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Agricultural Habitat Heterogenity Impact on the European Hare (*Lepus europaeus*) Density in Vojvodina Region (Serbia)

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IP, MK and VM presented the concept and designed methodology, analysed and interpreted the data. IP, VM and ZR collected data. IP and MK wrote the manuscript. MK, ZR and VL revised the manuscript. IP, MK and VL edited the manuscript. All authors have read and agreed to the published version of the manuscript.

Key words
European hare, Population density, Hunting ground, Vojvodina

ABSTRACT

Throughout Europe agriculture intensification during the last decades has dramatically changed the structure of the farmland landscape with an intensive impact on ecosystem stability. Changes in the production led to decreased habitat heterogeneity and to decline in biodiversity, including the European hare (*Lepus europaeus*), especially in the lowland regions. Even though European hare mostly adapted to intensive agricultural habitats, the population densities have decreased throughout Europe since the 1960s. Previous research reported field size to be one of the most important predictors of the hare population. We aimed to assess the effect of habitat heterogeneity and structure on hare habitat selection i.e. population density. Using hunting organization census data we explored the population density and habitat preference of the European hare in spring 2020 in the hunting ground, Bačka - Bački Petrovac. The average population density of European hare significantly differed between four fractions of the hunting ground - Bački Petrovac, Kulpin, Gložan, and Maglić. Density varied from 27 in Bački Petrovac to 50 individuals per 100 ha in Maglić. The population was negatively affected by mean patch size and by the area under no vegetation during the winter period. Conservation measures should focus on enhancing habitat heterogeneity by reducing field size, and fostering sowing during the late autumn period.

INTRODUCTION

Human activity has massively changed the land cover over the past decades (Goudie, 2018). Agricultural landscapes dominate in large parts of the world, and more than a third of Earth's ice-free surface is covered by agricultural land (Foley *et al*., 2011; Ramankutty *et al*., 2018), which is an important habitat for a wide range of biodiversity. In Europe, which is one of the most intensely used agricultural areas (Ramankutty *et al*., 2008), agriculture intensification during the last decades has dramatically changed the structure of the farmland landscape with an intensive impact on ecosystem stability which caused a strong reduction of animal biodiversity (Chamberlain *et al*., 2000; Donald *et al*., 2001). Agriculture intensification led to increased yields due to larger field sizes, the use of chemicals, and the improved efficiency of machinery (Smith *et al*., 2004). On the other hand, this intensification led to decreased habitat heterogeneity and to decline in biodiversity (Reidsma *et al*., 2006), including the European hare (*Lepus europaeus*) as one of the most widespread and most hunted game species in Europe, especially in the lowland regions. Brown hare, as a typical game of open grasslands, during the time has adapted to agroecosystems, or landscapes cultivated by human activity due to intensive agriculture development. Due to intensive susceptibility to habitat changes caused by agricultural intensification, European hare (*Lepus europaeus*) may be considered a good indicator of habitat quality (Edwards *et al*., 2000; Smith *et al*., 2005; Zellweger-Fischer *et al*., 2011). Although European hare has adapted to agriculturally influenced habitats, hare populations have decreased across Europe since the 1960s (Smith *et al*., 2004; Zellweger-Fischer *et al*., 2011; Kamieniarz *et al*., 2013; Petrovan *et al*., 2013; Lush *et al*., 2014; Panek, 2018; Pavliska *et al*., 2018). Research about the brown hare in Serbia, especially in the Vojvodina region (Northern Serbia) where the brown hare is the

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most common game species (population varies between 150.000 and 300.000) shows that numerous natural and human-induced conditions (management of hunting ground, climate factors, winter, and reproduction period loses, as well as red fox abundance on the population) impact on brown hare habitat, and directly on the number of game (Panek *et al*., 2006; Ristić *et al*., 2012; Beuković *et al*., 2013; Popović *et al*., 2014; Marković *et al*., 2017; Kovačević *et al*., 2019; Ponjiger *et al*., 2019; Ristić *et al*., 2021).

So, for sustainable management of natural areas such as hunting grounds, it is necessary to analyze these conditions to conclude why the number and density of game which is one of the most important elements of a population, varies from year to year and among hunting grounds. Land cover patches analysis through anthropogenic pressures is possible to apply for many ecological and geographical applications (Marković *et al*., 2014). As agricultural field size is one of the most important predictors of hare habitat preference (Mayer *et al*., 2018; Ullmann *et al*., 2018) we studied the effect of habitat heterogeneity and structure on hare habitat selection i.e. population density.

MATERIALS AND METHODS

In Northern Serbia the Autonomous Province of Vojvodina there is 21526.95 km² of areas considered as hunting grounds. Hunting associations manage 120 hunting grounds with an area of 20069.11 km² (Ristić *et al*., 2020). Our study areas were four neighboring parts of the hunting ground Bačka (Bački Petrovac (BP), Gložan (G), Kulpin (K), and Maglić (M)) located in Vojvodina province, municipality of Bački Petrovac (Fig. 1). Ministry of Agriculture, Trade, Forestry, and Water Management permits hunting organizations to manage these hunting grounds which are unfenced type. This means that the influence of the hunters consists of improving the environmental conditions of the habitat. This hunting ground is typical lowland. All four study areas mostly consisted of arable fields (BP: 88.6%, G: 98%, K: 96.6%, and M: 98.7%), tilled with maize, soy, wheat, sugar beet, potato, barley, and to a lesser degree other crops like rapeseed, hops, and tobacco. The rest of the areas consist of forest areas, orchards, pastures and meadows, water, and built-up areas. Also, notable is the very low forested areas (0.60%) and water (2.19%). The rest of the area is covered mostly by settlements and infertile land.

All hunting associations in the Vojvodina region, annually until 31st March, report the condition and number of game, including European hare, to the Ministry of Agriculture, Trade, Forestry, and Water Management and Hunting Association of Vojvodina. For this study, data were obtained from the Hunting Association of Vojvodina. In Serbia and the Western Balkan region, the census of small game such as European hare is done by directly counting individuals in 10% of the total area of each hunting ground. Counting is carried out during one day in three parts with different densities (high, medium, and low) estimated by experts and professional service of the hunting ground (Table I). After defining three equal areas of the hunting ground (which represent 10% of the total area of the hunting ground), counters which are usually hunters, are placed in a line along the counting area with the distance between each other's 50 m. When the counters start moving to the central point, they count hares only from the defined side (usually the left side) by driving them out from the counting area. This methodology requires highly skilled organizations and a high number of hunters and it is the practice in Serbia for decades.

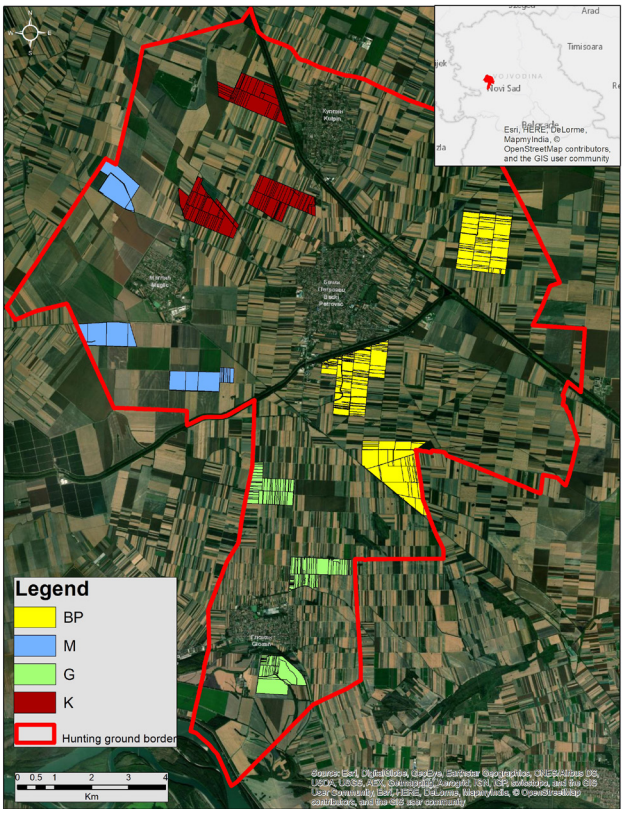

Fig. 1. Study area - Hunting ground Bačka

For each patch, we determined the land use using satellite images. All data collected for this study was imported to ArcGIS 10.1 software by ESRI to produce maps for more visual description and geo-statistical analysis. Maps were made in WGS_1984_UTM_Zone_34N Projected Coordinate System, D_WGS_1984

Datum, with Prime Meridian Greenwich. With the same software, we determined the average dimension of fields. The satellite images were taken in March, about the same time when the hare counts were done.

Table I. Results of correlation analysis.

Areas in hunting ground	Hare per 100 ha	Area size in ha
(BP) Bački Petrovac - 1	26	211
(BP) Bački Petrovac - 2	23	210.8
(BP) Bački Petrovac - 3	32.5	211.1
(G) Gložan - 1	25.8	100.2
(G) Gložan - 2	27.9	100.3
(G) Gložan - 3	37.3	100.9
(K) Kulpin -1	32.1	125.9
(K) Kulpin -2	33.1	127
(K) Kulpin -3	27.8	125.6
(M) Maglić - 1	54.4	87.5
(M Maglić - 2	48.1	88.4
(M) Maglić - 3	49.1	86.1

Statistical analysis. All analyses were performed using the IBM SPSS (ver. 23). Pearson's correlation coefficient r and linear regression models were applied to assess the relationship between the habitat variables and brown hare abundance. To generate predictive equations for the significance, non-significant variables were removed from the final regression model.

RESULTS AND DISCUSSION

Average hare densities vary throughout Europe. For instance in Austria, in several agricultural habitats, there were about 95 individuals per 100 ha. Contrary in the Czech Republic, a population density of 15.4 individuals per 100 ha was recorded in predominantly homogeneous habitats (Šálek, 2014). A similar result was obtained by Santilli and Galardi (2016), whose research on the structure of the habitat (variety of crops) was the most important factor that positively influenced the number of hare.

In our study area in 4 sample plots, the density of brown hare during spring 2020 was much higher than the recorded average for AP Vojvodina. According to Ristić *et al*. (2020) during the period 1967-2016, the density of the brown hare in the Vojvodina region was 13.15 individuals per 100 ha. The results of the spring counts showed notable differences between the four parts of the hunting ground. The number of brown hare per 100 ha in Bački Petrovac was 27, Gložan- 30.37, Kulpin- 31, and Maglić- 50.47 per 100 ha. The distinct difference between the four parts needs to be addressed knowing the fact that they are managed by the same organization applying the same game management methods and having similar habitat conditions and predator populations.

To determine the cause of this we determined the land use for each of the hunting ground parts. The results showed significant differences in the average field sizes (patch size) (it is noticeable in Fig. 1 in the North-West part of the study area) and the areas with crops in the winter period between Maglić and the rest of the hunting ground. Several studies have shown that there are negative effects on hare population in cases of large plots and smaller diversity of crops (Schröpfer and Nyenhuis, 1982; Tapper and Barnes, 1986; Lewandowski and Nowakowski, 1993; Panek and Kamieniarz, 1999; Vaughan *et al*., 2003; Jennings *et al*., 2006). Reichlin *et al*. (2006) found that habitat diversity is crucial, especially during summer when cereals are harvested because this is the period when hare change their diet in favor of weeds and legumes. However, this study shows this is disputable.

A strong negative correlation (r=-.901**) was found between the percentage of fields without winter crops and hare numbers (Table I). This means the hare is less abundant in areas with fewer winter crops. Similar results were already noted in previous research. Schmidt *et al*. (2004) found a significant positive correlation between root crops and hare abundance and a negative relationship between winter cereals. Pepin (1989) points out that the survival rate is higher for leverets born in areas where a higher percentage of winter cereals and alfalfa are grown. Genghini and Capizzi (2005) also points to the significance of winter cereals on habitat. Reichlin *et al*. (2006) state that winter cereals are a significant food source during the winter months, and therefore a significant factor in habitat conditions. All this attributes to the importance of winter crops for brown hare in intensive agriculture habitats.

Also, a positive correlation (r=.693*) between field size and brown hare abundance was notable. Large fields also proved to be a negative factor for the population. The main reason for this is mainly because such crops reach maturity at the same time and after harvest, the main source of food for hare is lost over a very large area (Frylestam, 1986; McLaren *et al*., 1997).

Contrary, all other variables shrubs, forest areas, settlements, water, orchards, and grassland were all marked as not significant. This may be because the study area is mostly agricultural land and the percentage of these areas is very small.

Table II. Results of correlation analysis.

Variables	Correlations (r)	Sig.	Correlations (r)-Maglić excluded	Sig.
No winter crops	-.901**	.000	-.535	not significant
Shrubs	.094	not significant	.370	not significant
Forest	.056	not significant	.614	not significant
Settlement	-.251	not significant	.261	not significant
Water	.273	not significant	-.161	not significant
Orchard	-.272	not significant	-.062	not significant
Grassland	-.050	not significant	.411	not significant
Mean field size	.693*	.013	-.673*	.047

Since it is clear there is a significant difference in hare population in Maglić and the rest of the hunting ground we tried to exclude it from the analysis to examine the strength of the relationship in other parts. Results have shown a strong negative relationship (*) between field size and hare abundance. This means that hares are more abundant in areas with smaller fields which matches some of the previous research (Schröpfer and Nyenhuis, 1982; Tapper and Barnes, 1986; Lewandowski and Nowakowski, 1993; Panek and Kamieniarz, 1999; Vaughan *et al*., 2003; Jennings *et al*., 2006). Correlation with the percentage of fields without winter crops was negative medium strong however not significant (Table II).

These results prove some of the previous studies however the case of Maglić proves that the presence of winter crops, or lack of aforementioned, significantly affects the hare population. This corresponds with the study by Smith *et al*. (2005) who also found that winter wheat is positively associated with hare abundance. This is because hares choose cereals when they lack other food (Tapper and Barnes, 1986; Smith *et al*., 2004).

Table III. Results of the multiple regression analysis.

	All parts (predictor: No winter crops)	All parts (predictor: Mean field size)	Maglić excluded (predictor: Mean field size)
R square	0.812	0.480	0.453
Adjusted R square	0.793	0.428	0.374
F	43.216	9.228	5.788
Sig.	0.000	0.013	0.047

In maglić, we found that 43.3% of the area had winter crops. This is significantly higher than the rest of the studied area (Bački Petrovac– 11.78%, Gložan– 10.93%, Kulpin– 12.86%).

This study did not determine the structure of winter crops, however, it can be noted that in the Maglić area there is a higher percentage of root crops, while in other areas winter crops are mostly wheat which corresponds with the results of the study by Schmidt *et al*. (2004).

To determine exactly to what extent these variables influence the number of brown hares a linear regression analysis was carried out. The results of the regression analysis also confirmed the correlation analysis where the field size was the main predictor (Table III).

CONCLUSION

Arable fields dominate agricultural land in many European countries, thereby forming the main habitat of hares. The brown hare population in Serbia is declining over the last few decades. This fact imposes the necessity for monitoring the population and finding the causes. This paper shows that the mean patch size of fields and vegetation presence during the winter period are important factors to describe habitat selection in agricultural landscapes. Hares avoid large parcels, especially without vegetation, because it does not provide high-quality forage and restricts their spatial movements. To conclude, conservation measures focusing on enhancing habitat heterogeneity by reducing field size, and fostering sowing during the late autumn period may be an effective tool to support populations of European hares in arable farmland landscapes. While this is widely known our paper also shows that there are also exceptions to these rules. Maglić hunting area is an unusual example where hare densities were significantly higher in conditions of large agricultural parcels. This can be attributed to the agricultural practices of this area, where there is a high percentage of winter crops and an especially high percentage of root crops which seem to be suitable for the brown hare population. This research also raises further questions which should be addressed in the following research. A similar approach could be used on a

larger scale such as comparing several hunting grounds in a larger area.

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Statement of conflict of interest

The authors have declared no conflict of interest.

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