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The habitat selection of a female lynx (*Lynx lynx*) in the northwestern part of the Vrancea Mountains, Romania

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Abstract. Despite having a large range in the Romanian Carpathians, the ecology of Eurasian lynx is relatively misunderstood, particularly concerning the size of its home range and utilized resources. By means of a collar equipped with a GPS device, the movements of a mature lynx female were monitored for a period of 305 days in the northwestern section of Vrancea Mountains. The area of the female's home range is estimated at 486.11 km², a significantly larger area than what had been recorded previously for Romania. The probability of lynx occurrence is slightly diminished with each 1% decrease in coniferous forest cover, mixed forest, natural grassland, and shrub cover, and is considerably augmented by increasing spatial heterogeneity. To protect the Romanian lynx population effectively, the application of landscape-scale forestry management strategies is needed, instead of multiple uncorrelated management plans for the different protected areas located in the region.

Key words: *Lynx lynx*, GPS monitoring, home range, resource selection probability function, Putna Vrancea Natural Park.

While possessing a pan-Carphatian range and high population density in Romania (vonArx et al. 2001), the Eurasian lynx (*Lynx lynx*) is a species whose ecology is relatively less known in comparison to other European countries (Murariu & Munteanu 2005). Current knowledge indicates that the main drivers of lynx distribution and abundance are: forest cover (large patches of mature forest favour lynx distribution), relief and snow cover (steep versants and average snow cover less than one meter in depth), availability of prey (primarily roe deer), and human activity (avoidance of highly disturbed habitats) (Breitenmoser et al. 2000, Linnell et al. 2001, Schadt 2002, Andrén et al. 2006, Podgórski et al. 2008).

The Romanian range of the Eurasian lynx overlaps the Romanian Carpathians, being about 59,600 km² wide, the lynx having an uneven distribution within mountain forests, while their abundance is higher in inaccessible and rocky areas (Maanen et al. 2005). The Romanian lynx population is estimated at about 2000 individuals (vonArx et al. 2001, Maanen et al. 2005), being potentially overestimated due to the inventorying procedure (Salvatori et al. 2002). Although the lynx movement estimations based on GPS studies are still lacking across the Carpathians, standard VHF radio-telemetry studies in the Romanian Carpathians estimated that the female home range is between 80 km² and 129 km² (Promberger-Fürpass et al. 2002, Promberger-Fürpass & Sürth 2003). Based on expert knowledge, Murariu & Munteanu (2005) estimated home ranges for both sexes from 10 km² to 26 km². In Outer Eastern Carpathians (Poland), the home range size of two radio-collared females was 124 km² and 190 km² respectively (Okarma et al. 2007).

The study objectives were to identify, map and describe the home range and habitat selection resources for an adult female Eurasian lynx in a heavily forested area from the Vrancea Mountains (Fig. 1). The present study is a 3rd order habitat study – resource selection by an animal within its home range (Manly et al. 2002).

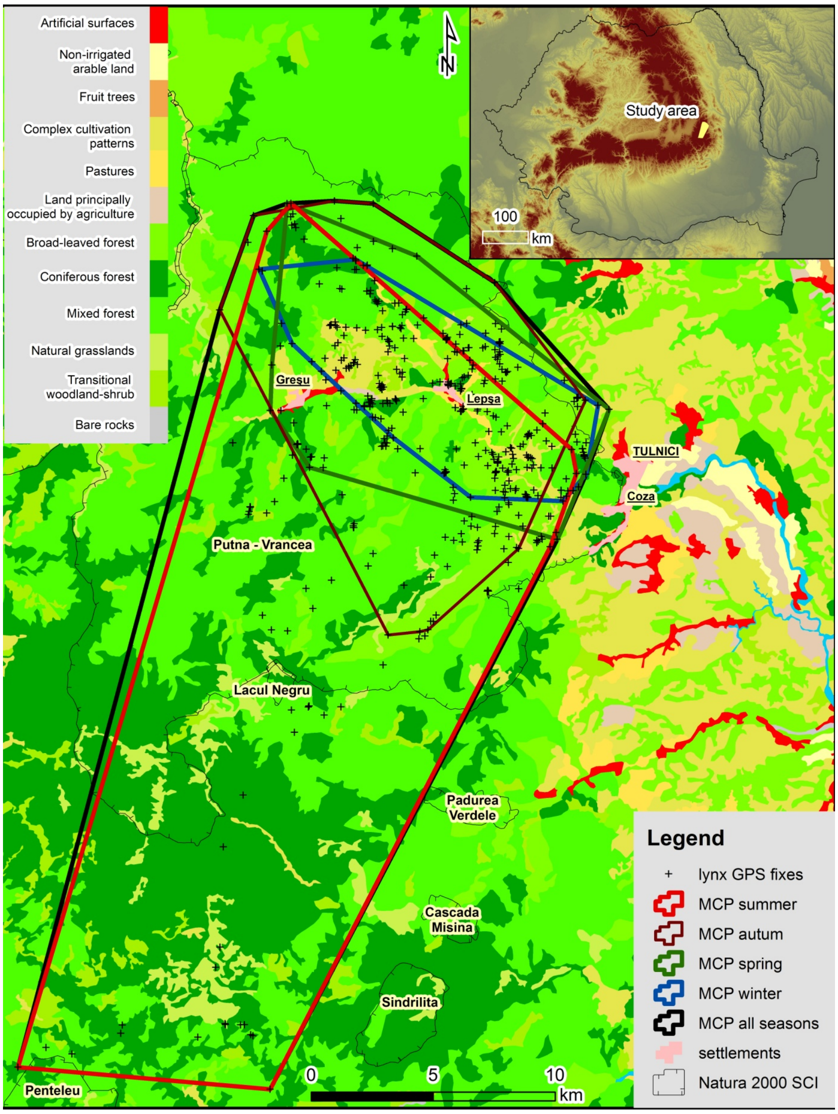

Figure 1. Land use classes in the northwestern part of the Vrancea Mountains, with the seasonally 100% minimum convex polygon (MCP) for one GPS-collared lynx female.

Within the study area, the average elevation is 1113.67 m (SD = 248.33; range = 1774 – 458 m). The dominant land-use is represented by coniferous and broad-leaved boreal forests (88.59%). The study area presents a low human impact, the only settlements being the villages Lepşa and Greşu (Iojă et al. 2004). The regions' transport infrastructure is underdeveloped, the area being crossed by two national roads (32 km) and by impracticable forest roads (102 km) (Manolache et al. 2009). The northwestern section of the Vrancea Mountains overlaps the Putna Vrancea Natural Park and some nature reserves, such as Lacul Negru (Rozylowicz et al. 2004). The nationally designated protected areas are also partially included in the Natura 2000 sites ROSCI0208 Putna Vrancea and ROSCI0097 Lacul Negru (see Fig. 1).

To calculate the probability that our study individual uses particular resources, we sampled the lynx's estimated home range in 2139 squares randomly with replacement (Keating & Cherry 2004). From the randomly selected squares, 401 were used and 1738 unused (sampling unit size was 150 m × 150 m). We consider that the number and size of sampling units is large enough to detect changes in animal movement and ensure multiple locations in each unit.

For the resource selection analysis, we selected six categories of potential predictors of lynx distribution from other studies: slope, terrain ruggedness, distance to locality, distance to road, percent from land cover classes and an index for land cover heterogeneity (e.g. Zimmermann 2004, Herfindal et al. 2005, Podgórski et al. 2008). ArcGIS Desktop 9.2 (Environmental Systems Research Institute, Redlands, CA, USA) and IBM SPSS Statistics 18 (SPSS Inc.) were used for all analyses. SRTM 90m Digital Elevation Data (Jarvis et al. 2008) was used to derive slope and terrain ruggedness. Terrain ruggedness was calculated using the Vector Ruggedness Measure Tool (Sappington et al. 2007) and land cover was extracted from the Corine Land Cover (CLC 2006) 100 m resolution (*available from http://etc-lusi.eionet.europa.eu/CLC2006*). The land use classes identified in the studied area is artificial surfaces (CLC code = 112), pastures (CLC code = 231), complex cultivation patterns (CLC code = 242), land primarily occupied by agriculture (CLC code = 243), broad-leaved forest (CLC code = 311), coniferous forest (CLC code = 312), mixed forest (CLC code = 313), natural grasslands (CLC code = 321), and transitional woodland-shrub (CLC code = 324). To add a measure of spatial heterogeneity to our study (Hartel et al. 2008), we used the Shannon-Wiener diversity index (Turner et al. 2001). The selected predictors were verified using Pearson's pair wise correlation analysis for identifying multicolinearity (Hosmer & Lemeshow 2000), excluding from the analysis the variables regarding the distances towards the road and settlements ($|r| > 0.6$).

In February 2009, we trapped an adult female lynx, 4 years old, weighting 20 kg by using Oneida Victor #3 Soft foot traps, baited with *Nepeta* (catnip) oil and embedded with trap transmitter. The lynx was trapped in the Lepşa watershed, approximately 7 km from the confluence of the Putna and Lepşa rivers. We attached to the individual a G2110 GPS collar (Advanced Telemetry Systems) weighting 350 g (1.84% of the animal's weight), programmed to store on board three locations per 24h, starting at 7 AM. After 305 days of operation, the collar automatically detached from the animal, and was recovered for data downloading.

The female lynx home range was generated from 535 locations recorded in 305 days, using Minimum Convex Polygon (MCP) tool (Beyer 2004). To identify the effect of potentially exploratory movements, the 95% MCP and 95% fixed kernel (White & Garrott 1990) was utilized.

Resource Selection Function (RSF) is estimated by binary logistic regression (Manly et al. 2002, Nielson et al. 2009), forward-stepwise model building procedure (α to enter = 0.15, α to exit = 0.20) (Hosmer & Lemeshow 2000).

The lynx's home range area was estimated at 486.11 km² (Table 1), a much larger area than 129 km² indicated by Promberger-Fürpass et al. (2002) from Romania, but within the limits of values reported in other European studies (average = 319 km², SD = 219 km²) (Herfindal et al. 2005). This home range value raises questions about lynx population sizes in Romania, considering that the small home range represented an argument for the high densities of individuals reported for Romania (Salvatori et al. 2002, Maanen et al. 2005).

The lynx showed the strongest site fidelity in winter (95% fixed kernel = 33 km²).

The selected model predicts the outcome better than the constant model; the explained variation expressed as Nagelkerke pseudo-R^2 being improved from 0.18 to 0.36. Hosmer and Lemeshow test rejects linear relationship between the predictor and the log odds of the criterion variable (χ^2 (7) = 14.19, p–value = 0.49). The sensitivity of the model was of 93.8% and its specificity 39.7%. Overall, the model success rate was of 83.3% (cut value = 0.5). The selected model (Table 2) includes as covariate to the intercept the coniferous forest cover (average = 10.42; 95%CI: 8.34 – 12.50) mixed forest cover (average = 25.44; 95%CI: 21.82 – 29.04), natural grasslands cover (average = 0.57; 95%CI: 0.03 – 1.11), transitional woodland-shrub cover (average = 4.15; 95%CI: 2.90 – 5.40), and the Shannon-Wiener Index (average = 0.67; 95%CI: 0.61 – 0.73).

The probability of the female lynx occurrence decreases by 0.034 for each 1% decrease in coniferous forest cover. The same tendency was observed for mixed forest, natural grassland and shrub cover. Because the value of beta is close to 1, the land cover variables alone had a slight influence on the probability of the presence, compared with intercept, being meaningful for refining the model. The spatial heterogeneity expressed by the Shannon - Wiener Index is much more influential, the probability of presence increasing by 1.02 for each 2.78 units (step increment = 0.01) increasing in Shannon - Wiener Index.

It can be concluded that the home range of the lynx in Romania has sizes as large as those characteristic to this species in Europe. The GPS-collared adult female under study was a non-breeding female, having a home range potentially larger than a breeding one. The 95%

Table 1. Home range area for the monitored lynx female in the northwestern part of the Vrancea Mountains.

Parameter	Total area (km²)	Winter	Spring	Summer	Autumn
100% MCP	486.11	71.19	114.07	426.66	161.05
95% MCP	213.51	62.20	100.40	275.82	126.57
95% Fixed kernel	409.27	33.00	183.21	513.42	280.17
Number of locations	535	88	167	139	141

Table 2. Habitat use estimates for the monitored lynx female in the northwestern part of the Vrancea Mountains.

Parameter	Estimates	Standard error	Wald χ^2	p–value	Beta
Intercept	–0.1575	0.13	1.52	0.217	–
Coniferous forest	–0.0339	0.002	191.17	<.0001	0.967
Mixed forest	–0.0228	0.002	170.99	<.0001	0.977
Natural grasslands	–0.0643	0.01	29.64	<.0001	0.938
Transitional woodland–shrub	–0.0222	0.005	22.83	<.0001	0.978
Shannon Diversity Index	1.0207	0.13	57.98	<.0001	2.775

fixed kernel and 100% MCP present almost the same value, consequently the exploratory movements are not significant. This suggests a potential larger home range for non-breeding female showing dispersal movements (Zimmerman et al. 2005). The studied lynx preferred forested areas with landscape heterogeneity (forests patches with natural grasslands and shrubs) instead of large patches of forests, a conclusion underlined by other European studies (Linnell et al. 2001, Schadt 2002, Podgórski et al. 2008). The low influence of land cover alone suggests that incorporating data as density of prey and habitat productivity (Herfindal et al. 2005) can lead to a more informal model. Unfortunately, reliable data is not available for the Romanian Carpathians. In this study, contrary with other studies (Kramer-Schadt et al. 2004, Niedziałkowska et al. 2006), the distances from roads and localities did not have a decisive influence on the presence of the lynx. This situation occurs probably because the very low density and intensity of use of these environmental factors and their relation must be tested in disturbed Romanian habitats.

We acknowledge that Eurasian lynx may have large home range in our study area, especially considering that males usually move more than female (Zimmermann et al. 2004, Herfindal et al. 2005). For the effective protection of the Romanian lynx population, habitat connectivity has to be ensured by using landscape-scale forestry management strategies instead of multiple, uncorrelated management plans developed for the various protected areas.

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