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Factors related with the distribution of Ural owl *Strix uralensis macroura* in Eastern Romania

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Abstract. Abstract. Ural owl has been poorly studied in Romania, where its distribution is only partially known. Based on 308 acoustic point-count stations across Eastern Romania, we investigated, a total of 87 Ural owls potential territories where detected. We employed a Boosted Tree Regression (BRT) to analyse the influence of 29 variables regarding the climate, disturbances and habitat over species distribution. The best predictor on the occurrence of Ural owls in the study area was forest age. Ural owl showed a high association with glades and forests with trees older than 80 years, while young forests and undergrowth were used much less. The species also showed a tendency to avoid forest edges and steep slopes.

Key words: habitat, raptor, forests, Ural owl, distribution.

Introduction

Ural owl *Strix uralensis* is one of the three European owls of the *Strix* genus. The species is evaluated as Least Concern by IUCN (http://www.birdlife.org/datazone/speciesfactsheet.php?id=2247), but it is listed in Appendix I of the Natura 2000 Bird Directive (http:// ec.europa.eu/environment/nature/natura2000/si tes_birds/index_en.htm), being one of the species important for designation of Special Protected Areas (Directive 2009/147/EC). It has a wide distribution across Palearctic, from Scandinavia, eastward across Asia's taiga, to the Pacific Ocean (Mikkola 1983, König et al. 2008).

There are eight subspecies of the Ural owl across its range (König et al. 2008) and three in Europe: *S. u. uralensis* Pallas, 1771, *S. u. liturata* Tengmalm, 1793 and *S. u. macroura* Wolf, 1810, although some studies question these subspecies (Hausknecht et al. 2014). South of the species' range in Central Europe, there are several disjunct populations that are considered postglacial relicts (Mikkola 1983). These populations are distributed across the Carpathians, Dinaric Alps and Balkan Mountains, and belong to *Strix uralensis macroura* subspecies (Kohl 1977, Mikkola 1983, Chmielewski et al 2005, Wójciak et al 2005, Bashta et al 2008). In the last decades, the population from the Carpathians shows a tendency to expand to lower altitudes northwards (Chmielewski et al 2005, Wójciak et al 2005, Bashta et al 2008) westwards (Kristin et al. 2007) and eastwards (Bashta 2009). In Romania, Ural owl was traditionally known to breed in the Carpathians (Munteanu et al. 2002, Munteanu 2012), but recent studies showed that the species breeds also outside the mountain range in the eastern part of Romania, in Moldova Region (Bolboacă et al. 2013).

Although it is a widespread species in the Palearctic, Ural owl distribution is still poorly known (König et al. 2008). Few studies have been focused on *S. u. macroura*, and even fewer on the Romanian population. Therefore, most of the data regarding Ural owls in Romania was incidentally gathered, in the absence of a dedicated study. The population of Ural owls in Romania was estimated to be between 6000 and 12000 pairs (http://monitorizareapasarilor.cndd.ro/documents/Atlasul-Pasarilor-2015.pdf), almost 10% of the estimated European population but this information may be inaccurate.

In its southern distribution range, Ural owls seem to prefer old forest, far from human settlements (Mikkola 1983, Vrezec 2000, Vrezec & Tome 2004, Bylicka et al. 2010, Kajotch et al. 2015). The forests inhabited by Ural owls are usually bordered by other forest areas, and connected among them. In Southern Europe the birds seem to prefer deciduous to coniferous forests (Vrezec & Mihelič 2012).

Considering the current breeding area expansion of the *S. u. macroura* subspecies, from the Carpathian mountains to the east, and that few studies exist on the ecology of Ural owl in central and southern part of Europe, we tried to determine the current distribution of this subspecies on the eastern portion of its range, on one side, and what would be the factors affecting its distribution, on the other side. No such data have been previously gathered for this subspecies in this geographic area.

Materials and methods

Study area

The study area is situated in eastern part of Romania, in the region Moldova (46°45′ N and 27°6′ E), covering an area of 46123.36 Km^2. To the north, it borders with Ukraine, to the east with the Republic of Moldova. In the western part of the region, there are the Carpathian Mountains, Moldavian Plateau at the centre and The Wallachian Plain to the south. The altitude ranges from 2 meters in the Danube Valley to over 2000 m in the Carpathians (Jarvis et al. 2008). Regarding the land use, 44.54 % is represented by agricultural land, orchards and vineyards, 32.47 % by forests, and 22.99% by other habitats. About forty five percent of the forests are composed by broadleaved tree species, 29.13% by coniferous trees and 25.82% are mixed forests (Corine Land Cover 2006). The coniferous forest are situated on highest part of the Carpathians, while at foothills, and at the Moldavian Plateau, there are mixed and broadleaf forests. The broadleaf forests are dominated by beech *Fagus sylvatica* and oak *Quercus robur*, while coniferous forests mainly by Norway spruce *Picea abies* and silver fir *Abies alba*.

Owl surveys

The owl distribution and abundance data was gathered between 2012 and 2015, in two periods each year: March-May, and August-November. Due to the fact that our study focused also in the mountain areas, we start to visit these sites in first period in August and

Table 1. Environmental variables

Category	Variables	Mean	Range
Climatic	Annual Mean Temperature	7.45	3 to 10.8 ˚C
	Mean Diurnal Range	0.75	0.30 to 1.10 ˚C
	Isothermality	2.93	2.80 to 3.00 ˚C
	Max Temperature of Warmest Month	23.55	17.20 to 28.00 ˚C
	Min Temperature of Coldest Month	-8.28	-10.9 to -4.9 ˚C
	Temperature Annual Range	31.84	27.70 to 33.50 ˚C
	Mean Temperature of Wettest Quarter	15.86	10.10 to 19.70 ˚C
	Mean Temperature of Driest Quarter	-1.95	-5.6 to 4.5 ˚C
	Mean Temperature of Warmest Quarter	17.32	11.80 to 21.20 ˚C
	Mean Temperature of Coldest Quarter	-3.35	-6.3 to 0.2˚C
	Annual Precipitation	634.2	466 to 870 mm
	Precipitation of Wettest Month	97.94	61 to 133 mm
	Precipitation of Driest Month	30.47	21 to 43 mm
	Precipitation Seasonality	43.67	24 to 54
	Precipitation of Wettest Quarter	264.5	156 to 367 mm
	Precipitation of Driest Quarter	94.97	64 to 135 mm
	Precipitation of Warmest Quarter	254.9	147 to 358 mm
	Precipitation of Coldest Quarter	97.02	66 to 138 mm
Disturbance	Distance to human settlements	3.91	0.2 to 39.4 Km
	Presence / absence of permanently used building	N/A	
Habitat	Altitude	538	13 to 1536 m asl
	Normalized Difference Vegetation Index	0.63	0 to 0.8
	Average slope	11.22	1 to 26 degrees
	Percent of open habitats in buffer area	18.66	0 to 96.70 %
	Percent of deciduous forest in buffer area	49.55	0 to 100%
	Percent of coniferous forest in buffer area	26.02	0 to 99.8%
	Percent mixed forest in buffer area	5.39	0 to 99.8%
	Distance to forest edge	1270.8	6.4 to 30630 m
	Dominant forest age class in buffer area	N/A	

we finished the observations in second one in late May so we could have access on the forestry roads, which are covered in snow a longer period in the mountain areas. In high areas, breeding period starts later, so we consider that chicks do not display adult vocalizations by the late May. There is however the possibility that in August young Ural owls could occupy unsuitable territories as a consequence of chick dispersing and could be considered a viable territory, though we consider these cases would not have a major influence on the results, as the observation stations were investigated at least twice.

We used a playback protocol as a survey method for the Ural owls. This method implies the broadcasting of recorded conspecific calls from fixed (pre-established) census stations. After arriving at an observation point, we silently waited for 2 min to allow birds recover from the disturbance created by our vehicle. Then recordings of Ural owl contact and territorial calls were broadcast for a period of 2 min, followed by a period of 5 min of silent listening for potential responses from local owls. The surveys started half of hour after sunset, and lasted until midnight, on calm nights (without precipitation or strong winds) (Redpath 1994). The responses were recorded on a form sheet. The estimated distance and direction of the responses were marked on a map. We considered a buffer area of 500 m around the survey point (Surface = 0.785 Km^2) as the effective survey area (Kajtoch et al. 2015, Vrezec & Tome 2004). The playback stations were located not closer than 800 m, avoiding double counting the same individuals. All individuals were marked on a map of the area. All the data was then converted into a Geographic Informational System (GIS) Database. It was considered one pair when: both male and female responded in the same time; when one male responded or when it was seen or heard an individual that could not be sex determined. A total of 308 survey stations were semi-randomly scattered over the forests across the study area, covering both large and small forest patches. Most of the stations were placed on forestry roads and other roads with low traffic intensity (Hausleitner 2006).

Environmental data collection

We selected 29 variables that were grouped into three classes: climatic, disturbance and habitat. Different variables were recorded on the observation point and on the buffer area (Table 1).

The climatic variables were obtained from the bioclim dataset version 1.4 (release 3). (http://www.worldclim.org/bioclim) at a spatial resolution of 1 sq. km (Hijmans et al. 2005). Data processing and points sampling was made in R statistical software version 3.2 (R Development Core 2015).

Among the disturbance variables, distance to human settlements was measured by ArcGIS software, using air photographs and satellite images (Google Earth 2013). Instead, for the presence/absence of buildings, we used both satellite imagery and direct observations from the field.

Among the variables describing the habitat, the forest age was divided into 5 classes according to mean tree age and spacing among them: undergrowth (thickets of trees younger than 20 years), young forest (21-40 years old), mature forest (41 – 80 years old), old forest (over 81 years old), and glades (trees or group of trees older than 81 years, separated by at least 25 meters one from another). The proportion of each habitat in the buffer area was similar to the proportion of the entire forested area of Romania (χ^2 = 1.7794, 2 d.f., P=0.41). The data regarding forest age was checked directly on the field based on the medium girth of the tree and compared with satellite imagery (Google Earth 2015) and from forestry maps (Forest Management Maps, scale 1:20000, georeferenced in Romanian National Stereographic 1970 System) when available. Thus, we compared the general aspect of the forest including the diameter of the trees from patches with known age to those unknown. This method is susceptible to errors as it leaves room to interpretations, though we consider we reduce the errors by using a low number of age classes (5).

Statistical Analysis

For statistical analysis we used 'dismo' package 1.0-12 version (Hijmans et al. 2015) developed for R software (R Development Core

2015). We applied the Boosted Regression Tree (BRT), a multivariate statistical modelling method, to compute the relations between the environmental conditions and the distribution of Ural owl in Eastern Romania.

BRT is an ensemble method, meaning that it comprises a large number of simple models, in our case binary regression trees. In boosting models, every decision tree is fitted iteratively to the training data, using the appropriate method and evaluated. These models are combined and averaged to get the best fitting model (Elith et al. 2008). For our study, we chose different parameter values to get the best area under the curve (AUC). When we detected more than one pair on a survey station, a separate sampling point was considered for each pair in the Boosted Tree Regression (BRT) analysis, as the model it takes into account only the presence of the species.

Results

Ural owls were present in a total of 84 survey stations. We found Ural owls through the Carpathians, as well as in Sub Carpathians. East of the Carpathians, the species distribution is limited to the northern and central part of the study area, in forests along the main foothills (Fig. 1). By reporting the total surveyed surface to the number of owl territories detected, we calculated a minimum occupancy density for the forested study area of 2.45 individuals/ 10 Km² ($N_{survey\ points}$ = 308, $N_{owl\ territories}$ = 84). Thus, considering the surface of the forested area, the estimated population of Ural owl in Moldova region is between 3000 and 4000 -individuals.

Regarding the BRT, the best fitted model, with an AUC =0.769, was achieved by using the following parameters: model type presence; error distribution family - binomial; learning rate - 0.001; number of regression trees - 1750.

The most important variables influencing the distribution of the species in our study area were (1) the age of the forest, (2) the distance to forest edge, (3) the average slope, (4) the precipitation seasonality (annual range in temperature and precipitation), (5) the distance to settlements, and (6) the proportion of open habitat in buffer area (Fig. 2). Regarding forest age, in our study area the Ural owl shows a high habitat selection towards glades and old forests, while young forests and undergrowth are not selected.

The BRT model shows that the Ural owl avoids the forest edges, as the response curve has negative values between 0 and 2500 m. Average slope of the terrain, which indicates the terrain roughness is positively associated with the Ural owl`s presence at low slope values (1 – 7º), to turn irrelevant at higher slope values (Fig. 3).

The climatic variable with highest influence on the occurrence of Ural owl in the study area is the precipitation seasonality (coefficient of variation). This is the measure of the variation in monthly precipitation totals over the course of the year. Our model suggests that the occurrence of Ural owl in the study area is positively related to a large variation in monthly precipitation (Fig. 3).

The distance to human settlements also shows some weight in the model, as the fitted function is negative at values ranging from 0 to 7 km (Fig. 3).

The proportion of open habitat in the buffer area was positively related to the presence of the species at low values (up to 30 %). Above this value, it was unrelated with the species occurrence (Fig. 3).

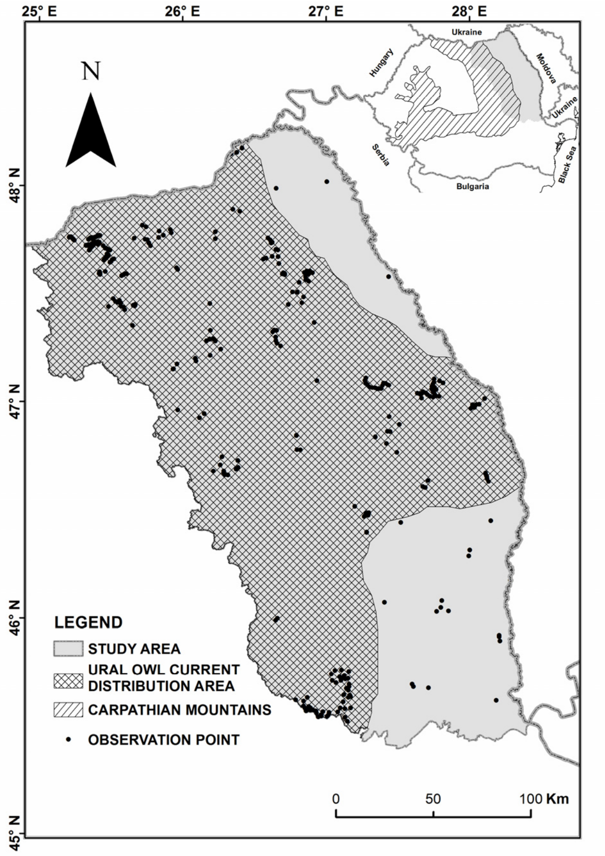

Figure 1. Study area, observation points and Ural Owl current distribution.

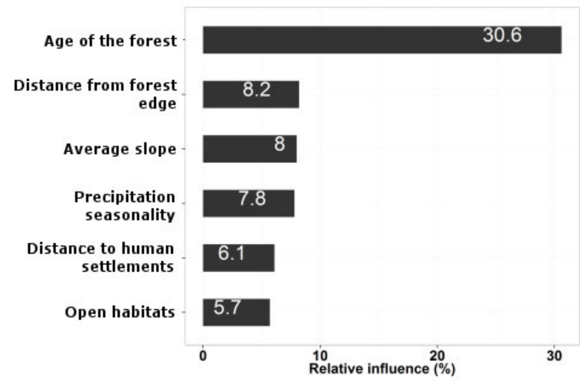

Figure 2. Relative influence of highest 6 variables (calculated using BRT).

Discussion

The Ural owl has a broader distribution to the east of Carpathian Mountains, breeding both in mountains as well as in a wide part of the Moldavian foothills, than previously known. In addition, it seems that the Romanian population has spread over the eastern part of the country. These novelties could be explained by the lack of previous studies regarding the species in these areas, or by an expansion of the Ural owl distribution (Kristin 2007, Bashta 2009, Bylicka et al. 2010). However, the distribution of the species east of Carpathians is limited to large forest patches. These forests

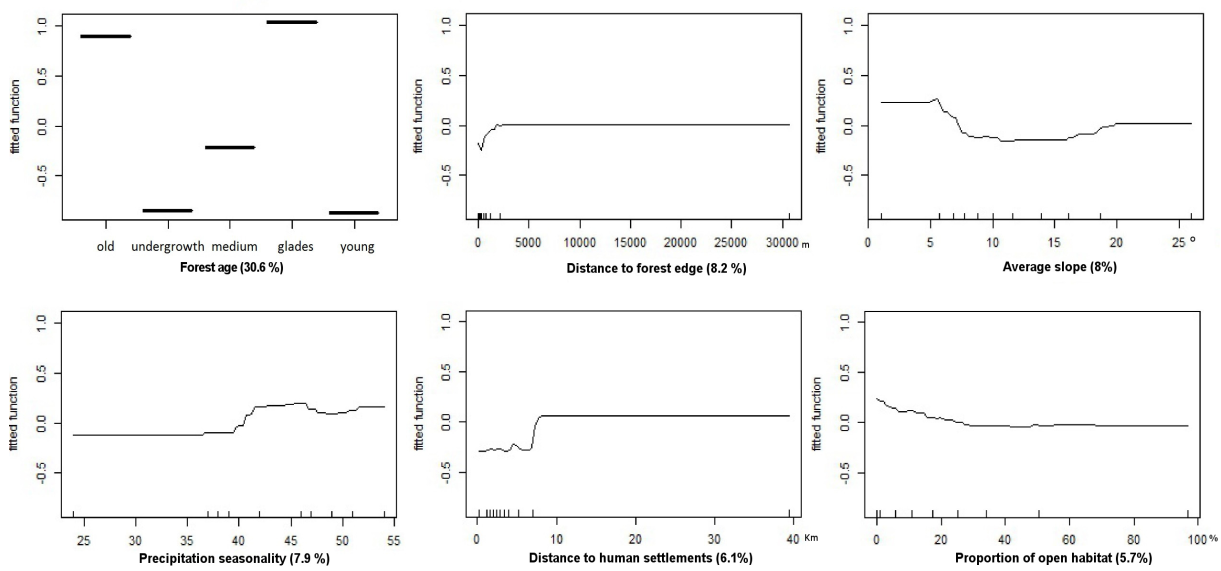

Figure 3. Response curve on the top 6 variables.

seem to play an important role for Ural owl distribution, as they use extensive forests for breeding in other parts of Europe (Kajtoch et al. 2015). The minimum density of Ural owls in our study area is comparable with densities in Croatia (Tutis et al 2009), and is higher than in Ukraine, Scandinavia and Belarus (Bashta 2009, Lundberd 1981, Pietiäinen 1989, Tishechkin & Ivanovsky 1998), but lower to those in Slovenia (Vrezec 2003, Vrezec & Mihelič 2013). Although located at the eastern limit of the subspecies range, the population investigated is relatively dense. This can be explained by the presence of large old-growth forests (e.g. 1064.20 ha, Codrii Seculari Slătioara (http://judetulsuceava.ro/locuri/arii-naturale-protejate/rezervatii-naturale/codrul-secular-slatioara), with almost 70% of the country's forests maintaining their natural appearance (forests with dead wood, snags, different age trees, different levels of vegetation) (Borlea et al. 2006).

Forest age had the highest explanatory power for the distribution of Ural owl in the study area. The species showed an association with forests above 80 years old, as well as with glades. Low canopy compactness areas, like glades are selectively used by Ural owls in other parts of its distribution area (Kajtoch et al 2015). The Ural owl is a species that breeds mostly in tree cavities, tree stumps and large snags (Lõhmus 2003). Since there is no artificial nest programme for Ural owls in the study area, the affinity of the species for glades and old forests could be explained by the possibility of finding suitable nesting places. In other parts of Europe, studies also showed that for Ural owls to breed, forests older than 60 years are needed (Bylicka et al. 2010), as these habitats provide the conditions needed for breeding. Another possible explanation for the affinity towards these habitats (not excluding higher nesting-substrate availability) is a higher availability of food resources in old growth forests (Schmiegelow & Mönkkönen 2002), though further studies are needed to advance knowledge on these subjects.

In our study area, it became evident that the species is more associated with the interior of large forest tracts, as also shown by other authors in different locations (Kajtoch et al. 2015). This may be related with the structure of the interior of the forests with older trees with gaps potentially used for hunting. This is evidenced by a negative relationship distance to the human settlements and the occurrence of Ural owls in both our study and studies conducted in other parts of the species range (Vrezec & Tome 2004). Both variables can be linked by the fact that most of the settlements are located at the edge of large forest tracts.

The relationship between the average slope and the occurrence of the species should be interpreted with caution, as this variable may affect detection probability. Lower values, which indicate a relatively gentle landscape, have a positive effect on detectability, while rough terrains may eventually complicate detection.

Ural owl was thought to breed in Romania only in the Carpathians (Munteanu et al. 2002), suggesting that the species occurrence is influenced by altitude. However, our study showed that the altitude was not related with the presence of the species in Eastern Romania. On the other hand, climate variables seem to play a negligible role on the occurrence of Ural owl. Of the weather variables, only the precipitation seasonality was moderately related to the occurrence of Ural owls in the study area, with low coefficients of variation negatively associating with the occurrence of owls. The seasonality of precipitation in eastern part of Romania is expressed very well by the continentalism character of the climate. During a year, in the lowland of eastern Romania there are two periods of drought, one in the spring and the other in autumn. This gives higher values of precipitation seasonality for the area, which in turn, has a positive influence on the occurrence of the Ural owl. As a rule of thumb, spring droughts are intensifying from north to south and west to east (Larion 2007). In the mountain area, the long-term seasonality of precipitations has lower values, but the precipitations are quantitatively important (Micu et al. 2015). In spring the Ural owls are sensitive to rain and cold weather associated with it, since this period in associated with nesting and chick raising. The bad weather can reduce the hunting success of the birds and can kill the fledglings.

Ural owls seems to prefer humid forests than dry one, as is specified by Cramp (1985) for the entire distribution of the species, though in our study, the model shows that the annual precipitation had weight on the model. But our result can be an artefact derived from a little variability of the annual humidity values over the study area.

At low values, the percent of open habitat in the buffer area is positively associated with owl presence, but as it increases, no association is detected by the model. This indicates a need for forests with relatively low canopy compactness for this species in the study area, as suggested by Kajtoch et al. (2015): trees mutually spaced, with small clearings. At an extreme, large open spaces are not used. Clearcut exploitation is applied intensively in Romania, especially in high altitude spruce forests. This exploitation technique creates large clearings, and later on, large patches of undergrowth that are unfavourable for Ural owls. On the other hand, in low altitude broadleaf forests, the group selection cutting exploitation technique provide small patches of open habitat, clearings as well as different age trees, so that Ural owls seems to prefer these areas. These shows the importance of forest practices for the habitat selection, and ultimately, the distribution patterns of Ural owls in the study area. Even though the Ural owl has a proper configuration of habitat at lowlands, the number of individuals (and presumably, territories) is smaller than in the Carpathian Mountain areas. At higher altitudes, there are more extensive forest tracts, with old forest patches, glades, far from human settlements, all conditions that have shown to be important for the distribution of Ural owls.

The Ural owl is still a relatively rare species in central Europe (Kajitoch et al. 2015) that needs to be protected. In eastern Romania, the species associates with large old growth forests. Considering the fact that the deforestation rate in Romania due to legal and illegal activities is high (www.wwf.ro, www.greenpeace.org), there is serious concern regarding the forest fragmentation, and this can lead to a decrease in Ural owl populations, especially in the Carpathian Mountains. Almost all of the forests in the study area are managed. Wood exploitation is an important activity in regional economy, especially in the Carpathians, thus most of the exploited forest are cut down when trees reach maturity. In order to maintain the Romanian populations of this species, more efforts should be put in the preservation of old-growth forests, in maintaining large forest patches, in encouraging selective cutting, and in the prohibition of forest cuts in protected areas.

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