

Habitat Requirements of the Lesser Spotted Eagle *Clanga pomarina* Brehm, 1831 (Aves: Accipitridae) at the Southern Periphery of the Distribution Range (Southeast Bulgaria)

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Abstract: Analyzing the habitat requirements of raptors is of crucial importance for wildlife conservation, since their role as bioindicators serves to assess the impact of different factors – anthropogenic, biotic and abiotic, as well as the “stress level” on the entire ecosystem. The Lesser Spotted Eagle is a strongly philopatric and territorial forest-dwelling raptor that tends to prefer foraging in different types of grasslands and avoid arable land. With regard to the micro-habitat selection, the eagle’s selectivity was strongly related to the topography and the proximity to open areas and water bodies, avoiding small forest patches. In the nesting stands the eagle definitely selected older and taller trees. The territory selection was related to the preferences for natural grasslands, agricultural mosaic and shrubs as well as the avoidance of large forests and arable land. The mean size of the fragments influenced significantly the selection of a home range by this raptor species, with a strong preference for large patches of grassland biotopes and shrubs, and strict avoidance of large forest tracts. The strongest habitat preferences were related to the habitat heterogeneity, so we observed that the species clearly selected territories of high habitat diversity. We found out that the habitat structure did not affect significantly the eagle’s density. Although the habitats of the species vary across its distribution area, in general the species follows the same habitat selection patterns throughout its European range. We would like to emphasize that the conservation of the habitats of this raptor should include not only conservation of nest sites, but also conservation of favourable foraging sites. Inappropriate practices in forest and agriculture management can adversely affect the species’ population both at a micro-habitat scale and as macro-habitat features by decreasing the quality of habitats. The significance of old growth trees, structurally diverse stands, share and condition of grasslands as well as landscape diversity must be taken into account in the management and the decision making related to the protection of the Lesser Spotted Eagle.

Key words: habitat selection, habitat use, top predator, raptor, forests, habitat alteration

Introduction

The habitat of an organism is the place where it lives (ODUM 1971). The habitat includes the resources and the conditions present in an area that enable occupancy, survival and reproduction of such an organism. It is not only vegetation, but also includes the combination of the specific factors such as cover,

water, temperature, precipitation, topography, food resources, presence or absence of predators and competitors, as well as other factors a species would need to survive and reproduce successfully (THOMAS 1979). There are numerous, also quite different interpretations of the concepts of habitat use, habitat

selection and habitat preferences. However, habitat use is the way an individual or a species uses the physical and the biological resources in a habitat (KRAUSMAN 1999). Studies on habitat use patterns describe the actual distribution of individuals across different habitat types. Habitat selection is a hierarchical process involving a series of innate and learned behavioural decisions made by an animal about which habitat it would use at different scales of the environment (HUTTO 1985, BLOCK & BRENNAN 1993). Thus, habitat use patterns are the end result of habitat selection processes. Habitat preferences are the consequence of habitat selection, resulting in the disproportionate use of certain resources over others (KRAUSMAN 1999).

Understanding the habitat requirements of a species of interest is crucial to making informed decisions about wildlife management, especially when the habitats are species-specific, on one hand, and, on the other, when they are subject to severe and rapid alteration. The interaction of raptors and habitats has been widely analyzed. Management and improvement of breeding raptors' habitats have marked a positive effect on biodiversity in general, since raptor populations can act as useful bioindicators of changes in and pressure on ecosystems, as they are sensitive to land use alterations, habitat structure and habitat fragmentation, being also highly vulnerable to local extinctions (SERGIO et al. 2005, BEDNARZ 2007, BURGAS et al. 2014, DONÀZAR et al. 2016). Raptors are limited by the lack of a suitable breeding habitat and have specific nest site requirements (NEWTON 1979, FERGUSON-LEES & CHRISTIE 2001). With forest-dwelling species a shortage of nest sites may also limit the density of the species below the carrying capacity of the habitat (NEWTON 1998).

The Lesser Spotted Eagle *Clanga pomarina* Brehm, 1831 (LSE) is a medium-sized forest-dwelling raptor that tends to prefer foraging in different types of grasslands and avoid arable land and woods (MIRSKI 2009, 2010, VÄLI et al. 2017, but see SCHELLER et al. 2001). As a food source, the species mainly uses medium-sized prey, whose distribution primarily determines the nest site selection of the LSE (ZUB et al. 2010). Throughout its breeding range, it prefers mainly broadleaved forests (TREINYS 2004, MIRSKI 2009, VÄLI et al. 2009), while in some parts of the southern limit the species has specialized in pine forest ecosystems, adjacent to forest openings and agricultural areas (POIRAZIDIS et al. 2007, 2019). Normally, in Europe this eagle shows a strong preference for grasslands, placing its nests near open landscapes and, in some regions, avoiding situating the nests near man-made infrastructures. This

sensitive forest raptor species selects continuous forest cover, clearly prefers to nest in natural, mature forests and builds its nests on large trees (LÖHMUS 2005, TREINYS et al. 2009). As a consequence of the large-scale changes in the land use patterns and the habitat loss processes, a decline of this species has been recorded over the past two decades in Lithuania, Latvia, Hungary, Slovakia and Germany (MEYBURG et al. 2004, BERGMANIS et al. 2006, TREINYS et al. 2007, LANGGEMACH & BÖHNER 2011, DRAVECKÝ et al. 2015a, PONGRÁCZ & SZITTA 2015). This process is related to the foraging habitat alteration including conversion of meadows and different types of grasslands into cultivated fields, overgrowth of vegetation in meadows and grasslands, as well as loss of nest sites caused by forestry practices. The LSE is a strongly philopatric and territorial bird of prey (MEYBURG et al. 2005, TREINYS et al. 2017) and once the optimal habitat has been damaged, the chances for recolonization of old territories by the eagle are low. Therefore, in order to predict the consequences of the changes in the forest management practices and the land use alteration with regard to the stability of the LSE population, the habitat preferences of the species need to be examined at a local level, since they vary significantly across the distribution range (MEYBURG et al. 2004, VÄLI et al. 2004).

In Bulgaria, the LSE 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 (DEMERDZHIEV et al. 2007). The size of the population is estimated at more than 600 breeding pairs (DEMERDZHIEV et al. 2019), which has turned the country into a stronghold for the conservation of the species in the southern part of its range, especially since a population decline was registered in Greece and Turkey (KIRWAN et al. 2008, LEGAKIS & MARAGOU 2009). Therefore, particular attention has to be paid to its conservation, because the landscape changes that occurred in the previous decade (DEMERDZHIEV et al. 2016) may affect the LSE in several ways: damaged breeding places due to the increased forest cutting rates within occupied nest sites and destroyed hunting biotopes as a result of the intensification of the agriculture. However, there is no detailed study on the habitat preferences of the species in Bulgaria, describing the main factors influencing the LSE habitat selection and their roles in the distribution of the species in this part of its range.

So far, large-scale studies on the habitat preferences of the LSE have been conducted in the northern and the central parts of the species' distribution range, where the world population of the species is

concentrated (SCHELLER et al. 2001, LANGGEMACH et al. 2001, VÄLI et al. 2004, 2017, TREINYS 2004, TREINYS et al. 2009, MIRSKI 2009, MACIOROWSKI & MIRSKI 2014, ZUB et al. 2010, DRAVECKÝ et al. 2015b, PAKUL et al. 2019). However, at the southern periphery of the species' range, data about the LSE habitat requirements is scarce and insufficient (ABULADZE 1996, 2001, VLACHOS & PAPAGEORGIU 1996, POIRAZIDIS et al. 2007, 2019, VÄLI et al. 2009). Such data would enhance the theoretical knowledge of the habitat requirements of this raptor of proven site fidelity and would provide a sufficient basis for efficient protection of the species in this part of the distribution range. A geographical variation in the LSE macro-habitat use was established at the distribution range level as variations were predetermined by both the resource availability in a landscape and the different response of the species to similar resource availability in a landscape (VÄLI et al. 2004).

Usually, the habitat of the species is considered at different scales, macro-habitat and micro-habitat. The macro-habitat refers to landscape-scale features, while the micro-habitat refers to finer scaled habitat features (KRAUSMAN 1999). The home range of the species includes the nest sites and the foraging area. The macro-habitat characteristics of the breeding home range, such as vegetation cover types, topography, weather conditions, human pressure, availability and accessibility of prey, also represent important components of the habitat selection, just like the nest sites at a micro-habitat scale (JANES 1985, MCGRADY et al. 2002, SERGIO et al. 2004, RODRÍGUEZ-LADO & TAPIA 2012).

In this study, we describe **(1)** nests, nest sites and nest stand requirements of the LSE and habitat selection at a micro-habitat scale, **(2)** territory preferences and selection at a spatial scale as macro-habitat features, **(3)** influence of the habitat structure on the species' density at the southern periphery of the distribution range. We have studied the nest site and territory selection by the eagles in three different aspects: nest characteristics, nest site features in terms of location and surrounding forest stand, and territory preferences (species' home range) at a large scale (within the study area). We have determined the species' preferences at micro- and macro-habitat scale by comparing land cover types, landscape diversity and fragmentation, topography and distances of nests/territories to landscape elements with random plots. We also compare the habitats of geographically different regions and different densities of the species. Comparing our results with existing published research, we also discuss the geographical variation of micro- and macro-habitat use patterns of

the species in different parts of its distribution range. The knowledge of the species' preferences in the southern part of the distribution range could subsequently be used in the conservation and management of this species.

We hypothesize that **(1)** the nest sites differ at a regional scale, and the eagle's choice is influenced by the forest stand characteristics, the access to the hunting grounds and the avoidance of human disturbance rather than the topography of the places. We also predict that the species prefers to nest in mature forests, avoiding dense woods; **(2)** the breeding territories differ at a regional scale and the macro-habitat selection is driven by the fragment characteristics, the landscape diversity and the landscape structure, so that the eagle avoids human disturbance, preferring grassland type of vegetation rather than arable lands and wooded and shrubby areas; **(3)** the habitats in areas with high density of eagles differ significantly from those in areas with low density.

Materials and Methods

Study area

Bulgaria, located in the south-eastern part of Europe and in the eastern part of the Balkan Peninsula, falls under the influence of two climate zones – the temperate zone, and its continental climate type in particular, and the Mediterranean zone, as well as the transitional area between these two climate zones. The presence of a large water basin (the Black Sea) next to the territory of the country, although east of it, affects the climate elements. This mitigating influence on the major climate elements and the formation of a general climate change is the ground for separating the territories along the Black Sea coast into a Black Sea climate area. This study area was selected since the aim of the study was to cover the densest and most abundant part of the species' population at a national scale, considered to be the most representative sample. 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 Derwent 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 (Byala Reka River valley) 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

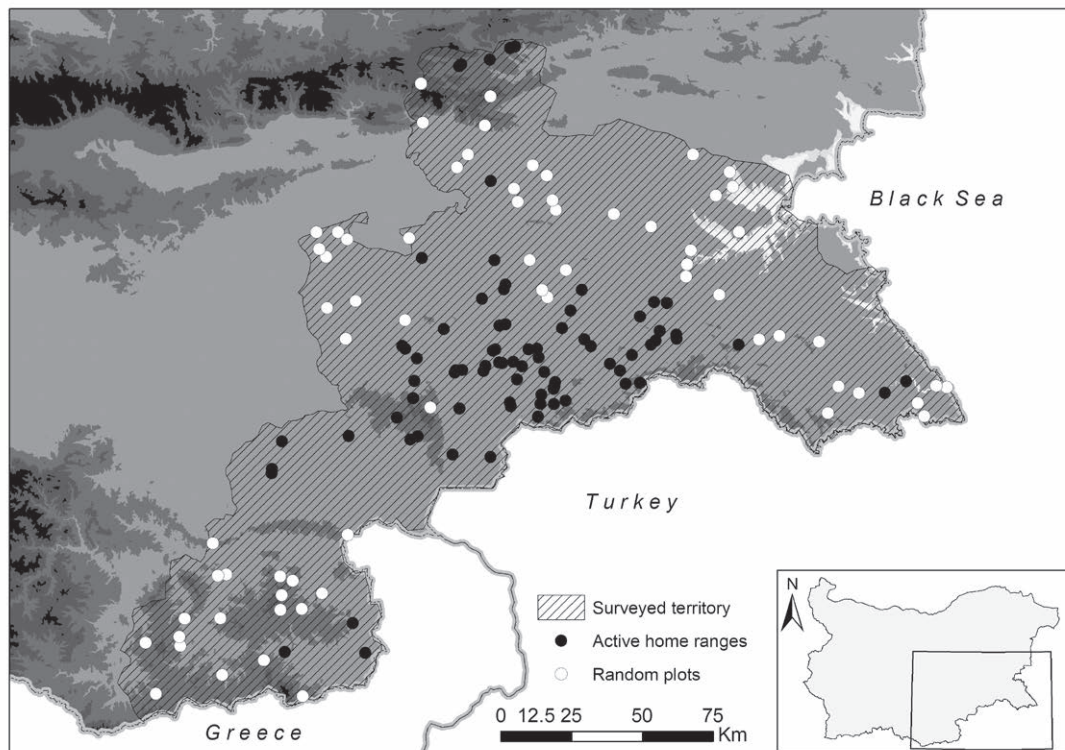


Fig. 1. Map of the study area (black dots indicate home ranges – occupied territories, white dots indicate random plots)

(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 study area stretches over 15500 km², comprising various climate zones. The northern and the north-western parts of the surveyed area are characterized by a transitional climate, the coastal zone by the typical local Black Sea climate, and the rest of the territory is under the influence of the continental-Mediterranean climate (BLASKOVA & TZENKOVA 1991). The topography varies, including flat grounds and hilly and low mountains with an elevation of 20–1130 m a.s.l. Different climate conditions and types of relief in the study area also determine the existence of different habitats, with vegetation types dominating agricultural areas and *vice versa*.

The Eastern Rhodopes are characterized by low mountain relief, with deeply cut valleys of the Byala Reka River, the Arda River and its larger tributaries - the rivers of Varbitsa, Krumovitsa and Perperek (GALABOV 1982). To the north, the Harmanliyska River valley separates the Eastern Rhodopes from the valley of the Maritsa River. The climate of the region is continental-Mediterranean, with autumn-winter peak rainfall rates and dry summer periods. Forests cover about 43% 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). The Eastern Rhodopes also hold artificial coniferous stands of Scots pine (*Pinus sylvestris* L.) and Black pine (*Pinus nigra* A.), some of which aged more than 50 years. They account for approximately 5% of the forests in this region. Deforested areas are occupied by significant formations of Prickly juniper (*Juniperus oxycedrus* L.) and Jerusalem thorn (*Paliurus spina-christi* Mill.), accounting for 14% of the land cover. The open spaces are represented by arable land, about 20%, mostly situated in the river valleys as well as in poor natural and semi-natural pastures (17%), developing mainly on rocky terrains. Settlements, roads and water bodies account for the remaining 6% of the landscape. The soil cover consists mostly of cinnamon forest soils, developing on sedimentary and volcanogenic rocks and in warmer climate. In general, the soils in the Eastern Rhodopes are shallow, skeletal, severely eroded. Only the areas along larger rivers and valleys harbour developed alluvial and alluvial-meadow soils. 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 varies between 550 and 800 mm, and thus determines the area as particularly dry in summer. The woodlands in the Sakar Mnt. (19%) 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). About 3% of the forests consist of coniferous stands, some of them about 50 years old. Significant parts of the mountain are occupied by agricultural areas (46%), mainly sown with wheat and sunflower, or pastures and natural meadows (16%). The secondary vegetation in the deforested areas is represented by shrubs (13%) of Jerusalem thorn, mixed with Wild jasmine (*Jasminum fruticans* L.) and xerothermic grass formations dominated by Yellow bluestem (*Dichantia ischaemi*), Bulbous bluegrass (*Poaeta bulbosae*, *Poaeta concinnae*), Scented grass (*Chrysopogoneta grylli*), and Ephemereta (*Ephemereta*) (BONDEV 1991). The territory of the Sakar Mnt. includes some thirty small settlements and a poorly developed road network, accounting for about 5% of the land cover. The mountain represents a hydrographic junction, harbouring the sources of many of the small tributaries of the rivers of Maritsa and Tundzha, most of which dry out completely or partially in summer. There are numerous artificial ponds, which, together with the rivers, account for 1% of the landscape types. The predominant soil types are mostly leached and podzolized cinnamon forest soils, in some places heavily eroded. 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. 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. The forest stands account for more than 26% of the landscape, of which 2% are coniferous plantations. Open areas overgrown with shrubs (20%) 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 (37%), vineyards and orchards (2%), and pastures (13%) are situated in the lower areas and in the plains around the hills. The region is sparsely populated, although settlements and roads cover 2% of the territory. 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 northeastern slopes. The autumn-winter peak of precipitation is particularly well-marked. 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 broad-leaved forests. 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 – Common rhododendron (*Rhododendron ponticum* L.), Common laurel (*Prunus laurocerasus* L.), Tree heath (*Erica arborea* L.) and Common heather (*Calluna vulgaris* L.), which gives them a specific character and uniqueness (BONDEV 1991). The forests cover about 82% of the area. Open areas have been shrinking due to natural succession and reforestation. They consist mainly of arable land – 12%, grasslands

– 3%, and orchards – 1%. The region is heavily depopulated as the infrastructure is extremely poorly developed. Settlements and roads form the remaining 2% of the landscape. The middle and lower reaches of the Tundzha River include the river basin south of the town of Sliven up to the point, where the river crosses the national border with Turkey (GALABOV 1982). The climate here is characterized by gradual transition from transitional-continental to transitional-Mediterranean along the southernmost parts of the river. These peculiarities are due to the lowland and hilly relief, the relatively low altitude (50–145 m a.s.l.), the lack of high orographic barriers to the south and the marked Mediterranean influence. The winter period is characterized by a transient and short-lasting snow cover, while the summer seasons are dry and hot. The freshet period is marked by autumn-winter maximum and summer minimum values. The soils are of several types, i.e. alluvial, alluvial-meadow and alluvial-bog, formed by river deposits and characterized by shallow groundwater. This part of the river has preserved the largest floodplain forests found in the interior of the country composed of Grayish oak (*Quercus pedunculiflora* K.), Common oak (*Quercus robur* L.), Field maple (*Acer campestre* L.), Field elm (*Ulmus minor* Mill.), Caucasian ash (*Fraxinus oxycarpa* Willd.), White Poplar (*Populus alba* L.), Black Poplar (*Populus nigra* L.), Willow (*Salix* sp.) and Elder (*Sambucus* sp.). The floodplain forests cover 42% of the area, followed by shrubs – 29%, arable land – 21%, grasslands – 6% and settlements – 2%. The territories around the river terrace remain submerged between March and May, sometimes in June, affecting the foraging and the breeding behaviour of the LSE. The Elhovo Plain is located on both sides of the lower reaches of the Tundzha River, between the Manastirski Heights to the west, the Sakar Mnt. to the southwest, the Derwent Heights to the south, and the southern extremities of the Bakadzhitsite Hills to the northeast. To the north, it is wide open to the Yambol Plain and to the south it narrows and connects to the Srem Gorge of the Tundzha River. It stretches from west to east, being 30–35 km long and 18–20 km wide. Its flat terrain determines an average altitude of 100–150 m. The climate is transitional-Mediterranean. The average annual precipitation is estimated at 539 mm. The area is drained by the Tundzha River and its tributaries Kalnitsa, Sinapovska, Popovska and Araplyiska. The predominant soils are of the type leached chernozem-vertisols; leached cinnamon forest soils and alluvial-meadow soils are also found there (along the river valleys). In the lower parts of the area, where the level of groundwater is high,

swamps and floods occur in high waters. The forests are broadleaved, composed mainly of Hungarian oak, Turkey oak and Manna ash. Along rivers, they form gallery forests including Black alder (*Alnus glutinosa* L.), Willows and Poplars. They occupy only 9% of the area of the Elhovo plain and form relatively small patches, scattered among arable plots or situated in the river valleys. About 55% of the plain area is occupied by intensively used arable land, forming large blocks of monocultures sown with wheat, sunflower or rape. Dry pastures account for 21% of the territory, and shrub formations – 5%. Orchards and vineyards cover 4% of the area. The rest of the open areas consist of poorly developed infrastructure, including small settlements and roads (3%) as well as water bodies (3%). The Kotlenska Mnt. rises in the western part of the Eastern Balkan Mountains, facing east-west, being about 40 km long and 15–20 km wide. The western part of the mountain, in its southern range, harbours the high ridge of Razboyna and its most elevated point – the peak of Razboyna (1128 m). The Kotlenska Mnt. is an important hydrographic site. A number of clearly shaped secondary ridges with steep slopes and deeply cut combs and dry valleys are descending from its main ridge to the valleys of the rivers Ticha and Luda Kamchiya. The terrain is steep and heavily intersected. The climate is temperate continental characterized by a transitional-continental influence, resulting in seasonal precipitation equals, reaching some 600 mm. The snow cover lasts for about 12 weeks. The soils in the northern part are of the type shallow brown forest and light grey forest soils, and in the southern areas - leached and podzolized cinnamon forest soils. The Kotlenska Mnt. is heavily wooded, with more than two-thirds of its territory (70%) covered with primary deciduous forests, composed mainly of Moesian beech (*Fagus moesiaca* Malý.) in the higher areas, mixed in places with European hornbeam, while the slopes are mostly occupied by oak forests of Sessile oak, mixed in places with European hornbeam and Oriental hornbeam, as well as mixed oak forests of Turkey oak and Hungarian oak (BONDEV 1991). The area is marked by considerable forestation (about 12%) of coniferous stands of Scots pine, Black pine, Spruce (*Picea* sp.), Douglas fir (*Pseudotsuga menziesii* Mirb.), Silver fir (*Abies alba* Mill.), and Cedar (*Cedrus* sp.) in areas where former indigenous deciduous forests have been felled. The ridge of the mountain is deforested and covered with grasses. The shrubs consist of Oriental hornbeam and are characterized by particularly limited distribution in the area (3%). The rest of the territory is occupied by open areas used as pastures

(15%) and agricultural lands, including arable fields (7%) and vineyards (2%). Three types of grass communities predominate in pastures: mesophilic, xeromesophilic and xerothermic grasslands. A significant part of the open spaces, also including farmland, are secondary features that developed in areas of former old forests. Wetlands and river valleys occupy a small part of the territory (1%). The region is relatively sparsely populated, mainly at the periphery, along river valleys (2%).

Conservation significance of the study area

The study area covers the territory of eighteen SPAs, three of which are part of the 5 most important areas for the population of the LSE in the country (KOSTADINOVA & GRAMATIKOV 2007). The scope of the study includes the territories of two nature parks, Sinite Kamani and Strandzha, eleven strict reserves and five managed reserves. Strandzha Nature Park is Bulgaria's biggest nature park, occupying an area of 1161 km². The territory of the park comprises five strict reserves covering a total area of 5447 ha, harbouring centuries-old oak-beech forests, some of which aged more than 200 years. Sinite Kamani Nature Park is located in the Eastern Balkan Mountains, covering an area of 11380.3 hectares and comprising centuries-old beech and oak forests. In order to preserve the old deciduous forests, Orlitsata Reserve, occupying an area of 559.4 ha, has been designated, entirely located within our study area. The survey area also comprises floodplain forests of unique nature and features, situated along the lower reaches of the rivers Ropotamo and Tundzha and protected within the strict reserves Ropotamo (1000.7 ha) and Gorna Topchiya (164.38 ha) as well as in the managed reserves Dolna Topchiya (467.47 ha) and Balabana (76.98 ha).

Study design

Data about the breeding territories and the nest sites were collected in the period 2014–2018. When analyzing the data, we also added the information related to three nests and breeding territories recorded in 2011–2014. We mapped the nests between the end of March and July as a result of intensive field research, applying a common methodology used in several other surveys on this species (VÄLI 2003, 2012, TREINYS et al. 2017, VÄLI et al. 2017, DEMERDZHIEV et al. 2019). In Bulgaria, the LSEs return from migration in the last ten days of March and in 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 (DEMERDZHIEV et al. 2019). Therefore, this is the most useful period for nest recording. Places where the eagles demonstrated breeding behaviour (mating display, defence of the breeding territory, provision of food, frequent visits to hidden places), but no nests were found, were re-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 confirm their occupation by eagles. A territory was considered occupied if we observed: territory defence, nest building, copulation or other reproductive activities by a pair. We considered pairs that laid at least one egg and started incubating as breeding pairs (KATZNER et al. 2006, DEMERDZHIEV et al. 2015, 2019). Nests were considered active if they were “decorated” with green sprays of foliage, contained incubating birds, nestlings, eggs or remains of eggshells (VÄLI 2012, 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. We monitored the demographic parameters such as productivity, breeding success and breeding frequency of the surveyed pairs on an annual basis (DEMERDZHIEV et al. 2019).

We investigated the habitat preferences of LSE at three levels: (1) we described the nest characteristics of all found nests ($n = 114$); (2) we analyzed the nest sites and the nest stand within a 50 m radius around the nest at a micro-habitat scale; (3) we drew the territory preferences within a 2 km radius around the nest as macro-habitat features. For the nest tree analyses we used all nest trees. To avoid pseudo replication, we used only the most frequently occupied nests in each breeding territory for micro- and macro-habitat scale analyses. Thus, we included 79 nests of 79 different nesting territories. In Bulgaria, 86% of the forests are state-owned and only 11% belong to private owners. Of all state-owned forests, 15% are municipal properties and 4.7% are forests falling within national parks and reserves (MINISTRY OF AGRICULTURE, FOOD AND FORESTRY 2017). There is no unified GIS forest database, comprising all available information and providing easy access to the data. Due to the impossibility to use some of the information concerning municipal forests or forests in reserves, fewer nests were considered in the analysis of some of the indicators of the nest stand, such as age of forests, forest structure etc. To detect the species preferences, nest sites and territory characteristics were compared to similar number of

random points selected within the study area. The area of 2 km radius around the nest is considered to be the species' home range in most of the LSE studies (SCHELLER et al. 2001, VÄLI et al. 2004, 2017, LÖHMUS & VÄLI 2005, MIRSKI 2009, MACIOROWSKI & MIRSKI 2014, MACIOROWSKI et al. 2015, TREINYS et al. 2017), as the nest is situated close to the center of the territory, rather than at its periphery (VÄLI et al. 2017). The land cover was examined within a 2 km radius around the nest trees and in random plots ($n = 146$) using digital maps based on satellite images of a Physical Blocks layer as of 2016 (<https://seu.dz.bg/seu/f?p=727:8500>). 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.

To describe the features at macro-habitat level we used 21 explanatory variables, and for those at micro-habitat level – 18 (Annex 1). In order to increase the power of the analysis at the macro-habitat scale, we pooled rare and probably biologically insignificant variables - vineyards, orchards, dust roads and clearings in a single category – “Other areas”. To avoid describing landscapes in geographically different regions, random points were selected at least 6 km from the nests or occupied territories. The variables related to the site topography (Slope, Aspect, Altitude) were applied using a digital elevation model (DEM). The spatial analysis of data was performed using the software ArcGIS 10 (ESRI 2016). The analysis of the individual fragments of the habitats was run through the application Patch Analyst for ArcGIS 10. Patch Analyst is an extension to the ArcGIS 10 software that facilitates the implementation of spatial analyses of landscape fragments and the modelling of the related features. The program provides options to characterize the fragmentation model and estimate the fragment values based on a combination of metric features of the fragments. We also calculated the Shannon Diversity Index using 34 original land cover types (H'):

$$H' = - \sum_{i=1}^R p_i \ln p_i$$

where p_i is the relative area of land cover type i . Many of the measured distances from nests or random points to different landscape elements, such as distance to the forest edge, roads, houses or settlements, ponds or rivers, were checked in the field as we made minor corrections in the few cases of discrepancies between the map data and

the actual situation. The data related to nest characteristics (height of tree and nest, diameter at the breast height), nest tree location, canopy cover, undergrowth and nest stand were measured and collected in the field. We estimated visually the mean canopy closure (scale 0 – 1) within 5 m around the nest tree, and the soil moisture, using a four-point scale from dry (1) to wet (4) (LÖHMUS & VÄLI 2005). Undergrowth or shrubs were also visually evaluated within a radius of 50 m around the nest tree (scale 0–1). We estimated the share of the dominant tree species in the nest stand (scale 0–1). Given the importance of forest structure, we calculated an index of stand density as a sum of the distances (m) from the nest tree to the neighbouring trees in all directions, divided by the number of neighbouring trees. Thus, the nest stand was divided in three classes: dense (0–2), loose (2.1–5) and open (> 5.1). However, part of the variables describing the nest stand, such as age of forest stand, height and diameter of the main tree species in the forest stand, were taken from the Bulgarian Forest Database (EXECUTIVE FOREST AGENCY 2011). The forests were divided into six age classes: I (0–40 y.), II (41–60 y.), III (61–80 y.), IV (81–100 y.), V (101–140 y.) and VI (over 140 y.). The forests of the first age class were defined as young growth forests; those of the second age class – as middle-aged; and the ones of the third to the sixth age classes - as mature forests (TREINYS & MOZGERIS 2010). Since the LSE is a forest-dwelling species, all random points were selected within woodlands, with a distance of at least 1 km between the individual random points or between the random points and the nests, in order to avoid pseudo-replication. This did not violate the assumption of sample independence because the nest stands and the random points, respectively, were described at a much smaller scale.

After exploring the inter-correlations of the variables (Spearman correlation coefficient, r), we selected 16 variables at a macro-habitat scale and 18 variables at a micro-habitat scale for further analysis (Annex 1). The explanatory variables were related to nest tree characteristics, nest stand characteristics, topography, proximity of sources of potential disturbance or environmental characteristics, landscape fragmentation and diversity. When (r) coefficient of a pair of correlated variables was > 0.6 (GREEN 1979) one of the variables was removed and the other was kept in the subsequent analysis. The decision as to which variable was to be retained was based on the results of a Principal Component Analysis (PCA), selecting the one with greater factor scores. In order to quantify the influence of the habitat structure

on LSE density, we divided the home ranges in two main classes: high density (where the eagle home range was inhabited by more than two conspecific pairs) and low density (up to one conspecific pair). In these analyses, we initially used 39 variables that described the nest sites and the home range preferences (Annex 1). Having explored the inter-correlations of the variables (Spearman correlation coefficient, r), we selected 8 predictors describing the nest sites and 15 predictors related to the home range scale for further analysis. The data was analyzed for normal distribution through the Kolmogorov–Smirnov test and was log-transformed. The aspect was transformed into north/south and east/west components, using cosine and sine, respectively. However, for ease of interpretation, we presented the mean values and the standard deviations in their untransformed states. We used the non-parametric Kruskal-Wallis ANOVA test and the General Linear Model (GLM) to analyze the habitat composition at micro- and macro-habitat levels. To assess whether the habitat varied between different regions and between different eagle’s densities, the models were started as follows: (1) using “region” as a fixed categorical predictor; (2) using “eagle’s density” as a fixed categorical predictor. All of the explanatory predictors that had shown significance ($p < 0.05$) in GLM, were included in a CLUSTER analysis to demonstrate comparison at a regional scale. In the CLUSTER analysis we used the mean Euclidean distances as a measure of region proximity. The habitat selection at micro- and macro-scale was estimated using GLM, where territories, nest sites respectively, and random points were used as fixed categorical predictors. In order to sift out the relative important factors affecting the eagle’s selection process, the whole set of explanatory variables that had shown significance ($p < 0.05$) in GLM was subsequently analyzed in PCA. At a micro-habitat scale there were 6 variables, and at a macro-habitat scale – 14. Components with an eigenvalue greater than 1.0 were accepted for further analysis and their factor scores were calculated for both random points and occupied territories, nest sites respectively. At the micro-habitat scale the first component (distances to landscape elements and altitude) explained 35% of the total variation, while the value of the second component (size of forest patch) described 21% of the variation (Table 1).

According to the macro-habitat features, the first component (habitat heterogeneity and availability of potential foraging conditions) accounted for 40% of the total variation, and the second component (nesting conditions) drew 21% of the variation (Table 2).

Table 1. Correlation coefficients of the six variables (micro-habitat scale) with the first two principal components from a Principal Components Analysis. Significant scores are given in bold (> 0.7)

Predictor	Principal component	
	1	2
Slope	-0.57	0.37
Aspect	0.23	0.59
Altitude	-0.71	-0.19
Distance to the forest edge	-0.75	0.11
Distance to water bodies	-0.76	-0.28
Size of the forest patch	-0.24	0.80
Explained variation percentage	34.62	20.76
Cumulative variation percentage	34.62	55.38

Table 2. Correlation coefficients of the fourteen variables (macro-habitat scale) with the first two principal components from a Principal Components Analysis. Significant scores are given in bold (> 0.7)

Predictor	Principal component	
	1	2
Number of water bodies	-0.63	-0.17
Number of landscape patches	-0.81	0.21
Number of forest patches	-0.10	0.82
Mean size of the forest patches	0.54	0.69
Mean size of the natural grassland patches	-0.62	-0.09
Mean size of the agricultural mosaic patches	-0.69	0.02
Mean size of the shrub patches	-0.31	0.52
Shannon H'	-0.92	0.22
Forest area	0.42	0.82
Arable lands	-0.63	-0.54
Natural grasslands	-0.76	0.29
Agricultural mosaic	-0.55	0.09
Shrubs	-0.54	0.60
Other area	-0.80	-0.01
Explained variation percentage	39.60	21.13
Cumulative variation percentage	39.60	60.73

Thus, after we defined the factors (with factor scores > 0.7) of the greatest importance for habitat selection at two scales (micro- and macro-), all possible combinations of these factors were fitted subsequently, selecting the best models through an exhaustive search, based on the lowest values of the Akaike Information Criterion corrected for small sample sizes (AIC_c) (BURNHAM & ANDERSON

2002). To estimate the effect of explanatory important factors on habitat selection, we used a mixed General Linear/Non-Linear Model (GLNLM) with a binomial distribution structure and a logit link function, where the dependent variable was eagle's selection (1 = presence, 0 = absence). We calculated the AIC_c for each of our candidate models and chose the model with the lowest AIC_c value. Models that produce lowest AIC_c values can be considered as ones showing smaller differences than the true model. AIC_c provides a simple and effective means of choosing the right model for the true model. All models with an AIC_c value < 2 from the model with the lowest AIC_c (AIC_{cmin}) were considered best models ($\Delta AIC_c = AIC_i - AIC_{cmin}$). We estimated the relative importance of each model from our set of candidate models ($\Delta AIC_c < 2$). We used AIC_c weights (w_i) for all candidate models to assess their relative support for the data. Akaike weights can be used in model averaging. The model weight was estimated through the normalized Akaike weights, $\exp(-0.5 \times \Delta AIC_c) / \sum_{r=1}^R \exp(-0.5 \times \Delta AIC_r)$. We also used explanatory parameter estimates with a standard error and a probability value (p) with regard to the explanatory factors.

Statistica for Windows, Release 10 (STATSOFT INC. 2011) and R v.2.15.2 (R CORE TEAM 2012) were used for the statistical analysis of the data.

Results

Habitat selection and preferences at a micro-habitat level (nest, nest site and nest stand)

The LSE builds its nest predominantly at the base of the tree (n = 96; or 86%). Side branches are used less often (n = 14; 12%), and the top of the crown – very rarely (n = 4; 4%). With 114 nests studied in Southeast Bulgaria, the nest tree was usually Oak (68%), and much less frequently Willow (11%), Ash (8%), and Poplar (7%). The share of other tree species was negligible (Fig. 2).

In 74% (n = 84) of the cases the nest was situated in a typical wood formation, but in 26% (n = 30) the nest tree was located in forested tree-lines along streams or rivers. The average height of the nest tree (n = 113) was 15 ± 4 m (range 6.50–27 m) and the nest height above the ground was 10.35 ± 3.78 m (range 4–23 m). The mean diameter at the breast height (DBH) (n = 104) was 0.49 ± 0.22 m (range 0.12–1.22 m), but in 75% of the cases DBH was 0.58 m on average. The LSE builds its own nest, although nests of other raptors can be used, too. We recorded cases of LSE occupying vacant nests of Long-legged Buzzard (*Buteo rufinus* Cretzschmar, 1829),

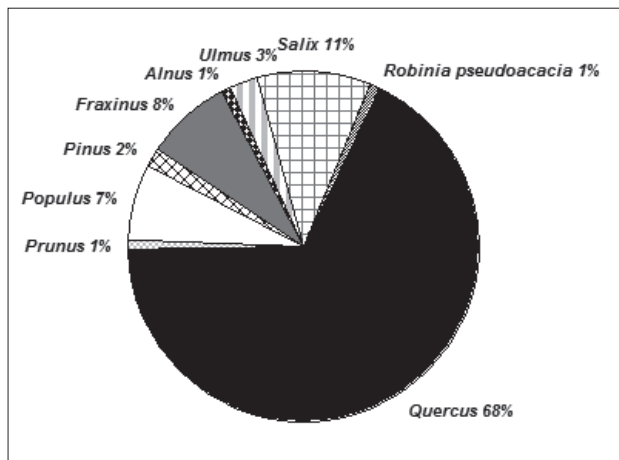


Fig. 2. Proportion of the tree species used by the Lesser Spotted Eagle for nest construction

Booted Eagle (*Hieraaetus pennatus* Gmelin, 1788) and Eastern Imperial Eagle (*Aquila heliaca* Savigny, 1809) – once for each species. We also recorded two cases of Common Buzzard (*Buteo buteo* Linnaeus, 1758) nests occupied by LSE. On the other hand, different forest-dwelling raptors and Black Stork (*Ciconia nigra* Linnaeus, 1758) often occupied LSE nests. We recorded that notably Common Buzzard bred in LSE nests (n = 6); yet, White-tailed Eagle (*Haliaeetus albicilla* Linnaeus, 1758), Northern Goshawk (*Accipiter gentilis* Linnaeus, 1758), Eagle Owl (*Bubo bubo* Linnaeus, 1758) and Black Stork were also found occupying its nests (n = 1). Usually, the LSE uses the same nest for several years, but one pair can have more (up to 4) nests, some of which re-used at several years' intervals. In our 79 studied territories, 65% (n = 51) of the pairs had one nest, 29% (n = 23) two nests, 5% (n = 4) three nests and one pair had four nests (1%). The distances between the different nests of a pair ranged from 12 m to 1173 m at a mean value of 319 ± 259 m. The diameter of the measured nests (n = 10) varied from 52 cm to 112 cm, 81.7 ± 18.04 cm on average, and the mean nest depth was 48 ± 19.53 cm (29–90 cm).

The stand composition was studied within 50 m around the nests. In Southeast Bulgaria the LSE nests were situated mainly in pure Oak stands (55%), or Oak formations mixed with Ash, Oriental hornbeam, Beech and Elm (15%). Stands dominated by Poplar accounted for 7% of the cases, and those dominated by Willow – 5%. Coniferous stands of Black Pine were recorded only for 3% of the nests. The remaining 15% of the nests were situated in mixed formations, composed of different deciduous tree species.

Contrary to our prediction with regard to the micro-habitat selection, the eagle's selectivity was strongly related to the topography, as the eagle

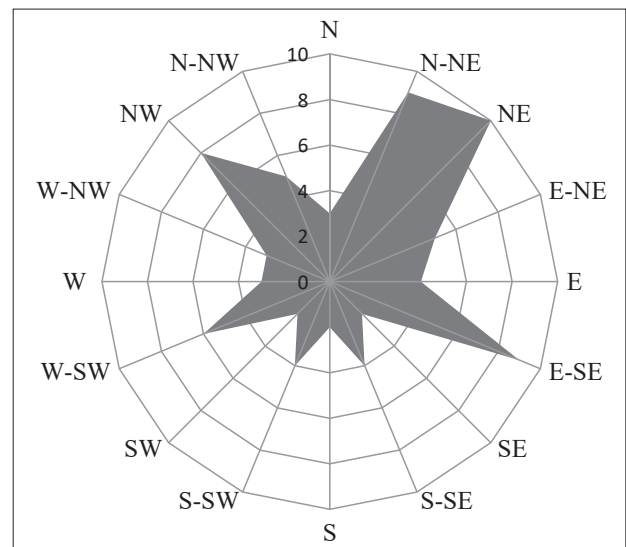
Table 3. Results of the Lesser Spotted Eagle micro-habitat selection analysis (GLM, ** statistically highly significant difference, *** statistically very highly significant difference)

Variable	Nest sites			Random sites			R	df	F	p
	N	Mean ± SD	Range	N	Mean ± SD	Range				
Stand age (y.)	63	58.73 ± 21.44	25 -135	65	68.15 ± 37.08	20-160	0.05	1	0.36	0.55
Slope (°)	79	5.54 ± 4.47	0.72-23.45	79	7.51 ± 4.99	0.91-25.10	0.24	1	9.53	**
Aspect (°)	79	161.69 ± 109.85	8.29-354.81	79	179.52 ± 108.34	3.01-356.01	0.25	1	10.59	***
Altitude (m)	79	233.68 ± 119.55	47-567	79	354.65 ± 163.46	76-881	0.41	1	31.53	***
Distance to the forest edge (m)	79	146.71 ± 178.28	2-797	79	726.15 ± 1556.14	5-11963	0.37	1	25.12	***
Distance to a road (m)	79	176.34 ± 137	2-705	79	151.11 ± 142.18	2-778	0.10	1	1.53	0.22
Distance to a settlement (m)	79	1549.80 ± 869.82	239-4670	79	1776.66 ± 1199.55	35-6307	0.01	1	0.01	0.93
Distance to water bodies (m)	79	392.20 ± 492.88	5-3060	79	1746.87 ± 1562.97	11-7403	0.58	1	79.58	***
Size of the forest patch (ha)	78	67.34 ± 135.34	0.39-760.30	72	11.38 ± 7.88	0.39-33.43	0.31	1	16.22	***

avoided steep slopes, south aspect, and high altitude (Table 3).

In Southeast Bulgaria, the species bred mainly in flat lowlands and hilly areas (47–567 m a.s.l.), choosing a NE aspect (Fig. 3). E-SE, N-NE and NW slopes were also preferred, while south and north directions were avoided.

As we expected, the species preferred to locate its nests near the forest edge, as well as in proximity to a water body (river or pond) (Table 3). The nests were situated near the forest edge, 75% of which located at less than 164 m from the edge of the forest patch. The mean distance from the nest to the forest edge was 146.71 ± 178.28 m. The most remote nest was located at 797 m from the edge of the forest stand, and the closest one was located only 2 m from the open spaces. The proximity to ponds or rivers, where the eagle could go foraging, varied significantly, from 5 m to 3060 m, but the mean value of this variable was 392.2 ± 492.88 m. However, 75% of the breeding pairs had located their nests at a distance of less than 500 m from the permanent water sources. The size of the forest patch also influences the eagle's selection, so in general the species avoids small stand patches (Table 3). Within the study area, 75% of the nesting forest tracts were of an average size of 77.01 ha. However, small forest patches were used less often, and 25% of the nests were situated in patches of a mean size of 3.48 ha. The size of the smallest forest stand was 0.39 ha, and that of the largest one was 760.3 ha. The mean size of the forest patch used for breeding was 67.34 ± 135.34 ha. Contrary to our assumptions, nest site selection was not influenced by the proximity of anthropogenic


Fig. 3. Aspect of the nests of the Lesser Spotted Eagle in Southeast Bulgaria

edges. The distances from the nests to a near settlement or to a road did not differ significantly from the distances measured for random points (Table 3). The mean distance from the nests to inhabited farms or human settlements (1549.8 ± 869.82 m) was even shorter than with random points (1776.66 ± 1199.55 m). The mean distance from the nest to a road (forest or paved) was 176.34 ± 137 m. The age of the forest stand did not affect the nest site selection (Table 3). The average age of the nest stands was 58.73 ± 21.44 years. Most of the nest stands used for breeding belonged to the middle-aged class (52%), while mature forests (third – six classes) accounted for 27% of the nesting stands. However, young growth

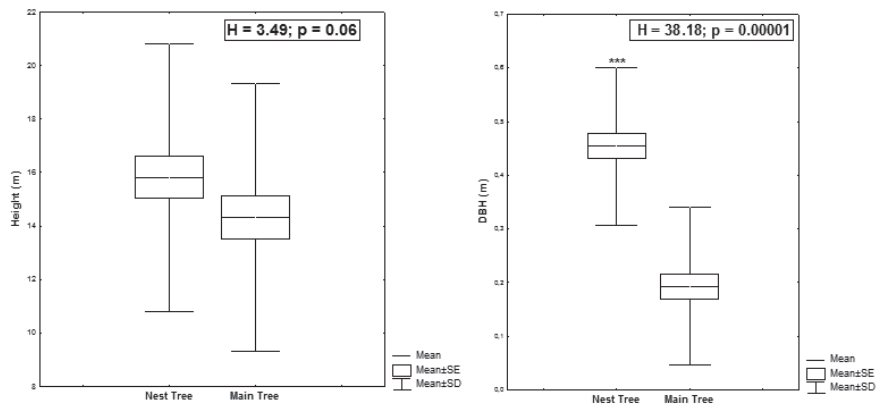


Fig. 4. Selectivity of the Lesser Spotted Eagle with regard to the breeding substratum (nest tree and main tree species within the stand)

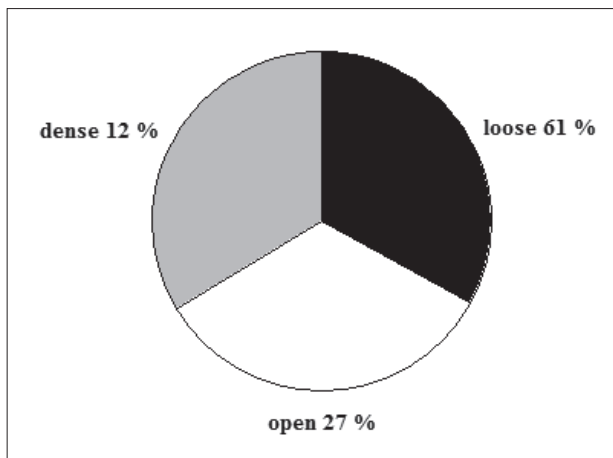


Fig. 5. Proportions of the forest types in the nest site selection by the Lesser Spotted Eagle

stands were represented by 21%. The diameter or the height of the main tree species in the stands ($n = 68$) had no effect on the eagle's selectivity (KW; $H = 0.09$, $p = 0.76$; respectively KW; $H = 0.14$, $p = 0.71$). Although the species can breed in younger forests, within the nesting stands the eagle strongly selected older and taller trees (Fig. 4).

The Lesser Spotted Eagle prefers breeding in loose and open forests, using dense stands to a lesser extent (Fig. 5).

When we tested the different categories of stand density with regard to the distance to the forest edge, we didn't find any correlation (Fig. 6).

In this part of the distribution range the LSE nested in dry woods with mean soil moisture index of 1.63 ± 0.92 . The mean canopy cover of the nest stand was 0.74 ± 0.2 (range from 0.2 to 0.95). The eagle often selected nest trees surrounded by impenetrable shrubs or dense undergrowth, as well as thinned forests with no underwood.

The modelling of the relationships between

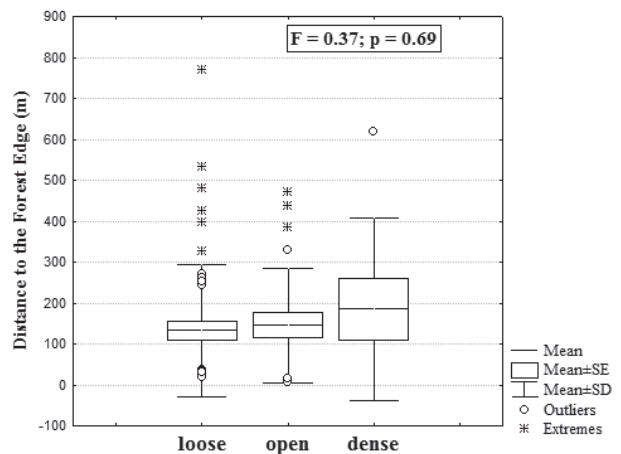


Fig. 6. Effect of the stand density on the location of the nest as regards the proximity to the forest edge

important explanatory factors (altitude, distance to forest edge, distance to water body, and size of forest patch) and the LSE nest site selection resulted in low weights of candidate models (Table 4), indicating high model selection uncertainty. The first ranked model indicates that given the data, it has only 19% chance of being the best one among those considered in the set of candidate models. Comparing the second ranked model to the first one, the evidence ratio indicates that the first model is approximately 1.46 times more likely to be the best approximating model than the second one. Assessing the importance of explanatory factors, only altitude showed considerable significance for our set of candidate models (Table 4). The low values of Wald Statistic for other explanatory factors suggested that they were of very weak importance in explaining the variation in the LSE nest site selection.

From a geographical point of view, the regions showed differences with regard to eight of all tested predictors (Table 5).

Table 4. List of generalized linear mixed models used for the analysis of the nest site selection by the Lesser Spotted Eagle (response variable). Explanatory variables: A – Altitude (m.s.l.), DFE – distance to the forest edge (m), DWB – distance to water bodies (m), SFP – size of the forest patch used for breeding (ha); + additive effect of explanatory variables; RI – relative importance value of each of the candidate models; Parameter estimates \pm SE of explanatory variables and their importance value (Wald Stat.) were taken from the average model. Significant importance (p) of explanatory variables for the models is given in bold.

Model Structure	Explanatory variables				AICc	Δ AIC _c	Weights	RI
	A	DFE	DWB	SFP				
A + A x SFP + DFE x DWB + DFE x SFP	+	+	+	+	98.24	0	0.19	1
A + SFP + DFE x DWB + DFE x SFP	+	+	+	+	99.10	0.85	0.13	0.65
A + A x DFE + DFE x DWB + DFE x SFP	+	+	+	+	99.62	1.37	0.10	0.5
A + A x DFE + A x SFP + DFE x DWB + DFE x SFP	+	+	+	+	99.66	1.42	0.09	0.49
A + A x SFP + DFE x DWB + DFE x SFP + DWB x SFP	+	+	+	+	99.68	1.43	0.09	0.49
A + DFE + A x SFP + DFE x DWB + DFE x SFP	+	+	+	+	99.73	1.48	0.09	0.48
A + DFE x DWB + DFE x SFP + DWB x SFP	+	+	+	+	99.85	1.6	0.09	0.45
A + DWB + A x SFP + DFE x DWB + DFE x SFP	+	+	+	+	100.12	1.88	0.08	0.39
A + SFP + A x SFP + DFE x DWB + DFE x SFP	+	+	+	+	100.16	1.92	0.07	0.38
A + A x DWB + A x SFP + DFE x DWB + DFE x SFP	+	+	+	+	100.17	1.92	0.07	0.38
Estimate \pm SE	0.012 \pm 0.005	0.002 \pm 0.005	0.002 \pm 0.001	0.02 \pm 0.04				
Wald Statistic	5.42	0.13	2.21	0.3				
p	0.02	0.72	0.14	0.59				

Of the topographic variables, slope and altitude showed a very highly significant variation between the regions (Table 5). Soil moisture was one of the variables that strongly determined the differences between the regions. Some of the nest stand characteristics, such as stand density ($F = 2.26$, $p = 0.04$), size of the forest patch ($F = 7.27$, $p = 0.000001$), and forest age ($F = 4.4$, $p = 0.0004$) also had a significant effect on the eagle's selectivity in different regions. The proximity to open grounds ($F = 3.79$, $p = 0.002$) and water sources ($F = 3.44$, $p = 0.003$) influenced the species' choice of a nesting place, while the distances to anthropogenic edges had no such effect. The height of the nesting tree showed a near significant effect in different regions (Table 5). When grouping the different regions in a CLUSTER analysis, Byala Reka River proved to be similar to Derwent Heights, Elhovo plain, and Sakar Mnt. with regard to the predictors that showed a significant effect on the eagle's nest site preferences. Considering the nest place selection by the eagle, the Tundzha

River valley showed similarities to the Harmanliyska River valley and this group was much the same as the first cluster (Fig. 7). On the other hand, eagles breeding in the Kotlenska Mnt. had micro-habitat preferences similar to those of the pairs distributed in the Strandzha Mnt., and this group was very different from all other clusters.

Habitat selection and preferences at a macro-habitat level (home range selection)

As we predicted, the territory selection was related to the preferences for natural grasslands and mixed land use patterns (agricultural mosaic), as well as the avoidance of large forests and arable land (Table 6). The home ranges of LSE contained 26% (range 0.63 – 74.8%) of grassland biotopes (natural grasslands and agricultural mosaic) on average, as this share was more significant than the one available in the landscape (Fig. 8). On average, 22.38% (range 0 – 64.02%) of the land cover of the breeding territories consisted of arable land and 32.87% (range

Table 5. Results of the analysis of the Lesser Spotted Eagle micro-habitat selection in geographically different regions (GLM, * statistically significant difference; ** statistically highly significant difference; *** statistically very highly significant difference)

Variable	R	df	F	p
Height of tree	0.40	7	1.98	0.07
Diameter at breast height	0.22	7	0.49	0.84
Soil moisture	0.75	7	12.80	***
Stand density	0.43	7	2.26	*
Slope	0.63	7	6.83	***
Aspect	0.22	7	0.50	0.83
Altitude	0.76	7	14.05	***
Size of the forest patch	0.65	7	7.27	***
Canopy cover	0.33	7	1.25	0.29
Undergrowth	0.27	7	0.82	0.57
Share of main tree species	0.20	7	0.43	0.88
Stand age	0.55	7	4.40	***
Distance to the forest edge	0.52	7	3.79	**
Distance to a road	0.34	7	1.36	0.24
Distance to a settlement	0.38	7	1.74	0.11
Distance to water bodies	0.50	7	3.44	**

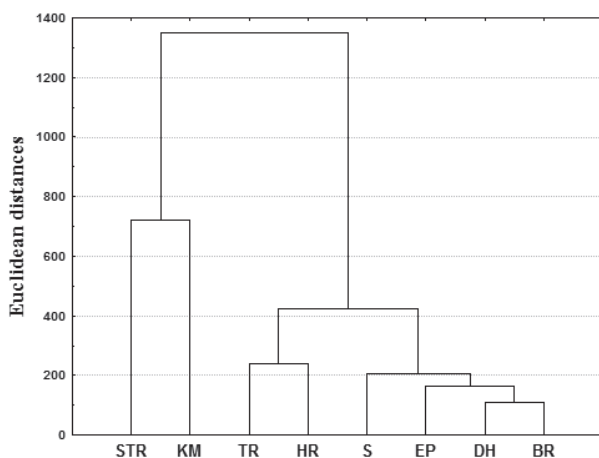


Fig. 7. Measured mean Euclidean distance between geographically different regions in the CLUSTER analysis (Lesser Spotted Eagle micro-habitat selection). STR – Strandzha Mnt; KM – Kotlenska Mnt; TR – Tundzha River; HR – Harmanliyska River; S – Sakar Mnt; EP – Elhovo plain; DH – Dervent Heights; BR – Byala Reka River

0 – 80.8%) were forest areas, as the shares of these habitat types within the home range were smaller than in the landscape (Fig. 8). Contrary to our expectations, the shrubs in the home ranges were significantly more (9.13% on average, range 0 – 31.08%)

than in the random plots (6.37% on average, range 0 – 30.71%) (Table 6, Fig. 8).

The assumption that the LSE strongly avoided anthropogenic elements (settlements, infrastructure, etc.) was not confirmed (Table 6). However, 3.35% (range 0–13.37%) of the home ranges on average were occupied by anthropogenic structures, while in the random plots this percentage was 8.63% on average (range 0.01–87.47%) (Fig. 8). The share of the “Other area” category within the home ranges was significantly bigger than in random plots. As we supposed, the strongest habitat preferences of the LSE were related to the habitat heterogeneity, so we observed that the species clearly selected territories of high habitat diversity (Table 6, Fig. 8). The habitat diversity index of the home ranges varied between 0.72 and 2.3 at a mean value of 1.56. The fragment characteristics also affected the eagle’s selectivity and we found out that the species clearly preferred mosaic structures of landscape, water ponds and rivers, as well as forest patch availability (Table 6). The mean size of the fragments influenced significantly the selection of a home range by this raptor species, with a strong preference for large patches of grassland biotopes (natural grasslands, and agricultural mosaic) and shrubs, and strict avoidance of large forest tracts (Table 6). However, the mean size of the natural grassland patches in the breeding territories ranged from 1.51 to 126.86 ha, i.e. 17.53 ha on average; the mean size of the agricultural mosaic patches was of an average value of 32.59 ha (range 0–97.41 ha); the mean size of the shrubs patches – 10.88 ha on average (range 0.97–92.23 ha); and the mean size of the forest patches ranged from 0 to 2100.34 ha, or 307.52 ha on average.

The home range selection was supported by two meaningful models from our set of best models ($\Delta AIC_c \leq 2$) (Table 7). The highest-ranked model ($\Delta AIC_c = 0.00$, weight = 0.25) included the number of forest patches, the habitat diversity index, the proportion of the forest area and the area of natural grasslands in the territory, while the second-ranked model ($\Delta AIC_c = 0.29$, weight = 0.21) included only the habitat diversity index and the proportion of forests and natural grasslands. Estimating the average importance of explanatory predictors, only the habitat diversity index, the area of forests and the natural grasslands showed relative importance to the eagle’s territory selection (Table 7). However, the habitat diversity index had the strongest effect in this process (Wald stat. 14.7, $p = 0.0001$).

From a geographical point of view, the significant differences were related to 14 of 16 tested predictors (Table 8). Only the number of landscape

Table 6. Results of the macro-habitat selection analysis (GLM, * - statistically significant difference; ** - statistically highly significant difference; *** - statistically very highly significant difference)

Variable	Home ranges			Random plots			R	df	F	p
	N	Mean ± SD	Range	N	Mean ± SD	Range				
Number of water bodies	79	4.22 ± 3.51	0-21	67	3.94 ± 5.88	0-42	0.17	1	4.22	*
Number of landscape patches	79	87.42 ± 25.75	21-157	67	62.66 ± 50.47	1-245	0.41	1	29.12	***
Number of forest patches	79	5.46 ± 4.05	0-20	67	3.72 ± 5.45	0-26	0.36	1	20.82	***
Mean size of the forest patches (ha)	79	307.52 ± 376.25	0-2100.34	67	679.24 ± 1271.48	0-5286.42	0.20	1	5.76	*
Mean size of the natural grassland patches (ha)	79	17.53 ± 18.89	1.51-126.86	67	13.68 ± 18.58	0-86.58	0.28	1	12.25	***
Mean size of the agricultural mosaic patches (ha)	79	32.59 ± 24.66	0-97.41	67	16.14 ± 25.34	0-129.21	0.39	1	26.38	***
Mean size of the shrub patches (ha)	79	10.88 ± 14.33	0.97-92.23	67	6.86 ± 8.12	0-35.50	0.27	1	11.59	***
Shannon <i>H'</i>	79	1.56 ± 0.31	0.72-2.30	67	1.08 ± 0.60	0.01-2.21	0.47	1	40.11	***
Forest area (ha)	79	412.47 ± 270.49	0-1014	67	488.02 ± 489.32	0-1252.54	0.23	1	7.73	**
Arable lands (ha)	79	280.85 ± 250.41	0-803.48	67	347.86 ± 399.12	0-1131.16	0.20	1	5.69	*
Natural grasslands (ha)	79	252.62 ± 174.63	7.80-695.38	67	96.51 ± 96.56	0-469.55	0.47	1	40.56	***
Agricultural mosaic (ha)	79	73.49 ± 81.97	0-305.15	67	62.92 ± 101.23	0-396.18	0.20	1	5.72	*
Shrubs (ha)	79	114.54 ± 92.05	0-390.06	67	79.99 ± 96.08	0-385.37	0.31	1	14.84	***
Anthropogenic area (ha)	79	42.08 ± 39.59	0-167.79	67	108.36 ± 200.12	0.15-1097.73	0.12	1	2.26	0.14
Water bodies (ha)	79	23.50 ± 23.08	0-104.28	67	24.03 ± 35.81	0-225.91	0.10	1	1.53	0.22
Other area (ha)	79	55.45 ± 54.77	0.41-301.47	67	47.31 ± 85.49	0-564.57	0.31	1	15.82	***

Table 7. List of generalized linear mixed models used for the analysis of the home range selection by the Lesser Spotted Eagle (response variable). Explanatory variables: NLP – number of landscape patches, NFP – number of forest patches, *H'* – Shannon Diversity Index of habitats, FA – forest area, NG – natural grasslands, OA – other area; + additive effect of explanatory variables; RI – relative importance value of each of the candidate models; Parameter estimates ± SE of explanatory variables and their importance value (Wald Stat.) were taken from the average model. Significant importance (p) of explanatory variables for the models is given in bold.

Model Structure	Explanatory variables							AICc	ΔAICc	Weights	RI
	NLP	NFP	<i>H'</i>	FA	NG	OA	RI				
NFP + <i>H'</i> + FA + NG		+	+	+	+			147.86	0	0.25	1
<i>H'</i> + FA + NG			+	+	+			148.15	0.29	0.21	0.87
NFP + <i>H'</i> + FA + NG + OA		+	+	+	+	+		148.32	0.46	0.20	0.79
<i>H'</i> + FA + NG + OA			+	+	+	+		148.76	0.9	0.16	0.64
NLP + NFP + <i>H'</i> + FA + NG	+	+	+	+	+			149.64	1.78	0.1	0.41
NLP + <i>H'</i> + FA + NG	+		+	+	+			149.86	1.99	0.09	0.37
Estimate ± SE	-0.004 ± 0.008	0.09 ± 0.06	-3.27 ± 0.85	-0.003 ± 0.0009	-0.006 ± 0.002	0.004 ± 0.004					
Wald Statistic	0.23	2.38	14.70	9.43	13.12	1.29					
p	0.63	0.12	0.0001	0.002	0.0003	0.26					

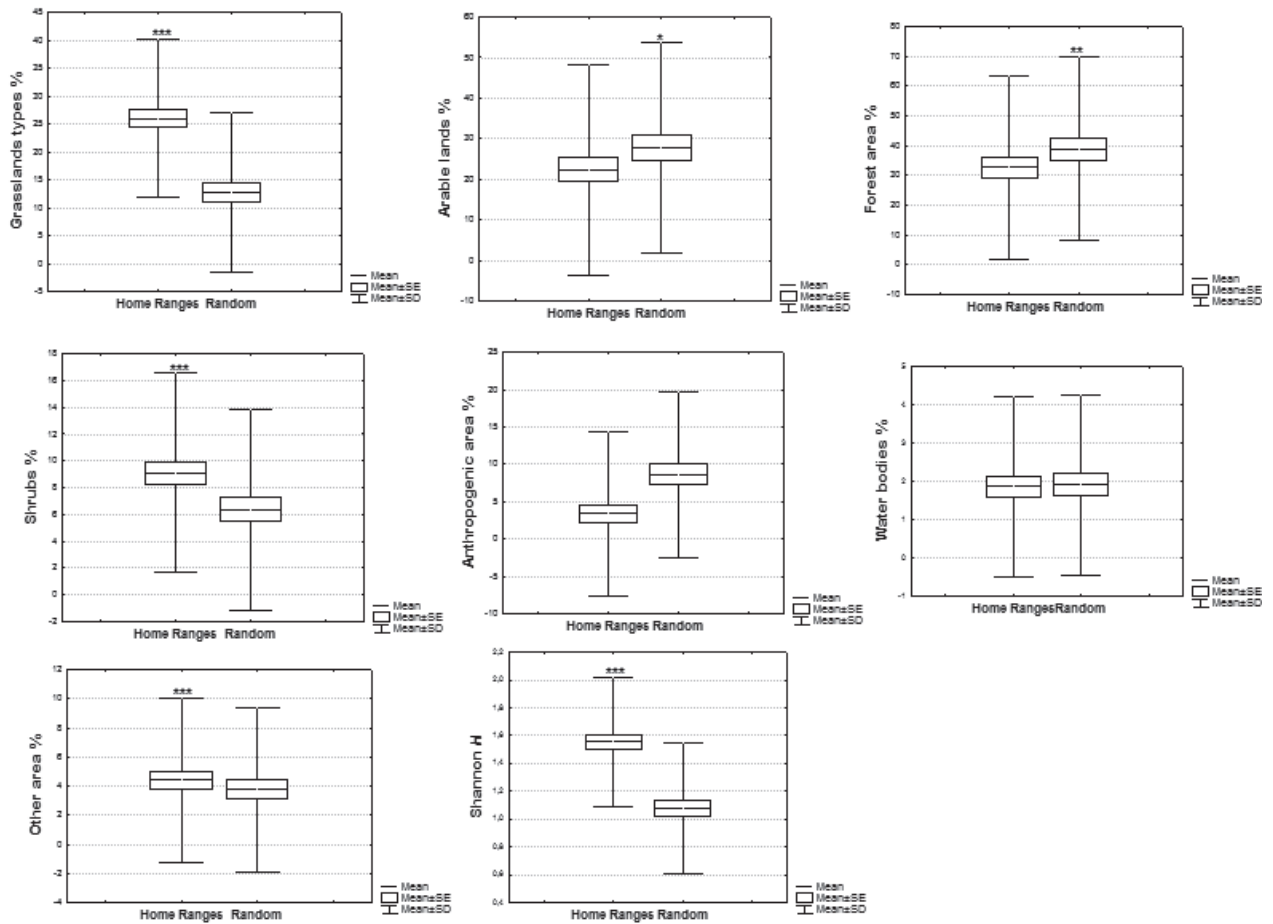


Fig. 8. Proportions of the different habitat types and Shannon Diversity Index in the Lesser Spotted Eagle home ranges and random plots

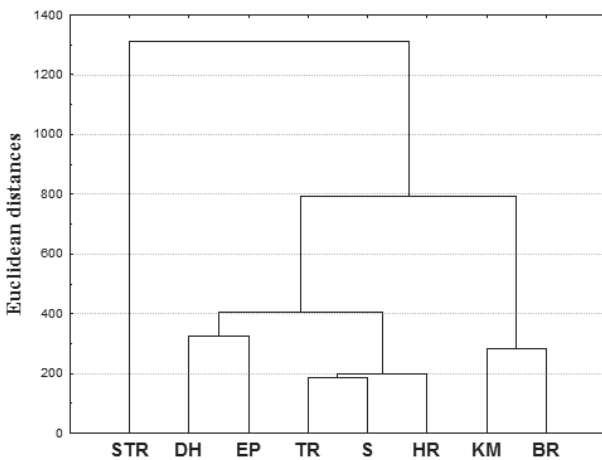


Fig. 9. Measured mean Euclidean distance between geographically different regions in the CLUSTER analysis (Lesser Spotted Eagle macro-habitat selection). STR – Strandzha Mnt; KM – Kotlenska Mnt; TR – Tundzha River; HR – Harmanliyska River; S – Sakar Mnt; EP – Elhovo plain; DH – Derwent Heights; BR – Byala Reka River

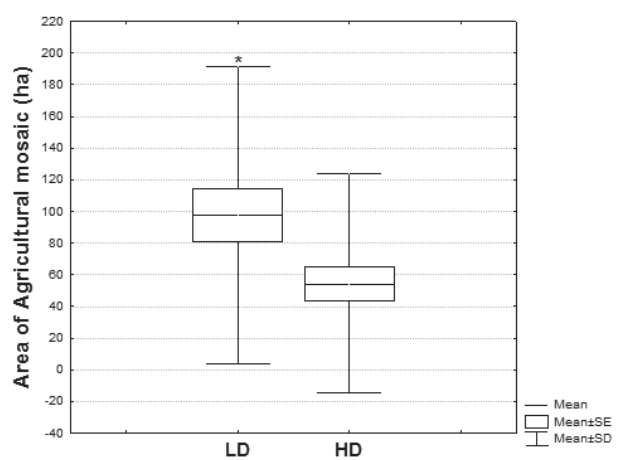


Fig. 10. Effect of the agricultural mosaic habitat type on the Lesser Spotted Eagle density (LD – low density, HD – high density).

Table 8. Results of the analysis of the Lesser Spotted Eagle macro-habitat selection in geographically different regions (GLM, ** statistically highly significant difference; *** statistically very highly significant difference)

Variable	R	df	F	p
Number of water bodies	0.56	7	4.64	***
Number of landscape patches	0.30	7	1.02	0.42
Number of forest patches	0.49	7	3.17	**
Mean size of the forest patches	0.55	7	4.36	***
Mean size of the natural grassland patches	0.51	7	3.50	**
Mean size of the agricultural mosaic patches	0.69	7	9.40	***
Mean size of the shrub patches	0.64	7	7.03	***
Shannon H'	0.59	7	5.36	***
Forest area	0.67	7	8.22	***
Arable lands	0.47	7	2.81	**
Natural grasslands	0.68	7	8.64	***
Agricultural mosaic	0.47	7	2.82	**
Shrubs	0.63	7	6.83	***
Anthropogenic area	0.35	7	1.45	0.20
Water bodies	0.61	7	5.94	***
Other area	0.46	7	2.72	**

patches and the area of anthropogenic structures did not differ significantly between the regions.

The most powerful factors describing the eagle's regional preferences at a macro-habitat scale were: number of water bodies, mean size of the forest patch, mean size of the agricultural mosaic patch, mean size of the shrubs patch, Shannon Diversity Index, as well as proportion of forests, natural grasslands, shrubs and water sources (Table 8). In terms of proximity of regions, these predictors (showing high significance) grouped the pairs breeding in the Tundzha River valley, the Sakar Mnt., and the Harmanliyska River valley into a single cluster (Fig. 9). The second cluster comprised the Kotlenska Mnt. and the Byala Reka River valley, while the third one included the Derwent Heights and the Elhovo plain. It is obvious that the home ranges of the LSE in the Strandzha Mnt. are definitely different from all other groups (Fig. 9).

Influence of the habitat structure on the eagle's density

Our expectations that the habitat structure significantly affected the eagle's density were not

Table 9. Effect of the habitat structure on the Lesser Spotted Eagle density (GLM analysis, significant factors are given in bold; Home ranges: in high density, n = 43, in low density, n = 32)

Variable	R	df	F	p
Aspect	0.21	1	3.25	0.08
Altitude	0.04	1	0.13	0.72
Canopy cover	0.01	1	0.01	0.94
Stand age	0.01	1	0.01	0.94
Distance to the forest edge	0.18	1	2.31	0.13
Distance to a road	0.07	1	0.31	0.58
Distance to a settlement	0.20	1	2.83	0.10
Distance to water bodies	0.02	1	0.04	0.84
Number of the water bodies	0.11	1	0.84	0.36
Number of the forest patches	0.08	1	0.48	0.49
Number of the natural grassland patches	0.04	1	0.13	0.72
Number of the agricultural mosaic patches	0.01	1	0.01	0.93
Number of the shrub patches	0.19	1	2.64	0.11
Mean size of the natural grassland patches	0.01	1	0.01	0.92
Mean size of the agricultural mosaic patches	0.12	1	1.04	0.31
Mean size of the shrub patches	0.10	1	0.76	0.39
Shannon H'	0.07	1	0.30	0.58
Arable lands	0.02	1	0.02	0.88
Natural grasslands	0.13	1	1.15	0.29
Agricultural mosaic	0.25	1	4.76	0.03
Shrubs	0.00	1	0.00	0.98
Water bodies	0.07	1	0.32	0.57
Other area	0.10	1	0.71	0.40

confirmed. Of the 23 tested variables related to the nest site and the home range selection, only the area of agricultural mosaic showed a significant effect on the eagle's density ($F = 4.76$, $p = 0.03$). It seems that pairs breeding in high densities avoid this factor (Table 9, Fig. 10). Indeed, the share of natural grasslands in the home ranges of the species harbouring high densities was bigger than in territories of low density, but the differences were not significant ($F = 1.15$, $p = 0.29$). Of the nest site characteristics, only the aspect showed a close to significant effect ($F = 3.25$, $p = 0.08$). Eagles in high density areas showed stronger preferences for S-SE orientated nest sites than those occupying low density ranges.

Discussion

The data related to the habitats of LSE in Bulgaria include only sporadic references, but there is no detailed study on the species' preferences neither at a micro-habitat level, nor as macro-habitat features. It was however mentioned that this eagle was found in different habitats, mainly in the southern and the eastern parts of the country (NANKINOV 1985, SIMEONOV et al. 1990, MILCHEV 1991, 1994, IANKOV et al. 1996, BAUMGART 1996, KUZMANOV 1996, MILCHEV & KOVACHEV 1998), inhabiting mostly deciduous and mixed forests, moist alluvial and, to a lesser extent, coniferous stands, avoiding high mountains (DEMERDZHIEV et al. 2007).

Our data confirm previous reporting, indicating that the species prefers building its nests close to the base of the trunk or the trunk branching, avoiding the top of the tree (ABULADZE 1996, PUGACEWICZ 1996, IVANOVSKY 1996, SKUJA & BUDRYS 1999, LANGGEMACH et al. 2001, VÄLI 2003, BERGMANIS 2004). In Southeast Bulgaria, near the southern periphery of the distribution range, the species prefers dry broad-leaved forests, avoiding coniferous woods (but see VLACHOS & PAPAGEORGIU 1996, POIRAZIDIS et al. 2007, 2019). Unlike the northern part of the distribution range, where the nest sites are situated mostly in Spruce-dominated stands and the LSEs use mainly Spruce as a nest tree (VÄLI 2003, LÖHMUS 2006), in our study area, the nests were situated predominantly in pure or mixed Oak forests as $\frac{2}{3}$ of the nesting trees belonged to different Oak species. In different parts of its distribution range this raptor breeds in deciduous stands or areas of dominating mixed forests, where the dominant trees species are Spruce, Birch, Black alder or Oak (SCHELLER et al. 2001, BERGMANIS 2004, TREINYS 2004, TREINYS & MOZGERIS 2010, PAKUL et al. 2019). However, in most of the countries the LSE builds its nests predominantly on Spruce, but nesting on different broad-leaved species was also reported (ABULADZE 1996, SKUJA & BUDRYS 1999, VÄLI 2003, BERGMANIS 2004, LÖHMUS 2006, MIRSKI 2009, VÄLI et al. 2009, TREINYS & MOZGERIS 2010, DRAVECKÝ et al. 2015b). In general, this species avoids nesting on Pine trees, but in some areas this nesting substratum is of relative importance (VLACHOS & PAPAGEORGIU 1996, POIRAZIDIS et al. 2007, 2019, MIRSKI 2009, DRAVECKÝ et al. 2015b).

Throughout its distribution range, the LSE is a typical forest-dwelling raptor, nesting more or less in large wood tracts. Breeding in forested tree-lines along rivers or small streams recorded in the south-eastern part of Bulgaria is not a distinctive characteristic of this species and appears to be an ecological

adaptation in this part of the distribution range. Since in some areas the habitats offer good foraging conditions, but lack typical forests, the eagles start building their nests in vegetation dominated by Poplar or Willow tree-lines along the rivers. Similar nesting biotopes of this eagle are known from the Caucasus region (ABULADZE 1996, 2001, VÄLI et al. 2009).

The height and the diameter of the nest tree were similar to those recorded in other parts of the distribution range (VLACHOS & PAPAGEORGIU 1996, SKUJA & BUDRYS 1999, POIRAZIDIS et al. 2007, VÄLI et al. 2009, DRAVECKÝ et al. 2015b). However, in the northern limit of the range and in the Caucasus region, where the eagle breeds on Spruce or Poplar, the average height of the nest tree, respectively the height of the nest above the ground, is bigger (ABULADZE 1996, VÄLI 2003, LÖHMUS 2006). In the southern part of the distribution range, the LSE is competing for nest sites with other raptor species. Most of the widely distributed forest-dwelling raptors, such as Common Buzzard, Northern Goshawk, Sparrowhawk (*Accipiter nisus* Linnaeus, 1758), European Honey Buzzard (*Pernis apivorus*, Linnaeus 1758) and Booted Eagle are smaller than the LSE, putting the species in a favourable position. Therefore, the LSE successfully occupies nests of other raptor species. On the other hand, Common Buzzard and Northern Goshawk are resident species and their breeding period begins earlier, before the arrival of the LSE. Thus, they may have occupied the LSE nest and started incubating prior to its return. In such cases, the eagles build a new nest or occupy a vacant one, but sometimes, when there are no suitable trees, they occupy the territory, but they miss the mating season and fail to breed. Then, in certain circumstances, other forest-breeding species may limit the reproductive performance of LSE. Cases of LSE nests occupied by Common Buzzard were reported for the Baltic region (SKUJA & BUDRYS 1999, VÄLI 2003, LÖHMUS 2006). Also, the Common Raven (*Corvus corax* Linnaeus 1758), due to its antagonistic and aggressive behaviour in its relationships with raptors, could limit the LSE reproduction in some cases. We observed a pair of ravens building a new nest at a distance of 10 m from the eagles' nest. When the eagles returned in the end of April, the ravens had chicks and defended the territory very aggressively. As a result, the eagles did not breed during that particular season. However, our data show that the LSE breeds successfully at a distance of several hundred meters from nesting Common Buzzard, Northern Goshawk and Booted Eagle. Probably, the competition with large apex forest-nesting predators such as White-tailed Eagle

and Golden Eagle (*Aquila chrysaetos* Linnaeus 1758) is not a common phenomenon, because their habitat requirements differ. In the northern part of its distribution range, the LSE coexists with White-tailed Eagle, breeding in high densities without suffering any adverse effects on its reproduction (DEMENTAVIČIUS et al. 2019). However, we recorded a case when a White-tailed Eagle had occupied an LSE nest and the meso-predator had to shift its territory. It is also possible that in some territories in the Strandzha Mnt., where the species coexists with Golden Eagle, breeding in this area in a relatively high density (MILCHEV 1994), the top predator could displace or limit the smaller LSE; however, this issue needs further clarification. Such an effect could be the reason why the LSE accepts urban proximity in Estonia, being forced by the Golden Eagle (VÄLI et al. 2004). Being an apex predator, the Eagle Owl could also have certain insignificant negative impact on the LSE.

Our results confirm previous findings recorded in other parts of the distribution range, indicating that the species notably selects nest sites in proximity to open spaces and avoids forest interior (VÄLI 2003, MIRSKI 2009, ZUB et al. 2010, MACIOROWSKI & MIRSKI 2014, PAKUL et al. 2019). However, the mean distance from the nest to the forest edge was bigger than reported for the northern limit of the range (VÄLI 2003, LÖHMUS 2006), and smaller than the one recorded in the core of the population (BERGMANIS 2004, TREINYS 2004, ZUB et al. 2010, MACIOROWSKI & MIRSKI 2014, PAKUL et al. 2019). Similar distances to open areas were measured in other parts of the southern periphery of the range (POIRAZIDIS et al. 2007) and the westernmost limit (LANGGEMACH et al. 2001). The species demonstrated a different response regarding the proximity to water sources. Like our findings show, in some regions the LSE prefers to place its nest near rivers or water ponds (VÄLI et al. 2004, LÖHMUS & VÄLI 2005, POIRAZIDIS et al. 2007), while in others there is no such effect (TREINYS 2004, MACIOROWSKI & MIRSKI 2014). But why does the species definitely prefer the proximity to water sources in some areas, while in others it has no such preferences? The simplest explanation is the effect of prey abundance and prey accessibility. Throughout its distribution range the LSE hunts mainly in different grassland landscapes, feeding mostly on voles and other small mammals (LÖHMUS & VÄLI 2004, DRAVECKÝ et al. 2008, ZUB et al. 2010, VÄLI 2012), being able to capture them effectively in low vegetation (MIRSKI 2010), and preferring habitats where these prey species are more accessible. Grassland management has a positive effect on both

the nest site occupancy and the reproductive success (VÄLI et al. 2017). Although non-managed grasslands are rich in various prey species, these are not accessible under tall vegetation. On the other hand, inappropriate management of grasslands could have a detrimental effect on biodiversity, shrinking and adversely affecting the populations of different prey species (DEMERDZHIEV et al. 2016). Alternatively, water ponds and rivers may provide supplementary prey, such as amphibians and reptiles, especially in years of poor availability of voles (TREINYS & DEMENTAVIČIUS 2004). Amphibians and reptiles form an important part of the eagle's diet in some parts of the species' distribution range (ABULADZE 1996, IVANOVSKY 1996, VLACHOS & PAPAGEORGIU 1996) with amphibians being a substantial food resource especially in spring (VÄLI 2012). Therefore, we assume that the LSE prefers to breed near water bodies where the concentration of amphibians is highest.

We found out that the anthropogenic proximity did not affect the eagle's nest site selection. This was similar to the findings related to the center and the northern limit of the species' population (VÄLI et al. 2004, MACIOROWSKI & MIRSKI 2014, PAKUL et al. 2019), and differed from the results achieved in other countries, where the LSE was reported to be strongly avoiding human structures (LANGGEMACH et al. 2001, TREINYS 2004). On the other hand, just like other studies found, the nests of the eagle were situated near roads rather than settlements. Human settlements proved to be a more serious disturbance factor than roads. Consequently, when selecting breeding sites, the LSE would rather avoid settlements. Since roads in forests are used less often, mainly by people hiking or collecting mushrooms and herbs, and may only accidentally get visitors to the nest sites, such human activities do not affect the eagle's selectivity. However, when foresters implement activities such as logging, timber transportation etc. during the pre-breeding season (when the eagles have already arrived) or during the incubation period, they could cause displacement or breeding failure of birds. Therefore, the history of use of the landscape also affects the nest site selectivity. In the selection of nest sites, the LSE faces a trade-off decision related to the proximity of foraging grounds (grasslands, fields, water ponds) and human disturbance (settlements, farms, roads) (VÄLI et al. 2004). It is of particular importance to keep in mind that the sensitivity of eagles to human pressure depends on the level of human presence. In the Baltic countries the areas are poorly populated and the settlements are mostly individual farms or small villages, which explains the eagle's tolerance.

At the southern periphery of the distribution range (Bulgaria and Greece), where human settlements are more densely populated, the eagle places its nests in more remote sites.

Stand composition and forest structure were evaluated throughout the whole area of the species distribution (SKUJA & BUDRYS 1999, BERGMANIS 2004, LÖHMUS 2005, 2006, LÖHMUS & VÄLI 2005, TREINYS & MOZGERIS 2006, POIRAZIDIS et al. 2007, TREINYS et al. 2009, MACIOROWSKI & MIRSKI 2014, PAKUL et al. 2019). Our results confirmed that the availability of old growth trees, rather than the age of the forest stand, determines the nest site selection of LSE. The eagles prefer mature forests (SKUJA & BUDRYS 1999, BERGMANIS 2004), and natural stands (LÖHMUS 2005) but can breed successfully in middle-aged and even young growth woods; however, they always select older and taller trees for nest building. This is a particularly important fact from the conservation point of view and should be taken into account in forest management. Hence, when planning forest logging in stands, patches of older and taller trees of natural crown structure should be set aside. However, currently we do not evaluate the possible differences in the species' occupancy rates between young and mature stands. Since the LSE is a long-lived raptor showing site fidelity (TREINYS et al. 2017, VÄLI & BERGMANIS 2017), old forests may guarantee the long-term occupancy of nest sites, yet this assumption needs further investigation. Unbalanced forestry usually reduces the availability of some structural elements in forests. As a result of such exploitation, many species, which require such elements of the habitat, suffer population decline, become threatened or go extinct (LÖHMUS 2005). It has been proven that forest operations represent one of the most important factors affecting the LSE population in large areas (TREINYS & MOZGERIS 2006). It should be taken into account that the increasing structural diversity in forests raises the probability of raptor nesting and may be a successful restoration technique in degraded forests or plantations (LÖHMUS & VÄLI 2005). In general, published data concerning the size of the forest patches used by the LSE for breeding are insufficient and little-known (VÄLI 2003). We found out that the species bred in forest patches of different size, but demonstrated avoidance of relatively small patches. The LSE is a shy raptor, building its nests hidden in the crown, but small patches do not offer good cover, increasing the probability of disturbance and the risk of predation. Hence, the eagle may become vulnerable to thinning of nest stands. In some cases, the species is put in a trade-off situation, choosing the proximity

of abundant feeding habitats and compromising on nest sites. We found out that the eagles often selected trees with Ivy (*Hedera helix* L.) into the crown, providing very good cover for the nest. Since very small patches are less preferred by the species, they are possibly less often occupied in the long run, yet this hypothesis needs additional verification. Like in the other parts of the southern distribution area, the LSE bred mainly in open and loose forests avoiding dense stands (POIRAZIDIS et al. 2019, but see ABULADZE 1996, 2001, VÄLI et al. 2009). Similar to Greece, we found out that the eagle mainly bred in dry forests, in contrast to the center and the northern parts of the distribution range, where the species breeds in forests of a constant or periodically increasing level of humidity (SKUJA & BUDRYS 1999, IVANOVSKY 2000, LANGGEMACH et al. 2001, SHELLER et al. 2001, BERGMANIS 2004). The mean canopy closure was similar to the findings in the other countries. The species prefers dense canopy, which is considered protection against bad weather conditions or predation by other forest-dwelling raptors (IVERSON et al. 1996, KRÜGER 2002). Within the study area, some of the nests were surrounded by impenetrable shrubs or dense undergrowth, while others were situated in forest areas with no bush vegetation. The first pattern differs from the model of nest site selection reported by TREINYS et al. (2009), where the LSE avoided shrubs in the immediate vicinity of the nest. But such a discrepancy only appears at first sight. TREINYS et al. (2009) clarify that the low avoidance of shrubland was in the context of intensive timber harvesting, where shrubland was mostly clear-cut areas at different stage of development, which is completely different from our "bush selecting strategy". In the cases reported by TREINYS et al. (2009), the LSE actually avoided clear-cuts of different age, but the reaction of the species was not related to bushland in stands as a particular habitat type. We consider the building of a nest on a tree surrounded by shrubs or dense undergrowth to be the species' adaptation to resist disturbance and persecution. In its life-history the LSE, like other raptors, used to be persecuted in the country for years. Nowadays, the species is strictly protected by the law, but the long-term persecution may have forced the eagle to develop a mechanism to counteract extermination. On the other hand, in our geographical area human settlements are of higher population density, compared to the Baltic region, and many of the eagle's home ranges are easily accessible by humans, which is the reason why the species places its nests in more remote sites. Hence, it is possible that this shy raptor selects places with dense shrubs or undergrowth to

limit the access to its nest and to guarantee successful reproduction. In support of our hypothesis, we observed that in almost all cases of eagles breeding in small thin patches, the nests were surrounded by impassable vegetation.

Contrary to our prediction, the LSE nest site selection was strongly influenced by the topographic characteristics of the place. This deviation, however, was due to the effect of the surveyed territory, rather than the actual choice of the eagle. The avoidance of steep slopes and high altitude was related to the eagle's preferences as regards foraging habitats. In our study area, the elevation ranged between 20 and 1130 m. a.s.l., with no high mountains. The favoured foraging habitats, such as natural grasslands (including pastures and meadows), were situated in open fields, often in river valleys, far from higher mountain areas covered with continuous forests. Hence, this determines the species' nest site selection in plain and hilly areas as well as in some low mountains, where the eagle places its nest at the foot of the slopes, near river valleys. The LSE is a medium-sized bird of prey and, unlike large species, it does not need a steep slope where air currents would help the eagle gain height when flying off the nest. In some areas of the distribution range this species prefers low altitude (POIRAZIDIS et al. 2007, 2019), but in others it is well distributed in uplands at about 1000 m a.s.l. (DRAVECKÝ et al. 2015b). In Bulgaria, some of the breeding localities are found in high mountains, reaching 1500 m a.s.l. (DEMERDZHIEV et al. 2007). Thus, we assume that the presence of grasslands in the habitat, rather than elevations or slopes, determines the eagle's nest site selectivity. Finally, we would like to emphasize that the aspect of the nest site obviously plays an important role in the eagle's choice. The species avoids southward and northward directions, as this is related to the weather conditions. Southeast Bulgaria is situated in the Transitional-Mediterranean Climate Region, characterized by a high level of solar radiation in summer and long periods of high temperatures. The avoidance of direct south exposure probably protects the nest from prolonged sunshine and overheating of the juveniles. Direct north exposure is also unfavourable, because in April and early May sudden spells of cold weather and continuous rainfall, which are not uncommon, would increase the risk of breeding failure. Similar avoidance of north-facing slopes was reported for a small population of the species breeding in Northern Greece (POIRAZIDIS et al. 2007), as well as for eagles nesting in Lithuania (SKUJA & BUDRYS 1999).

As we expected, the eagle's nest site selection

demonstrated differences between the regions for most of the tested variables. The species' nest sites in the neighboring regions of Sakar Mnt., Elhovo plain and Dervent Heights were similar to those in the Byala Reka River valley, while the ones in the Tundzha River valley showed similarities to the Harmanliyska River valley, as this group was analogous to the first cluster. In support of our expectations, the eagles breeding in the Kotlenska Mnt. had micro-habitat preferences similar to those of the pairs distributed in the Strandzha Mnt., as this group was very different from the other clusters.

The current study confirmed that with regard to territory selection, the LSE clearly preferred grassland biotopes (natural grasslands and agricultural mosaic), and strongly avoided arable lands and large forested areas. The home ranges of the species contained more grassland type vegetation than available in the landscape composition. The shares of grasslands in the eagle's territory were similar to those reported for the other parts of the species' distribution range (LANGGEMACH et al. 2001, MACIOROWSKI & MIRSKI 2014, VÄLI et al. 2017), or even bigger (VLACHOS & PAPAGEORGIU 1996, ZUB et al. 2010, PAKUL et al. 2019). The presence of forests in the species' home ranges within our study area was obviously lower than reported for most of the distribution range (VLACHOS & PAPAGEORGIU 1996, VÄLI 2003, VÄLI et al. 2004, 2017, ZUB et al. 2010, MACIOROWSKI & MIRSKI 2014, PAKUL et al. 2019), but slightly higher than recorded in Germany, on the westernmost limit of the species' range (LANGGEMACH et al. 2001, SHELLER et al. 2001). However, our results confirmed other findings related to the avoidance of large forest areas by LSE (VÄLI 2003, VÄLI et al. 2004, ZUB et al. 2010, MACIOROWSKI & MIRSKI 2014). On the other hand, the mean share of arable land in the eagle's home ranges in Southeast Bulgaria was twice the size of the ones reported for the other countries (VLACHOS & PAPAGEORGIU 1996, ZUB et al. 2010, MACIOROWSKI & MIRSKI 2014, VÄLI et al. 2017). Surprisingly beating our expectations, in this study the presence of shrubs in the home ranges was significantly higher than in the random plots and their relative share was bigger than reported for the other parts of the distribution range (VLACHOS & PAPAGEORGIU 1996, MACIOROWSKI & MIRSKI 2014, VÄLI et al. 2017). But does the LSE really prefer territories with a bigger share of shrublands or, since their proportion within the home range is smaller compared to other land cover types, they do not play a particular role, neither do they affect the eagle's selection? There are two possible explanations to this apparent contradiction. In the first scenario, the LSE

does not really prefer territories harbouring a bigger share of shrublands, because this raptor mainly prefers natural grasslands and mixed land use patterns, hence the greater abundance of shrublands in the selected territories than in the random plots was just a coincidence. In support of this statement, the LSE hunts mainly in grasslands and other agricultural biotopes (MIRSKI 2009, 2010, VÄLI et al. 2017) and uses shrubland only as an opportunistic strategy (LÖHMUS 2001). According to the second scenario, although the eagle prefers foraging in different types of grasslands, the share of shrubs has a direct influence on the species' selectivity. The simple explanation to this phenomenon lies in the species' diet and the habitats of its prey. In our study area, the second most frequently captured prey was the Northern White-breasted Hedgehog (*Erinaceus roumanicus* Barrett-Hamilton, 1900), providing the major share of the biomass (DEMERDZHIEV et al. 2019). This species prefers places overgrown with bushes, where it can easily find shelter. Within the surveyed area, the shrubs are scattered among pastures and various types of grassland vegetation, forming a mosaic type of habitat. Thus, the eagle can easily capture hedgehogs that use shrubs for shelter, but often forage and roam in grasslands. Particular preferences were demonstrated for shrubs, which were thinned and scattered in small groups in the grassland habitats. Such habitat types are quite suitable for the eagle to hunt, since the vegetation is usually low, due to grazing, and the clear spaces between the shrubs enable the predator to swoop down and catch the hedgehogs. The groups of shrubs provide an appropriate habitat for voles, LSE's most frequently captured prey, but also for various species of lizards and snakes that represent additional items of the eagle's diet. In many of the eagle's territories, shrubs represent a habitat preferred by the colonies of voles and other small rodents, found there in high densities, turning the territories into particularly attractive areas. Therefore, we assume that shrubs are definitely preferred by LSE in the territory selection process, and this specific habitat formation plays an important role in the macro-habitat selection. However, all things considered, the breeding territories of the LSE in this part of the distribution range are characterized by a bigger share of open habitats (grasslands and arable lands) compared to the proportion of forested areas. Normally, eagles avoid arable lands, but these areas could also provide foraging habitats although less commonly used (MIRSKI 2009, 2010, ZUB et al. 2010, VÄLI et al. 2017). Like in another survey, our study found that the LSE did not demonstrate strong avoidance of anthropogenic structures

in its home ranges (MACIOROWSKI & MIRSKI 2014, but see TREINYS 2004). However, the average share of infrastructure in the home ranges of the species was smaller than that in random plots. The artificial surfaces did not provide foraging places for the eagle and represented a potential source of disturbance. The preferences for the category "Other areas" can be explained by the fact that it comprises vineyards and orchards, dust roads, etc., which, although not being of primary importance, can also be used for hunting, especially their edges.

Throughout its distribution range, the LSE inhabits mosaic landscape structures, where forests alternate with different types of grasslands, arable lands, river valleys and water ponds (LANGGEMACH et al. 2001, SHELLER et al. 2001, VÄLI 2003, 2012, VÄLI et al. 2004, 2017, BERGMANIS 2004, TREINYS 2004, LÖHMUS & VÄLI 2005, POIRAZIDIS et al. 2007, 2019, TREINYS & MOZGERIS 2010, ZUB et al. 2010, MACIOROWSKI & MIRSKI 2014, PAKUL et al. 2019). As we expected, habitat heterogeneity was the most important factor driving the eagle's territory selection. Probably this factor strongly determines the macro-habitat preferences in the northern limit of the species' distribution range (VÄLI et al. 2017), affecting the process in two different aspects: space and time. On the other hand, although habitats differ within the species' distribution range, in the Baltic region landscape diversity shows no geographical variation in the preferences of the eagle (VÄLI et al. 2004). But why does habitat diversity play such an important role in territory selection in certain parts of the distribution range of this raptor, while in others the species does not follow the same pattern? We believe that different vegetation cover, formed by different climate, is the reason for the eagle's different response. In hemiboreal climate, plant coenoses are considerably less numerous than in the Transitional–Mediterranean Zone (BONN & NEHUHASL 2004). Hence, fewer types of vegetation form and characterize the heterogeneity of the habitat. In landscapes of lower heterogeneity, the eagle has to select territories, where habitats are generally uniform. This is also related to the land use history, which is known to be correlated with the distribution of many forest-dwelling birds in Europe (MIKUSIŃSKI & ANGELSTAM 1998, TOMIAŁOJĆ 2000). However, land use history is the main factor affecting the habitat relationships of LSE, behind the geographical variation (VÄLI et al. 2004). Probably these are the reasons why, when choosing a habitat in the Baltic region, the eagle shows no difference in its response to landscape diversity between the territories and the random plots. On the contrary, in the Transitional–Mediterranean Climate Zone, the

landscape diversity is in general much greater due to the participation of more types of vegetation in its formation on one hand, and the different land use history on the other. Thus, in Southeast Bulgaria the different types of grasslands are mostly dispersed among plots of arable land, forest fragments, shrubs and other agricultural biotopes, forming a unique mosaic landscape. Habitat heterogeneity has been recognized as one of the main landscape characteristics, determining biodiversity patterns (TUANMU & JETZ 2015), and creating conditions for the availability of more abundant and different victims that positively affect the distribution of the birds of prey (DEMERDZHIEV 2011). Therefore, at the southern periphery of the distribution range, LSE is probably more selective when choosing a home range, selecting more diverse habitats and rejecting those characterized by greater monotony. This hypothesis, however, requires further scrutiny and clarification.

The previous studies on the habitat requirements of the LSE did not analyze the effect of fragment characteristics of different landscape types on the species' selectivity, but similar surveys are known for other raptors (HOTHORN et al. 2011). Our study presents for the first time the relationship between the eagle's choice and the availability and size of fragments of different habitat types. We found out that the species clearly preferred mosaic structures of landscape, as well as sufficient abundance of water bodies and forest patches. The first two factors are related to the foraging of the eagle, because the mosaic structure of landscape provides more and diverse prey species and the water bodies ensure additional food resources such as amphibians and some reptiles. On the other hand, the sufficient number of forest patches guarantees nest sites availability and *vice versa* – the shortage of forest patches reduces the nesting options. Last but not least, the size of the fragments also strongly affects the LSE macro-habitat selection, especially with regard to suitable feeding habitats. Large-sized natural grasslands and agricultural mosaic provide more favourable foraging sites, while the large areas of shrubs harbour more key prey species. The eagle avoids large forest tracts in the territory selection process, because they are not suitable for foraging and are therefore rarely used for hunting (MIRSKI 2009, 2010, ZUB et al. 2010, VÄLI et al. 2017, but see SHELLER et al. 2001).

Our modelling demonstrated that with regard to the macro-habitat selection of the LSE, the number of forest patches, the relative availability of forests and natural grasslands, and the habitat diversity dictated the species' preferences. However, in this process habitat heterogeneity proved to be of great

importance, shaping the eagle's selectivity.

In regional context, the most powerful factors that determined the eagle's preferences at a macro-habitat scale were: abundance of water bodies, mean size of the forest patch, agricultural mosaic, landscape diversity, proportions of forests, natural grasslands, shrubs and water sources. With regard to these factors the regions were split in four groups. The first cluster included pairs breeding in the Tundzha River valley, the Sakar Mnt., and the Harmanliyska River valley. The second cluster comprised the Kotlenska Mnt. and the Byala Reka River valley, while the third one included the Dervent Heights and the neighboring Elhovo plain. Not surprisingly, the home ranges of eagles breeding in the Strandzha Mnt. were completely different from all other groups, characterized by a big share of forests – more than $\frac{2}{3}$ of the territory, a small part of open areas, lack of water bodies, as well as a low value of landscape diversity.

Our expectations of a habitat impact on the eagle's density did not find support. It seems that pairs breeding in a relatively high density avoid agricultural mosaic. Yet, this habitat type provides hunting places, but it is of less importance and appears to be a suboptimal foraging habitat, while natural grasslands are definitely optimal feeding biotopes. However, although the share of natural grasslands in territories of high density was not significantly different from that recorded in low density areas, it was still bigger. The LSE is a territorial raptor showing strong site fidelity (MEYBURG et al. 2004, TREINYS et al. 2017); it is a long-lived species and occupies the territory for a long period of time (VÄLI & BERGMANIS 2017). We speculate that inter- and intra-specific competition, as well as availability and density of prey species are more powerful factors driving the LSE density, than habitat relationships.

Conservation implication

This study found that the species prefers dry broad-leaved forests, avoiding coniferous woods. The LSE shows preference for mature, natural forests, but, as an ecological adaptation, it can breed in middle-aged and even young growth stands, selecting older and taller trees for nest building. Therefore, some unfavourable forestry practices can have a negative impact on the eagle's distribution and population in two aspects – space and time. In the regions harbouring the highest density of breeding pairs, the Sakar Mnt. and the Dervent Heights (DEMERDZHIEV et al., 2019), an existing forestry practice is that after the felling of the local tree species, consisting of different oak species, the site of the wood stand which has been cut is reforested with species that are not

typical of the region, such as Scots pine and Black pine. These species, not typical of the dry and hot climate in these particular areas, contribute to the further drying of the local climate, increase the risk of fires, and represent a habitat that is not suitable for the breeding of the species in the future. According to the Program of Measures for adaptation of the forests of the Republic of Bulgaria to climate change by vulnerability zones, considering a realistic scenario for 2020, the forest ecosystems in Southeast Bulgaria will be highly vulnerable. In these areas, typical clear-cut logging is undertaken only after the burning of the forest massifs. Another negative practice is the afforestation of open areas, mainly different grassland types, again using the two pine species, including also introduced tree species such as Atlas cedar (*Cedrus atlantica* Endl.), Northern red oak (*Quercus rubra* L.), Black locust (*Robinia pseudoacacia* L.), etc. Thus, huge areas of favourable foraging habitats of the LSE are turned into unusable habitats for the species, where the eagles can neither feed nor breed in the future, because the above-mentioned trees do not have appropriate crown structure and are therefore avoided by the species.

Although these two inappropriate forestry practices, launched in the 1950s as a consequence of the Soviet-style communist forest management policy, have already been implemented at much lower intensity, they are still used. Under Measure 223 of the Rural Development Program (RDP) 2007-2013, significant resources for afforestation were used in the forestry sector to support initial afforestation of non-agricultural land. Although the law prohibits afforestation on meadows and glades in forest areas, in order to secure more efficient utilization of the subsidies under this measure, some glades were reclassified as barren areas and then afforested. The afforestation of open spaces in forests, representing non-agricultural land, as well as natural forestation (natural succession due to lack of maintenance) result in destruction or deterioration of the LSE foraging habitats. It is known that in Northern Greece, also part of the southern periphery of the species' distribution range, the open spaces in the forests represent a favourable foraging habitat for the eagle and their abandonment and gradual overgrowth result in the displacement of the LSE to new, less suitable and agriculture dominated habitats (POIRAZIDIS et al. 2007, 2019). Similarly, here, due to the decline of pastoral stockbreeding, a significant part of the open spaces in the forests - glades and small pastures, are being occupied by shrub and tree vegetation as a result of succession processes, and eventually turn into forests. Probably this is the main reason for the

dramatic decline in the abundance of the species in the Strandzha Mnt. (DEMERDZHIEV et al. 2019). However, the new forestry projects take all these negative practices into account when it comes to the management of Natura 2000 sites designated under the Habitats (92/43/EEC) and the Birds Directives (2009/147/EC). Over the past decade, there has been a positive trend in forest management, aimed at converting the coniferous stands back into deciduous forests of indigenous trees species, thus contributing to the formation of new breeding habitats of the species in the future. It is necessary to plan and carry out logging activities, supporting the natural process of conversion of coniferous stands into deciduous and mixed forests of locally sourced forest species, typical of the respective regions, in areas of key significance for the LSE. The loss of structural forest diversity leads to the formation of even-aged stands as a result of the simultaneous felling of trees on a large area, such as in the case of logging followed by a short period of recovery (short-term - gradual). These practices result in the loss of structural elements in the forests crucial for the successful breeding of LSE. Such elements are the old groups of tall trees and the forest refugia that provide protection and limited visibility to the nest. Therefore, proper forest management, preserving the structural diversity of the stands, will provide a favourable nesting habitat for the LSE.

By Order No. 49-421 of 2 November 2016, the Minister of Agriculture and Foods designated woodlands found in state-owned forest areas managed by the Ministry of Agriculture, Food and Forestry and falling within Natura 2000 sites as old-growth forests. The old-growth forests (OGF) are elements of the system for maintaining the favourable conservation status of the Natura 2000 forest habitats in Bulgaria. The designation of OGF has a definitely positive effect on the LSE as it secures the preservation of the breeding habitats of the species. However, this effect should be assessed when implementing a targeted national survey and analyzing the information gathered.

Within LIFE12 NAT/BG/001218 project a number of measures aimed at protecting the habitats of the species have been implemented. These measures include promotion of agri-environmental activities that contribute to the maintenance of permanent grasslands (open spaces) in forests, representing suitable foraging habitats of the species. A specialized environmental forestry activity has also been developed to preserve the breeding habitats of the species by improving forest management and limiting disturbance within a buffer of 300 m around the

recorded nests of the species. The implementation of this activity at national level will ensure sustainable breeding and preservation of the suitable nesting conditions. The existence of areas providing protection around the nests has a proven positive effect in a number of countries where LSE is found (VÄLI 2003, 2015, BERGMANIS et al. 2006, MEYBURG et al. 2008, DRAVECKÝ et al. 2015b, PONGRÁCZ & SZITTA 2015).

This study confirmed that the home ranges of the LSE contained more grasslands and agricultural mosaic types of vegetation than expected given the general landscape composition. It is absolutely clear that the factor of greatest significance with regard to the species' availability is habitat heterogeneity. The management of grasslands and the land use history are the most important factors shaping the eagle's distribution and demography (VÄLI et al. 2004, 2017). Since the collapse of the communist system of planned economy in Bulgaria in 1989, agriculture, including stockbreeding, has been very negatively affected. With no clear vision and strategy for preservation and development of this sector, the agricultural land was returned to the former owners for private farming and the herds of farm animals were distributed among the population. This led to a subsequent decline in pastoral livestock farming, which in turn affected the use of farmland. Part of the abandoned fields turned gradually into grasslands, which, initially, had a positive effect on the LSE. However, due to the decline of pastoral stockbreeding, a significant part of these communities and part of the pastures were occupied by shrub and tree vegetation and eventually turned into forests, as a result of succession processes. This process affected negatively a significant part of the foraging habitats of the LSE and caused the disappearance of the species from territories where it was previously well distributed (DEMERDZHIEV et al. 2019). Bulgaria's accession to the EU in 2007 set the beginning of the implementation of the Common Agricultural Policy (CAP). Direct subsidies, market support to farmers and the rural development policy have resulted in intensive development of agriculture and livestock farming in the country. This, in turn, has led to significant rapid and sudden changes in the land use practices, strongly affecting the biodiversity and the birds of prey, and LSE in particular. The intensification of agriculture is related to a dramatic increase of chemisation, land consolidation and transition to monoculture production. The greatest negative impact on birds of prey is caused by the plowing of large areas managed as extensive grasslands and being key habitats of the species, the complete eradication of the shrub vegetation and the large-scale

application of pesticides in agriculture. Plowing has a severe negative impact, resulting in direct destruction of grasslands and the related species. The LSE diet is dominated by species associated with grassland communities (DRAVECKÝ et al. 2008, ZUB et al. 2010, VÄLI et al. 2017). Plowing results in disappearance or decreased abundance of these species, which has a strong negative effect on the LSE. The sites subject to plowing are usually grasslands - former arable lands, not included in the crop rotation for five years or more, and considered "fields" with regard to the land use designation. There are also numerous cases of plowing of semi-natural and even natural (primary) grasslands. The main incentives for plowing grasslands are the subsidies under the "single area payment scheme", which represent major elements of the EU's CAP, and gaps in the nature conservation legislation (ORDINANCE No 2/17.02.2015). Although the prohibition on plowing and conversion of pastures into arable land and perennial crops has been laid down in the Biological Diversity Act, this prohibition only applies to agricultural activities and land plots considered meadows and pastures in terms of land use designation on paper. At the same time, there is no procedure for assessing the impact of the agricultural activities on the environmental components, especially when they are not designed as investment projects. However large they are, agricultural activities (mainly related to the single area payment scheme) are not considered plans, programs, projects or investment proposals. Therefore, they are not subject to an Environmental Impact Assessment. At the same time, these are large-scale activities of significant cumulative negative impact on natural habitats, habitats of species and species subject to protection within the Natura 2000 sites. On one hand, promoting the maintenance of grasslands (European Union greening policy) results in the improved status and the restoration of the foraging habitats of the species in a number of regions throughout the country, which is beneficial for the LSE. On the other hand, however, the intensive exploitation of grasslands, especially using shredders, mulching equipment or trimmers, has a negative impact, since the removal of the shrub vegetation through such devices has a very negative effect on its prey species. The use of these techniques results in severe disturbance and direct extermination of individuals, and in many cases, in the destruction of entire local populations of various small and/or slow-moving species. The impact is further multiplied when the shrub vegetation is removed during the active periods of the species (March-September), including their breeding

seasons. The factors that stimulate the removal of tree and shrub vegetation include the payments under the single area payment scheme and the respective criteria for eligibility of agricultural areas for subsidies, the gaps in the related laws (see above), and the severely decreased on-site control over the enforcement of the nature conservation legislation. According to the legal requirements, “areas eligible for subsidies are permanent grasslands harbouring up to 100 trees and/or bushes per hectare of a height of more than 0.5 m, situated in a mosaic pattern.” Despite the possibility of keeping 100 trees and/or shrubs per hectare, farmers generally prefer to remove all shrubs, thus reducing the risk of financial penalties to a minimum. As a result of the inefficient management, grasslands are being damaged and, in a number of cases, destroyed. This affects the species associated with this type of habitats, many of which dominate the food spectrum of the LSE. The inefficient management of grasslands includes: inappropriate use of these areas as pastures (in cases of unsuitable terrains of scarce forage grasses); abandonment and burning of pastures; disturbance of the water regime of wet meadows; abandonment of the haymaking regime of meadows (TZONEV & GUSSEV 2013). Shrub vegetation is a key element of the habitats of many animal species that are major items in the dietary response of the LSE. The removal of the shrub vegetation results in permanent damage and, in a number of cases, destruction of breeding sites, shelters and foraging grounds of the prey species, which also affects the normal course of the LSE’s life cycle. Probably, this factor has a great impact on the offspring feeding and rearing, hence on the demographic indicators of the species as a whole. In 2016 and 2017, this threat assumed significant proportions due to the destruction of huge areas of typical habitat types that had developed for decades in the areas of greatest significance to the species within the regions of Sakar and Derwent Heights. Besides direct devastation of habitats of paramount importance to the species, the combination of the two highly detrimental approaches to grassland management, namely plowing and complete eradication of shrub vegetation, also results in destruction of the habitat mosaic – the most powerful factor determining the LSE territory selection. Obviously, the latter forms an ecological trap for the LSE, as suggested in the current study, which has a negative impact on the territory occupancy and the reproductive success in favourable habitats, but this needs further research.

The appropriate management of foraging habitats is beneficial for the territory occupancy rate

and the reproductive success of the LSE, but intensive agriculture has a controversial effect (VÄLI et al. 2017). We believe that the management of the habitats of the species should secure the availability of 40 – 60% cover of shrub vegetation for each open area, in order to provide optimal conditions for the presence of key victims, such as hedgehogs, reptiles, small rodents etc. The most appropriate option for the maintenance of the foraging habitats is the extensive exploitation through free roaming grazing sheep, applying pasture rotation, in order to avoid overgrazing and excessive trampling of grass communities that provide a food base for the species. In addition, prohibitions or restrictions should be introduced with regard to the use of shredders, mulchers or other machinery that leads to direct and uncontrolled extermination of hedgehogs, reptiles, small rodents and other groups of organisms providing most of the items in the LSE food spectrum. Besides the favourable status of the optimal foraging habitats of LSE, the maintenance of suboptimal habitats is also of great significance. Suboptimal habitats consist of agricultural mosaic and arable land. The rotation of different crops is also important for the habitat selection process, with the eagle obviously preferring certain crops to others (VÄLI et al. 2017). The alfalfa offers a proper foraging habitat because it supports the abundance of voles, the most frequent prey species, while some crops like rape and sunflower have a negative effect on the eagle, reducing the farmland biodiversity and the diversity of prey species (VÄLI et al. 2017, POIRAZIDIS et al. 2019). In the light of these findings, the recent trends in agriculture in Bulgaria, as seen in the other regions, are alarming as regards this protected raptor species. The significant increase in the area planted with sunflower and rape over the past decade has reduced the availability of secondary hunting grounds for the LSE.

Conclusions

Although the habitats of the LSE vary across its distribution area, in general the species follows the same habitat selection patterns throughout its European range. These micro- and macro-habitat selection patterns are based on the geographically consistent preferences for grasslands, landscape diversity and old and large nesting trees. However, land use history is the main factor affecting the habitat relationships of the LSE, behind the geographical variation. It should be noted that local wildlife-habitat relationships have to be used for building large-scale predictive models when planning large-scale conservation

actions. We would like to emphasize that the conservation of the habitats of the LSE should include not only conservation of nest sites, but also conservation of favourable foraging sites. Inappropriate practices in forest management and agriculture management can adversely affect the LSE population both at a micro-habitat scale (nest sites) and as macro-habitat features (home range level) by decreasing the quality of habitats. The significance of old growth trees, structurally diverse stands, share and condition of grasslands as well as landscape diversity must be taken into account in the management and the decision making related to the protection of the LSE.

Raptors can adapt their behaviour, including habitat selection, according to the persecution pressure (FERRER et al. 1990, NEWTON 1998) or the habitat alteration (POIRAZIDIS et al. 2019). The availability of suitable foraging habitats is probably the main limiting factor for the forest raptor populations, but this does not mean that their nest sites need no attention. The described generally rapid and sudden changes in the foraging and, to a lesser extent, in the nesting habitats of the species represent a powerful “stress” factor to which the LSE needs to respond. Despite its high adaptive capacity in terms of foraging and nesting, it is not clear whether the LSE will be able to adapt to the dramatically changing environment and this process depends to a great extent on the intensity of the numerous and various factors, both anthropogenic and abiotic (climate change), which have a negative effect on the species. There are several possible scenarios of this stochastic process, which, however, require further and in-depth verification.

Yet, we will draw some possible aspects concerning the future of the species at the southern periphery of its range. If the dramatic anthropogenic pressure continues at the same intensity and extensive areas of importance for its feeding are being destroyed, the species’ population will shrink and at the periphery of its distribution the LSE will be only found in optimal habitats. If these changes caused by human activities are added to the dramatically changing climate conditions manifested in these geographic areas primarily through drying-up and aridisation, as well as to the cumulative effect of the interaction of all factors, it is quite likely that in the next few decades the LSE will disappear as a breeder from these areas and the southern border of the species’ distribution range will be shifted northwards to more humid and moderate climate. This requires urgent measures and decisive actions to be undertaken by different responsible institutions in cooperation with key stakeholders in order to stop the destruction

of the species’ foraging and breeding habitats, as well as to restore those already damaged. Therefore, this process cannot take place without the adequate involvement of all parties concerned.

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Annex 1. List of variables used in the analyses

Micro-habitat scale
Height of tree (m)*
Diameter of the tree at the breast height (m)*
Nest tree species – biological species of the tree used for breeding*
Nest tree location – position of the nest tree (tree lines; forest patches)*
Soil moisture index* - from 1 to 4
Stand density index* - dense (0-2), loose (2.1-5) and open (>5.1)
Slope (°)*
Aspect (°)**
Altitude (m.a.s.l.)**
Size of the forest patch (ha)*
Canopy cover (scale 0-1)**
Undergrowth (scale 0-1)*
Share of main tree species (scale 0-1)*
Stand age (y.)*
Distance to the forest edge (m)**
Distance to a road (m)**
Distance to a settlement (m)**
Distance to water bodies (m)**
Macro-habitat scale
Number of the water bodies**
Number of the landscape patches*
Number of the forest patches**
Number of the natural grassland patches**
Number of the arable land patches
Number of the agricultural mosaic patches (mixed land use patterns) **
Number of the shrub patches**
Mean size of the forest patches (ha)*
Mean size of the natural grassland patches (ha)**
Mean size of the arable land patches (ha)
Mean size of the agricultural mosaic patches (mixed land use patterns) (ha)**
Mean size of the shrub patches (ha)**
Shannon Diversity Index of habitats H' **
Forest area (ha)*
Arable lands area (ha)**
Natural grasslands area (ha)**
Agricultural mosaic area (mixed land use patterns) (ha)**
Area of shrubs (ha)**
Anthropogenic area (ha)*
Area of water bodies (ha)**
Other area (ha)** - vineyards, orchards, dust roads and clearings
* predictors used for the micro- and macro-habitat analyses after exploring the inter-correlation
** predictors used for density analysis

