Research Article

ACTA ZOOLOGICA BULGARICA
Acta zool. bulg., Suppl. 14, 2019: 15-33

Distribution, Abundance and Breeding Performance of Lesser Spotted Eagle *Clanga pomarina* Brehm, 1831 (Aves: Accipitridae) in Southeast Bulgaria

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Abstract: The Lesser Spotted Eagle *Clanga pomarina* Brehm, 1831 is a long-lived, territorial raptor, distributed mainly in Eastern and Central Europe. Southeast Bulgaria is a part of the southern limit of the species distribution range. During the period 2014-2018, 76 active nests were found and 173 occupied territories were mapped in Southeast Bulgaria. About 60% of the breeding population of the Lesser Spotted Eagle in this region was situated in Special Protected Areas but only 2.3% was located within reserves. The highest breeding density was recorded in the Dervent Heights – western foothills of the Strandzha Mnt., while the lowest breeding density values were established in the central part of the Strandzha Mnt. The measured nearest neighbour distance ranged from 0.68 km to 4.5 km, at a mean value of 2.43 km ± 1.16. The average productivity was 0.5, average breeding success 0.67, and average breeding frequency 0.74. Higher values of productivity were reported for the Strandzha Mnt. and the Harmanliyska River and lower productivity was recorded in the Byala Reka catchment area with no significant differences between the regions. In general, the population of the species in Southeast Bulgaria was stable, with a possible slight increase in the Sakar Mnt. and the Dervent Heights and a decline only in the Strandzha Mnt. The Lesser Spotted Eagle population breeding in the country had been significantly underestimated. The increasing anthropogenic pressure, mainly in terms of dramatic alteration of the species foraging and breeding habitats, and the lack of efficient legal protection, pose a serious risk to the future of the Lesser Spotted Eagle in this part of the species distribution range.

Key words: breeding population, dynamics, distribution, Bulgaria, Lesser Spotted Eagle

Introduction

Lesser Spotted Eagle *Clanga pomarina* Brehm, 1831 (Accipitridae) is a long-lived, medium-sized migratory bird of prey distributed mainly in Eastern and Central Europe as a breeder and wintering in Central and Southern Africa. Along with the northern territories of Greece and Turkey, Southeast Bulgaria is a part of the southern limit of the species distribution range. This forest-nesting raptor, foraging in open habitats, feeds mainly on voles and other small mammals but can switch to alternative prey such as amphibians and small birds (Cramp & Simmons 1980, Treinys & Dementavičius 2004, Dravecky et al. 2008). Although the population size is considered to be stable, in recent decades the numbers of mature individuals have been declining in many parts of the species range (BirdLife International 2018), especially in the core of the population (Treinys et al. 2007, Bergmanis et al. 2015). Lesser Spotted Eagle is characterized by low productivity, usually producing only one fledgling per successful brood. The

reproduction rate fluctuates significantly between years and many pairs of the local populations may not raise any fledglings in some years (Meyburg et al. 2001, Bergmanis et al. 2001, 2006, Väli 2003, 2012, Lõhmus & Väli 2004).

In Bulgaria, the species inhabits mainly deciduous and mixed forests, moist alluvial and, to a lesser extent, coniferous forests, avoiding high mountains (Iankov 2007). The species is found at an altitude ranging from the sea level to approximately 1500 m a.s.l., mostly between 100–1000 m a.s.l. At national level, the species has been classified as vulnerable (VU) and listed in Bulgaria's Red Data Book (Golemanski et al. 2011). The breeding population of the Lesser Spotted Eagle in Bulgaria was estimated at 350–400 pairs (Iankov 2007) and 460–520 pairs (Birds Directive 2009/147/EC [Art. 12.1]). However, the species is unevenly distributed in the territory of the country, with more than 70% of the population concentrated in Southeast and East Bulgaria, and poorly represented in the western part of the country (Iankov 2007). In 1950–1990, the data on the distribution of the Lesser Spotted Eagle in the southeast of Bulgaria were scarce, including only individual records (Baumgart 1971, 1996, Donchev 1974, Shubert 1982, Profirov & Nyagolov 1984, Nankinov 1985, Iankov 1991, Kuzmanov 1996). A survey of the avifauna in the Strandzha Mnt. revealed that the species was abundant in that region (Milchev 1991, 1994). The intensified bird studies since 1990 have established a significant breeding density of the Lesser Spotted Eagle in the southeast of Bulgaria (Iankov et al. 1996, Stoychev et al. 2004, 2008, Iankov 2007).

We studied the distribution, breeding density and breeding performance of the Lesser Spotted Eagle – a philopatric, territorial raptor, in southeast Bulgaria as a region, which is a part of the southern limit of the species distribution range. Based on the results of this study as well as the historical data, we tried to assess the population trend of Lesser Spotted Eagle in this well-distributed species with an abundant local population. We also tried to analyze which factors were predicting breeding density and breeding performance at different regional scales.

Materials and Methods

Study area

Southeast Bulgaria comprises the eastern slopes of the Balkan Mountains, the Tundzha Hilly Plain, the Eastern Rhodope Mountains, the neighbouring Sakar Mnt. with the adjacent Dervent Heights, and the Strandzha Mnt. to the east, up to the Black Sea (Fig. 1). The southern limit of the study area lies along Bulgaria-Greece and Bulgaria-Turkey state borders (41.308355°, 25.633622°; 41.978829°, 28.025584°). To the north, the study area (42.856350°, 26.352422°; 42.753143°, 27.391336°) extends across the Tundzha Hilly Plain reaching the southern and the eastern parts of the Balkan Mountains. To the west, the study area (41.614202°, 25.340057°; 42.276339°, 25.928069°) is determined by the valleys of Varbitsa, Perperek, Harmanliyska and Suzliyka rivers, bordering the Black Sea to the east. The Eastern Rhodopes are characterized by low mountain relief, with deeply cut valleys of the Arda River and its larger tributaries – the rivers of Varbitsa, Krumovitsa and Perperek (Galabov 1982). The climate of the region is continental-Mediterranean, with autumn-winter peak rainfall rates and dry summer periods. The average temperature in January is above 0°C, and that in July – some 23–24°C. Forests cover 1/3 of the Eastern Rhodope area, consisting mainly of Sessile Oak (*Quercus petraea* Matt.), Hungarian Oak (*Quercus frainetto* Ten.) and Downy Oak (*Quercus pubescens* Willd.), including undergrowth of Oriental Hornbeam (*Carpinus orientalis* Mill.) and Manna Ash (*Fraxinus ornus* L.). The high parts of the mountain also harbour two beech species – European Beech (*Fagus sylvatica* L.) and Oriental Beech (*Fagus orientalis* Lipsky). Deforested areas are occupied by significant formations of Prickly Juniper (*Juniperus oxycedrus* L.) and Jerusalem Thorn (*Paliurus spina-christi* Mill.). Sakar is a low mountain situated between the valleys of Maritsa and Tundzha Rivers and characterized by a slightly dissected ridge and step-shaped slopes, furrowed by a dense river network (Galabov 1982). The climate is continental-Mediterranean with a well-marked autumn-winter maximum and summer minimum of precipitation. The annual rainfall is between 550 and 800 mm, and thus determines the area as particularly dry in summer. The woodlands in the Sakar Mnt. are of limited distribution, occupying mostly areas situated along the main ridgeline. Mixed deciduous forests of Hungarian Oak, Downy Oak and Oriental Hornbeam are common in the area, while single-species forests, mainly formed of Hungarian Oak or Sessile Oak, are rare (Galabov 1982). Significant parts of the mountain are agricultural areas, mainly sown with wheat and sunflower, or pastures and natural grasslands. The secondary vegetation in the deforested areas is represented by shrubs of Jerusalem Thorn, mixed with Wild Jasmine (*Jasminum fruticans* L.) and xerothermic grass formations dominated by Yellow Bluestem (*Dichantieta ischaemi*), Bulbous Bluegrass (*Poaeta bulbosae*, *Poaeta*

concinnae), Scented Grass (*Chrysopogoneta grylli*) and Ephemera (*Ephemereta*) (Bondev 1991). The Dervent Heights are heights situated in Southeast Bulgaria (about 40%) and European Turkey (about 60%). They are located between the Srem Gorge of the Tundzha River to the west and the valleys of Popovska and Chengerlidere rivers to the east, separating them from the Strandzha Mnt. Morphologically, the Dervent Heights are connected to the Strandzha Mnt., being separated only by a saddle where the Popovska River takes its source. To the north and south, the hills extend to the Elhovo Plain and the Edirne Lowland in Turkey, respectively. The terrain is mostly hilly and semi-mountainous. The ridge of the heights is flat and slightly hilled, elevated at an altitude of 300-450 m, with rising rounded peaks, the highest being Gyurgenbair (555.2 m). They are primarily composed of limestone and granite. The climate is transitional-Mediterranean, with a winter peak of precipitation and warm dry summer seasons. The snow cover is more durable in the higher areas, although it does not last long there either. Shallow leached cinnamon soils are predominant in the Dervent Heights. Significant areas of the ridge and the slopes are overgrown with mixed broad-leaved oak forests, most often composed of Turkey Oak (*Quercus cerris* Lam.) and Hungarian Oak, in places mixed with Oriental Hornbeam and Mediterranean elements (Bondev 1991). Less often, mainly in the southernmost parts, mixed oak forests of *Quercus polycarpa* Schur., a little known oak species of the Sessile Oak aggregate (*Quercus petraea* s. lat.), and Hungarian Oak predominate. Open areas overgrown with shrubs of Jerusalem Thorn, mixed with Jasmine, and combined with xerothermic grass communities comprising Mediterranean elements, e.g. Love-in-a-Mist (*Nigella damascena* L.), are scattered among the forest stands (Bondev 1991). The hills are separated by a number of small river valleys of typical riparian vegetation. Arable lands and pastures are situated in the lower areas and in the plains around the hills. Strandzha is a low mountain range, characterized by rolling hills framed by deep river valleys. The climate of the Strandzha Mnt. is of a transitional-Mediterranean type with a strong Black Sea influence on its north-eastern slopes. The autumn-winter peak of precipitation is particularly well-marked. The average annual temperature is around 11–12°C, as the temperature in January is about 1–2° C, and that in July – about 20–21°C. The relative humidity is higher in the eastern part of the region influenced by the Black Sea. Annual precipitation rates range between 550 and 1000 mm, being mostly rainfall in winter (Galabov 1982). The soil types prevailing in the Strandzha Mnt. include cinnamon forest, cinnamon brown and Zheltozem podzolic soils. The vegetation cover in the area is composed mainly of deciduous tree species. The best-represented formations of the forest vegetation are those consisting of Hungarian Oak, Turkey Oak, Downy Oak, European Hornbeam (*Carpinus betulus* L.) and Oriental Hornbeam. The area harbours specific forests of Oriental Beech and Sessile Oak. The undergrowth of the Oriental Beech and Hungarian Oak forests supports evergreen Pontic vegetation consisting of the Common Rhododendron (*Rhododendron ponticum* L.), Common Laurel (*Prunus laurocerasus* L.), Tree Heath (*Erica arborea* L.), Common Heather (*Calluna vulgaris* L.), which gives them a specific character and uniqueness (Bondev 1991). The Tundzha Hilly Plain comprises the basin of the Tudnzha middle reaches with poorly defined borders to the west, south and east (Galabov 1982). It is best delineated to the north, framed by the slopes of the Sliven Mnt. and the Karnobat-Aytos Mnt. The area includes the elongated and isolated Svety Iliysky and Manastirsky Heights, the depression lying between them as well as the open wide and interconnected fields of Yambol, Elhovo, Straldzha, Karnobat, Sliven and Kermen to the north. They are situated along the middle course of the Tundzha River and its left tributary – the Mochuritsa River. The relief is marked by ridges, hills and valleys, with clearly distinct morphographic units – elevations, fields and stretches of lowland lying between the hills. The maximum altitude of the region is 600 m; yet, most of the areas are situated at 150 to 300 m a.s.l. The climate of the region is transitional-continental. Humidity is insufficient and in summer the area gets particularly dry. Winter precipitation is predominantly rain, with snow cover only rarely formed, lasting for several hours to 1–2 days. Shallow leached cinnamon forest soils are typical of Svety Iliysky and Manastirsky Heights, while flatter areas are characterized by alluvial-meadow and meadow-marsh soils, vertisols and meadow vertisols. The dark leached cinnamon soils are also found in this region. The natural vegetation is represented by forests composed mainly of Downy Oak and Virgil Oak (*Quercus virgiliana* Ten.) but also mixed coenoses of Hungarian Oak, Turkey Oak and Oriental Hornbeam. These ecosystems occupy individual patches amongst arable lands. There are limited areas of woodlands and shrubs of Oriental Hornbeam and Jerusalem Thorn with xerothermal grass formations (Bondev 1991). The eastern parts of the Balkan Mountains, subject to this study, include the Sliven Mnt., the Kotlenska Mnt., the Stidovska Mnt. and

the hills of Grebenets, Razboina and Terziysky Bair. The relief varies from low mountain to hilly, dominated by lands of 200 to 1000 m altitude. The region is characterized by transitional continental climate, as the low altitude and the influence of the Black Sea result in increased precipitation rates in winter and spring and a decrease in the summer rainfall rates. The soil cover consists mainly of shallow brown forest and light-grey forest, leached and podzolic cinnamon forest soils. The vegetation is composed mostly of primary deciduous forests, mainly of European Beech mixed in places with European Hornbeam. Forests of more limited distribution include those of Sessile Oak, mixed in places with European Hornbeam and Oriental Hornbeam as well as mixed oak forests of Turkey Oak and Hungarian Oak. The rest of the territory is occupied by open areas used as pastures and agricultural land. Pastures are dominated by three types of grass communities: mesophilic, xeromesophilic and xerothermic grasslands (Bondev 1991).

Conservation significance of the study area

The study area covers the territory of eighteen Special Protected Areas (SPAs), three of which are part of the 5 most important areas for the population of the Lesser Spotted Eagle in the country (Kostadinova & Gramatikov 2007). The scope of the study includes the territories of two nature parks, Sinite Kamani and Strandzha, eleven strict nature reserves and five managed reserves.

Field data collection

We collected data on the breeding distribution of the Lesser Spotted Eagle in the study area in the period 2014-2018. The study area was divided into 2 x 2 km grids. The distance of 2 km corresponded to the size of the home range of the species (Sheller et al. 2001, Väli et al. 2017). We visited each grid at least once in the period April–July, with observations carried out in favourable weather conditions from observation points of good visibility, lasting 1–2 hours (Bibby et al. 1999, Andersen 2007). In general, there was a single observation point in each grid, except for those marked by a highly rugged terrain, where two to three observation points were identified (Gilbert et al. 1999). The equipment used for the observations included binoculars (10 x 42) and a spotting scope (20 x 60). Each sighting of a bird of prey was recorded using the SmartBirds Pro mobile app. (Popgeorgiev et al. 2015) – an electronic diary for quick and easy entry of sightings of birds, amphibians, reptiles and mammals in Bulgaria. Through the built-in GPS device, the app indicates the position on a Google map (normal, satellite and hybrid). The platform allows individual entries of observations directly on the relevant map. The app structure enables the researchers to gather essential field data. We entered the number and the species of all recorded birds and, whenever possible, age, height and direction of flight, behaviour for each individual. In case of a newly found nest, we recorded its characteristics and geographic coordinates, taking photographs of the nest tree. The grids where Lesser Spotted Eagles demonstrating breeding behaviour (mating display, defence of the breeding territory, provision of food, frequent visits to hidden places) were recorded; however, grids where no nest were found at this stage, were subsequently visited in November–March, after the leaf-shedding period, to locate and record the nests. These nests were subsequently visited during the following breeding period to record their possible occupation by eagles. We started monitoring eleven territories in 2014 but, with the increasing intensity of the monitoring efforts, the number of all annually surveyed territories reached 47 in 2016, 46 in 2017 and 44 in 2018. A total of 175 territories were monitored during the study period. In Bulgaria, the Lesser Spotted Eagles return from migration in the last ten days of March and early April. Upon their arrival in the breeding grounds, the eagles are particularly recognizable, since for most of the day they perform demonstrations including wavy and synchronous mating flights, display flights over the nest as well as border flights, often accompanied by noisy screams. The first visit to the monitored territories was carried out in the second half of April to establish if the territory was occupied. A territory was considered occupied if we observed territory defence, nest building, copulation or other reproductive activity by a pair (Demerdzhiev et al. 2015). In May, all monitored occupied territories were inspected to record active nests and breeding pairs. We considered pairs that laid at least one egg and started incubating as breeding pairs (Katzner et al. 2006, Demerdzhiev et al. 2015). Nests were considered active if they were "decorated" with green sprays of foliage, contained incubating birds, nestlings, eggs or remains of eggshells (Väli et al. 2017). However, sometimes eagles bring greenery to more than one nest. In these cases, alternative nests were always searched for near the "decorated" ones. All pairs recorded to be incubating were visited again in June to establish the presence of chicks. The last visit was carried out in the second half of July in order to identify the number of fledglings. In Bulgaria, the juvenile Lesser Spotted Eagles fledge

in the second half of July, with only few staying until the beginning of August.

Data analysis

We estimated three parameters in order to assess the reproductive success. We calculated (i) productivity, as the number of fledglings divided by the number of all occupied territories that we monitored, (ii) breeding frequency, as the number of nests where at least one egg was laid divided by the number of all occupied territories that we monitored, and (iii) breeding success as the number of fledglings divided by the number of all breeding pairs.

With regard to the breeding density, we measured the nearest neighbour distance (NND, a surrogate variable for breeding density) between known neighbouring active nests and evaluated the active nests and the occupied territories per 100 km^2 in the areas where they were distributed.

In the results presentation and discussion, the western foothills of Strandzha are presented as a single region including the Dervent Heights, separated from the main range of the Strandzha Mnt., due to the fact that the landscape is particularly different from the central and the eastern parts of the mountain (Galabov 1982). Although there is no distinct geographical boundary separating the two parts of the mountain, the differences in habitats also determine the differences in the Lesser Spotted Eagle distribution, breeding density and breeding performance. The western foothills of Strandzha and the adjacent Dervent Heights are considered as a single region due to the similarity of the habitats they harbour, determining the Lesser Spotted Eagle's biology and ecology within these territories.

The data was analyzed for normal distribution through the Shapiro-Wilk test (Shapiro et al. 1968). Results with $p < 0.05$ [$\alpha = 5$ %] were considered significant. Multiple regression with stepwise standard selection was used for analyzing breeding parameters. Statistica for Windows, Release 10 (Statsoft Inc. 2011) was used for the statistical analysis of the data.

Results

Breeding distribution and density

For the study period, we found 76 active nests of the Lesser Spotted Eagle and mapped 173 occupied territories in Southeast Bulgaria (Fig. 1).

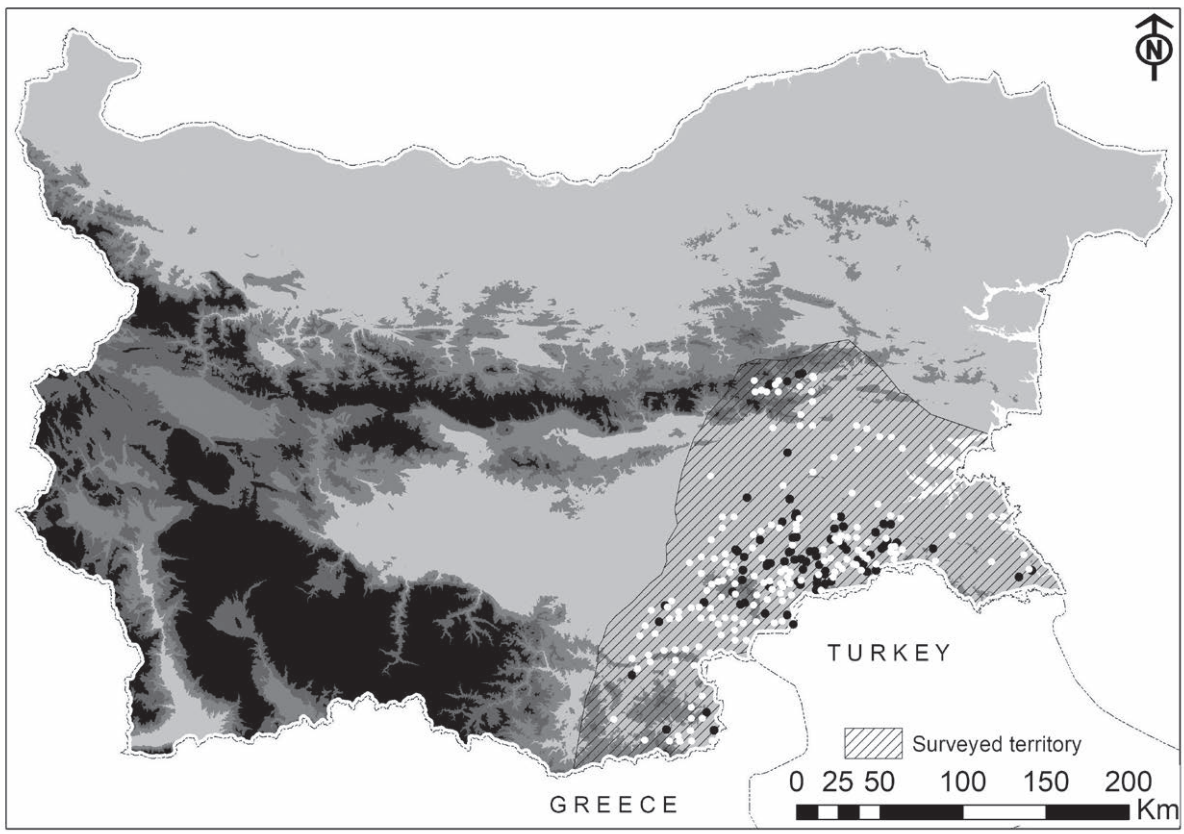

Fig. 1. Breeding distribution of Lesser Spotted Eagle in Southeast Bulgaria (black dots indicate active nests; white dots indicate occupied territories)

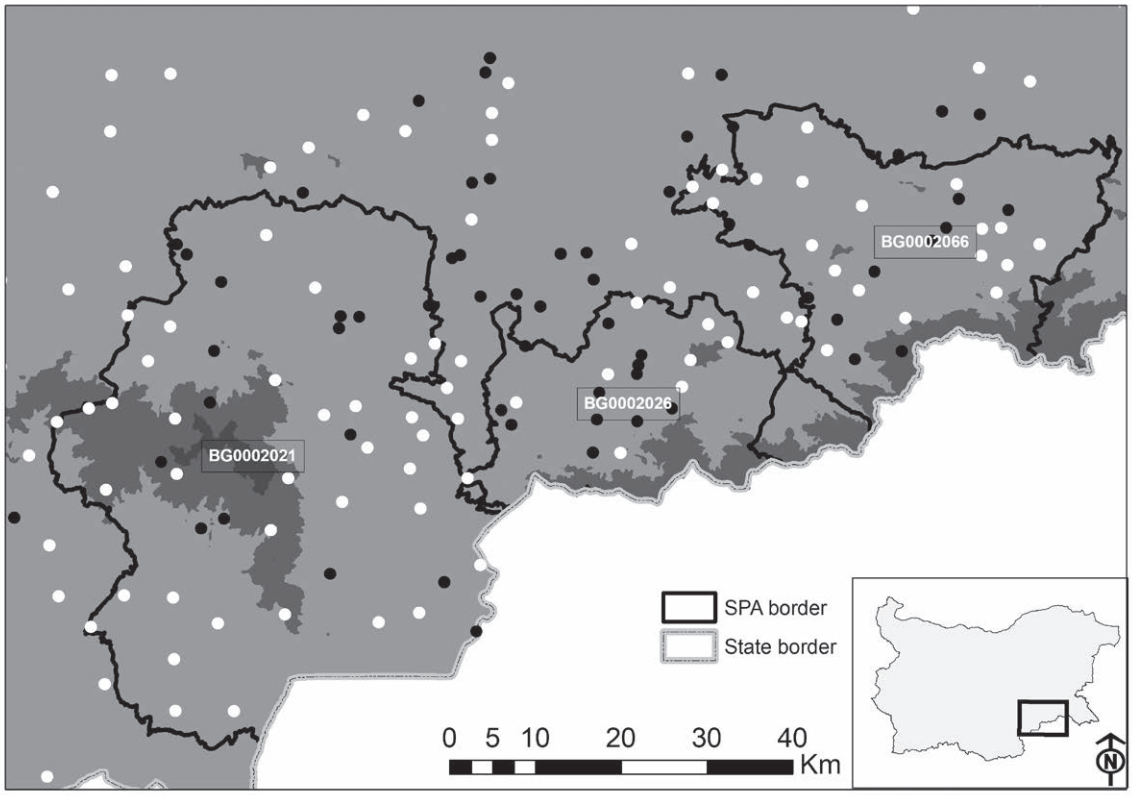

Fig. 2. Breeding distribution of Lesser Spotted Eagle in the Sakar Mnt. (SPA BG0002021), Dervent Heights (SPA BG0002026), and the western foothills of the Strandzha Mnt. (SPA BG0002066) (black dots indicate active nests; white dots indicate occupied territories)

The breeding pairs were distributed mainly in the Dervent Heights and western foothills of the Strandzha Mnt., harbouring 36 active nests and 42 occupied territories of the species. (Fig. 2). In the adjacent region of the Sakar Mnt., we found 16 active nests and observed other 45 occupied territories (Fig. 2). In the central and the eastern parts of the Strandzha Mnt., we could only find 3 active nests and 11 occupied territories, distributed mainly in the Veleka River valley and along the lower reaches of the Ropotamo River (Fig. 3).

In Kotlenska Mnt., the species was represented by five active nests and twelve occupied territories, situated mostly within Kotlenska Planina SPA. (Fig. 4). Along the lower reaches of the Tundzha River, south of the town of Yambol, we found nine active nests and, in addition, identified other five occupied territories. In the Manastirsky Heights and the Svety Iliyski Heights (situated north of the Sakar Mnt.), the breeding density of the species was low, with only two active nests and five more occupied territories recorded during the study. South of the Maritsa River, along the lower reaches of the Harmanliyska River, we found two active nests and identified nine territories occupied by eagles. In the Eastern Rhodopes, higher breeding numbers of Lesser Spotted Eagle were recorded in the Gorata Hills (eleven occupied territories) and the Byala Reka catchment area, where we found three active nests and other twelve occupied territories during the breeding season (Fig. 5). In the river valleys of Krumovitsa and Arda, we found individual pairs.

About 60% of the breeding population of the Lesser Spotted Eagle in Southeast Bulgaria was situated within SPAs but only 2.3% was found in reserves.

The highest breeding density of the species was recorded in the Dervent Heights/western foothills of the Strandzha Mnt. (6.3 pairs/100 km^2). High breeding density was also recorded along the lower reaches of the Tundzha River (5.6 pairs/100 km^2) as well as in the Gorata Hills in the Eastern Rhodopes (5.5 pairs/100 km^2). In the Kotlenska Mnt., the species was represented by a relatively good breeding density (4.6 pairs/100 km^2). In the Sakar Mnt., the Lesser Spotted Eagle was recorded to be breeding at lower density, 3.5 pairs/100 km^2. Low density of breeding pairs was also reported for the region of the Byala Reka catchment area – 2.8 pairs/100 km^2. The lowest breeding density of the species was the one we recorded in the central part of the Strandzha Mnt., with only 1.7 pairs/100 km^2. The measured nearest

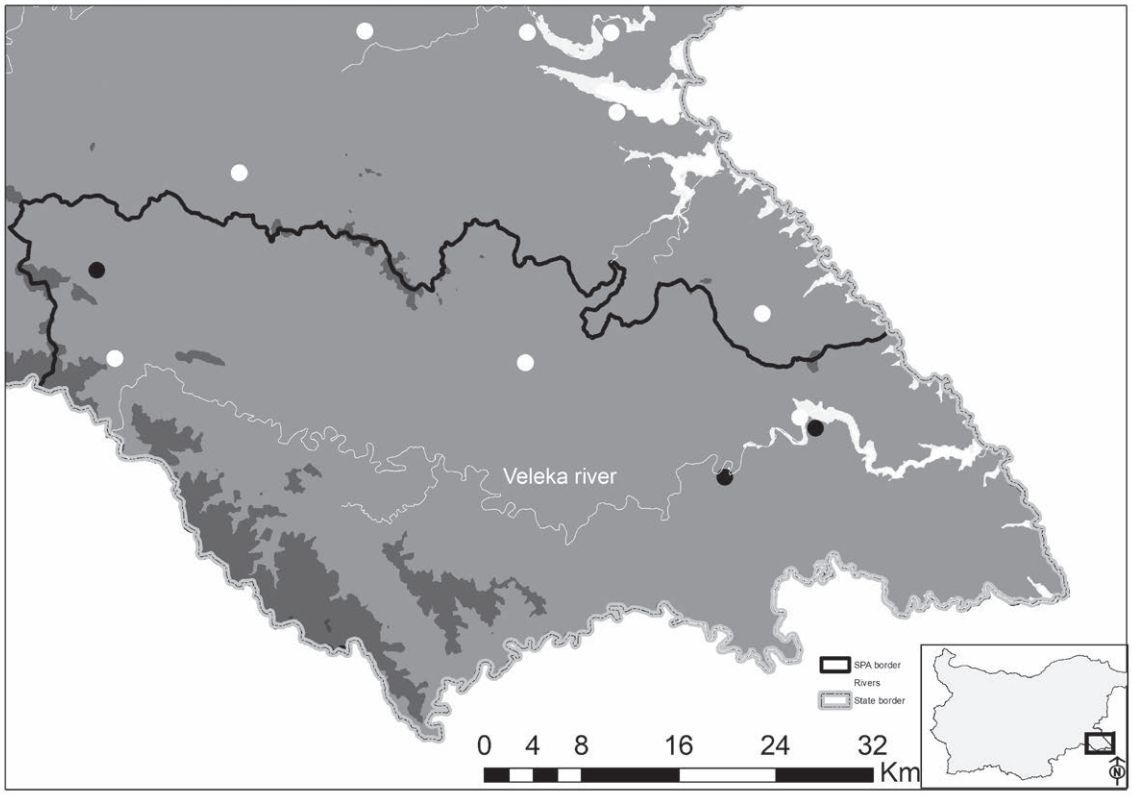

Fig.3. Breeding distribution of Lesser Spotted Eagle in the central and the eastern parts of the Strandzha Mnt. (black dots indicate active nests; white dots indicate occupied territories)

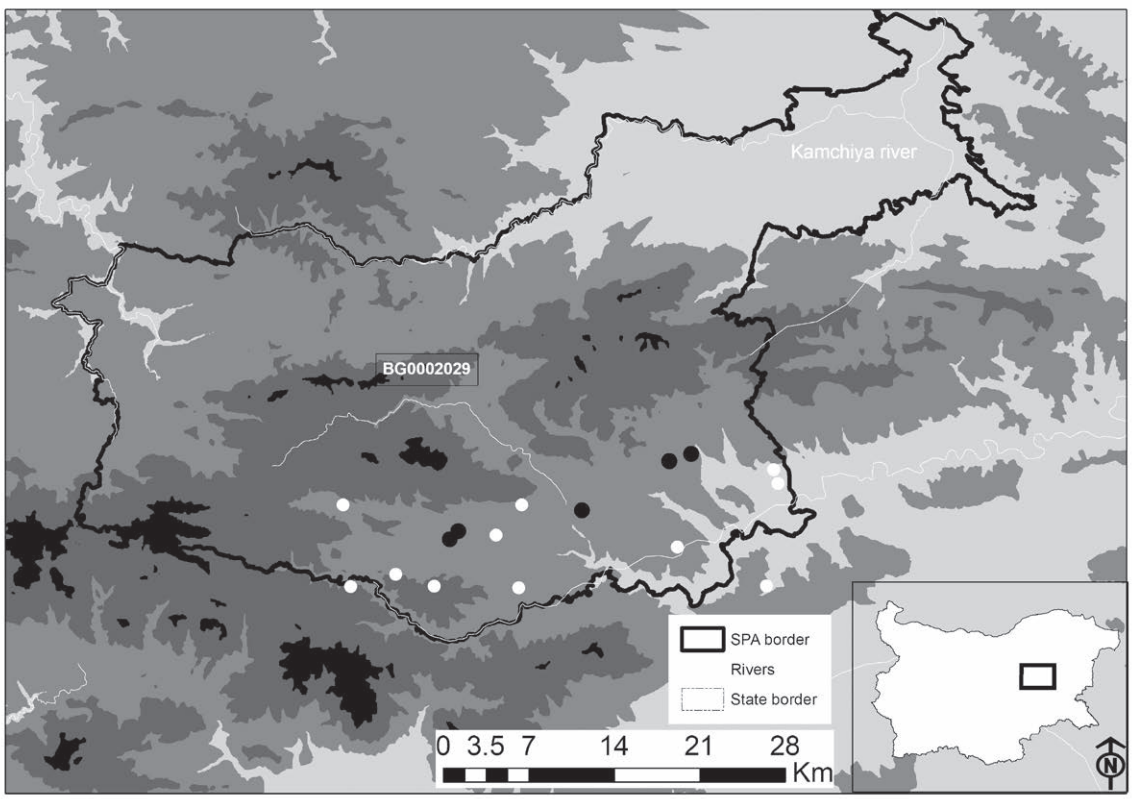

Fig. 4. Breeding distribution of Lesser Spotted Eagle in the Kotlenska Mnt. (black dots indicate active nests; white dots indicate occupied territories)

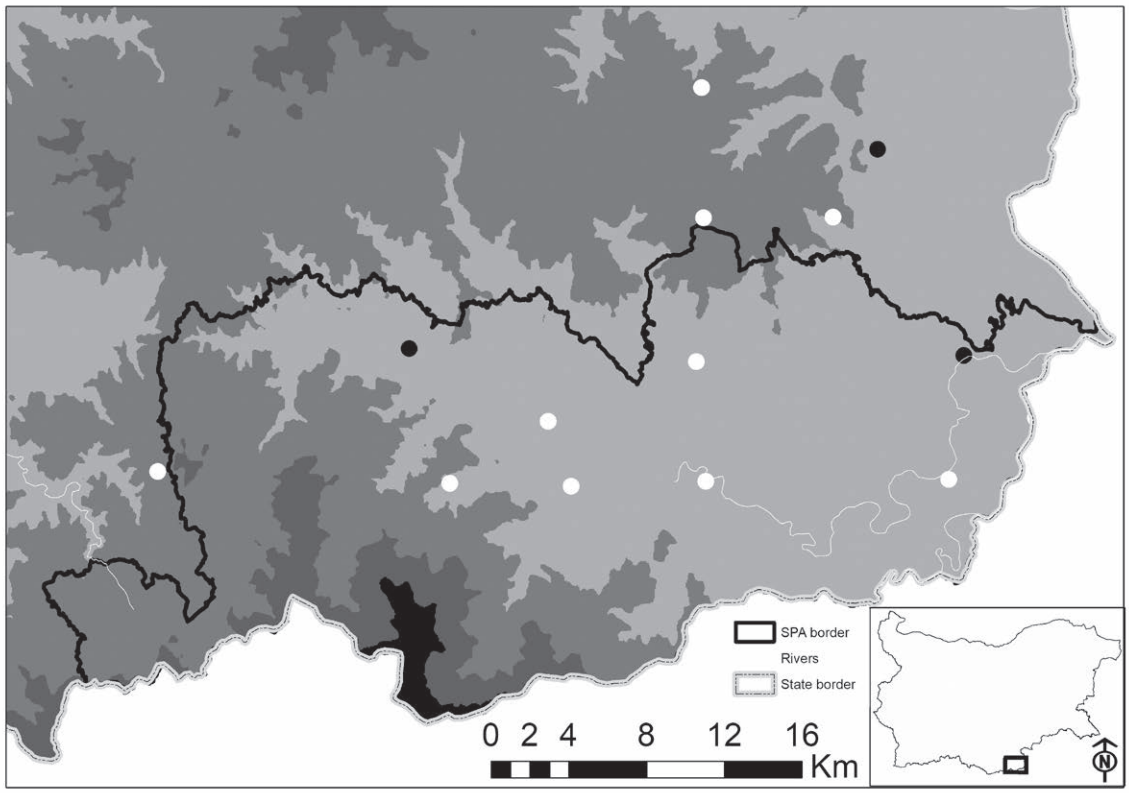

Fig. 5. Breeding distribution of Lesser Spotted Eagle in Byala Reka SPA (black dots indicate active nests; white dots indicate occupied territories)

neighbour distance (NND) (n=28) ranged from 0.68 km to 4.5 km, at a mean value of 2.43 km ± 1.16. This variable did not differ significantly between the two well-studied neighbouring regions: the Sakar Mnt. (n=5) 2.58 km ± 1.59, and the Dervent Heights/ western foothills of the Strandzha Mnt. (n=18) 2.74 km ± 0.93.

Breeding performance and breeding failure

The number of monitored territories varied from eleven in 2014 to 47 in 2016, a total of 175 for the study period (Table 1). No statistical differences were recorded for the tested breeding parameters over the years. The productivity ranged from 0.44 to 0.55, i.e. 0.5 on average. Lower breeding success was established in 2014, with a value of 0.55; high values were recorded in 2016 – 0.78. The average breeding success, including all breeding cases, was 0.67. The average breeding frequency for all cases was 0.74 (Table 1).

Higher values of productivity were recorded for the Strandzha Mnt. and the Harmanliyska River, while lower productivity was established in the Byala Reka catchment area (Table 2). No significant differences were established between the regions with regard to this variable ($F = 7.28$, $p = 0.07$, $df = 1.3$). In the different regions, the breeding success ranged from 0.5 in the Byala Reka catchment area. to 0.83 in the Strandzha Mnt. The breeding pairs nesting in the rest of the regions also had a high breeding success (Table 2) but no statistical differences were observed between the regions ($F = 2.14$, $p = 0.24$, $df = 1.3$). However, a lower value of breeding success (0.65) was recorded in the Dervent Heights/ western foothills of the Strandzha Mnt. where high breeding density was established. High values with statistical differences ($F = 10.06$, $p = 0.05$, $df = 1.3$) of the breeding frequency were recorded in different regions over the years (Table 2). The value of this parameter was high in the Strandzha Mnt. and the Tundzha River valley, and lowest in the Sakar Mnt.

We monitored twenty-nine cases of breeding failure (Fig. 6). In most of these cases, we had no possibility of detecting the reason for the breeding failure. In three cases of eggs abandoned during incubation the reason was disturbance caused by human activities taking place in the vicinity of the nest. In two of the cases, the disturbance was a result of logging near the nests while in the third – the birds had been disturbed by truffle collectors. In three other cases, the breeding failure was due to nest collapse caused by a storm. In two of these cases the storm had resulted in clutch loss, while in the third one it caused the death of the chick at the

Table 1. Parameters of the breeding performance of the Lesser Spotted Eagle population in the period 2014-2018 (*in 2014 breeding of pairs was recorded in all visited territories)

Parameter	2014*	2015	2016	2017	2018	TOTAL	p	F	df
N of visited territories	11	27	47	46	44	175			
Productivity	0.55	0.44	0.5	0.5	0.5	0.5	0.79	0.08	1.3
Breeding success	0.55	0.62	0.78	0.63	0.71	0.67	0.3	1.59	1.3
Breeding frequency	1	0.72	0.64	0.8	0.7	0.74	0.3	1.59	1.3

Table 2. Parameters of the breeding performance of the Lesser Spotted Eagle population in different studied regions in Southeast Bulgaria (statistical significance is indicated with "*").The regions in the Kotlenska Mnt. and the Harmanliyska River were not included in the analysis due to the insufficient data sample size.

Region	N of territories	Productivity	Breeding success	Breeding frequency*
Byala Reka river valley	9	0.33	0.5	0.66
Sakar Mnt.	22	0.41	0.69	0.59
Dervent heights/Western Strandzha Mnt.	64	0.5	0.65	0.77
Strandzha Mnt.	7	0.71	0.83	0.86
Tundzha river valley	7	0.57	0.67	0.86
Kotlenska Mnt.	4	0.5	0.67	0.75
Harmanliyska river	4	0.75	0.75	1

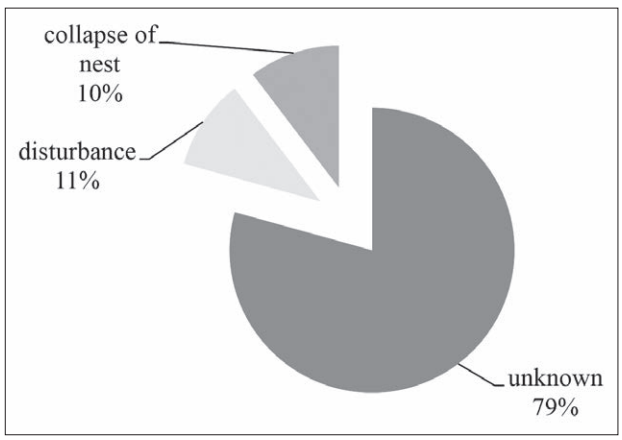

Fig. 6. Different causes of breeding failure of Lesser Spotted Eagle in Southeast Bulgaria

age of about 20 days. We recorded the loss of two more aeries but the cause of chick mortality was unknown. Beyond the breeding season, we recorded two cases of cut nest trees.

Discussion

Until 2014, there was no systematic research on the breeding distribution and the breeding performance of Lesser Spotted Eagle in Bulgaria. Intensified bird studies after the millennium showed that the species was unevenly distributed, concentrating mainly in the southern and the eastern part of the country (Iankov 2007). The population estimate of Lesser Spotted Eagle in the Sakar Mnt. and the adjacent Dervent Heights and the western foothills of the Strandzha Mnt. was twice as low as in previous assessments and surveys (Demerdzhiev 2007, Iankov 2007, Stoychev et al. 2007, 2008), mainly due to the lack of a systematic study of this forest-nesting species. However, until the collapse of the communist regime in Bulgaria the access of people to the border areas including the Sakar Mnt., the adjacent Dervent Heights and the western foothills of the Strandzha Mnt. was strictly restricted. At that time, ornithologists could only make rare short visits to this part of the country, not being able to carry out real research activities. Therefore, until the early 1990s the Lesser Spotted Eagle was described as rare and poorly represented in the southeast of Bulgaria (Nankinov 1985, Kuzmanov 1996, Baumgart 1996). The intensified surveys of the avifauna in the Strandzha Mnt. revealed that the species was well-distributed in that region (Milchev 1991, 1994, Iankov et al. 1996). The data from the Eastern Rhodopes, dating back to the mid-20th century, show that the Lesser Spotted Eagle was distributed mainly along the Byala Reka River valley and in Gorata Hills situated in the northern parts of the mountain (Profirov & Nyagolov 1984, Iankov 1991, Iankov et al. 2007a). Due to the lack of suitable habitats along the valleys of the rivers Arda and Krumovitsa, the species was only represented by individual breeding

pairs or was not found at all in this area of the Eastern Rhodopes (Iankov et al. 2007 b, c, d). For the study period (2014–2018), we had no case of territories abandoned by monitored pairs. We considered that the population of the Lesser Spotted Eagle in Southeast Bulgaria was generally stable. A slight increase could be possible in the Sakar Mnt. and the Dervent Heights, both due to the insufficient study of the species in previous surveys and the appearance of new pairs. For the past 20 years, the population probably decreased only in the Strandzha Mnt. In the early 1990s, the Lesser Spotted Eagle was well-represented in the territory of the mountain (Milchev 1991, 1994, Iankov et al. 1996), where 20 breeding pairs were confirmed (Milchev 1994). In addition, there were 19 territories of possible and 18 of probable breeding (Milchev 1994). Ten years later, the population of the species in the region of Strandzha SPA, comprising a smaller area, was estimated at 16–24 breeding pairs (Kovachev & Yordanov 2007). During our study in the Strandzha Mnt., we established fourteen territories occupied by the species, eight of which situated within Strandzha SPA and in the nearby surrounding areas. It should be noted that the abundance of the Lesser Spotted Eagle established by Milchev (1994) concerned a territory comprising both the main range of the Strandzha Mnt. and the foothills stretching west- and northwards, as well as the river valleys formed by the middle reaches of the rivers Sredetska and Popovska. However, comparing the species distribution map published by Milchev (1994) to the present study, it is obvious that we did not confirm the distribution of Lesser Spotted Eagle in at least four localities in the southern and the central parts of the Strandzha Mnt. On the other hand, no change was recorded in the distribution and abundance of the breeding pairs in the western foothills of the Strandzha Mnt., comprising mainly Zapadna Strandzha SPA, as well as the region stretching northwards, including the middle reaches of the Sredetska River. Abandonment of territories was established in the area of Strandzha SPA, where twenty years ago there were twice as many breeding pairs as currently recorded. The collapse of the communist regime and the subsequent transition from a command economy to a free market also entailed significant abandonment and depopulation of huge areas across the country. This was particularly visible in the region of Strandzha SPA, where most of the settlements got severely depopulated over the past thirty years. Such depopulation and abandonment of villages and the related decline in extensive stockbreeding resulted in intensified succession in open grasslands. Overgrowth of tree and shrub vegetation or increased sward height results in disappearance or decreased numbers of rodents – important prey species, hence a shrinking food resource for the species. The large-scale desertification of agricultural land recorded since 1990 has had a similar effect. Although some of the rodent species did not disappear, they became prey difficult to access. Significant areas in the Strandzha Mnt., which were pastures or arable lands in the early 1990s, are currently covered with a naturally afforested wood (authors, unpublished data). The overgrowth of forest pastures due to the reduced number of extensively bred livestock was the reason for the disappearance of the Lesser Spotted Eagle in some foothill areas of Hungary (Pongràcz & Szitta 2015). The decline of the Lesser Spotted Eagle population in some parts of Latvia was associated with the overgrowth of meadows following their abandonment (Bergmanis et al. 2006). Perhaps the abandonment of territories in the Strandzha Mnt. began already in the late 1990s and continued for two decades. The current distribution of the species in the main range of the Strandzha Mnt. is mainly in the western and the northern foothills as well as in the river valleys of Veleka and Ropotamo, still harbouring open habitats as proper hunting grounds.

Estimating the population size is especially problematic in birds with gradual differences in density, such as the Lesser Spotted Eagle (Väli 2015). Considering the data gathered during the present study and the availability of suitable habitats, we estimated the population of the Lesser Spotted Eagle in Southeast Bulgaria at 270-300 breeding pairs. However, a more precise assessment of the size of the breeding population in the country as well as the population trends requires targeted, systematic research in other regions of the species distribution. Considering this fact, we speculated that the population of the species at national level was underestimated and probably the number of pairs breeding in the country exceeded 600. The annual monitoring of territories of a sufficiently representative sample of different distribution areas of the species is also of particular importance for studying the population trends over time (Väli 2015). Long-term monitoring of the population trend, as well as identification of the actual size of the population is particularly important since the country is part of the southern limit of the species distribution range, far from the core population distributed in Latvia, Belarus, Lithuania and Poland (Bergmanis et al. 2015), parts of which suffered from population decline (Treinys et al. 2007, Bergmanis et al. 2015, Dravecký et al. 2015a). Slightly more than half of the Lesser Spotted

Eagle pairs breeding in Southeast Bulgaria were found in SPAs, while the percentage in reserves was insignificant. Following Bulgaria's accession to the European Union and the launch of the subsidies in agriculture related to the implementation of the Common Agricultural Policy (CAP), significant changes occurred in the land-use patterns applied in vast territories. These changes had particularly strong impact on the Sakar Mnt., the adjacent Dervent Heights, and the western foothills of the Strandzha Mnt., where huge grasslands, managed as pastures for more than twenty years, were intensively cultivated and converted into arable lands (Authors' unpublished data). Moreover, since 2016 there has been a trend towards the devastation of grassland habitats with shrub vegetation, related to the provision of direct payments per land unit within Natura 2000 sites. Thus, in order to avoid penalties and sanctions, farmers prefer to remove the entire shrub vegetation from the areas they declare for direct subsidies within NATURA 2000 sites instead of leaving the required 25% of the shrub cover. In the Sakar Mnt. and the Dervent Heights, extensive grassland habitats with shrubs are being changed, with shrub vegetation being either burnt down or destroyed by shredders and bulldozers. This leads to direct extermination of a number of slowly moving animals such as Northern White-breasted Hedgehog (*Erinaceus roumanicus* Barrett-Hamilton, 1900), tortoises (*Testudo graeca* Linnaeus, 1758, *Testudo hermani* Gmelin, 1789) and lots of reptiles, all being part of the diet of the Lesser Spotted Eagle. On the other hand, the change in the landscape features also affects the habitats of the prey species, turning them into areas of unfavourable conditions, thus forcing the animals to avoid these territories. It seems that grasslands subject to intensive anthropogenic management are poor habitats for many prey species (Reidsma et al. 2006) and have no positive effect on the productivity of Lesser Spotted Eagle (Väli et al. 2017). The reduced food recourses in the territory could be a reason for abandonment. Such process was reported for the Eastern Imperial Eagle (*Aquila heliaca* Savigny, 1809) breeding in the same areas, where changes occurring in habitats had affected the breeding success but had a strong negative influence on the occupancy rate of the territories (Authors' unpublished data). The Lesser Spotted Eagle prefers foraging in grasslands and avoids arable lands (Treinys 2004, Väli et al. 2004, 2017, Mirski 2009, Zub et al. 2010). For the past ten years, a severe decline of various types of grasslands, between 20% and 25%, was reported for the Sakar Mnt. and the western foothills of the Strandzha Mnt. (see above), the regions harbouring a numerous population of the species. Hence, fast-changing and deteriorating habitats of Lesser Spotted Eagle in regions of highest abundance and density in the country could, in general, threaten the population in this part of the species range. Significant population decline due to changes in the land-use practices was reported for Hungary, where, for a couple of decades, the area of grasslands decreased by 41% (Pongràcz & Szitta 2015). In some regions of Lithuania, the dramatic decrease in the number of Lesser Spotted Eagle breeding pairs was associated with the conversion of meadows into cultivated fields and the intensive forest harvesting (Treinys et al. 2007). As a result of the intensification of agriculture and forestry after the millennium, a numerous population of the species in Latvia dropped down (Bergmanis et al. 2015). Destruction and fragmentation of suitable habitats were the main factors that led to a population decline in Germany, at the westernmost border of the species distribution range (Scheller et al. 2001, Meyburg et al. 2008, Langgemach & Böhner 2011). In Estonia, the decline of meadows and the increased area of maize and oilseed rape crops negatively correlated with the reproductive success of the Lesser Spotted Eagle (Väli et al. 2017). The conservation of Lesser Spotted Eagle within SPAs in Slovakia proved to be inefficient, with a population decline by 26% recorded for the past fifteen years due to the loss of breeding habitats (Dravecký et al. 2015b). Almost all SPAs in Southeast Bulgaria, where Lesser Spotted Eagle is currently common and abundant, lack management plans, although the orders for their designation were issued a couple of years ago. Practically, the protection of this species as well as other species of conservation significance is totally inefficient due to the lack of clear regulations, stipulating which of the anthropogenic activities implemented in Natura 2000 sites have a direct and (or) indirect negative impact on habitats. Thus, the insufficient protection of foraging and breeding habitats of the species on one hand, and the increasing varied anthropogenic pressure in these areas on the other, cannot guarantee the stability of the population in these sites. The loss of foraging and breeding habitats is known to be a crucial factor for the population decline of Lesser Spotted Eagle (Meyburg et al. 2001). The fact that the population supported by reserves is of negligible size is particularly alarming, so we assume that the Lesser Spotted Eagle has not been sufficiently protected in this dynamic changing situation. We believe that there is an urgent need to adopt management plans for those Natura 2000 sites where the species is distributed at

high density and abundance, in order to guarantee the sustainable management of localities and habitats that are of key significance for the conservation of the Lesser Spotted Eagle breeding population in the country. Designation of territories under protection around the nests had a significant positive effect on the breeding success in Slovakia, where pairs whose nests were located within such protected territories successfully raised more chicks than those, whose nests were not surrounded by such zones (Dravecký et al. 2015a). In Germany, Poland, Lithuania, Estonia and Hungary, the availability of sites of protection around the nests of the Lesser Spotted Eagle has been legally regulated. Setting up such areas where activities for restoration and maintenance of the species breeding and foraging habitats are allowed, would undoubtedly contribute to the prevention of an anticipated future decline of a population subject to strong pressure as well as to efficient conservation of this forest-nesting species vulnerable to habitat changes.

In Southeast Bulgaria an average population density of 4.18 pairs/100 km^2 was determined. However, the south-eastern part of the country harbours the main part of the population of the species, being particularly abundant in this area. In the other parts of the country where the species is found, the breeding density is expected to be significantly lower, corresponding in general to the low density typical of populations situated on the edge of the species distribution range. A rather low breeding density (av. 1.03 pairs/100 km^2) was reported for the population of Lesser Spotted Eagle in Estonia, situated on the northern limit of the species range (Väli 2015). Low density of av. 2.71 pairs/100 km^2 was reported for Slovakia, part of the western edge of the species distribution range (Dravecký et al. 2015a). The high breeding density recorded in the Dervent Heights and the western foothills of the Strandzha Mnt. was similar to the one established in some regions of Slovakia – 6.34 pairs/100 km^2, 7.05 pairs/100 km^2 (Dravecký et al. 2015a,b). However, these values were far from the high density established in some areas of Latvia, where values between 26.6 pairs/100 km^2 and 33 pairs/100 km^2 were reported over the years (Bergmanis et al. 2015), Lithuania – 28.6 pairs/100 km^2 (Drobelis 1996), Belarus – 20 pairs/100 km^2 (Dombrovski & Ivanovski 2005) and Poland – 22 pairs/100 km^2 (Rodziewicz 1996), all being part of the species core population. Although local densities of the species vary, the areas close to the geometric centre of the species distribution range have the highest average density, since better conditions for the species are expected to occur there (Newton 1998a). High breeding density was also established in the possibly isolated population of the species in the Northern Caucasus, Russia, 18 pairs/100 km^2 (Väli et al. 2009). The low density recorded in the Strandzha Mnt. corresponded to that found in the Tatra Mountains – 1.1 pairs/100 km^2 (Dravecký et al. 2015a) and northeast Germany – 1.4 pairs/100 km^2 (Scheller et al. 2001). According to the density classes determined by Bergmanis et al. (2015), the population in the Dervent Heights/western foothills of the Strandzha Mnt., the Tundzha River valley, Gorata Hills and the Kotlenska Mnt. should be assigned to the moderate class, the one in the Sakar Mnt., Harmanliyska River, and Byala Reka River valley to the medium class, and that in the Strandzha Mnt. should be categorized under the low-density class. The variations in the regional breeding density of raptors are affected by changes in the environmental conditions such as altitude, vegetation type, land use, but two main factors are of significant importance: food availability and presence of nesting sites (Newton 1979, 2003). Food availability is mostly related to the presence of suitable habitats, where prey species are abundant. The optimal foraging habitat for the Lesser Spotted Eagles includes natural grasslands, pastures, meadows and lands with semi-natural vegetation (Väli et al. 2004). The perfect biotopic habitat for this species in Bulgaria consists of a mosaic of fragments of grassland and arable fields scattered amongst forest patches and small ponds or streams (Demerdzhiev et al. 2019). This landscape is typical of the Dervent Heights and the western foothills of the Strandzha Mnt. where the population of the highest density was recorded. The habitats in the Sakar Mnt. are similar, but the small water bodies are fewer and areas with dry vegetation, orchards and transitional woodland-shrub vegetation cover significant parts, influencing the habitat quality and the breeding density. The Lesser Spotted Eagle avoids large forested areas and the great forest cover is associated with low density of this species (Väli et al. 2004, Treinys et al. 2017). The low density in the Byala Reka River valley and the Strandzha Mnt. corresponded to the amount of forest areas and shrubs reducing open landscapes where eagles tend to feed.

Our mean value of NND was lower than the one reported for Estonia (3.35 km), situated at the northern limit of the species distribution range, and higher than for Lithuania (2.03 km) and Latvia (1.7 km), which are close to the core area of the species distribution (Treinys et al. 2017). The nearest distance between breeding neighbour pairs in Bulgaria was also bigger than that (0.19 km) established in

the northern populations of the species. Eagles differed significantly in conspecific proximity across geographical areas (Treinys et al. 2017). However, our results indicated that the breeding density of the population of Lesser Spotted Eagle close to the southern edge of its distribution was higher than in the northern limit. The conservation implications are that the Lesser Spotted Eagle density is a robust and simple criterion for conservation programmes and necessary conservation actions in habitat restoration areas in a landscape and even regional context (Treinys et al. 2017).

The reproduction success of the Lesser Spotted Eagle fluctuates significantly between years (Bergmanis et al. 2001, Väli 2003, Väli et al. 2017) and between geographical areas (Treinys et al. 2017), strongly correlates with food abundance (Lõhmus & Väli 2004, Treinys & Dementavičius 2004, Väli 2012) and is influenced by weather conditions (Bergmanis et al. 2001, Väli 2012), land use (Väli et al. 2017) or human disturbance (Langgemach & Böhner 2011). However, in different parts of the species distribution range different factors predetermine reproduction in different years with stochastic interaction. The average productivity (fledgling/occupied territories) was similar to that recorded in Estonia for different periods (0.44 for 2002-2010; 0.56 for 1992-2009) (Väli 2012, Treinys et al. 2017), Latvia (0.49) (Bergmanis et al. 2015) and Slovakia and Mecklenburg-Pomerania (0.51) (Scheller et al. 2001, Dravecký et al. 2015a) but lower than in Lithuania and the German state of Brandenburg (0.65) (Böhner & Langgemach 2004, Treinys et al. 2017) and Poland (0.69) (Mirski et al. 2013). Extremely high productivity was reported for Georgia (0.98; Abuladze 1996), Transcaucasia (0.94; Abuladze 2001) and North Caucasus (0.71; Väli et al. 2009). We had no broods of two fledglings of the monitored forty-three cases of successful breeding. Fledging of two eaglets was reported for Estonia (1.9% of broods; Väli 2012), Latvia (1.6%; Bergmanis et al. 2015), Poland (2.5%; Rodziewicz 1996), Lithuania (3%; Treinys & Dementavičius 2004), Belarus (3.4%; Ivanovsky 1996) and Slovakia (1.8%–3.6% for different periods; Maderič et al. 2008, Dravecký et al. 2015a). The breeding success (fledglings/breeding pairs) fluctuated over the years but the average value was lower than reported for Slovakia (0.69; Dravecký et al. 2015a), Latvia (0.74; Bergmanis et al. 2015) and Estonia (0.78; Väli 2012). This corresponded to the 'abundant-center' hypothesis (Sagarin et al. 2006) that the population situated at the limit of the distribution range would have the poorest rates of reproduction, because better conditions for the species were expected to occur in the centre of the range rather than in the periphery (Newton 1998a). The low breeding success in 2014 could be explained by the bad weather conditions during the breeding season characterized by excessive and continuous rainfall and natural disasters. Storms in that particular year caused the collapse of nests of about 30% of the monitored pairs, thus resulting in the loss of clutches and broods. In contrast, the high reproduction value recorded in 2016 was probably due to the food abundance and the suitable weather conditions reported for that breeding year. This year was also marked by good breeding success of the population of Eastern Imperial Eagle distributed in the same area and sharing similar food resources (unpublished data). Many European raptors seem to suffer from precipitation (Newton 1998a) but such effect was not found for Lesser Spotted Eagles breeding in Estonia (Väli 2012). In most places in Southeast Bulgaria the climate is characterized by dry and hot summer, so the high precipitation rate could be expected to have a positive effect on the reproduction success of the birds of prey. Such effect of weather on the pre-breeding period is usually related to abundance or availability of food (Newton 1998a). For Lesser Spotted Eagle this could be of indirect importance because the occurrence of water ponds increases the reproduction and survival of amphibians (Berven 1990, Semlitch et al. 1996) - an important food resource for eagles, especially in the beginning of reproduction (Väli 2012). In dry climate, such as in southeast Bulgaria, the insufficient rainfall could be the limiting factor for amphibians. On the other hand, excessive and continuous rainfall combined with storms results in destruction of nests and failed breeding of some pairs, reflecting on the breeding success in general. Heavy rain during the incubation period had a significant negative effect on the clutches of Long-legged Buzzard (*Buteo rufinus* Cretzschmar, 1829) studied in an area harbouring high densities (Demerdzhiev in preparation). Some of the prey species are not active in rainy or stormy weather and would thus become unavailable to Lesser Spotted Eagles. With many raptor species it seems that rain during the chick-rearing phase prevents adults from foraging, resulting in food shortage for the offspring (Penteriani 1997, Sergio 2003, Bionda & Brambilla 2012). However, Väli (2012) established that the breeding success of Lesser Spotted Eagles was strongly associated with rainfall in the preceding season, spring temperature and vole abundance. The annual average breeding frequency was slightly higher

than that reported for Latvia (0.66, Bergmanis et al. 2015) and Estonia (0.69, Väli 2012) and similar to that in Slovakia (0.75, Dravecký et al. 2015a) and Mecklenburg–Pomerania (0.78) (Scheller et al. 2001). According to Väli (2012), the breeding frequency correlated strongly with the temperature in April and the amount of rain in the preceding breeding season. Warm weather during the pre-laying time is an important factor for egg-laying, which affects successful foraging on one hand and the achieving of physical condition and a hormonal level necessary for breeding on the other (Newton 1979, Wingfield 1984). Bad weather conditions in the pre-breeding phase may influence the behaviour of birds and they may choose to not breed or even to abandon the territory (Elkins 2004). These mechanisms drive the breeding frequency of Lesser Spotted Eagle, working together and mediating the availability and abundance of prey (Väli 2012). The south-eastern part of the country is in the continental-Mediterranean area, which is characterized by milder winter and warm spring combined with increased rainfall in spring. Consequently, these more favourable conditions in the pre-breeding period of Lesser Spotted Eagle also explain the higher breeding frequency than that of the eagles breeding in hemiboreal Estonia, where fewer eagles are expected to start breeding and lay eggs. A significant proportion (*c*. 10-90%) of the pairs in the local northern populations may not raise any fledglings in a given year (Meyburg et al. 2001, Lõhmus & Väli 2004, Treinys & Dementavičius 2004, Bergmanis et al. 2006). Synchronous climate-related factors, such as temperature and rainfall, synchronize prey species (Liebhold et al. 2004) and this spatial synchrony phenomenon explains the spatial difference in the breeding performance of the Lesser Spotted Eagle over large geographical areas or at regional level. From the conservation point of view, spatial synchrony in breeding performance requires necessary conservation actions in landscape or even regional context and populations at the limit of the distribution range should not be considered as sink populations and should not be excluded from the conservation priorities (Treinys et al. 2017).

The higher value of the breeding performance of the eagles nesting in the Strandzha Mnt., mostly support the density dependent fecundity hypothesis (Newton 1991, 1998b, Ferrer & Donazar 1996, Sergio & Newton 2003, Krüger 2004, Ferrer et al. 2006, 2008, Krüger et al. 2012). In the Strandzha Mnt., the breeding pairs are spaced more or less irregularly, occupying suitable sites, probably having larger territories and avoiding the rest of the areas, which do not offer good habitat conditions. In this scenario, pairs located far from each other, occupying only territories of good quality, avoid the effect of conspecific proximity and reproduce successfully. However, the lack of a good sample of monitored territories could have a bias effect since it is expected that some of the unknown pairs may have failed breeding attempts and thus reduced the breeding parameters of the locally distributed population. Thus, the insufficient sample could possibly explain the high values of the breeding parameters, recorded for the pairs in the regions of the Harmanliyska River, the Kotlenska Mnt. and the Tundzha River valley. On the other hand, pairs breeding in the Byala Reka River region, nesting in low breeding density, have low productivity and low breeding success. The Lesser Spotted Eagles tend to forage in different types of grasslands, avoiding arable lands and large forests (Zub et al. 2010, Treinys et al. 2017, Väli et al. 2017). The habitats in the Byala Reka River region consist of grasslands, large forest patches and arable lands of different sizes. In this region, the Lesser Spotted Eagle occupies suboptimal habitats, including a lower percentage of grasslands and a bigger share of forested areas. Pairs occupying optimal habitats breed successfully and raise offspring, while breeders situated in suboptimal habitats in poor food years produce fewer chicks or do not breed (Ferrer & Donazar 1996). The breeding nucleus in the Dervent Heights/western foothills of the Strandzha Mnt. is characterized by densely breeding pairs, nesting close to each other, where conspecific antagonistic interaction increases driven by the limited availability of food resources and suitable nesting sites, which results in a lower breeding success. In addition, large areas of grasslands in the Dervent Heights/western foothills of the Strandzha Mnt. were ploughed in past decade (see above). Perhaps some of the optimal or suboptimal habitats of Lesser Spotted Eagle in this region were negatively affected by this agriculture practice, reducing the breeding output of eagles. Consequently, in habitat heterogeneity distribution, habitat destruction could affect the population viability in different ways, depending on which parts of the habitat were affected (Newton 1991, 1998, Ferrer & Donazar 1996). Intensive agriculture has an indirect effect on the population of Lesser Spotted Eagle, deteriorating the habitat quality by decreasing the share of the most abundant prey and that of substitute prey species, which has a negative impact on the main productivity (Treinys & Dementavičius 2004). However, this explanation conditioned by density dependent fecundity driven by habitat

heterogeneity requires further support. Searching for links between wildlife-habitat management and population shapes as an important field for future research. It is not only an issue of single-species management but also has implications for using an indicator or a focal species in such management (Angelstam et al. 2004). In different geographical regions, as well as at different stages of the breeding season, the Lesser Spotted Eagle exploits different prey species (mainly voles) that fluctuate in abundance, and can switch to alternative prey (other mammals, amphibians, small birds) in years of scarce main prey species (Cramp & Simmons 1980, Abuladze 1996, Haraszthy et al. 1996, Vlachos & Papageorgiou 1996, Zawadzka 1999, Treinys & Dementavičius 2004, Lõhmus & Väli 2004, Dravecký et al. 2008, Zub et al. 2010, Väli 2012). The high value of the breeding success recorded in the Sakar Mnt. adjacent to the Dervent Heights/western foothills of the Strandzha Mnt. was due to the good quality of the nesting and foraging habitats, lower breeding density and the types of the main food resources. The breeding pairs of Lesser Spotted Eagle in the Sakar Mnt. seemed to be regularly spaced with similar distances between nearest pairs. Then, in this part of the species distribution range, the population is probably regulated through territoriality (Treinys et al. 2017). However, the diet composition of the pairs nesting in the Sakar Mnt. differed from the food resources used by the eagles in the Dervent Heights/western foothills of the Strandzha Mnt. In the Sakar Mnt., the eagles mainly fed on Northern White-breasted Hedgehog accounting for 32.4% of taken prey, followed by 24.3% voles (*Microtus* sp.) and 16.2% reptiles (unpublished data). In contrast, the diet composition of the Lesser Spotted Eagles in the Dervent Heights/western foothills of the Strandzha Mnt. was dominated by *Microtus* voles (57%) with insignificant shares of hedgehogs (11.4%) and reptiles (7.6%). Various factors affect the breeding success and the productivity of raptors (Newton 1979, Mearns & Newton 1988, Margalida & Garcia 1999, Sanchez-Zapata et al. 2000, Krüger 2004, Catry et al. 2012), as in case of no "human disturbance", the type and availability of food resources are of utmost significance (Newton 1979, Watson 1997). The eagles nesting in the Sakar Mnt. captured larger prey than those feeding on small rodents in the Dervent Heights/western foothills of the Strandzha Mnt. Large prey is more profitable, although energetically costly, but provides more biomass for the offspring. This corresponds to the findings related to the Eastern Imperial Eagle, a top predator, where pairs feeding mostly on larger prey raise more chicks than those capturing small-size prey (Horváth et al. 2010, Demerdzhiev 2011). On the other hand, rodent-eating eagles are more dependent on the cycles of rodent abundance (Newton 1979) and their productivity fluctuate more often over the years parallel to voles' abundance (Lõhmus & Väli 2004, Treinys & Dementavičius 2004, Väli 2012). According to the alternative prey hypothesis (Angelstam et al. 1984), eagles breeding in optimal habitats switch to alternative prey when the population of a dominant prey species decreases or disappears, and continue nesting, successfully producing offspring, while birds in suboptimal habitats, with no sufficiently abundant alternative food source, suffer from nutritional shortage and abandon the territories or do not breed. A great percentage of the Lesser Spotted Eagles nesting in the Sakar Mnt. occupy their territories but do not make any breeding attempts. The interspecific competition could possibly play an important role with regard to this phenomenon. A bit more than a third of the Eastern Imperial Eagle population in Bulgaria is concentrated in the Sakar Mnt. (Demerdzhiev et al. 2014), as many of the Lesser Spotted Eagles occurring in this region and occupying smaller territories, also breed within the territories of all Imperial Eagle pairs. Being a top predator, the Imperial Eagle dominates the smaller raptor species within its territory, sometimes using them as a food source. Lesser Spotted Eagles have also been found in the food remains of Eastern Imperial Eagles in southeast Bulgaria (Demerdzhiev 2011). On the other hand, hedgehogs account for a significant share of the diet of Lesser Spotted Eagles in the Sakar Mnt., which inevitably results in competition with the stronger and larger dominant Imperial Eagle, feeding mostly on hedgehogs in this region (Demerdzhiev 2011). Probably, in years of food shortage the Lesser Spotted Eagle has evolved a mechanism to avoid competition with the Imperial Eagle and either uses another type of prey that is currently available in the area, or occupies a territory but does not breed. Thus, the Lesser Spotted Eagles breeding in the Sakar Mnt. have a lower breeding frequency. In support of this hypothesis, the Lesser Spotted Eagles occurring in the Dervent Heights/western foothills of the Strandzha Mnt., although breeding at almost twice the density of the pairs in the Sakar Mnt., have a higher breeding frequency. In the region of the Dervent Heights/western foothills of the Strandzha Mnt., the Eastern Imperial Eagles breed at a lower density than the one recorded in the Sakar Mnt. (Demerdzhiev et al. 2011, 2014). The interspecific

competition with the larger and stronger Imperial Eagle has probably a stronger impact on the breeding frequency of the Lesser Spotted Eagle than the intraspecific competition. In support of the mechanism of avoiding competition, the Lesser Spotted Eagles in the Dervent Heights feed mainly on voles and, less frequently, on hedgehogs, since this is a prey species that would be a reason for competition with the dominant Imperial Eagle.

Establishing the causes of breeding failure for this secretive forest breeder is difficult. We do not discuss the phenomenon of Cainism, typical of the Lesser Spotted Eagle (Meyburg 1969, Meyburg et al. 2008). Probably, the disturbance caused by anthropogenic activities is not as great as with the Eastern Imperial Eagle, having significant negative impact (Demerdzhiev et al. 2014, 2015) on this raptor breeding in the open landscape. However, since the Lesser Spotted Eagle is shier, with no tolerance to human disturbance, and inhabits wooded areas, some specific human activities such as logging or mushrooms and herbs collection could have a strong negative impact on the breeding performance of some pairs. Probably a significant part of the cases, where the cause of breeding failure could not be established, resulted from such specific human disturbance. Nest robbing for the purpose of trafficking eggs and individuals, as well as for private collections, is a growing threat. So far, at least two cases of Lesser Spotted Eagle eggs stolen for private collections have been proven in Bulgaria (unpublished data). With the Eastern Imperial Eagle, egg stealing accounted for 26% of the breeding failure, while the share related to stolen chicks was 8% (Demerdzhiev et al. 2014). Egg stealing by poachers was also found in Transcaucasia (Abuladze 2001). Storms in the southeast of the country are of local significance, but in some years, they could often be the reason for breeding failure. With Eastern Imperial Eagles breeding in this area, storms caused chick mortality or destroyed nests during the incubation period, accounting for 5% to 16% of the studied mortality factors (Demerdzhiev et al. 2014). Cases of egg and chick predation by Corvids or other natural predators were known in Transcaucasia region and Latvia (Abuladze 2001, Bergmanis et al. 2015).

Summarizing the breeding performance of this long-lived territorial raptor reported in this study, we did not find strong support for regulation of the population either through the density dependent mechanism or through strong territoriality. In some regions, density dependent fecundity could possibly affect the local population, while in other regions the strong territoriality mechanism regulates the population; however, in order to illustrate this process in a greater territory of the southern limit of the species distribution range, future research in different geographical regions should be undertaken. Hence, habitat alteration, trophic interaction with prey species, prey availability and dynamics, inter- and intra-specific competition should be some of the main conservation issues in future research of the Lesser Spotted Eagle in Bulgaria.

Acknowledgments: We would like to thank Vanya Ratarova, Dimitar Plachiiski, Georgi Popgeorgiev, Vera Dylgerska, Vanyo Angelov, Aleksandar Georgiev, Vasilena Georgieva, Valentin Velev, Tzeno Petrov, Vladimir Mladenov, Ralica Georgieva, Dimitar Gradinarov, Svetoslav Stanchev, Atanas Delchev, Vanya Angelova, Anton Stamenov, Dimitar Hanev, Veronika Ferdinandova, Nedko Nedyalkov, Stoycho Stoychev, Vladimir Dobrev, Georgi Gerdzhikov, Mihail Iliev, Atanas Demerdzhiev, Krasimira Demerdzhieva, Petar Yankov, Yanina Klimentova, Ivaylo Angelov, Ivan Kaferzhiev, Girgina Daskalova and Petar Shurulinkov who took part in the field work or provided data about the species distribution. Without their assistance this survey would not be possible. Special thanks are also given to the staff of the EFA – eng. Dimitar Batalov, eng. Veselin Raychev, eng. Luben Jelev, eng. Nikolay Vasilev, who provided valuable logistic support and assistance for this research. This work was funded by the LIFE+ Program of the European Union under "Preserve Key Forest Habitats of the Lesser Spotted Eagle (*Aquila pomarina*) in Bulgaria" LIFE12 NAT/BG/001218 project.

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