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Habitat selection of the Common Quail *(Coturnix coturnix)* in an intensively managed agricultural environment

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Abstract This study investigated the habitat selection of the Common Quail *(Coturnix coturnix)* during the breeding season of 2014 in an intensively managed agricultural environment (LAJTA Project, North-West Hungary). In order to assess the habitat preferences of the Common Quail, habitat composition around occupied plots were compared with unoccupied control plots. To characterize the habitat, a total of 11 variables related to vegetation structure and diversity, food availability and landscape were quantified. Multivariate methods (PCA and GLMs) were used to distinguish the main factors influencing habitat selection and to model the presence of the Common Quail. Based on our results, in the LAJTA Project, high probability of Common Quail presence can be predicted in plots with higher herbaceous cover and more abundant arthropod communities. The network of ecotone habitats, particularly the proximity to woody habitats, also appeared to have significant importance during the breeding season.

Keywords: Common Quail, plant cover, food availability, field margin, forest belt

Összefoglalás Kutatásunkban a fürj *(Coturnix coturnix)* élőhelyválasztását vizsgáltuk intenzív agrárkörnyezetben (LAJTA Project), fészkelési időszakban, 2014-ben. Az élőhely jellemzéséhez a növényzet struktúrájára, az ízeltlábú táplálékkínálatra és a tájszerkezetre vonatkozó változókat számszerűsítettünk. A fürj élőhely-preferenciáinak értékelésére a tényleges territóriumok mellett random kontroll pontok felmérését is elvégeztük, az esetleges elkülönülést és az elkülönülést okozó változókat többváltozós statisztikai módszerekkel (PCA, GLMs) elemeztük. Vizsgálataink alapján a LAJTA Projectben a fürj jelenléte az olyan, erdősávoktól távolabb eső nyílt területeken valószínűsíthető, ahol magasabb a növényborítás és ízeltlábú abundancia. Az ökotonhálózat, ezen belül különösen az erdősávok nem elhanyagolható jelentőségűek.

Kulcsszavak: fürj, növényborítás, táplálékkínálat, táblaszegély, erdősáv

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Introduction

Understanding the relationships between species and their habitat is a central question in ecology. Habitat defines the available range of resources and living conditions for a species, thus habitat has an important impact on vital rates, such as survival and reproduction (Hall *et al*. 1997). The aim of most habitat selection studies is to understand the roles of different factors, which determine the spatial distribution of individuals (Morris 2003). These diverse components of habitat selection patterns include for example the distribution and availability of food resources, available space (Morris & Davidson 2000), or both intra- and interspecific interactions (Rosenzweig 1981, Morris 1999). Sometimes, however, individuals can only occupy habitats of lesser quality (Morris 2003). This often happens when the coverage of the suitable habitat is limited due to complete habitat loss or habitat fragmentation. It is widely known that agricultural intensification is one of the main reasons of the decline of farmland bird populations across Europe (e.g. Chamberlain & Fuller 2000, Donald *et al*. 2001, 2006, Báldi 2008, Voříšek *et al*. 2010). However, regional differences in the degree of decline are recognized (Wretenberg *et al*. 2006, Báldi & Faragó 2007, Báldi & Batáry 2011, Tryjanowski *et al*. 2011); therefore more specific population studies are required to better understand the processes. Furthermore, some farmland birds have more habitat flexibility i.e. nesting site or foraging requirements, which could change the patterns of the bird population in the given region (Fuller 2012).

The Common Quail *(Coturnix coturnix)* is widely distributed throughout the Palaearctic region and it is the only long-distance migratory species of Phasianidae (Cramp 1980, McGowan *et al*. 1994). The Common Quail is a typical species of grassland areas, primarily prefers open land, usually without shrubs and trees, either in lowlands or in the mountainous regions. Due to habitat transformations associated with agricultural development, this species became one of the typical species of farmland breeders (Udvardy 1941, George 1990, Guyomarc'h *et al*. 1998). Until the early 1900s, the Common Quail was a common species in Europe, although a slight population decrease was already observed at the end of the 19th century (Glutz von Blotzheim *et al.* 1994). In the 1980s, a large decline in its West-European population was observed (Perennou 2009) and has continued to show a declining trend in most European countries (BirdLife International 2018). In Hungary, the Common Quail is a protected species showing moderate population decline both locally and nationwide (Szép *et al.* 2012, Németh *et al.* 2014, MME 2018). The breeding population is estimated between 74,000 and 90,000 pairs (Hadarics & Zalai 2008, BirdLife International 2018). Studies on Common Quail were mainly carried out in Western Europe (France, Germany, Spain), which were related to its habitat use, movements, hybridization with Japanese Quail *(Coturnix japonica)* or population distribution (e.g. Saint-Jalme & Guyomarc'h 1989, George 1990, 1996, Guyomarc'h 2003, Puigcerver *et al.* 1999, 2007). Common Quail is a less studied species in Hungary, research on its ecology is poorly represented in the Hungarian avian literature (i.e. Keve *et al.* 1953), while mostly faunistic papers have been published (e.g. Szűts 1898, Barthos 1917, Külley 1924, Bán & Igmándy 1939, Keve 1955, Rapos 1957, Kovács 1965, Debreceni *et al.* 1990, Kovács 2005, Faragó 2012b).

The main goal of this study was to assess the habitat selection of the Common Quail in a human-transformed habitat. Our aim was to find out which parameters influence the habitat selection the most in an intensively managed agricultural environment.

Material and Methods

Study area

The study was carried out in the area of the LAJTA Project, which covers 3,065 ha of land in the Kisalföld (Little Hungarian Plain), North-West Hungary *(Figure 1)*. Until 1995, the area had been managed exclusively by the Lajta-Hanság Co. However, in 1995, due to compensations/privatization, 50% of the area was transferred to the hands of smallholders. This area has a continental climate (mean annual temperature is 9.6 °C, annual precipitation is 504 mm, mean relative humidity is 73%) where mainly cereals, corn, alfalfa, rape and maize are cultivated. About 94% of the farming is large scale (Lajta-Hanság Joint Stock Company, average field size 40 ha) and 6% is small scale (small holders, average field size 2.5 ha). In both cases, there is intensive technology which, from the point of view of mechanization and the use of chemicals, has not changed in the past few decades. Fields are separated from each other by forest belts (110 ha), tree rows (8 ha) and hedgerows (1 ha) (Faragó 2012a). Pasturing did not take place in the Project territory and the fodder demand of animal husbandry was supplied by growing alfalfa and silo maize.

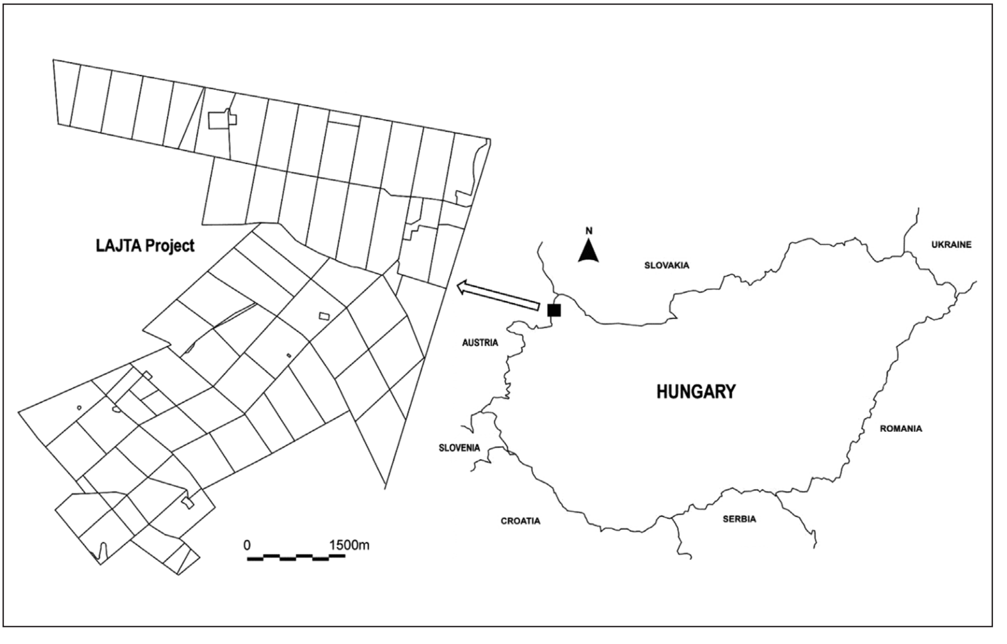

Figure 1. Map of the study area (LAJTA Project)
1. ábra A vizsgálati terület (LAJTA project)

Field surveys

In Hungary, no specific survey technique has been proposed for the Common Quail, the used survey method is therefore roughly based on the guidance provided by Rodríguez-Teijeiro *et al*. (2010). Calling Common Quail males were counted during the breeding season between late April and August (28 survey days in total, 11 of which were in the beginning of the breeding season) in the entire study area by listening to the calls and crowing of the territory holding males. Surveys were carried out under favourable weather conditions, starting at dawn and lasting about 2.5–3 hours. At every survey point, during the first two minutes of stay we detected and counted the number of singing males. After this first step of detection, a digital bird caller (model NEWGOOD Speaker-92A) was used to play the female call lasting 20–25 seconds to stimulate silent males. The approximate position of each detected males were recorded by walking in the direction of the singing male until the bird rose up. The place from where quails delivered their first spontaneous calls at dusk has been regarded as the centre of activity. We considered a territory occupied if we documented multiple detections.

In order to assess the habitat preferences of the Common Quail, habitat composition for a total of 18 occupied territories were compared with 18 unoccupied control plots randomly selected in the study area. To characterize the habitat around territories, a total of 11 variables were quantified related to vegetation structure and diversity, food availability and landscape. Since the core daily activity area was described as a 1.5–2 ha (Perennou 2009), a 75 m radius plot was chosen for the determination of the following variables: plant species richness (Plant_S), plant diversity (Plant_Div), plant cover (Plant_Cov), arthropod number (Arth_N), arthropod dry weight (Arth_W) and arthropod diversity (Arth_Div). Furthermore, a 500 m radius plot was chosen to account for the following landscape characteristics: total length of woody ecotones like forest belts, tree rows, hedgerows (Wood_Lgth) and distance from the nearest one (Wood_Dist), total length of grassy field margins (Margin_Lgth) and distance from the nearest one (Margin_Dist); and total length of roads (Road_Lgth). With respect to grassy field margins, only those that appeared separately from woody ecotones were considered. For botanical analysis, species list and cover were recorded in randomly selected 5×5 m quadrats (N = 5). For measuring arthropod food availability, pitfall trapping was conducted. In each quadrat, a Barber trap (plastic cup of 300 ml capacity, with 80 mm diameter and 120 mm depth) was placed fitted with aluminium roofs to prevent trapping small vertebrates (e.g. lizards, rodents, shrews). For preserving solution 5% formaldehyde was used. Barber traps were installed following the detection and localization of the quails, and were operated for two months, roughly covering both the incubation and rearing periods. Traps were emptied in every two weeks.

Data analysis

Principal Component Analysis (PCA) was used to describe the habitat structure based on data of both the Common Quail occupied and non-occupied control plots and to distinguish the main factors influencing habitat selection. Only PCA factors with eigenvalues more than 1.0

were selected (Kaiser Criterion). Factor loadings were rotated with a varimax raw transformation. Mean factor scores between the occupied and control plots were compared by using *t*-test. Normality and homogeneity of variances were tested for all parameters, and in case of necessity, transformed to fit the assumptions of parametric tests.

Generalized linear models (GLMs) were used to evaluate the presence of Common Quails, based on the obtained principal components (PCs). Since territory occupation by quails was considered as a binary response variable (presence – 1, absence – 0), the logistic link functions was applied with binomial error structure. Forward stepwise (likelihood ratio) method was applied to select the final variable in the model. Each variable was tested for significance and only those contributing significantly ($p<0.05$) to the model were retained. The performance of the GLMs was assessed using Cohen's Kappa statistics, describing the proportion of the correctly classified predictions after the probability of chance agreement has been removed (Cohen 1960). According to Landis and Koch (1977), strength of agreement can be considered slight to fair for κ values 0–0.4, moderate for 0.4–0.6, substantial for 0.6–0.8 and almost perfect for 0.8–1.0, respectively. Statistical analyses were computed using SPSS ver. 20 (IBM Corp. Released, 2011) and SAS statistical package ver. 9.1 (SAS 2012).

Results

The PCA performed on the habitat variables yielded four new variables with eigenvalues higher than 1.0 that together explain 87.85% of the total variance *(Table 1)*. The first component (PC1) accounted for 36.85% of the total variance and it is principally governed by variables connected with herbaceous cover (Plant_Cov) and diversities (Plant_S, Plant_Div). Other major contributors to PC1 are the abundance of arthropods (Arth_N) and distance from the nearest woody ecotone (Wood_Dist). Mean factor scores on this axis differ significantly between the Common Quail occupied and non-occupied control plots (*t* test, $t = 5.023$, $p < 0.01$). The second component (PC2) accounted for 22.36% of the total

Table 1. Factor loadings after varimax rotation for the principal components in PCA on the habitat variables used

1. táblázat Az élőhelyváltozókon végzett főkomponens analízis (PCA) eredménye: komponens-együtthatók mátrixa varimax forgatás után

	Principal component			
	PC1	PC2	PC3	PC4
Plant_S	**0.514**	0.183	0.319	0.264
Plant_Div	**0.603**	–0.098	0.290	–0.119
Plant_Cov	**0.863**	0.244	–0.180	0.096
Arth_N	**0.667**	0.340	–0.187	0.022
Arth_W	–0.231	**0.801**	–0.196	–0.231
Arth_Div	–0.214	**0.870**	0.144	0.097
Wood_Lgth	0.311	–0.372	**0.796**	0.159
Wood_Dist	**–0.696**	–0.313	0.134	0.221
Margin_Lgth	0.319	**0.576**	0.276	–0.202
Margin_Dist	–0.361	–0.344	**–0.625**	–0.033
Road_Lgth	0.193	–0.209	0.220	**–0.678**
Eigenvalues	4.054	2.460	1.920	1.229
Explained variance %	36.85	22.36	17.46	11.17
Cumulated variance %	36.85	59.22	76.68	87.85

variance, with loadings large for arthropod diversity (Arth_Div) and weight (Arth_W); and total length of field margins (Margin_Lgth). On this axis, no significant difference has been observed between the mean factor scores of occupied and control plots (*t* test, $t = 0.892$, NS). The third component (PC3), accounted for an additional 17.46% of the total variance, is determined by the woody ecotone length (Wood_Lgth) and distance from the nearest field margin (Margin_Dist). No significant difference was observed among the Common Quail and control plots on this axis (*t* test, $t = 1.873$, NS). The fourth component (PC4), accounted for 11.17% of the total variance, was mainly governed by the total length of roads (Road_Lgth). Nevertheless, mean factor scores showed no significant difference on this axis (*t* test, $t = 1.516$, NS).

Table 1. Summary of GLMs for the probability of presence of Common Quail

2. táblázat Az általánosított lineáris modell (GLMs) eredménye a fürj jelenlétének predikciójára

Factors	β	SE	χ^2	p
(intercept)	2.018	0.747	7.114	0.008
PC1	0.076	0.017	34.073	0.000
PC3	–0.625	0.210	3.988	0.047
Residual deviance	17.963			

A summary of the final GLM model is presented in *Table 2*. PC1 showed a positive influence ($\beta = 0.076$) on Common Quail presence probability, and it was the most influential new variable ($\chi^2 = 34.073$) derived from the PCA. PC3 was less influential ($\chi^2 = 3.988$) and showed a negative relationship ($\beta = -0.625$) to the presence probability of quails. The model performed better in correctly predicting Common Quail habitat where presence occurred (70.4%) than in correctly classifying unoccupied habitat (62.6%). According to the κ statistic (0.341) the model had only fair agreement with the testing dataset.

Discussion

In Hungary, the Common Quail once inhabited grasslands and wooded steppes (Faragó 2002). Nowadays, significant part of the population is breeding in agricultural environments, systematically choosing open land (Németh *et al.* 2014), usually preferring areas with a dense herb layer (Perennou 2009). Based on our results, in the LAJTA Project, two key components of the environment that positively affected the occurrence of Common Quails were protective cover and food availability. This dual requirement has been shown to be equally important for several other farmland bird species including the Grey Partridge *(Perdix perdix)* or Eurasian Skylark *(Alauda arvensis)*. The dense herbaceous cover provides nesting site, more protection against rough weather conditions and predators (Rands 1986, Green & Stowe 1993, Eggers *et al.* 2011). According to Capdevila *et al.* (2016), plant height may also have importance because taller vegetation has better suitability for hiding nests from predators. This is also demonstrated by the fact that in the course of crop harvesting the Common Quail moves to new, more suitable habitats with taller vegetation, as demonstrated by Rodríguez-Teijeiro *et al.* (2010) and Németh and Winkler (2017). As previously reported, the Common Quail did not avoid large arable fields with permanent crops (George 1990, Michailov 1995, Broyer 1996, Aunins & Priednieks 2003). Moreby and Aebischer (1992) and Panek (1997) supposed that permanent cover tends to increase the number of insects, which is an essential food supply for gamebird chicks (e.g. partridges, quails) and maintains higher reproductive success of birds. Our results showed that arthropod abundance plays a crucial role in habitat selection, while diversity and biomass of arthropod prey seem to have less importance. Although seasonal variations occur in the diet of quails (Gál & Marosán 2003), invertebrate species represent a significant proportion of Common Quail food during the breeding season (Keve *et al.* 1953, Combreau & Guyomarc'h 1992). During the first few weeks after hatching, the chicks are feeding mainly on insects therefore growth is mainly determined by the available invertebrate food resources (Combreau & Guyomarc'h 1989, Guyomarc'h *et al.* 1998). As the Common Quails also feeds on a wide range of seeds, apart from the plant cover the diversity of herbaceous vegetation seems to have great importance in the LAJTA Project, as indicated by the results of PCA. Managed cereal field, where the most Common Quail territories were found, usually support lower seed resources than field margins (Wilson *et al.* 1999, Vickery *et al.* 2002, Holland *et al.* 2012). Nevertheless, some cultivated fields (e.g. winter wheat, phacelia) in the LAJTA Project are characterized by considerable herbaceous cover and species richness, not reaching, however the conditions observed in the field margins. In our study, we found only slight effect of field margins. Capdevila *et al.* (2016) found that female quails preferred to nest near field margins, which might be related to the greater food resources and more suitable nest cover. Although a number of studies have emphasized the higher probability of predation risk in field margins (e.g. Paton 1994, Batáry & Báldi 2004), Capdevila *et al.* (2016) found no edge effect in Common Quail nest predation probability. Apart from grassy strips, previous studies in Europe emphasized the role of woody ecotones (e.g. hedges, shrubs, forest shelterbelts) in relation to certain farmland birds (e.g. Jánoska 1998, Hinsley & Bellamy 2000, Batáry *et al*. 2010, Faragó *et al.* 2012, Morelli 2013). In the LAJTA Project, the network of woody ecotones proved to have a non-negligible impact on Common Quail habitat selection through breaking the continuity of large fields. As the results revealed, the Common Quail showed avoidance of the forest belts and was mainly detected far from their edges, which is in good agreement with observations conducted in similar environments (e.g. Panek 1998, Perennou 2009).

Our results in the LAJTA Project indicate that the Common Quail is likely to occur in large-scale farming landscape, which can be classified as intensively managed agricultural environment. The importance of adequate vegetation structure (permanent, tall and dense) identified as protective rather than obstructive cover for farmland birds (e.g. Erdős *et al*. 2009, Eggers *et al*. 2011), has also been confirmed for Common Quail by our study.

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