# LIFE CONNECT CARPATHIANS

**Enhancing landscape connectivity for brown bear and wolf through a regional network of NATURA 2000 sites in Romania**

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# LIFECONNECT

**Enhancing landscape connectivity for brown bear and wolf through a regional network of NATURA 2000 sites in Romania**

## ANALYSIS OF OFFICIAL WILDLIFE DATA

***- report -***


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**BACKGROUND**

Obtaining accurate data on the status and trends of wildlife populations is one of the prerequisites of viable management decisions, including trophy hunting (Treves 2009; Edwards *et al.* 2014). For decades, large carnivore management in Romania has been dominated by regulated hunting aimed at maintaining stable populations (Adamescu *et al.* 2014). Hunting is carried out under the supervision of the Romanian wildlife management authorities (Adamescu *et al.* 2014), and public and private game managers are the beneficiaries of much of the revenue generated by these activities. Hunting targets are set based on rough abundance estimates derived from a mixture of track data, sightings at feeding stations, and expert opinion, without incorporating uncertainty. For example, the methodology for recording and reporting data on brown bears (*Ursus arctos*) is detailed in the Romanian Brown Bear Management Plan, (*www.mmediu.ro/app/webroot/uploads/files/17%20Management_Action_Plan.pdf*), Romanian Ministry of Environment.

In general, the wildlife monitoring protocol is: game wardens record and measure tracks on snow or mud during one occasion per year, usually between March and April. The number of tracks is then transformed into abundance of individuals based on subjective evaluations at the level of Game Management Units (GMU). These administrative units may cover 100 – 150 $km^2$, have complex topography or land cover, and are not suitable for large carnivore census and monitoring, which is usually performed at broader spatial scales (1000's of $km^2$). The data is then compared with the expert-based optimal abundance (i.e., carrying capacity), and hunting quotas are set based on the difference between estimated and optimal abundance using simple rules aimed at ensuring stable populations and sustained yield (i.e., the maximum number of individuals that can be hunted without causing population declines) (Order of Romanian Ministry of Agriculture, Food, and Forests 478/2002). Further on, the Romanian wildlife management authorities aggregate the data at county level, and then nation-wide without statistical analysis, using correction factors for adjusting abundances which are also expert opinion-based opinion, and are not public. The outcome of this process, which also does not account for other sources of bias (e.g., unbalanced sampling, observer error, other sources of mortality, etc.), have the potential to propagate errors, and produce misleading abundance estimates. When used for management decisions, biased abundances may promote overmortality and have potential impacts on long term population viability (Rechow 1994; Harwood & Stokes 2003; Artelle *et al.* 2013).

One of the objectives of the LIFECONNECT project is to evaluate the accuracy and biological plausibility of official wildlife data, and propose alternative monitoring methods for improve estimation of abundance of target species: 3 carnivore species (brown bear, *Ursus arctos*, wolf, *Canis lupus*, and lynx, *Lynx lynx*), and 3 ungulate (prey) species (red deer, *Cervus elaphus*, roe deer, *Capreolus capreolus*, and wild boar, *Sus scrofa*). All these species are important game species, and are targeted for trophy hunting (mainly bear, red deer), and regulated hunting. The approach taken in the project is to implement several other monitoring methods for carnivores and ungulates aimed at evaluating relative or absolute abundances and densities, including: camera trapping, DNA-based surveys (for carnivores only), pellet counts (for ungulates only), and focused track surveys. The project team will then contrast the findings from these surveys with the official data, and determine whether the current monitoring methods are adequate, and whether the data reported is reliable for setting hunting quotas and for monitoring trends of wildlife populations. The first step to achieving this overarching goal is to collate the official data on abundance estimates, yearly quotas, and harvested animals, and identify potential mismatches between population parameters from reported data and other European wildlife populations. Specifically, the study objectives are:

- Asses gaps in data reporting, and patterns oof reported abundances for the 6 target species within the project area at the Game Management Unit-level
- Evaluate the biological plausibility of reported data for carnivore species at county level

## METHODS

### Data

***County level data*** – We compiled official abundance estimates, hunting quotas, and the number of harvested individuals for ***brown bear***, ***wolf*** and ***lynx*** between 2005-2012 for the 8 counties overlapping with the project area, using data from the Romanian Ministry of Environment (www.mmediu.ro) (Table 1).

***Game management unit level data*** – A total of 200 GMU's overlapped with the project area (Figure 1). We obtained reported abundance data, as well as hunting quotas and realized hunting for 3 carnivore species (***brown bear, wolf***, and ***lynx***) and 3 ungulate (prey) species (***red deer, roe deer*** and ***wild boar***) for 145 GMU's in the project area between 2005 and 2010; data for this period of time was not available for the other 55 GMU's overlapping the project area.

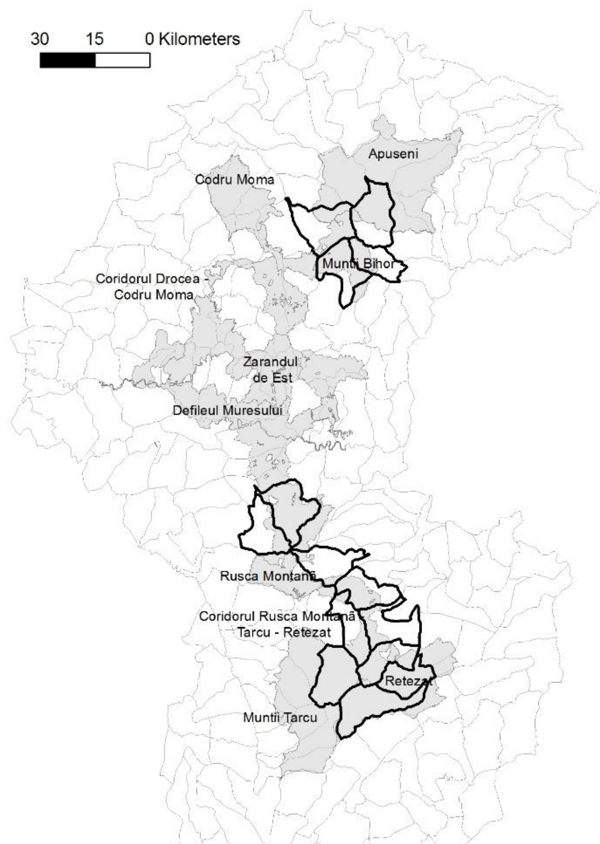



**Figure 1.** *Game Management Units overlapping with the LIFECONNECT project area. Units highlighted in black correspond to target areas where other monitoring methods are implemented.*

**Table 2.** *County-level reported abundance estimates, quotas and number of individuals hunted legally for large carnivores.*

| County | Abundance | | | | | | | | Quota | | | | | | Hunted | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **‘05** | **‘06** | **‘07** | **‘08** | **‘09** | **‘10** | **‘11** | **‘12** | **‘06** | **‘07** | **‘08** | **‘09** | **‘10** | **‘11** | **‘05** | **‘06** | **‘07** | **‘08** | **‘09** | **‘10** | **‘11** |
| | **WOLF (*C. lupus*)** | | | | | | | | | | | | | | | | | | | | |
| Alba | 233 | 242 | 241 | 253 | 250 | 262 | 270 | 289 | 21 | 18 | 20 | 21 | 25 | 19 | 10 | 5 | 6 | 7 | 7 | 3 | 2 |
| Arad | 107 | 104 | 114 | 112 | 125 | 129 | 136 | 121 | 12 | 12 | 8 | 12 | 9 | 4 | 2 | 1 | 1 | 0 | 0 | 1 | 0 |
| Bihor | 110 | 80 | 67 | 95 | 86 | 89 | 85 | 139 | 11 | 9 | 11 | 10 | 8 | 10 | 1 | 0 | 4 | 0 | 1 | 1 | 1 |
| Caras-Severin | 250 | 320 | 335 | 339 | 320 | 281 | 271 | 253 | 28 | 37 | 36 | 22 | 14 | 9 | 17 | 21 | 30 | 0 | 0 | 2 | 1 |
| Cluj | 228 | 255 | 130 | 174 | 156 | 301 | 316 | 317 | 26 | 16 | 18 | 15 | 14 | 18 | 11 | 18 | 5 | 6 | 3 | 4 | 1 |
| Gorj | 64 | 63 | 81 | 94 | 95 | 97 | 94 | 135 | 10 | 8 | 8 | 11 | 9 | 10 | 4 | 4 | 5 | 4 | 3 | 2 | 5 |
| Hunedoara | 284 | 298 | 292 | 304 | 325 | 320 | 344 | 486 | 27 | 20 | 20 | 14 | 10 | 30 | 11 | 8 | 12 | 8 | 7 | 6 | 7 |
| Timis | 65 | 73 | 74 | 23 | 89 | 123 | 105 | 93 | 12 | 9 | 105 | 12 | 10 | 9 | 5 | 2 | 1 | 12 | 7 | 0 | 0 |
| | **BROWN BEAR (*U. arctos*)** | | | | | | | | | | | | | | | | | | | | |
| Alba | 124 | 125 | 132 | 144 | 159 | 166 | 165 | 200 | 4 | 3 | 3 | 3 | 3 | 3 | 2 | 0 | 1 | 2 | 1 | 1 | 0 |
| Arad | 11 | 13 | 13 | 14 | 14 | 15 | 15 | 16 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Bihor | 22 | 21 | 25 | 26 | 28 | 29 | 22 | 31 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Caras-Severin | 95 | 98 | 86 | 89 | 96 | 102 | 97 | 108 | 4 | 2 | 2 | 2 | 2 | 4 | 0 | 1 | 0 | 0 | 1 | 1 | 1 |
| Cluj | 140 | 150 | 73 | 83 | 77 | 101 | 92 | 97 | 3 | 0 | 0 | 1 | 1 | 3 | 0 | 0 | 0 | 0 | 1 | 0 | 1 |
| Gorj | 154 | 168 | 164 | 179 | 164 | 184 | 187 | 214 | 4 | 4 | 6 | 4 | 3 | 6 | 0 | 2 | 1 | 0 | 1 | 1 | 2 |
| Hunedoara | 315 | 303 | 318 | 329 | 311 | 315 | 325 | 386 | 10 | 9 | 9 | 6 | 6 | 12 | 0 | 7 | 5 | 6 | 5 | 5 | 5 |
| Timis | 10 | 11 | 11 | 10 | 13 | 10 | 7 | 13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **EURASIAN LYNX (*L. lynx*)** | | | | | | | | | | | | | | | | | | | | |
| Alba | 126 | 138 | 125 | 138 | 131 | 139 | 142 | 147 | 5 | 6 | 4 | 6 | 6 | 2 | 3 | 0 | 0 | 0 | 0 | 0 | 0 |
| Arad | 74 | 60 | 53 | 62 | 59 | 53 | 53 | 39 | 4 | 4 | 3 | 5 | 3 | 2 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| Bihor | 28 | 25 | 21 | 23 | 25 | 24 | 28 | 37 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Caras-Severin | 83 | 109 | 115 | 121 | 114 | 88 | 83 | 86 | 6 | 7 | 6 | 6 | 1 | 1 | 4 | 5 | 5 | 0 | 0 | 0 | 0 |
| Cluj | 75 | 85 | 50 | 81 | 74 | 68 | 81 | 64 | 5 | 3 | 2 | 0 | 1 | 2 | 4 | 3 | 0 | 0 | 0 | 0 | 0 |
| Gorj | 46 | 50 | 46 | 47 | 43 | 48 | 47 | 53 | 2 | 2 | 2 | 4 | 3 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Hunedoara | 173 | 172 | 166 | 174 | 164 | 166 | 178 | 198 | 9 | 8 | 7 | 6 | 3 | 7 | 2 | 1 | 1 | 0 | 1 | 0 | 1 |
| Timis | 21 | 9 | 11 | 7 | 22 | 17 | 17 | 15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

We focused on 3 target areas (Rusca Montana – Tarcu – Retezat Corridor [8 GMU's], Podisul Lipovei – Poiana Rusca – Tinutul Padurenilor [3 GMU's], and Bihor Mountains [4 GMU's]) (Figure 1), where a variety of monitoring activities are being conducted to evaluate population densities of large carnivore and ungulates (camera trapping, snow tracking, DNA surveys). For these 15 GMU's, we also obtained official abundance data for 2012 and 2013, and data on approved quotas for 2014-2016.

**Analysis**

**Game Management Unit-level data for carnivore and ungulate species**

We investigated trends in the carnivore and ungulate populations for the available period of time (2005-2010), as well as in proposed quotas and achieved hunting. In addition, we evaluated the spatial distribution of reported abundance estimates for 2010, the last year for which we had a complete dataset for the 6 species.

**County-level data analysis for carnivore species**

First, we explored whether the year-to-year variation in official county-level estimates between 2005 and 2012 were realistic given published growth rates for other European populations (Table 2). For each county and species, we calculated the difference in reported estimates between consecutive years. Incorporating known hunting for each year, we then estimated yearly population growth rates suggested by yearly changes in official population estimates, using the equation:

$$N_t = N_{t-1} \times \lambda_t - Hunted_{t-1} \qquad \text{Eq. 1}$$

where $\lambda_t$ = estimated yearly population growth rate; $N_t$ = population at time $t$; $Hunted_{t-1}$ = individuals hunted in previous year; $N_{t-1}$ = population in previous year.

We calculated the difference between the estimated population growth rate ($\lambda_t$) and the maximum published population growth rate ($\lambda_{lit\text{-}max}$) for each species and county. We considered unrealistically high population growth rates (i.e., $\lambda_t > \lambda_{lit\text{-}max}$) to be suggestive of overly optimistic estimations. For each species, we calculated the number of times the assumed population growth rate ($\lambda_t$) exceeded the maximum population growth rate.

Second, to evaluate whether the reported population trajectories are biologically plausible given the recorded levels of hunting, we simulated abundances using the reported 2005 estimates as the starting value, using the formula:

$$N_{t+1} = (N_t \times \lambda_{lit}) - Hunted_t - (c \times N_t) \qquad \text{Eq. 2}$$

where $N_t$ = population at time t ($N_1$ is the 2005 estimate); $\lambda_{lit}$ = population growth rate drawn randomly from a uniform distribution bounded by the range of published growth rates ($\lambda_{lit-min}$ to $\lambda_{lit-max}$); $Hunted_t$ = individuals hunted at time t; term [$c \times Nt$] = additional mortality from poaching, roadkill, etc.

We ran 1000 simulations for each species using randomly selected values for $\lambda_{lit}$, constant across years for each simulation, thus capturing the full range of biologically possible population trajectories. We estimated additional mortality from poaching, roadkill and other sources based on expert opinion: we conservatively assumed an additional mortality rate of 5% (c = 0.05) of the estimated population for *U. arctos* and *L. lynx*, and 10% for *C. lupus* (c = 0.10). *U. arctos* is the main focus of large carnivore hunting in Romania, thus game managers are more likely to enforce anti-poaching actions; *L. lynx* is a secretive felid, and has lower hunting pressure. On the other hand, *C. lupus* has a very long history of persecution in Romania, generates frequent human-wildlife conflicts, and is at higher risk of poaching (Geacu 2009).

For each county, we calculated how often the reported populations were out of bounds of the simulated population trajectories, and whether populations were either higher than maximum population trajectories ($\lambda_{lit-max}$) or lower than the minimum population trajectories ($\lambda_{lit-min}$), thus not biologically plausible.

**Table 2.** *Annual population growth rates for European large carnivores from literature.*

| Species | Annual population growth rate | Location | Study period | Source |
|---|---|---|---|---|
| *Ursus arctos* | *1.015* (with hunting at 5.5 ± 2.1%) | Sweden | 1943 – 1991 | (Swenson *et al.* 1994) |
| | *1.017* (in an expanding population) | Slovenia | 1945 – 1995 | (Jerina & Adamič 2008) |
| | *1.045* (national average)<br>*1.0* to *1.102* (at county level) | Sweden | 1998 – 2007 | (Kindberg *et al.* 2011) |
| *Canis lupus* | *1.29 ± 0.035* (mean ± SD) | Scandinavia | 1991 - 1998 | (Wabakken *et al.* 2001) |
| | *1.135* (with poaching)<br>*1.238* (in the absence of poaching) | Scandinavia | 1998 – 1999 to 2008 – 2009 | (Liberg *et al.* 2012) |
| *Lynx. lynx* | *1.19* to *1.33* (at regional level, in the absence of poaching and hunting)<br>*1.01* to *1.19* (at regional level with poaching and hunting) | Sweden | 1995 – 2002 | (Andrén *et al.* 2006) |

## RESULTS

### Game Management Unit-level data for carnivore and ungulate species

The reported ***ungulate*** population across 145 GMU's within the project area were stable between 2005 and 2010 (Figure 2). With the exception of ***wolf***, for which official data indicate an increase in absolute abundance, ***brown bear*** and ***lynx*** also showed stable populations (Figure 2). Hunting quotas tended to decrease throughout the period for all ***large carnivore*** species (Figure 3); quotas for ***red deer*** and ***roe deer*** have been stable, which the quotas for ***wild boar*** have been increasing steadily. Hunting for ***lynx*** has not been allowed since 2010.

The levels of hunting were well below quotas for all species, in particular for ***large carnivores*** (Figure 3). No reports of poaching were recorded in the database, despite that fact that poaching of both ungulates and carnivores is a known as one of the main threats in the project area. Because hunting is aimed at maintaining stable populations, not achieving the target quota should result in continually increasing populations (in the absence of poaching); however, there is no increasing trend or any species, with the exception of ***wolf***; these data suggest potential flaws in the monitoring and reporting system, leading to biases when setting quotas. New monitoring methods applied at the appropriate spatial scales (for carnivores at a regional scale, not at GMU-level) are needed for both large carnivores and ungulates.

**Figure 2.** *Trends in carnivore and ungulate populations from 145 Game Management Units within the LIFECONNECT project area (72% of all GMUS's) from 2005-2010 official data.*

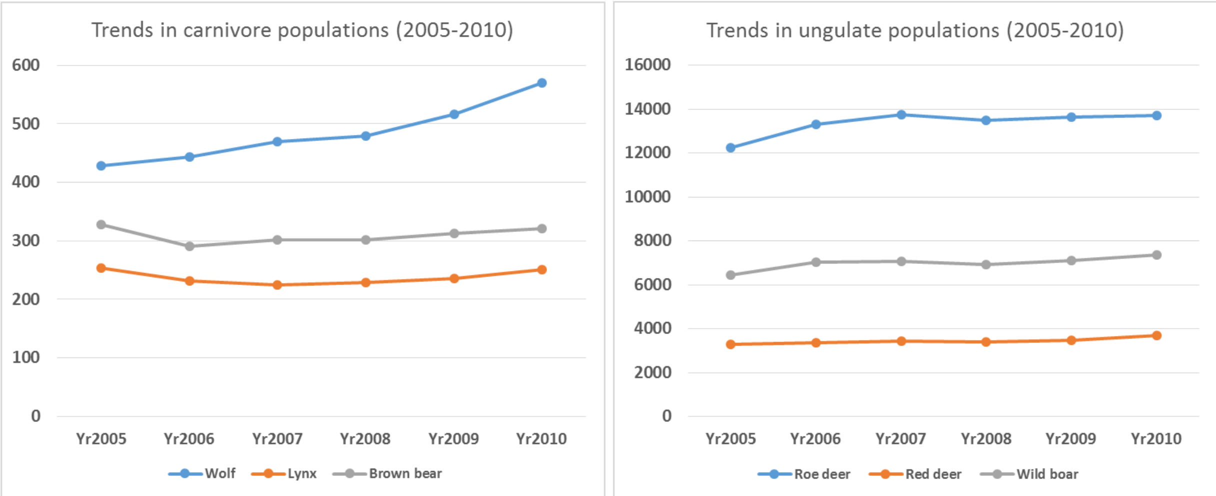
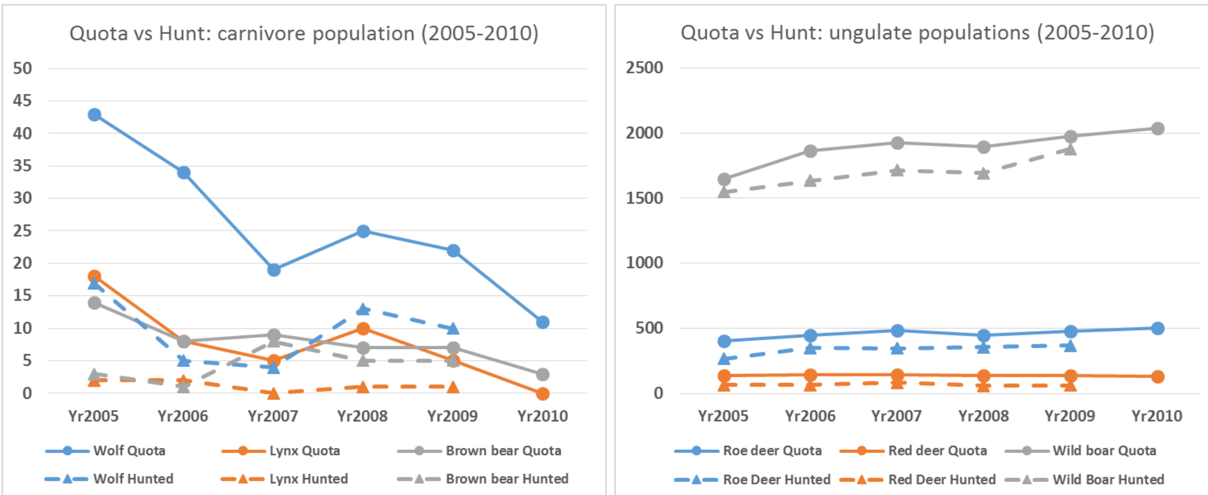


**Figure 3.** *Trends in quotas and hunting for carnivore and ungulate species from 145 Game Management Units within the LIFECONNECT project area (72% of all GMUS's) from 2005-2010 official data (hunting in 2010 was no available; Lynx lynx hunting has not been allowed starting with 2010).*



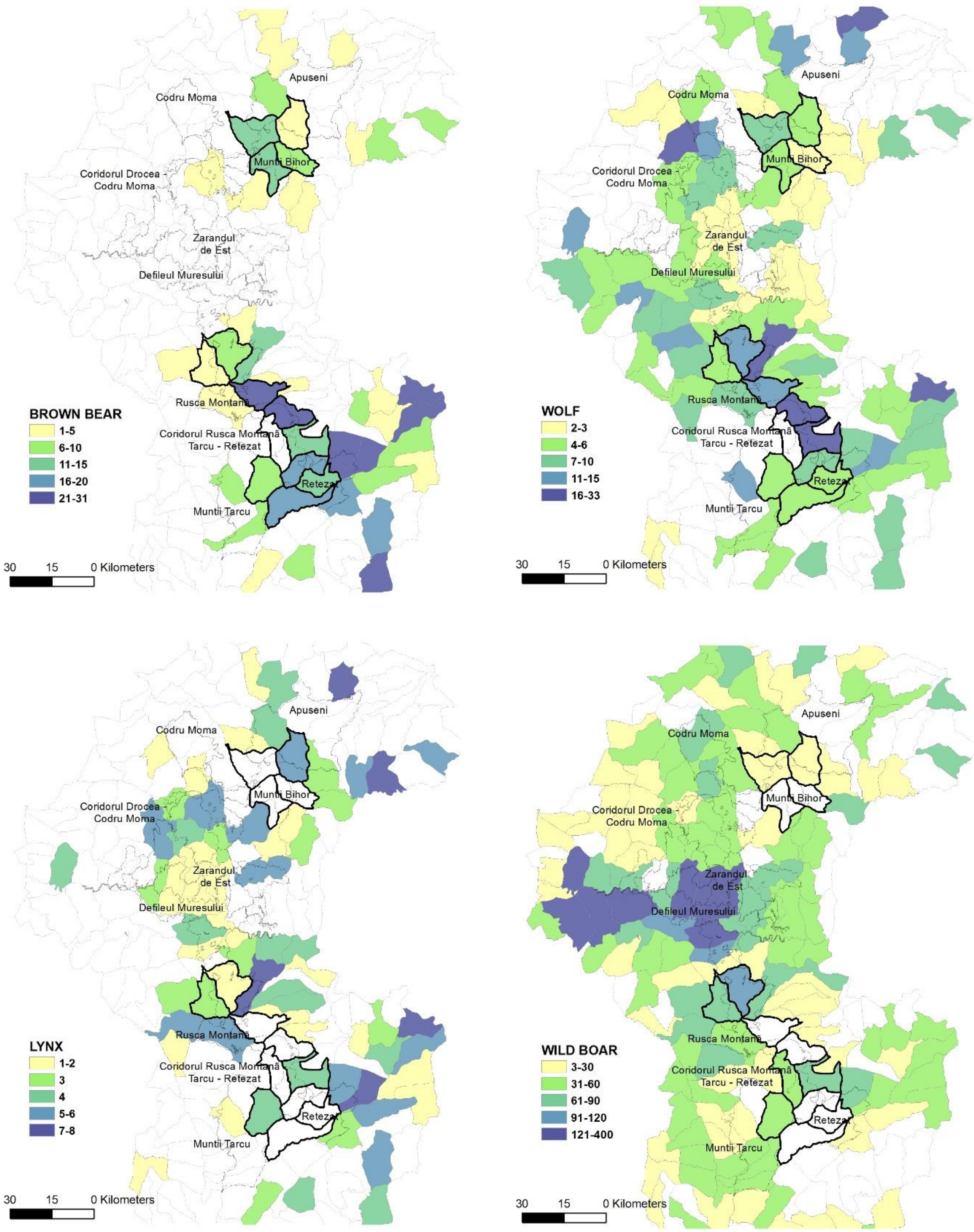

The total quotas for 2014-2015 across all 200 GMU's overlapping the project area were: 47 ***brown bears***, 95 ***wolves***, 433 ***red deer***, 1290 ***roe deer***, and 3564 ***wild boar*** (Annex I). The approved quotas for ***brown bear*** and ***wolf*** are currently done at the level of manager, not Game Management Unit (a single institution or organization can manage multiple GMU's, and which decides internally how to fulfil the quota from the GMU that it manages).

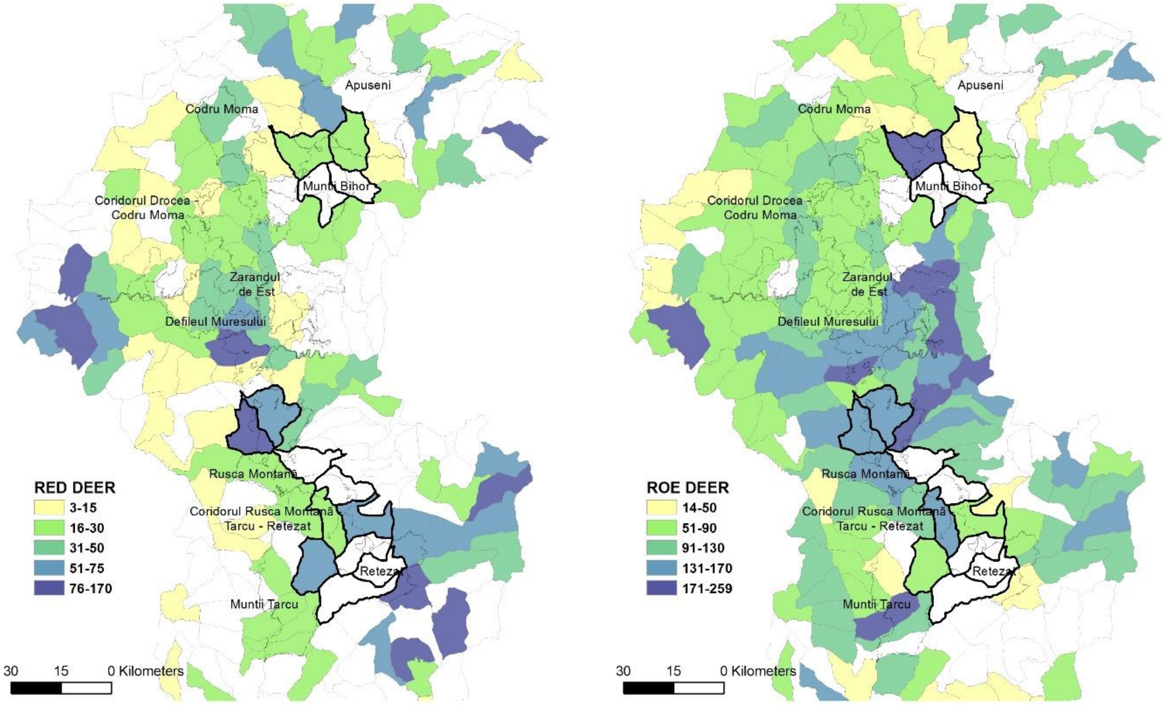
Although there were some gaps in the GMU-level abundance data available, the spatial distribution of the 6 target species presents expected patterns (Figure 4). Greatest ***brown bear*** reported abundance were in Retezat-Tarcu, Rusca Montana and Rusca Montana – Tarcu – Retezat Corridor, with a maximum of 31 individuals reported in GMU Lunca Cernii (Hunedoara County). ***Wolf*** abundances are more homogeneous, with greater abundances reported in Rusca Montana – Tarcu – Retezat Corridor and lowest in the central-eastern part of the project area. Greater ***lynx*** abundances were also reported in Tarcu and Retezat, as well as Apuseni, but overall, the figures were lower that for the other 2 carnivores (up to 8 individuals per GMU). Reported abundances for ***wild boar*** were very high in the Defieul  Muresului and Zarandul de Est, with up to 400 individuals reported in a GMU in 2010 (Arad County, GMU Cladova). Official ***red deer*** abundances were high in the southern part of the project area (Rusca Montana, Retezat), as well as in the western part, where GMU Neudorf (Arad County) reported 170 individuals in 2010. Finally, reported ***roe deer*** abundances were greatest in the central part of the project area (up to 259 in GMU Vorta, Hunedoara County): Dealurile Lipovei, Rusca Montana, Tinutul Padurenilor.

**Table 3.** *Reported abundances and quotas for Game Management Units overlapping 3 target regions where other monitoring methods are being implemented.*

| Region | County | Game Management Unit | Manager | Area (ha) | Forest cover (ha) | Quotas 2014-2015 | | | | | Reported abundance 2013 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Bear | Wolf | Red Deer | Roe Deer | Wild Boar | Bear | Wolf |
| Retezat Tarcu | HD | 45_VALEA_FIERULUI | AVPS VIDRA Buc. | 11368 | 7498 | 1 | 1 | 6 | 8 | 28 | 28 | 33 |
| | | 54_BORASCU_GODEANU | DS Hunedoara | 17097 | 4986 | 8 | 5 | 3 | 1 | 0 | 17 | 5 |
| | | 55_RETEZAT | | 10132 | 4699 | | | 0 | 0 | 0 | 11 | 5 |
| | | 52_ZEICANI | AVPS Cinegetica Hunedoara | 12788 | 5337 | 1 | 3 | 5 | 5 | 31 | 13 | 21 |
| | | 43_LUNCA_CERNII | | 11585 | 6085 | | | 1 | 3 | 25 | 31 | 12 |
| | | 53_RAUL_MARE | SC OS Retezatul Clopotiva - Rau de Mori SRL | 11427 | 7959 | 0 | 0 | 4 | 4 | 10 | 17 | 9 |
| | CS | 15_POIANA_MARULUI | DS CARAS-S | 15176 | 10935 | 2 | 2 | 3 | 1 | 3 | 9 | 6 |
| | | 17_BAUTAR_BUCOVA | ACV Iezerul Bucovii | 11092 | 8500 | 1 | 0 | 4 | 8 | 25 | | |
| Lipova Rusca Padureni | TM | 26_POIENI | Asoc. Banat Jagd | 15198 | 10942 | 1 | 2 | 2 | 6 | 15 | 6 | 11 |
| | | 27_LUNCANI | AJVPS TIMIS | 12445 | 8742 | 1 | 3 | 6 | 3 | 20 | 4 | 5 |
| | HD | 25_BATRANA | DS Hunedoara | 13833 | 10029 | 8 | 5 | 3 | 3 | 12 | 14 | 33 |
| Bihor Apuseni | BH | 66_BIHAREA | AVPS Diana Hunting BH | 15787 | 8575 | 1 | 1 | 5 | 7 | 40 | 12 | 7 |
| | AB | 1_ARIESUL_SUPERIOR | DS ALBA IULIA | 15019 | 10314 | 1 | 2 | 1 | 3 | 2 | 2 | 4 |
| | | 5_AVRAM_IANCU | AV AVRAM IANCU | 10021 | 5855 | 0 | 1 | 7 | 6 | 13 | 9 | 3 |
| | AR | 63_LEUCA_GAINA | AVPS BREAZA | 12126 | 9301 | 1 | 1 | 5 | 10 | 22 | 11 | 6 |

**Figure 4.** *Reported abundances of wildlife populations in Western Carpathians in 2010. Game Management Units (GMU) highlighted in* ***black*** *are target areas for other monitoring methods (****data for brown bear and wolf in these areas are from 2013****); GMUs in* ***white*** *are* ***no data****.*






## Biological plausibility of county-level data for carnivore species

When compared to the maximum published growth rates, we found that reported estimates suggested biologically unrealistic yearly population growth rates for ***brown bear*** ($\lambda > \lambda_{lit\text{-}max}$ of 1.102) up to 2 out of 7 years in several counties throughout the entire period (2005-2012) (Figure 5).

Estimated population growth rates for ***lynx*** were occasionally higher than the literature maximum ($\lambda > \lambda_{lit\text{-}max}$ of 1.33 for one year for 3 out of 8 counties; Figure 5). Reported estimates for ***wolf*** yielded greater than maximum published growth rates ($\lambda > \lambda_{lit\text{-}max}$ of 1.29) for 4 out 8 counties for 2 years (Figure 5).

We found discrepancies between the reported estimates and the simulated estimates for ***brown bear*** and ***lynx***, and to a lesser degree for ***wolf*** (Figure 6, 7). Reported ***brown bear*** populations were mostly out of bounds of simulated populations in Arad and Alba, with a clear tendency of overestimating abundances. Reported populations in Gorj and Hunedoara were close to the maximum simulated populations. In contrast, reported estimates for ***lynx*** were usually below the minimum simulated populations (Figure 6, 7). Without exception, reported ***wolf*** populations were within the bounds of simulated populations (Figure 6, 7).

**Figure 5.** *The frequency that estimated growth rates of Romanian large carnivore populations calculated from annual differences in reported estimates for (a) Ursus arctos, (b) Canis lupus, and (c) Lynx lynx, exceeded the maximum growth rates in other European large carnivore populations ($\lambda_{lit\text{-}max}$ for Ursus arctos = 1.102, Canis lupus = 1.29, and Lynx lynx = 1.33). Counties overlapping the project area are highlighted by the black line.*

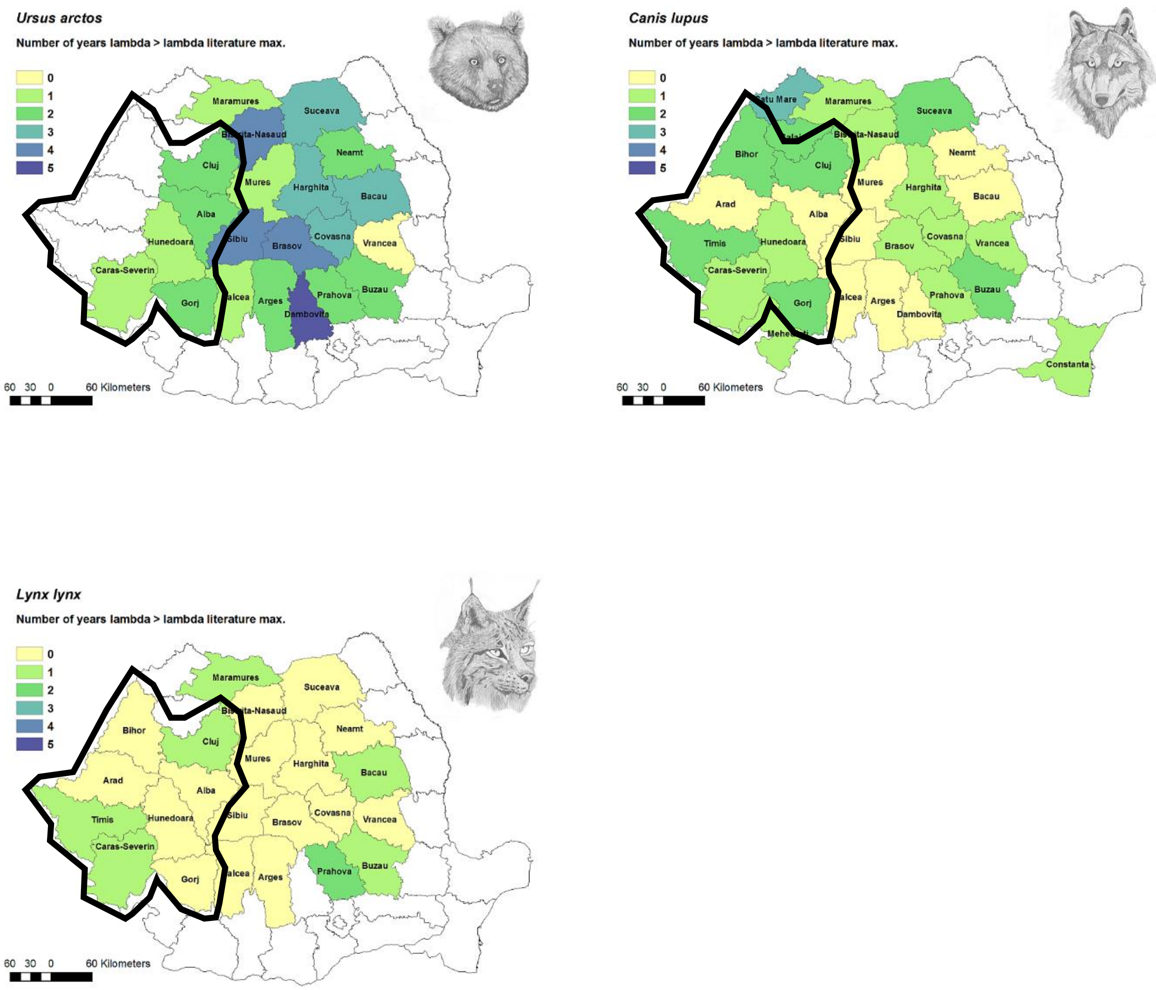
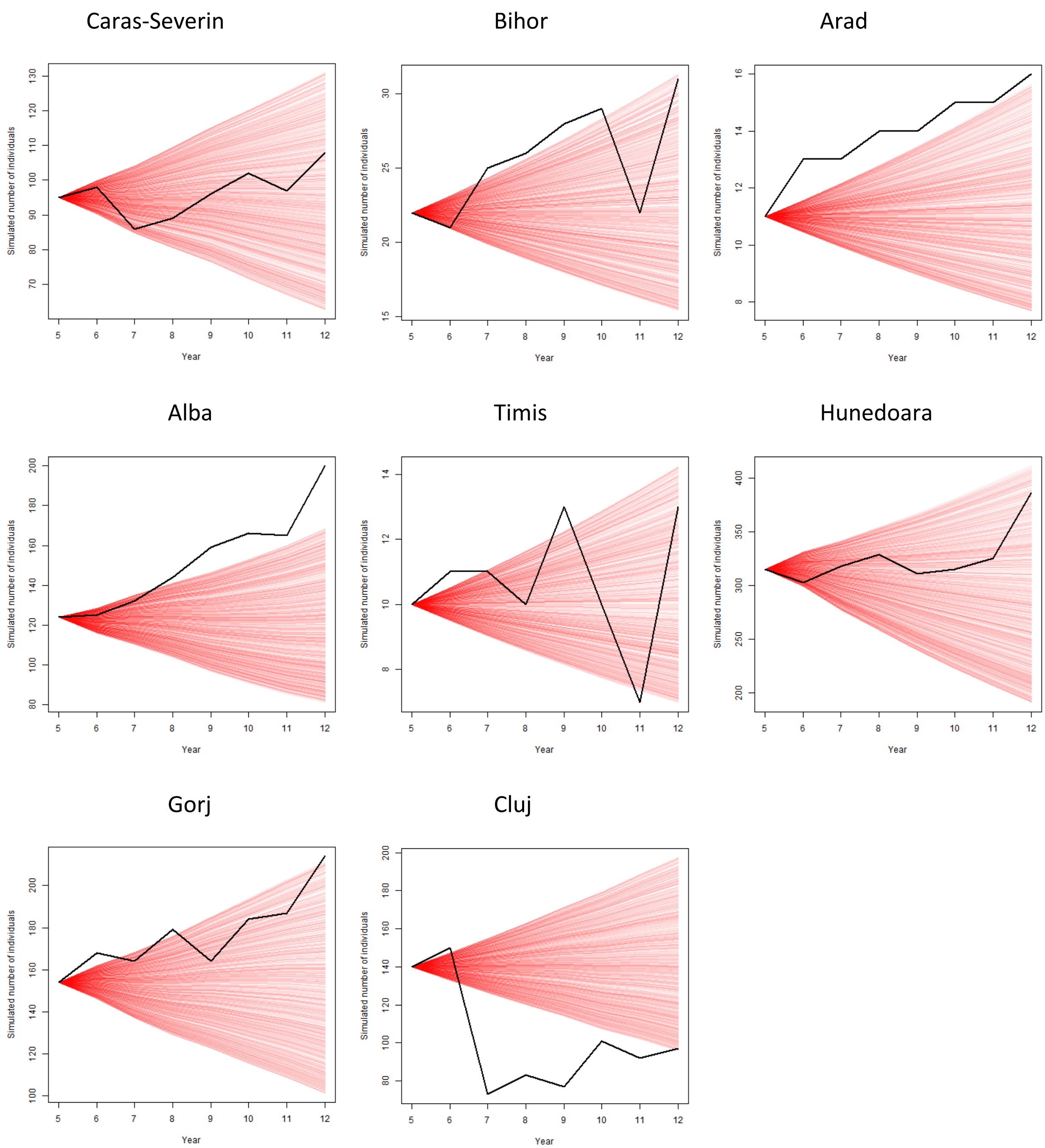


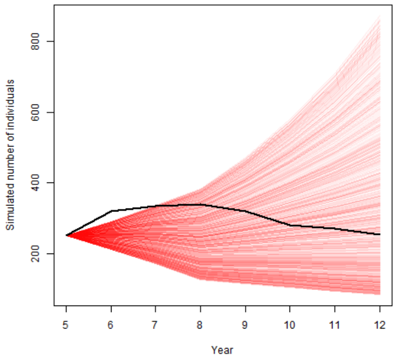
**Figure 6.** *Reported estimates versus simulated population trajectories (n=1000) for LIFECONNECT counties. The upper and lower bounds of the simulated populations correspond to maximum and minimum annual population growth rates from literature. Simulated populations included actual hunting mortality, as well as other sources of mortality. Black line = reported estimates; red lines = simulated abundances.*

### Brown bear (*Ursus arctos*)

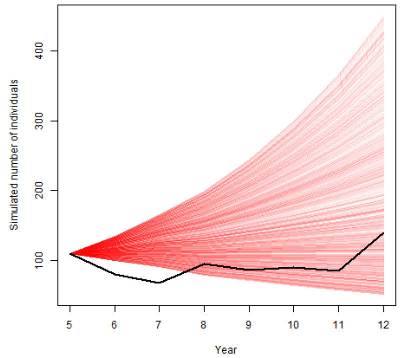


## Wolf (*Canis lupus*)

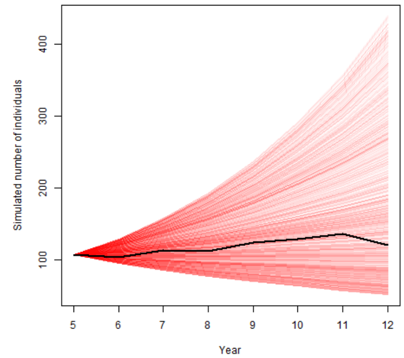
Caras-Severin



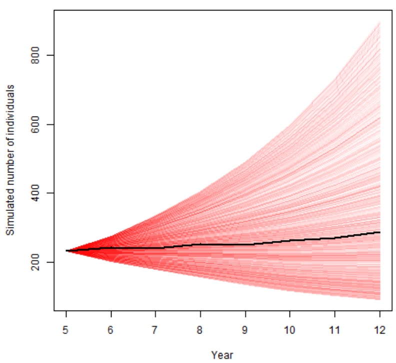

Bihor



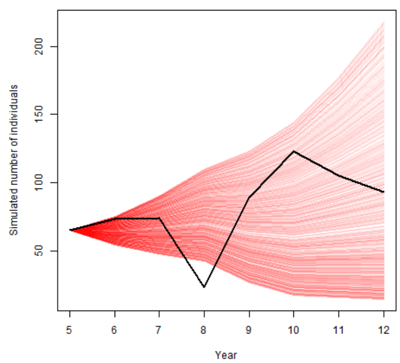

Arad



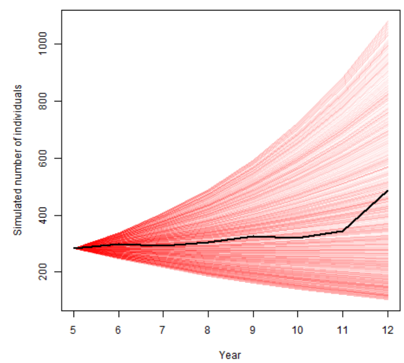

Alba



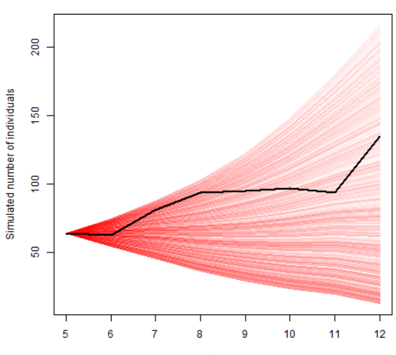

Timis



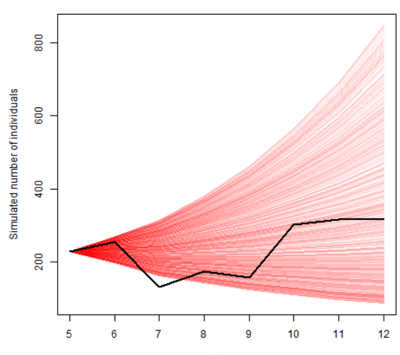

Hunedoara




Gorj

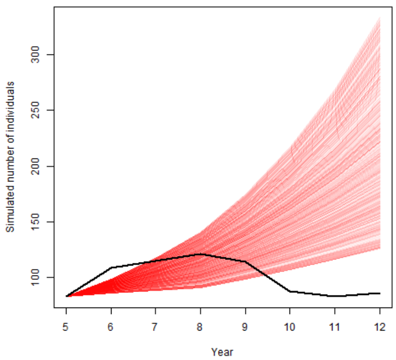



Cluj

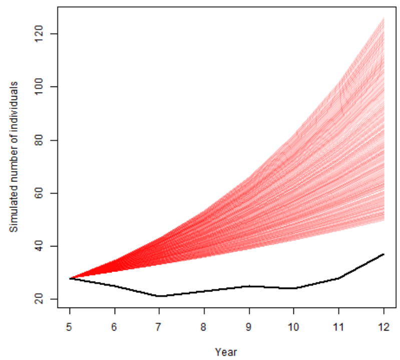


## Lynx (*Lynx lynx*)

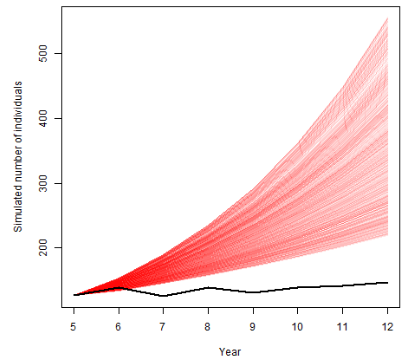
Caras-Severin



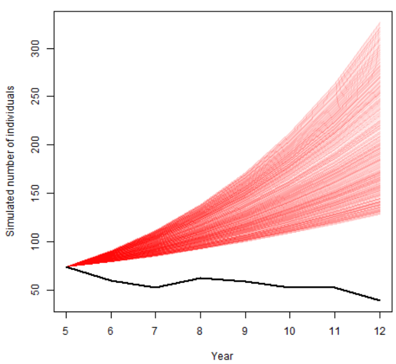

Bihor



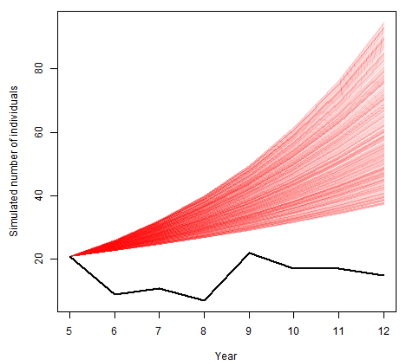

Arad



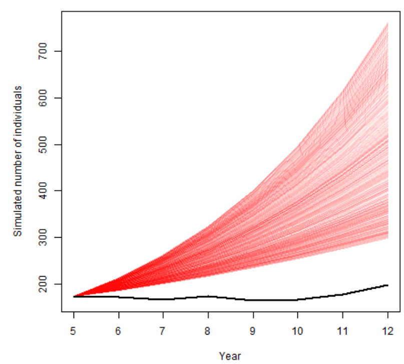

Alba



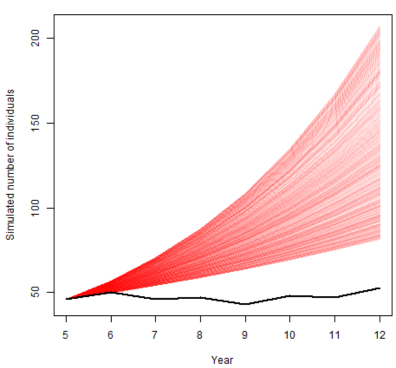

Timis




Hunedoara




Gorj




Cluj

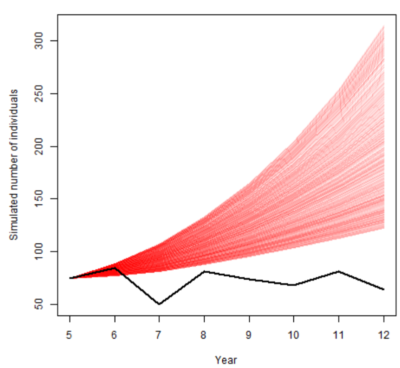
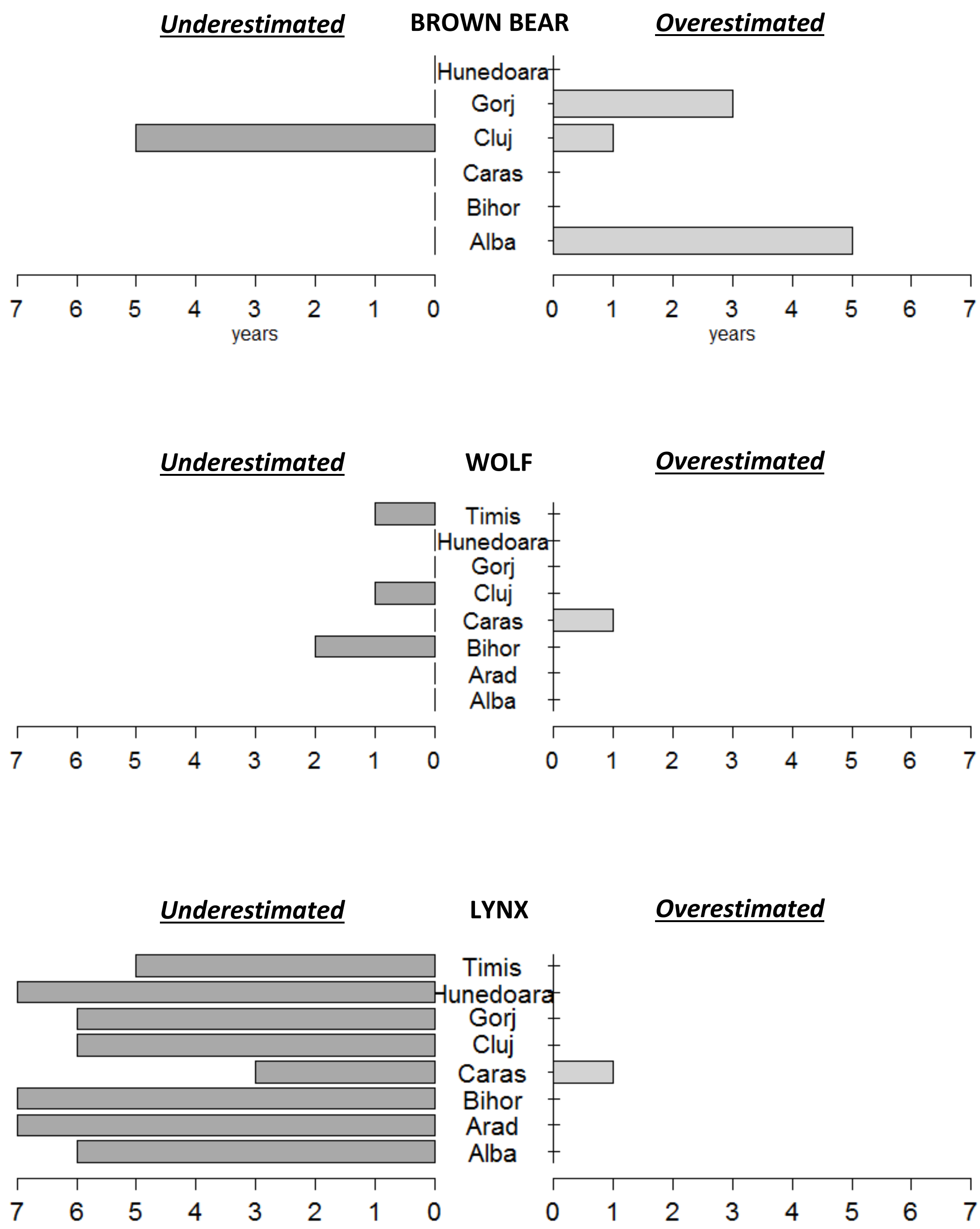


**Figure 7.** *Number of years (out of 7) that reported carnivore populations were out of bounds compared to simulated population trajectories across the range of empirically-derived growth rates from other European large carnivore populations (Underestimated = reported estimates < simulated populations at $\lambda_{lit\text{-}min}$; Overestimated = reported estimates > simulated populations at $\lambda_{lit\text{-}max}$). Only counties with >30 bears and >10 lynx and wolves reported are shown.*



## SUMMARY

### Trends in carnivore and ungulate populations

- With the exception of ***wolf***, for which reported data showed a constant increase in abundance, ***all other target species*** had virtually no fluctuation in the overall abundance for the period 2005-2010.
- This finding would suggest that, with the exception of ***wolf***, management for ensuring stable populations is successful (the number of animals produced every year is hunted over the next hunting season); yet, the hunting quotas are never reached, especially for carnivore species. This should result in increasing abundances through time for all species, unless populations are at carrying capacity, and are self-regulating.
- The above findings are suggestive of the following: (1) poaching occurs at levels that basically supplement quotas to achieve stable populations (yet no poaching is acknowledged in the official data) or (2) the reported abundances are biased by the current monitoring method, which does not acknowledge issues imperfect detection and has no uncertainty estimates (a single estimate of abundance per GMU per species is reported), and the management for maintaining stable populations has no solid ecological basis.

### Reporting data at Game Management Unit level

- Analysis of GMU level data yielded unlikely high numbers for some species (for example, up to 170 ***red deer*** individuals on a 19,000 ha GMU)
- Simply summing GMU-level abundances is not likely to be a correct estimate of the regional population. This is particularly true for large carnivores, whose home ranges can be much larger than a single GMU. While some corrections are performed on the data by the Romanian wildlife authorities when aggregating to county level (as well as country level), this process is not transparent, and no indication of the types of correction factors and their scientific basis is given in any public document.
- The information provided by GMU-level data (Figures 2,3, and 4) should not be considered at "face value" as absolute abundances; these official data form the baseline data collected using traditional monitoring methods to be compared against other monitoring methods based on strong scientific approaches implemented in LIFECONNECT.

### County-level data for large carnivores

- Wildlife data aggregated at county-level revealed that large carnivores had population growth rates greater than any other population in Europe during 1 or 2 years per county (out of 7 years analyzed).
- There were clear discrepancies between species in regards to the likelihood that reported populations were within biologically-plausible bounds (Figure 6, 7): ***lynx*** populations were likely underestimated, ***wolf*** populations were within bounds of simulated populations, while ***brown bear*** populations were both underestimated and overestimated depending on county.

- In the absence of long term monitoring of species it is impossible to draw conclusions on the veracity of reported abundance, especially since these figures are a result of using unknown 'correction' factors applied when aggregating GMU's level raw data.
- The discrepancy between counties and between species identified by the county-level analyses point to a need to evaluate carnivore abundances using scientific methods that are transparent, acknowledge sources of uncertainty (such as imperfect detection) and provide estimates of uncertainty, which can be used to set hunting quotas.

Comparing GMU- and county-level estimates to estimates of abundance and density from ongoing monitoring activities in LIFECONNECT (camera traps, snow tracking, genetic surveys, pellet counts) will provide the benchmark against which the official data will be compared. While we expect the regional patterns to be similar to the ones described by the official data (e.g., lower brown bear densities in Apuseni compared to Retezat-Tarcu), we also expect that monitoring will negate extreme abundance values reported by some GMUs.

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**Annex I.** *Approved quotas for 2014-2015 for 200 Game Management Units within LIFECONNECT project area. The quotas for* ***wolf*** *and* ***brown bear*** *are approved at the level of manager, not at the level of spatial unit (managers decide how to best allocate the quotas within their GMUs).*

| County | Game Management Unit | | Manager | Approved Quotas 2014-2015 | | | | |
|---|---|---|---|---|---|---|---|---|
| | No. | Name | | Brown Bear | Wolf | Red Deer | Roe Deer | Wild Boar |
| AB | 4 | VALEA BISTREI | Asociaţia "Căpriorul" Certege | 0 | 1 | 3 | 5 | 7 |
| AB | 3 | HOREA | SC OS Horea Apuseni | 0 | 1 | 1 | 6 | 3 |
| AB | 2 | ARIESUL MIJLOCIU | AVPS Bendis | 0 | 1 | 0 | 5 | 6 |
| AB | 1 | ARIESUL SUPERIOR | DS ALBA IULIA | 1 | 2 | 1 | 3 | 2 |
| AB | 9 | LUPSA | AJVPS ALBA | 2 | 4 | 6 | 8 | 10 |
| AB | 6 | VIDRA | AJVPS ALBA | | | 1 | 9 | 8 |
| AB | 5 | AVRAM IANCU | AV AVRAM IANCU | 0 | 1 | 7 | 6 | 13 |
| AB | 10 | POSAGA | SC OS MUNTELE MARE | 1 | 1 | 5 | 5 | 13 |
| AB | 11 | OCOLIS | AVPS Ocolis Hunter 1 | 1 | 2 | 5 | 6 | 25 |
| AR | 69 | RECEA | DS ARAD | 0 | 4 | 2 | 3 | 55 |
| AR | 37 | BATUTA | | | | 1` | 2 | 35 |
| AR | 65 | SLATINA | | | | 2 | 2 | 48 |
| AR | 73 | NEUDORF | | | | 13 | 12 | 115 |
| AR | 55 | MONEASA | | | | 2 | 4 | 16 |
| AR | 59 | MADRIGESTI | | | | 1 | 1 | 15 |
| AR | 60 | DUMBRAVA | | | | 1 | 1 | 25 |
| AR | 67 | SAVARSIN | | | | 2 | 3 | 50 |
| AR | 66 | TROAS | | | | 2 | 2 | 52 |
| AR | 31 | COVASANT | AVPS Şoimul Lipova | x | x | 0 | 8 | 10 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| AR | 68 | PETRIS | Asociatia Vanatorilor Sportivi Ghioroc-Păuliș | x | x | 5 | 4 | 53 |
| AR | 34 | MILOVA | AJVPS ARAD | | | 2 | 4 | 28 |
| AR | 41 | TARNOVA | | | | 0 | 7 | 5 |
| AR | 47 | ROVINA | | | | 1 | 5 | 5 |
| AR | 49 | MINERAU | | | | 1 | 6 | 12 |
| AR | 56 | ROSIA | | | | 1 | 6 | 11 |
| AR | 36 | MONOROSTIA | | | | 0 | 3 | 20 |
| AR | 61 | CROCNA ZIMBRU | | | | 0 | 6 | 20 |
| AR | 70 | FIAC | | | | 0 | 5 | 35 |
| AR | 71 | ZABALT | | | | 1 | 6 | 45 |
| AR | 72 | LIPOVA | | | | 5 | 9 | 51 |
| AR | 43 | SELEUS | | | | 0 | 5 | 0 |
| AR | 48 | MINIS | Asoc. Lazăr Hunting | x | x | 1 | 12 | 31 |
| AR | 57 | CHISINDIA | | x | x | 3 | 20 | 38 |
| AR | 38 | NADAS | SC OS P Nădaş SRL | x | x | 1 | 15 | 35 |
| AR | 53 | HASMAS | Asoc. Vânătorii Codrilor Urviş | x | x | 3 | 8 | 14 |
| AR | 30 | SIRIA | AVP Cetatea Siria | 0 | 0 | 2 | 8 | 20 |
| AR | 35 | CONOP | AVP Crişana | 0 | 1 | 7 | 20 | 65 |
| AR | 39 | TAUT | AV Lunca Tauţ | x | x | 2 | 11 | 30 |
| AR | 40 | ARANEAG | AVP Arsilva | 0 | 1 | 6 | 10 | 40 |
| AR | 50 | ARCHIS | Asociaţia Agro-Silvo-Cinegetică Ineu | 0 | 1 | 0 | 9 | 22 |
| AR | 52 | BOTFEI | | | | 4 | 16 | 43 |
| AR | 46 | BALTA | | | | 9 | 22 | 82 |
| AR | 51 | SUSAG | AVPS Cervus Elafus | 0 | 0 | 4 | 10 | 5 |
| AR | 54 | PRUNISOR | AV Petrişana | | | 1 | 12 | 24 |
| AR | 58 | RADESTI | AVPS CRISIUS SOCODOR | 0 | 0 | 1 | 10 | 15 |
| AR | 62 | A. IANCU-MAGULICEA | | | | 1 | 15 | 15 |
| AR | 63 | LEUCA-GAINA | AVPS BREAZA | 1 | 1 | 5 | 10 | 22 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| AR | 64 | TISA-LUNCSOARA | AVPS Grizzly | 0 | 0 | 10 | 20 | 30 |
| AR | 33 | CLADOVA | AVPS Hubertus Lipova | x | x | 13 | 10 | 130 |
| AR | 32 | GHIOROC | | x | x | 0 | 3 | 5 |
| AR | 74 | ZABRANI | Asoc. Cinegetică Timisoara | x | x | 0 | 14 | 5 |
| AR | 42 | PANCOTA | AVPS Bizon Bonasus | x | x | 1 | 20 | 5 |
| BH | 66 | BIHAREA | AVPS Diana Hunting BH | 1 | 1 | 5 | 7 | 40 |
| BH | 64 | DUMBRAVANI | DS ORADEA | 0 | 0 | 0 | 2 | 5 |
| BH | 67 | REMETI | | | | 0 | 4 | 3 |
| BH | 68 | VALEA IADULUI | | | | 0 | 0 | 3 |
| BH | 63 | PIETROASA | Universitatea din Oradea | 0 | 1 | 3 | 4 | 10 |
| BH | 69 | VALEA DRAGANULUI | Asoc. Cinegetica Apuseni | 1 | 1 | 5 | 2 | 6 |
| BH | 58 | SOHODOL | | | | 5 | 7 | 25 |
| BH | 57 | ROSIA | AJVPS BIHOR | 0 | 2 | 2 | 10 | 25 |
| BH | 46 | LUNCA SPRIE | | | | 3 | 10 | 25 |
| BH | 62 | CUSUIUS | | | | 0 | 7 | 21 |
| BH | 41 | HODISEL | | | | 2 | 13 | 10 |
| BH | 61 | FERICE | | | | 0 | 7 | 15 |
| BH | 56 | CURATELE | | | | 0 | 8 | 6 |
| BH | 59 | FINIS | | | | 2 | 8 | 30 |
| BH | 47 | CRANCESTI | | | | 0 | 17 | 25 |
| BH | 65 | VARATEC | AV Varatec Codru Moma | x | x | 0 | 12 | 25 |
| BH | 55 | FORAU | FC ASOCIAŢIA GLIGANU | 0 | 0 | 7 | 9 | 32 |
| BH | 60 | DUMBRAVITA | | | | 9 | 12 | 70 |
| BH | 52 | BALNACA | AV SELINA | 0 | 0 | 2 | 11 | 18 |
| CJ | 47 | GILAU | AJVPS CLUJ | 2 | 4 | 1 | 10 | 20 |
| CJ | 49 | VALEA BELISULUI | | | | 5 | 4 | 5 |
| CJ | 41 | VALEA IERII | | | | 9 | 4 | 15 |
| CJ | 22 | STOLNA | | | | 1 | 13 | 17 |
| CJ | 53 | CALATA | Asociaţia Vânătorească | 1 | 0 | 1 | 17 | 13 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| CJ | 54 | HUEDIN | Regal | | | 1 | 10 | 13 |
| CJ | 55 | VALEA DRAGANULUI | | | | 6 | 12 | 26 |
| CJ | 52 | CALATELE | | | | 3 | 17 | 16 |
| CJ | 51 | RACHITELE | AV CORNUL DE AUR | 1 | 1 | 11 | 9 | 18 |
| CJ | 50 | GIURGUTA | Asoc. Vânătorul Alpin | 0 | 0 | 9 | 5 | 13 |
| CJ | 44 | VALEA RACATAULUI | S.C OCOLUL SILVIC HOREA APUSENI | 0 | 0 | 3 | 5 | 5 |
| CJ | 43 | SOMESUL RECE | AV SAMUS SYLVESTRIS | 1 | 1 | 8 | 6 | 12 |
| CJ | 42 | CAPRITA | DS CLUJ NAPOCA | 0 | 0 | 2 | 2 | 6 |
| CJ | 40 | BAISOARA | | | | 6 | 3 | 40 |
| CJ | 46 | DUMBRAVA | AM VP Pro Mediu | 1 | 1 | 4 | 22 | 30 |
| CJ | 45 | SOMESUL CALD | USAMV Cluj-Napoca | 0 | 1 | 2 | 7 | 15 |
| CS | 16 | RUSCA | DS CARAS-S | 2 | 2 | 1 | 3 | 5 |
| CS | 5 | ILOVA | | | | 0 | 2 | 2 |
| CS | 20 | HIGEG | | | | 1 | 5 | 7 |
| CS | 15 | POIANA MARULUI | | | | 3 | 1 | 3 |
| CS | 14 | MARU | | | | 2 | 1 | 2 |
| CS | 63 | VALIUG | | | | 1 | 0 | 0 |
| CS | 56 | PATAS | | | | 0 | 0 | 3 |
| CS | 30 | VALEA CERNEI | | | | 0 | 0 | 0 |
| CS | 31 | PECINISCA | | | | 1 | 3 | 5 |
| CS | 27 | POLOM | | | | 0 | 5 | 5 |
| CS | 12 | OTELU | AJVPS CARAŞ-SEVERIN | 1 | 4 | 0 | 2 | 8 |
| CS | 22 | TEREGOVA | | | | 0 | 3 | 6 |
| CS | 24 | BELENTIN | | | | 1 | 3 | 12 |
| CS | 57 | BORLOVENI | | | | 0 | 3 | 7 |
| CS | 29 | CRAIOVA | | | | 0 | 3 | 10 |
| CS | 2 | TURNU RUIENI | | | | 1 | 3 | 8 |
| CS | 7 | POIANA | | | | 0 | 3 | 7 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| CS | 10 | MATNICU PRISACA | | | | 0 | 9 | 12 |
| CS | 25 | DOMASNEA | | | | 0 | 3 | 10 |
| CS | 4 | VARCIOROVA | | | | 0 | 3 | 4 |
| CS | 13 | MAGURA | | | | 1 | 3 | 8 |
| CS | 19 | ARMENIS | | | | 0 | 5 | 12 |
| CS | 18 | MARGA | | | | 1 | 3 | 10 |
| CS | 6 | GOLET PETROSENITA | AV CERNA 2010 | x | x | 1 | 16 | 18 |
| CS | 26 | CORNEREVA | AVP Haiducii în Rotunda | 1 | 0 | 0 | 2 | 4 |
| CS | 21 | HIGIGEL | | | | 1 | 6 | 10 |
| CS | 1 | TINCOVA MACIOVA | ICAS Caransebes | 0 | 0 | 1 | 1 | 11 |
| CS | 3 | BORLOVA | | | | 2 | 1 | 5 |
| CS | 62 | VALIUGEL | AVPS Arthemis Otelec | x | x | 1 | 5 | 11 |
| CS | 23 | SLATINA | AVPS Jneapănu Banatului | 0 | 1 | 0 | 13 | 25 |
| CS | 17 | BAUTAR BUCOVA | ACV Iezerul Bucovii | 1 | 0 | 4 | 8 | 25 |
| GJ | 8 | SUSITA | ASOC. CERBUL CARPATIN | | | 13 | 4 | 20 |
| GJ | 3 | PADES | AJVPS GORJ | 0 | 0 | 0 | 4 | 3 |
| GJ | 17 | BRADICENI | | | | 0 | 4 | 4 |
| GJ | 1 | MOTRU SEC | AVPM Acvila Cernei | 0 | 2 | 3 | 6 | 6 |
| GJ | 2 | MOTRU MARE | DS TG. JIU | 3 | 4 | 3 | 3 | 7 |
| GJ | 5 | TISMANA | DS TG. JIU | | | 4 | 3 | 7 |
| GJ | 4 | DUMBRAVA | DS TG. JIU | | | 0 | 4 | 8 |
| GJ | 7 | RUNCU | DS TG. JIU | | | 5 | 3 | 9 |
| GJ | 6 | BISTRITA | AVPS Ursul Carpatin Gorj | 1 | 1 | 14 | 6 | 27 |
| GJ | 28 | BOBOIESTI | Asociaţia Diana Gorj | 0 | 0 | 0 | 0 | 0 |
| GJ | 27 | MOTRU | AVPS EGRETA GORJ | 0 | 0 | 0 | 4 | 4 |
| HD | 7 | BLAJENI | AJVPS HUNEDOARA | 4 | 8 | 2 | 6 | 14 |
| HD | 39 | DEALU GROSI | | | | 0 | 3 | 9 |
| HD | 2 | BULZESTI | | | | 1 | 3 | 15 |
| HD | 11 | MICANESTI | | | | 2 | 6 | 36 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| HD | 12 | GURA SADA | | | | 0 | 6 | 29 |
| HD | 47 | HATEG | | | | 0 | 3 | 2 |
| HD | 26 | LAPUSNIC | | | | 1 | 6 | 15 |
| HD | 57 | FEDERI | | | | 1 | 6 | 10 |
| HD | 70 | GANTAGA | | | | 2 | 4 | 12 |
| HD | 61 | BANITA | | | | 4 | 8 | 12 |
| HD | 10 | RUDA BRAD | AVPS DEER HUNTER | | | | | 16 |
| HD | 27 | VETEL | AVPS Cinegetica Hunedoara | 1 | 3 | 1 | 5 | 15 |
| HD | 48 | SILVAS | | | | 0 | 6 | 8 |
| HD | 49 | BRETEA | | | | 0 | 3 | 6 |
| HD | 52 | ZEICANI | | | | 5 | 5 | 31 |
| HD | 43 | LUNCA CERNII | | | | 1 | 3 | 25 |
| HD | 25 | BATRANA | DS HUNEDOARA | 8 | 5 | 3 | 3 | 12 |
| HD | 54 | BORASCU GODEANU | | | | 3 | 1 | 0 |
| HD | 59 | RAUL BARBAT | | | | 5 | 3 | 11 |
| HD | 4 | BIRTIN | | | | 0 | 6 | 14 |
| HD | 23 | TISA | | | | 1 | 3 | 23 |
| HD | 60 | VALEA STREIULUI | | | | 3 | 1 | 10 |
| HD | 34 | GODEANU | | | | 3 | 1 | 2 |
| HD | 55 | RETEZAT | | | | 0 | 0 | 0 |
| HD | 62 | CAMPUSEL | | | | 4 | 1 | 0 |
| HD | 13 | VORTA | | | | 0 | 5 | 13 |
| HD | 42 | BALEA | RPL Ocolul Silvic Ținutul Pădurenilor | 0 | 0 | 0 | 6 | 19 |
| HD | 38 | VALEA ROATEI | AVS DIANA HUNEDOARA | 0 | 0 | 1 | 15 | 20 |
| HD | 40 | RUNCU MARE | AVPS Corviniana HD | 1 | 2 | 2 | 16 | 25 |
| HD | 41 | GHELARI | | | | 0 | 10 | 25 |
| HD | 63 | DEALU MARE | | | | 5 | 5 | 5 |
| HD | 64 | SIGLAU | AVPS Băniceana | 2 | 2 | | | 10 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| HD | 65 | VULCAN | AVPS Şoimul Românesc | 0 | 0 | 0 | 3 | 10 |
| HD | 24 | LAPUGIU | | | | | | 15 |
| HD | 6 | RIBITA | AVPS Muflonul Brad | 0 | 2 | 5 | 18 | 73 |
| HD | 5 | VALEA LUNGA | | | | 0 | 15 | 15 |
| HD | 1 | TOMESTI | AV Cota Zero | x | x | 1 | 14 | 14 |
| HD | 56 | RAUL ALB | AVPS Ursul Brun Retezat | 1 | 2 | 0 | 4 | 7 |
| HD | 58 | MARGINEA | | | | 7 | 6 | 18 |
| HD | 51 | CARNESTI | AV Vodas Reghin | 0 | 0 | 1 | 3 | 6 |
| HD | 14 | BRANISCA | AVPS Acvila Chiscadaga | 0 | 0 | 0 | 10 | 18 |
| HD | 15 | VALISOARA | AV Rex Băiţa | x | x | 0 | 7 | 7 |
| HD | 46 | CIULA MICA | AVPS Lopătarul 2011 | 0 | 0 | 1 | 12 | 18 |
| HD | 44 | HUNEDOARA | AVPS Căpăţâna | 1 | 1 | 2 | 10 | 20 |
| HD | 50 | URSICI | | | | 5 | 10 | 26 |
| HD | 53 | RAUL MARE | OS Retezatul Clopotiva - Rau de Mori srl | 0 | 0 | 4 | 4 | 10 |
| HD | 3 | CIUNGANI | AVPS Cerbul Carpatin Deva | x | x | 1 | 8 | 12 |
| HD | 45 | VALEA FIERULUI | AVPS VIDRA Buc. | 1 | 1 | 6 | 8 | 28 |
| MH | 6 | PODENI | AVPS CORADO | 1 | 1 | 2 | 4 | 9 |
| MH | 7 | ISVERNA | AJVPS MEHEDINŢI | 1 | 1 | 0 | 3 | 3 |
| MH | 11 | BALA | | | | 0 | 3 | 10 |
| MH | 8 | OLANUL | AVPM ACVILA CERENI | x | x | 0 | 0 | 0 |
| MH | 9 | CERNISOARA | | | | 0 | 0 | 0 |
| MH | 10 | BAIA DE ARAMA | | | | 0 | 3 | 7 |
| TM | 20 | BARA | Asociaţia Cacit Venatum | x | x | 0 | 12 | 13 |
| TM | 22 | BETHAUSEN | AVP Artemis Mănăştiur | | | 0 | 8 | 30 |
| TM | 25 | CURTEA | | | | 0 | 6 | 7 |
| TM | 34 | NEVRINCEA | | | | 0 | 6 | 4 |
| TM | 23 | FAGET | AJVPS TIMIS | 1 | 3 | 0 | 8 | 15 |
| TM | 27 | LUNCANI | | | | 6 | 3 | 20 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| TM | 30 | TRAIAN VUIA | | | | 0 | 6 | 15 |
| TM | 19 | PANIOVA | | | | 2 | 8 | 30 |
| TM | 28 | NADRAG | AV Căpriorul Nădrag | x | x | 2 | 6 | 17 |
| TM | 21 | OHABA | Asociaţia de Vânătoare Valea lui Liman - Făget | 0 | 0 | 0 | 10 | 36 |
| TM | 15 | ALIOS | | | | 10 | 10 | 40 |
| TM | 26 | POIENI | Asoc. Banat Jagd | 1 | 2 | 2 | 6 | 15 |
| TM | 29 | SURDUC | DS TIMIS | 1 | 4 | 0 | 5 | 15 |
| TM | 31 | DRANOVA | | | | 0 | 4 | 15 |
| TM | 32 | TAPIA | | | | 0 | 4 | 10 |
| TM | 33 | VALEA LUNGA | | | | 0 | 2 | 15 |
| TM | 24 | MARGINEA | | | | 0 | 5 | 20 |
| | | | **TOTAL** | **47** | **85** | **433** | **1290** | **3564** |

# LIFECONNECT

**Enhancing landscape connectivity for brown bear and wolf through a regional network of NATURA 2000 sites in Romania**

## ANALYSIS OF TRACKS RECORDED DURING SINGLE SURVEYS

***- report -***


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## BACKGROUND

Animal signs recorded on transects is one of the most common wildlife survey methods employed worldwide. Sign surveys are an effective and cheap method for evaluating the spatial distribution of a species, as well as for assessing the differences in relative abundance between areas of interest (for example through indices such as the Kilometric Abundance Index, KAI). Track sign surveys are widely used in Romania for yearly evaluations of wildlife population abundances, due to their ease of implementation relative to methods such as camera traps or DNA surveys. Yet, the type and amount of information yielded by sign surveys, and assumptions related to the statistical analysis of track data may limit their usefulness in wildlife management, particularly for detecting population trends or for setting harvest quotas. Fundamentally, tracks can be a poor indicator of absolute abundance, especially for species that live in groups or occur at higher densities, such as ungulates. This particularly problematic if surveys are performed once, because imperfect detection, one of the most prominent issues in wildlife ecology, biases the estimates of abundance (e.g., only a pair of individuals crossed a given transect and were recorded, while the 'true' abundance could be double or triple at a given site) or occupancy of a site (e.g., a species was not detected during the survey, despite the fact that it occupies a given site or habitat).

Although not as information-rich as abundance or density estimates, estimating the probability of occurrence of species as a function of habitat or other variables, is a key quantity commonly used in wildlife ecology. Evaluating the probability of occurrence is valuable in that it can identify animal – habitat relationships using advanced statistics, and can directly inform management about actions required to increase habitat quality, or address threats to species persistence. Track surveys are a common source of data used to quantify the probability of occurrence for a given species, and to identify species interactions; for example, *do competitor species occur in the same area*? or *does the presence or abundance of prey species influence the occurrence of predators*? Conventional occupancy modeling which draws inferences about occupancy or abundance, are based on multiple, repeated surveys (e.g., repeated visits on a transect, repeated deployment of camera traps), thus accounting for imperfect detection in wildlife surveys (MacKenzie *et al.* 2002; Tyre *et al.* 2003). However, many wildlife monitoring surveys consist of single visits to a site, which do not account for imperfect detection (for example, the fact that a species was not detected was due to the species being truly absent, or because the species was not detected during the survey?). To help with this dilemma, recent advances in biostatistical modeling have brought to the forefront modeling techniques that can deal with detection issues using single surveys. These methods require large sample sizes (e.g., large number of sites surveyed) and are suitable for drawing inferences over large areas; the first implementations were for the province of Alberta, Canada (www.abmi.ca), and for the Canadian Boreal Avian Monitoring project (www.borealbirds.ca), across areas spanning 100,000's of $km^2$.

The goal of this study was to evaluate the use of single-visit track sign surveys as a viable monitoring method for carnivores and their prey base in the Western Carpathians. We focused on 4 predator species: wolf (*Canis lupus*), Eurasian lynx (*Lynx lynx*), fox (*Vulpes vulpes*), and wildcat (*Felis sylvestris*), and 4 prey species: red deer (*Cervus elaphus*), roe deer (*Capreolus capreolus*), wild boar (*Sus scrofa*), and hare (*Lepus europaeus*). The survey period corresponded to the hibernation period for brown bear (*Ursus arctos*), so track recordings were only accidental. Two other non-target species, badger (*Meles meles*) and marten (*Martes martes*)

Specifically, our study had the following objectives:

- To evaluate the spatial distribution of carnivore and ungulate species during winter
- To evaluate the relative abundance of carnivores and ungulates and compare across target areas
- To evaluate the probability of occurrence of carnivores and ungulates
- To identify environmental factors (both natural and human) affecting the distribution of carnivores and ungulates

## METHODS

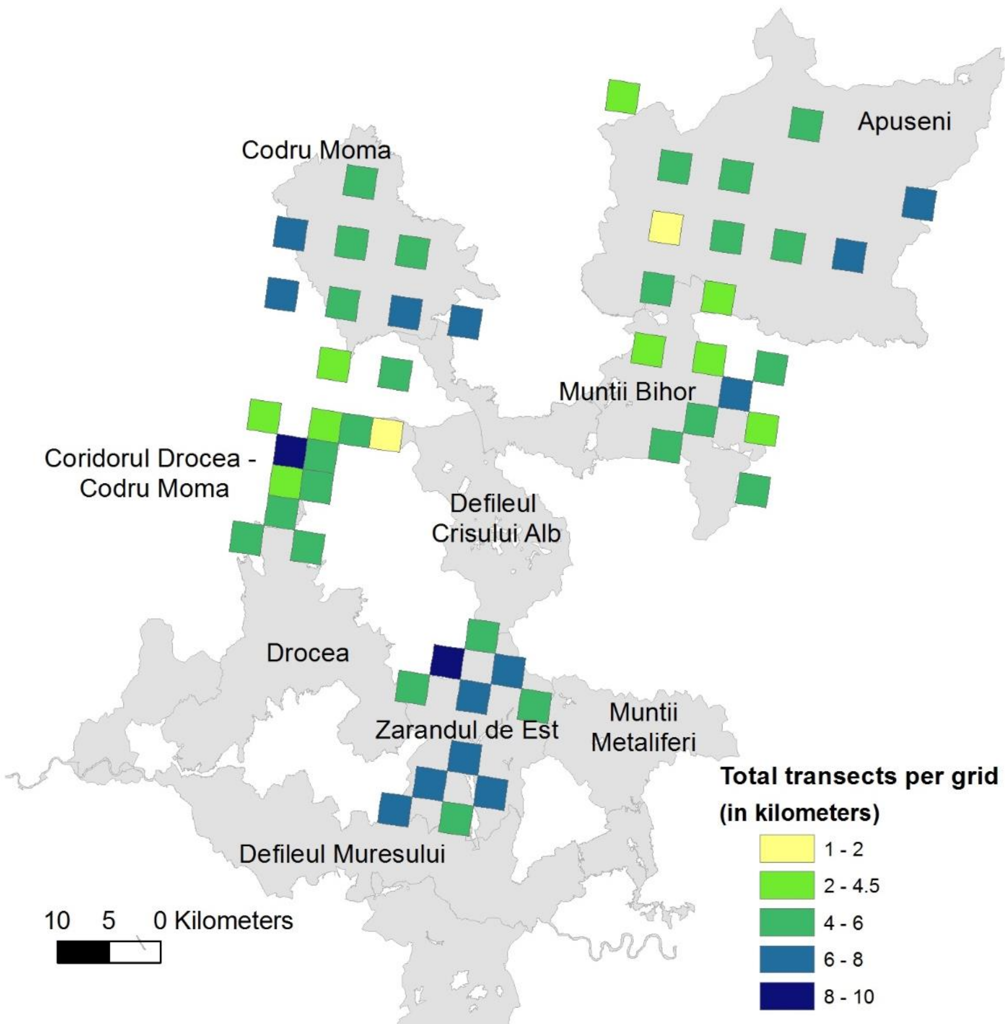
### Field surveys

We performed surveys for animal tracks on snow on forest roads and accessible trails between 3 January and 28 March 2015. We targeted the northern and central part of the project area and visited 51 grid cells, encompassing 5 regions: SCI Zarandul de Est (n=11 grid cells), Drocea-Codru Moma Corridor (n = 11 grid cells), SCI Codru Moma (n=10 grid cells), SCI Muntii Bihor (n=10 grid cells), and Apuseni Natural Park (n= 9 grid cells). In each grid cell, we selected between 2 and 20 500-m transects (N = 568 transects across all grid cells for a total of 284 km of transects), which were searched for tracks once during the sampling season. The mean number of kilometers per grid cell was 5.65 ± 0.22 km. Within each grid cell, transects were equally divided between valley bottoms and ridges.

The length of transects per region: Apuseni (45.5 km); Bihor (50.5 km); Codru Moma (60.5 km); Drocea – Codru Moma Corridor (53.5); Zarandul de Est (78 km) (Figure 1).

During the surveys, we identified and recorded the number of tracks for each of the 8 target species, as well as survey conditions (snow cover), time and date of the survey, habitat type, and habitat disturbance. We also recorded tracks of dogs, people, and sheep, as an indicator of human presence.

**Figure 1.** *Survey effort (km of transects per grid).*




## DATA ANALYSIS

Prior to all analyses, we aggregated the track data for each species at the level of grid cell, resulting in a sample size of N = 51 for all subsequent analyses.

***Kilometric abundance index (KAI)*** – A simple method for evaluating the relative abundance of ungulates and carnivores is represented by the number of tracks recorded per kilometer of transect surveyed. While KAI estimated via direct observation of animals produces reliable abundance and density estimates for ungulates (for example, red deer in Spain (Acevedo *et al.*

2008)), using tracks on transects surveyed only once can only produce a relative index of abundance. We calculated KAI for tracks for the 8 target species, as well as all the other tracks identified during surveys: marten (*Martes martes*), badger (*Meles meles*), and feral dogs. One drawback of KAI calculated from a single survey is that they cannot accommodate the issue of variable detection probability across sites and across time. These issue become less important if the number of transects is high, the survey area is large, and surveys are conducted within a short sampling window.

We investigated differences in the KAI values for the target species between sampling regions: Zarandul de Est, Muntii Bihor, Apuseni Natural Park, Codru Moma, and Codru Moma-Drocea Corridor, using non-parametric Kruskal-Wallis tests (data did not meet assumprions of normality needed for parametric statistics) and examining boxplots.

***Probability of occurrence*** –We applied single visit occupancy models in program R, package *detect*, function *svocc* (Lele, Moreno & Bayne 2012; Sólymos, Lele & Bayne 2012) to the data collected on transects in 51 3x3 km grid cells in the central and northern part of LIFECONNECT project area (Figure XXX). Track count data for the 8 target species was aggregated at grid cell level was converted to presence/absence data. Because the survey effort differed across the grid cells, we modeled the probability of detection as a function of length of transects surveyed within a grid cell (*Length*). Also used the date of the survey, and mean altitude of transects (*Alt_mean*) within a grid cell to model detection. The best detection model for all species was the length of transects surveyed in each grid cell (*Length*). We subsequently used this detection model to build models for estimating the probability of occurrence of the 8 species for each grid cell; each species was modeled as a function of land use variables (percent of pasture and different types of forest in the grid cell), the presence of humans, and presence of prey or predator species (Table 2). For each species we only used variables that were ecologically and biologically meaningful (e.g., presence of prey species for carnivore models, presence of feral dogs for certain carnivores, and presence of food, cover, human disturbance, and feral dogs for ungulates).

We used a stepwise algorithm implemented via function *svocc.step* in package *detect* to identify the best predictors of occupancy from the set of variables selected each species. We used a *data cloning* optimization procedure with N=1000 clones for each model iteration, implemented in JAGS 3.4.0, a program for analysis of Bayesian hierarchical models using Markov Chain Monte Carlo (MCMC) simulation.

***Predictors of KAI*** – In addition to the occupancy analyses, which relate the presence of tracks to environmental features, thus presenting a coarse overview of wildlife presence in the project area, we used generalized mixed effects models (Pinheiro & Bates 2000) to identify predictors for relative abundance of the 8 target species. Similarly to occupancy analyses, we developed models for each species individually, based on potential variables that could influence the local abundance of animals (Table 3). For each species we only used variables that were ecologically and biologically meaningful (e.g., presence of prey species for carnivore models, presence of food and cover for ungulates). We used *Region* (the 5 regions targeted for sampling) as a random effect in order to account for latent variation in the data (variation that cannot be accounted for) as (*1* | *Region*).

***Spatial analyses*** – We used the KAI metric and performed a hot-spot analysis using the Getis-Ord Gi statistic to identify contiguous clusters of relative abundance of carnivore and ungulate species higher or lower than expected (Ord & Getis 1995). The Getis-Ord Gi statistic uses the local matrix of grid cells to identify aggregations of high and low relative abundance by assigning Z-scores to each grid cell (Z-scores >1.96 denote significant hot spots of high animal abundance grid cells). We computed Getis-Ord Gi Z-scores in ArcGIS 10 (ESRI, Redlands, CA) using a threshold of 8.5 km, in order to assess each grid cell in relation to its closest neighboring grid cells.

## RESULTS

### 1) Kilometer Abundance Index (KAI)

We recorded 3482 tracks for all 8 target species throughout the study period. Roe deer and wild boar tracks were most common: 1192 and 1085 total tracks. Eurasian lynx had the fewest number of tracks (N=16), and we recorded brown bear tracks during 8 surveys. The Kilometric Abundance Index values for the 8 species in 51 grid cells are given in Annex I.

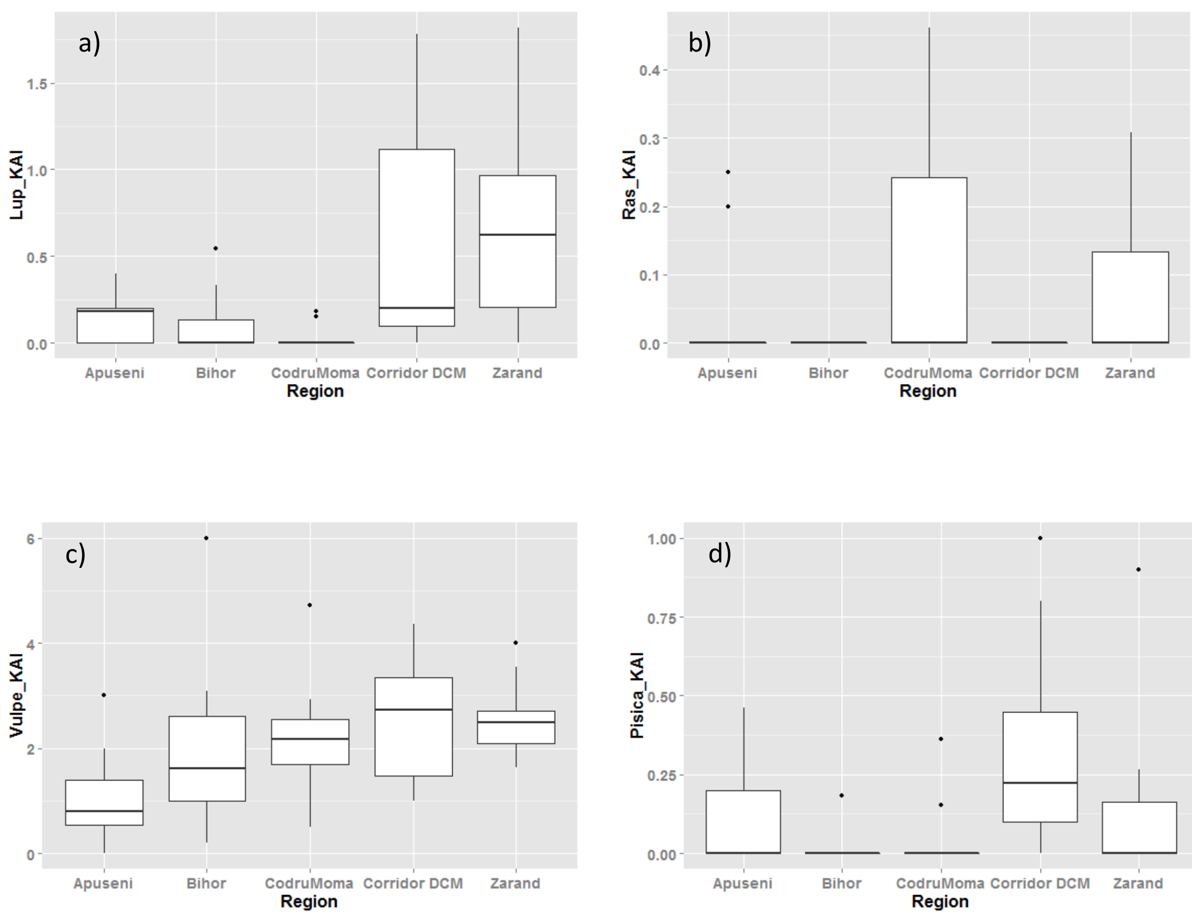
***Differences in KAI between target areas –*** We evaluated differences in KAI between the 5 regions for each species using non-parametric Kruskal-Walis tests and boxplots. Kruskal-Wallis tests were significant (p-values <0.05), suggesting that there were differences in KAI between the 5 areas (at least one area different from all the other ones) for all 8 species (Figure 1; Table 1).

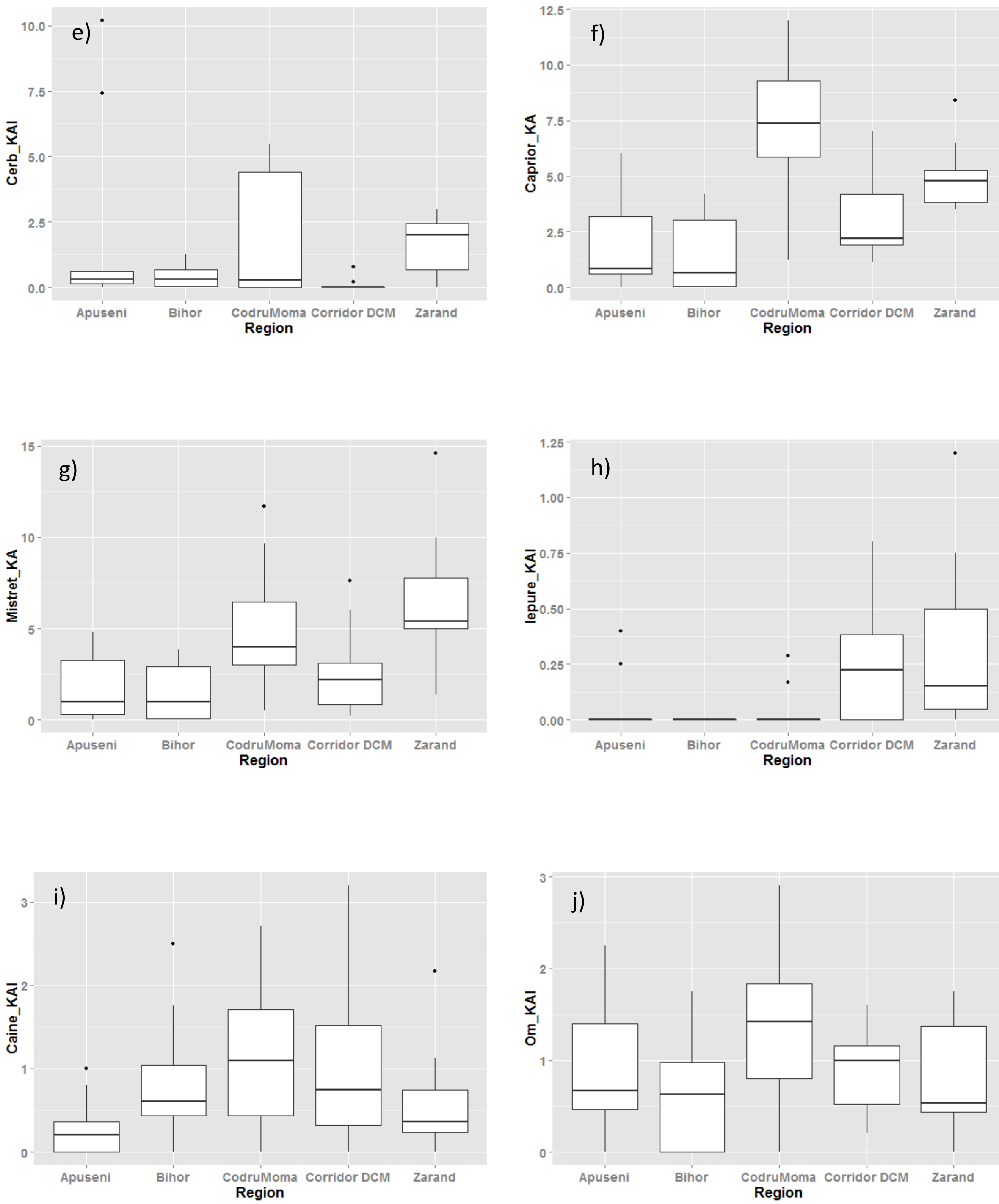
- *Canis lupus* – Relative abundance of wolf tracks was highest in Zarand, followed by the Drocea - Codru Moma Corridor (Figure 2a).
- *Lynx lynx* – Relative abundance of wolf tracks was highest in Zarand and Codru Moma (Figure 2b).
- *Vulpes vulpes* – Relative abundance of fox tracks was fairly similar across the 5 regions, but Apuseni had the lowest abundance, and Zarand had the highest abundance (Figure 2c).
- *Felis sylvestris* – Relative abundance of wildcat tracks was greatest in the Drocea – Codru Moma Corridor (Figure 2d).

- *Cervus elaphus* – Relative abundance of red deer tracks was greatest in Zarand, as well as Codru Moma (Figure 2e).
- *Capreolus capreolus* – Relative abundance of roe deer tracks was highest in Codru Moma, and lowest in Apuseni and Bihor (Figure 2f).
- *Sus scrofa* – Relative abundance of wild boar tracks was greatest in Codru Moma and Zarand (Figure 2g).
- *Lepus europaeus* – Relative abundance of hare tracks was greatest in the Drocea – Codru Moma Corridor, and hare tracks were not recorded in Bihor (Figure 2h).

In addition, the relative abundance of ***dog*** tracks was lowest in Apuseni, and highest in Codru Moma (Figure 2i); ***human presence*** was most prevalent in Codru Moma, but all areas showed significant signs of human disturbance (Figure 2j).

**Figure 2.** *Differences in relative abundance of tracks (KAI, Kilometric Abundance Index) between 5 survey areas in the Western Carpathians.*

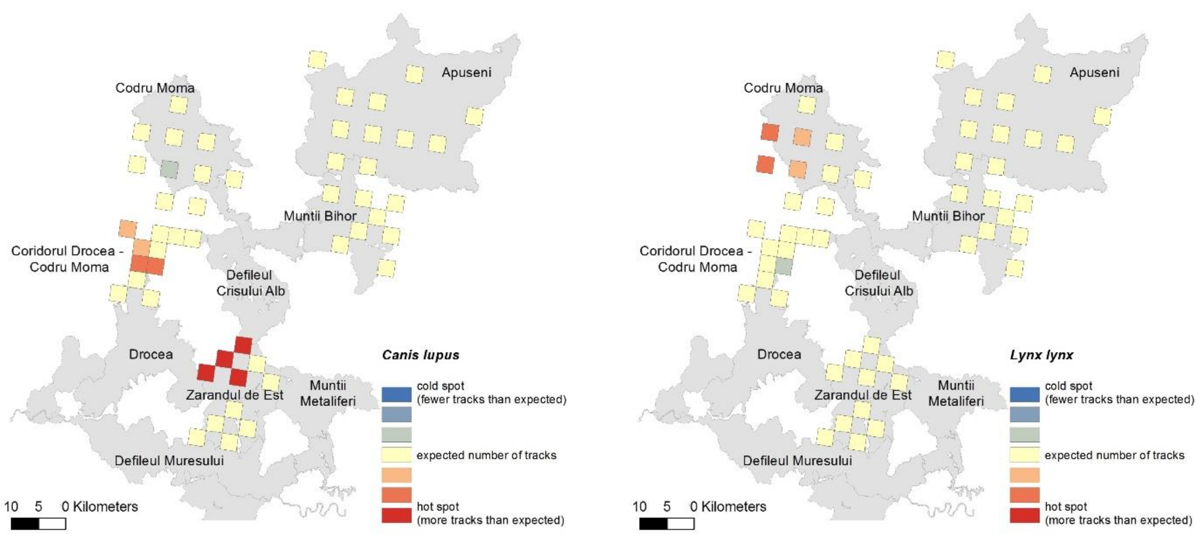


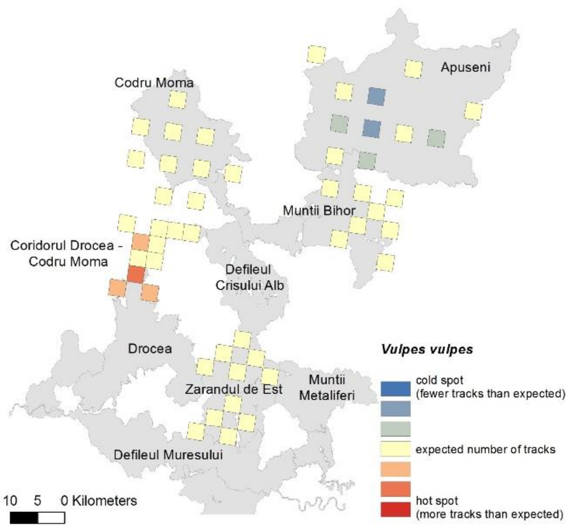

e)
Cerb_KAI
Region
Apuseni
Bihor
CodruMoma
Corridor DCM
Zarand
f)
Caprior_KA
g)
Mistret_KA
h)
Iepure_KAI
i)
Caine_KAI
j)
Om_KAI

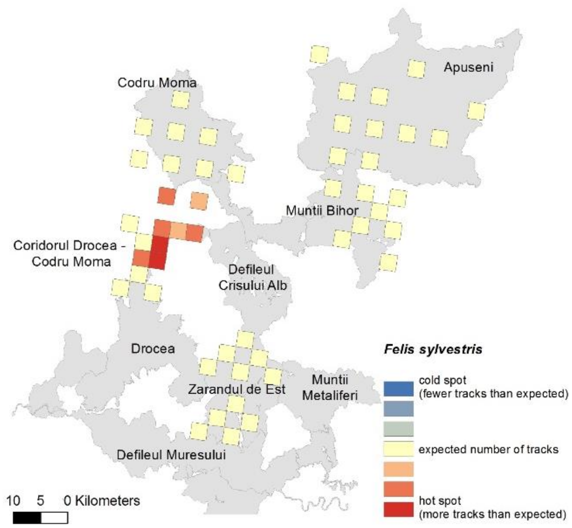
2) **Spatial distribution of wildlife species**

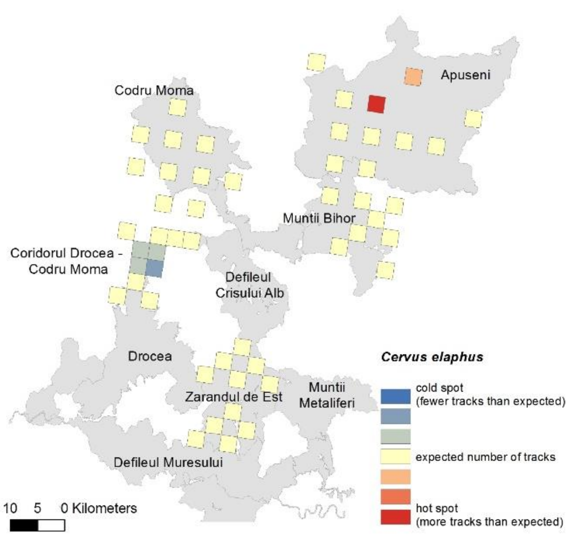
The Getis-Ord hot spot analysis complemented the results of the Kruskal-Wallis tests, and identified areas with greater than expected abundance of tracks (Figure 3), and offered a more detailed examination of the spatial distribution of relative track densities within surveyed regions. For example, ***wolf*** relative abundance was highest in northern Zarand and central part of the Drocea – Codru Moma Corridor. ***Lynx*** distribution was relatively uniform across the project area, with the exception of northern Codru Moma. There was lower than expected relative abundance of ***roe deer*** in the northwestern part of Bihor, and lower than expected abundance of ***red deer*** in the central part of Drocea – Codru Moma Corridor. For ***wild boar***, fewer than expected tracks were recorded in NW Bihor, and higher than expected counts in southern Zarand and northern Codru Moma.

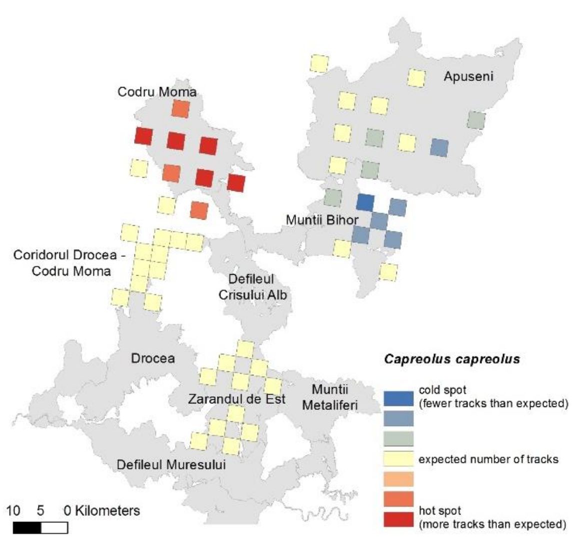
**Figure 3.** *Hotspots of relative abundance of tracks (KAI, Kilometric Abundance index) in 5 regions in the Western Carpathians. The radius for evaluating hot spots was 8.5 km, to include at least 4 nearby grid cells.*

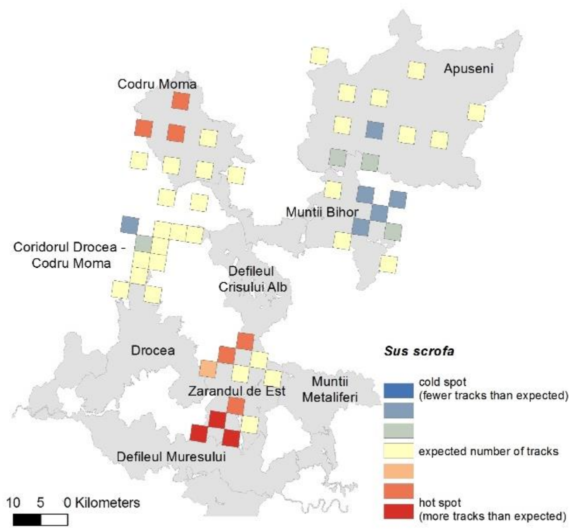


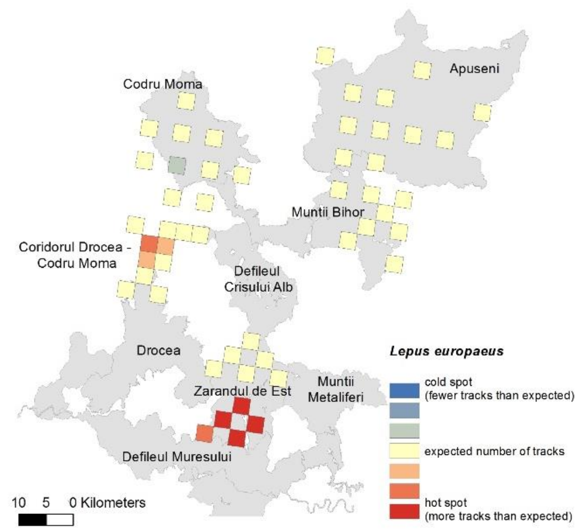

Apuseni
Codru Moma
Muntii Bihor
Coridorul Drocea -
Codru Moma
Defileul
Crisului Alb
Drocea
Zarandul de Est
Muntii
Metaliferi
Defileul Muresului
10 5 0 Kilometers
Vulpes vulpes
cold spot
(fewer tracks than expected)
expected number of tracks
hot spot
(more tracks than expected)


Apuseni
Codru Moma
Muntii Bihor
Coridorul Drocea -
Codru Moma
Defileul
Crisului Alb
Drocea
Zarandul de Est
Muntii
Metaliferi
Defileul Muresului
10 5 0 Kilometers
Felis sylvestris
cold spot
(fewer tracks than expected)
expected number of tracks
hot spot
(more tracks than expected)


Apuseni
Codru Moma
Muntii Bihor
Coridorul Drocea -
Codru Moma
Defileul
Crisului Alb
Drocea
Zarandul de Est
Muntii
Metaliferi
Defileul Muresului
10 5 0 Kilometers
Cervus elaphus
cold spot
(fewer tracks than expected)
expected number of tracks
hot spot
(more tracks than expected)


Apuseni
Codru Moma
Muntii Bihor
Coridorul Drocea -
Codru Moma
Defileul
Crisului Alb
Drocea
Zarandul de Est
Muntii
Metaliferi
Defileul Muresului
10 5 0 Kilometers
Capreolus capreolus
cold spot
(fewer tracks than expected)
expected number of tracks
hot spot
(more tracks than expected)




***Species richness*** – Based on the raw number of tracks, the highest species richness (10 species out of 11: ***8 target species*** plus ***brown bear, badger*** and ***marten***) was in southern Zarand (Figure 4).

Relatively high species richness was recorded in the Drocea – Codru Moma Corridor, and a small number of grid cells in Apuseni (Figure 3). Very low richness was recorded in northern Bihor and southern Apuseni. However, the low species richness recorded in some areas of Apuseni and Bihor is likely due to lower levels of effort (km per transects) in those particular grid cells (Figure 1). We further analyzed the relation between the length of transects per grid and the number of species detected; we found that survey effort was a significant predictor, and positively correlated with the number of species detected (Figure 5a; $R^2 = 0.313$).

There were differences between the 5 regions in the strength of the relationship between effort and number of species detected. The relation was weak for the Drocea – Codru Moma Corridor, and strongest for Apuseni, Bihor and Codru Moma (Figure 5b).

**Figure 4.** *Species richness from raw track count data.*

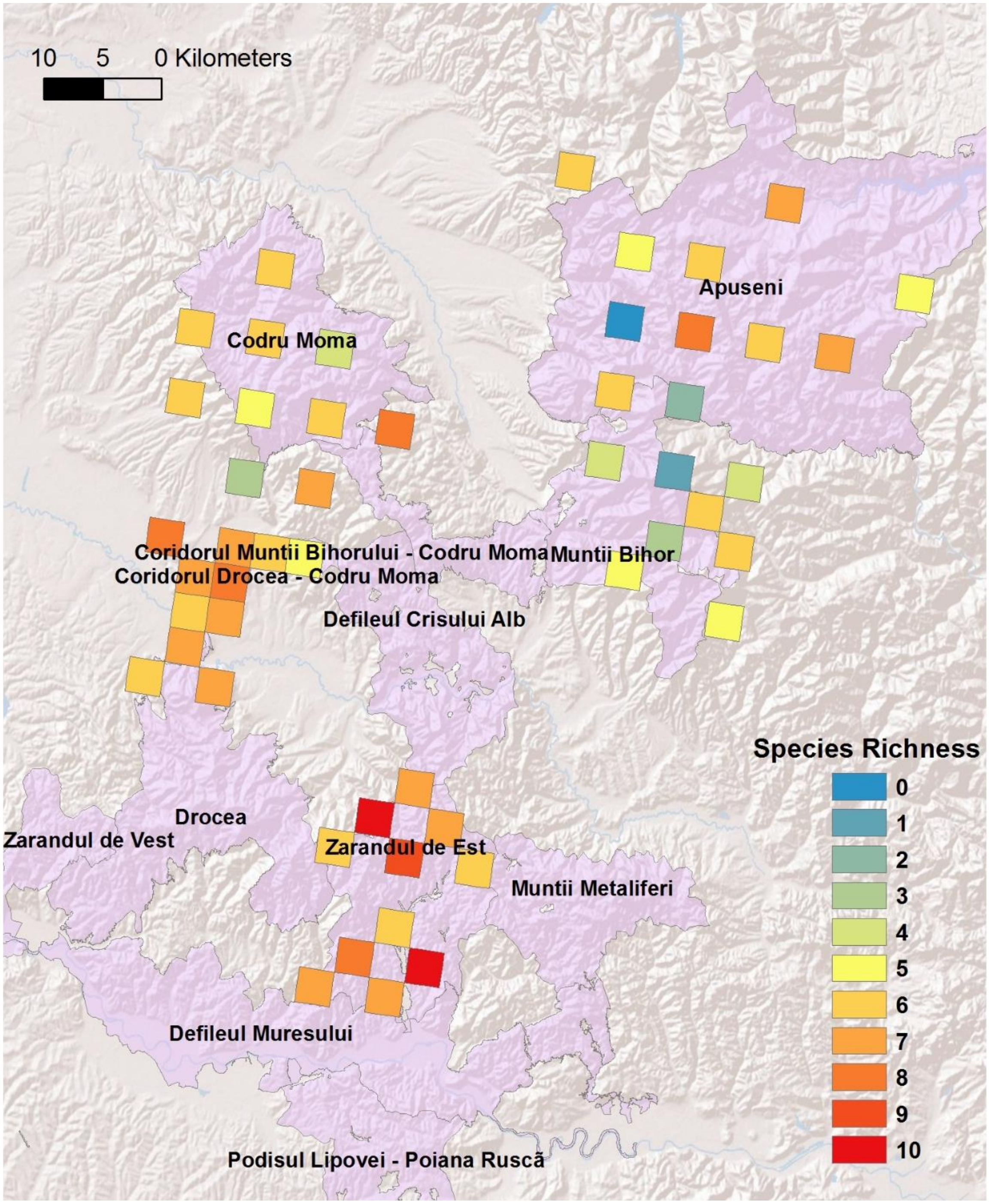
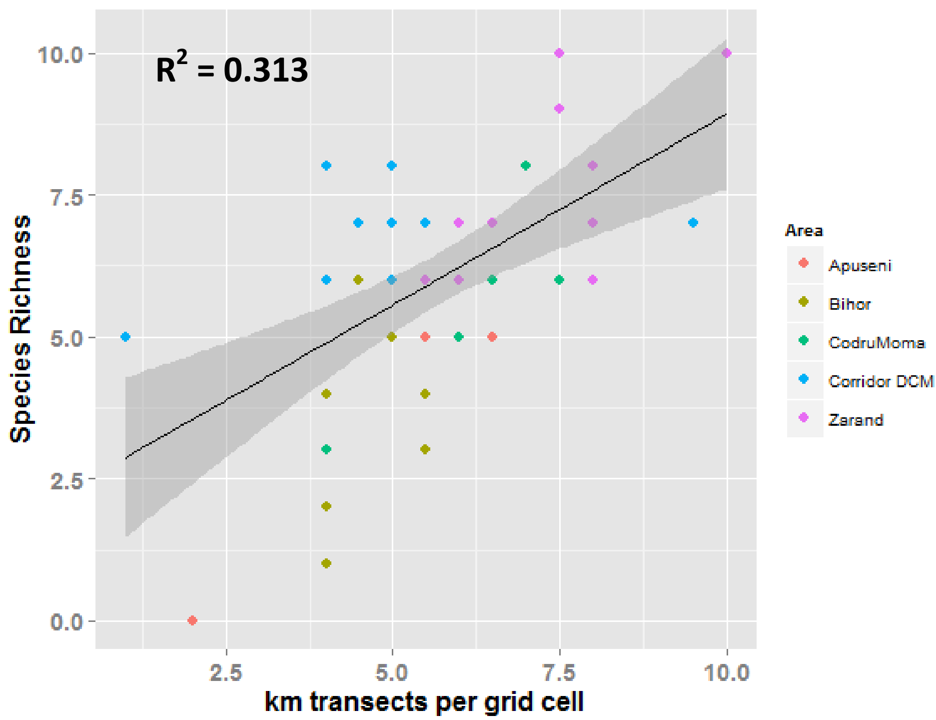
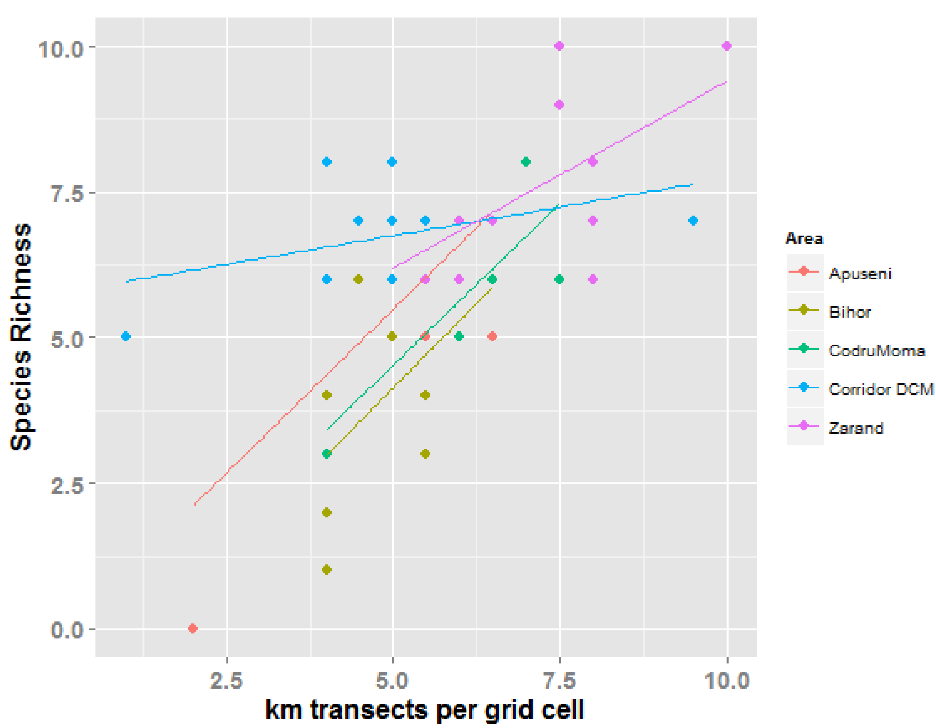


**Figure 5.** *Species richness per grid cell versus survey effort.*




a)




b)

3) **Occupancy modeling**

Three species (***wild boar, fox***, and ***roe deer***) occurred in >90% of the grid cells, and were not suitable for the occupancy modeling framework. The best predictor for detecting tracks (for any of the 8 target species) was the length of transect surveyed in a given grid cell (*Length*), but it was significant only for ***wolf*** and ***lynx***. We incorporated imperfect detection via variable *Length* in the single-survey occupancy models, we identified predictors for the occurrence of 5 target species. Overall, the models had good predictive ability (AUC>0.7; Table 2).

For several species, the analysis yielded significant predictors of occurrence (Table 2):

- *Canis lupus* occurrence had a positive association with relative abundance of red deer, and a negative association with and mean altitude, abundance of roe deer and wild boar. Detection of wolf tracks was high (0.818), and wolves were predicted to occur in 67% of grid cells.
- *Lynx lynx* occurrence had a positive association with the proportion of mixed forests in the grid cell, and a lower probability of detection (0.429).
- *Felis sylvestris* occurrence had a negative association with the relative abundance of feral dogs, mean altitude and proportion of deciduous forests within the grid cell, and a relatively high detection probability (0.638).
- *Cervus elaphus* occurrence had a negative association with the proportion of pastures in the grid cell and with the relative abundance of feral dogs. Detection of red deer was high (0.879).
- *Lepus europaeus* occurrence was not significantly influenced by environmental variables, and had a relatively high probability of being detected on transects (0.664).

4) **Predictors for KAI**

There was considerable variation in the Kilometric Abundance Index between regions (Table 1), as well as within regions for all species. All target species were considered in the analysis, and we found one or more variables explaining

- *Canis lupus* relative abundance had a positive association with the relative abundance of red deer (*Cervus elaphus*) and percent pasture in grid cell, and a negative association with and mean altitude, and abundance of roe deer (*Capreolus capreolus*).
- *Lynx lynx* relative abundance had a positive association with the relative abundance of roe deer (*Capreolus capreolus*).
- *Felis sylvestris* relative abundance was not significantly influenced by either habitat variables or prey presence.
- *Vulpes vulpes* relative abundance had a positive association with the relative abundance of hares (*Lepus europaeus*).

- *Cervus elaphus* relative abundance was not significantly influenced by either habitat variables or presence of feral dogs.
- *Capreolus capreolus* relative abundance had a positive association with the percent of deciduous forest in the grid cell.
- *Sus scrofa* relative abundance had a positive association with the percent of deciduous forest in the grid cell, and a negative association with feral dogs.
- *Lepus europaeus* relative abundance had a positive association with the percent of mixed forest and the percent of pasture in the grid cell, and a negative association with mean altitude.

**SUMMARY**

**Lessons learned about detecting species:**

- The number of species detected was proportional to the amount of effort in any given (more km of transects = more species detected in a grid cell; Figure 5a); However, this relation was not strong in the Drocea-Codru Moma Corridor, where the number of species detected increased only slightly with the survey effort (Figure 5b). Apuseni, Codru Moman and Bihor had a similar increase in species detected with increasing effort (Figure 5b).
- Detecting signs of target species in a single survey (when accounting for the level of effort in a given cell) was high for ***wolf*** and ***red deer*** (>0.8; Table 2), as well as for ***wild boar***, ***fox***, and ***roe deer*** (species found on >90 of transects). ***Lynx*** had the lowest detection probability (<0.4).
- Detection of ***wolf*** in a grid cell had a significant positive association with the length of transects in that grid cell.

**Lessons learned about occurrence of target species (Table 2):**

- ***Wild boar***, ***roe deer*** and ***fox*** were ubiquitous (occurred in >90% of grid cells) and their occurrence could be related to any environmental or human foot print variables.
- The relative abundance of ***feral dogs*** had a significant negative effect on the occurrence of ***red deer*** and ***wildcat***.
- Overall, the mean altitude of the grid cell had a negative effect on the occurrence of the majority of species
- Habitat variables influenced occurrence of target species to a lesser extent

**Lessons learned about the predictors of relative abundance (KAI) (Table 3):**

- The relative abundance of carnivores was associated with the relative abundance of prey species: ***lynx*** was positively associated with abundance of ***roe deer***; ***fox*** was positively associated with abundance of ***hare***, and ***wolf*** was positively associated with abundance of ***red deer***.
- The relative abundance of ***feral dogs*** had a negative effect of the relative abundance of both carnivores and herbivores: ***lynx***, ***wildcat***, ***red deer***, ***wild boar*** (significant effect), and ***hare***.
- Habitat variables influenced the relative abundance of target species to a lesser extent

**Distribution of species within the survey areas:**

- Hotspot analysis revealed higher than expected relative abundance of several meso-predator species in the Drocea-Codru Moma Corridor: ***fox, wildcat, badger***, and ***marten*** (Figure 3 and Annex I). This is consistent with the meso-predator release hypothesis. Although wolves have been recorded in the area (also higher than expected abudance of wolves), it is likely that they are only transiting the area, and that the corridor is not part of permanent ranges of woof packs. At the same time, the corridor had least than expected ***red deer***.
- Zarand had higher than expected abundance of ***wolf*** (in the northern part), as well as ***wild boar*** and ***hare***.
- Relative abundance of animals was always at expected values or less than expected (for ***fox***, ***roe deer*** and ***wild boar***) in Apuseni and Bihor.

**Recommendations for future sign transect surveys:**

- The survey effort should be as balanced as possible across grid cells, especially when performing single surveys (detecting species was directly correlated with length of transects, so comparisons between areas could be biased by the different levels of effort).
- Track counts can only yield results on the relative abundances of animals; these values should not be used decisions of regulated hunting.
- Increasing survey effort to 6-7 km per grid cell (during the study period) will result in detecting the majority of the species present in that particular grid cell

## ALTERNATIVE MONITORING METHODS

For wildlife species in general, and large mammals in particular, monitoring methods for evaluating abundances and densities, and for detecting population trends can be divided into 2 classes: methods that use ***marked*** animals (animals tagged or with unique identifiable patterns are captured, and subsequently recaptured; for example, genetic surveys, camera traps for species with unique patterns), and methods that use ***unmarked*** animals (animals that cannot be individually recognized; for example, via camera traps, sign surveys, pellet counts). The fundamental difference between the 2 classes of monitoring methods is that analyzing data on ***marked*** animals can yield estimates of *absolute abundance*, while analysis of ***unmarked*** animals can only yield inferences on *relative abundance*. However, statistical methods applied to data from both marked and unmarked animals have to comply with specific statistical requirements, and will yield uncertainties (confidence intervals) around estimates. The accuracy and precision of abundance estimates, as well as the range of uncertainty depend on the robustness of the data (large sample size is better, sampling is performed spatial resolutions that are relevant to the biology of the species) and the statistical method. In very rare cases (for small populations or reintroduced populations), it is possible to obtain a full account of the animals in the population; for the target species of LIFECONNECT, large carnivores and their prey basis, this is not possible, thus reporting single abundance estimates (the traditional way of reporting wildlife data) is incorrect.

For large carnivores, DNA-based studies provide the best inference on animal abundance and density. Individuals can be identified from genetic samples (***marked*** animals), and along with the spatial location of the samples, such data can be reliably analyzed in a spatial capture-recapture framework (Kéry *et al.* 2010; Royle *et al.* 2013). In contrast, methods that are based on ***unmarked*** animals, such as signs (tracks, scat, and urine) or camera traps (for cases when individuals cannot be identified) are less reliable, or require a high level of effort (repeated visits on transects, repeated deployment of camera traps). New advances in occupancy modeling allow for estimating densities from sign surveys for both ungulates (Gopalaswamy *et al.* 2012) and carnivores (Hines *et al.* 2010; Karanth *et al.* 2011), and these methods have to be implemented across broad spatial scales. The key point with methods based on unmarked animals is that if detection of individuals is low, the number of repeat visits, thus effort, increases considerably. Augmenting data from unmarked animals with telemetry data can improve the estimates of abundance .

**1) CARNIVORES.** Available methods for carnivore monitoring that can be deployed within LIFECONNECT are: genetic surveys using scat and hair snags (***marked*** animals), and track surveys (multiple repeats per transect) and camera traps (***unmarked*** animals).

- **Genetic surveys –** Monitoring for both brown bear and wolf will be focused on gathering data on individual (***marked***) animals using scat and hair traps (for brown bear only). Collecting wolf scats can be done opportunistically throughout the year, but will likely be most productive during winter, when field crews can follow wolf tracks and identify signs (fresh scat, urine or saliva). Genetic surveys for bears are implemented during winter (October-December) to meet the assumption of population closure (no new individuals added to the population) required by capture-recapture analyses. The low abundance of bears in the project areas poses several problems for gathering genetic data through the two methods available: scat and hair snags. Bear scat surveys will be focused on areas of higher density (Retezat-Tarcu and Bihor-Apuseni), but not in the central part of the project area. Baited hair snags are more effort-intensive compared to collecting scats, but will be necessary to attract bears in low density areas to address questions related to population structure and relatedness (see the *LIFECONNECT Genetic monitoring protocol* for details on planned genetic surveys).

- **Repeated track surveys on transects** during a short sampling period (for example, 3-4 repeat visits within 4-6 weeks; see (Pop *et al.* 2013)) are a feasible monitoring technique for ***brown bears only***, but estimating absolute abundance and density is more problematic, as they rely on assumptions of known home range areas. Repeated visits require high levels of effort (compared to single visits), and ideally are conducted in good conditions (immediately after fresh snow). Thus, within LIFECONNECT, repeated surveys for identifying tracks on snow can only be conducted in high altitude areas (Retezat-Tarcu). Repeated track surveys for bears could be implemented in Retezat-Tarcu to allow a comparison with density estimates from genetic surveys.

- **Camera traps** can be used in conjunction with hair snag traps or at known feeding sites (for ***brown bears***), or at rendez-vous sites (for ***wolves***). Deploying cameras for evaluating presence/absence or abundance of bears necessary for occupancy-type modeling (see details on a similar monitoring protocol for ***Prey species*** below), particularly in low density areas, will likely have low success of detecting animals (based on similar studies from Eastern Carpathians), and it is not recommended for evaluating abundances and densities of carnivore populations.

**2) PREY SPECIES.** To understand the distribution of carnivores relative to the distribution of their prey species, available monitoring techniques for herbivores are: ***pellet counts***, ***snow track counts***, and ***camera traps***.

- **Pellet counts** are more time intensive than sign surveys on transects, but it is currently the most accepted method for monitoring ungulate populations across brad geographic areas. The most reliable estimates are based on repeated visits in which pellets are removed each visit in order to evaluate the pellet accumulation rates. The simplest pellet count method, which we recommend for LIFECONNECT are based on single visits, in which pellets are counted and their age is determined based on known decay rates. An ***index of ungulate relative density*** (***D***) can be calculated from the number of observed pellet groups on transects as:

*D = pellet group per km$^2$ / [decay (days) x daily defecation rate (pellet groups per days)]*

Pellet decay rates and defecation rates are readily available from other ungulate studies in the Carpathians. This method is useful in calculating relative densities of ***red deer, roe deer, wild boar*** and ***hare***.

- **Camera traps** could yield reliable estimates of relative abundance and occurrence if the number of detections is large enough. The method implemented in LIFECONNECT involved deploying 90 camera traps in 45 3x3 km grid cells for a period of 6 weeks (see *LIFECONNECT Protocol for monitoring ungulates using camera traps*). This period of time is then split in several intervals (similar to repeated visits of transects), and data is analyzed in an occupancy framework (thus incorporating imperfect detection; (MacKenzie & Royle 2005)). The level of effort involved is lower compared to pellet counts, and camera trapping could yield additional data on carnivore presence or abundance. The advantage of camera traps is that habitat data can be incorporated into the models, thus identifying predictors for abundance or occurrence. The significant drawback is that estimating animal densities from abundance estimates at camera is difficult, as the effective sampling areas around cameras are unknown. Moreover, camera trapping without baiting also misses important prey species such as ***hares***, and active methods, such as pellet counts are preferable to increase the amount of data gathered and addressing all prey species.

- **Repeated track surveys on transects** during a short sampling period (for example, 3-4 repeat visits within 4-6 weeks); by doing so, occupancy type models can provide better estimates of detection probability, resulting in more reliable estimates of relative abundances. Similarly to camera traps, the drawback is that estimating animal densities from abundance estimates on transects is difficult, as the effective sampling areas around transects are unknown. In addition, the statistical methods are very sensitive to large differences in counts on the same transect (for example, 5 roe deer tracks are recorded during the first visit, and 50 tracks during the second visit). In such cases, it is likely that an overall overestimation of relative abundances will occur. In addition, snowpack has to be long-lasting to allow for repeated surveys in good conditions (fresh snowpack).

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**Table 1.** *Mean Kilometric Abundance Index (and standard errors) for 8 species recorded from single surveys in 5 regions in Western Carpathians..*

| **Region** | ***Canis lupus*** | ***Lynx lynx*** | ***Vulpes vulpes*** | ***Felis sylvestris*** | ***Capreolus capreolus*** | ***Cervus elaphus*** | ***Sus scrofa*** | ***Lepus europaeus*** |
|---|---|---|---|---|---|---|---|---|
| Apuseni | 0.15 ± 0.05 | 0.05 ± 0.03 | 0.10 ± 0.30 | 0.10 ± 0.05 | 2.23 ± 0.73 | 2.15 ± 1.21 | 1.90 ± 0.59 | 0.07 ± 0.05 |
| Bihor | 0.11 ± 0.06 | 0.00 | 0.02 ± 0.54 | 0.02 ± 0.02 | 1.45 ± 0.54 | 0.41 ± 0.14 | 1.47 ± 0.49 | 0.00 |
| Codru Moma | 0.03 ± 0.02 | 0.12 ± 0.05 | 0.05 ± 0.35 | 0.05 ± 0.04 | 7.49 ± 1.01 | 1.93 ± 0.76 | 5.08 ± 1.09 | 0.05 ± 0.03 |
| Corridor DCM | 0.63 ± 0.22 | 0.00 | 0.34 ± 0.37 | 0.34 ± 0.10 | 3.18 ± 0.59 | 0.09 ± 0.08 | 2.54 ± 0.75 | 0.24 ± 0.08 |
| Zarand | 0.68 ± 0.17 | 0.08 ± 0.03 | 0.15 ± 0.22 | 0.15 ± 0.08 | 4.99 ± 0.46 | 1.62 ± 0.36 | 6.35 ± 1.17 | 0.33 ± 0.12 |

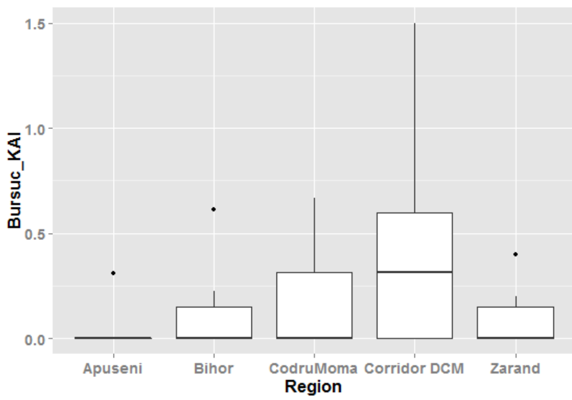
**Table 2.** *Results of occupancy modeling using single-surveys. The best variable for detection was the length of transects per grid cell (significant positive association for Canis lupus and Lynx lynx only). Variables in* ***bold*** *are significant predictors at α = 0.05. Occurrence probability is the predicted proportion of grid cell with animal occurrence. Detection probability is the probability of detecting a species during a single survey.*

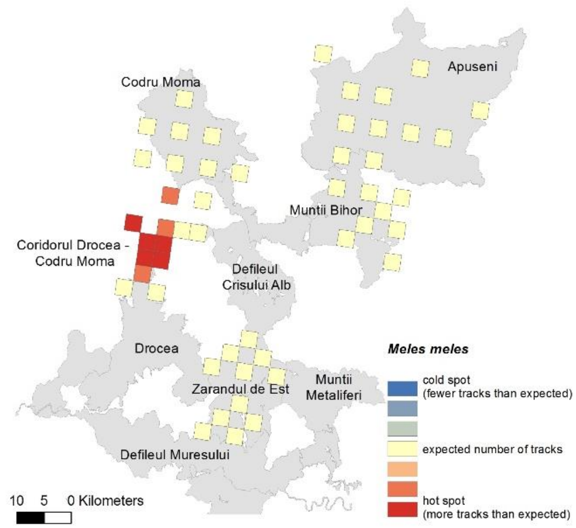
| **Species** | **# transects with tracks** | **Best Occupancy Model** | **Variable influence on occurrence** | **Occurrence probability (mean ± SE)** | **Detection probability (mean ± SE)** | **AUC of best model** |
|---|---|---|---|---|---|---|
| *Canis lupus* | 28 | Caprior_KAI + Cerb_KAI + Mistret_KAI + Alt_medie + Pasuni | **Cerb_KAI (+)**<br>**Caprior_KAI (-)**<br>**Mistret_KAI (-)**<br>Pasuni (+)<br>**Alt_medie (-)** | 0.673 ± 0.056 | 0.818 ± 0.044 | 0.917 |
| *Lynx lynx* | 11 | P_mixte + Lup_P + Caine_KAI + Iepure_KAI | **P_mixte (+)**<br>Lup_P (-)<br>Caine_KAI (-)<br>Iepure_KAI (+) | 0.495 ± 0.016 | 0.429 ± 0.037 | 0.757 |
| *Vulpes vulpes* | 50 | Not run (too fewer non-detections) | - | - | - | - |
| *Felis sylvestris* | 19 | P_foioase + Alt_medie + P_mixte + Iepure_KAI + Caine_KAI | **Alt_medie (-)**<br>**P_foioase (-)**<br>**Caine_KAI (-)**<br>P_mixte (-)<br>Iepure_KAI (-) | 0.595 ± 0.052 | 0.638 ± 0.009 | 0.776 |
| *Cervus elaphus* | 31 | Caine_KAI + Pasuni + Regenerare | **Caine_KAI (-)**<br>**Pasuni (-)**<br>Regenerare (+) | 0.706 ± 0.033 | 0.879 ± 0.038 | 0.837 |
| *Capreolus capreolus* | 47 | Not run (too fewer non-detections) | - | - | - | - |
| *Sus scrofa* | 47 | Not run (too fewer non-detections) | - | - | - | - |
| *Lepus europaeus* | 19 | Pasuni + P_conifere | Pasuni (+)<br>P_conifere (-) | 0.544 ± 0.040 | 0.664 ± 0.023 | 0.800 |

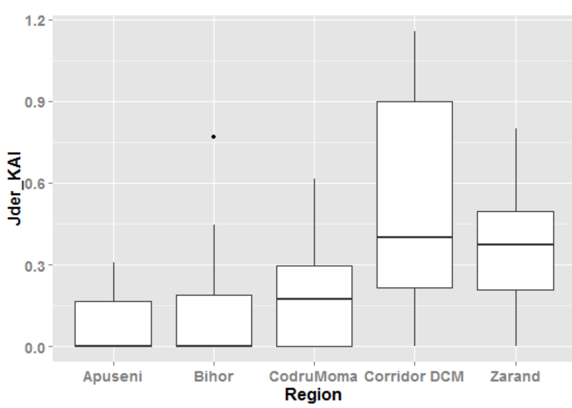
**Table 3.** *Results of generalized mixed models investigating environmental predictors of relative abundance of tracks (Kilometric Abundance Index, KAI).*

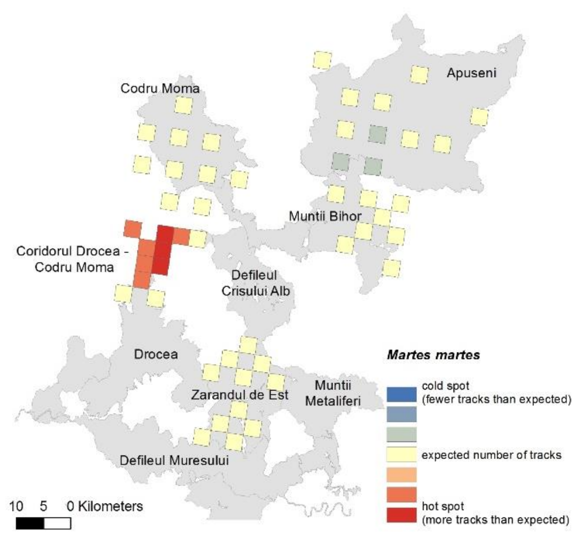
| **Species** | **transects with tracks** | **Best KAI Model** | **Variable influence on KAI** | **Predicted KAI (mean ± SE)** |
|---|---|---|---|---|
| *Canis lupus* | 28 | Caprior_KAI + Cerb_KAI + Mistret_KAI + Alt_medie + Pasuni | **Cerb_KAI (+)**<br>**Caprior_KAI (-)**<br>Mistret_KAI (+)<br>**Pasuni (+)**<br>**Alt_medie (-)** | 0.336 ± 0.041 |
| *Lynx lynx* | 11 | P_mixte + Lup_P + Caine_KAI + Caprior_KAI | P_mixte (+)<br>Lup_P (-)<br>Caine_KAI (-)<br>**Caprior_KAI (+)** | 0.569 ± 0.016 |
| *Vulpes vulpes* | 50 | P_mixte + Iepure_KAI + Caine_KAI + Pasuni_KAI | P_mixte (-)<br>**Iepure_KAI (+)**<br>Caine_KAI (+)<br>Pasuni_KAI (-) | 2.117 ± 0.076 |
| *Felis sylvestris* | 19 | P_foioase + Alt_medie + P_mixte + Iepure_KAI + Caine_KAI | Alt_medie (+)<br>P_foioase (+)<br>Caine_KAI (-)<br>P_mixte (-)<br>Iepure_KAI (-) | 0.135 ± 0.015 |
| *Cervus elaphus* | 31 | Caine_KAI + Pasuni + Regenerare + Alt_medie + P_mixte | Caine_KAI (-)<br>Pasuni (-)<br>Regenerare (-)<br>P_mixte (+)<br>Alt_medie (+) | 1.205 ± 0.113 |
| *Capreolus capreolus* | 47 | Caine_P + Alt_medie + Pasuni + Regenerare + P_foioase | Caine_P (+)<br>Alt_medie (+)<br>Pasuni (+)<br>Regenerare (-)<br>**P_foioase (+)** | 3.908 ± 0.312 |
| *Sus scrofa* | 47 | Alt_medie + Pasuni + P_foioase + Caine_KAI | Alt_medie (-)<br>Pasuni (-)<br>**P_foioase (+)**<br>**Caine_KAI (-)** | 3.538 ± 0.296 |
| *Lepus europaeus* | 19 | Pasuni + Regenerare + P_mixte + Caine_KAI + Alt_medie | **Pasuni (+)**<br>Regenerare (+)<br>**P_mixte (+)**<br>Caine_KAI (-)<br>**Alt_medie (-)** | 0.372 ± 0.045 |

**Annex I.** *Additional information for badger (Meles meles) and marten (Martes martes): Kilometric Abundance Index (KAI) by region and hotspots of relative abundance (red color denote regions with higher than expected KAI).*



**Annex II**. *Kilometric Abundance Index (number of tracks per kilometer) for 8 target species and 3 additional species in Western Carpathians*

| Grid Cell ID | Region | Km transects | Species richness | TARGET SPECIES | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Wolf | Lynx | Fox | Wildcat | Red deer | Roe deer | Wild boar | Hare | Marten | Badger | Dog |
| 73 | Apuseni | 4.00 | 6 | 0.00 | 0.25 | 3.00 | 0.00 | 0.50 | 6.00 | 3.25 | 0.25 | 0.00 | 0.00 | 0.25 |
| 76 | Apuseni | 5.00 | 7 | 0.20 | 0.00 | 0.80 | 0.20 | 7.40 | 3.20 | 4.80 | 0.00 | 0.00 | 0.00 | 0.20 |
| 95 | Apuseni | 5.50 | 5 | 0.18 | 0.00 | 0.55 | 0.00 | 0.00 | 2.91 | 0.55 | 0.00 | 0.18 | 0.00 | 0.36 |
| 96 | Apuseni | 6.00 | 6 | 0.33 | 0.00 | 1.33 | 0.00 | 0.17 | 0.83 | 2.67 | 0.00 | 0.17 | 0.00 | 1.00 |
| 99 | Apuseni | 6.50 | 5 | 0.00 | 0.00 | 0.62 | 0.00 | 0.15 | 0.31 | 0.31 | 0.00 | 0.15 | 0.00 | 0.15 |
| 113 | CodruMoma | 6.50 | 6 | 0.00 | 0.46 | 1.38 | 0.00 | 4.62 | 6.00 | 11.69 | 0.00 | 0.62 | 0.00 | 0.00 |
| 114 | CodruMoma | 5.50 | 6 | 0.18 | 0.00 | 1.82 | 0.36 | 0.00 | 5.09 | 3.27 | 0.00 | 0.18 | 0.00 | 0.36 |
| 115 | CodruMoma | 5.50 | 4 | 0.00 | 0.00 | 2.55 | 0.00 | 0.00 | 6.91 | 2.91 | 0.00 | 0.18 | 0.00 | 1.82 |
| 119 | Bihor | 5.50 | 6 | 0.55 | 0.00 | 2.18 | 0.18 | 1.27 | 4.18 | 3.09 | 0.00 | 0.00 | 0.00 | 1.09 |
| 120 | Bihor | 4.00 | 2 | 0.00 | 0.00 | 2.75 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.25 | 0.00 | 2.50 |
| 133 | CodruMoma | 6.00 | 6 | 0.00 | 0.00 | 1.67 | 0.00 | 5.50 | 11.50 | 9.67 | 0.17 | 0.00 | 0.33 | 0.17 |
| 138 | Apuseni | 2.00 | 0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 139 | Apuseni | 5.00 | 8 | 0.40 | 0.20 | 1.40 | 0.00 | 10.20 | 5.60 | 0.20 | 0.40 | 0.00 | 0.00 | 0.00 |
| 140 | Apuseni | 5.00 | 6 | 0.20 | 0.00 | 0.20 | 0.20 | 0.60 | 0.60 | 1.00 | 0.00 | 0.00 | 0.00 | 0.80 |
| 141 | Apuseni | 6.50 | 7 | 0.00 | 0.00 | 2.00 | 0.46 | 0.31 | 0.62 | 4.31 | 0.00 | 0.31 | 0.31 | 0.00 |
| 160 | DCM Corr | 4.00 | 8 | 1.50 | 0.00 | 1.75 | 0.50 | 0.00 | 2.00 | 1.25 | 0.25 | 0.75 | 1.50 | 0.25 |
| 161 | DCM Corr | 4.50 | 7 | 1.78 | 0.00 | 1.11 | 0.22 | 0.00 | 1.11 | 0.22 | 0.22 | 0.00 | 0.44 | 0.22 |
| 162 | DCM Corr | 1.00 | 5 | 0.00 | 0.00 | 1.00 | 1.00 | 0.00 | 7.00 | 6.00 | 0.00 | 1.00 | 0.00 | 0.00 |
| 168 | Bihor | 6.00 | 5 | 0.33 | 0.00 | 1.00 | 0.00 | 0.00 | 1.50 | 3.83 | 0.00 | 0.00 | 0.00 | 0.67 |
| 177 | CodruMoma | 4.00 | 3 | 0.00 | 0.00 | 2.00 | 0.00 | 0.00 | 1.25 | 0.50 | 0.00 | 0.00 | 0.00 | 1.25 |
| 178 | CodruMoma | 6.00 | 7 | 0.00 | 0.17 | 0.50 | 0.00 | 3.83 | 9.33 | 5.83 | 0.00 | 0.17 | 0.00 | 2.33 |
| 183 | Bihor | 5.50 | 3 | 0.18 | 0.00 | 3.09 | 0.00 | 0.36 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.55 |
| 191 | CodruMoma | 7.50 | 6 | 0.00 | 0.27 | 2.53 | 0.00 | 0.40 | 7.87 | 6.67 | 0.00 | 0.00 | 0.27 | 0.93 |
| 192 | CodruMoma | 6.00 | 5 | 0.00 | 0.00 | 2.33 | 0.00 | 0.00 | 5.83 | 3.67 | 0.00 | 0.33 | 0.67 | 0.67 |
| 194 | CodruMoma | 7.00 | 8 | 0.00 | 0.29 | 4.71 | 0.00 | 0.14 | 12.00 | 2.29 | 0.29 | 0.57 | 0.43 | 2.71 |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 197 | Bihor | 4.00 | 4 | 0.00 | 0.00 | 0.25 | 0.00 | 0.25 | 0.75 | 2.75 | 0.00 | 0.00 | 0.00 | 1.75 |
| 199 | Bihor | 5.50 | 4 | 0.00 | 0.00 | 1.45 | 0.00 | 0.36 | 0.55 | 0.36 | 0.00 | 0.00 | 0.00 | 0.55 |
| 239 | Zarand | 8.00 | 6 | 0.88 | 0.00 | 1.88 | 0.13 | 0.00 | 3.50 | 1.38 | 0.25 | 0.00 | 0.00 | 0.63 |
| 256 | Zarand | 5.50 | 6 | 1.82 | 0.18 | 1.64 | 0.00 | 1.45 | 3.82 | 5.09 | 0.00 | 0.00 | 0.00 | 0.36 |
| 257 | Zarand | 7.50 | 9 | 0.93 | 0.13 | 2.00 | 0.00 | 2.27 | 4.80 | 7.33 | 0.13 | 0.40 | 0.40 | 0.27 |
| 258 | Zarand | 6.00 | 6 | 0.17 | 0.00 | 2.50 | 0.00 | 0.00 | 5.33 | 1.83 | 0.00 | 0.67 | 0.17 | 2.17 |
| 275 | Zarand | 5.00 | 7 | 1.00 | 0.00 | 2.20 | 0.20 | 3.00 | 4.80 | 8.20 | 0.00 | 0.80 | 0.00 | 0.00 |
| 288 | DCM Corr | 5.00 | 6 | 0.20 | 0.00 | 1.20 | 0.40 | 0.00 | 1.80 | 2.20 | 0.00 | 0.00 | 0.60 | 0.60 |
| 289 | DCM Corr | 5.00 | 7 | 1.60 | 0.00 | 2.80 | 0.40 | 0.80 | 4.40 | 7.60 | 0.00 | 0.80 | 0.00 | 0.80 |
| 305 | DCM Corr | 5.00 | 7 | 0.20 | 0.00 | 3.20 | 0.20 | 0.20 | 2.20 | 3.20 | 0.00 | 0.40 | 0.00 | 0.40 |
| 433 | Zarand | 6.50 | 7 | 0.00 | 0.31 | 3.54 | 0.00 | 1.23 | 3.69 | 14.62 | 0.15 | 0.46 | 0.00 | 0.15 |
| 434 | Zarand | 6.00 | 7 | 1.17 | 0.00 | 4.00 | 0.00 | 2.00 | 5.17 | 10.00 | 0.50 | 0.17 | 0.00 | 0.33 |
| E1 | Zarand | 8.00 | 8 | 0.25 | 0.00 | 2.63 | 0.13 | 2.88 | 6.50 | 5.38 | 0.75 | 0.38 | 0.00 | 1.13 |
| E2 | Zarand | 7.50 | 10 | 0.53 | 0.13 | 2.67 | 0.27 | 2.53 | 8.40 | 4.93 | 1.20 | 0.53 | 0.13 | 0.53 |
| E5 | Zarand | 10.00 | 10 | 0.10 | 0.10 | 2.30 | 0.90 | 0.10 | 3.80 | 5.20 | 0.10 | 0.30 | 0.20 | 0.20 |
| E6 | Zarand | 8.00 | 7 | 0.63 | 0.00 | 2.75 | 0.00 | 2.38 | 5.13 | 5.88 | 0.50 | 0.25 | 0.00 | 0.88 |
| E751 | DCM Corr | 5.50 | 7 | 0.73 | 0.00 | 4.36 | 0.00 | 0.00 | 2.18 | 2.55 | 0.36 | 0.18 | 0.18 | 1.45 |
| E752 | DCM Corr | 4.00 | 6 | 0.00 | 0.00 | 3.50 | 0.00 | 0.00 | 1.50 | 1.25 | 0.50 | 0.25 | 1.00 | 0.75 |
| E753 | DCM Corr | 9.50 | 7 | 0.74 | 0.00 | 2.74 | 0.00 | 0.00 | 3.16 | 0.32 | 0.11 | 1.16 | 0.32 | 1.58 |
| E754 | DCM Corr | 5.00 | 8 | 0.20 | 0.00 | 4.00 | 0.20 | 0.00 | 5.60 | 0.40 | 0.80 | 1.00 | 0.60 | 3.20 |
| E755 | DCM Corr | 5.00 | 6 | 0.00 | 0.00 | 2.20 | 0.80 | 0.00 | 4.00 | 3.00 | 0.40 | 0.40 | 0.00 | 2.20 |
| E759 | Bihor | 5.00 | 5 | 0.00 | 0.00 | 0.20 | 0.00 | 0.80 | 3.80 | 3.00 | 0.00 | 0.00 | 0.20 | 0.40 |
| E763 | Bihor | 6.50 | 6 | 0.00 | 0.00 | 6.00 | 0.00 | 0.15 | 0.15 | 0.15 | 0.00 | 0.77 | 0.62 | 0.00 |
| 184 | Bihor | 4.50 | 6 | 0.00 | 0.00 | 1.78 | 0.00 | 0.89 | 3.56 | 1.56 | 0.00 | 0.44 | 0.22 | 0.89 |
| 198 | Bihor | 4.00 | 1 | 0.00 | 0.00 | 1.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 193 | CodruMoma | 6.50 | 6 | 0.15 | 0.00 | 2.92 | 0.15 | 4.77 | 9.08 | 4.31 | 0.00 | 0.00 | 0.00 | 1.38 |

**LIFE CONNECT CARPATHIANS - CAMERA TRAPPING SUMMARY**

**Study area**

Camera trapping was implemented in 3 distinct regions of the LIFE CONNECT project area:

- SCI Muntii Bihor
- SCI Dealurile Lipovei-Poiana Rusca and SCI Tinutul Padurenilor
- SCI Coridorul Rusca Montana-Tarcu-Retezat, SCI Muntii Tarcu and Retezat National Park

**Camera trapping protocol**

A total of 82 cameras were available for implementing this study, which were deployed across the 3 target regions (Table 1). Cameras were deployed in the field between June and July 2015, for a total sampling window of 6 weeks. This period was considered ideal for sampling ungulates, as it represents the calving season for roe deer and red deer. During calving season, these species have restricted home ranges, which are important for ensuring the independence of photo captures observations between camera trap stations. After 3 weeks since deployment, cameras were relocated 200-400 m away for another 3 weeks, resulting in 6 distinct sampling occasions to be used in the subsequent analysis.

Of the 492 sampling occasions [82 camera traps × 6 occasions], 17 sampling occasions were removed due to camera technical errors and cameras missing, resulting in 475 camera trap occasions for data analysis. These amounted to a total of 3290 camera trap days. The initial camera placement period started on 9 June 2015; starting with 30 June 2015, cameras were relocated to the new randomly selected locations. The last day of trapping was 24 July 2015.

Roe deer (*Capreolus capreolus*), red deer (*Cervus elaphus*), and wild boar (*Sus scrofa*) were detected during 30.74%, 18.74%, and 13.68% of sampling occasions (see table below).

| | **Area** | | | | |
|---|---|---|---|---|---|
| | **Bihor** | **Retezat** | **Rusca** | **Total** | **% of total number of occasions** |
| # Roe deer detections | 53 | 21 | 72 | 146 | 30.74% |
| # Red deer detections | 33 | 21 | 35 | 89 | 18.74% |
| # Wild boar detections | 24 | 8 | 33 | 65 | 13.68% |
| # camera stations | 28 | 24 | 30 | 82 | |

These data are being processed to be analyzed in an occupancy modeling framework, which accounts for imperfect detection of wildlife. Habitat data (forest, pasture) within 500 m buffers around the initial camera locations and relocations will be used as variables for estimating differences in abundance between the 3 regions surveyed.

In addition, the following species were detected: Eurasian lynx (*Lynx lynx*), red fox (*Vulpes vulpes*), wolf (*Canis lupus*), badger (*Meles meles*), hare (*Lepus europaeus*), wildcat (*Felis silvestris*), marten (*Martes martes*), brown bear (*Ursus arctos*), as well as dogs and people.