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NON-BREEDING RANGE IN SAHEL OF LESSER KESTRELS ORIGINATING FROM RECOVERED BULGARIAN POPULATION

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Abstract

The Lesser Kestrel (Falco naumanni) is a long-distance migratory species, with its primary breeding areas in Spain, Italy, and Greece, and smaller populations in Portugal, France, Bulgaria, and other countries. Birds from the three peninsulas (Iberian, Apennine, and Balkan) follow distinct migratory routes to reach their non-breeding areas in the Sahel. This study aims to identify and describe the core wintering areas of the Bulgarian population, focusing on migratory patterns and habitat use during the non-breeding season. We hypothesized that the spatial distribution and individual presence in these areas would reveal patterns of site fidelity and migration strategies. The study was based on satellite tracking data from Lesser Kestrels tagged in Bulgaria, with data from nine individuals tracked over 11 winters. Two core wintering areas were identified: the first, covering about 138,700 km², spans territories in Niger and Nigeria; and the second, covering over 78,458 km², is located in central and southeastern Chad. These two areas are critical zones, showing relatively high concentrations of individuals, indicating their importance for roosting and foraging, and emphasizing the need to protect these habitats.

***Key words**: Balkan population, Falco naumanni, wintering grounds.*

INTRODUCTION

The Lesser Kestrel (*Falco naumanni*) is a migratory raptor that exhibits specific wintering patterns, migrating from breeding grounds in southern Europe to wintering areas in the Sahel region of Africa (Iñigo & Barov, 2010). After the end of the breeding season, the birds initially disperse and later begin to migrate on a broad front (Forsman, 1999). Understanding this species' seasonal movements and wintering behavior is crucial for effective conservation strategies (Briedis & Bauer, 2018; Kramer et al., 2018), as these periods and sites are key to its survival. Despite the importance of the wintering phase, detailed information on the locations and characteristics of these areas remains scarce, especially concerning the species' interaction with its environment during the non-breeding period.

Migratory birds divide their annual cycle between two areas separated by hundreds or thousands of kilometres (breeding and non-breeding grounds), usually under different environmental conditions and selective pressures, such as food distribution and abundance, offspring rearing constraints, and competition (Briedis & Bauer, 2018; Kramer et al., 2018). The movements of migratory birds are driven by a complex set of environmental factors that often differ between breeding and non-breeding areas. In Lesser Kestrel's case, identifying key wintering areas is particularly important for understanding how environmental factors influence their survival during the non-breeding period.

In recent years, advancements in tracking technology have allowed researchers to gather more precise data on the ecology, evolution and behaviour of migratory birds (López-López, 2016; López-Ricaurte et al., 2023; López-Ricaurte et al., 2024).
Based on the satellite tracking dataset from nine individuals of the Bulgarian population tracked over 11 winters, we performed a spatial and temporal analysis of wintering areas use and migratory phenology in Lesser Kestrel.
This study aims to identify and characterize core wintering areas of Lesser Kestrel in Niger, Nigeria, and Chad (Sarà et al., 2019), focusing on migratory patterns and habitat use during the non-breeding season. We hypothesized that the spatial distribution and individual presence within these areas would reveal patterns of site fidelity and migratory strategies. Additionally, we expected the wintering duration to be relatively consistent among individuals, with entry and exit dates clustering around similar timeframes. Areas with high concentrations of individuals were anticipated to emerge as critical conservation priorities (Iñigo & Barov, 2010), guiding future monitoring and protection efforts to ensure the species' survival.

MATERIALS AND METHODS

Study Area and Period

In the past, the species was widely distributed and numerous in Bulgaria, but by the end of the 20th century its numbers decreased significantly. In the early 21st century, there were no confirmed data of breeding in the country. In 2014, the Lesser Kestrel was restored successfully as a breeding species in Bulgaria by Green Balkans NGO in collaboration with DEMA and EuroNatur, on the territory of "Sakar" SPA part of NATURA 2000. Later, another unknown breeding site was found in the Burgas region (Gradev et al, 2016a; Marin et al, 2020). In 2021, there are four different breeding territories in Bulgaria - located from 8 to 243 m above sea level and the national population is estimated to be more than 40 pairs (Gradev et al., 2016a; Gradev et al., 2021). We tracked the movement of birds between their breeding territories in Bulgaria and their main wintering grounds in Africa, with our attention focused on the wintering areas in the Sahel, specifically in Niger, Chad, and Nigeria (Sarà et al., 2019), which are the main wintering locations for the Balkan population, particularly the Bulgarian subset, during the non-breeding period. The research period spans from 2015 to 2024.

Data Collection

The study was conducted using different types of satellite transmitters' GPS data from Lesser Kestrels tagged in Bulgaria and originating from the recovered population of the species in the country (Gradev et al., 2016b). Between 2014 and 2024, 9 satellite transmitters (5g Solar PTT-100 backpack - Platform Terminal Transmitters, Microwave Telemetry – 7 pieces), and GPS/GSM transmitters (one GPS-GSM Logger MINI, provided by INTERREX-RINGS) and one Wildlife Tracker HQBG1204 Hunan Global Messenger Technology Co., Ltd. were used (Gradev et al., 2016c). The first two types of devices were attached to the back of the birds using the standard "backpack" method (applied to eight individuals) shown on Figure 1 (Garcelón, 1985) and the last type was attached using the leg-loop harness method (Mallory & Gilbert, 2008). The combined weight of the harness (transmitter, teflon ribbons, stitching, and glue) used to secure the device to the bird's body did not exceed 2.4-2.8% of the bird's body mass. Following the guideline that the total weight of the equipment should not surpass 4% of the bird's weight, this ensures that the behaviour of the birds of prey is not negatively impacted (Sergio et al., 2015).

Figure 1. A real-size model of male Lesser Kestrel with a satellite transmitter attached on the back of the bird as a "backpack" (original)

Based on the tracking dataset of Bulgarian individuals (n = 9; 8 females and 1 male), we performed a spatial and temporal analysis of wintering site use and migratory phenology of the Lesser Kestrel.
The dataset consists of locations recorded in the Sahel region during the non-breeding period, focusing on the central-eastern Sahel.

Spatial Density Analysis

To identify and characterize the wintering areas, a spatial density analysis was performed using the Density Analysis Plugin in QGIS, which implements the Kernel Density Estimation (KDE) technique. This method assigns a density value to each pixel based on the proximity of points within a specified radius, allowing for the identification of areas with high concentrations of individuals. The technique helped identify not only the general density of individuals but also the specific zones that truly concentrate their activity during the non-breeding period.
For the density calculation, a pixel size of 250 meters and a search radius of 500 meters were selected to assess the overall spatial distribution of activities across the study area. The resulting continuous raster map represented the relative density of the locations, highlighting areas with higher concentrations of individuals during the non-breeding season.
The contour lines were then transformed into vector polygons representing high-density areas. These polygons were merged into two distinct areas, named Polygon 1 and Polygon 2, which encompass the main concentration zones of Lesser Kestrels during the wintering period.
A total of 450 GPS positions were identified within Polygon 1 and 327 GPS records within Polygon 2, providing a detailed representation of the spatial distribution of the individuals.

Statistical Analysis

A statistical analysis was performed using R to assess the migration patterns of Lesser Kestrels during the wintering period. The analysis focused on defining the arrival date as the first GPS record within each polygon and the exit date as the last GPS record. A new season was defined when a gap of 80 days between records occurred. The number of days each individual stayed within each polygon was calculated by determining the time between the arrival and exit dates. To summarize the temporal data, we calculated the arithmetic mean (± SD) and 95% confidence intervals for both the duration of stay and the entry and exit dates for individuals within each zone. These statistical measures helped quantify the variability in the migration timing and duration, providing insights into the wintering habitat use and migratory behaviour of the species.

RESULTS AND DISCUSSIONS

Wintering Areas and Phenology of Lesser Kestrel

The spatial density analysis using Kernel Density Estimation (KDE) in QGIS identified two core wintering areas for the Lesser Kestrel in the Sahel. The first polygon, covering approximately 138,700 km², spans regions in Niger and Nigeria, with a higher concentration in Niger. The second polygon, covering 78,458 km², is located in central and south-eastern Chad. The distance between the breeding and wintering areas is nearly 3,500 km, while the distance between the two polygons is approximately 800 km.
Figure 2 illustrates the spatial distribution of individuals within these polygons, highlighting their concentration during the wintering period. It provides a clear visual representation of both the identified wintering areas and the locations of the individuals within them.

Individual Presence and Variability

In this study, individuals located within the identified wintering areas were considered. In Polygon 1, a total of four individuals were included, although one of them only had the entry date available, as it disappeared abruptly without records of departure or duration. In Polygon 2, five individuals were considered, with a similar situation in one of them, which only had the entry date recorded due to its sudden disappearance.
Individuals 5N and B00 used both polygons but in different wintering seasons. No individual was recorded using both areas within the same season, indicating a pattern of site fidelity within a given year but flexibility across different years.

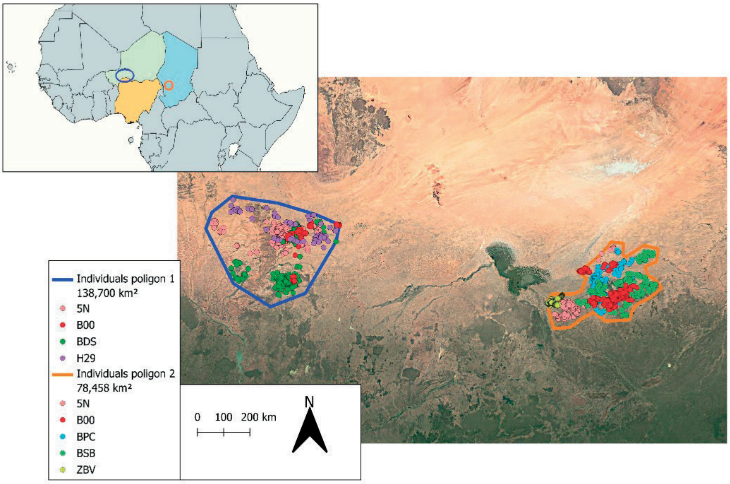

Figure 2. Spatial distribution of Lesser Kestrel individuals within the identified wintering areas in the Sahel, based on Kernel Density Estimation (KDE) analysis (original)

Timing of Migration and Duration of Stay

The wintering period, marked by the time spent within these polygons, varies across individuals. In Polygon 1, the mean entry date was September 30 ± 5.03 days (95% CI: September 24 to October 6, n = 4). In Polygon 2, the mean entry date was October 6 ± 7.59 days (95% CI: September 24 to October 18, n = 5). These results indicate that individuals in Polygon 2 tend to arrive later and exhibit greater variability in entry dates compared to those in Polygon 1.

Exit dates show only slight differences. In Polygon 1, the mean exit date was March 16 ± 14.48 days (95% CI: February 27 to April 3, n = 3), whereas in Polygon 2, the mean exit date was March 12 ± 18.43 days (95% CI: February 12 to April 10, n = 4). This suggests that individuals in Polygon 2 tend to depart slightly earlier, with some variability in their exit dates.

The mean duration of stay in Polygon 1 was 168 days ± 16.14 days (95% CI: 148-188 days, n = 3), while in Polygon 2, it was 158.5 days ± 15.41 days (95% CI: 132.96–184.04 days, n = 4). Therefore, individuals in Polygon 1 remained an average of 10 days longer than those in Polygon 2, though the variability in duration is similar between both areas.

The two core wintering areas for the Lesser Kestrel identified in this study confirmed the existing until now presumption for the wintering areas of the Balkan population of the species. Until now, the non-breeding areas in Africa for Mediterranean birds from the central-eastern regions (including Italy and the Balkans) were unidentified, as there was a lack of data on sub-Saharan ring recoveries or migration tracking (Sarà et al., 2019).

The timing of migration and the duration of stay within the wintering polygons show consistent patterns by the Lesser Kestrels. The entry dates for both polygons are similar, although individuals in Polygon 2 tend to arrive slightly later, with greater variability. The data from the satellite transmitters showed that the birds did not follow the same routes as other species along the coast until reaching Africa, through Via Pontica; they made direct flights to Africa across the Mediterranean Sea, and entered through Libya and Egypt (Gradev, 2018; Sahili, 2022). However, these differences are not substantial, indicating relatively synchronized migration.

Exit dates showed minimal differences, with individuals in Polygon 2 departing slightly earlier. While synchronization remained high, these small variations could be attributed to differences in resource availability or environmental conditions. This aligns with the idea that migration is driven by seasonal variations in food availability, climatic conditions, and other ecological factors, leading to coordinated movement of individuals within a relatively short time window (Cote et al., 2017).

The duration of stay is slightly longer in Polygon 1, but variability is similar in both polygons. This suggests that, although some individuals stay longer in one polygon, habitat conditions are comparable in both areas.

CONCLUSIONS

The identification of the core wintering areas of the Lesser Kestrel has provided crucial insights into its migratory and non-breeding behaviour. The two polygons identified in Niger, Nigeria, and Chad represent critical zones where individuals concentrate their activity during the non-breeding period, highlighting the need to preserve these habitats. Both polygons show relatively high concentrations of individuals, suggesting that these regions serve as key roosting and foraging grounds for the species.

The results also confirm that the spatial distribution and presence of individuals in these areas reflect patterns of site fidelity. The entry and exit dates were relatively consistent among individuals, indicating a synchronization in the start and end of the wintering period. This underscores the importance of maintaining the quality of these habitats and protecting them from potential anthropogenic disturbances.

Given the essential role these areas play in the species' lifecycle, it is crucial to implement targeted conservation measures to safeguard them from future threats (Iñigo & Barov, 2010).

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