Annex to the II. Progress Report LIFE13/NAT/HU/000081

conservation of the
EUROPEAN ROLLER
www.rollerproject.eu

Study on the potential range expansion of the species in Hungary

Action A2

2018

The work was supported by the European Union's LIFE - Nature Fund

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NATURA 2000

Present habitat suitability of the historical breeding area of the European roller in Hungary

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Abstract

1. Decline of farmlands and grasslands' biodiversity is one the major conservation concerns nowadays. The European roller is a secondary cavity nester species inhabiting typically grasslands and farmlands. It has suffered large declines both in size and range of the population since the 1960s, but applying direct conservation actions, this negative trend has been reversed in several countries.
2. In this study, we aimed to evaluate the current habitat suitability of the historical breeding area of the species in Hungary to promote the recolonization and the enlargement of the breeding range in the Carpathian basin and evaluate potential significance of the Natura 2000 network in this process. We applied species distribution modelling (SDM) to map potential areas for nest-box supplementation.
3. Grasslands, broad-lived forests, agriculture sites with significant areas of natural vegetation were found as the most important predictors. The majority (71%) of the predicted area was without current nest-box occupancy data. Significantly larger proportion of grid cells with archive data still preserve suitable land cover composition for rollers than cells where the former breeding wasn't confirmed, and only small proportion of former breeding area has become completely unsuitable for the species. Our results indicate large overlaps between Nature 2000 network and the predicted area, 16.9% overlaps with Special Protection Area (SPA) sites and 48.6% with Special Area of Conservation (SAC/SCI) sites.
4. Policy implications Our study highlights the importance to promote the recolonization of the Europen roller in the Transdanubian part of Hungary and provides a useful tool for direct conservation planning for the species. Our results also suggest that coordinated network of protected areas such as Natura 2000 can potentially serve as core areas in the recolonization processes.

Keywords: *Coracias garrulus*, MaxEnt, species distribution modelling, Natura 2000

Introduction

Adaptation to environmental conditions may induce restrictions or expansion of a species' distribution area. Contrary to long-term variance of species distribution throughout geological times, human-induced climate change triggered much faster population declines and modification of the breeding grounds (Huntley *et al.* 2008). Large-scale habitat elimination and/or degradation due to the intensification of agriculture and forestry management already resulted in faster biodiversity declines since the middle of the 20th century. Most of the typical farmland and grassland bird species have decreased since that period (Pain & Pienkowski, 1997; Donald *et al.* 2001; Donald *et al.* 2006), and many of them have suffered range contractions as well (Fuller *et al.* 1995). The process of agricultural intensification was different in Central-Eastern European countries and Western part of Europe (Guerrero *et al.* 2012). The intensive socialist agriculture characterized by large state farms and increased chemical use also resulted in the decline of farmland birds, but after the socialist regime collapsed, farmland biodiversity increased again during the political and economical transition due to extensification and abandonment (Báldi & Batáry, 2011). After joining the EU's Common Agricultural Policy (CAP), the negative effects of agricultural intensification have been detected in both Central and Eastern European countries (Nagy *et al.* 2009; Báldi & Batáry, 2011; Szép *et al.* 2012). However, several species have been able to increase and recolonize former distribution areas due to conservation management or decreased/forbidden persecution (in Hungary, e.g. Imperial Eagle (Horváth *et al.* 2011), Saker Falcon (Bagyura *et al.* 2012). In an attempt to mitigate the recent adverse anthropogenic effects, a large variety of conservation management techniques including the establishment of artificial nesting sites, habitat restoration and management or supplementary feeding sites have been developed to promote the survival as well as the recolonization of threatened bird populations. As these actions are usually expensive, well-designed and evidence-based programmes are essential to perform fruitful and cost-effective conservation management.

The European roller (*Coracias garrulus*) is a medium size bird, populations of which has undergone large population declines and range contractions since the 1960s in Europe and in the whole breeding range as well. In the Carpathian basin, it used to be a widespread species, breeding regularly in lowlands and upland regions up to foothill valleys and plain areas of the Carpathian Mountains. Nowadays, Hungary harbours one of the largest populations in the Central European region, but contrary to its historical distribution, the roller population is now restricted to lowlands, plain areas in the eastern part of the country (Kiss & Tokody, 2017). As the European roller is a secondary cavity-nesting species, the shortage of nest sites was successfully counterbalanced by artificial nest-box provisioning in several countries (Avilés *et. al.*, 1999; Kiss *et al.* 2014; Kiss *et al.* 2017). The nest-box program started in 1980s in Hungary and successfully assisted the recovery of the population in the Hungarian Great Plain in the eastern part of the country (Kiss *et al.* 2014; Kiss & Tokody, 2017). Even though large conservation efforts were made also to save the small populations in Slovakia and Austria, the Slovakian population have become extinct (Bohus, 2011) and the Austrian is possibly extinct (Nebel *et al.* 2019). In contrast, the roller population in Vojvodina, Serbia, adjacent to the Hungarian population, is increasing sharply (Ruzic *et al.* 2017).

Species distribution modelling (SDM) has become an important tool in nature conservation (Rodríguez *et al.* 2007) which can be used to identify priority areas of conservation management of birds (Bosso *et al.* 2018; Guisan *et al.* 2013; Marini *et al.* 2010; Tarjuelo *et al.* 2014; *Na et al.* 2018) or mammals (Bassi *et al.* 2015), estimating population size (Krüger *et al.* 2017), locating potential wintering range (McFarland *et al.* 2013; Rodriguez-Ruiz *et al.* 2018), and predicting the effects of climatic variance on species distribution (Huntely *et al.* 2006; Monadjem *et al.* 2012; Morganti *et al.* 2017; Sandor & Đomsa, 2017).

In this study, we aim to use SDM based on current nest-box occupancy and land-cover data to assign potential areas for European rollers' conservation management in Hungary. Until the collapse of the population in the 1970s, the species' historical breeding area was more extended in the Carpathian

Basin than nowadays, and despite of the continuous increase of the Hungarian population, its former distribution area has not yet been recolonised. Therefore, we aim to evaluate the current suitability of historical breeding area for a nest-box program to promote the recolonization and enlargement of the breeding range in Hungary. Natura 2000 is an ecological network in the European Union for threatened species and habitats which aims to develop ecologically and economically sustainable management, to maintain the condition of the natural habitats and species' populations. However, its efficiency to achieve this goal is contradictory (Jantke et al. 2011; Zisenis 2017), whereas Special Protected Areas for birds (SPAs) seem to have positive effect on birds' populations (Gamero et al. 2017); therefore targeted conservation measures should at least partially rely on areas with long-term, nature-friendly management strategies such as Natura 2000 sites. In this paper, we also examine the potential significance of the Natura 2000 network in roller conservation in Hungary by calculating overlap between the predicted areas and Nature 2000 sites in the country.

Methods

The study species

The European roller is a medium size species breeding in the temperate zone, its breeding range reaches from North-Africa, Europe, the steppe region of Asia, and the Middle-East to Mongolia and China. Throughout their breeding range, rollers use various habitats for nesting such as deciduous forest patches, treelines, pine forests or old buildings and sand walls. In the Carpathian basin, rollers typically breed in tree cavities, where the main cavity excavator species are the Green woodpecker (*Picus viridis*) and Black woodpecker (*Dryocopus martius*). Nesting in human buildings and sand walls was rarely recorded. However, trees are required for breeding, the species avoids closed forests; it is connected to the open habitats such as grasslands or extensive agricultural areas in heterogeneous landscape where it typically feeds on large insects and occasionally on vertebrates.

The European roller is a migratory species wintering in the sub-equatorial Africa. They arrive in the breeding grounds in late April and commence autumn migration in late August. They usually have one brood; the breeding season is between May and July.

Breeding data

The nest-box occupancy data was collected in 2016 in the framework of LIFE13/NAT/HU/000081 Life+ Nature project. The study covered the entire current breeding range of the species in Hungary. We collected only artificial nest-box occupancy data (n=1449), natural breeding sites were not included into this analysis. The nest boxes were checked at least once during the breeding period (from beginning of June to the middle of July). A nest-box was considered to be occupied when at least one egg was laid. Both successful and unsuccessful breeding attempts were used as occupied breeding sites. The historical breeding occurrences were derived from data published in Kiss and Tokody (2017).

Environmental data

As environmental predictors, we used land cover data derived from CORINE Land Cover 2015 vector map (1:100 000), Copernicus high resolution forest layers (Forest Type and Tree Cover Density raster map (100 m resolution) https://land.copernicus.eu/). We also used vector layers of the Hungarian Land Parcel Identification System (MePAR) such as scattered trees, treelines, environmentally sensitive and non- environmentally sensitive permanent grasslands. Occurrence data of the main cavity-maker species was derived from the Hungarian Bird Atlas program.

Species distribution model (SDM)

We employed the MaxEnt bioclimatic modelling software (Philips & Dudík, 2008) to estimate the suitability of present environmental conditions for breeding Rollers (Elith *et al.* 2010). MaxEnt applies a machine-learning algorithm using maximum entropy framework to predict the potential range of species calculating presence-only data and environmental parameters, and considered as the leading statistical approach to SDM (Philips *et al.* 2017). To assess the importance of predictors, we used the jackknife test provided by MaxEnt, formulating models with each bioclimatic proxy alternatively excluded. This procedure generates models including each proxy in isolation to calculate variable importance (Shcheglovitova & Anderson 2013). To provide a different independent estimate of the importance of environmental parameters, we calculated permutation importance, obtained from the final MaxEnt model disregarding the path of model development. The contribution of each parameter is calculated by randomly permuting predictor values among birds' presences and background training points and then estimating the resulting decrease in training area under the curve (AUC); large increases in this measurement indicate that the model depends on the specific variable (Phillips & Elith, 2010). The discrimination performance of all bioclimatic models was assessed by AUC, in order to distinguish reliably between the presences and the background points. AUC ranges between 0.0 and 1.0, where 1.0 is considered perfect prediction, while values lower than 0.5 indicate predictions that are not better than random (Fielding & Bell, 1997). During variable selection, we considered the results of the jackknife test and biological information on the studied species, as follows. First, we analysed the results of the jackknife test of the full set of environmental variables (AUC = 0.883) which showed the importance of sensitive stable grasslands and the extent of broad-leaved forests. As both members of this set of supported proxies are expected to have a substantial impact on the distribution of the European Roller, we choose to apply all of these proxies for generating MaxEnt models. MaxEnt model results generate logarithmically scaled calculations of the presence probability estimated by the 10-percentile training presence threshold (Radosavljevic & Anderson, 2014). By using this threshold, suitable habitats are identified which include 90% of the data included in the model formulation.

All bioclimatic modelling was carried out in the statistical framework provided by the MaxEnt programming environment, applying the "dismo" package of the R statistical programming environment (R Development Core Team 2017). All other data management and analyses were conducted applying the R environment, by employing its topic-specific "maptools" (Lewin-Koh *et al.*

2011), "spatstat" (Baddeley & Turner, 2005), "raster" (Hijmans & Van Etten, 2014), "rgdal" (Bivand *et al.* 2014), and "rJava" packages (Urbanek, 2013).

Results

Evaluation of MaxEnt models and importance of bioclimatic predictors

MaxEnt modelling of the breeding distribution under current conditions was highly robust and performed well (model AUC = 0.864), showing that the extent of sensitive, stable grasslands was the most important predictor of Roller breeding, as represented by the highest value of variable support (TG=0.864), calculated as training gain of models including each variable separately (Table 1). The extent of broad-leaved forests proved to be only of secondary importance (TG=0.347). Land principally occupied by agriculture, with significant areas of natural vegetation category was also found as important predictor (TG=0.1233). Distribution of suitable areas for breeding Rollers under current conditions is shown in Fig. 1.

Historical breeding range

The overlaps among current distribution, historical breeding range and predicted potential areas was investigated at the level of 10x10 km UTM national grid. Our prediction showed 51% of Hungary (51888 km^2 in 913 grid cells) to be potentially suitable for roller conservation management (Fig.1). At 10x10 km spatial level altogether 87.5 % of grid cells contained predicted area which covered on average 57.46 ±33.2 % of cell area (n= 913, range 0.09-100%). The majority of the predicted area (71% (37023 km^2) in 727 10x10 km cells) was in cells without current nest-box occupancy data. Concerning the historical breeding distribution, 30% of the predicted area was in cells containing archive data points without current nest-box occupancy data, however 12 % was in cells with archive and current data as well (Fig. 2). Significantly larger proportion of cells with archive data still preserve suitable land cover composition for rollers than cells where the former breeding wasn't confirmed (90.7 % versus 85.5 % respectively, $p < 0.015$, Fisher's exact test). Not more than 36 grid cells (3417 km^2) were found where, contrary to the former presence of the study species, no potential area for roller recolonization was predicted (Fig. 2.)

Natura 2000 sites and roller conservation

Our prediction showed that large proportion of the potential roller conservation area overlaps with the Nature 2000 network in Hungary. 16.9% of the predicted area overlaps with Special Protection Area (SPA) sites and 48.6% with Special Area of Conservation (SAC/SCI) sites. On average, 98.4% (range 88-100) of currently occupied SPAs and 98.5% currently occupied SAC/SCI sites were predicted to be suitable for rollers. Concerning Natura 2000 sites where roller breeding was not detected in 2016 on the average 45.6 % (range 1-100) of SPAs and 73% (range 0-100) of SAC/SCI sites areas is potentially suitable roller nest-box provisioning in the future.

Discussion

In this study we predicted potential areas for direct conservation actions targeting the European roller. Researches using species distribution modelling for conservation purposes often focus on habitat suitability of target species by the identification of key environmental variables of nesting and foraging habitats (Brambilla & Saporetti 2014; Kosicki *et al.* 2015; Stachura-Skierczynska *et al.* 2009; Stachura-Skierczynska & Kosinski 2013; Engler *et al.* 2017). However, less studies address practical conservation tasks such as nest-box provisioning (Brambilla *et al.* 2013; Fehérvári *et al.* 2012) or predict recovery areas (Cianfrani *et al.* 2010). Contrary to the Red-footed falcon, another typical steppe species (Fehérvári *et al.* 2009), our study showed that unlike the current restricted distribution of the European roller in Hungary, large areas are still/again available for the recolonization of the former breeding range. Although, the Hungarian population of the species started to recover during the last decades (Kiss *et al.* 2014), it hasn't been able to recolonize most of the potential regions all over the country, but the process seems to be started during the last few years (Kiss & Tokody, 2017). Our analysis found the presence of sensitive, stable grasslands as most important predictor but agricultural areas with significant amount of natural vegetation were beneficial as well However, the area of grasslands in Hungary decreased largely during the last century (Báldi & Batáry, 2011) they still have high conservation value. Natural and semi-natural grasslands are considered the most important agricultural habitat for biodiversity in Hungary (Ángyán *et al.* 2003) which are still preserving generally very high species richness (Batáry *et al.* 2013).

The Kiskunság region is located between the Danube and Tisza river, and maintains one of the largest core population of the European roller in Hungary (Kiss & Tokody, 2017), even though this region suffered intensive loss of semi-natural grasslands between 1987 and 1999 (Bíro *et al.* 2013). The study species was found sensitive for the agricultural intensification (Avilés & Parejo, 2004) and showed negative trend such as many farmland and grassland bird species (Donald *et al.* 2006). The European roller use various open areas for foraging and compositional landscape heterogeneity may favour its occurrence without conservation measures (Kiss *et al.* 2016). Scattered patches of natural/semi-natural areas may have high conservation value for the study species because roller pairs breeding even on small grassland patches in farmland mosaics are able to achieve the same reproductive performance than pairs using extended natural habitats (Kiss *et al.* 2014). Low intensity grasslands in agricultural landscape are essential foraging sites as they harbour more preys than other land use category (Bouvier *et al.* 2014), similarly to follow lands (Catry *et al.* 2017), and they are available during the late-breeding season as well (Sackl *et al.* 2004).

The European roller was a widespread species in Hungary until the 1980s and the large reduction of size and range of the population following that was most probably attributed to the overall land use changes affecting both the breeding and foraging habitats (Kovács *et al.* 2008). Comparing with the historical breeding range, 30 % of the predicted area was in cells containing archive data points without current nest-box occupancy data, suggesting that large proportion of the former breeding area may be suitable for rollers. Moreover, significantly larger proportion of cells with archive data still preserve suitable land cover composition for rollers. This result may lead to the conclusion that suitable foraging habitats (mainly grasslands) have been at least partially preserved. Fehérvári *et al.* (2012) also found that large-scale land use changes were presumably not responsible for the population decline of the Red-footed falcon (*Falco vespertinus*) in Serbia. However, the historical changes of agricultural practices might result in temporary or permanent shortage of foraging habitats. The European roller used to breed in wood pastures typically located in the Transdanubian and upland region in Hungary (Varga & Bölöni, 2009). The traditional use of this habitat was a various gazing regime performed by smallholder farms which maintained various pastures and large amount of other gazed habitats (Varga *et al.* 2015), potentially serving as foraging habitats for rollers. Many unfavourable changes since then might cause temporary decrease in food availability such as intensive use of synthetic fertilisers and chemicals during existence of cooperatives and significant changes in livestock number and grazing activity (Varga *et al.* 2015) which might contribute to the disappearance of rollers from these habitats (Kiss & Tokody, 2017). However, the area of grazeable land, therefore the area of potential foraging habitats, have not changed considerably in these habitats (Varga *et al.* 2015). The number of grazing cattle increased significantly between 2007 and 2015 in Hungary and a structure of beef stock is dominated by Hungarian breeds and other beef cattle e.g. water buffalo (Nagy & Tasi, 2017). This may contribute to preserve good quality foraging sites for rollers as grasslands grazed by cattle could preserve a rich Orthoptera fauna in Hungary (Batáry *et al.* 2007) and grazing was also found effective to maintain arthropod biodiversity (Torma *et al.* 2019).

Our findings showed that provision of artificial nesting places allows large areas of the country to be suitable for rollers, therefore it highlights the significance of other causal factors behind the former decline of the roller population such decrease of suitable nesting places, migration or increased pesticide use (Kovács *et al.* 2008). Scattered trees and other non-forest woody vegetations have been acknowledged as keystone elements to maintain biodiversity in agricultural landscape (Manning *et al.* 2006; Prevedello *et al.* 2018). However, the amount of these landscape structures declined during the last century. In Germany, the strongest losses were experienced by alleys and tree rows, whereas the greatest decreases occurred in the 1970s -1980s (Plieninger, 2012), similarly to the rollers decline in Europe. Novotný *et. al*. (2017) also found decrease in woody vegetation strips and tree alleys between 1953 and 2014 in Czech Republic as well.

As a secondary cavity nester species, the European roller is highly dependent on the presence of primary excavators. We supposed that the occurrence of the large woodpecker species may indicate good quality habitats for rollers as well. Similarly, to the study species, Green woodpeckers also rely on the presence of cultivated lands (Rolstad ·*et al.* 2000), good quality grasslands especially short grazed and mown grasslands (Adler and Marsden, 2010) and generally requires mosaic landscape structure (Hehl-Lange, 2001). Moreover, grassland patches interspersed within woodlands were found important for Black Woodpecker as well (Brambilla & Saporetti, 2014). In our study, we didn't find the occurrence of any large woodpecker species to be an important predictor. We thus presume that the occupancy data of nest-boxes at this large spatial scale was not suitable to detect such a relationship of between rollers the woodpecker species or/and the grasslands, the most important predictors in our study, indicated the shared important habitats as well. Note that although not remote sensing landscape data alone were used for the analysis, the forest habitat data might not be detailed enough for predicting trees outside forests used by rollers and the woodpeckers as well. Many studies proved the remote sensing data to be useful in distribution modelling, but their limitations are also recognized (Thuiller *et al.* 2004; Kosicki *et al.* 2015; Engler *et al.* 2017)

Natura 2000 is considered the largest coordinated multinational network of protected areas in the world. Being a key conservation tool for preserving European biodiversity, many studies targeted to evaluate its effectiveness (Kleijn & Sutherland, 2003; Kleijn *et al.* 2006, Princé *et al.* 2012; Palacín & Alonso, 2016) and socio-economic context (Kati *et al.* 2014, Popescu *et al.* 2014). Surprisingly, in comparison to their presence in the European directives, birds were underrepresented in articles focusing on Natura 2000 network (Orlikowska *et al.* 2016). In Hungary, the area of Nature 2000 site is large (1.95 million ha, 21% of the country area), and 39% of it were national protected sites before the EU accession. The overlap between Special Protection Area (SPA) sites and with Special Area of Conservation (SAC/SCI) is 43%. Although, SPAs primarily aim to safeguard the European bird species considered to be of particular importance, our results showed only that 16.9% of the predicted area overlaps with SPA sites, which amounts to 48.6 % considering SAC/SCI sites. This result could be explained by the criteria of the latter category. Special Areas of Conservation are established under the European Union Habitats Directive (92/43/EEC), which secures steppic grasslands of the Pannonian biogeographical region. The European roller is able to occupy landscapes consisting of small mosaic patches (Kiss *et al.* 2016), therefore the breeding population of the species is not exceptionally concentrated on large grassland areas like the SPAs on the Hungarian Plains, but it may use smaller grassland areas which are not harbouring significant populations of bird species listed in Annex I of Bird Directive. Other studies also found the effectiveness of Natura 2000 network in bird conservation controversial. Natura 2000 networks cover major large proportion of threatened species' distribution area, but low coverage was found in 42% of the threatened bird species (Trochet & Schmeller, 2013). SPAs provided more favourable conditions for the flagship species, but the reverse was found for farmland and steppe species (including the European roller) (Santana *et al.* 2013). Similarly, positive effects of SPAs on their target species was found in Poland, but agri-environment schemes (AES) were not able to reach this goal (Żmihorski *et al.* 2015).

Conclusions

In this study we confirm the possibility of further conservation measures for the European Roller in its former breeding distribution area. Our results highlight the importance of conservation of natural or semi-natural grasslands. Furthermore, we suggest that more attention should be paid to scattered old trees, forest formations and hedges, because of the lack of these elements from the landscape may be behind the lack of recolonization of species. This study also showed that Natura 2000 network may have high conservation value for the European roller, if both SPA and SAC sites are included.

Authors' Contributions:

OK and ZsV conceived the ideas, designed methodology. BT, OK and KN collected the data. ZsV analysed the data and OK drafted the manuscript. All authors contributed critically to the drafts and gave final approval for publication.

Data accessibility

The European roller has a protected status in Hungary, therefore the locations of occupied nest-boxes cannot be accessible publicly. The results of modelling procedure will be available via the Dryad Digital Repository.

Acknowledgements

We would like to thank the help of all national park rangers and volunteers of Birdlife Hungary who participated in the field work. We are also grateful to Bükk National Park, Kiskunság National Park, Hortobágy National Park, Körös-Maros National Park, and Duna-Ipoly National Park to let us work in national park areas. We are also grateful to all volunteers participating in Hungarian Bird Atlas program and the Ministry of Agriculture for providing MePar data.

Funding

This work was supported by LIFE13/NAT/HU/000081 and Orsolya Kiss was supported by the NKFI KH 130338 project.

References

Alder, D. & Marsden S. (2010). Characteristics of feeding-site selection by breeding Green Woodpeckers Picus viridis in a UK agricultural landscape. Bird Study, 57, 100–107.

Ángyán, J., Tardy, J., Vajnáná-Madarassy, A. (eds). (2003). Védett és érzékeny természeti területek mezőgazdálkodásának alapjai,Mezőgazda, Budapest (in Hungarian).

Ansell, D., Freudenberger, D., Nicola Munro, N. Gibbons, P. (2016). The cost-effectiveness of agri-environment schemes for biodiversity conservation: A quantitative review, Agriculture, Ecosystems and Environment, 225, 184–191.

Avilés, J.M. & Parejo, D. (2004). Farming practices and Roller Coracias garrulus conservation in south-west Spain. Bird Conservation International, 14, 173–181.

Avilés, J.M., Sánchez, J.M., Sánchez, A., Parejo, D. (1999). Breeding biology of the Roller (Coracias garrulus) in farming areas of the southwest Iberian peninsula. Bird Study 46, 217–223.

Baddeley, A. & Turner, R. (2005). Spatstat: an R package for spatial point patterns. Journal of Statistical Software, 12: 1–42.

Bagyura, J. Szitta, T. Haraszthy, L., Viszló, L, Fidlóczky, J., Prommer, M. (2012). Results of the Saker Falcon (Falco cherrug) conservation programme in Hungary between 1980–2010. Aquila, 119, 105–110.

Baldi, A. & Batary, P. (2001). The past and future of farmland birds in Hungary. Bird Study, 58, 365-377.

Báldi, A., Batáry, P. & Kleijn, D. (2013). Effects of grazing and biogeographic regions on grassland biodiversity in Hungary – analysing assemblages of 1200 species. Agriculture, Ecosystems and Environment , 166, 28–34.

Bassi E, Willis SG, Passilongo D, Mattioli L, Apollonio, M. 2015. Predicting the spatial distribution of wolf (Canis lupus) breeding areas in a mountainous region of Central Italy. PLoS ONE 10, e0124698.

Bíró, M., Czúcz, B., Horváth, F., Révész, A., Csatári B., Molnár, Zs. (2013). Drivers of grassland loss in Hungary during the post-socialist transformation (1987–1999). Landscape Ecology, 28, 789–803.

Bivand, R., Keitt, T. & Rowlingson, B. (2014). rgdal: Bindings for the Geospatial Data Abstraction Library. R package version 0.8-16. URL http://CRAN. R-project. org/package= rgdal

Bohus, M. (2011). Breeding and occurrence of the European Roller (Coracias garrulus) in SW Slovakia during 2007–2011. Tichodroma 23: 13–20

Bosso, L., Smeraldo, S., Rapuzzi, P., Sama, Garonna, G. A.P., Russo, D. (2018). Nature protection areas of Europe are insufficient to preserve the threatened beetle *Rosalia alpina* (Coleoptera: Cerambycidae): evidence from species distribution models and conservation gap analysis. Ecological Entomology, 43, 192–203.

Bouvier, J. C., Muller, I., Génard, M., Lescourret, F. & Lavigne, C. (2014). Nest-site and landscape characteristics affect the distribution of breeding pairs of European rollers Coracias garrulus in an agricultural area of southeastern France. Acta Ornithologica, 49: 23–32.

Brambilla, M. & Saporetti, F. (2014). Modelling distribution of habitats required for different uses by the same species: Implications for conservation at the regional scale. Biological Conservation, 174, 39-46.

Catry, I., Marcelino, J., Franco, A. M. A., Moreira, F. (2017). Landscape determinants of European roller foraging habitat: implications for the definition of agri-environmental measures for species conservation. Biodiversity and Conservation, 26, 553–566.

Cianfrani, C., Le Lay, G., Hirzel, A.H., Loy, A. (2010). Do habitat suitability models reliably predict the recovery areas of threatened species? Journal of Applied Ecology, 47, 421–430.

Cramp, S. (Eds) (1998): The birds of the western Palearctic on CD-ROM. Oxford University Press, Oxford.

Donald, P.F., Green, R.E. & Heath, M.F. (2001). Agricultural intensification and the collapse of Europe's farmland bird populations. Proceedings of the Royal Society B, 268, 25–29.

Donald, P.F., Sanderson, F.J., Burfield, I.J., van Bommel, F.P.J. (2006). Further evidence of continent-wide impacts of agricultural intensification on European farmland birds, 1990–2000. Agriculture, Ecosystems and Environment, 116, 189–196.

Elith, J., Phillips, S. J., Hastie, T., Dudík, M., Chee, Y. E. and Yates, C. J. (2011). A statistical explanation of MaxEnt for ecologists. Diversity and Distribution, 17, 43–57.

Engler, J.O., Stiels, D., Schidelko, K., Strubbe,D., Quillfeldt ,P., Brambilla, M. (2017). Avian SDMs: current state, challenges, and opportunities. Journal of Avian Biology, 48, 1483–1504.

Fehérvári, P., Harnos, A., Neidert, D., Solt, S., Palatitz, P. (2009). Modelling habitat selection of the Red-footed Falcon (Falco vespertinus): a possible explanation of recent changes in breeding range within Hungary. Applied Ecology and Environmental Research, 7, 59–69.

Fehérvári, P., Solt, S., Palatitz, P., Barna, K., Ágoston, A., Gergely, J., Nagy, A., Nagy, K., Harnos, A. (2012). Allocating active conservation measures using species distribution models: a case study of red-footed falcon breeding site management in the Carpathian Basin. Animal Conservation, 15, 648–657.

Fuller, R.J., Gregory, R.D., Gibbons, D.W., Marchant, J.H., Wilson, J.D., Baillie, S.R., Carter, N. (1995). Population declines and range contractions among lowland farmland birds in Britain. Conservation Biology, 9, 1425–1441.

Gamero, A., Brotons, L., Brunner, A., Foppen, R., Fornasari, L., Gregory, R. D., Herrando, S., Hořák, D., Jiguet, F., Kmecl, P., Lehikoinen, A., Lindström, Å, Paquet, J-Y., Reif, J., Sirkiä, P.M., Škorpilová, J., van Strien, A., Szép, T., Telenský, T., Teufelbauer, N., Trautmann, S., van Turnhout, C. A.M., Vermouzek, Z., Vikstrøm, T. (2017). Tracking progress toward EU biodiversity strategy targets: EU policy effects in preserving its common farmland birds. Conservation Letters, 10, 395–402.

Guerrero, I., Morales, M.B., Onate, J.J., Geiger, F., Berendse, F., de Snoo, G., Eggers, S., Pärt, T., Bengtsson, J., Clement, L.W., Weisser, W.W., Olszewski, A., Ceryngier, P., Hawro, V., Liira, J., Aavik, T., Fischer, C., Flohre, A., Thies, C., Tscharntke, T. (2012). Response of ground-nesting farmland birds to agricultural intensification across Europe: landscape and field level management factors. Biological Conservation, 152, 74–80.

Guisan A., Tingley R., Baumgartner J.B., Naujokaitis-Lewis I., Sutcliffe P.R., Tulloch A.I.T., Tracey J. Regan, T.J., Brotons, L., McDonald-Madden, E., Mantyka-Pringle, C., Martin, T.G., Rhodes, J. R., Maggini, R., Setterfield, S. A., Elith, J., Schwartz, M.W., Wintle, B. A., Broennimann, O., Austin, M., Ferrier, S., Kearney, M.R., Possingham, H.P. Buckley, Y.M. (2013). Predicting species distributions for conservation decisions. Ecology Letters, 16:1424–35.

Hehl-Lange, S. (2001). Structural elements of the visual landscape and their ecological functions, Landsc Urban Plan. 54, 105-113.

Hijmans, R. J. and Van Etten, J. (2014). raster: Geographic data analysis and modelling R package version 22-31 URL http://CRAN R-project org/package= raster.

Horváth, M., Szitta, T., Fatér, I., Kovács, A., Demeter, I., Firmánszky, G., Bagyura, J. (2011). Population dynamics of the Eastern Imperial Eagle (Aquila heliaca) in Hungary between 2001 and 2009. Acta Zoologica Bulgarica (Suppl. 3), 61-70.

Huntely, B., Collingham, Y. C., Willis, S. G., Green, R. E. (2008). Potential impacts of climatic change on European breeding birds. PLoS One 3: e1439.

Huntley, B., Collingham, Y. C., Green, R. E., Hilton, G. M., Rahbek, C. and Willis, S. G. (2006). Potential impacts of climatic change upon geographical distribution of birds. Ibis, 148, 8–28.

Jantke, K., Schleupner, C. & Schneider, U.A. (2011). Gap analysis of European wetland species: priority regions for expanding the Natura2000 network. Biodiverstiy and Conservation, 20, 581–605.

Kati, V., Hovardas, T. Dieterich, M., Ibisch, P.L., Mihok, B., Selva, N. (2014). The challenge of implementing the European network of protected areas Natura 2000. Conservation Biology, 29, 260–270.

Kiss, O., Elek, Z., Moskát,C (2014). High breeding performance of European Rollers Coracias garrulus in heterogeneous farmland habitat in southern Hungary. Bird Study, 61, 496-505.

Kiss, O., Tokody, B., (2017). Distribution, population changes and conservation of the European Roller (Coracias garrulus) in Hungary. Aquila, 124, 75–90.

Kiss, O., Tokody, B., Deák, B., Moskát, C (2016). Increased landscape heterogeneity supports the conservation of European rollers (Coracias garrulus) in southern Hungary. Journal for Nature Conservation, 29, 97–104.

Kiss, O., Tokody, B., Ludnai, T. & Moskát, C. 2017. The effectiveness of nest-box supplementation for European rollers (Coracias garrulus). Acta Zoologica Academiae Scientiarum Hungaricae, 63, 123–135.

Kleijn, D., Baquero, R.A., Clough. Y., Díaz. M., De Esteban, J., Fernández, F., Gabriel, D., Herzog, F., Holzschuh, A., Jöhl, R., Knop, E., Kruess, A., Marshall, E.J., Steffan-Dewenter, I., Tscharntke, T., Verhulst, J., West, T.M., Yela, J.L. (2006). Mixed biodiversity benefits of agri-environment schemes in five European countries. Ecology Letters, 9, 243-54.

Kleijn,D., William J. Sutherland, W.J. 2003. How effective are European agri-environment schemes in conserving and promoting biodiversity? Journal of Applied Ecology, 40, 947-969.

Kosicki, J.Z., Krystyna Stachura, K., Ostrowska, M., Rybska, E. (2015). Complex species distribution models of Goldcrests and Firecrests densities in Poland: are remote sensing-based predictors sufficient? Ecological Research, 30, 625–638.

Kovács, A., Barov, B., Urhun, C., Gallo-Orsi, U. (2008). International Species Action Plan for the European Roller Coracias garrulus garrulus

Krüger, l., Paiva, V.H., Petry, M.V., Montone, R. C., Ramos, J.A. (2018). Population estimate of Trindade Petrel Pterodroma arminjoniana by the use of Predictive Nest Habitat Modelling. Bird Cons. Inter. 28, 197-207.

Manning, A. D., Fischer, J. & Lindenmayer,D.B. (2006). Scattered trees are keystone structures – Implications for conservation, Biological Conservation, 132, 2311-321.

Marini,M. A., Morgane Barbet-Massin, M., Lopes, L. E., Jiguet, F. (2010). Predicting the occurrence of rare Brazilian birds with species distribution models. Journal of Ornithology, 151, 857–866.

McFarland, K. P., Rimmer, C.C., Goetz, J.E., Aubry, Y., Wunderle, J.M., A. Sutton, A., Townsend, J.M., Sosa, A.L., Kirkconnell, A. 2013. A winter distribution model for Bicknell's Thrush (Catharus bicknelli), a conservation tool for a threatened migratory songbird. PLoS One 8, e53986.

Monadjem, A., Virani, M. Z., Jackson, C., Reside, A. (2013). Rapid decline and shift in the future distribution predicted for the endangered Sokoke Scops Owl Otus ireneae due to climate change. Bird Conservation Intational, 23, 247–258.

Morganti, M., Preatoni, D. & Sarà, M. (2017). Climate determinants of breeding and wintering ranges of lesser kestrels in Italy and predicted impacts of climate change. J. Avian Biol. 12, 1595-1607.

Na, X., Zhoub, H., Zanga, S., Wuc, C., Lid, W., Lia, M. 2018. Maximum Entropy modeling for habitat suitability assessment of Red crowned crane. Ecological Indicators, 91, 439–446.

Nagy, s., Nagy, K. & Szép, T. (2009). Potential impact of EU accession on common farmland bird populations in Hungary. Acta Ornithologica, 44, 37-44.

Nagy, G. &Tasi J., 2017. A legelők és a legeltetés szerepe a húsmarhatartásban, Állattenyésztés és takarmányozás, 66, 347-364. (in Hungarian)

Nebel, C., Kadletz, K., Gamauf, A., Haring, E., Sackl, P., Tiefenbach, M., Winkler, H. Zachos, F.E. (2019). Witnessing extinction: Population genetics of the last European Rollers (Coracias garrulus) in Austria and a first phylogeographic analysis of the species across its distribution range. Journal of Zoological Systematics and Evolutionary Research, 2018, 1–15.

Novotný, M, Skalos, J. & Plieninger,T. (2017). Spatial-temporal changes in trees outside forests: Case study from the Czech Republic 1953-2014. Applied Geography, 87, 139-148.

Orlikowska, E. H., Roberge, J.-M., Blicharska, M., Mikusiński, G. (2016). Gaps in ecological research on the world's largest internationally coordinated network of protected areas: a review of Natura 2000. Biological Conservation, 200, 216–227.

Pain, D.J. & Pienkowski, M.W. (eds) (1997). Farming and birds in Europe. The common agricultural policy and its implications for bird conservation. London: Academic Press.

Palacin, C. & Alonso, C.J. (2018). Failure of EU Biodiversity Strategy in Mediterranean farmland protected areas. Journal of Nature Conservation, 42, 62-66.

Phillips, S. J. & Elith, J. (2010). POC plots: calibrating species distribution models with presence-only data. Ecology 91, 2476–2484.

Phillips, S.J. & Dudík, M. (2008). Modeling of species distributions with Maxent: new extensions and a comprehensive evaluation. Ecography 31, 161–175.

Plieninger, T., Christian Schleyer, C., Mantel, M., Hostert, P. (2012). Is there a forest transition outside forests? Trajectories of farm trees and effects on ecosystem services in an agricultural landscape in Eastern Germany. Land Use Policy 29, 233-243.

Plieninger,T., Schleyer,C., Mantel, M., Hostert, P. (2012). Is there a forest transition outside forests? Trajectories of farm trees and effects on ecosystem services in an agricultural landscape in Eastern Germany. Land Use Policy 29, 233-243.

Popescu, V. D., Rozylowicz, L., Niculae, I.M., Adina L. Cucu, A.L. , Hartel,T. (2014). Species, Habitats, Society: An Evaluation of Research Supporting EU's Natura 2000 Network. PLoS ONE 9(11): e113648.

Prevedello, J.A., Almeida-Gomes. M., Lindenmayer, D.B. 2018. The importance of scattered trees for biodiversity conservation: a global meta-analysis. J Appl. Ecol. 55, 205-214.

Princé, K. Jean-Pierre Moussus, J-P., Jiguet, F. (2012). Mixed effectiveness of French agri-environment schemes for nationwide farmland bird conservation. Agriculture, Ecosystems and Environment , 149, 74–79.

Radosavljevic, A. & Anderson, R. P. (2014). Making better Maxent models of species distributions: complexity, overfitting and evaluation. Journal of Biogeography, 41, 629–643.

Rodríguez, J.P., Brotons, L., Bustamante, J. Seoane, J. (2007). The application of predictive modelling of species distribution to biodiversity conservation. Diversity and Distribution, 13, 243–251.

Rodríguez-Ruiz, J., Mougeot, F., Parejo, D., De la Puente, J., Bermejo, A., Avilés, J. M. (2018). Important areas for the conservation of the European Roller Coracias garrulus during the non-breeding season in southern Africa. Bird Conservation International, 0:1-17.

Rolstad, J., Løken, B. & Rolstad, E. (2000). Habitat selection as a hierarchical spatial process: the green woodpecker at the northern edge of its distribution range. Oecologia, 124, 116–129

Ruzic, M., Szekeres, O., Ágoston, A., Balog, I., Brdarić, B.,Gergely, J., Đapić, D., Đorđević, I., Hám,I.,Márton,F., Pantović, U., Radišić, D., Rajkovic, D., Rankov, M., Sihelnik, J., Šimončik, S., Szekeres, I., Szekeres, L., Sučić, A., Tucakov, M., Vida, N., Vučanović, M. (2017). The recovery of the European Roller (Coracias garrulus) population in Vojvodina Province, Serbia. Adriatic Flyway 193-201

Sackl, P., Tiefenbach, M., Ilzer, W., Pfeiler, J., Wieser, B. (2004). Monitoring the Austrian relict population of European roller Coracias garrulus – a review of preliminary data and conservation implications. Acrocephalus, 121: 51–57.

Sandor, A.D &Domşa, C. (2018). Climate change, predictive modelling and grassland specialists: assessing impacts of changing climate on the long‑term conservation of Lesser Grey Shrikes (Lanius minor) in Romania. Journal of Ornithology, 159, 413–424.

Santana, J., Reino, L., Stoate, C., Borralho, R. (2013). Mixed effects of long-term conservation investment in Natura 2000 farmland. Conservation Letters, 7, 467–477.

Shcheglovitova, M. & Anderson, R. P. (2013). Estimating optimal complexity for ecological niche models: a jackknife approach for species with small sample sizes. Ecological Modelling, 269: 9–17.

Stachura-Skierczyńska, K., Kosiński, Z. (2014). Evaluating Habitat Suitability for the Middle Spotted Woodpecker Using a Predictive Modelling Approach. Annales Zoologici Fennici, 51, 349-370.

Stachura-Skierczynska, K., Tumiel, T., Skierczynski, M. (2009). Habitat prediction model for three-toed woodpecker and its implications for the conservation of biologically valuable forests. Forest Ecology and Management, 258, 697–703.

Szép, T., Nagy, K., Nagy, Z., Halmos, G. (2012). Population trends of common breeding and wintering birds in Hungary, decline of long distance migrant and farmland birds during 1999–2012. Ornis Hungarica 20, 13—63. doi: 10.2478/orhu-2013-0007

Tarjuelo, R., Morales, M.B. Traba, J., Delgado, M. P. (2014). Are Species Coexistence Areas a Good Option for Conservation Management? Applications from Fine Scale Modelling in Two Steppe Birds. PLoS ONE 9, e87847.

Thuiller W., Araújo, M.B., Pearson, R.G., Whittaker, R.J., Brotons, L., Lavorel, S. (2004). Biodiversity conservation: uncertainty in predictions of extinction risk. Nature, 427, 145–148

Torma, A., Császár, P., Bozsó, M., Deák, B., Valkó, O., Kiss, O., Gallé, R. (2019). Species and functional diversity of arthropod assemblages (Araneae, Carabidae, Heteroptera and Orthoptera) in grazed and mown salt grasslands. Agriculture, Ecosystems and Environment, 273, 70-79.

Trochet A. & Schmeller, D.S. (2013). Effectiveness of the Natura 2000 network to cover threatened species. Nature Conservation, 4: 35–53.

Urbanek, S. (2013) rJava: Low-level R to Java interface.

Varga, A.& Bölöni, J. (2009). Erdei legeltetés, fás legelők, legelőerdők tájtörténete. Természetvédelmi Közlemények, 15, 68-79. (in Hungarian)

Varga, A., Odor, P., Molnár, Z., Bölöni, J. (2015). The history and natural regeneration of a secondary oak-beech woodland on a former wood-pasture in Hungary. Acta Societatis Botanicorum Poloniae, 84, 215–225.

Zisenis, M. (2017). Is the Natura 2000 network of the European Union the key land use policy tool for preserving Europe's biodiversity heritage? Land Use Policy 69, 408-416.

Żmihorski, M., Kotowska, D., Berg, Å., Pärt, T. (2016). Evaluating conservation tools in Polish grasslands: The occurrence of birds in relation to agri-environment schemes and Natura 2000 areas. Biological Conservation, 194, 150–157.

Figure legends

Fig 1. The locations of occupied nest-boxes used for the modelling procedure and the predicted area for roller conservation

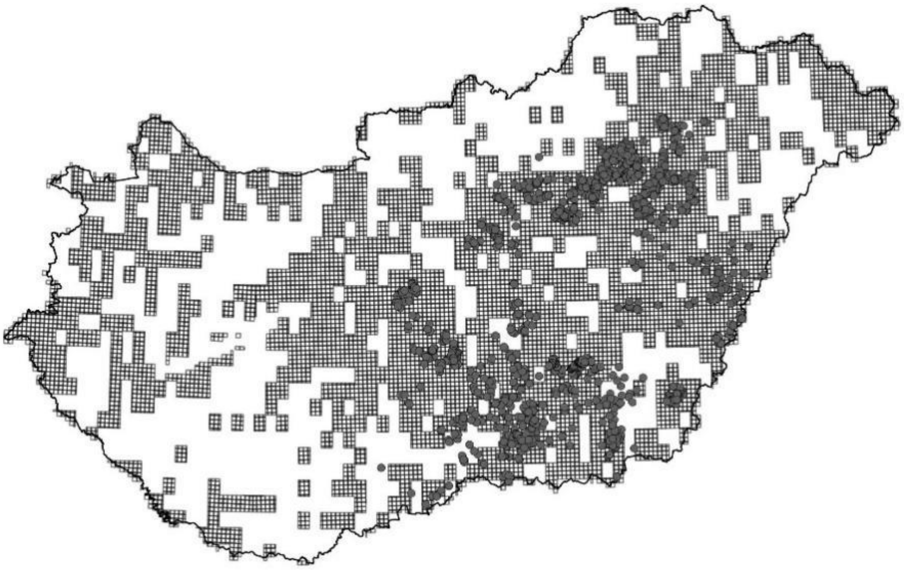

Fig 2. The overlaps between historical distribution range, current breeding locations and predicted areas

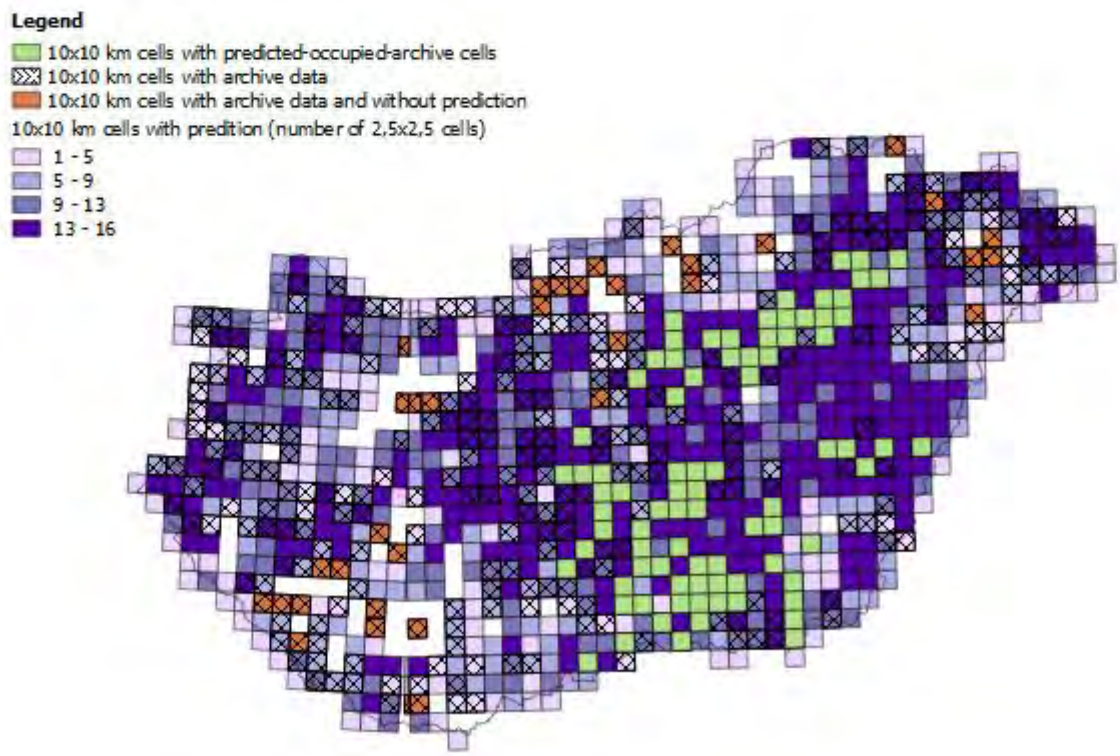

Fig 3. Natura 2000 sites in Hungary and predicted area

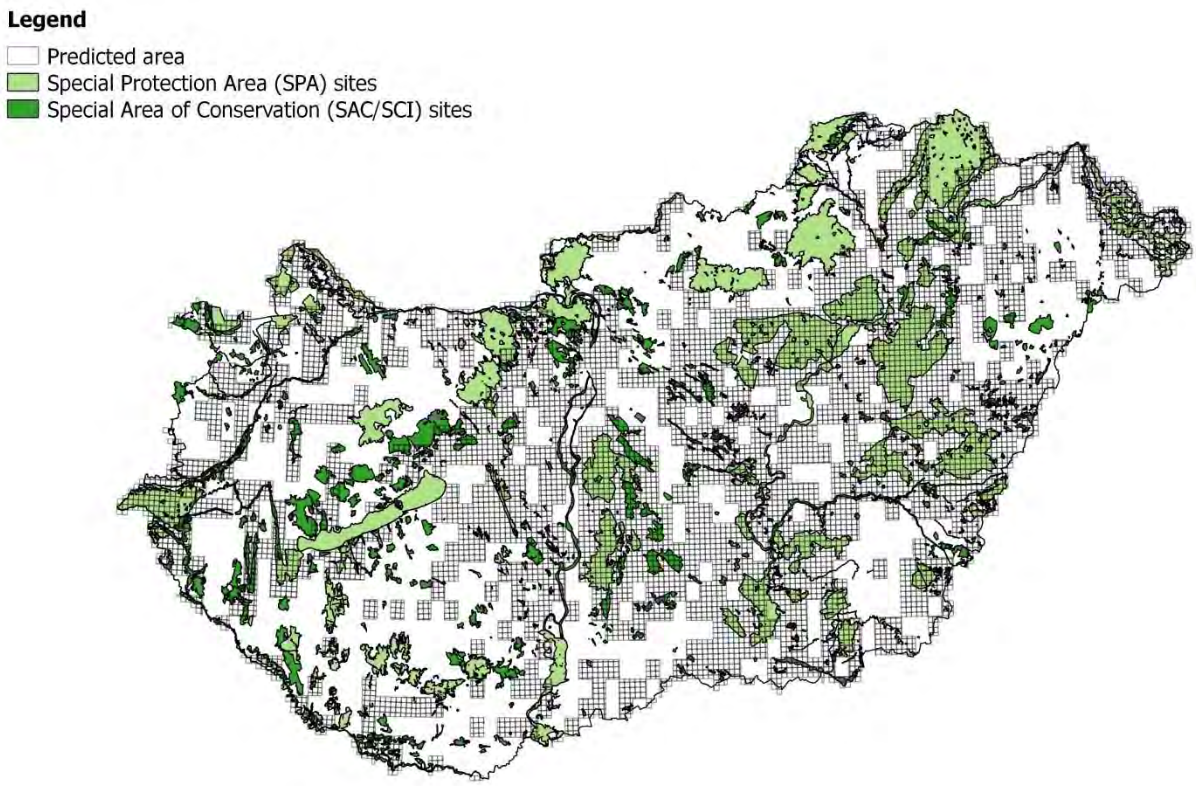

Table 1. Statistical properties of MaxEnt model performance fitted on the occurrence points

Predictor	Training gain
Permanent sensitive grasslands	**0.4208**
Broad-leaved-forest (CLC-311)	**0.357**
Land principally occupied by agriculture, with significant areas of natural vegetation	**0.1233**
Non irrigated arable (CLC 211)	0.0922
Tree Cover Density 2015	0.0887
Inland marshes (CLC 411)	0.0778
Black woodpecker	0.0708
Forest Type 2015	0.0641
Non sensitive permanent grasslands (2018)	0.056
Transitional woodland-scrub (CLC-324)	0.0548
Mixed forest (CLC-312)	0.0506
Fruit tree plantation (CLC-222)	0.0313
Complex cultivation patterns (CLC 242)	0.0291
Coniferous forest (CLC 312)	0.024
Green woodpecker	0.0124
Vineyards	0.011
Water bodies	0.0072
Tree lines (2018)	0.0048
Scattered trees (2018)	0.0022
AUC	**0.8825**

Journal of Applied Ecology - Receipt of manuscript JAPPL-2019-00193

Beérkező levelek

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27-Feb-2019

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JAPPL-2019-00193
Research Article
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Kiss, Orsolya; Tokody, Béla; Nagy, Károly; Végvári, Zsolt

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