**Population densities and habitat use of the golden jackal (*Canis aureus*) in
farmlands across the Balkan Peninsula**

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Abstract

The main objective of this study was to analyze habitat use and population densities of the golden jackal in four countries across lowland regions of the Balkan Peninsula, known as the core area of the species' distribution in Europe. Using indirect (acoustic) method for detecting territorial golden jackals, we surveyed jackal presence and densities on 331 monitoring sites in four countries, in total covering area of 4296 km² during April and May 2007-2012. We used GIS to assess landscape and environmental characteristics in a 2-km circular buffer (12.6 km²) around calling stations. Average population density of golden jackals in the study areas ranged between 0.6 – 1.1 territorial groups / 10 km² (mean ± SE, 0.6 ± 0.06 groups / 10 km²), with several high-density areas with up to 4.8 territorial groups / 10 km². Analysis of habitat use showed that for both, jackal occurrence and number of jackal groups, the only significant parameter was the interaction between country and intensity of agriculture, indicating that jackals adapt their habitat selection patterns in relation to the habitat availability. We observed that selection of the more suitable habitats (shrub-herbaceous vegetation/heterogeneous agricultural vegetation) increased with lower proportion of these habitat types in the study area. Our study confirms high habitat plasticity of the golden jackal and offers explanation for its recent range expansion, which might be connected with the land-use changes during the last decades in the Balkan Peninsula.

Keywords: golden jackal; acoustic monitoring; population density; habitat use; GIS; farmland; Balkan Peninsula

Introduction

The golden jackal (*Canis aureus*) is a territorial, widely distributed medium-sized generalist carnivore, occurring in northeastern Africa, South Asia, southeastern and central Europe (Jhala and Moehlman 2004). In Europe the golden jackal populations changed significantly during the 20th century, presumably due to agricultural intensification, habitat loss and past extermination programmes (Kryštufek et al. 1997; Arnold et al. 2012). During the first half of the 20th century, the golden jackal population numbers declined dramatically, which led to several local extinctions and its distribution became highly fragmented (Kryštufek et al. 1997). Following protection in core areas of the Balkan Peninsula, number of jackals increased in the second half of the last century and currently its populations are scattered mainly along the Eastern Mediterranean and Black Sea, with recent rapid spread to western and Central Europe (Arnold et al. 2012).

Due to their habitat plasticity and opportunistic feeding habits, golden jackals can live in a wide variety of natural and/or semi-natural habitats, including human-dominated agricultural landscapes. According to the available knowledge of its distribution in Europe, jackals are mainly associated with shrub vegetation and mosaic of cultural landscape and lowland wetlands (Giannatos 2004; Sillero-Zubiri et al. 2004). Dense shrub vegetation is considered an important habitat, which provides adequate resource availability, such as prey and den sites, as well as better cover to avoid persecution by people (Giannatos 2004). However, information on habitat selection of golden jackal in Europe is still very limited and according to our knowledge no study is available to better understand habitat selection on a large geographical scale.

The main goal of this study was to assess the population densities and habitat use of the golden jackal during the breeding season in four countries across its distribution range in

Eastern and Southeastern Europe. In particular, our analysis was focused on habitat use and factors affecting population densities. Our results bring the first detailed information about golden jackals' habitat use, which could be used for local landscape planning, assessing conservation priorities and development of management plans.

Material and Methods

Study areas

To compare habitat use and population densities of the golden jackal across lowland regions with different landscape patterns and land-use composition we selected four countries in the Balkan Peninsula: 1) Bulgaria (size of study area: 2864 km²), 2) Serbia (565 km²), 3) Croatia (452 km²) and 4) Romania (415 km²) (see Table 1). The climate differs considerably among selected regions. In general, the study region in southern Croatia is mainly influenced by Mediterranean climate, with hot summers and low precipitations (150 mm) and the rest of the areas exhibit combination of continental and Mediterranean climate with higher precipitations during summer months (270-698 mm). The study areas are characterized by predominantly flat or gently rolling relief with altitudes ranging between 8 and 505 (mean = 179) m a.s.l. The agricultural vegetation is dominated by a mosaic of crops (mainly cereals and corns), vineyards and grasslands. The grasslands are comprised of a variety of types including meadows, xerophytic and mesophytic grasslands and extensively used pastures (mainly for sheep and cattle).

Table 1 approximately here

Study design

The occurrence of golden jackals was monitored using acoustic monitoring at linear transects that consisted of five calling stations. To achieve geographical independence of the sites, the distance between neighboring calling stations was four kilometers (total length = 20 km). Two kilometers are maximum human hearing distance on windless nights from vantage point in an open terrain with no background noise (Giannatos et al. 2005; Szabó et al. 2007). Moreover, the transect method was supplemented with jackal monitoring on individual calling stations not included (contained) in transects, however we still controlled for minimal distance criterion between individual monitoring sites. The study areas were chosen prior to the field work, based on digitalized aerial maps (1:5 000) using a geographical information system (QGIS 1.8.0 and ArcGIS Desktop 10.0) and previous information about jackal presence. Position of the calling stations was adjusted according to the topographical characteristics, infrastructure and human settlements in order to optimize sound transmission.

Golden jackal monitoring

The acoustic monitoring is an effective and widely used method to determine the distribution patterns and occurrence of social and vocal territorial canids (Harrington and Mech 1982). Similarly, this method has been recently successfully used for golden jackal monitoring in Europe (Giannatos et al. 2005; Krofel 2008). The localities were visited once during early breeding period (April – May, see also Szabó et al. 2007; Krofel 2008) when jackal activity was expected to be concentrated mainly to the core area inside territory around their dens (Jhala and Moehlman 2004). Monitoring was conducted during the highest golden jackal vocal activity (one hour after sunset till midnight) (Giannatos et al. 2005; Krofel 2008), with favorable meteorological conditions (no rain or strong wind). The

acoustic monitoring was based on broadcasting of jackal howling, which stimulated the jackals to respond and thus enabled identification of the accurate position of territorial animals. We used 50 Watt Etrion MR 800gr and 100 Watt Monacor PA-302 Megaphone connected with mobile phone, MP3 player or portable computer. At the calling station the recorded yip-howl of three to four golden jackals was broadcasted for 30 seconds followed by 5 minute pause. This set of broadcast and pause was repeated until jackals responded, maximum 5 times at each calling station giving a total maximum time of approximately 30 minutes per station. For each calling station we recorded geographical coordinates and altitude by GPS device, as well as the number of howling jackals (single or group) and number of groups. In order to avoid double counting of two neighboring groups we used hand-operated compass to determine an accurate direction (azimuth) of each howling group. It was assumed that each response-direction coincides with a territorial group (Giannatos et al. 2005). In addition, this method was supplemented by direct observation of the golden jackals in the surrounding of the calling stations using spotlights or night vision goggles by detecting animals by eye shine.

GIS analysis

Habitat use of the golden jackal were studied using comparison of occupied versus unoccupied localities, which is a standard approach used in habitat selection studies (Huck et al. 2011). To reveal the environmental factors that affect golden jackal occurrence, we investigated main habitat and environmental characteristics in a 2 km buffer zone (12.6 km²) around each monitoring site. The size of the buffer zones (sample plots) was derived as an equivalent to the average home range size from radio-tracked animals (Giannatos 2004). We identified six land-use characteristics that were reported as important spatial predictors of

jackal occurrence (Giannatos et al. 2005; Simeneh 2010). In particular, we assessed proportion of each of these six habitat types: forest, arable land, heterogeneous agricultural vegetation, shrub-herbaceous vegetation, pastures, urban area and water bodies (for detailed description see Appendix 1). Land use variables were obtained from 1: 100 000 Corine Land Cover maps (Corine 2006), that were updated using actual aerial maps (Google Maps, 2012) using GIS tools (QGIS 1.8.0 and ArcGIS Desktop 10.0). Landscape metrics were calculated within ESRI environment with batch processing in script for individual calling station (ArcGIS Desktop 10, Python 2.6). Elevation for individual calling station was derived from global GMTED raster dataset.

Statistical analyses

To avoid autocorrelations of percentage data on habitat proportions we performed PCA analysis in CANOCO software (ter Braak and Šmilauer 1998) with log-transformed values. We also calculated correlations of each habitat variable with first and second canonical axis using Monte Carlo permutation tests. For subsequent analysis, we used scores from these axes. Habitat use was assessed by GLMM using R software v. 2.8.1 (R Development Core Team 2009). We used lmer function to develop null models with transect as a random factor and (1) golden jackal occurrence (0/1) and (2) number of jackal groups as dependent variables. A binomial error distribution was used for presence (0/1) and a Poisson distribution was used for the number of jackal groups detected per calling station.

Independent variables included elevation (m a.s.l.), country, agricultural intensity (score from first canonical axis) and gradient between urban and forested areas (score from the second canonical axis). We also tested the effect of interactions among these factors. We used forward selection based on AIC criterion to build the best model for each dependent

variable. Particular differences in habitat proportions for each country were analyzed using Mann-Whitney U test (presence/absence) and single regression (number of groups) using Statistica v. 9.1 (StatSoft, Inc. 2010).

Results

Population status

In total, we monitored presence of golden jackal and population densities from 331 calling stations (covering a total area of 4296 km², Table 2). The presence of 266 golden jackal groups was recorded at 147 monitoring sites (44 %). The proportion of occupied sites in different countries ranged from 9 % to 67% in Romania and Serbia, respectively. Mean density in individual countries was 0.6 groups /10 km² (0.1 – 1.1 groups /10 km²; Table 2), however locally we recorded up to 4.8 groups /10 km² (~ 6 groups from single calling station). The number of territorial groups on individual calling station in the studied countries is presented in the Appendix 2.

Table 2 approximately here

Habitat use

The first two canonical axes in PCA explained together 42.8 % of data variability. Proportions of arable areas, heterogeneous agricultural areas and shrub-herbaceous vegetation were correlated with first canonical axis. Arable areas showed negative correlation and heterogeneous agricultural areas and shrub-herbaceous vegetation showed positive relationship with jackal presence. The first canonical axis in PCA expressed the intensity of agriculture (with increasing score agricultural intensity decreases). Proportion of forests and urban areas were correlated with the second canonical axis (higher score on the second

canonical axis indicates higher proportion of urban areas and lower proportion of forests; Table 3).

In both models, with jackal presence/absence or with number of jackal groups, the only significant parameter was the interaction between overall agricultural intensity (expressed by scores on first ordination axis) and country (Table 4). Results of binomial model on presence/absence of jackals showed that the differences were significant only for Croatia and Serbia, the two countries showing opposite trends (Appendix 3; Mann-Whitney U tests; Croatia: $U = 88.0$, $P = 0.02071$; Serbia: $U = 85.0$, $P = 0.00078$). In Croatia, the occupied sites comprised significantly higher proportion of arable areas than unoccupied sites (Appendix 5). In Serbia, occupied sites showed significantly lower proportion of arable areas and significantly higher proportion of heterogeneous agricultural area and shrub-herbaceous vegetation than unoccupied sites. Higher proportion of shrubs at occupied sites compared to unoccupied ones was found also in Bulgaria (Appendix 5). Number of groups was significantly affected by overall agricultural intensity only in Serbia (Appendix 4, Single regression; $\beta = 0.527$, $P = 0.00002$). In particular, the number of groups increased with increasing proportion of extensive agricultural sites (shrub-herbaceous vegetation and heterogeneous agricultural areas) and decreased with increasing proportion of arable areas. We also found significant positive relationship between proportion of shrub-herbaceous vegetation and number of groups in Bulgaria (Appendix 5).

Table 3 approximately here

Table 4 approximately here

Discussion

Our results bring the first complex data on population densities and habitat use of the golden jackal from several regions across the Balkan Peninsula. The highest population

density was found in the lowlands around Danube River in Serbia, where average density of 1.1 groups /10 km² was recorded. This area has been described as core area of jackal distribution in Serbia (Ćirović et al. 2008). In contrast, average density of only 0.1 groups/10 km² were recorded in the agriculture dominated landscape in the southeastern Romania. We assume that the differences in population densities across studied regions could be associated with different agricultural management and land-use intensity, such as proportion of shrub-herbaceous and heterogeneous agricultural vegetation, which were noted as the main predictors of golden jackal occurrence (see below). For, example in Romania, the study area with lowest proportion of preferred habitats, there was also the lowest density of jackal groups. Differences in densities are probably also in connection with food availability (especially anthropogenic food sources) and management practices (especially intensity of human persecution), i.e. parameters that were not included in our analysis. The results of the average group density from our regions were comparable with other studies from various parts of Romania (Banea et al. 2012), Hungary (Szabó et al. 2007) and Greece (Giannatos et al. 2005). Finally, in concordance with previous studies (Giannatos 2005; Szabó et al. 2007), our results also found locally high-density areas where population densities reached up to 4.8 groups /10 km². Although golden jackals are known as habitat generalists that inhabit variety of different habitat types (Giannatos 2004; Jhala and Moehlman 2004; Stoyanov 2012), our data showed that the key factor among habitat characteristics affecting their occurrence in human-dominated landscapes was intensity of agricultural management. These results were identical for both types of analyses. The golden jackal occurrence probability increased in localities with higher proportion of shrubs-herbaceous vegetation and heterogeneous agricultural vegetation and decreased with increasing proportion of arable area. Different

types of shrub and extensively used heterogeneous agricultural habitats (consisting of woody shrubs and herbaceous vegetation) are structurally highly diverse and provide suitable environment for jackals. These habitats offer cover and serve for protection against human hunting pressure (Giannatos 2004; Simeneh 2010). Shrub vegetation and extensively used agricultural areas have been previously reported as important habitats for small mammals (e.g. Alain et al. 2006), which are known as a primary food for golden jackals in Europe (Lanszki et al. 2009; Markov and Lanszki 2012; Stoyanov 2012). Additionally, various shrub species provide a seasonal source of fruits and berries, which also comprise a large part of golden jackal diet (Markov and Lanszki 2012). Therefore we assume that habitats where we observed higher probability of jackal occurrence also offer higher food availability for jackals.

Our results showed significant differences in habitat use among individual study areas. This result indicates that selection patterns may differ due to geographical and regional variations in agricultural intensity and land-use composition. In Croatia, the landscape is characterized by extensive agricultural use and small proportion of arable habitats (9% arable land). In contrast, Serbian study sites comprised large proportion of arable area (48 % arable land). Golden jackals selected the extensive and non-agricultural habitats (shrub-herbaceous vegetation and heterogeneous agricultural vegetation) in the landscapes where intensive agricultural management predominated, while significant selection for intensive agricultural habitats (arable land) was found in the area with predominantly extensive agricultural use. In intensively used agricultural landscapes with high proportion of arable land, the importance of edge habitats has been repeatedly stressed as the crucial structure for carnivore persistence (Šálek et al. 2009, 2010; Červinka et al. 2011; 2013). Our results

indicate remarkable habitat plasticity of the golden jackal throughout its distribution range and highlight area-specific jackal use across its distribution range. According to our results, it seems possible that population increase of golden jackals in Eastern European farmlands could be partly connected to land abandonment and depopulation of traditional rural regions (Kuemmerle et al. 2009; Müller et al. 2009), which led to the abandonment of arable land and other intensively used habitats, resulting in an increase in the proportion of shrub vegetation and habitat edges. Results from jackal habitat use presented in this study indicate that shrub vegetation and abandoned farmlands present the most suitable habitat for golden jackal. Thus, these land-use changes and human emigration from rural areas appear beneficial for the golden jackal, and probably also several other generalist species.

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