protected and natural areas.

The GIS analysis is based on three steps. First, a habitat suitability model is created by using CorridorDesign. It identifies patches of suitable habitats by assigning different suitability values to ecological factors for each species. The model returns the suitability value (0-100%) indicating the appropriateness of a particular land cover patch for the dispersal of a species. The second step consists on reclassifying the suitability values by considering the presence of species-specific ecological factors. It enables to identify core areas for each species. The third step seeks to identify ecological corridors by using LinkageMapper; it allows to detect the most probable corridors by applying a minimum-cost analysis and calculating the least cost paths for passing through the land cover matrix. This comprehensive GIS approach has been applied in two protected areas at the border of Romania and Serbia. The on-going study is enabling us to highlight the role of protected areas in maintaining viable wildlife populations identifying the main core areas and dispersal paths for terrestrial and aquatic mammals. Additional aims are also to study the barriers blocking the dispersal and to suggest policy recommendations for their overcome.

Keywords

Carpathians, umbrella species, ecological connectivity, barrier

Introduction

Road infrastructures endanger many wildlife populations by reducing connectivity among the habitat patches (Forman et al. 2003). Fragmentation increases the risk of collisions with vehicles and limits the access to resources (Jaeger & Madriñán 2011). Ecological corridors are "landscape elements which serve as a linkage between historically connected habitat areas" (McEuen 1993). A regional ecological network can provide connectivity between spatially separated populations, countering biological processes that lead to species extinction (Beier 1995; Bennett 1998, 2003; Taylor et al. 2006). The project *BioREGIO* Carpathians applies a combination of *CorridorDesign* (Majka et al. 2007) and *Linkage Mapper* (http://code.google.com/p/linkage-mapper/), two ESRI ArcGIS 10 spatial analysis tools to build a Habitat Suitability Model (HSM) and Network Linkages for selected umbrella species in the Carpathians. The present study aims to detect the most probable core areas and least-cost paths for the Eurasian Lynx and to highlight the role of protected areas at the Romanian/Serbian border as linkage nodes. The objectives are to give an answer to the following research questions: Which are the most suitable landscape patches for the lynx? Are there chances that a lynx will reach another patch? If yes, using which path? Are there barriers in the identified routes? Are they surmountable? What is the role of protected areas for the maintenance of the regional ecological connectivity? To reply efficiently to these questions it is fundamental to: (i) set the parameters for the HSM, (ii) assess the connectivity via the visualization of core areas and least-cost paths, and (iii) identify possible barriers.

Study area

The study areas are the Iron Gate Nature Park in Romania and Djerdap National Park in Serbia (Fig. 1). Iron Gates Nature Park, at the south Romanian borders with Serbia, is a site of Community importance ROSCI0206 and a Ramsar site no. 1946. National Park Djerdap present a high level of wilderness and it is situated in the north-east of the Republic of Serbia, along the international border with Rumania. In both areas lynxes are reported as residents (Sommerwerk et al. 2009).

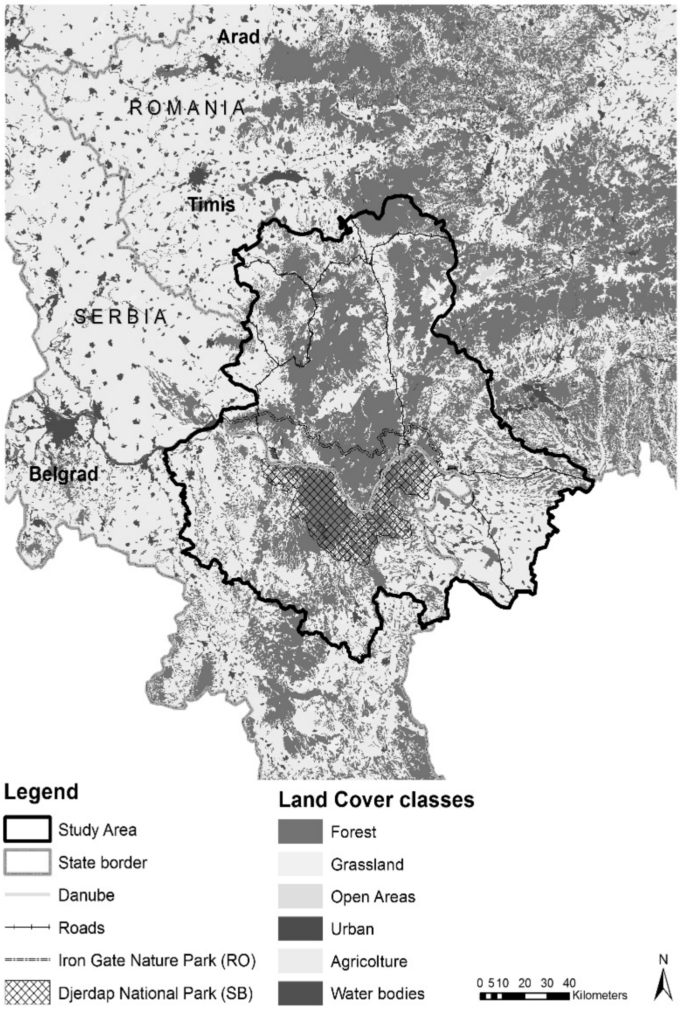

Figure 1: Study Area

Methods

<u>Umbrella species</u>

The Eurasian Lynx (*Lynx lynx* L.) is a highly selective mammal which prefers forest sites with at least 60% of forest cover (FAWCETT 1997). It avoids human activities and disturbed habitats. Lynx has large spatial requirements, which vary according to prey density and composition. Lynxes have a home range estimated between 70 (females) and 200 (males) km² (SCHADT et al. 2002). In non-wooded habitats, they can use alternative cover such as scrub and rocks. Lynxes do not stay permanently in forest areas < 30 km² and the minimum core area sizes (100 km² – breeding patch; 200 km² – population patch) can be interrupted by open areas, but not by human infrastructures (SCHADT et al. 2002; KRAMER-SCHADT et al. 2004, 2011).

<u>Habitat Suitability Model (HSM)</u>

The creation of a HSM is a two-steps process perused by applying the *CorridorDesign* GIS tool. In the first step, the habitat suitability is identified on the bases of the species' ecological preferences. According to the preferred land-cover types their suitability is valued from 0 to 100. The pixels having a suitability values above 50 were selected, in the second step, to identify breeding and population patches (core areas) following species' landscape perception. For a complete explanation of the model refer to MAJKA et al. (2007). Table 1 shows the selected values for the lynx used in our study.

Table 1: Factors, classes and weights used for the calculation of the first step Habitat Suitability Model

LC (40%)	***V %***	**Topo (20%)**	***V %***	**Elev meter asl (10%)**	***V %***	**Dist Human m (15%)**	***V %***	**Dist Roads m (15%)**	***V %***
Forest	*100*	0-30°	*50*	0-500	*50*	0-100	*0*	0-50	*0*
Grassland	*50*	30-60°	*100*	500-1000	*100*	100-500	*25*	50-200	*50*
Open areas	*25*	60-90°	*100*	1000-1500	*100*	500-1000	*50*	>200	*100*
Urban	*0*			1500-2000	*100*	>1000	*100*		
Agriculture	*25*			2000-2500	*50*				
Water bodies	*25*			>2500	*0*				

LC: Land Cover classes; Topo: Topographic Position classes; Elev: Elevation classes; Dist Human: Euclidean distance from the closest human settlement classes; Dist Roads: Euclidean distance from the closest main road classes; V: Suitability Value. In brackets the weight of each factor

Factors' classes and weights are combined through a geometric mean. The pixel remains 0 if only one category is 0. Each pixel can then be assigned to a certain suitability class:

1. Suitability: 50 - 100% = Optimal habitat
2. Suitability: 25 - 50% = Sub-optimal habitat
3. Suitability: 0 - 25% = Occasional habitat
4. Suitability: 0 = Avoided, barrier

In the second step, a moving window of 200-m radius around each pixel with > 50% suitability was applied to select those patches fulfilling the species' spatial requirements (Table 2):

Table 2: Classification of suitable patches' size

Patch size (ha)	Patch
0-10.000	Suitable but smaller than a breeding patch
10.000-20.000	Potential breeding patch
> 20.000	Potential population patch – core area

<u>Lynx connectivity/Least-Cost Paths (LCPs)</u>

The identification of probable connectivity is perused by applying the GIS tool Linkage Mapper. Resistance values for the landscape patches were necessary in order to calculate the LCPs between the identified core areas. Resistance values are defined as the opposite of the suitability and reflect the energetic cost for a certain species to move across those cells. The basic assumption of the model supposes that species move where the landscape provides less resistance (BEIER et al. 2009; CONRAD et al. 2012).

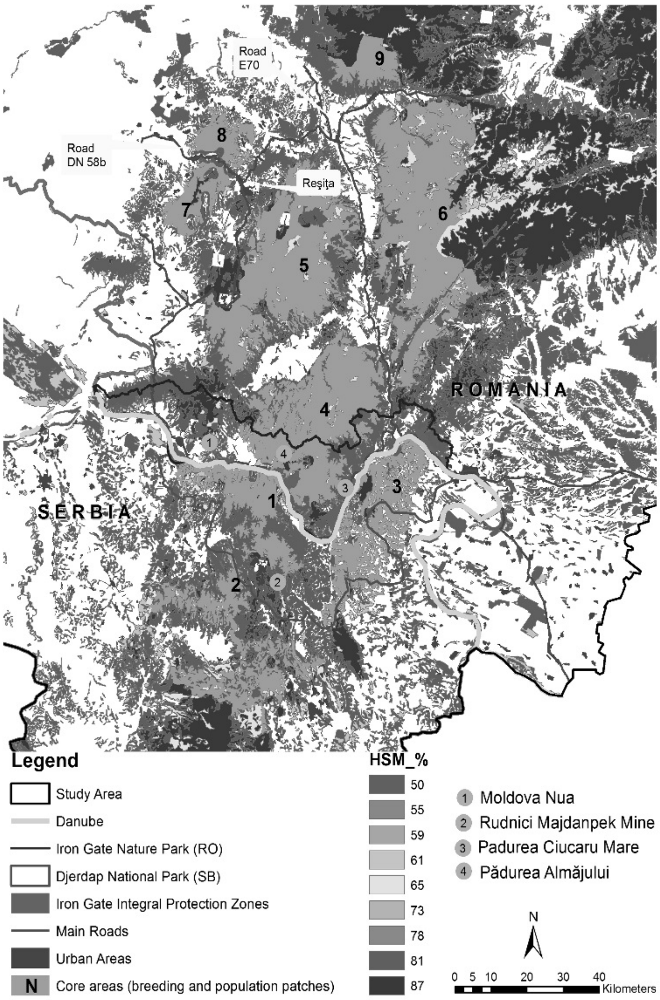

Figure 2: Habitat Suitability Model and core areas

Dataset

Land cover and additional geographical data were acquired for the countries considered. CORINE Land Cover 2006 at a resolution of 100x100m was used as a database for the habitat suitability model and the identification of the cost-path analyses. The first step in the preprocessing of digital maps was the standardization to the Projected Coordinate System ETRS 1989 LCC with the projection Lambert Conformal Conic. The environmental variables were acquired from the European Environmental Agency, the Joint Research Center and from the protected areas administrations. Digital Elevation Model (DEM) of the study area was used as a factor because the species occurs within a certain range of elevation. The topographic position was generated from the command Spatial analyst/surface/slope tool in ArcGIS 10. Distance to human settlements and distance to roads were created as a raster image by using the tool Euclidean distance in the ArcGIS toolbox. The cell size was set to that of the CORINE land cover grid.

Results

The HSM steps highlighted the complex mosaics of forest landscapes which are highly preferred by the lynx. The model identified the core areas displayed in Figure 2. Six population patches (core areas 1–6) located on both sides of the Danube, and three breeding patches in Romania (7–9) indicate a high probability that the lynx could be distributed in the study area.

In the Serbian side, the potential distribution of the lynx is spread all over the Djerdap National Park, in direct connection with the Balkan populations. One population is represented by core area 1 and 2 (separated by the Rudnici Majdanpek mine), the second by core area 3. As concerning the Rumanian side, the lynx populations are separated in 6 main population and breeding patches (Fig. 2). The south-western Carpathians' lynx populations are known to inhabit the entire area north from the Danube (i.e., Rozylowicz et al. 2011). Core area 4 includes the inner part of the Iron Gate Nature Park and some "integral protection zones" (1, 3 and 4 in Fig. 2). These areas could represent the passage sites of emigrating lynxes from Romania to Serbia. Core area 5 is part of the National Parks Semenic-Cheile Caraşului and Cheile Nerei-Beuşniţa where the lynx is reported as residential (Stanciu 2008). This area, although big enough (87.000ha) to support 4 male lynxes is separated from the rest of the Carpathians population by a highly frequented international road – E70. Core area 6 is the biggest in the study area and is connected with the Carpathians Mountains. Breeding patches 7 and 8 are separated by the national road DN58b close to the city of Reşiţa (Fig. 2). Breeding patch 9 is represented only partially in the study area.

The ecological connectivity for the lynx has been estimated starting from each of the identified core areas. *Linkage Mapper* detected 31 LCPs in the territories with the lower resistance. We selected 16 LCPs as those highlighting a general view of the ecological network (Fig. 3). LCPs were categorized according to: the CWD (cost-weighted distance), their length, the presence of barriers that increase their mortality risk (LCP risk), and the presence of a protected area, which increases their safety (LCP safe). LCPs were then divided in 5 cut-off categories (1 – Best; 5 – Worst) to identify the sites where the lynx may disperse most likely (Table 3).

Table 3: LCPs classification

LCP ID	CWD (Meters)	LCP (Meters)	LCP risk	LCP safe	Land Cover*	Barrier	Usage	Category
16	34.082	1838	0	1	1	None	Highly Probable	**1**
14	167.728	7887	0	1	1	Agriculture	Highly Probable	**1**
10	87.806	3455	1	1	1-6	DN57/ Danube	(?)	**2**
12	83.860	3289	1	1	1-6	DN6/ DN57/ Danube	(?)	**2**
15	147.597	10.166	0	0	1-3	Agriculture	Probable	**2**
9	41.314	865	1	1	1-6	DN57/ Danube	(?)	**3**
13	225.601	13.340	0	0	1	Urban zone	Possible	**3**
1	28.443	624	1	0	1	DN58b	Possible	**3**
2	247.331	11.142	1	0	1-4-5	DN58	Possible	**3**
6	154.113	4462	1	0	1-3-4	DN68	Possible	**3**
8	482.063	28.736	0	2	1-6	DN57/ Danube	(?)	**3**
11	77.503	2997	1	0	1-5	DN6	Possible	**3**
7	172.290	5797	1	0	1-3-5	DN6/ Agriculture	Possible	**3**
4	240.811	10.315	2	0	1	DN58/ Urban zone/ Mine	Difficult	**4**
3	771.166	29.277	1	0	1-4-5-6	DN6/ Agriculture	Extremely Difficult	**5**
5	679.716	23.185	2	0	1-4-5-6	DN6/ DN58b/ Agriculture	Extremely Difficult	**5**

*Land Cover classes: 1 = Forest; 2 = Grassland; 3 = Open Areas; 4 = Urban Areas; 5 = Agriculture; 6 = Water Bodies

From the 16 selected LCPs, only 2 can be assigned to Category 1 because they are inside a forest in a protected area and do not meet any barrier. All the LCPs through the Danube have been marked with a (?) because of the uncertainties if the lynx has ever crossed it by swimming. It is more likely to assume the presence of the Danube as an insurmountable barrier, although sporadic lynx observations in this region were made and Serbian lynx populations have acquired some of the characteristics of the Balkan ones (Atanasov 1968; Paunovic et al. 2001). Nevertheless, the Danube has a seasonal changeability and for the lynx it could be passable during some winter months (SIMEONOVSKI & ZLATANOVA 2001; SPASSOV 2001). The LCPs belonging to Categories 1 to 3 seem to be usable by the lynx. The 4 and 5 ones are unlikely to be used due to the less suitable landcover classes the lynx would have to pass through and on the kind of barriers encountered.

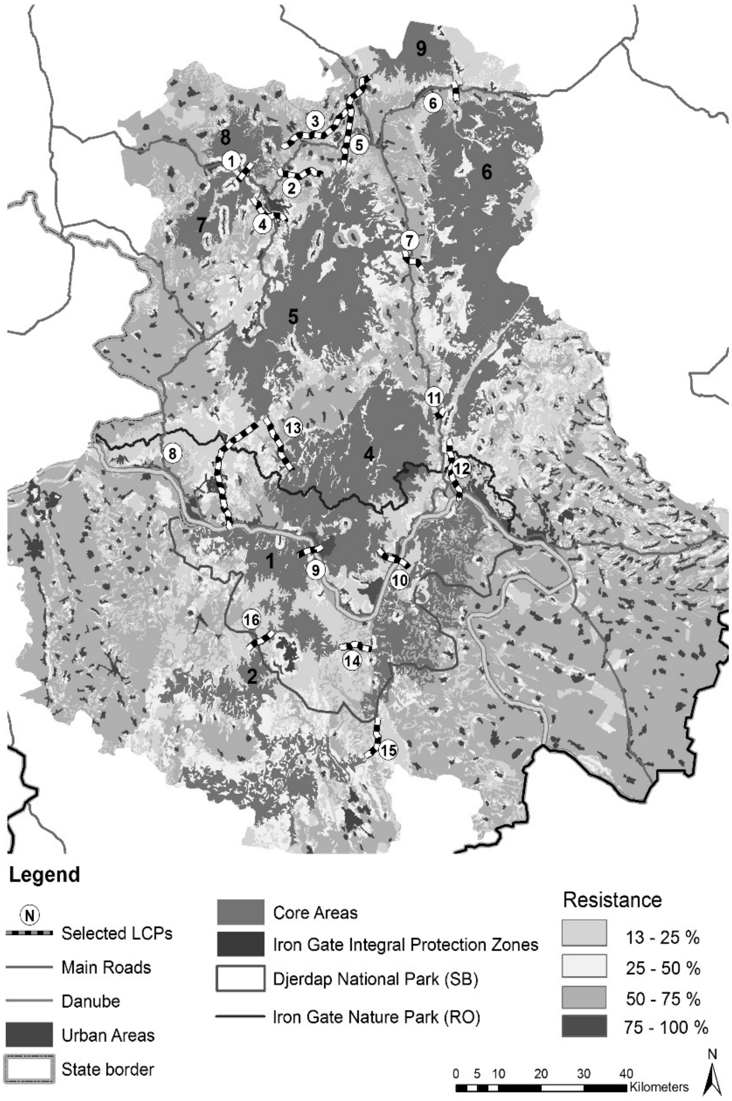

Figure 3: Selected Least-Cost Paths

Discussion

The suitability and connectivity results indicate that the majority of the study area is highly suitable for the lynx. The GIS model is useful to study the distribution of suitable habitats and patch connectivity and to promote actions in wildlife conservation, when field data are limited. *CorridorDesign* has proven to be efficient for the detection of the lynx's most suitable habitat, only referring on ecological habits. *Linkage Mapper* has enabled the identification of the main possible connections between probable core areas to enhance the areas' ecological connectivity. The lynx's spatial requirements are huge and the large forest habitats in the Carpathians could soon become a fragmented landscape mosaics, thus large-scale cross-boundary approaches are needed (MLADENOFF et al. 1995). The Serbian part of the study area confirmed of being a highly suitable habitat for the lynx, due to the National Park Djerdap and to the lower presence of roads and big urban areas. The Djerdap National Park represents the most northern lynx distribution from the Balkans with which it is directly connected. A ecological connection between core areas 1, 2 and 3 (total size: 112.351 ha) could sustain 10 residential lynxes. The "Nature Park Iron Gate" and the rest of the Romanian study area (including two National Parks) play a major role in protecting this species at the southern borders of its Carpathians' distribution. An enhanced connectivity between core areas 4, 5 and 6 (total size: 260.548 ha) could sustain more than 20 residential lynx, which is the prerequisite for the survival of a viable population (SCHADT et al. 2002). The *Linkage Mapper* analysis enabled the identification of the gaps in the potential ecological connections. Figure 4 shows the LCP number 7 connecting core areas 5 and 6 in the vicinity of the city of Fenes, identifying the site where possible engineering intervention for the maintenance of the ecological network could be placed. In this case, the site selected is where the National Road DN6 runs closer to fragmented forested and open areas which could be used by the lynx as stepping stones. DN6 is a highly frequented road, but the presence of stepping stones in the vicinity, joined by a green infrastructure facility could render possible the establishment of an ecological connection between the two core areas (Fig. 4).

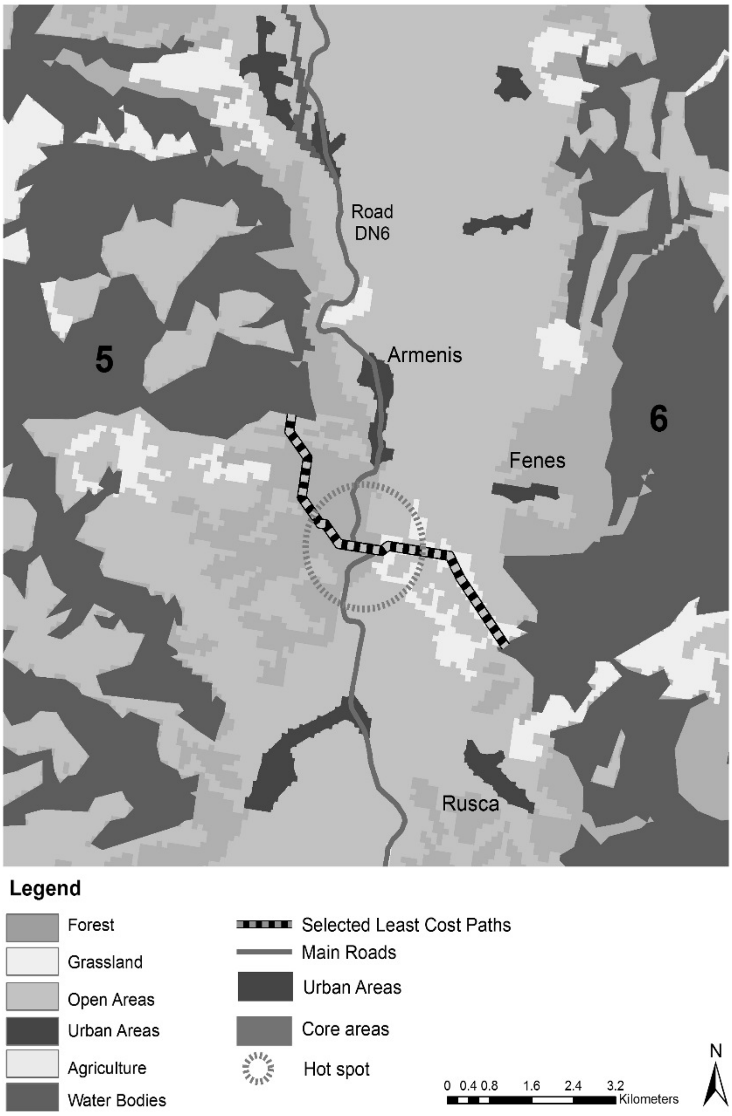

Figure 4: Closer view of the LCP 7 and barrier

Conclusions

The questions addressed at the beginning of the study have now been answered showing that some of the identified routes are of highly improbable lynx use due to the kind of encountered barriers and landcover changes. The “integral protection zones” inside of the Iron Gate National Park have proved their importance for wildlife protection and connectivity. The GIS approach gave us the opportunity to highlighting the role of protected areas as “safe passage zones”, requiring only few data and offering a good picture about landscape fragmentation and ecological connectivity. Some of the LCPs have the characteristics to be effectively used for connecting the lynx’s main patches. Generally speaking, following only a visual interpretation of the results, the ecological connectivity inside of the studied area seems rather good. Main roads and urban areas act as barriers for the lynx’s connectivity. Nevertheless, the sites which could be important for enhancing ecological connectivity and for deriving specific recommendation can be selected. In this next phase, the role of local expert will be decisive for concrete actions.

References

ATANASOV, N. 1968. Der Luchs (Lynx lynx L.) in Bulgarien. 25.32 p. In: KRATOCHVIL, J. 1968. (ed.). History of the distribution of the lynx in Europe. Acta Sc. Nat. Acad. Pracha, Brno, 2 (4), 50 p.

BEIER, P. 1995. Dispersal of juvenile cougars in fragmented habitat. Journal of Wildlife Management 59: 228–237.

BEIER, P., MAJKA, DR., NEWELL, SL. 2009. Uncertainty analysis of least-cost modeling for designing wildlife linkages. Ecological Applications 19: 2067-2077.

BENNETT, AF. 1998, 2003. Linkages in the Landscape: The Role of Corridors and Connectivity in Wildlife Conservation. IUCN, Gland, Switzerland and Cambridge, UK. xiv + 254 pp.

CONRAD, JM., GOMES, CP., VAN HOEVE, WJ., SABHARWAL, A., SUET, JF. 2012. Wildlife corridors as a connected subgraph problem. Journal of Environmental Economics and Management 63: 1-18.

FAWCETT, JK. 1997. Roe Deer. The Mammal Society & The British Deer Society, London, UK

FORMAN, RTT., SPERLING, D., BISSONETTE, JA., CLEVENGER, AP., CUTSHALL, CD., DALE, VH., FAHRIG, L., FRANCE, R., GOLDMAN, CR., HEANUE, K., JONES, JA., SWANSON, FJ., TURRENTINE, T., WINTER, TC. 2003. Road ecology — Science and solutions, Island Press, Washington DC, USA, 481 pp.

JAEGER, AGJ., MADRIÑÁN, LF. 2011. Landscape Fragmentation in Europe. EEA Report 2/2011: 1-92.

KRAMER-SCHADT, S., KAISER, TS., FRANK, K., WIEGAND, T. 2011. Analysing the effect of stepping stones on target patch colonisation in structured landscapes for Eurasian Lynx. Landscape Ecology 26: 501-513.

KRAMER-SCHADT, S., REVILLA, E., WIEGAND, T., BREITENMOSER, U. 2004. Fragmented landscape, road mortality and patch connectivity: modelling influences on the dispersal of Eurasian Lynx. Journal of Applied Ecology 41: 711-723.

MAJKA, D., JENNESS, J., BEIER, P. 2007. CorridorDesigner: ArcGIS tools for designing and evaluating corridors. Available at http://corridordesign.org

MCEUEN, A. 1993. The wildlife corridor controversy: A review. Endangered species update 10. (11 & 12).

MIRIĆ, D., PAUNOVIC, M. 1992. A new record of Lynx lynx (Linnaeus, 1758) (Felidae, Carnivora) in East Serbia. Bull. Nat. Hist. Mus. Belgrade, B 47: 171-174.

MLADENOFF, DJ., SICKLEY, TA., HAIGHT, RG., WYDEVEN, AP. 1995. A regional landscape analysis and prediction of favorable gray wolf habitat in the northern Great Lakes region. Conservation Biology 9:279–294.

PAUNOVIC, M., MILENKOVIC, M., IVANOVIC-VLAHOVIC, C. 2001. The lynx populations in the Federal Republic of Yugoslavia. Kora Bericht 7: 12-17.

ROZYLOWICZ, L., POPESCU, VD., PĂTROESCU, M., CHIŞAMERA, G. 2011. The potential of large carnivores as conservation surrogates in the Romanian Carpathians. Biodiversity Conservation 20: 561-579.

SCHADT, S., KNAUER, F., KACZENSCKY, P., REVILLA, E., WIEGAND, T., TREPL, L. 2002. Rule-based assessment of suitable habitat and patch connectivity for the Eurasian Lynx. Ecological application 12: 1469-1483.

SIMEONOVSKI, V., ZLATANOVA, D. 2001. Some notes on the systematics of the Balkan Lynx. Kora Bericht 7: 24-25.

SOMMERWERK, N., BAUMGARTNER, C., BLOESCH, J., HEIN, T., OSTOJIĆ, A., PAUNOVIĆ, M., SCHNEIDER-JACOBY, M., SIBER, R., TOCKNER, K. 2009. The Danube River Basin. In: TOCKNER, K., UEHLINGER, U., ROBINSON, CT. (Eds) The Rivers of Europe. Academic Press 2009. 700 pp.

SPASSOV, N. 2001. Brief notes on the status and problems of the lynx in Bulgaria. Kora Bericht 7: 26-27.

STANCIU, E. 2008. Wilderness and Wildlands in Romanian Carpathians. International Journal of Wilderness 14: 37-42

TAYLOR, PD., FAHRIG, L., WITH, KA. 2006. Landscape connectivity: a return to the basics. In: CROOKS, KR, SANJAYAN, M (Eds) Connectivity conservation. Cambridge University Press, Cambridge, UK, pp 29-43.

Contact

Filippo Favilli
filippo.favilli@eurac.edu

EURAC Research
Institute for Regional Development and Location Management
Viale Druso 1
39100 Bolzano
Italy