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Population size, distribution and habitat selection of the white-tailed eagle *Haliaeetus albicilla* in the alluvial wetlands of Croatia

Andreja Radović[1] & Tibor Mikuska[2]

[1]*Institute for Ornithology, Croatian Academy of Sciences and Arts, Gundulićeva 24, HR-10000 Zagreb; e-mail: anradovic@hazu.hr*
[2]*Management Office, Kopački Rit Nature Park, Petefi Šandora 33, HR-31327 Bilje; e-mail: tibor@kopacki-rit.com*

Abstract: From 2003–2006, research on the breeding distribution of the white-tailed eagle (*Haliaeetus albicilla*) was conducted in Croatia in order to assess the size of the national population. In 125 locations, clear signs of breeding activity were found. An additional 10 presumably active territories were detected but it was not possible to locate the exact position of the nests and confirm the breeding. Based on this, it is concluded that the national breeding population is not less than 135 breeding pairs. The present distribution can be compared with previous reports with the exception of the area along the Ilova and Lonja rivers that have never been reported as an important breeding site. Analysis of the characteristics of 138 nest positions as well as preferences/avoidance of specific structural features were performed. The results showed that white-tailed eagles prefer to build their nests on pedunculate oaks, narrow-leafed ash and white poplars with the greatest preference for mature trees with a diameter above 92.5 cm. The minimal distance between two active pairs was 348 meters. More than 50% of the national population breed less than two km from a large water area and 95% of the population less than four km. More than 95% of the population breed at altitudes lower than 140 m above sea level and are further than one km away from the nearest human settlement, regardless of the availability of forests. According to several parameters (distance to a large water area, elevation, forest presence, distance to the nearest settlement, distance to highways and railways) geographic information system (GIS) helped to determine potential white-tailed eagle breeding areas.

Key words: *Haliaeetus albicilla*; population size; habitat selection; human disturbance; nesting place; Pannonian plain

Introduction

The white-tailed eagle (*Haliaeetus albicilla* L., 1758) occurs as a breeding bird from Kamtjatka, the Kuriles and Japan in the east, to the Nordic countries including Iceland and Greenland in the west (Helander & Stjernberg 2002). In the last decades, it has spread to Alaska (Tobish & Balch 1987). A drastic decrease of the world population lasted until the second half of the twentieth century (Tucker & Heath 1994). Since then, the breeding population has been increasing, mostly due to the abandonment of pesticides and the legal protection in most European countries (Helander & Stjernberg 2002). The exceptions are the countries in the Mediterranean region where the conditions for recovery are significantly poorer (Mizera 1999). The population of the Danube River basin, where the Croatian population is situated, is increasing (Schneider-Jacoby 2003). Today, the European population is assessed at 5000–6600 breeding pairs, which probably holds over 50% of the global population (Birdlife International 2004).

In the Mediterranean region of Croatia, the white-tailed eagle used to breed on the Island of Cres in the northern part of the Adriatic Sea at the beginning of the 20th century (Depoli 1928). A small isolated population in the Delta Neretva River survived until the nineteen-sixties (Rucner 1998) but since then there has been no breeding attempts in this region. Today the white-tailed eagle breeds in the lowland areas of the central and eastern parts of Croatia (Radović et al. 2003). A research program covering the complete Croatian national population has not been carried out before. As part of the colour wing-tagging programme, groups of nests in a few isolated areas (e.g., Kopački Rit and Lonjsko Polje wetlands, Pokupsko depression) had been monitored occasionally during the late nineteen-eighties (J. Mikuska, pers. comm; D. Radović, pers. comm; Schneider-Jacoby 1996). Based on these data, Radović & Sušić (1997) assessed the national population at 60–70 breeding pairs and later Schneider-Jacoby et al. (2003) assessed it at 70–80 pairs by the end of the 20th century. The latest estimates, accepted by BirdLife International were, according to Radović et al. (2003), set at 80–90 breeding pairs.

This study, for the first time, gives a comprehensive assessment on the breeding size and distribution of white-tailed eagles in Croatia, which can serve as the basis for high quality estimates of the size of the national breeding population. It also presents the first partial data on breeding success.

Breeding habitat characteristics of the white-tailed eagle along the entire area of distribution differs greatly. For nest building it prefers the crowns of tall, strong, mature trees, although nesting on cliffs or crags have been recorded (Olsson 1972; Hauff 2001). Unusually, it breeds on the ground, such as along the inner coast of Norway, Greenland, and Iceland (Cramp 1982). Besides northern populations that breed along sea coasts, populations further into the continent are always connected with vast alluvial wetlands and large rivers. The selection of the breeding site is important, even a key factor that affects the distribution of birds of prey (Janes 1985). In an ideal situation specimen of some species would occupy areas that suit them the most (Fretwell & Lucas 1970), and then inhabit less preferable places as their population grows. Selection of the site for breeding is, among other things, influenced by different disturbance factors. It is difficult to prove the effect of it on the breeding success of any particular bird species also because of the different tolerance rate of geographic populations to a specific disturbance factor. Some authors suggest the presentation of the overall disturbance factor at nest consisting of the set of various disturbances occurring in the area (Grubb & King 1991). Several authors presented the undesirable impact of human disturbance on nest abandonment by the birds of prey (Boeker & Ray 1971), decreased reproduction (Wiley 1975), relocation (Andersen et al. 1986), and on changes in wintering habitat (Stalmaster & Newman 1978). Andersen et al. (1990) showed that the increase in magnitude of human activities in areas of usually low disturbance rates, results in the behavior change of a great number of birds of prey. Helander (1985) proved that the failure of 36 broods in Sweden was due to the disturbance of the nest during incubation. The avoidance of humans by white-tailed eagles has been proved by Lőhmus (2001). The distance from where some human activities disturb white-tailed eagles differs greatly (Mizera 1999), most likely because of the different disturbance rates in specific regions. In addition, in the last decades, a slight increase of disturbance acceptance in some parts of the distribution area is the result of lower persecution rates (Helander & Stjernberg 2002). Stalmaster & Kaiser (1998) proved the difference in disturbance acceptance according to the age of the birds, showing that sub-adult birds of the closely related species *H. leucocephalos* has fewer possibilities to accommodate human disturbance. To consider an area suitable for the breeding of the white-tailed eagle, three conditions must be fulfilled: (i) the proximity to the feeding place (in this paper presented by proximity to the water; (ii) the presence of suitable forest stand and trees for nest building and (iii) a tolerable amount of human disturbance (Thompson & McGarigal 2002). The purpose of this study was to describe nesting site selection and quantify the habitat characteristics. Special attention was given to the placement of the nests with regard to the sources of the disturbances, such as human built structures, settlements and roads. Using GIS tools, we have extracted potential breeding areas for the white-tailed eagles throughout the country.

Study area

The research was conducted in the lowland areas of Central and Eastern Croatia (Crkvenčić 1974). The central part of Croatia is rather flat surrounded by the Sava, Kupa, Drava and Mura rivers. The area contains the biggest net of surface streams in Croatia, which is a result of soil composition and their hydro-geological characteristics (Crkvenčić 1974). Along the streams of Lonja and Ilova, a series of small fishponds were constructed. Within the alluvial plains of the Sava and Lonja rivers, ecological conditions are favorable for oak (*Quercus* sp.) and hornbeam (*Carpinus* sp.) forests. However, these stands are reduced over the majority of the area (Crkvenčić 1974).

Eastern Croatia (Slavonia and Baranya region) is a typical lowland area bordered by the Drava River to the north, the Danube River to the east and the Sava River to the south. Hydrological characteristics of the area changed dramatically with melioration and land-use processes during the 19th and 20th centuries. Vast natural alluvial forests made from oak (*Quercus* sp.), ash (*Fraxinus* sp.), poplar (*Populus* sp.) and willow (*Salix* sp.) were reduced and turned into agricultural land (Crkvenčić 1975). However, important and extensive alluvial forests are still available along the Drava (Dravske forests, alluvial forests from Slatina to Koška), the Danube (Kopački Rit wetlands) and the Sava (Spačva forests). Several large fishponds were constructed in this region, too.

Material and methods

During 2002, different land-users (protected area managers, foresters etc.) were contacted in order to collect initial information about known nests of the white-tailed eagles. Field work was carried out in the period from 2003−2006. During 2003 and 2005 almost all of the known territories were visited in both years. In several locations where the eagles were regularly seen, the work was hampered by the minefields left from the recent war and we were not able to confirm the breeding due to the inaccessibility of these areas. According to our experience, the minimal distance between two active nests almost always exceeded 600 m. Thus, in the inaccessible areas we considered two potential territories occupied if they were at least one kilometer apart from each other and birds were present throughout the breeding season. In order to find the eagles' nests, the territories were visited during the winter period (November – January) when lack of leaves would not obstruct the view. To confirm the breeding and calculate the percentage of successful breeding attempts, active nests were visited at least twice during the breeding season. During the first visit in March, we recorded the incubating pairs, and during the second visit in May we recorded if the pair had been successful in raising chicks. At the beginning of May, the chicks are already big enough to fledge, and some early breeders already have chicks that can leave the nest. However, during the nest inspection that was done from the ground, we were not able to determine with certainty the total number of chicks per nest because of the anti-predator behavior of chicks who would lay down as a response to the parents' alarm calls. For that reason, we cannot give the actual breeding success for these areas, but only the percentage of successful breeding attempts. According

to the described methodology, during 2006 we conducted research of part of the population in alluvial forests along the lower part of the Sava River, incl. the Spačva forests. In total, 70 breeding pairs (>50% of the national population) were covered by this part of the study (Table 1).

During the field work, using laser range finders, compasses and tape measures, we have recorded the following nest and tree parameters: tree species, circumference at the observer's breast height, height and the geographical position of the nest. The position of the nest was marked using GPS units. The nearest distances to the large water bodies (running waters and large water bodies, <8 ha, that are represented with a polygon on the 1:50.000 map), small streams (streams that are represented with a line on the 1:50.000 map), roads and settlements were calculated through the Nearest Feature function of ArcView Software Version 3.2.

To extract the potential breeding area we have prepared following GIS layers: large water bodies, small streams, floodplain forests, roads and settlements. Apart from their size, we did not categorise waters in any other way (e.g., amount of fish, water quality and pollution, turbidity, depth etc.). Settlements were defined by their presence on the 1:25.000 map (holding at least 50 inhabitants). Roads were categorized according to the national classification scheme (Official gazette of the Republic of Croatia no. 110/01) in six categories: 1 – highways (with over 14000 vechiles/day); 2 – 1st category (state road with >12000 vechiles/day); 3 – 2nd category (state road with 7000–12000 vechiles/day); 4 – 3rd category (state road with 3000–7000 vechiles/day); 5 – 4th category (county road with 1000–3000 vechiles/day); and 6 – 5th category (local road with <1000 vechiles/day).

Four parameters were used for the identification of potential breeding areas and are defined as follows: 1 – distance to the large water bodies; 2 – elevation; 3 – presence of a forest; 4 – distances to the nearest settlements and roads of the 1st and 2nd category. Using basic descriptive statistics we have identified values for those parameters holding or excluding 95% of the national breeding population. Based on these results, we have defined buffers of 4 km around large water bodies and 1700 m around small streams (as a potential food source) that generated the maximum possible breeding area. Then we clipped this theme with forest covers (as a potential breeding habitat), altitude (95% of pairs breed bellow 140 m above sea level), and buffers around roads and settlements, as sources of disturbance (over 95% of the nests are placed more than 500 m from the nearest road and more than one km from the nearest settlement). This resulted in the potential breeding area representing food and breeding availability as well as disturbance-free conditions. Human disturbance was considered by distance to settlements and infrastructure. In this paper, we did not consider other types of disturbance, in particular that coming from the intensity and timing of forestry management and hunting, because it is impossible to get the appropriate data at a national level. On the other hand, one would assume that there should be a difference in the intensity and timing of these activities between protected and unprotected areas. On the legislative lever, there are certain buffer zones (up to 500 m) around the eagle's nests in the protected areas that prohibit any activities during the breeding season (e.g., in Kopački rit, Official gazzette no. 77/2000), but in practice this legislation is not efficiently enforced at all.

The analyses of the nest positions according to settlements, roads and small streams were performed separately for the two parts of the population: inside and outside the protected area borders. Additionally, an equal set of points were randomly dispersed, with help of Random point extension, suitable for white-tailed eagles due to the proximity to the feeding location and the presence of forest. Privately owned forests were not included in the research at all because of the lack of digitalised data on them. However, their total, as well as their individual size is very small and the possibility of containing white-tailed eagle nests is extremely low due to their small size and poor age structure. To be able to prove the assumption that nests placed inside the protected area borders (the Kopački Rit and Lonjsko Polje Nature Parks) are placed in favorable positions in comparison to the nests outside the borders, we compared two parts of the population according to the above-mentioned parameters. Similar analyses were performed in order to confirm the hypothesis that white-tailed eagles do not place their nests randomly according to the same parameters by comparing real nest positions and randomly dispersed points. We used appropriate statistics for every test made according to parameter distributions (Table 3).

The analysis of the preference in selecting a tree for nest building according to circumference of the tree with the nest was performed on 48 forest compartments in the Central part of Croatia. For those compartments we collected information on the total number of trees according to the absolute frequencies of their diameter class. Forest habitat parameters, e.g. the total number of trees in the forest compartment, mean diameter and height of trees in the forest, were obtained from the appropriate forest management plans. For a total number of trees in the forest we took the sum of all trees that we knew that eagles choose to breed on. The part of the population from Kopački Rit Nature Park was not included in this analysis due to the suspected reliability of the local forest management plans. Selectivity is presented through Manly index (w) (Krebs 1999) and his standardized form B.

The analysis of nest positions was performed with regard to several parameters: the distance to the nearest settlement, number of settlements in the buffer zone of 3 km, the distance to the nearest road of the 1st and 2nd category and the distance to the nearest road of the 3rd and 4th category. All the analyses described below were performed along areas where two assumptions were accomplished – the distance to the large water bodies and the presence of a forest.

Results

Population size and distribution

In total, 155 localities were visited during the study period. Clear signs of breeding activities were found in 125 locations, and in addition, 10 active territories were detected without locating the exact position of the nests and the confirmation of breeding. Based on this, we conclude that the national breeding population is not smaller than 135 breeding pairs. This was the second largest population of neighbouring Central European countries (Hungary 60–100, Serbia and Montenegro 52–58, Romania 28–33, the Czech Republic 21–28, Bulgaria 7–10, Austria 4 pairs, Slovakia 0–5 and Slovenia 1–3 pairs, respectively) (Birdlife International 2004).

In other words, Croatia supports at least 1.9–2.5% of the European population. The present breeding distribution of the white-tailed eagle in Croatia is spread throughout Central and Eastern Croatia bordered by

Table 1. The most important breeding areas and number of pairs of white-tailed eagles.

	Area	No. of breeding pairs
1	Alluvial wetlands of the Danube River, incl. Kopački Rit Nature Park	42–45
2	Alluvial wetlands of the Sava River – upper parts, including Lonjsko Polje Nature park	28–30
3	Alluvial forests along Ilova and Lonja rivers with adjacent fishponds	20–25
4	Alluvial forests along the lower part of the Sava River, incl. Spačva forests	10–15
5	Pokupsko depression	10–12
6	Alluvial forests of the Drava in Slavonia (from Požega to Koška)	6–8
7	Alluvial forests of the lower Drava River	5–10
	Total	121–145

Table 2. Success of breeding attempts in the four most important selected sites.

Year	Area	Protection status	No. of incubating pairs	No. of pairs with fledglings	Breeding successful (%)
2003	Alluvial wetlands of the Sava River (incl. Lonjsko Polje Nature Park)	Yes	24	17	70.8
2005	Alluvial wetlands of the Danube River (incl. Kopački Rit Nature Park)	Yes	11	9	81.8
2006	Alluvial wetlands of the Danube River (incl. Kopački Rit Nature Park)	Yes	24	18	75.0
2006	Alluvial wetlands along the lower Sava River (incl. Spačva forests)	No	9	7	77.7
2006	Alluvial forests along Ilova and Lonja rivers	No	13	11	84.6

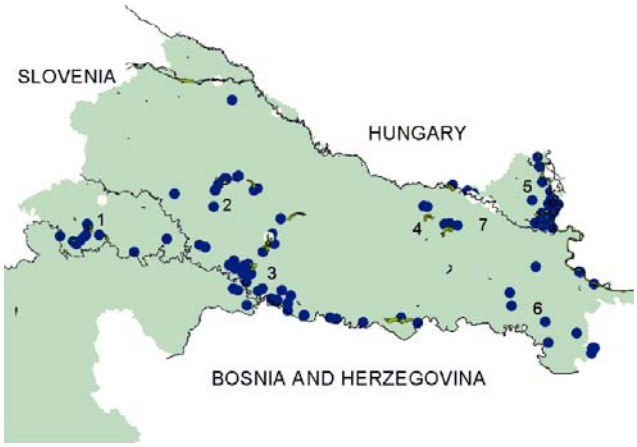

Fig. 1. Active territories of the white-tailed eagle (*Haliaeetus albicilla*) in Croatia during the 2003–2006 period. Filled circles: nesting confirmed; white circles: presumably active territories, but nesting not confirmed.

the Sava and Kupa rivers to the south and the Mura and Drava rivers to the north (Fig. 1). The most important breeding areas are listed in Table 1.

Results on the success of breeding attempts are given in Table 2. They range from 70.8% to 84.6% per breeding season and site. Interestingly, we have found almost no differences in the success of the breeding attempts between protected and unprotected areas.

Habitat selection

Some parameters describing habitat selection of white-tailed eagles are shown in Table 3. We have recorded breeding of the white-tailed eagle on eight tree species: pedunculate oak (*Quercus robur*), sessile oak (*Quercus petraea*), narrow-leafed ash (*Fraxinus angustifolia*), white poplar (*Populus alba*), black poplar (*Populus nigra*), beech (*Fagus sylvatica*), Euro-american poplar (*Populus* sp.) and white willow (*Salix alba*). We calculated using Manly selection index w (Krebs 1999) and standardised selection index B for every tree species, except white willow due to the lack of data on this type of forest. The three highest selection indices were determined for the pedunculate oak (*Quercus robur*) ($w = 6.1267$; $B = 0.7337$), narrow-leafed ash (*Fraxinus angustifolia*) ($w = 0.8473$; $B = 0.1015$) and for the white poplar (*Populus alba*) ($w = 0.5976$; $B = 0.0716$). We examined the statistical importance of the difference in indices with G-test (Krebs 1999) between selectivity for pedunculate oak and narrow–leafed ash ($\chi^2_{(\text{Quercus robur, Fraxinus angustifolia})} = 176$, df = 1, $P < 0.001$) which proved to be significant. The difference between selectivity for *Fraxinus* and *Populus* was not statistically significant ($\chi^2_{(\text{Fraxinusangustifolia,Populusalba})} = 0.24$; df = 1; $P < 0.05$).

Pedunculate oak was the tree with the smallest circumference that housed a nest (C = 84 cm; d = 26.73 cm) while white poplar was the biggest ($C = 472$ cm; $d = 150.24$ cm). The greatest preference was found for the large-tree class of $d > 92.5$ cm ($C > 290$ cm) ($w = 103.33$; $B = 0.947$) then for the class with $d = 67.6$–92.5 cm ($C \sim 210$–290 cm) ($w = 5.66$; $B = 0.052$). The G-test of the difference in selectivity for two classes with the highest selectivity indices, showed a statistically

Table 3. Some habitat characteristics of breeding places of white-tailed eagles.

Parameter and its description	Min.	Max.	Mean	SD	Kurtosis
Distance between nearest active nests during 2005 (m)	348	40738	4339	5636	3.7
Circum at breast height – transferred into diameter (cm)	26.7	150.2	84.3	21.1	1.9
Height of the nest (m)	15.2	37.2	24.5	3.7	1.4
Distance to the nearest water greater than 8 ha (m)	20	10015	1500	1665	12.4
Heights above sea level (m)	79	170	95.9	204.2	12.2
Age of forest when logging/clear-cut would occur (years)	25	140	114	35	0.3
Distance to the nearest water of any kind (m)	15	860	265	214	0.3
Distance to the nearest big river stream (m)	80	53700	8517	12736	5.7
Distance to the nearest fishpond (m)	220	66700	7738	10493	14.3
Distance to the nearest road of the 1st or 2nd category (m)	30	5690	1304	117	2.5
Distance to the nearest road of the 3rd or 4th category (m)	40	2950	610	54	6.4
Distance to the nearest human settlement (m)	425	7500	2742	1457	1.3
Number of the settlements in the buffer of 3 km	0	8	2.2	2.1	0.1

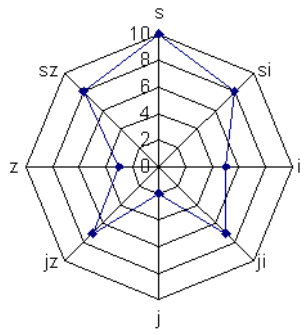

Fig. 2. Exposition of the not-centrally placed nests to the sides of the world.

Fig. 3. Potential breeding area for white-tailed eagles in Croatia.

significant result (χ^2 = 23.55; df = 1; $P < 0.005$).

The average height of the nest was 24.75 m with some difference among nests on different tree species. The nests built on trees of genus *Fraxinus* (Group 2; n = 14) are on the highest positions with an average height of 25.2 m, nests on genus *Quercus* 22.5 m (Group 1; n = 58), and on genus *Populus* 21 m (Group 3; n = 10). With information about the average height of tree species with a nest, we were able to calculate a specific ratio between the average nest heights made on one tree species, with the average height of that species of trees in the forest compartments. The result of this analysis was the conclusion that nests on poplars were built on the highest part of the tree (0.93), similar to those on *Fraxinus* (ratio = 0.88), but those on oaks were placed the lowest on the tree (ratio = 0.73). The analysis of the difference among nest heights between the three groups was conducted by one-way ANOVA. Post hoc Tuckey's (HSD) test revealed the statistically significant difference between Group 1 and Group 2. Group 3 did not differ from any other group.

The analysis of the simple association between heights of the nests and parameters describing the disturbance rate (distance to the roads of the 1st and 2nd category, distance to the roads of the 3rd and 4th category, distance to the nearest settlement and number of settlements in the buffer of 3 km) revealed a moderate (r = –0.29) but statistically significant ($P < 0.05$) correlation among heights of the nests and distance to the nearest human settlement.

Exposition of the nests was recorded for 94 nests of which 44 were placed on the centre of the tree without the obvious exposition to any side of the world. The position of remaining nests (n = 50) is presented in Fig. 2.

The mean number of the human settlements within the 3 km buffer zone for the population inside the protected areas is 0.6 and 2.5 settlements for the population outside the protected areas respectively. The results of the comparisons between the two parts of the population (inside and outside protected areas (further in the text PA) as compared to randomly dispersed points are presented in Table 4.

According to the described methodology, approximately 3% of total the area (Fig. 3) can be regarded as a potential area for breeding for the white-tailed eagles in Croatia.

Discussion

The breeding distribution of the population is comparable with previous studies (Radović et al. 2003; Schneider-Jacoby et al. 2003) with the only exception of the area along the Ilova and Lonja rivers that were not

Table 4. Results of comparisons of nest placement among part of the population inside and outside protected areas as between real nest positions and randomly dispersed points on forested area close enough to feeding place.

Parameter	Random points		Nests positions		Statistics	Result	H_0 reject
	inside PA	outside PA	inside PA	outside PA			
H_0 = the nests are placed randomly in accordance with the parameter tested / no difference between groups of nests and random points							
Small streams							
1		x		x		$t = 5.4$; df = 77; $P < 0.0000001$	yes
Roads 1st and 2nd							
2	x	x			*t*-test	$t = 6.1$, df = 155; $P < 0.000001$	yes
3	x		x		Mann-Whitney	$Z = 1.1$; $P < 0.5$	no
4		x		x	*t*-test	$t = 2.5$; df = 110; $P < 0.01$	yes
Roads 3rd and 4th							
5	x	x			*t*-test	$t = -5.9$; df = 115; P < 0.000001	yes
6	x		x		*t*-test	$t = 3.1$; df = 77; $P < 0.005$	yes
7		x		x	*t*-test	$t = 3.3$; df = 110; $P < 0.001$	yes
Distance to the nearest settlement							
8	x	x			*t*-test	$t = -4.4$; df = 115; $P < 0.0001$	yes
9	x		x		*t*-test	$t = -3.6$; df = 77; $P < 0.0005$	yes
10		x		x	*t*-test	$t = -2.6$; df = 110, $P < 0.01$	yes
Number of settlements in buffer of 3 km							
11	x	x			Mann-Whitney	$Z = -4.4$; $P< 0.00001$	yes
12	x		x		Mann-Whitney	$Z = -2.3$; $P < 0.05$	yes
13		x		x	Mann-Whitney	$Z = 1.46$; $P < 0.5$	no

reported in previous studies as an important breeding site. Recent surveys along the Drava River suggest that the number of breeding eagles is higher than previously expected (Grlica, pers.comm). Our assessment of the number of breeding pairs of the white-tailed eagle of at least 135 breeding pairs is larger than the assessments given by Radović & Sušić (1997) and Radović et al. (2003), which could be attributed to the increased research effort and general population increase. Even during this study, which covers the whole potential breeding area, it is not likely that we managed to find all of the nests/territories, particularly in the dense complex of the Spačva forests. The increase of the white-tailed eagle breeding population was also recorded in most of the European countries (Kollmann et al. 2002; Mizera 2002; Probst 2002; Prochazka 2002; Birdlife International 2004) and it has been evident in Croatia since the nineteen-nineties. The breeding areas are distributed in lowland areas near large rivers and carp fishponds. The highest breeding densities are concentrated in the large intact floodplains of the Sava and Danube rivers. These results are in accordance with previous studies (Schneider-Jacoby 1996; Schneider-Jacoby et al. 2003). Over 51% of the population breeds in the two protected areas of Kopački Rit and Lonjsko Polje Nature Parks, suggesting the importance of protected areas for the survival of the population. Similar results were recently obtained in Hungary where 53% of the population were breeding in protected areas (Horvath & Pinter 2005).

For successful breeding, in addition to good feeding conditions, eagles are dependent on large complexes of alluvial hardwood and softwood forests that secure an adequate breeding habitat and peacefulness. However, despite a recent increase, the Croatian population is threatened with large infrastructural and transport projects (e.g., the Danube-Sava canal, navigation TEN-T project on the Danube, building the large reservoirs on the Drava and Sava rivers) that are putting the existence of the remaining floodplains (Schneider-Jacoby 2005) and their forests in jeopardy. A large part of the Pannonian population is specific in its dependence on carp fishponds as a food resource. The densest active nests were found for nests placed near fishponds. The two nearest active nests were placed only 348 meters apart from each other and both were successful during 2005. But, reliance on fishponds as a food source makes the population more vulnerable, since the production of freshwater fish in Croatia is uncertain, that can cause abandonment of production as a whole (Schneider-Jacoby 2003).

For a population to be considered healthy, a breeding success of 60–80% is necessary (Helander 1994). Beside the reports on poor breeding success during the second half of the 20th century for populations affected by environmental contamination (Randla 1976; Struwe-Juhl 2002), the breeding successes of European populations ranged from 63 to 77% (Helander 1994; Hansen 1979; Struwe-Juhl 2002). Our results on the success of breeding attempts suggest that the Croatian population is healthy and viable at least within the given period. Long-term data on breeding success for the national population would give us an opportunity to investigate whether there are significant differences between the part of the population inside and outside of the pro-

tected areas or between part of the population placed more closely to the big river streams with those more closely related to fishponds.

This study gives a good basis for establishing a long-term national monitoring program but it is necessary to obtain further information on other population parameters such as (i) fecundity,(ii) the demographic structure of the population and (iii) the possible extent of sub-adult birds' dispersion. The importance of knowing the exact fecundity rate is important because of its high correlation ($r = –0.97$; $P < 0.0001$) with adult survival rates (Morrison & Pollock 1997). Thus, fecundity can be seen as surrogate for impractically monitored adult survival rates which has the biggest influence on population dynamics for long-living species (Katzner et al. 2007). We also need to improve our knowledge on the demographic structure of the population and mortality rates for sub-adult birds since their high mortality rate can greatly influence the dynamic and stability of the breeding part of the population (Casagrandi & Gatto 2002).

Since suitability of habitat is the ability of a neighborhood to provide conditions for survival and breeding of the population, thus the distribution and number of particular species in some areas is limited by physical factors (Block & Brennan 1993). Literature data about maximal distance from the nest to the feeding place of white-tailed eagles are extremely scarce and contradictory. Some authors consider that white-tailed eagle can build its nests as far as 10 km away from its feeding place (Glutz et.al. 1971) but, based on the results of this study, this can be considered as an exception rather than the general rule. Closely related species like the bald eagle (*Haliaeetus leucocephalos* L., 1766) fulfill all their needs for food in a radius of 1.5 km around the nest (Livingston et al. 1990).

Several authors assumed that the crucial factor in nest-site selection of white-tailed eagles is good visibility (Mori 1980; Love 1983) and adequate canopy opening to assure safe and easy landing (Brown & Amadon 1968, Love 1983). Similar patterns in selecting trees for nest building is described for related species (*H. leucocephalus*) (Anderew & Mosher 1982; McEwan & Hirth 1979). We doubt that eagles place their nests in greater proximity to small streams by reason of looking for a feeding place (although in some cases it could be true). Several authors (Shiraki 1994; Mizera 1999) state that white-tailed eagles do not place their nests in the areas with low visibility, such as areas deep in the forest. Part of the forest near a small stream or canal has a break in the forest canopy and better visibility. Besides that, a substantial percentage of nests were built in lowland flooded forests. Water stays in the area during the early incubation period which in a certain way makes nests more difficult to access for different kinds of predators, and humans. Having a small stream or big canal near the nest can prolong the period in which the nests are inaccessible during the most critical part of the breeding season.

It is difficult to compare the results of the breeding tree selection from different studies. Variations in forest structure and composition in different areas makes the comparison of absolute frequencies uncertain. The results of this research correspond to previous reports from southern Europe (Cramp 1982). In other regions white-tailed eagles use different kinds of trees, depending on vegetation differences in the area. On the Japanese island of Hokkaido, the white-tailed eagle most commonly breeds on *Picea glehnii* and *Alnus japonica* (Shiraki 1994). Tree selection analysis involves a comparison between the proportions of trees selected for breeding and the available trees. The Manly selectivity index shows a high preference of eagles for *Quercus robur*, following *Fraxinus angustifolia*. The highest selectivity was found for the class of trees with a diameter greater than 150 cm although the absolute frequencies are the lowest. This discrepancy arose due to the unavailability of a bigger class of trees in the habitat. The rotation period in forest management in Croatia does not allow the presence of preferable trees class in the forest. The stage after which some type of forest is considered mature and in a favourable condition for cutting is too young to produce the trees with greater diameter.

The relative heights of the white-tailed eagle nests are diverse on different tree species. The highest average height of the nests was found in nests built on trees of genus *Fraxinus* (25.4) and the lowest on the trees of genus *Quercus* (22.5). The difference in relative positions on different tree species among groups can be explained by the differences in shapes and structure of different tree genera. A similar conclusion can be made for the results involving the exposition of the nests. We need more detailed research to detect whether the exposition of the nest is in correlation with factors like direction to the nearest feeding place or the preference of exposition to a specific side of the world. The obtained significant correlation among heights of the nests and distances to the nearest settlements cannot be explained with causality between parameters since we are not able to prove the random dispersal of different forest types and therefore different tree species along the area. In closely related species (*H. leucocephalus*) disturbance rates on breeding pairs of eagles differ greatly, but a distance of 500 m is generally considered as a distance at which birds are disturbed through human activities (www.fs.fed.us). Most of the white-tailed eagles' nests were placed 1–2 km away from the nearest settlement. This is not a result of absence of forests closer to the settlement, but the result of eagles looking for the places further away in the area, where possible (Table 4, Tests 9 and 10). The different nest positions inside and outside protected areas, when looking at the parameter distance from the nearest settlement, are confirmed with the comparison (Table 4, Test 8). The number of settlements in the buffer zone of 3 km significantly differs for the part of the population outside and inside the protected areas (Table 4, Test 11). The positions of real nests differ significantly from randomly dispersed points (Table 4, Test 13). On the other hand, a similar comparison for population outside protected areas did

not produce a statistically significant difference. This is the result of the deficiency of peaceful areas, in this part of its breeding range. The extension of urban areas, especially in the central part of the country, represents a real obstacle for the further growth of the white-tailed eagles' breeding area.

Everything presented gave us grounds to conclude that white-tailed eagles' nests in Croatia are placed outside the borders of protected areas and are placed closer to the human settlements than ones inside, as well as having a greater number of settlements in the buffer zone of 3 km around the nest. That suggests that overall the exposure to human disturbance for this part of the population has to be higher than for the part of the population inside the borders. In years to come we will have to answer the questions: in which way and to what extent has the proximity to humans influenced the national population? The answers from this survey open a set of new questions about the possible avoidance of eagles flying across settlements above a certain size, and by that influencing the real distance to the nearest feeding place. Although research on the success of breeding attempts for both groups of nests did not show a difference, special attention has to be given to the white-tailed eagles that breed outside the protected areas. They are endangered by two important threats: high disturbance rates and reliance on carp fishponds as food source. The same conclusions can be made looking at the comparison results of parameters distance to the nearest roads (Table 4; Tests 2–7). When considering the management of the area with a breeding population of white-tailed eagles in Croatia the results of the analysis indicates that the population can not be seen as a unique entity, since its spreading and increase in numbers in different areas is restricted by different ecological factors.

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