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Causes and consequences of European Roller's (*Coracias garrulus*) habitat selection

Summary of the PhD thesis

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1. Introduction

Birds are ideal subjects of habitat selection studies as they are highly mobile, easily detectable, use different habitats in their home-range, represent different trophic levels and have various life history traits. Selection for suitable breeding sites influences reproductive success and survival therefore it has significant effects on population dynamics, as well. Different characteristics can be used to evaluate quality of a certain habitat patch such as vegetation structure or presence and reproductive success of conspecifics. Individuals can use the same nesting sites over years or select new territories between or within breeding seasons. Nest-site fidelity or dispersal pattern are characteristic for a bird species and it usually depends on their reproductive strategies, former breeding performance and predation rate. Besides, suitable foraging sites, ensuring good quality and quantity of food, also play important roles in birds' reproductive success. Nowadays, as a result of various habitat mapping projects all over the world; national and international databases provide possibility to investigate birds‘habitat selection on the landscape scale. These analyses contribute to determine factors responsible for populations' distribution patterns and reveal how the recent changes in landscape structure and composition had affected bird populations.

The European roller (*Coracias garrulus*) is a threatened bird species in Europe. This population declined considerably in the 1970s, disappearing as a breeding species from Finland, Denmark, Germany and the Czech Republic. The Hungarian population also suffered from this decline from 1980s: European rollers completely disappeared from western Hungary, and the larger populations of the eastern and southern regions also declined. The main causes could be the loss of suitable habitats due to the changing in agricultural practices and loss of proper nesting hollows. The lack of nesting hollows proved to be the main limiting factor, since nest-box programs successfully increased the breeding population in several countries (Austria, Spain, France and Hungary). However, in Estonia nest-box supply could not change the negative population trend. Moreover, this conservation management should be applied with caution, as nest-boxes in low-quality habitats may serve as ecological traps. Besides the lack of nesting places, decrease quality and quantity of foraging sites mean also serious threats for rollers. European roller was found one of the farmland and grassland bird species those populations decreased significantly due to agricultural intensification. Several farming practices were identified as negative factors on breeding success and clutch size in Spain. In Portugal agricultural intensification and land abandonment caused population decline and fragmentation of rollers' natural habitat. The aim of this thesis to investigate which factors influence rollers habitat selection at the local and landscape scales. We also aimed the determine factors affecting occupancy rate of newly provided nest-boxes to contribute the design of more effective conservation programs.

2. Aims

I. Food availability, food preference and breeding parameters in different habitats

I./a. Food availability and its effect on breeding performance of rollers

- Does the food availability for rollers differ between the two habitats?
- Does the food availability affect breeding parameters?
- Is there a difference in quantity and seasonal changes of potential food supply between the two habitats?

II./b. Food preference and different sampling methods

- Does sampling methods affect the evaluation of food preference and how?
- Is there a difference in food preference of rollers between study sites?

II. The role of landscape scale factors in habitat selection of rollers

- We aim to determine density and distribution of rollers nesting in artificial nest-boxes and natural breeding sites in the southern region of Hungary.
- Which factors affect the occurrence of European rollers in landscapes without artificial nest-boxes at large spatial scales (5×5 km, 10×10 km)?
- Which landscape components are preferred by rollers at the individual-territory level?

III. Nest-site fidelity and dispersal

- What are the characteristics of natal and breeding dispersal of rollers?
- Is there a difference between the dispersal distances of adult male and female rollers?
- Is there a difference between the distance of natal and breeding dispersal of rollers?

IV. Occupancy rate of newly provided nest-boxes

- Which factors affect the occupancy rate of rollers in newly provided nest-boxes?
- Which factors influence the permanent occupancy of nest-boxes?

3. Materials and methods

European roller (*Coracias garrulus*)

Roller is a secondary cavity nesting species; rollers usually use the former holes of Green woodpeckers (*Picus viridis*) and Black woodpeckers (*Dryocopus maritus*). They are typically feed on insects, but occasionally also prey on vertebrates. Rollers main foraging sites are grasslands and various agricultural fields. The breeding season is between May to August, rollers usually arrives from Africa in late April and start to migrate in early September. They typically have one brood per year.

Study sites and sampling methods

I. The study was conducted in two sites: (i) Baksi-puszta (46°32'N; 20°03'E), this habitat was alkaline natural grassland, which was characterized by salt and dry grassland patches. (ii) Farmland mosaics, near the village Szatymaz (46°24'N; 19°57'E). The second site is an agricultural area, which is the mosaic of salt grassland patches (23% of the whole area) and extensive cereal cultures (3%), arable fields (53%) and artificial forest monocultures (4% of the whole area). We studied the availability of prey in 12 and 14 plots at the Baks and Szatymaz sites, respectively, in 2009. At both sites plots were established in grassland patches of the habitat, within the breeding territories of Rollers. Our sampling plots were established within 150 m radius around the nest-boxes, because about 165-170 m foraging radius of rollers in the nesting period was reported in a Spanish study. We used pitfall traps and sweep-net sampling to estimate arthropod abundance and potential prey species diversity. In each study plot we randomly placed five pitfall traps of plastic cups with the diameter of 65 mm in a line, 1 m apart from each other. Ethylene glycol (30-50%) was used as killing-preservative solution. We also sampled potential prey by sweep netting in three transects within a territory, under good weather conditions. Pitfall-traps were active for two weeks between 16 June and 20 July, which overlapped the feeding period of nestlings. This resulted in two samples by pitfall traps and three samples by sweep netting. Rollers usually feed on arthropods larger than 1 cm hence we selected the food items larger than 1 cm from the collected samples for further analyses. We identified arthropods to families, then dried and their biomass was measured (accuracy: 0.001g).

II. Our study took place in Csongrád (N46° 25' 35.25"; E20° 14' 05.75") and Bács-Kiskun counties (N46° 34' 01. 59"; E19° 22' 42.17") in southern Hungary. The distribution of rollers was surveyed at the landscape-scale in 2010. Rollers' occurrence was surveyed by territory mapping based on two visits. The first visit was in the early breeding season (between May 10-20) and the second visit was in the middle of the breeding season (between June 10-20) before nestlings fledged. For detecting factors that influence rollers' occurrence under natural circumstances we used presence/absence data without artificial nest-box supply at different spatial scales. Two spatial scales were considered for the analysis of environmental variables and rollers' occupancy pattern (5×5 km and 10×10 km UTM grids). We used five classes of land cover data from CORINE 50 Land Cover maps, such as arable lands, grasslands, heterogeneous agricultural areas, broadleaved forests, permanent crops, the number of patches of different land cover classes and Shannon's diversity. Different landscape metrics, such as diversity indices (Shannon, Simpson, evenness, and dominance), fragmentation metrics (degree of landscape division, effective mesh size, and splitting index), edge and form analysis were calculated by using a vector-based landscape analysis tool (V-Late 1. extension for ArcGIS 9, ESRI, Redlands, USA).

III. Nest-boxes involved in this study were installed in new sites between the autumn of 2010 and early spring of 2011 as a part of a conservation management program by local amateur ornithologists of BirdLife Hungary. All new nest-boxes were available for rollers during the breeding season of 2011. The nest-box design was the same in all cases of newly installed boxes (height: 40 cm, width: 30 cm, depth: 25 cm). The following parameters of the boxes were recorded in the field after installation: orientation, height (m) and holder type (pylon or tree). We compiled occupancy records in nest boxes between 2011 and 2014. We considered a nest-box occupied by rollers if eggs or nestlings were present. The occupancy of nest-boxes was checked at least once during June or July.

IV. Breeding and natal dispersal of rollers were analysed based on database of Hungarian Bird Ringing Centre between 1930 – September of 2015. Rollers which were caught during incubation were considered adults (age category 2y or 2+). Altogether, we analysed 66 dispersal distances of 57 individuals (37 male and 22 female). In natal dispersal two groups were created: one for rollers which were recaptured in their second year (2y) (54 individuals) and one for all individuals which were ringed as a nestling and were recaptured as an adult (141 data).

Data analysis

Four different models were used to reveal relationship between food availability and breeding performance transformed: (1) The first linear model described how reproductive success (as a response variable) was affected by the nesting parameters, such as feeding rate, date of the first egg laid and clutch size as covariates, also including habitat type as a fixed factor. (2) The next model estimated how the feeding rate was affected by the nesting parameters, such as feeding rate, date of the first egg laid and clutch size, also including habitat types. The first model was the simple effect model, while in the second variant the linear predictor was corrected by clutch size. (3) Additional models were built to describe the relationship between reproductive success and food resources. Four models were tested and compared by multi-model inference. In the models, reproductive success was the response variable and food resources (orthopterans, coleopterans and the total abundance of prey) with their interaction with habitat types were used as predictors. (4) Three single argument models were built (to avoid collinearity) to describe how food resources (orthopterans, coleopterans and the total abundance of prey as response variables) vary between habitat types and sampling methods (also including their interactions).

We used Savage electivity index to determined Roller prey preferences in insects groups. Savage selectivity index $w_i = U_i/D_i$ where U_i is the proportion of units used in one territory and D_i is the proportion of units available (Savage 1931). This index varies from 0 (maximum negative selection) to infinity (maximum positive selection), with 1 indicating no selection. The statistical significance of the selection for each of the taxonomic groups considered is obtained by comparing the statistic $(w \; -1)2/\mathrm{se}(w_i)^2$ with theoretical value of a χ^2 distribution with one degree of freedom, with w_i being the Savage index for the taxonomic group and se(w_i), the standard error of the index. [es(W_i)] is the standard error of the index approximately given by $\sqrt{[(1-D_i)/(u+D_i)]}$. Non-parametric tests were used to find differences in prey composition collected by different methods.

We analyzed the effects of landscape composition on territory occupancy of rollers by canonical correspondence analysis (CCA) using CANOCO 4.5. We included the occupied artificial nest-boxes, unoccupied artificial nest-boxes and natural breeding holes in the analyses and used the CLC coverage data for characterizing land cover types. Shannon and Simpson diversity scores together with the Mean Shape Index of the patches were used as environmental variables. At the smaller and larger spatial scales, the presence or absence of rollers outside the 1.5 km zone of occupied nest-boxes was used as the binary response variable in the analysis of rollers occurrence. Here we applied autologistic regression analysis. After a preliminary evaluation of the Pearson's correlation matrix including all variables, we selected only one variable from the set of inter-correlated variables ($r > 0.5$) for model building. These variables were used as independent variables for linear modelling, and the presence or absence of rollers in a grid cell was used as the binary dependent variable. We performed autologistic regression analysis using the SAM version 4.0 program package. The Akaike information criterion was used to rank models and to select the 'best approximating' models for both spatial scales.

We also used linear models to evaluate the effects of the environmental variables, nearby presence of rollers, and nest-box placement conditions (mounting type and orientation) on the occupancy rate of nest-boxes. Two main models were used: (i) dependent variable was "ad -hoc occupancy", expressing the maximal potential usability of nest-boxes on the binary basis. We used binary logistic regression for revealing which factors and covariates are responsible for this preference for nest-box occupancy. The analysis was carried out by the program nominal regression in SPSS version 17 (ii) We also used generalized linear modelling to reveal how the former variables affect "duration of occupancy" as dependent variables.
Non-parametric tests were used to compare dispersal distances of rollers (SPSS 22).

4. Main results

I. Food availability, food preference and breeding parameters in different habitats

a. Food availability and its effect on breeding parameters

We revealed similar clutch sizes, hatching success, number of hatchlings and fledging success in that two habitats. The only habitat-related difference in reproductive performance was found in breeding success that proved to be higher in the mosaic than in the grassland habitat. Higher abundance of Orthopterans collected by sweep-netting was found in grassland. Shannon's diversity of the arthropod families, when it was calculated from sweep-net samplings, was significantly higher in the mosaics than in the grassland. These videos revealed that rollers typically fed their nestlings by insects, mainly by orthopterans (in 40.1% of feeding) and coleopterans (23.3%), but contribution of other insects was also relevant (25.3%). Although the frequency of delivered vertebrates was only 9.3%, but their contribution to nestling diet by mass was more important.

Our generalized linear model revealed that reproductive success of Rollers was affected by egg laying date and habitat type, showing higher reproductive success in the farmland mosaics than in grassland patches. This result could be explained by a general phenomenon in birds; pairs with more experiences start breeding earlier and have higher breeding success than young birds. Including clutch size in the model improved it, suggesting that differences due to habitat were probably not restricted to adults' quality and reflected the quantity or quality of food. Clutch size affected the feeding rate of Rollers, as individuals with larger clutches showed higher feeding provisioning ability to nestlings. However, feeding rate did not differ between sites. These results suggest that the abundant orthopterans seem to be the most important prey type, which affects reproductive success; however coleopterans have more importance in the farmland mosaics.

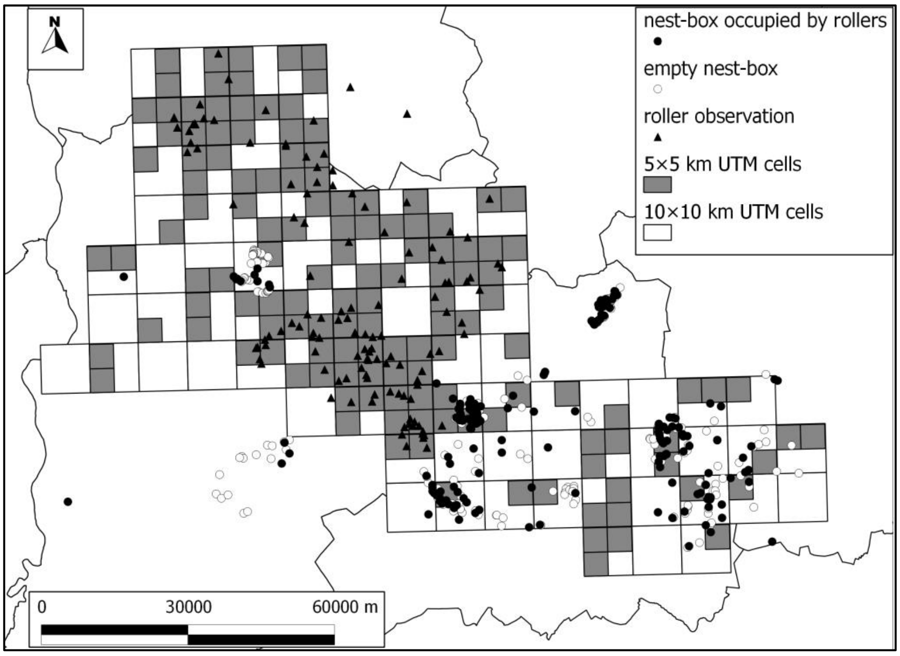
I./b. Food preference and different sampling methods

Both sampling methods revealed similar prey types, but their frequencies in nesting diet were different. These results suggest that orthopterans and coleopterans are the most important taxa in nestlings’ diet, however nest-box content indicates higher consumption of coleopterans and video recordings show higher consumption of orthopterans. The European mole cricket (*Gyrllotalpa gyrllotalpa*) was highly overrepresented in nest-box content;

however we found higher amount vertebrates on video recordings. Based on Savage electivity index prey items were not selected in proportion to their availability both in case of nest-box content and video recordings. We found differences in preference caused by sampling methods. Preferences for main prey types differed significantly obtained by different sampling methods. The next-box content indicated high preference for coleopterans and lower preference (avoidance) for orthopterans than video recordings. We found that the Savage index did not differed significantly between study sites, neither in case of nest-box content nor in video recordings.

II. Landscape scale factors affecting rollers habitat selection

At the larger 10 × x10 km spatial scale we detected either roller territories or occupied nest-boxes in 70.5% of the UTM cells (Fig. 1.). Rollers bred in natural holes in 41% of these cells. The mean density of roller pairs breeding in natural holes was 1.55/100 km2 ± 2.8. The average distance between the closest neighboring occupied nest-box was 1487 m, but 69.01% of the occupied nest-boxes were closer than 1 km to each other.



1. figure Rollers' observation points, occupied and empty nest-boxes in the study area

The most typical land cover type in the studied breeding territories was arable lands, which covered about 50% of the total area. Pastures, natural grasslands and heterogeneous a*gricul*tural habitats had mean coverage higher than 10%. CCA ordination showed that the territories with natural breeding were characterized by higher habitat diversity and more irregular shape. CCA also revealed that territories with natural breeding were predominantly characterized by some kind of woody vegetation, e.g. grasslands with trees and forested areas, such as broadleaved forest, mixed forest or even woodland-shrubs. We found that farmsteads and heterogeneous agricultural areas were typical in the territories of the rollers in case of the natural breeding. Grasslands without trees and arable lands with small arable lands were typical both for natural breeding territories and the surroundings of the nest-boxes as well. Nest-box provisioning contributed to making large arable lands, marshes and scarce vegetation suitable habitat for rollers.

At landscape level we investigated which factors have affected rollers' occurrences without nest-box supply. At the 5 ×5 km spatial scale, the number of Corine Land Cover types and arable fields, and MSI (mean shape index) positively, while permanent crops negatively affected rollers' occupancy pattern. At this spatial level Shannon diversity had positive, but Simpson diversity had negative effects on rollers' occurrences. At the larger 10x10 km spatial scale, we found the same effect of Shannon diversity than at the 5x5 km spatial scale. Natural grasslands positively, mean patch size and marshes negatively influenced rollers' occurrence. High fragmentation was also favourable.

III. Nest-site fidelity and dispersal

We aimed to investigate the nest-site fidelity, breeding and natal dispersal of rollers. We found that adult rollers showed high breeding site fidelity, 89.4% of the recoveries were found within 5 km distance from the former breeding site and 56% used the same nesting place as a year before. The dispersal distance of females were longer than that of males (females 6.27 ± 2.9 SE km, males 0.967 ± 0.27 SE km), however sexes did not differ in the elapsed time until recovery. The average natal dispersal distance of individuals ringed as pullus and refound in following year) was 41.2 km (41.2 ± 6.4 SE), and it was significantly longer than their breeding dispersal. Although most of the juveniles started to breed in 40 km area of their natal sites, several individuals moved more than 100 km to their breeding sites, and ensure the connection between other populations. According to ringing recoveries, the majority of fledglings started to breed in the next breeding season, and 87.9% of fledglings were refound in three years after they had fledged.

IV**. Factors affecting the occupancy rate of newly provided nest-boxes**

From the 132 newly provided nest-boxes 75.75% were occupied at least once by rollers during the four-year study period (between 2011 and 2014), and 29.5% were occupied at the first time in 2011. Only a smaller proportion (14.4%) were occupied in each of the years in the four-year study period, 29.5% were occupied three times, 18.9% twice and also 18.9% were used only once by rollers. However, 10.1% of the nest-boxes remained empty in each of the four years. Logistic regressions revealed among the nest-box characteristics, mounting type (placed on a pylon or in a tree), as well as the height of the nest-boxes had significant effects on rollers'nest-box occupancy. The presence of nearby rollers' potentially breeding in adjacent natural breeding sites was also significant. A generalized linear model on the effects influencing nest-box occupancy within the 4-year study period revealed that height and mounting influenced the occupancy rate. Frequency of typical feeding sites, such as grasslands and small arable lands, did not influence the duration of occupancy. We found a slightly positive effect of the proximity of breeding pairs both in the nest-box area and in natural breeding site on repeated usage of nest-boxes.

5. Publications related to the thesis

MTMT identifier: 10032069

Scientific papers

Kiss, O., Tokody, B., Ludnai, T., Moskát, C (2016) The effectiveness of nest-box supplementation for European rollers (*Coracias garrulus*). *Acta Zoologica Academiae Scientiarum Hungaricae* (under revision)

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. IF:1,65

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Kiss, O., Tokody, B., Moskát, Cs. (2012) Food availability and breeding parameters of Rollers (*Coracias garrulus*) in two different habitats. *International Eurasian Ornithological Congress*, Baja

Kiss, O. & Tokody, B. (2012) Landscape composition of European Roller's habitats in Southern Hungary. *International Eurasian Ornithological Congress*, Baja

Kiss, O., Felde, O., Moskát, C. (2011) A mozaikgyepek szerepe a szalakóta (*Coracias garrulus*) táplálkozó területeinek megőrzésében. *Magyar Természetvédelmi Biológiai Konferencia*, Debrecen

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6. Publications not directly related to the thesis

Scientific papers

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