

Article

Small Ranging Area and Less Mobile Pattern of a Long-Distance Migratory Raptor During the Post-Fledging Dependence Period, Determined by Fledging Date and Forest Preferences

Dimitar Atanasov Demerdzhiev ^{1,*} , Dobromir Damyanov Dobrev ¹ , Atanas Georgiev Delchev ¹,
Nikolay Georgiev Terziev ¹, Mihail Danailov Iliev ^{1,2}, Volen Stanislavov Arkumarev ¹ 
and Georgi Stoychev Georgiev ³

- ¹ Bulgarian Society for the Protection of Birds/BirdLife Bulgaria, 4000 Plovdiv, Bulgaria; dobromir.dobrev@bspb.org (D.D.D.); atanas.delchev@bspb.org (A.G.D.); nikolai.terziev@bspb.org (N.G.T.); mihail.iliev@bspb.org (M.D.I.); volen.arkumarev@bspb.org (V.S.A.)
² National Museum of Natural History, 1000 Sofia, Bulgaria
³ Rusenski Lom Nature Park, 7000 Ruse, Bulgaria; gggeorgistoychev@gmail.com
* Correspondence: dimitar.demerzhiev@bspb.org

Simple Summary

The post-fledging dependence period is a critical life-history stage in the life cycle of altricial birds, influencing their future long-term survival, fitness, and reproduction. In this study, we analyzed for the first time the regulation of the duration of this phase and the size of the ranging area of fourteen Lesser Spotted Eagles (*Clanga pomarina*) during the dependence period, testing the importance of various extrinsic (habitat type, territory, region) and intrinsic (body condition, sex, fledging date, fledging age) factors. Our results show that the fledging date is the main determinant shaping the dependence period both temporally and spatially. We established a relatively small ranging area inhabited by eagles and a low-mobility pattern with a gradual increase in movements that is highly individual-specific. The duration of the post-fledging dependence period and the size of the ranging area were constrained by the onset of first migration, coinciding with the beginning of birds' independence.

Abstract

The central point of evolutionary ecology is understanding the drivers of variation in life-history strategies among organisms. The post-fledging dependence period is a critical life-history stage in the life cycle of altricial birds, influencing their future long-term survival, fitness, and reproduction. This period represents the transition between fledging and the onset of natal dispersal or migration, when offspring are highly dependent on parental care. In this study, we used GPS-GSM telemetry to analyze for the first time the duration of this phase and the size of the ranging area of Lesser Spotted Eagles during the dependence period, testing the importance of various extrinsic (habitat type, territory, region) and intrinsic (body condition, sex, fledging date, fledging age) factors. Our survey was conducted between 2020 and 2025 in Bulgaria, Southeast Europe. The mean duration of the post-fledging dependence period (PFDP) in the juveniles was 47 ± 5 days (SD) ($n = 14$). The age of independence of eagles ranged from 71 to 110 days (median = 95 days). Our results show that the fledging date is the main determinant shaping the dependence period both temporally and spatially. The size of the ranging area (90% home range) of juveniles during the PFDP varied from 0.03 to 16.72 km², with a mean value of $2.41 \text{ km}^2 \pm 4.34$ SD ($n = 14$). Home range was influenced mainly by surrounding habitats (grassland types and forests). In line with our hypothesis, we found that birds are habitat-selective,



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strongly preferring forests and avoiding human-modified landscapes (infrastructure and agricultural fields) during this early life-history stage. We established a relatively small ranging area inhabited by eagles and a low-mobility pattern with a gradual increase in movements that is highly individual-specific. In general, forests occupied the largest share of the home range of eagles, ranging from 0.38% to 87.45%, with a mean value of $49.47\% \pm 26.57$. The duration of the post-fledging dependence period and the size of the ranging area were constrained by the onset of first migration, coinciding with the beginning of birds' independence. The home range overlap of eagles varied from 56.35% to 100%, with an average value of 87.94%. The high similarity among ranging areas identified in this study emphasizes the importance and consistency of environmental conditions, such as habitat features, compared to others that would vary yearly. The key aspects (spatial and temporal) of the post-fledging dependence pattern, identified by our study, are important for species conservation and must be integrated into future landscape planning. Our results also contribute to a better understanding of the complex factors shaping raptors' space-use pattern in this key, a poorly studied life-history trait of raptors, thus enhancing knowledge for similar species of conservation concern.

Keywords: Lesser Spotted Eagle; *Clanga pomarina*; GPS-tracking; satellite telemetry; altricial birds; dispersal; habitat selection; home range; demography; conservation

1. Introduction

Understanding the drivers of variation in life-history strategies is a central point of evolutionary ecology [1]. The post-fledging dependence period (hereafter PFDP) is a crucial stage in the life cycle of altricial birds, influencing their long-term survival, fitness, and reproductive outcome in the future [2,3]. This is the time between fledging and the onset of natal dispersal [4,5]. The development and duration of the PFDP are driven by multiple factors, which are both species- and individual-specific. These factors include bird anatomy (body weight and size) [6], species life-history strategies (slow, *K* or fast, *r*) [7,8], and ecological and environmental constraints, such as breeding latitude and hemisphere, migratory status, habitat features, sex, diet, and climatic conditions [9–13]. During this period, altricial birds are highly dependent on parental care and need more time to develop skills necessary for independent life and survival.

The PFDP is a stage of the life history of birds belonging to highly mobile or elusive species, which are difficult to study due to limitations such as methodological or species-specific constraints [3,6]. This is particularly true for raptors—a diverse group of birds with great morphological and ecological variability, occupying large areas of distribution, developing different biological strategies, and being at the top of the food chains [14]. After fledging, investigation is challenging since offspring become more mobile and/or elusive and their locations become less predictable, making research on the PFDP harder [10,15]. This charismatic group of birds with a widely recognized ecological role in ecosystems is currently suffering severe declines in global populations in general [16]. Therefore, urgent action is needed to study these understudied topics and develop effective conservation policies [10,17,18]. However, the development of satellite telemetry and GPS devices, allowing the tracking of individuals, has made possible the evaluation of these specific periods [5,11,19]. Recently, an increasingly larger number of studies have been focused on PFDP, onset of natal dispersal, and the factors shaping this transitional point, gradually filling the knowledge gap [10]. During the PFDP, raptors strengthen their fitness, develop their flight abilities, refine their hunting skills and techniques, learn how to use the land-

scape features, find food, and develop strategies to avoid predators, gaining experience that will prove vital in their future life history. This important transitional period ends with the onset of natal dispersal or the beginning of the first migration. Therefore, identifying the key aspects of the PFDP in an individual's life cycle is crucial for understanding the ecology and demography of a certain species, hence for its effective management and conservation.

Lesser Spotted Eagle (*Clanga pomarina*) (hereafter LSE) is a medium-sized forest-dwelling raptor, distributed in the northern hemisphere, from southern and eastern Europe to the Baltic region and North Caucasus [20]. This long-distance migratory species is characterized by strong territoriality and site fidelity [21,22], and every year breeding individuals occupy their territories, returning after long migration from their winter quarters situated in South Africa. There has been considerable research focused on distribution, migration patterns, breeding demography, diet, habitat requirements, survival rate or mortality factors [21–32], but no systematic research on the stage between fledging and the onset of natal dispersal of the species. Sporadic publications include only individual specimens, either tagged with satellite transmitters as juveniles in their nests or translocated [33,34] yet not providing detailed information on the duration and factors influencing the PFDP or covering the time between fledging and the beginning of dispersal. Since the LSE usually raises only one chick per reproductive attempt [35], between-sibling variability in the duration of the PFDP typical of species with larger broods [36] makes the assessment of environmental factors, affecting its behavior during the PFDP, more precise.

In this study, we analyzed the factors impacting the duration of the dependence period of juvenile LSEs by testing the influence of different factors such as fledging date, age of fledging, habitat, sex, and body condition. Intra-specific variability in the PFDP involves both differences in duration and spatial scale. The ranging areas occupied during the dependence period may show individual-specific variations that can be determined by prey abundance and/or availability [37] along with suitable foraging sites [38]. Furthermore, the areas occupied by juveniles during their PFDP may be larger when prey abundance and availability of foraging sites are low. Given that body condition determines movement behavior of raptors, since better-provisioned juveniles may be able to travel further [9], birds that fledge earlier most likely occupy larger areas and travel greater distances. However, it is known that sex and spatial heterogeneity also have a strong influence on the movement pattern and the duration of the PFDP of raptors [11]. Additionally, in accordance with the resource competition hypothesis [39,40], we expected a longer dependence period in fledglings with better body condition (larger size and weight). Alternatively, according to the ontogeny hypothesis [9,41,42], we anticipated the opposite, i.e., that fledglings in better body condition attain independence earlier than those in worse conditions. Moreover, the ranging area analysis during the PFDP of eagles from the same breeding territories in different years is relevant to account for potential issues related to the scarcity of suitable territories for both breeding and foraging in territorial raptors [11]. Finally, habitat features and vegetation cover are known to influence the home range size of the LSE [27] and may also contribute to the variability in the space-use pattern during the species' PFDP.

Our publication examines for the first time the PFDP of the LSE, filling the gap regarding the duration and the factors influencing this early but important stage of the species' life history. The aims of this study were fivefold. First, to provide data on the LSE's PFDP duration and age of independence. Second, to identify the factors driving the PFDP. To achieve this, we predicted that the duration of the PFDP was negatively correlated with the fledging date, i.e., birds leaving the nest later in time would have a shorter PFDP and a smaller ranging area and, vice versa, eagles fledging earlier would have a longer PFDP and occupy larger areas. We then thought that different factors, such as habitat type, fledging age, sex, territory, or the body condition of eagles would affect the PFDP duration,

expecting that birds with different physical conditions would extend the duration of their dependence period differently, and such responses would vary according to sex and be spatially constrained. Third, to investigate the home range size of juveniles and the area overlap between individuals born in the same breeding territory, but in different years. We supposed that the size of the ranging area would vary greatly between the eagles and would be influenced by factors such as fledging date, habitat features, and duration of the post-fledging period. We postulated a negative influence of the fledging date and a positive influence of the post-fledging period duration on the eagle's home range. Additionally, we predicted that eagles born in the same breeding territories but in different years would demonstrate a high overlap in their home range areas due to scarcity of suitable breeding and foraging places [11,43,44]. Fourth, to establish the habitat-use pattern of juvenile LSEs during the PFDP. Since the LSE prefers grassland habitats for hunting [32] and territory selection [25], we expected that juvenile eagles would demonstrate selectivity for the habitat features, preferring forest and grassland habitat types and avoiding infrastructure and arable fields. Fifth, to explore the daily activity pattern and the exploratory movements of eagles during the PFDP. We thought that the daily travel distance and the exploratory flights would vary significantly between different individuals and would also increase over time. Our assumption for the exploratory movements included a marked difference between individuals with regard to the maximum daily travel distance and the maximum daily displacement distance. We also supposed that the exploratory flights originating from the same nest could vary substantially across years.

Detailed information of the PFDP provides valuable knowledge about the risks and threats eagles face during this early exploratory life stage. Identifying key habitats and areas for juveniles during the pre-dispersal phase is important for their future preservation. One of our objectives was to provide information that could be integrated into future landscape planning. Finally, by understanding the drivers of the PFDP, we recommend conservation measures crucial to the species' effective management. Our results help comprehend the complex factors shaping juvenile LSEs' space-use pattern during this vulnerable early life stage, addressing critical knowledge gaps for the preservation of this or similar species of conservation concern.

2. Materials and Methods

2.1. Study Area

This six-year study was carried out in three regions of Bulgaria (south-east, central-east and north-east), where the main population of the species is concentrated [45] (Figure 1). We sampled nine active nests covering the species' stronghold range in the country. The habitat surrounding six south-eastern nests is characterized by hilly and low-mountainous terrain, dotted with small forest fragments of Turkey oak (*Quercus cerris* Lam.) and Hungarian oak (*Quercus frainetto* Ten.) with a mosaic of scattered grasslands, shrubs, and agricultural fields [24]. The habitat of only one of the studied nests in the central-eastern part of the country consists primarily of large arable lands and fragmented woodlands with an agricultural mosaic. The north-eastern nests are located in more rugged areas, situated on a steep slope in a river canyon or dry river valley dominated by forest tracts of Common oak (*Quercus robur* L.), Turkey oak, Silver lime (*Tilia tomentosa* M.) and European hornbeam (*Carpinus betulus* L.), with large-scale cereal monocultures and small patches of pastures.

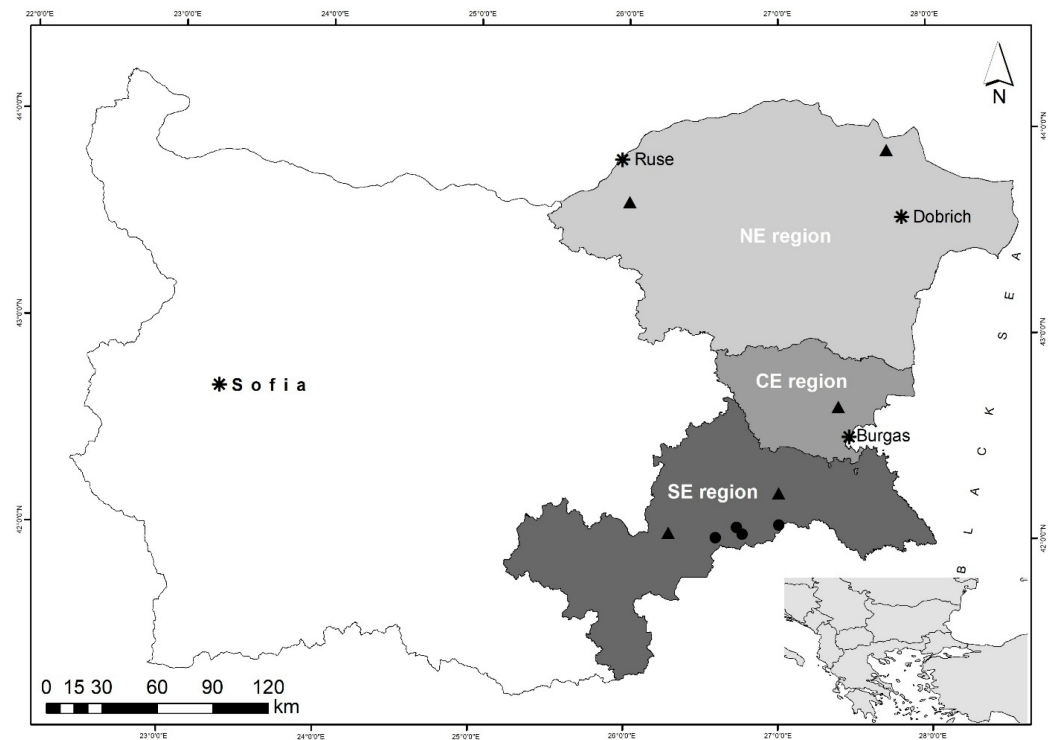


Figure 1. Location of the studied breeding territories of the Lesser Spotted Eagle (*Clanga pomarina*). The triangles indicate the nests, where two juvenile eagles were tagged in different years ($n = 5$), while the circles indicate the nests, where only one nestling was tagged ($n = 4$).

2.2. Bird Tagging

In this study we obtained data from 14 juvenile LSEs, fitted with solar-powered GPS/GSM 30 g Ornitrack-30 transmitters without antenna (Ornitela, Lithuania). The devices were fitted in the period between 2020 and 2025 when birds were between 34 and 55 days old. The age was assessed using data collected through photo-traps, installed in five nests, where the hatching date was precisely documented. For the remaining nine chicks, the age was determined by intensive monitoring every seven days until hatching, taking the median date between two visits, when the chick had not hatched and the next visit when it had already hatched. Body size and plumage development of chicks, compared to the data collected through the photo-traps, were used as a correction factor. The birds were tagged using Teflon ribbon harnesses through a leg-loop configuration [46]. The combined weight of the transmitter and harness remained below 3% of the bird's body mass, in accordance with recommended limits to avoid any adverse effects on flight performance and survival [47,48]. The average tagging time per individual was approximately 20 min. We tagged the eaglets in five of the nests in two different years to search for possible differences in their PFDP pattern, unaffected by the territory factor (Table 1). The remaining four birds were tagged in four separate nests (Figure 1). In this research, each individual was identified using the code assigned by the field team that performed the bird tagging; the code includes the year of tagging and the unique identification number of the tagged bird (Table 1).

Table 1. Juvenile identification and information on the collected data.

N	ID	Nest	Number of Used Points	Fledging Date	Date of Independence	PFDP Duration (Days)	Sex	Age of Fledging (Days)	Age of Independence (Days)	Home Range Size (km ²)	Exploratory Movements (n)
1	1_2020	Slivovo	254	24 July 2020	11 September 2020	49	F	45	94	2.92	2
2	2_2020	Melnitsa	809	28 July 2020	11 September 2020	45	F	45	90	16.72	14
3	3_2020	Sakartsi	314	25 July 2020	13 September 2020	50	F	52	102	1.8	3
4	9_2021	Alexandria	510	30 July 2021	18 September 2021	50	F	41	91	0.16	10
5	8_2021	Koshov	256	28 July 2021	13 September 2021	47	M	44	91	0.05	9
6	7_2021	Lalkovo	509	28 July 2021	12 September 2021	46	F	49	95	1.2	14
7	10_2021	Strandzha	235	6 August 2021	8 September 2021	33	F	38	71	0.04	2
8	6_2021	Iglik	273	28 July 2021	15 September 2021	49	M	49	98	0.94	6
9	4_2021	Mirolubovo	351	22 July 2021	9 September 2021	49	F	48	97	0.59	6
10	5_2021	Slivovo	189	28 July 2021	18 September 2021	52	F	48	100	1.58	0
11	11_2022	Alexandria	327	5 August 2022	13 September 2022	39	Unknown	52	91	0.03	4
12	12_2023	Koshov	56	30 July 2023	16 September 2023	48	F	46	94	0.36	0
13	13_2024	Mirolubovo	521	30 July 2024	16 September 2024	48	F	62	110	4.72	11
14	14_2025	Sakartsi	71	25 July 2025	13 September 2025	50	F	48	98	2.56	7

2.3. Data Processing

GPS fixes and associated sensor data were collected at temporal resolutions ranging from every 30 min to 4 h from one location, with all transmitters programmed to reduce activity or enter dormancy at night. The number of locations used in analyses for different individuals ranged from 56 to 809, with a mean value of 334 ± 199 (Table 1). However, the variances were not significantly different, $F_{1,12} = 3.18$, $p = 0.10$, indicating no considerable bias in the sample size. Tracking data from all individuals were uploaded, stored, and managed in the online animal-movement platform MoveBank (www.movebank.org, accessed on 1 October 2025). Prior to analysis, datasets were visually inspected to identify outliers. Erroneous GPS fixes were removed using general-purpose data filters [49,50], applying a maximum plausible ground-speed threshold of 90 km/h to exclude biologically unrealistic movements. Abrupt location records were treated as outliers and excluded from further analyses.

The post-fledging dependence period (PFDP) was defined as a period between the first successful flight of birds, leaving the nest and the moment when they stopped returning to the home range area [36,51]. In our case, for all studied birds, the day of their independence and the end of the PFDP coincided with the onset of their first migration. To separate the first flight of the eaglets from the standard bias sometimes obtained in the GPS data, we used a location at least 30 m away from the nest. Data from the five photo-traps were also used for verification. Thus, for the first day of their PFDP, we took the date of the first departure from the nest, and for the last day, the day before the beginning of their independence and the start of their first migration. All the analyses described below are based solely on data from this dependence period.

DNA samples were collected from 93% ($n = 13$) of the tagged individuals to determine sex. Due to the uneven distribution of male ($n = 2$) and female ($n = 11$) individuals (Ülo Väli, Freddy Rothla, per. comm.), sex was included in the analyses, but these results should be interpreted with caution. To determine the sex of eaglets, the size difference of Z- and W-specific fragments of the chromo-helicase-DNA-binding (CHD) gene was analyzed according to Fridolfsson and Ellegren [52].

We measured forearm length (mm) using a ruler and recorded the body weight (g) with a digital scale to determine the physical condition of the birds. Because the measurements were taken, on average, two days before the beginning of the PFDP, we consider the data on the physical condition of the birds to be sufficiently realistic. We calculated the body condition index (BCI) using the residuals of a regression of body mass and forearm length [53,54]. The weight of two of the birds was not measured due to a scale battery failure, hence BCI could not be calculated for these individuals.

2.4. Home Range Estimation

To understand how juvenile eagles explored the area around the nest during their dependence period, we estimated 90% of the kernel home ranges for each individual. We applied dynamic Brownian bridge movement models and calculated utilization distributions (UDs) for the studied eagles based on the dBBMM in the move2 package [55] in R v 4.0.2 [56]. For UD calculations, we set a grid size of 50×50 m in our study. We defined the 90% dBBMM isopleth contour as a home range during the dependence period for all studied individuals. Since some of them were born in the same territory but in different years, we assessed the consistency of utilization of home ranges by juveniles of different years, we used the function 'overlap' in the 'ctmm' package to analyze the proportion of area used by a sibling that matched that of the others born in the same breeding territory.

2.5. Movement Analysis

To assess eagles' movement patterns, we derived three metrics from the GPS tracking data. *Daily travel distance* was calculated for each individual by summing the distances between all successive GPS locations recorded within a day. At first, juveniles limited their flights to a small area around the nest, but as their flight abilities developed, they initiated flights beyond this area, the so-called *exploratory movements*. To identify which movements were exploratory, we used a 90% kernel polygon corresponding to our definition of the designated home range used by juvenile eagles [36]. Therefore, any flight beyond the home range area was considered an exploratory movement. Each independent flight started when the eagle left the nest or a usual nearby perch and ended when it returned to the nest vicinity [36]. *Maximum daily displacement* was defined as the greatest straight-line distance between the first location of the day within the home range and the furthest location recorded that day, representing the maximum extent of daily exploratory movement. Daily travel distances were calculated using Geospatial Modeling Environment software operating with R version 0.7.3.0 [56,57].

2.6. Habitat Analysis

The habitat analysis was applied using digital maps based on a Physical Blocks orthophoto layer (5 m resolution, WGS 84) valid for 2025 (<https://shape.mzh.government.bg/> (accessed on 17 June 2026)). Physical blocks represent a continuous land area limited by permanent topographic elements, presenting the actual land-use practices. The physical blocks are based on aerial orthophoto images.

In order to increase the power of the analysis, we pooled rare and likely biologically insignificant variables, such as vineyards, orchards, and undersized non-agricultural areas in a single category, under the category "Other areas". However, this approach was already used in species habitat analysis [25]. For habitat use, we utilized the prime habitat categories. We used Spearman correlation coefficient (r_s) to explore the inter-correlations of the tested variables. When the coefficient of a pair of correlated variables was >0.8 , one of the variables was removed and the other, considered to make more biological sense, was retained in the subsequent analysis [58]. Then, the categories "other areas", "arable lands", and "hatching date" were dropped from the PFDP duration and home range habitat analysis. Furthermore, habitat types such as "water bodies", "agricultural mosaic", and "infrastructure" were excluded from the PFDP duration and home range habitat analysis due to heteroscedasticity of residuals or weak average representation (less than 2%).

2.7. Statistical Processing

We modeled the extent of the PFDP (in days) and the size of the home ranges (in km²) separately, using simple general regression models (GRMs) with sigma-restricted parameterization. Our tested factors were as follows: sex (male, female), individual BCI, fledging date, age of fledging, habitat types, regions, and breeding territory (spatial heterogeneity), while eagle identity was included as a random effect. Due to the small sample sizes, we did not include the interaction of the different predictors as a mixture effect.

To determine whether eagles exhibit any preferences for different habitat types, we used a binomial distribution model with a logit link function, where bird locations were coded as 1 (used), and randomly generated locations were coded as 0 (available). Random points were generated for each eagle separately throughout its entire territory distribution (Minimum Convex Polygon) during the PFDP in a 2:1 ratio with the actual bird locations. In the habitat use analysis, all originally defined habitat types were used (see above). In this model, habitat types were included as "Fixed" predictors and eagle identity as a "Random" effect. To determine whether eagles demonstrated selectivity towards any of the available

habitats, we used a resource selection ratio (RSR) [59]—a measure for selection estimation in a “use-availability” design. In this method, if the value of the measure is 1, the resource is used exactly according to its availability, and the animal exhibits a neutral attitude towards the environment. Accordingly, if the value is >1 , there is a preference, and if the value is <1 , there is avoidance. The farther the value is from 1, the stronger the animal’s reaction to the available resource.

The percentage data were converted into proportions and then Arcsin transformed, while the rest of the data was log-transformed with the function $\log(x + 1)$ to achieve a close to normal distribution. An adjusted R^2 value as a correction factor, explanatory parameter estimates (β^2) with lower (95%) and upper CL (95%), and a probability value (p) of the explanatory factors were evaluated. Results with $p \leq 0.05$ were considered significant. Values were provided as means $\pm$ standard error (SE) or standard deviation (SD). Analyses were performed using Arc GIS 10.4.1 [60], R Core Team [56] and Statistica for Windows, Release 12 [61].

3. Results

3.1. Duration of the PFDP and Age of Independence

The mean duration of the PFDP of juvenile LSEs was 47 ± 5 days (SD) ($n = 14$). The shortest PFDP lasted 33 days, and the longest lasted 52 days, but there were no significant differences between eagles ($\beta^2 = 0.01 \pm 0.29$, CL $-0.62/0.64$, $p = 0.97$). The median date of fledging for the LSE was 28 July (± 4 days (SD), $n = 14$), and the median date of independence, i.e., the onset of the first migration was 13 September (± 3 days (SD), $n = 14$).

The age of independence of juveniles, i.e., when they left their parental territory, always coincided with the onset of their first migration, ranging from 71 to 110 days (median = 95 days). However, there was no statistically significant variation in the eagles’ age of independence ($\beta^2 = 0.27 \pm 0.28$, CL $-0.33/0.88$, $p = 0.35$). It is worth noting that the eagle (ID 10_2021) with the shortest PFDP became independent at the earliest age (Table 1).

3.2. Factors Affecting PFDP

The duration of PFDP was influenced mainly by the fledging date, as this relationship was strongly negative ($\beta^2 = -0.79 \pm 0.18$, CL $-1.18/-0.41$, $p = 0.0007$) (Figure 2). With regard to the habitat types, only the share of Grasslands with shrubs was significantly positively related to the duration of the dependence period of the eagles ($\beta^2 = 0.57 \pm 0.24$, CL $0.05/1.09$, $p = 0.03$). However, none of the other habitat parameters or any of the other tested factors, such as fledging age, sex, territory or region, demonstrated a significant effect on the duration of the PFDP of LSEs (Table 2). Our expectations that the BCI of fledglings would affect the duration of the dependence period of the eagles did not find confirmation ($\beta^2 = -0.24 \pm 0.31$, CL $-0.92/0.45$, $p = 0.46$).

3.3. Home Range and Effects of Predictors

The size of the ranging area (90% isopleth) of LSE juveniles during the PFDP varied from 0.03 to 16.72 km², with a mean value of $2.41 \text{ km}^2 \pm 4.34 \text{ SD}$ ($n = 14$), although the differences between eagles were not significant ($\beta^2 = -0.13 \pm 0.29$, CL $-0.75/0.49$, $p = 0.66$). In general, forests occupied the largest share of the home range of juvenile LSEs, ranging from 0.38% to 87.45%, with a mean value of $49.47\% \pm 26.57\% \text{ SD}$ (Figure 3). The next most abundant habitat type in the ranging area was grasslands with shrubs, with a mean of $13.59\% \pm 13.46 \text{ SD}$ (range 0 to 40.83%), followed by arable lands (mean $12.34\% \pm 16.26 \text{ SD}$; range 0 to 53.99%) and permanent grasslands (mean $11.66\% \pm 14.96 \text{ SD}$; range 0 to 38.10%).

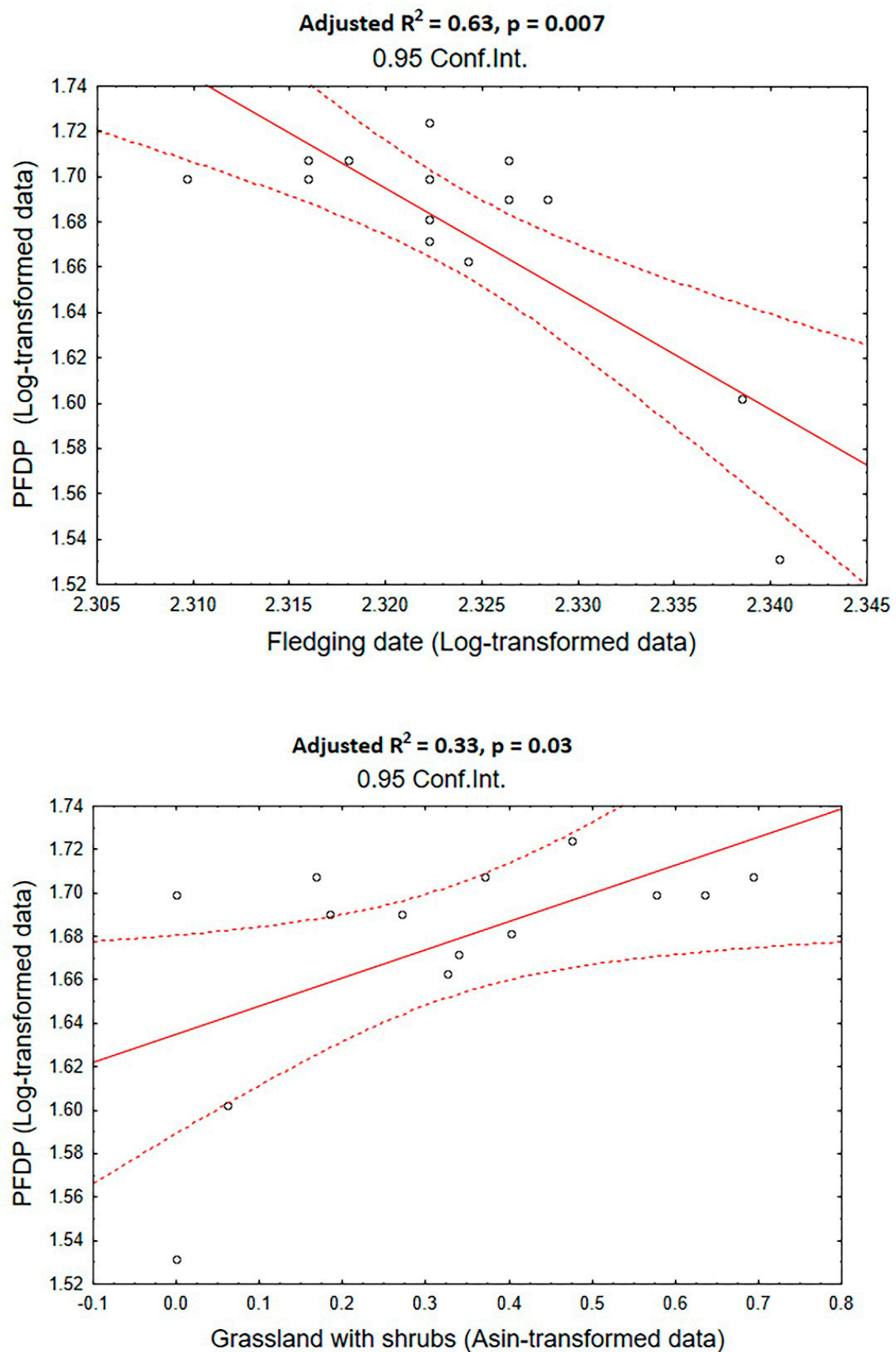


Figure 2. Duration of the post-fledging dependence period (PFDP) of Lesser Spotted Eagles as significantly influenced by the variables fledging date and grasslands with shrubs.

Table 2. Results of General Regression Models (GRMs) with sigma-restricted parameterization. Predictors such as sex (male, female), individual BCI, fledging date, age of fledging, habitat types, regions, and breeding territory were included as a fixed effect, while eagle identity was included as a random effect. Explanatory parameter estimates $\beta^2 \pm$ Std. Err. with lower (95%) and upper CL (95%), an F-ratio test, probability values (p), and degrees of freedom (df) of the explanatory factors are given below. Significant values are indicated in bold.

Parameter	Factor	Effect	β^2	Std. Err.	Lower CL	Upper CL	df	F	p
PFDP duration	Eagle	Random	0.01	0.29	−0.62	0.64	1	0.001	0.97
	Territory	Fixed	−0.22	0.28	−0.84	0.39	1	0.63	0.44
	Region	Fixed	0.09	0.29	−0.54	0.72	1	0.10	0.76
	Sex	Fixed	0.07	0.30	−0.59	0.73	1	0.05	0.82
	BCI	Fixed	−0.24	0.31	−0.92	0.45	1	0.59	0.46
	Fledging date	Fixed	−0.79	0.18	−1.18	−0.41	1	20.41	0.0007
	Fledging age	Fixed	0.36	0.27	−0.22	0.95	1	1.81	0.20
	Forests	Fixed	−0.31	0.27	−0.91	0.29	1	1.27	0.28
	Grasslands	Fixed	0.29	0.28	−0.31	0.89	1	1.11	0.31
	Grasslands with shrubs	Fixed	0.57	0.24	0.05	1.09	1	5.78	0.03
Ranging area	Eagle	Random	−0.13	0.29	−0.75	0.49	1	0.21	0.66
	Territory	Fixed	−0.24	0.28	−0.85	0.37	1	0.71	0.42
	Region	Fixed	−0.23	0.28	−0.84	0.38	1	0.66	0.43
	Sex	Fixed	−0.35	0.28	−0.97	0.27	1	1.53	0.24
	BCI	Fixed	0.34	0.30	−0.33	1.00	1	1.27	0.29
	Fledging date	Fixed	−0.53	0.24	−1.07	−0.001	1	4.76	0.049
	Fledging age	Fixed	0.41	0.26	−0.17	0.98	1	2.37	0.15
	Forests	Fixed	−0.52	0.25	−1.06	0.01	1	4.54	0.054
	Grasslands	Fixed	0.65	0.22	0.18	1.13	1	9.00	0.01
	Grasslands with shrubs	Fixed	0.53	0.25	−0.01	1.06	1	4.62	0.053

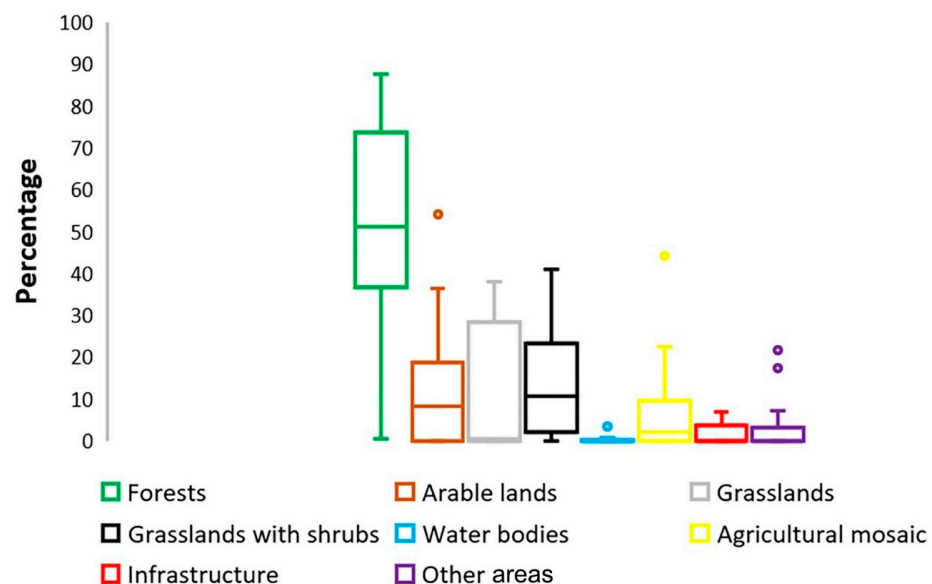


Figure 3. Percentage distribution of different habitat types in the home range of juvenile Lesser Spotted Eagle's ($n = 14$) during their post-fledging dependence period.

In line with our prediction, the fledging date affected the size of the juveniles' home range as this relationship was negative ($\beta^2 = -0.53 \pm 0.24$, CL $-1.07 / -0.001$, $p = 0.049$) (Figure 4, Table 2). As we supposed, habitat features significantly impacted the size of the home range of LSE juveniles (Table 2). However, the presence of grasslands

($\beta^2 = 0.65 \pm 0.22$, CL 0.18/1.13, $p = 0.01$) and grasslands with shrubs ($\beta^2 = 0.53 \pm 0.25$, CL $-0.01/1.06$, $p = 0.053$) positively related to the size of the eagle's home range, while this relationship was inverse for forests ($\beta^2 = -0.52 \pm 0.25$, CL $-1.06/0.01$, $p = 0.054$) (Figure 4).

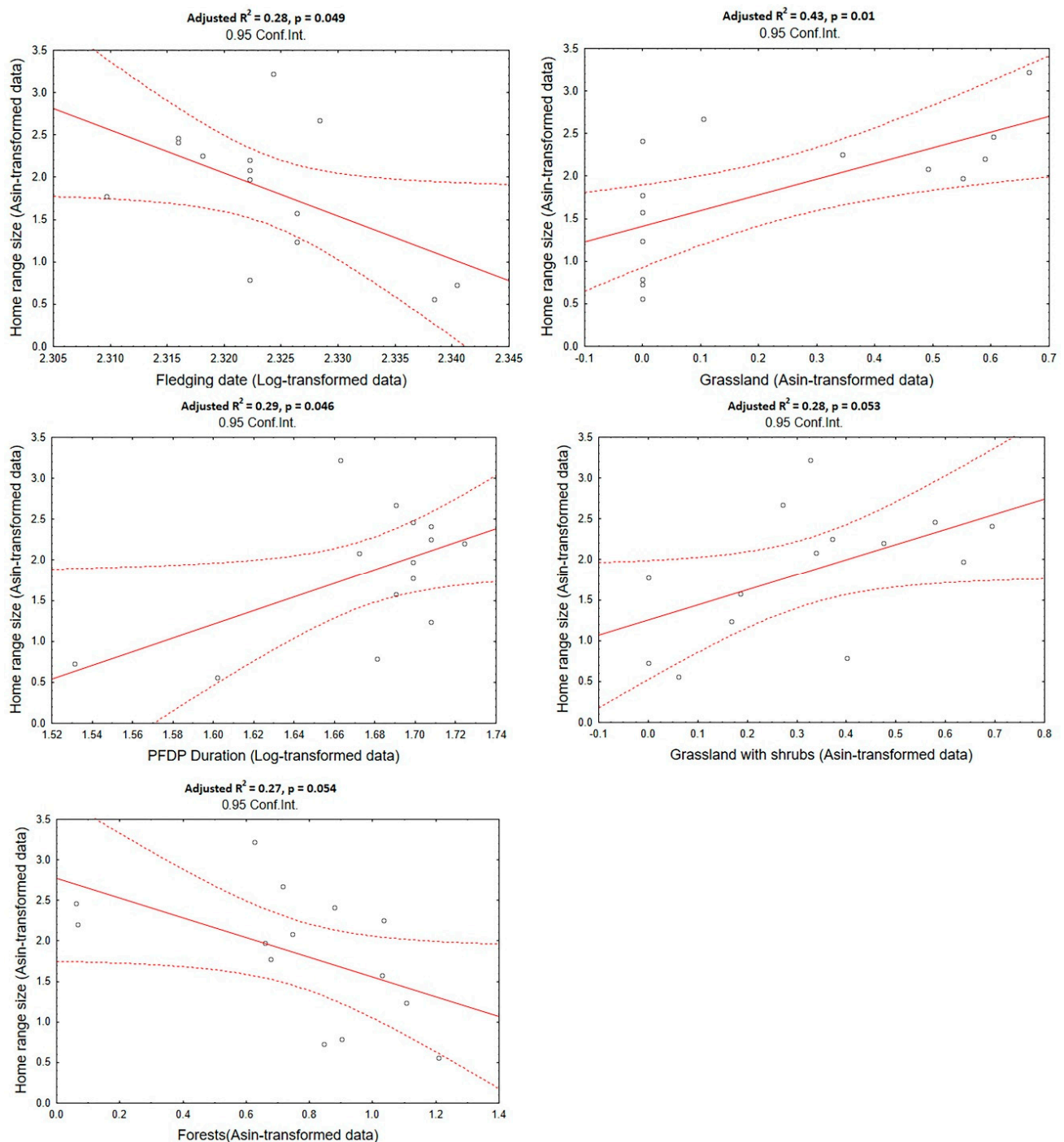


Figure 4. Home range size of juvenile Lesser Spotted Eagles during their post-fledging dependence period (PFDP) as significantly influenced by different variables.

Our initial hypothesis of a positive dependence of the size of the home range of juvenile LSEs on the duration of their PFDP found confirmation ($\beta^2 = 0.54 \pm 0.24$, CL 0.01/1.07, $p = 0.046$) (Figure 4).

3.4. Home Range Overlap

In each of five breeding territories, two juveniles were tracked in different years, providing five between-year comparisons involving ten individuals. For these eagles, the values of home range overlap varied from 56.35% to 100%, with an average value of 87.94% (Figure 5).

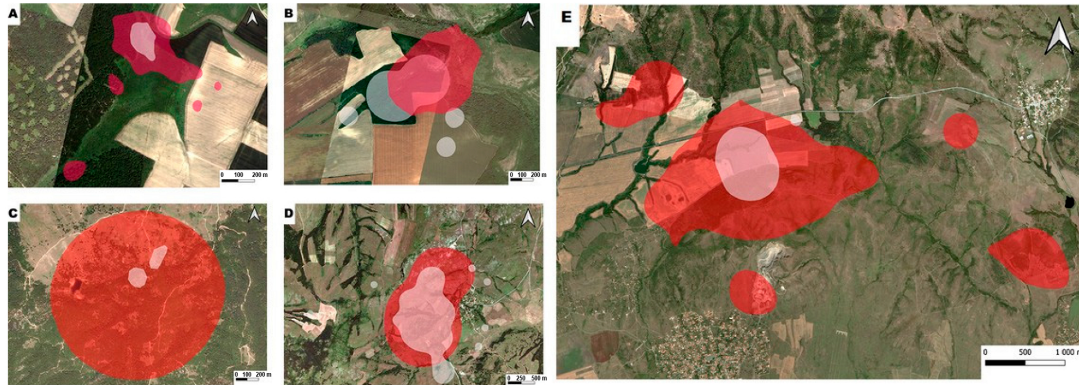


Figure 5. Ranging area (90% isopleth) of juvenile Lesser Spotted Eagles during their post-fledging dependence period in NE Region (A,B), SE Region (C,D), and CE Region (E). The five breeding territories, where more than one Lesser Spotted Eagle fledgling was born and tagged in different years (i.e., the triangles in Figure 1).

3.5. Habitat Use

We found that during their PFDP, juvenile LSEs exhibited overall selectivity in terms of habitats (random Effect, $F_{13} = 42.65$, $p < 0.001$), with the exception of three birds. However, in ten of the eleven habitat types studied (fixed Effect, $F_{10} = 471.37$, $p < 0.001$), the eagles demonstrated a significant reaction, with only the ravine habitat type lacking a response. During their dependence period, LSEs strongly preferred forests ($t = -2.92$, $p = 0.003$) and gorges ($t = 8.99$, $p < 0.001$) and avoided the rest of the habitats (Table 3). The availability of forests in the study area (MCP-polygon) was only 4.72%, but the eagles used them 74.59% of the time (RSR = 15.79). Gorge availability was negligible (0.19%) in the area, but the eagles selected them in 3.28% of cases (RSR = 17.41). As we assumed, the birds strongly avoided infrastructure ($\beta^2 = -0.25 \pm 0.01$, CL $-0.27/-0.22$ [44.06% availability vs. 0.46% use; RSR = 0.01]) and arable land ($\beta^2 = -0.41 \pm 0.02$, CL $-0.44/-0.37$ [12% availability vs. 3.69% use; RSR = 0.31]). In contrast to our hypothesis, juvenile LSEs significantly avoided grasslands ($\beta^2 = -0.37 \pm 0.01$, CL $-0.40/-0.34$ [9.55% availability vs. 3.43% use; RSR = 0.36]), grasslands with shrubs ($\beta^2 = -0.32 \pm 0.01$, CL $-0.35/-0.30$ [9.78% availability vs. 3.47% use; RSR = 0.35]), and agricultural mosaic ($\beta^2 = -0.21 \pm 0.01$, CL $-0.23/-0.19$ [9.65% availability vs. 1.15% use; RSR = 0.12]). With regard to the other habitat types, such as orchards, water bodies, and rocks, eagles also showed avoidance, but their importance was less significant (Table 3).

Table 3. Habitat types available to and used by fourteen Lesser Spotted Eagles studied in their post-fledging dependence period. The Resource Selection Ratio (RSR) indicates the bird's reaction. The ravine category is not included because it lacks a statistical response. An RSR value of 1 indicates a neutral response; <1 indicates avoidance; and >1 indicates preference.

Habitat	Availability	Use	RSR	Selection
Agricultural mosaic	9.65	1.15	0.12	Avoidance
Arable land	12.00	3.69	0.31	Avoidance
Forests	4.72	74.59	15.79	Preference
Gorges	0.19	3.28	17.41	Preference

Table 3. Cont.

Habitat	Availability	Use	RSR	Selection
Grasslands with shrubs	9.78	3.47	0.35	Avoidance
Grasslands	9.55	3.43	0.36	Avoidance
Infrastructure	44.06	0.46	0.01	Avoidance
Orchards	3.35	1.45	0.43	Avoidance
Rocks	0.03	0	0.00	Avoidance
Water bodies	4.17	0.2	0.05	Avoidance

3.6. Daily Activity

The daily distance ($n = 370$) that the eagles traveled varied significantly between individuals (adjusted $R^2 = 0.19$, $F_{14} = 7.05$, $p < 0.001$) with a mean value of $2.289 \text{ km} \pm 7.996$ (range 0 to 114.213 km). As we assumed, over time, the eagles notably increased their activity ($\beta^2 = 0.27 \pm 0.05$, $F_{1,37} = 28.72$, $p < 0.001$), covering longer distances in the days prior to emancipation (Figure 6).

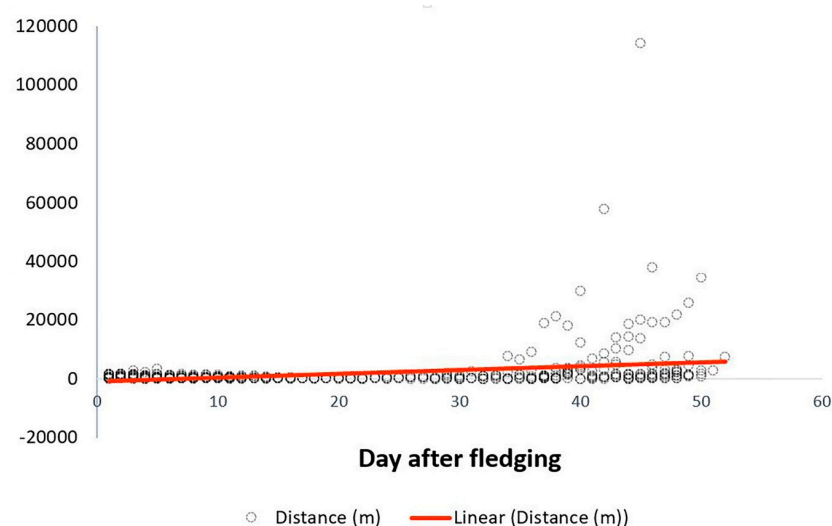


Figure 6. Daily travel distance (m) ($n = 370$) of juvenile Lesser Spotted Eagles ($n = 14$) during their post-fledging dependence period.

3.7. Exploratory Movements

The 14 studied eagles made a total of 88 exploratory movements during the dependence period. This number fluctuated non-significantly ($\beta^2 = -0.21 \pm 0.28$, CL $-0.83/0.40$, $p = 0.47$) among individuals, from 0 to 14 movements (Table 1). The maximum daily travel distance ($\beta^2 = 0.37 \pm 0.10$, CL $0.17/0.57$, $p < 0.001$) and the maximum daily displacement ($\beta^2 = 0.48 \pm 0.09$, CL $0.29/0.66$, $p < 0.001$) during the exploratory flights varied markedly between eagles. The maximum daily travel distance ranged from 0.169 km (eagle ID 10_2021) to 68.430 km (eagle ID 2_2020), with a median of 5.728 km, and from 0.169 km (eagle ID 10_2021) to 28.332 km (eagle ID 2_2020), with a median of 1.473 km for the maximum daily displacement. All the juveniles completed their exploratory flights within the same day, night-roosting in the nest or nearby. However, none of the studied factors, such as territory, sex, BCI, fledging date, and fledging age, influenced the flight length or the distance reached during the exploratory movements ($p > 0.05$).

Exploratory flights originating from the same nest could vary substantially across years, as observed in the Sakartsi nest, unlike other nests ($n = 4$), where individuals were tagged in different years. For this particular nest we observed significant yearly differences

in both distance to the nest (adjusted $R^2 = 0.42$, $F_1 = 7.48$, $p = 0.03$) and flight length (adjusted $R^2 = 0.47$, $F_1 = 8.89$, $p = 0.02$) (Figure 7).

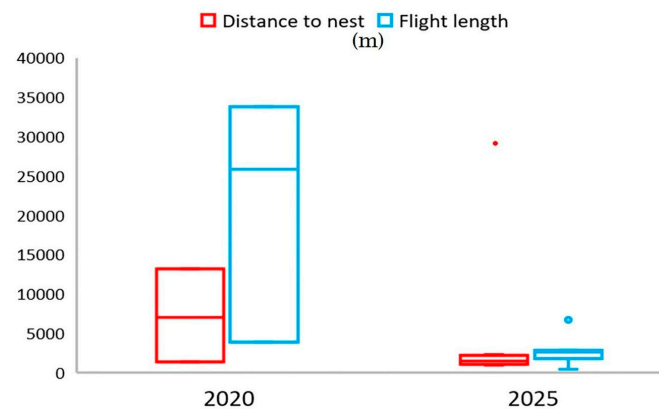


Figure 7. Box-plots of distance variables of the exploratory movements of juveniles born in the Sakartsi nest in different years (Eagle ID 3_2020 and Eagle 14_2025).

Eagles undertook longer flights (adjusted $R^2 = 0.60$, $F_7 = 19.68$, $p < 0.001$) and reached farther distances from the nest (adjusted $R^2 = 0.76$, $F_7 = 15.25$, $p < 0.001$) during their exploratory movements as the post-fledging period progressed (Figure 8). The number of exploratory flights also increased significantly over time (Two-tailed G-test with Yates' correction = 144.99, $p < 0.001$), intensifying just prior to emancipation (Figure 8).

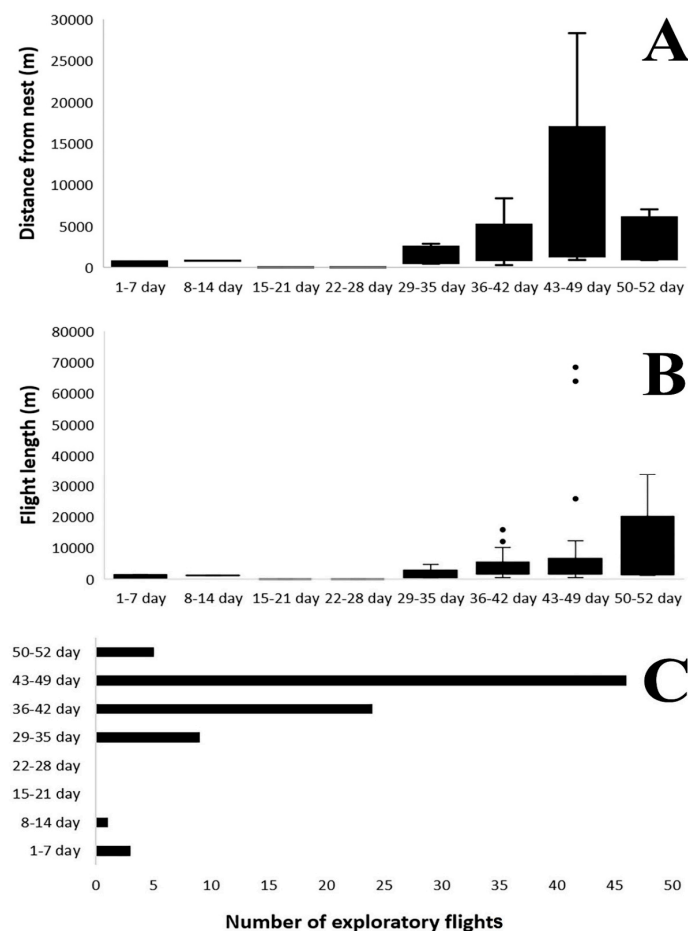


Figure 8. Weekly variations of the exploratory movements of juvenile Lesser Spotted Eagles during their post-fledging dependence period. (A)—maximum distance from nest; (B)—overall length of flights; (C)—number of exploratory flights. Error bars represent SE.

4. Discussion

To our knowledge, this is the first systematic study presenting spatial and temporal patterns of the PFDP for the LSE, including different drivers of variation (intrinsic and extrinsic). Our findings reinforced the importance of the fledging date as the strongest factor determining the duration of this critical stage of the LSE's life cycle. Additionally, the size of ranging area used by juvenile eagles was conditioned mainly by the surrounding habitats (grassland types and forests) along with the fledging date. We also discovered a high similarity between areas used by juveniles born in the same breeding territory during their PFDP in different years, which emphasized the importance of some environmental factors, such as habitat features compared to others that would vary yearly like prey abundance or intra- and inter-specific competition. Finally, we found that eagles are habitat-selective with their mobility increasing over time and being individually specific.

4.1. Duration of the PFDP

Our prediction of the negative effect of the fledging date on the duration of the dependent phase of the LSE found full confirmation (Figure 2). We found that birds leaving their nests later in the breeding season had a shorter dependence period compared to those fledging earlier, suggesting that the dependence time was constrained by migration. Although PFDP duration was individually specific, it varied insignificantly between eagles. The age at which juveniles gained independence did not vary significantly either, but always coincided with the onset of their first migration, suggesting the migration-limited duration of the dependent period. However, the eagle (ID 10_2021) with the shortest PFDP became independent at the earliest age, indicating the earliest onset of migration (Table 1). In contrast to our suggestion, only the habitat predictor Grassland with shrubs of all tested factors significantly affected the PFDP duration. More shrubby grasslands in the area meant more opportunities for hunting and potentially more prey availability, since LSEs forage predominantly in grassland-type vegetation [32,62,63] and prefer grassland with shrubs when selecting a territory at these latitudes [25]. Thus, the opportunity for better nutrition and better fitness before the long and risky first migration, when birds are least experienced and particularly vulnerable, may extend the duration of the dependent period. Neither fledging age nor spatial heterogeneity (region, territory), BCI or sex had an impact on the duration of the PFDP in our study. The lack of an established relationship between BCI and the duration of the dependence period in our research neither supported nor rejected the resource competition or the ontogeny hypothesis. The absence of such a relationship might be due to the similar environment in which the juveniles develop, hence leading to similar body conditions. Then, their similar fitness would not affect the duration of their dependent period. Indeed, BCI did not differ significantly among individuals ($F_1 = 2.90$, $p = 0.12$). The lack of spatial correlation with the duration of PFDP also supported the idea of similarity in environmental conditions. Another plausible explanation would be the small sample size in our study, which could not capture such a relationship. Sex did not show any correlation with the PFDP duration either, probably due to the highly uneven distribution among the tested individuals, biased in favor of females (11:2).

4.2. Home Range, Ranging Area Overlap, and Habitat Use

Our study established a relatively small ranging area inhabited by juvenile eagles compared to the breeding species' home ranges [27,28]. For half of the studied birds, the home range was even smaller than 1 km², indicating low mobility and strong attendance to the nest vicinity during the dependent period. Our expectations of significant individual-specific variations in the size of the ranging area occupied by eagles during the PFDP were not met. However, these results support the concept of uniformity of the environmental

conditions governing eagles' distribution. Moreover, the sex and the physical fitness (BCI) of the birds did not correlate considerably with the size of the ranging area either. As we supposed, vegetation cover markedly affected the size of the juveniles' home range, as all of the tested habitat types showed a significant effect. Grassland and Grassland with shrubs were positively associated with the size of the ranging area while the presence of Forest revealed the opposite pattern (Figure 4).

Grassy vegetation is preferred for hunting and foraging by the species [21,63]. Its presence in the landscape attracts the eagles and they tend to visit these suitable feeding sites, thus increasing the size of the ranging area. On the other hand, the areas occupied by juveniles during their PFDP may be larger when prey abundance and availability of foraging sites are low, as it was previously documented [37,38]. However, this question needs further investigation.

Conversely, the presence of large forest tracts reduces the foraging opportunities and the lack of suitable open sites leads to smaller home ranges. As we found, nearly half of the home range area on average was occupied by forests (Figure 3).

As we assumed, the fledging date negatively influenced the size of the ranging area, as later fledging birds had a smaller home range and vice versa, those that left the nests earlier had a larger ranging area. Early fledging gives birds time to gradually develop their flying abilities and hunting skills, to adapt to the landscape features and thus increase the size of their home range over time. Conversely, late fledging is constrained by the onset of migration and juveniles do not have the opportunity to gradually increase their home range size. They must quickly adapt to the environment and get fit for the difficult period of their first migration. It is likely that later departure is associated with lower survival rate and increasing mortality, but this issue needs further clarification. However, our hypothesis of a positive dependence of the home range size of juvenile eagles on the duration of their PFDP was confirmed. The longer duration of the dependence period results in more time to the onset of migration and a gradual increase in the mobility of the birds, which leads to a larger size of the ranging area.

Ranging areas during the PFDP of juveniles born in the same breeding territory but in different years had a remarkable rate of overlap. It is worth noting that of the five analyzed cases of territory overlap, the weakest overlap (56.35%) was observed between two individuals of different sexes. However, this single case is insufficient to test this issue. On the other hand, a possible explanation of the observed high degree of area overlap could be related to the uniformity and/or consistency of environmental conditions. Food abundance and availability are heavily affected by habitat or other time-persistent factors, making them repeatable across years, and are, therefore, easily predictable for the LSE, irrespective of climate or individual specifics.

Our initial hypothesis that eagles would exhibit habitat selectivity during their dependence period, preferring predominantly forest and grassland habitats (resting and feeding sites) and avoiding arable lands and infrastructure, was partially confirmed. We established that they strongly preferred Forests and definitely avoided Arable fields and Infrastructure (Table 3) as found in other studies [25,32]. Being a typical forest-dwelling raptor, the LSE spends a significant part of its life cycle in the woods. This pattern was observed also in the current study, where juvenile eagles ranged over a small area near the nest, dominated by forest stands, during their dependence period (see above). Cultivated fields offer lower prey availability and abundance, and are less productive for eagles, while infrastructure represents a habitat unsuitable for hunting and foraging. This species prefers different grassland vegetation for feeding, but see [64]. Conversely to our assumption, we observed that juvenile eagles significantly avoided grassland habitats in our study. Why does this contradiction arise? We propose the following explanation. During their PFDP, eagles

are highly dependent on their parents who continue to provide food and can protect the young from predators. As they learn to hunt, the juvenile birds gradually decrease their reliance on parental care and support for food. During this transition period, juvenile LSEs are less mobile and inhabit small ranging areas near the nest, as we found in the current study. Actually, the birds become more active and undertake more movements in the days just before their emancipation, which, in our study, coincided with the onset of their first migration. Thus, the strong dependence on parents and the low mobility of the youngsters, combined with the relatively short period of dependence before their first migration, always coinciding with the beginning of their independence, explains this behavior demonstrated by the juvenile eagles. In our opinion, this is the main reason that they “avoid” grassy habitats. However, we discovered that eagles also strongly preferred gorges, although their presence in the studied area was negligible, at less than one percent. This preference is more related to the topography and relief than to the habitat. Gorges offer a good opportunity for the emergence of updrafts, which are particularly suitable for soaring birds such as the LSE to fly and gain altitude. This is especially true for juvenile eagles, which are still developing their motor skills and flight abilities.

4.3. Movement Pattern

In line with our expectations, we found individual-specific movement patterns in eagles both in terms of daily mobility and exploratory movements. For exploratory flights, the two studied indicators—the maximum daily travel distance and the maximum daily displacement—varied markedly between eagles. As found in another study [36], eagles gradually increased their activity, peaking in the days before their emancipation (Figure 6). In the first days after departure, the birds’ activity was weak as they flew short distances, mainly in the area near the nest. During this period, they were particularly dependent on parental care and relied entirely on adults for food supplies and protection from predators—information confirmed during our visits to the nests (authors’ data). Fledglings transitioned to full independence gradually. By improving their flying skills and fitness over time, usually after the third ten-day period following the departure from the nest, fledglings moved away from the natal area and initiated exploratory flights, which became more frequent, longer, and distant from the nest (Figure 8). However, it is worth noting that all of the exploratory flights of the eagles we studied ended within the same day. Although our research included a relatively small number of eagles ($n = 14$), we also observed individual-specific variations in the number of exploratory flights between birds. Thus, two of the studied individuals did not undertake any exploratory flights, the other two made only two flights, while another two specimens carried out fourteen exploratory movements each prior to the onset of migration (Table 1). When testing different factors, such as territory, sex, BCI, fledging date, and fledging age, we did not find any evidence of dependence of the exploratory movements on these predictors. The overall poor mobility of eagles during the dependence period also affected their exploratory flights, with the eagles moving away an average of 1.5 km from the nest and traveling less than 6 km per day. Interestingly, the individual (ID 10_2021) with the shortest PFDP ($n = 33$ days), which became independent at the earliest age (71 days) and migrated earliest (8 September), being one of the eagles with the smallest ranging area (0.04 km^2), was also the bird with the shortest distance traveled before the onset of migration ($n = 0.169 \text{ km}$). We found that exploratory flights (maximum distance from the nest and overall flight length) could vary substantially across years within the same breeding territory, unlike other nests, where individuals were tagged in different years, demonstrating individual specificity.

4.4. Comparison with Other Raptor Studies

The PFDP is a fundamental stage of the life history of altricial birds that influences their fitness, long-term survival, and, eventually, future reproductive output. The duration and the drivers of this crucial and uncertain transition period for raptor species are understudied for more than two-thirds of the threatened and near-threatened guild representatives [10]. Globally, considering thirty-eight raptors distributed throughout the world, body weight, latitude, and migratory status significantly affect PFDP duration such that larger and heavier species experience a longer dependent period, northern breeders (species or populations) have a shorter dependence period than those distributed in the southern hemisphere, while resident species show a longer average PFDP than migratory ones [10].

Since our study is the first published research on the LSE, we cannot compare it with other relevant surveys on the species or on its sister species, the Greater Spotted Eagle (*Clanga clanga*), where similar research is currently lacking. Therefore, we present data from comparable investigations involving other raptors, focusing primarily on similar species inhabiting analogous habitats. Our findings on the PFDP duration are generally consistent with the results established for the Spanish Imperial Eagle (*Aquila adalberti*), where the dependence period lasted between 29 and 76 days, with a mean of 54 days [5], and differed greatly from the duration of this period in other large eagles such as the White-tailed Eagle (*Haliaeetus albicilla*) (range 44–158 days) [4], (range 46–160 days, 93 days on average) [19], Golden Eagle (*Aquila chrysaetos*) (range 60–120 days) [65], (range 44–250 days, median 156 days) [15], and Steppe Eagle (*Aquila nipalensis*) (range 30–82 days, 58 days on average) [66]. However, large, slow-developing resident tropical raptors such as the Chaco Eagle (*Buteogallus coronatus*), Harpy Eagle (*Harpia harpyja*) and Philippine eagle (*Pithecophaga jefferyi*) had an extended dependence period, reaching between 250 and 650 days on average for different species [11,67]. Bigger or heavier species required more time to develop and needed extended parental care after fledging to acquire the necessary skills for independent life and survival. However, another similar forest-dwelling raptor such as the Booted Eagle (*Hieraaetus pennatus*) had a shorter dependent period (41 days, range 23–61 days) [54], while the medium-sized Bonelli's Eagle (*Aquila fasciata*) demonstrated a prolonged PFDP (77 days, range 50–114) [68]. Notably, the Golden Eagle from Denali National Park, Alaska, which is a complete migrant, had an analogous dependence period consistent with our results, lasting between 39 and 63 days (50 days on average), and these early life stages were constrained by migration time [4], a finding that was confirmed by our study, too. In fact, in line with our records, the end of the PFDP of the Golden Eagles from Alaska coincided with the onset of their first migration. Migrants try to avoid harsh winters after the breeding season, so their time for development is limited. Principally, migration constrains the time available for post-fledging dependence, forcing juveniles to disperse earlier [69,70]. Environmental factors may accelerate or delay the duration of the PFDP, and since they vary greatly, the same species may be affected by different conditions across its range of distribution and hence develop separate life-history strategies accordingly.

The age of independence was the same as the one recorded for the Booted Eagle [54] and lower than the age identified for the White-tailed Eagle, i.e., an average of 148 days [19] or 164 days (range 115–244 days) [44], the Golden Eagle, ranging between 140 and 180 days [65], or the Spanish Imperial Eagle, i.e., 129 days on average (range 104–155 days) [5] and a median of 137 days (range 93–153 days) [36].

Fledging date was not related to the PFDP duration in Golden Eagle [15], which was not consistent with our findings on the strongly negative impact of the date of fledging on the duration of the dependence. However, we consider that this difference was due to a constraint on the PFDP resulting from the onset of migration, a constraint valid for migratory species [69], but irrelevant for resident species. Furthermore, migratory Golden

Eagles indicated a strong negative relationship between the hatching date and the PFDP duration [4]. Since the hatching date correlated significantly with the fledging date in altricial birds [71], this study, the migratory Golden Eagle demonstrated a similar pattern of the PFDP duration limited by the migration time.

In contrast to our findings, there are many studies reporting that physical condition [5,11,54] and sex [11,66,72] affect the PFDP duration or the size of the ranging area. Individuals with better health conditions start dispersal earlier than those in poor condition, which is related to the ontogeny hypothesis [9,41,42]. However, the opposite is also true in some cases, corresponding to the resource competition hypothesis [39,40,69]. The lack of any relationship between the fitness of individuals and the duration of the dependent period or the size of the ranging area they inhabited in our study may be due to the small sample size ($n = 14$ studied birds) or to the constancy of the habitat conditions (feeding and nesting sites, as well as abundance and availability of prey). It is well known that the availability of foraging sites [38] and prey abundance and access [69] influence the PFDP duration and the size of the juveniles' home range. The lack of impact of the physical condition or the sex on the duration of the PFDP and the size of the occupied territory was also reported for Bonelli's Eagle [3] and Golden Eagle in Alaska [4].

Spatial heterogeneity affects the dependence period of some raptors [11], unlike that of others [66] that are related to habitat quality [68]. A relatively small ranging area (mean 6.94 km^2) during the PFDP was also reported for the Steppe Eagle, where the average size of the juvenile home ranges differed significantly between sexes (for males, 11.18 km^2 ; for females, 1.64 km^2) [66]. However, other large eagles, such as the Chaco Eagle [11], occupied larger areas during their PFDP. An age-dependent expansion of the juvenile home range was also reported for the Spanish Imperial Eagle, where, during the first two months post-fledging, the eagles had smaller ranging areas (median 232 ha), which progressively increased until the end of the dependence period, although not all of the studied individuals followed this pattern [36]. Therefore, the initial ranging area reported by [36] was almost equal to our results. However, our results are consistent with other findings of high ranging-area overlap among juveniles born in the same territory but in different years reported for the Chaco Eagle [11], a species raising one fledgling per year. Therefore, we support the hypothesis of the species' strong range consistency during the PFDP when the environmental conditions are time-persistent or interannually repeatable.

The demonstrated selectivity in terms of habitats during the PFDP was also observed for other raptor species. The White-tailed Eagle preferred forests and seminatural habitats and avoided agricultural areas in Finland [44], and the post-fledging Golden Eagles in Sweden favored forests, too [73].

Our individual-specific daily movement pattern of juvenile birds was strongly corroborated by other studies [15,51,65,74]. As we pointed out, the exploratory movements differed greatly, being determined by individual- and species-specific factors. No continued increase in mobility prior to emigration was reported for the Eagle Owl (*Bubo bubo*) [75] and the Golden Eagle [15], unlike the findings reported by [65] for the Golden Eagle, [66] for the Steppe Eagle, and [19] for the White-tailed Eagle, who reported a marked increase in the exploratory movements during the period before emancipation. Consistent with our observations, many publications reported that the number of exploratory flights could vary between individuals and the lack of any exploratory flights before the end of the dependence period was not an exception at all [19,36,66]. However, the variance in exploratory movements differs substantially across raptor species, being individual- and species-specific, and can be modified by intrinsic (individual decision, body condition, sex, and parent-offspring conflict) [5,42,54,66], or extrinsic factors (habitat quality, prey abundance/availability, and weather conditions) [68,69,76]. Additionally, the exploratory

movements can differ markedly between individuals born in the same breeding territory, but in different years, as has been previously reported in another study [36].

4.5. Consequences for Conservation

The majority of the raptor species worldwide are currently experiencing population declines, showing high sensitivity to anthropogenic pressure [16]. Fledging represents an abrupt transition for the inexperienced juveniles with poor locomotory skills, suddenly facing unknown challenges and having to cope with the risks within their natal habitats, which results in increased mortality during the first weeks after fledging. A number of studies reported a high mortality rate during the PFDP [2,3,77]. Therefore, a better understanding of the PFDP (ranging areas and drivers of their variation) is vital for future conservation efforts, as it would help identify hazards and improve the chances of survival for threatened species [10,11,18]. Usually, raptor research and conservation efforts are generally focused on the protection of the breeding home range areas and nest sites, neglecting the juvenile ranging areas. Since juvenile survival is a far more critical driver of the population dynamics and viability than the production of progeny per se, research concerning the PFDP duration and constraints must be intensified. Moreover, high mortality during the dependence period in species of conservation priority and/or low reproduction can compromise the long-term population prospects [78]. However, our study highlights the need to protect the area used by the LSE juveniles during the first months of the post-fledging phase (the period prior to the onset of the first migration). Any measures to conserve this forest-dwelling raptor should be temporally extended beyond the breeding season, as well as concentrated in the relatively small area around the nests (about 300 ha) to ensure more effective and long enough conservation of the species during this extremely risky and vulnerable for the offspring transition period. Furthermore, the pronounced range consistency observed among LSEs in this study highlights the importance of already established areas that are key for juvenile birds. The spatially consistent pattern of the breeding performance of the species in this part of its distribution was already documented in previous research [26]. Therefore, the less mobile pattern, along with the strong attachment to the nest area and the presence of mature forest tracts and different grassland vegetation in the ranging area are of crucial importance and should be taken into account when designing effective conservation plans and strategies to ensure the long-term persistence and survival of the LSE populations.

Our study highlights the importance of forests and grasslands for LSEs during their dependence period. This pattern clearly indicates that the loss or alteration of natural habitats (resulting from the development of various types of artificial structures such as solar parks or wind farms, and conversion of grassland into arable lands) [25,79] reduces the availability of foraging and roosting habitats for LSEs in the post-fledging period. Therefore, our results concerning the habitat use by juvenile LSEs during the PFDP must be integrated into landscape planning, including solar photovoltaic infrastructure and wind-energy development, both of which poses a threat to LSEs. Considering the importance of the area around the nest, not only during the breeding season but also beyond, we propose the introduction of regulations within an extended radius around the nest sites. The designation of a strict 100 m protective zone around the nest, where forestry activities such as logging, road construction, and clearings, as well as hunting and herb and mushroom gathering (between March and September), are prohibited, and a wider zone, up to 300 m, where only regeneration felling and/or salvage logging operations can be carried out in order to preserve the forest structure, will reduce the disturbance during the breeding season and the fragile period of dependence of juvenile birds and will thus ensure the long-term preservation of the vitality of the LSE population in the southern periphery of the species'

distribution. Incorporating such regulations into governmental plans and programs will not only support the LSE population but will also benefit other forest-dwelling species of conservation importance inhabiting similar habitats.

Although our study is the first to address the factors describing the PFDP in the LSE in a spatial and temporal context, integrating bird behavior, many aspects of this important but fragile period of the species' life history remain understudied and unknown. What is the survival rate of juvenile birds, what is the role of parents during the dependence period, and how does it affect the survival of fledglings? Do parents depart their breeding territory before their offspring, and does their departure influence the departure of their offspring? How do weather and prey abundance and availability affect juvenile survival during the PFDP? All of these issues are of particular interest, and their clarification will help to more effectively conserve the species in the future. Last but not least, the strong intensification of natural forest fires in the country in the last decade [26], mainly due to climate change, leads to both a direct threat to the lives of birds and a severe loss and degradation of habitats, a question that needs urgent research and clarification.

However, we also encourage similar studies to be conducted in other parts of the species' distribution range, as well as with similar forest-dwelling raptors, notably its sister species, the GSE, especially in the context of their widespread hybridization [80].

As suggested above, species-specific conservation strategies should be implemented to further contribute to reducing disturbance and ensuring landscape consistency in areas of key significance to the juvenile LSEs during the post-fledging period. Our findings emphasize the necessity of extending the measures to conserve this forest-dwelling raptor species. Ultimately, our results are relevant for all similar raptor species, sensitive to human-related disturbance, as they support the increasing importance of spatiotemporal-specific regulations for breeding raptor populations in human-inhabited areas with increasing alteration of land-use patterns.

4.6. Study Limitations

We should highlight several limitations of our study, such as the relatively small sample size of eagles ($n = 14$), a sex bias, and the lack of BCI for two individuals. Thus, our results should be interpreted with caution when generalizing to larger populations and extents. Nevertheless, our findings present the general species pattern during the PFDP and provide a comprehensive framework for scaling up future studies.

5. Conclusions

Our study is the first to characterize the post-fledging dependence period of juvenile Lesser Spotted Eagles, using modern techniques (GPS tracking) to understand their behavioral pattern in relation to the natal environment. Testing different factors (intrinsic and extrinsic), we found that the fledging date is a main driver shaping the dependence period both temporally and spatially. Additionally, the size of the ranging area used by juvenile eagles was determined mainly by the surrounding habitats (grassland types and forests). Our results indicated that birds are habitat-selective, strongly preferring forests and avoiding human-related landscapes (infrastructure and agricultural fields) during their fragile PFDP. In this early life-history stage, they inhabit a relatively small area around the nest, gradually increasing their mobility, which is determined by individually specific factors. The high similarity between the ranging areas used by birds originating from the same breeding territory emphasizes the importance and consistency of the environmental conditions, such as habitat features, compared to others that would vary yearly, such as weather, prey abundance and availability, or intra- and inter-specific competition.

Loss or alteration of natural habitats due to the development of various types of artificial structures (solar parks or wind farms) or changes in the land-use pattern resulting from human activities (transformation of grassland into arable lands) and/or natural factors (wildfires) endangers the lives of birds and leads to severe habitat loss and degradation, an issue that needs urgent research and clarification. Finally, we also encourage similar studies to be conducted in other parts of the species' distribution range, as well as with similar forest-dwelling raptors.

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References

1. Martin, T.E. Life history evolution in tropical and south temperate birds: What do we really know? *J. Avian Biol.* **1996**, *27*, 263. [CrossRef]
2. Cox, W.A.; Thompson, F.R.; Cox, A.S.; Faaborg, J. Post-fledging survival in passerine birds and the value of post-fledging studies to conservation. *J. Wildl. Manag.* **2014**, *78*, 183–193. [CrossRef]
3. Naef-Daenzer, B.; Gruebler, M.U. Post-fledging survival of altricial birds: Ecological determinants and adaptation. *J. Field Ornithol.* **2016**, *87*, 227–250. [CrossRef]
4. McIntyre, C.L.; Collopy, M.W. Post fledging dependence period of migratory golden eagle (*Aquila chrysaetos*) in Denali National Park and preserve, Alaska. *Auk* **2006**, *123*, 877–884. [CrossRef]
5. Muriel, R.; Ferrer, M.; Balbontín, J.; Cabrera, L.; Calabuig, C.P. Disentangling the effect of parental care, food supply, and offspring decision on the duration of the post-fledging period. *Behav. Ecol.* **2015**, *26*, 1587–1596. [CrossRef]
6. Russell, E.M.; Yom-Tov, Y.; Geffen, E. Extended parental care and delayed dispersal: Northern, tropical and southern passerines compared. *Behav. Ecol.* **2004**, *15*, 831–838. [CrossRef]
7. Cardillo, M. The life-history basis of latitudinal diversity gradients: How do species traits vary from the poles to the equator? *J. Anim. Ecol.* **2002**, *71*, 79–87. [CrossRef]

8. Rowley, I.; Russell, E. Demography of passerines in the temperate southern hemisphere. In *Bird Population Studies*; Perrins, C.M., Lebreton, J.D., Hiron, M., Eds.; Oxford University Press: Oxford, UK, 1991; pp. 22–44.
9. Delgado, M.M.; Penteriani, V.; Revilla, E.; Nams, V.O. The effect of phenotypic traits and external cues on natal dispersal movements. *J. Anim. Ecol.* **2010**, *79*, 620–632. [[CrossRef](#)] [[PubMed](#)]
10. Gallego-García, D.; Sarasola, J.H. Ecological drivers of variation in the extent of the post-fledging dependence period in the largest group of diurnal raptors. *Ibis* **2025**, *167*, 345–356. [[CrossRef](#)]
11. Gallego-García, D.; Watts, B.D.; Sarasola, J.H. Individual and environmental effects on the extent of the post-fledging dependence period in an Endangered neotropical raptor. *Endanger. Species Res.* **2025**, *58*, 193–204. [[CrossRef](#)]
12. Russell, E.M. Avian life histories: Is extended parental care the southern secret? *Emu* **2000**, *100*, 377–399. [[CrossRef](#)]
13. Vergara, P.; Fargallo, J.A.; Martínez-Padilla, J. Reaching independence: Food supply, parent quality and offspring phenotypic characters in kestrels. *Behav. Ecol.* **2010**, *21*, 507–512. [[CrossRef](#)]
14. Newton, I. *Population Ecology of Raptors*; T. and A. D. Poyser: London, UK, 1979; p. 399.
15. Weston, E.D.; Whitfield, D.P.; Travis, J.M.; Lambin, X. The contribution of flight capability to the post-fledging dependence period of golden eagles. *J. Avian Biol.* **2018**, *49*, e01265. [[CrossRef](#)]
16. McClure, C.J.W.; Westrip, J.R.S.; Johnson, J.A.; Schulwitz, S.E.; Virani, M.Z.; Davies, R.; Symes, A.; Wheatley, H.; Thorstrom, R.; Amar, A.; et al. State of the world's raptors. Distributions, threats, and conservation recommendations. *Biol. Conser* **2018**, *227*, 390–402. [[CrossRef](#)]
17. Morrison, J.L.; Wood, P.B. Broadening our approaches to studying dispersal in raptors. *J. Raptor Res.* **2009**, *43*, 81–89. [[CrossRef](#)]
18. Serrano, D. Dispersal in raptors. In *Birds of Prey: Biology and Conservation in the XXI Century*; Sarasola, J.H., Grande, J.M., Negro, J.J., Eds.; Springer International Publishing: Cham, Switzerland, 2018; pp. 95–121.
19. Engler, M.; Krone, O. Movement patterns of the White-tailed Sea Eagle (*Haliaeetus albicilla*): Post-fledging behaviour, natal dispersal onset and the role of the natal environment. *Ibis* **2022**, *164*, 188–201. [[CrossRef](#)]
20. Del Hoyo, J.; Elliot, A.; Sargatal, J. *Handbook of the Birds of the World. Falconiformes to Galliformes*; Lynx Edicions: Barcelona, Spain, 1995; Volume 2.
21. Väli, Ü.; Bergmanis, U. Apparent survival rates of adult Lesser Spotted Eagle *Clanga pomarina* estimated by GPS-tracking, colour rings and wing-tags. *Bird. Study* **2017**, *64*, 104–107. [[CrossRef](#)]
22. Väli, Ü.; Rohtla, F. Apparent survival and population turnover in a long-lived generalist raptor: A comparison of estimation methods. *Basic Appl. Ecol.* **2025**, *82*, 28–34. [[CrossRef](#)]
23. Bergmanis, U.; Amerika, K.; Väli, Ü.; Treinys, R. Nest site selection and turnover patterns in support of conservation decisions: Case study of the lesser spotted eagle in the core area of its global population. *For. Ecol. Manag.* **2019**, *448*, 67–75. [[CrossRef](#)]
24. Demerdzhiev, D.A.; Dobrev, D.D.; Arkumarev, V.S.; Terziev, N.G.; Georgiev, G.S. Distribution, Abundance and Breeding Performance of Lesser Spotted Eagle *Clanga pomarina* Brehm, 1831 (Aves: Accipitridae) in Southeast Bulgaria. *Acta Zool. Bulg.* **2019**, *14*, 15–33.
25. Demerdzhiev, D.A.; Popgeorgiev, G.S.; Dobrev, D.D.; Arkumarev, V.S.; Terziev, N.G. Habitat Requirements of the Lesser Spotted Eagle *Clanga pomarina* Brehm, 1831 (Aves: Accipitridae) at the southern periphery of the distribution range (southeast Bulgaria). *Acta Zool. Bulg.* **2019**, *14*, 35–65.
26. Demerdzhiev, D.; Dobrev, D.; Delchev, A.; Iliev, M.; Georgiev, G.; Terziev, N.; Angelov, I.; Arkumarev, V. Temporally Determinate, but Spatially Consistent Breeding Performance of Lesser Spotted Eagle (*Clanga pomarina*) Along the Southern Periphery of Its Distribution. *Diversity* **2025**, *17*, 566. [[CrossRef](#)]
27. Mirski, P.; Cenian, Z.; Dagys, M.; Daróczy, S.; Dementavičius, D.; Maciorowski, G.; Menderski, S.; Nowak, D.; Pongrácz, Á.; Prommer, M.; et al. Sex-, landscape- and climate-dependent patterns of home-range size—A macroscale study on an avian generalist predator. *Ibis* **2021**, *163*, 641–657. [[CrossRef](#)]
28. Treinys, R.; Bergmanis, U.; Väli, Ü. Strong territoriality and weak density-dependent reproduction in Lesser Spotted Eagles *Clanga pomarina*. *Ibis* **2017**, *159*, 343–351. [[CrossRef](#)]
29. Väli, Ü. Factors limiting reproductive performance and nestling sex ratio in the Lesser Spotted Eagle *Aquila pomarina* at the northern limit of its range: The impact of weather and prey abundance. *Acta Ornithol.* **2012**, *47*, 157–168. [[CrossRef](#)]
30. Väli, Ü.; Mirski, P.; Sein, G.; Abel, U.; Tõnisalu, G.; Sellis, U. Movement patterns of an avian generalist predator indicate functional heterogeneity in agricultural landscape. *Landsc. Ecol.* **2020**, *35*, 1667–1681. [[CrossRef](#)]
31. Väli, Ü.; Treinys, R.; Lõhmus, A. Geographical variation in macrohabitat use and preferences of the Lesser Spotted Eagle *Aquila pomarina*. *Ibis* **2004**, *146*, 661–671. [[CrossRef](#)]
32. Väli, Ü.; Tuvi, J.; Sein, G. Agricultural land use shapes habitat selection, foraging and reproductive success of the Lesser Spotted Eagle *Clanga pomarina*. *J. Orn* **2017**, *158*, 841–850. [[CrossRef](#)]
33. Bosch, J.; Meyburg, B.-U. The Lesser Spotted Eagle *Aquila pomarina* in Catalonia (Spain)—Breeding attempt and migration. *Vogelwelt* **2012**, *133*, 89–97.

34. Meyburg, B.-U.; Scheller, W.; Meyburg, C. Zug und Überwinterung des Schreiadlers *Aquila pomarina*: Satellitentelemetrische Untersuchungen. *J. Ornithol.* **1995**, *136*, 401–422. [\[CrossRef\]](#)
35. Bergmanis, U.; Petrīns, A.; Cīrulis, V.; Matusiak, J.; Kuze, J. Lesser spotted eagle *Aquila pomarina* in Latvia—Current status, endangerment and perspectives. *Popul. Greifvogel Eulenarten* **2006**, *5*, 95–115.
36. Ramos, R.F.; Silva, J.P.; Carrapato, C.; Rocha, P.; Marques, P.A.M.; Palmeirim, J.M. Spatial behaviour of Spanish Imperial Eagle *Aquila adalberti* juveniles during the dependence period revealed by high-resolution GPS tracking data. *J. Ornithol.* **2019**, *160*, 463–472. [\[CrossRef\]](#)
37. Gallego, D.; McCabe, R.; Goodrich, L. Homeward bound: Annual breeding home range size and overlap in Broad-winged Hawks (*Buteo platypterus*) and the effects of sex, productivity, and ecoregion. *J. Field Ornithol.* **2023**, *94*, 9. [\[CrossRef\]](#)
38. Moss, E.H.R.; Hipkiss, T.; Ecke, F.; Dettki, H.; Sandström, P.; Bloom, P.; Kidd, J.; Thomas, S.E.; Hörnfeldt, B. Home-Range Size and Examples of Post-Nesting Movements for Adult Golden Eagles (*Aquila chrysaetos*) in Boreal Sweden. *J. Raptor Res.* **2014**, *48*, 93–105. [\[CrossRef\]](#)
39. Howard, W.E. Innate and environmental dispersal of individual vertebrates. *Am. Midl. Nat.* **1960**, *63*, 152. [\[CrossRef\]](#)
40. Murray, B.G. Dispersal in vertebrates. *Ecology* **1967**, *48*, 975–978. [\[CrossRef\]](#)
41. Ferrer, M. Juvenile dispersal behaviour and natal philopatry of a long-lived raptor, the Spanish Imperial Eagle *Aquila adalberti*. *Ibis* **1993**, *135*, 132–138. [\[CrossRef\]](#)
42. Ferrer, M. Natal dispersal in relation to nutritional condition in Spanish Imperial Eagles. *Ornis Scand.* **1992**, *23*, 104–107. [\[CrossRef\]](#)
43. Sarasola, J.H.; Gallego, D.; Martínez-Miranzo, B. Chaco eagle ecology and conservation. In *Imperiled: The Encyclopedia of Conservation*; Della Salla, D., Goldstein, M.I., Eds.; Elsevier: Amsterdam, The Netherlands, 2022; pp. 102–112.
44. Balotari-Chiebao, F.; Brommer, J.E.; Tikkanen, H.; Laaksonen, T. Habitat use by post-fledging white-tailed eagles shows avoidance of human infrastructure and agricultural areas. *Eur. J. Wildl. Res.* **2021**, *67*, 39. [\[CrossRef\]](#)
45. Demerdzhiev, D.; Stoychev, S.; Grozdanov, A.; Tonchev, B.; Stoyanov, E.; Mitev, I. Lesser Spotted Eagle *Aquila pomarina*. In *Atlas of Breeding Birds in Bulgaria*; Iankov, P., Ed.; Conservation series, Book 10; BSPB: Sofia, Bulgaria, 2007; pp. 158–159.
46. Anderson, D.; Arkumarev, V.; Bildstein, K.; Botha, A.; Bowden, C.G.R.; Davies, M.; Duriez, O.; Forbes, N.A.; Godino, A.; Green, R.E.; et al. A practical guide to methods for attaching research devices to vultures and condors. *Vulture News* **2020**, *78*, 1–72.
47. Bodey, T.W.; Cleasby, I.R.; Bell, F.; Parr, N.; Schultz, A.; Votier, S.C.; Bearhop, S. A phylogenetically controlled meta-analysis of biologging device effects on birds: Deleterious effects and a call for more standardized reporting of study data. *Methods Ecol. Evol.* **2018**, *9*, 946–955. [\[CrossRef\]](#)
48. Kenward, R.E. *A Manual for Wildlife Radio Tagging*; Academic Press: London, UK, 2001.
49. Douglas, D.C.; Weinzierl, R.; Davidson, S.C.; Kays, R.; Wikelski, M.; Bohrer, G. Moderating Argos location errors in animal tracking data. *Methods Ecol. Evol.* **2012**, *3*, 999–1007. [\[CrossRef\]](#)
50. Walter, W.D.; Fischer, J.W.; Baruch-Mordo, S.; Ver Cauteren, K.C. What is the proper method to delineate home range of an animal using today's advanced GPS telemetry systems: The initial step. In *Modern Telemetry*; Krejcar, O., Ed.; InTech: Rijeka, Croatia, 2011.
51. Ferrer, M. Regulation of the period of postfledging dependence in the Spanish Imperial Eagle *Aquila adalberti*. *Ibis* **1992**, *134*, 128–133. [\[CrossRef\]](#)
52. Fridolson, A.K.; Ellegren, H. A Simple and Universal Method for Molecular Sexing of Nonratite Birds. *J. Avian Biol.* **1999**, *30*, 116–121. [\[CrossRef\]](#)
53. Green, A.J. Mass/Length Residuals: Measures of body condition or generators of spurious results? *Ecology* **2001**, *82*, 1473–1483. [\[CrossRef\]](#)
54. Morandini, V.; García-Macía, J.; Ferrer, M. Regulation of the Dependence Period in Booted Eagles: Effects of Nutritional Condition. *Birds* **2026**, *7*, 12. [\[CrossRef\]](#)
55. Kranstauber, B.; Safi, K.; Scharf, A. move2: R package for processing movement data. *Methods Ecol. Evol.* **2024**, *15*, 1561–1567. [\[CrossRef\]](#)
56. R Core Team. *R: A Language and Environment for Statistical Computing*; R Foundation for Statistical Computing: Vienna, Austria, 2021. Available online: <https://www.R-project.org/> (accessed on 1 December 2025).
57. Beyer, H.L. *Geospatial Modelling Environment, version 0.7.3.0*; Spatial Ecology: Cornwall, UK, 2012. Available online: <http://www.spatalecolgy.com/gme> (accessed on 17 June 2026).
58. Green, R. *Sampling Design and Statistical Methods for Environmental Biologists*; John Wiley and Sons: New York, NY, USA, 1979.
59. Johnson, C.J.; Nielsen, S.E.; Merrill, E.H.; McDonald, T.L.; Boyce, M.S. Resource Selection Functions Based on Use-Availability Data: Theoretical Motivation and Evaluation Methods. *J. Wildl. Manag.* **2006**, *70*, 347–357. [\[CrossRef\]](#)
60. ESRI. *ArcGIS Desktop*, version 10.4.1; Environmental Systems Research Institute: Redlands, CA, USA, 2016.
61. StatSoft Inc. *STATISTICA (Data Analysis Software System)*, version 12; StatSoft Inc.: Tulsa, OK, USA, 2013. Available online: <https://www.statsoft.de/en/home/> (accessed on 24 October 2025).
62. Mirski, P. Effect of selected environmental factors on hunting methods and hunting success in the Lesser Spotted Eagle *Aquila pomarina* in North-Eastern Poland. *Russ. J. Ecol.* **2010**, *41*, 197–200. [\[CrossRef\]](#)

63. Mirski, P. Selection of nesting and foraging habitat by the Lesser Spotted Eagle *Aquila pomarina* (Brehm) in the Knyszynska forest (NE Poland). *Pol. J. Ecol.* **2009**, *57*, 581–587.
64. Scheller, W.; Bergmanis, U.; Meyburg, B.U.; Furkert, B.; Knack, A.; Röper, S. Raum-Zeit-Verhalten des Schreiadlers (*Aquila pomarina*). *Acta Ornithoecol.* **2001**, *4*, 75–236.
65. Soutullo, A.; Urios, V.; Ferrer, M.; Peñarrubia, S.G. Post-fledging behaviour in Golden Eagles *Aquila chrysaetos*: Onset of juvenile dispersal and progressive distancing from the nest. *Ibis* **2006**, *148*, 307–312. [[CrossRef](#)]
66. Karyakin, I.V.; Nikolenko, E.G.; Shnayder, E.P.; Zinevich, L.S.; Pulikova, G.I.; Bartoszek, K.; Horváth, M.; Juhász, T.; Aghababian, K.; Andreenkova, N.G. Results of the GPS/GSM-Tracking of Juvenile Steppe Eagles from Russia and Kazakhstan. *Raptors Conserv.* **2019**, *39*, 71–227. [[CrossRef](#)]
67. Muñoz-López, R.; Limiñana, R.; Cortés, G.D.; Urios, V. Movements of harpy eagles *Harpia harpyja* during their first two years after hatching. *Bird Study* **2012**, *59*, 509–514. [[CrossRef](#)]
68. Balbontín, J.; Ferrer, M. Factors affecting the length of the post-fledging period in the Bonelli's Eagle *Hieraetus fasciatus*. *Ardea* **2005**, *93*, 189–198.
69. Arroyo, E.B.; de Cornulier, T.; Bretagnolle, V. Parental investment and parent–offspring conflicts during the postfledging period in Montagu's harriers. *Anim. Behav.* **2002**, *63*, 235–244. [[CrossRef](#)]
70. Bennett, P.M.; Owens, I.P.F. *Evolutionary Ecology of Birds*; Oxford University Press: Oxford, UK, 2002.
71. Verhulst, S.; Nilsson, J.A. The timing of birds' breeding seasons: A review of experiments that manipulated timing of breeding. *Philos. Trans. R. Soc. London. Ser. B Biol. Sci.* **2008**, *363*, 399–410. [[CrossRef](#)] [[PubMed](#)]
72. Kenward, R.E.; Marcström, V.; Karlbom, M. Post-nestling behaviour in Goshawks, *Accipiter gentilis*: I. The causes of dispersal. *Anim. Behav.* **1993**, *46*, 365–370. [[CrossRef](#)]
73. Sandgren, C.; Hipkiss, T.; Dettki, H.; Ecke, F.; Hörnfeldt, B. Habitat use and ranging behaviour of juvenile Golden Eagles *Aquila chrysaetos* within natal home ranges in boreal Sweden. *Bird Study* **2014**, *61*, 9–16. [[CrossRef](#)]
74. Spiegel, O.; Leu, S.T.; Bull, C.M.; Sih, A. What's your move? Movement as a link between personality and spatial dynamics in animal populations. *Ecol. Lett.* **2017**, *20*, 3–18. [[CrossRef](#)] [[PubMed](#)]
75. Delgado, M.; Penteriani, V.; Nams, V.O. How Fledglings Explore Surroundings from Fledging to Dispersal. A Case Study with Eagle Owls *Bubo bubo*. *Ardea* **2009**, *97*, 7–15. [[CrossRef](#)]
76. Ferrer, M. Wind-influenced juvenile dispersal of Spanish Imperial Eagles. *Ornis Scand.* **1993**, *24*, 330. [[CrossRef](#)]
77. Wiens, J.D.; Noon, B.R.; Reynolds, R.T. Post-fledging survival of Northern Goshawks: The importance of prey abundance, weather, and dispersal. *Ecol. Appl.* **2006**, *16*, 406–418. [[CrossRef](#)] [[PubMed](#)]
78. Oppel, S.; Dobrev, V.; Arkumarev, V.; Saravia, V.; Bounas, A.; Kret, E.; Veleviski, M.; Stoychev, S.; Nikolov, S.C. High juvenile mortality during migration in a declining population of a long-distance migratory raptor. *Ibis* **2015**, *157*, 545–557. [[CrossRef](#)]
79. Demerdzhiev, D.; Dobrev, D.; Popgeorgiev, G.; Stoychev, S. Landscape alteration affects the demography of an endangered avian predator by reducing the habitat quality. *Avian Res.* **2022**, *13*, 100030. [[CrossRef](#)]
80. Väli, Ü.; Dombrovski, V.; Treinys, R.; Bergmanis, U.; Daróczy, S.J.; Dravecky, M.; Ivanovski, V.; Lontkowski, J.; Maciorowski, G.; Meyburg, B.U.; et al. Widespread hybridization between the Greater Spotted Eagle *Aquila clanga* and the Lesser Spotted Eagle *Aquila pomarina* (Aves: Accipitriformes) in Europe. *Biol. J. Linn. Soc.* **2010**, *100*, 725–736. [[CrossRef](#)]

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