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Nest-site use by Black Stork and Lesser Spotted Eagle in relation to fragmented forest cover: case study from Lithuania

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Black Stork and Lesser Spotted Eagle are forest-dwelling species that nest in mature forests, thus are in conflict with the timber harvesting. No recent research has evaluated the demand for continuous forest cover around nest-trees of these species. This article analyses nest-site use by Black Stork and Lesser Spotted Eagle in relation to ground cover, specifically comparing the nest-tree environment with availabilities in the forest landscape. Strong avoidance of field, low avoidance of shrubland (clearcuts and forests up to 30 years of age) and preference of continuous forest cover (older than 30 years of age) are characteristic of the Black Stork nest-site use. Nest-sites of Lesser Spotted Eagle in relation to ground cover did not differ from availabilities in the forest landscape, except in the environment nearest to the nest-trees, where eagles preferred continuous forest cover and weakly avoided shrubland. We assume that the relatively low avoidance of shrubland by both species could be related with the present level of forest landscape fragmentation, ongoing adaptation to the fragmented forests, or the importance of a suitable nest-tree with only the immediate surrounding to provide protective cover. Some implications for conservation are discussed.

Key words: *Ciconia nigra*, *Aquila pomarina*, nest-site, preference, forest fragmentation

INTRODUCTION

Intensive forestry has a negative impact on the habitats of large forest-dwelling raptors, changing the structure of breeding territories, destroying nest-sites and structural elements necessary for breeding (Duncan, 1997; Ewins, 1997; Sulkava, Huhtala, 1997; Saurola, 1997; Widén, 1997; Lõhmus, 2003; Treinys, Mozgeris, 2006). The conflict between the habitat needs of large forest birds and forest exploitation arises because species prefer large, old trees and mature forests (Jedrzejewski et al., 1988; Boal, Mannan, 1998; Gutiérrez et al., 1998; Sergio et al., 2003; Bergmanis, 2004; Lõhmus et al., 2005; Bielański, 2006). The availability of nest-sites and nest-trees can act as limiting factors for local populations when other resources are sufficient (Newton, 2003), therefore, to mitigate the impact of forestry on large raptor species, such measures as construction of artificial nests (Saurola, 1997), green tree retention (Lõhmus, 2006) and the preservation of forest patches around nest-trees (Lõhmus, 2005) could be applied.

Black Stork *Ciconia nigra* and Lesser Spotted Eagle *Aquila pomarina* are species of international importance (Annex I EU Bird Directive, Annex II of Bern and Bonn Conventions) that breed in mature forests (Drobelis, 1993, 1994). In the Baltic countries, over the past two decades, the populations of Black Stork have markedly decreased (Sellis, 2000; Stazds, 2005; Treinys et al., 2008), whereas Lesser Spotted Eagle numbers declined in Lithuania and Latvia (Lõhmus, Väli, 2001; Bergmanis et al., 2006; Treinys et al., 2007). In the Baltic states, during the last two decades, the volumes of cutting have increased 2–3 times (Anonymous, 2001, 2002; Muiste et al., 2006); therefore, a decline in populations size is linked

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with the intensive forest exploitation (Strazds, 2003; Bergmanis et al., 2006). Although nest-sites of Black Stork and Lesser Spotted Eagle are periodically destroyed by forest cutting, no evidence exists that the more intensive forest use has resulted in the decreased size and / or productivity of these populations (Rosenvald, Lõhmus 2003; Lõhmus et al., 2005; Treinys et al., 2007, 2008). Moreover, changes in nest-stand and nest-tree quality indicate a possible adaptation of both species to the modern forest landscape (Treinys, Mozgeris, 2006; Treinys et al., 2008).

Previous research on nest-site requirements of Black Stork and Lesser Spotted Eagle (Drobelis, 1993, 1994; Skuja, Budrys, 1999; Lõhmus, Sellis, 2003; Lõhmus, 2005, 2006; Lõhmus, Väli, 2005; Treinys, Mozgeris, 2006; Treinys et al., 2008), assessed mainly: 1) nest-trees, 2) nest-stand or 3) nest-tree surroundings within a radius of 30 m. However, applying these approaches it is difficult to explore habitat use in a greater but ecologically still important nest-tree environment. Inadequate spatial scale selection can lead to the wrong assessment of habitat preference and consequently to wrong conclusions concerning conservation actions. Furthermore, no research has statistically confirmed the demands of the two species for continuous forest cover around nest-trees and their avoidance of environments fragmented by forest harvesting.

In this study, we analyse ground cover use by Black Stork and Lesser Spotted Eagle on the nest-site scale with the aim to answer whether the mentioned forest-dwelling species avoid the fragmented nest-tree environment.

MATERIALS AND METHODS

In 2005–2006, Black Stork and Lesser Spotted Eagle nests in 22 administrative districts of Lithuania (Fig. 1) were monitored from June to July. A nest was assessed as occupied if it contained eggs or nestlings (or their remains), or if it had been repaired by a non-breeding pair or a single bird in spring. For analysis, 62 and 64 nests of Black Stork and Lesser Spotted Eagle respectively were used. Only one nest of the pair was included into analysis; 65 forest random points were searched using the GIS technique. The first digital layer was created with five circular buffers at distances of 50, 100, 150, 200 and 250 m around each nest-tree and random point. The second digital layer of ground cover was created using orthophotos (scale 1 : 10 000, made in 2005–2006) and the Forest Inventory Data Base of the State Forest Survey Service, with four land cover categories established: "fields", "forest", "shrubland" and "others". Meadows and agricultural lands were attributed to the "field" category, whereas ≥IV age class stands (i. e. older than 30 years) were considered as "forest". This age class was regarded as marginal in terms of "forest cover" because we have no data on Black Stork and Lesser Spotted Eagle regularly nesting in younger stands. Clear cuttings and young stands (I–III age class, i. e. 0–30 years of age) were assigned to the "shrubland" category. Some natural (wetlands, water bodies) and anthropogenic (roads, buildings) cover types in nest-sites (random plots) were found occasionally, thus they were attributed to the "others" category. In the further analysis, the "others" category was excluded because of

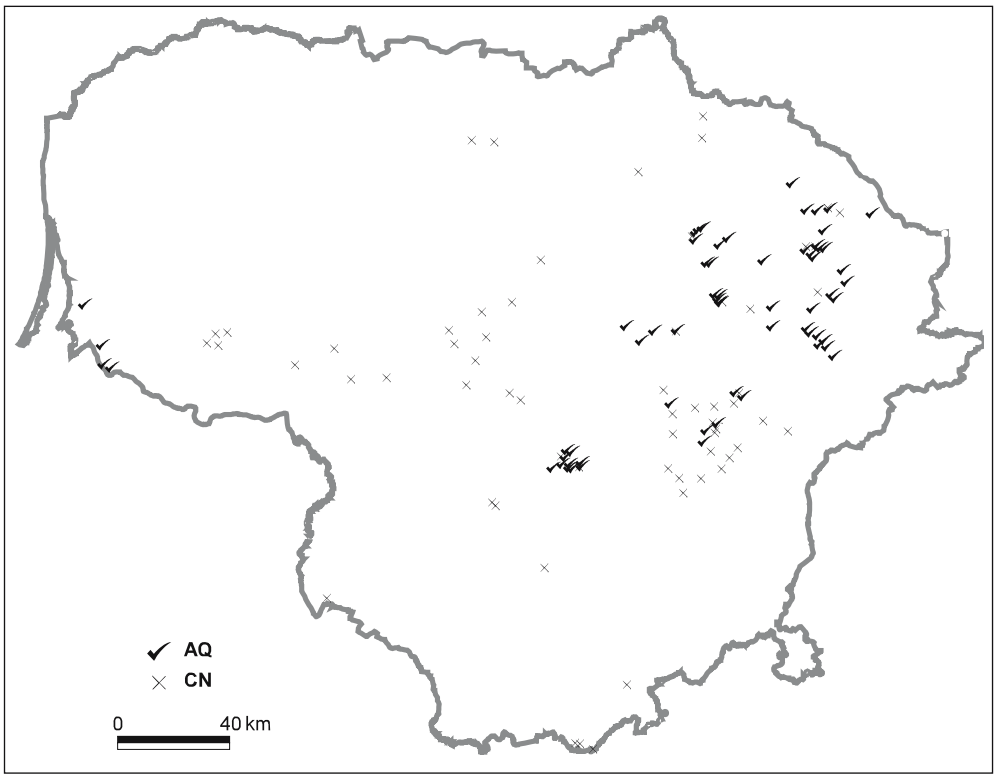

Fig. 1. Distribution of Lesser Spotted Eagle (AQ) and Black Stork (CN) nests

its insignificant part in nest-sites (random plots). Variables were checked for normality (Kolmogorov–Smirnov test) and arcsine-square-root transformed. Two-way ANOVA was used to test the variation in different radii from the nest-trees (random points) and preferences to ground covers. *Post-hoc* comparisons were made using Tukey's honestly significant difference (HSD) test.

RESULTS

Descriptive statistics of untransformed variables are given in Table. Significant variations were found in the forest ($F_{8,940} = 2.44, P = 0.01$), shrubland ($F_{8,940} = 2.60, P = 0.01$) and field covers ($F_{8,940} = 2.76, P = 0.01$) within five radii of different species sites (random plots).

Table. **Descriptive statistics of shrubland, field and forest cover at a distance of 50–250 m around nest-trees of the Black Stork (CN), Lesser Spotted Eagle (AQ) and random points (RP)**

Radius (m) area (ha)	Cover	Species	Mean (ha)	SD (ha)	Min (ha)	Max (ha)
50 0.79	Shrubland	RP	0.12	0.23	0.00	0.79
		AQ	0.04	0.09	0.00	0.34
		CN	0.01	0.03	0.00	0.18
	Field	RP	0.04	0.11	0.00	0.71
		AQ	0.00	0.01	0.00	0.09
		CN	0.00	0.00	0.00	0.01
	Forest	RP	0.62	0.25	0.00	0.79
		AQ	0.75	0.09	0.44	0.79
		CN	0.77	0.03	0.60	0.79
100 3.14	Shrubland	RP	0.42	0.68	0.00	2.61
		AQ	0.32	0.42	0.00	1.48
		CN	0.17	0.30	0.00	1.57
	Field	RP	0.23	0.45	0.00	1.87
		AQ	0.11	0.21	0.00	0.75
		CN	0.02	0.08	0.00	0.51
	Forest	RP	2.41	0.81	0.10	3.14
		AQ	2.72	0.42	1.66	3.14
		CN	2.91	0.32	1.57	3.14
150 7.07	Shrubland	RP	0.92	1.20	0.00	5.03
		AQ	0.92	1.04	0.00	4.03
		CN	0.67	0.93	0.00	5.06
	Field	RP	0.69	1.14	0.00	4.42
		AQ	0.54	0.75	0.00	2.53
		CN	0.10	0.29	0.00	1.82
	Forest	RP	5.28	1.56	1.53	7.07
		AQ	5.61	1.13	3.04	7.07
		CN	6.17	1.02	2.01	7.07
200 12.56	Shrubland	RP	1.70	1.99	0.00	9.52
		AQ	1.89	1.83	0.00	7.13
		CN	1.57	1.72	0.00	9.06
	Field	RP	1.55	2.27	0.00	8.73
		AQ	1.41	1.67	0.00	6.08
		CN	0.26	0.68	0.00	3.28
	Forest	RP	8.99	2.66	3.05	12.56
		AQ	9.26	2.21	4.34	12.56
		CN	10.46	1.93	3.50	12.56
250 19.63	Shrubland	RP	2.70	3.02	0.00	14.47
		AQ	3.12	2.70	0.00	10.28
		CN	2.84	2.74	0.00	13.81
	Field	RP	2.91	3.96	0.00	15.24
		AQ	2.85	3.01	0.00	10.31
		CN	0.53	1.25	0.00	5.82
	Forest	RP	13.51	4.20	4.10	19.63
		AQ	13.66	3.49	6.11	19.42
		CN	15.76	3.11	5.83	19.63

The Black Stork preferred continuous forest cover at a distance of 50, 100 and 150 m from the nest-tree (Tukey's HSD tests: P = 0.00003–0.01), at 200 and 250 m, however, forest share did not significantly differ from availability in the landscape (Tukey's HSD tests: P = 0.13 ir P = 0.28, respectively) (Fig. 2). The Lesser Spotted Eagle preferred continuous forest cover only at a distance of 50 m from the nest-tree (Tukey's HSD test: P = 0.0001), whereas at a distance of 100–250 m it used forest according to the availability (Tukey's HSD tests: P = 0.41–1.0) (Fig. 2).

The share of shrubland was significantly smaller at a distance of 50 m from a Black Stork nest-tree (Tukey's HSD tests: P = 0.001), whereas at a distance of 100, 150, 200 and 250 m it did not significantly differ from availability in the landscape (Tukey's HSD tests: P = 0.31–1.0) (Fig. 3). The Lesser Spotted Eagle only weakly avoided shrubland at 50 m from the nest-tree (Tukey's HSD test: P = 0.09); at greater distances, however, shrubland was used proportionally to the availability (Tukey's HSD tests: all P = 1.0) (Fig. 3).

The Black Stork strongly avoided fields (at distances of 100–250 m from the nest-tree; Tukey's HSD tests: P = 0.04–0.00003), except at a distance of 50 m (Tukey's HSD test: P = 0.30) (Fig. 4). The Lesser Spotted Eagle used fields according to their availability in the landscape (at a distance of 50–250 m from the nest-tree; Tukey's HSD tests: P = 0.50–1.0) (Fig. 4).

The distance from Black Stork nest-trees to the forest edge was significantly greater than that of random points (t_{125} = –2.77, P = 0.007). The Lesser Spotted Eagle nest-trees were nearly significantly closer to the forest edge than were random points (t_{127} = 1.88, P = 0.06). The share of field (at a distance of 100–250 m from the nest-tree) was negatively correlated with the distance from a Black Stork nest-tree to the forest edge (r = –0.40 – –0.64, all $P \leq 0.001$). Field share and distance to the forest edge was significantly negatively correlated in random plots and Lesser Spotted Eagle nest-sites at a distance of 50–250 m from nest-tree / random point: r = –0.26 – –0.71, all $P < 0.04$ and r = –0.37 – –0.79, all $P \leq 0.003$, respectively. However, the share of continuous forest cover around the Black Stork nest-trees (at a distance of 50–250 m) was not related to the distance from the nest-tree to the forest edge (r = 0.06–0.23, all $P > 0.05$). In random plots and in the nest-sites of Lesser Spotted Eagle at a distance of 100–250 m, the share of continuous forest cover significantly positively correlated with the stand distance from forest edge: r = 0.30–0.55, all $P < 0.02$ and r = 0.30–0.54, all $P < 0.02$.

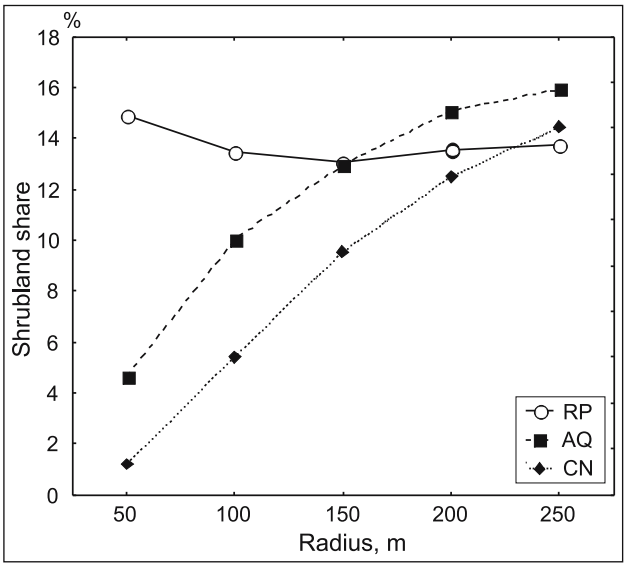

Fig. 3. Mean share of shrubland in the random plots (RP), Lesser Spotted Eagle (AQ), Black Stork (CN) sites at different radii from the nest-trees (random points)

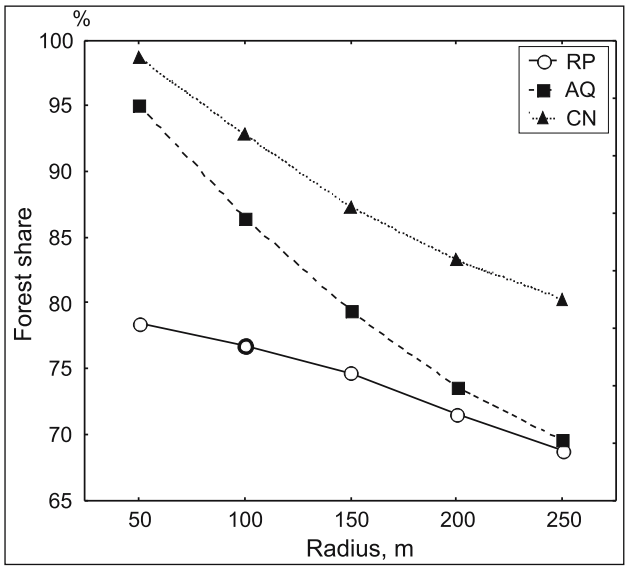

Fig. 2. Mean share of forest in the random plots (RP), Lesser Spotted Eagle (AQ), Black Stork (CN) sites at different radii the nest-trees (random points)

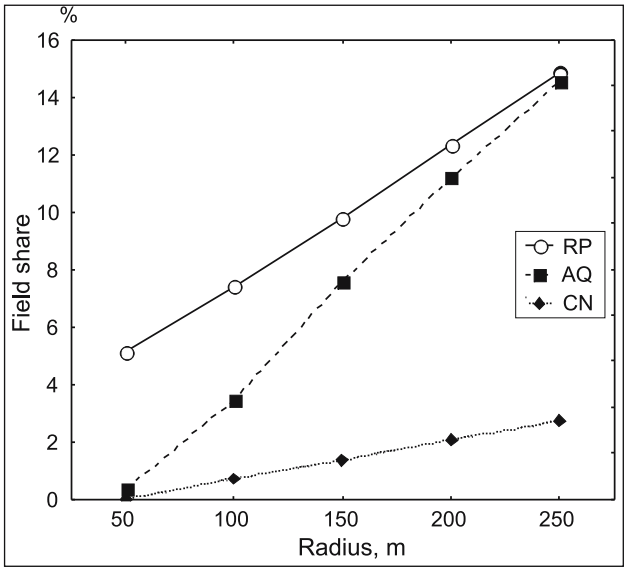

Fig. 4. Mean share of in the random plots (RP), Lesser Spotted Eagle (AQ), Black Stork (CN) sites at different radii from the nest-trees (random points)

DISCUSSION

Strong avoidance of field, low avoidance of shrubland and preference to continuous forest cover are characteristic of the Black Stork nest-site use. Nest-sites of Lesser Spotted Eagle in relation to ground cover did not differ from the availability in the forest landscape, except in the immediate surroundings of the nest-tree.

In contrast to the preference of forest cover, the avoidance of fields by the Black Stork is related to the nest-tree distance from the forest edge. Our results support the previous findings that the Black Stork is a typical forest interior specialist (*sensu* Villard 1998) who prefers forest at the both landscape and nest-site spatial scales (Drobelis, 1993; Angelstam et al., 2004; Jiguet, Villarubias, 2004; Lõhmus et al., 2005).

A low avoidance of shrubland by the Black Stork implies that this species is not sensitive to the forest environment fragmented by cuttings of different age. These findings do not contradict previous data on stable Black Stork productivity over the period of the past 15–30 years in Lithuania (Treinys et al., 2008), despite more intensive forest use in the country. In Estonia, where forest cuttings increased at about the same time and rate as in Lithuania, a marked decline in the Black Stork population and productivity is not considered to be directly related to forestry activities or changes in the forest structure (Rosenvald, Lõhmus, 2003; Lõhmus et al., 2005). We assume that the relatively low avoidance of shrubland by the species is related to: 1) the fact that the present level of forest landscape mosaic caused by forest harvesting over time does not exceed the tolerance limits of the species, 2) the ongoing adaptation of the species to the fragmented environment and / or 3) nest-tree as the key attribute of the nest-site.

First, forest patch occupancy of a forest dweller can abruptly change depending on the threshold value (Suorsa et al., 2005). We don't known any study to quantitatively analyse forest patch occupancy by the Black Stork in relation to the forest fragmentation threshold, thought goshawk, a typical forest interior species dependent on mature forests (Widén, 1997), could be an approximate example. Penteriani & Faivre (2001) have found that goshawk tolerate timber harvesting within a nesting stand, as long as the cover reduction does not exceed the threshold of about 30%. Young tree stands (0–30 years of age) cover about 22% of the Lithuanian forest landscape (Anonymous, 2001); moreover, at a distance of 250 m around the analyzed random points, the mean share of shrubland constituted only 14%. Secondly, the Eagle Owl, traditionally regarded as a "wilderness species", has adapted to man's neighbourhood, and the "anthropogenic" populations have similar parameters as "traditional" ones (Marchesi et al., 2002). The increasing Black Stork population in Western Europe is adapting to the agricultural landscape (Janssen et al., 2004); some evidence of the adaptation of the Black Stork population to the novel habitats has also been observed in Lithuania (Treinys et al., 2008). Third, the Black Stork nests in trees whose mean age is 24–77 years greater than the mean age of the surrounding stand (Lõhmus, Sellis, 2003). Recently, in Lithuania the mean age of the nest stand has decreased, but the nest-tree age increased (Treinys et al., 2008), indicating that suitable nest-trees, which are rare in Baltic forests (case study from Estonia, Lõhmus, Sellis, 2003), could govern the whole nest-site selection of this species.

The Lesser Spotted Eagle in relation to the ground cover of the nesting environment can be characterised as opportunistic. In ground cover use, the species adjusts to availabilities in the landscape, except at a close proximity to a nest-tree (50 m), with a strong preference for forest, a tendency to avoid shrubland, and a proportional use of field. Nesting near the forest edge is a typical attribute of the species in Europe (Bergmanis, 2004; Väli et al., 2004) with eagles spending 86% of their hunting time in the open, extensively used landscape (Bergmanis, 1999). Our data confirm the opinion that the Lesser Spotted Eagle does not avoid forest fragmented by clearcuts (Drobelis, 2004). Lõhmus (2005) reported that the Lesser Spotted Eagle preferred natural to managed forest stands, but the preference, when controlled by other stand characteristics, was not significantly related to the presence of cuttings. Moreover, eagles use clearcuts as foraging areas (Drobelis, 2004); therefore, forest fragmentation can have a double effect on this species: a negative one is related to the destruction of potential nesting habitats, and a positive one is related to the creation of new foraging places (a similar effect was suggested for *Strix nebulosa*, see Duncan, 1997; Sulkava, Huhtala, 1997). Lõhmus, Väli (2005) found that for the nest-site selection of the ecologically and taxonomically close species Greater Spotted Eagle (*Aquila clanga*) important are stand characteristics within a <200 m radius from the nest-trees. We assume that the demands of the Lesser Spotted Eagle in nest-site selection are basically related to the presence of suitable nest-trees (e. g. Bielanski, 2006) and / or preference for only immediate forest stands (Treinys, Mozgeris, 2006) to provide a protective cover from predators and bad weather conditions (references in Lõhmus, Väli, 2005).

Finally, we would like to draw attention to the fact that the low avoidance of shrubland (i. e. mostly clearcuts of different age) observed in both forest-dwelling species by no means denies the interest of conservationists in the populations of these species in the context of intensive timber harvesting. First, there is no evidence that "fresh" clearcuts have the same value for birds as overgrown cutting places e. g. 20 years of age. Secondly, in this study we analysed only nest-site use in relation to its availability in the forest landscape. Habitat use is a dynamic process during which species–habitat relationships can change depending on the population size (Lõhmus, 2001), on the degree of adaptation (Marchesi et al., 2002) and the extent of alterations in the nesting environment (Penteriani, Faivre, 2001). Thirdly, recently we have found that the Lesser Spotted Eagle prefers mature forest at the territory level (Treinys, Mozgeris, unpublished), and this preference could be hardly explained by the presence of suitable nest stands only. Consequently, the effective protection of these

bird species will require regularly renewed knowledge on the species–habitat interaction.

Implications for conservation. Habitat requirements of the species strongly depend on geographical location (Väli et al., 2004; Treinys et al., 2009), thus, our recommendations for conservation and forest management planning are restricted to Lithuania only. Buffer zones within 100 m around the Lesser Spotted Eagle and 200 m around the Black Stork nest-trees should be maintained free from clear felling (as confirmed by order No. 670 of 19 December 2003 of the Ministry of Environment of the Republic of Lithuania). Under some exploitation conditions, however, these buffer zones could be "legally minimized"; thus, we recommend to leave ≥2.4 ha and ≥9.6 ha of continuous forest older than 30 years within buffer zones for the Lesser Spotted Eagle and the Black Stork, respectively. The recommended values correspond to 25% of quartile range, which can be directly used to define the safe minimum standards for conservation (Lõhmus, 2006). The same area of continuous forest cover could be used also to extend the list of criteria that could be applied to detect potential nesting patches for the Black Stork in planning Special Protected Areas and set aside areas (Treinys et al., 2009).

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JUODOJO GANDRO IR ERELIO RĖKSNIO LIZDAVIEČIŲ PASIRINKIMAS NEVIENTISOJE MIŠKO DANGOJE: PAVYZDYS IŠ LIETUVOS

S a n t r a u k a

Juodasis gandras ir erelis rėksnys yra tipiškos brandžių miškų rūšys, dėl to neigiamai veikiamos miško kirtimų. Tačiau neištirtas šių rūšių poreikis vientisai miško dangai lizdavietėse.

Analizavome šių dviejų rūšių lizdaviečių pasirinkimą žemės dangos atžvilgiu palygindami lizdaviečių aplinką su galimybėmis miškų kraštovaizdyje. Juodasis gandras laukų, krūmynų (t. y. kirtaviečių ir jaunuolynų iki 30 metų amžiaus) vengė tik artimiausioje lizdinio medžio aplinkoje ir pirmenybę teikė vientisam miškui (senesniam nei 30 metų amžiaus) iki 150 m atstumu nuo lizdinio medžio. Erelio rėksnio lizdavietės nesiskyrė nuo galimybių miškų kraštovaizdyje pagal analizuotas žemės dangas, išskyrus artimiausią lizdo aplinką, kur jie vengė krūmynų ir pirmenybę teikė vientisai miško dangai. Esame linkę manyti, kad nežymus abiejų rūšių krūmynų vengimas gali būti susijęs su dabartiniu miškų fragmentacijos lygiu, prisitaikymu prie fragmentacijos ar dėl to, kad pasirenkant lizdavietes svarbiausia yra tinkamas lizdinis medis ir jo tiesioginė miško aplinka. Trumpai aptariamos šių rūšių apsaugos rekomendacijos.

Raktažodžiai: *Ciconia nigra*, *Aquila pomarina*, lizdavietė, pasirinkimas, miško fragmentacija