

Census and Population Dynamics of the White Stork *Ciconia ciconia* in Croatia in the years 2004/05

Jasmina Mužinić^{1*} and Branimir K. Hackenberger²

¹Department of Ornithology, Croatian Academy of Sciences and Arts and Croatian Society of Bird and Nature Protection, Gundulićeva 24, 10000, Zagreb, Croatia.

²Department of Biology, Sub Department of Quantitative Ecology, Josip Juraj Strossmayer University, Laboratory for Biological Systems Analysis, Cara Hadrijana 8/A, 31000, Osijek, Croatia.

Authors' contributions

This work was carried out in collaboration between both authors. Author JM designed the study, organized the surveys, interpreted the data and wrote the paper. Author BKH performed statistical analysis. Both authors read and approved the final manuscript.

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ABSTRACT

Aims: This study was carried out to determine the population dynamics of the White Stork *Ciconia ciconia* in Croatia and to compare it with that of neighbouring countries in Europe.

Study Design: The study is based on the analysis of the data of the 5th and 6th International surveys in Croatia on the pattern of 24 comparable municipalities.

Place and Duration of Study: Fieldwork was carried out on the territory of Croatia in the breeding area of the White Stork in the ten years of breeding period from 1994/95 to 2004/2005.

Methodology: On each White Stork location the data on nest placement and census work HPa, HP0, HPx, HPm and JZG were collected. From these data further parameters were derived: JZa, JZm, StD/100 km² and StDBiol. Nest placements were divided into four categories. Using the software R version 3.0.1., statistical methods as Wilcoxon signed rank test and Friedman rank sum test were used in analysis.

Results and Conclusion: In Croatia, overall assessment of the White Stork pairs in 2004/05 (HPa_{estim}) is 1 714 on overall surface of 25 481 km² with 6.73 pair/100 km² and biological density (StDBiol) of 11.56 HPa/100 km². Roofs and chimneys of residential and farm buildings were the

*Corresponding author: E-mail: jasmina@hazu.hr;

most frequent nest placement (57.97%), then electric poles (38.36%) and trees (2.19%). In ten years the population trend indicates a stability of White Stork in Croatia with increase of 5.16%. Breeding success (JZa) is 2.39 ± 0.93 and population density (StD) is 7.94 HPa/100 km². The shift in the nest placement from the roofs/chimneys, trees and other objects to electric poles shows 15.16% nests less on roofs and 96.40% more on electric poles. The area of Nature Park Lonjsko polje is the most significant for the living and preserving the White Stork population supporting Čigoč with 37 and Osekovo with 35 pairs as villages with the most breeding pairs in Croatia, mainly on roofs/chimneys.

Keywords: Population trends; breeding success; biological density; nest placement; conservation measurements.

1. INTRODUCTION

Due to its extremely large range and population size as well as specificity of habitats under the anthropogenic impacts the White Stork *Ciconia ciconia* in Europe has frequently been used as a model for population studies [1]. Even more, the White Stork is considered indicator species of environmental changes [2] especially a good biodiversity indicator [3,4]. So, changes in population size of White Stork can be used as one of the indicators of environmental changes such as was the case of decline of this species in early 20th century highlighting the problems in the environment notably the loss of wetlands and the changes in agriculture [5] such as intensification or changes in biotic/abiotic conditions of habitats [6].

There is no other bird than White Stork for which statistics on populations trends exist for such a comparably long period of time [7]. The data needed to calculate the population trend were collected by surveys (census methods), which is in Europe on the international level since 1934 [8] and after 1974 conducted every 10 years [9]. The European population of White Stork is considered to be stable since 1982, and appears even to increase [10] although some populations are decreasing [11]. In 1994/1995 the total European population of White Stork was estimated to 166 000 and East-European populations to 138 000 HPa [7]. At that time Croatian population of White Storks was 0.9% of the total European population and 1.08% of East-European populations to which it belongs.

The first census for area of Croatia has been conducted in 1984 under the frame of 4th [12] and continued in 1994/95 under the 5th International White Stork Census [13]. Nevertheless, population dynamics and trend of White Stork in the country could not be estimated because of lack of comparable data: in 1984 the area

covered by census was 28% and in 1994/95 56% of the total breeding area. In 2004/05, under the 6th International White Stork Census, aiming to determine the population dynamics and trend of White Stork in Croatia, the census had been carried out in nearly the whole breeding territory, so the comparable area with the data of previous census done in 1994/95 was available.

First knowledge on breeding success of Croatian population of White Stork were obtained in the year 1994/95 when 2 538 fledged young were recorded [13]. According to the opinion that average breeding success keeping the population stable is $JZa = 2$ [14] the Croatian population of White Stork in the period 1994/95 with JZa 2.27 and JZm 2.63 [13] was stable.

It is expected that first information of the trends in population size, density and breeding success of the White Stork in Croatia, would provide important knowledge to be used to highlight potential changes in human environment at present or in future.

2. METHODS

In Croatia White Stork is the breeding bird of inner continental area that encompasses 43 former municipalities (Fig. 1) used as survey units to enable comparison among different period. This breeding territory represents inundated valleys along the rivers of Sava, Drava, Danube and Kupa with associated wetlands that are important for feeding of this species. During the census field work in the breeding season in the period from 1984 to 2005 the foraging habit of White Stork was observed. This allowed the selection of White Stork habitat type used for feeding. Dominant feeding habitat was wetlands in category of temporary and permanent wet meadows, pasture and agricultural land during the early process of cultivation. Surface area of such potential complex of feeding habitats is

14 777, 77 km². Each of the habitat was extracted from Habitat Map of Republic of Croatia [15] using ArcGIS 10 and Fme SAFE programs.

The census in 2004/05 has been conducted by applying the same methods as for two previous ones in 1984 [12] and 1994/95 [13]. The difference is in the area of investigation covering 94.12% of the total breeding area in 2004/2005 (estimated on 25 481 km²). To complete data for the whole breeding territory, HPa for four municipalities (Orahovica, Zelina, Ozalj i Pakrac), not covered by census in 2004/2005, were estimated on the basis of 1994/1995 data. So, the overall estimation of the breeding population of the White Stork in 2004/05 was based on census conducted in 39 municipalities (25 in 2004 and 14 in 2005) and estimation of total of 27 pairs for four municipalities: 15 pairs for Orahovica and 12 pairs for Zelina, Ozalj and Pakrac.

Fieldwork was carried out in the period before juvenile left the nest, between 25 Jun and 10 Jul in both years of surveys. This is the period when fledged young can be easily seen and counted from the ground. Binoculars were used for observing the breeding parameters. At each nest the following data were gathered using

abbreviation already established [16,17]: HP0 - pairs without young; HPx - pairs with unknown number of young; HPm - pairs with fledged young (1-5). For each county where White Storks were found, the following parameters were calculated from these data: HPa - the number of adult pairs, including pairs without young (HP0), pairs with unknown number of young (HPx) and pairs with 1-5 young (HPm1-5); JZG – the number of young; JZa (JZG/HPa – average number of fledge young related to HPa); JZm (JZG/HPm – average number of fledged young related to HPm); StD (population density or “stork density” as HPa per 100 km²) and StDBiol (“Biological” population density = number of HPa per 100 km² of potential feeding habitat).

Differences between number of breeding pairs (HPa), number of pairs with young (HPm) and number of young birds (JZG) in 1994/95 and 2004/05 periods, were tested with Wilcoxon signed rank test. Shift in nest position in 1994/95 and 2004/05 was tested with generalized Friedman rank sum test for replicated blocked data, followed by Wilcoxon rank sum test as post hoc test. All data analyses were performed using the statistical software R version 3.0.1. [18]. Standard deviation (SD) of breeding success parameters (JZa and JZm) was calculated.



Fig. 1. Breeding area of white stork *Ciconia ciconia* in Croatia, StD and 43 municipalities mentioned in the text

For each location where White Storks were found the data on nest placement were collected. Nest placement were divided into four categories: 1) roof/chimney; 2) electric pole; 3) tree and 4) other (all type of constructions: church and fire towers, grain elevators, transformer buildings, silos, mills, haystacks, etc).

Trend in population size, density, breeding success, frequency of different nest placement and shift in choice of nest position are based upon the data for 24 municipalities (14 503 km²) common for both censuses which had been investigated in 1994/95 [13] and in 2004/2005. For this purpose comparable data on total size of HPa, HPm, JZG, JZa, JZm, and StD in 1994/95 were recalculated.

3. RESULTS

3.1 Population Size, Density and Nest Placement

In Croatia, 6th international census of White Stork in 2004/05 was conducted on the territory of 39 municipalities at the area of 23 984 km². The results show the HPa of 1 687 ranging from 1 (Zabok municipality) to 307 (Sisak municipality) (Table 1). However, the total estimation of White Stork on the overall surface of breeding territory (25 481 km² on 43 counties) reveals $HPa_{estim} = 1 714$ with StD 6.73 HPa/100 km² ranging from 0.45 to 29.18. Seven municipalities (Sisak, Vrbovec, Kutina, Novska, Ivanić grad, Dugo Selo and Ludbreg) have the greatest StD ranging from 10.70. to 29.18 HPa/100 km² (Table 1), highlighting the role of specific type of habitats preferred by White Stork (Table 1a, Fig. 2).

From a total of 109 types of habitats listed in a Habitat Map of Republic of Croatia 11 were selected as White Stork feeding habitats (Fig. 2). Feeding habitat coverage distributed in 39 municipalities is presented in Table 1a. Biological density (StDBiol) of White Stork population in Croatia in 2004/05 was 11.56 HPa/100 km² of feeding habitats.

The highest number of nest on roof/chimneys was recorded in Sisak (260) and Kutina (71) municipalities but in Vrbovec the highest number (93) were placed on electric poles (Table 2).

Nest placement surveyed in 2004/2005 reveals the majority of nest (58%) situated on roofs and chimneys. The further most chosen nest site were electric poles (38%) then trees (2.19%) and other (1.48%) (Fig. 3).

3.2 Ranking the Villages with the Highest HPa

These data presented through ranking of villages used to justify the choice of "European stork village" compared to other villages in the very close number of HPa.

In 20 villages in Croatia there are more than 10 pairs of White Stork most of them are those from the Lonjsko polje area (Čigoč, Gušće, Mužilovčica, Lonja, Sunjska Greda, Jasenovac) (Table 3). Lonjsko polje is covered by two municipalities (Sisak and partly Novska) and are today mostly situated in Sisačko-moslavačka County where 11 villages with more than 10 HPa belong. This county combines 7 types of feeding habitats as complex of mesophil and wet meadows in combination with mixed oak-hornbeam forest, cultivated and intensively cultivated area with rural area. The majority of nests have been noted in Čigoč (37), the "European stork village" recognised as the village with the most White Stork breeding pairs in Croatia since 1994.

Following Čigoč is the Osekovo village on the edge of Lonjsko polje with 35 pairs. Brodsko-posavska County represented by intensively cultivated arable land with poorly vegetated stream banks of stagnant and permanent water has four and Zagrebačka County covered with 5 types of feeding habitats has three villages with 10 or more HPa (Table 3).

4. DISCUSSION

4.1 Population Size

The most increase of breeding pairs and above 100% have been recorded in Križevci, Garešnica and Varaždin municipalities not bordering each to other (Table 4). Further trend of breeding pairs in Croatia can be followed on regional level as Podravina, Posavina, Pokupsko, Međimurje, NW Croatia, and Central Croatia.

Table 1. Results of the 2004/05 white stork *Ciconia ciconia* census in Croatia * Census in 2004; + Census in 2005

	Municipality, km ²	HPo	HPx	HPm 1-5					HPm	HPa	JZG	JZm	JZa	StD
				1	2	3	4	5						
1	* Sisak, 1 052	11	11	14	90	121	54	6	285	307	803	2.81	2.61	29.18
2	+ Vrbovec, 514	76	0	5	28	24	7	0	64	140	161	2.52	1.15	27.24
3	* Kutina, 596	4	10	1	9	27	33	0	70	84	232	3.31	2.76	14.10
4	* Slavonski Brod, 1 065	17	1	5	22	27	5	0	59	7	150	2.54	1.95	7.23
5	* Nova Gradiška, 969	3	2	10	24	29	5	2	72	77	183	2.54	2.38	7.95
6	* Novska, 585	7	0	6	18	25	7	1	57	64	150	2.63	2.34	10.94
7	* Koprivnica, 715	1	0	10	10	24	7	1	52	53	135	2.60	2.55	7.41
8	* Đurđevac, 680	5	0	7	18	17	5	0	47	52	114	2.43	2.19	7.65
9	* Jastrebarsko, 632	1	4	3	12	13	12	4	44	49	134	3.05	2.74	7.75
10	* Vukovar, 606	9	0	23	11	4	1	0	39	48	61	1.56	1.27	7.92
11	* Bjelovar, 732	0	0	1	3	13	24	3	44	44	157	3.57	3.57	6.01
12	* Donji Miholjac, 471	0	0	1	12	25	6	0	44	44	124	2.82	2.82	9.34
13	* Čazma, 455	0	0	0	5	15	22	0	42	42	143	3.40	3.40	9.23
14	* Vinkovci, 1 024	0	0	5	28	6	2	0	41	41	87	2.12	2.12	4.00
15	+ Ivanić Grad, 380	24	0	4	2	10	1	0	17	41	42	2.47	1.02	10.79
16	+ Županja, 815	39	1	0	1	0	0	0	1	41	2	2.00	0.05	5.03
17	+ Grubišno Polje, 435	0	1	0	5	13	20	1	39	40	134	3.44	3.35	9.20
18	+ Požega, 1 249	4	0	1	3	12	16	1	33	37	112	3.40	3.03	2.96
19	+ Đakovo, 833	27	0	3	3	2	0	0	8	35	15	1.88	0.43	4.20
20	* Dugo Selo, 223	4	0	1	13	12	3	1	30	34	80	2.67	2.35	15.25
21	+ Daruvar, 610	4	0	0	6	8	11	2	27	31	90	3.33	2.90	5.08
22	+ Karlovac, 637	6	0	7	8	3	4	0	22	28	48	2.18	1.71	4.40
23	* Osijek, 659	4	0	7	10	7	0	0	24	28	48	2.00	1.71	4.25
24	* Ludbreg, 223	0	0	4	5	12	6	0	27	27	74	2.74	2.74	12.11
25	* Našice, 675	0	2	0	8	11	3	1	23	25	66	2.87	2.64	3.70
26	+ Križevci, 548	9	1	1	9	4	1	0	15	25	35	2.33	1.40	4.56
27	* Čakovec, 724	5	4	0	4	9	2	0	15	24	43	2.86	1.79	3.31
28	+ Garešnica, 419	0	0	0	2	11	11	0	24	24	81	3.38	3.38	5.73
29	* Beli Manastir, 1 147	2	0	0	11	7	3	0	21	23	55	2.62	2.39	2.00
30	* Valpovo, 360	3	0	2	4	7	3	0	16	19	43	2.69	2.26	5.28
31	+ Virovitica, 642	0	0	0	3	11	4	1	19	19	60	3.16	3.16	2.96

	Municipality, km²	HPo	HPx	HPm 1-5				HPm	HPa	JZG	JZm	JZa	StD	
32	+ Velika Gorica, 549	12	0	5	0	0	0	5	17	5	1.00	0.29	3.10	
33	* Slatina, 781	0	0	0	0	8	8	0	16	16	56	3.50	2.05	
34	* Varaždin, 375	0	0	1	4	6	0	11	11	27	2.45	2.45	2.93	
35	* Petrinja, 390	0	0	0	3	3	0	7	7	20	2.86	2.86	1.80	
36	* Ivanec, 345	0	0	0	1	5	1	7	7	21	3.00	3.00	2.03	
37	* Novi Marof, 283	0	0	0	3	0	0	3	3	6	2.00	2.00	1.06	
38	+ Kostajnica, 365	0	0	0	1	1	0	2	2	5	2.50	2.50	0.55	
39	+ Zabok, 221	0	0	0	0	1	0	1	1	3	3.00	3.00	0.45	
	Total: 23 984 km²	277	37	127	399	533	289	25	1 373	1 687	3 805	2.77	2.26	7.03
Estimation for:														
40	Orahovica									15				
41	Zelina									4				
42	Ozalj									2				
43	Pakrac									6				
	Total: 25 481 km²									1 714			6.73	

In western part of Podravina, the area along the Drava (Koprivnica and Đurđevac municipalities) represented by mosaic of cultivated and intensively cultivated arable land with poorly vegetated stream banks and permanent stagnant water, the increase was +41.89%. In the eastern part (Donji Miholjac, Valpovo and Slatina municipalities) where 6 types of feeding habitats are distributed (Table 1a) already recorded in the western part but with additional mesophil and wet meadows with mixed oak-hornbeam and hornbeam forest, decrease of -47.85% was recorded.

In the Posavina (Sava river basin, municipalities of: Sisak, Nova Gradiška, Slavonski Brod and Županja municipalities) covered by mesophil and wet meadows, cultivated and intensively cultivated arable land, active rural areas with poorly vegetated stream banks and permanent stagnant water, the increase was +31.93%. Lonjsko polje as a part of Posavina, covered by Sisak (and partly by Novska) municipalities has the increase of +52%.

Table 1a. Types of feeding habitats in the 39 municipalities (according to legend of Fig. 2.)

	Municipality, km²	Types of feeding habitats
1	Sisak, 1 052	C22; I21; C23; I21/J11/I81; A27/A22/A11
2	Vrbovec, 514	I21; I21/J11/I81; C23/C22/E31
3	Kutina, 596	I31; I21; I21/J11/I81
4	Slavonski Brod, 1 065	I31; C23; C24; A27/A11
5	Nova Gradiška, 969	I31; C23; C22
6	Novska, 585	C22; I31; C23
7	Koprivnica, 715	I21; I31; A27/A22/A11
8	Đurđevac, 680	I21; I31; A27/A11
9	Jastrebarsko, 632	I21; I31; A27/A11
10	Vukovar, 606	I31
11	Bjelovar, 732	I31; I21/J11/I81
12	Donji Miholjac, 471	I31; A27/A11
13	Čazma, 455	I21; I21/J11/I81
14	Vinkovci, 1 024	I31; C23
15	Ivanić Grad, 380	I21; C23; I31
16	Županja, 815	I31
17	Grubišno Polje, 435	I21/J11/I81; C23/C22/E31
18	Požega, 1 249	I31; C23/C22/E31
19	Đakovo, 833	I31; C23/C22/E31; C24
20	Dugo Selo, 223	I21; C23; I31
21	Daruvar, 610	I31; C23/C22/E31
22	Karlovac, 637	I21; I21/J11/I81
23	Osijek, 659	I31; A27/A22/A11
24	Ludbreg, 223	I21; C23; A27/A22/A11
25	Našice, 675	I31; A27/A11
26	Križevci, 548	I31; I21/J11/I81
27	Čakovec, 724	I21; I31; A27/A22/A11
28	Garešnica, 419	I31; I21; A27/A11
29	Beli Manastir, 1 147	I31; A12; C22
30	Valpovo, 360	I31; C23; C22; A12
31	Virovitica, 642	I31; A13/A41/J44
32	Velika Gorica, 549	I21; I21/J11/I81
33	Slatina, 781	I31; C23/C22/E31
34	Varaždin, 375	I31; I21
35	Petrinja, 390	C23/C22/E31; I21
36	Ivanec, 345	I31; I21
37	Novi Marof, 283	I31
38	Kostajnica, 365	C23/C22/E31; I21
39	Zabok, 221	I21; I21/J11/I81

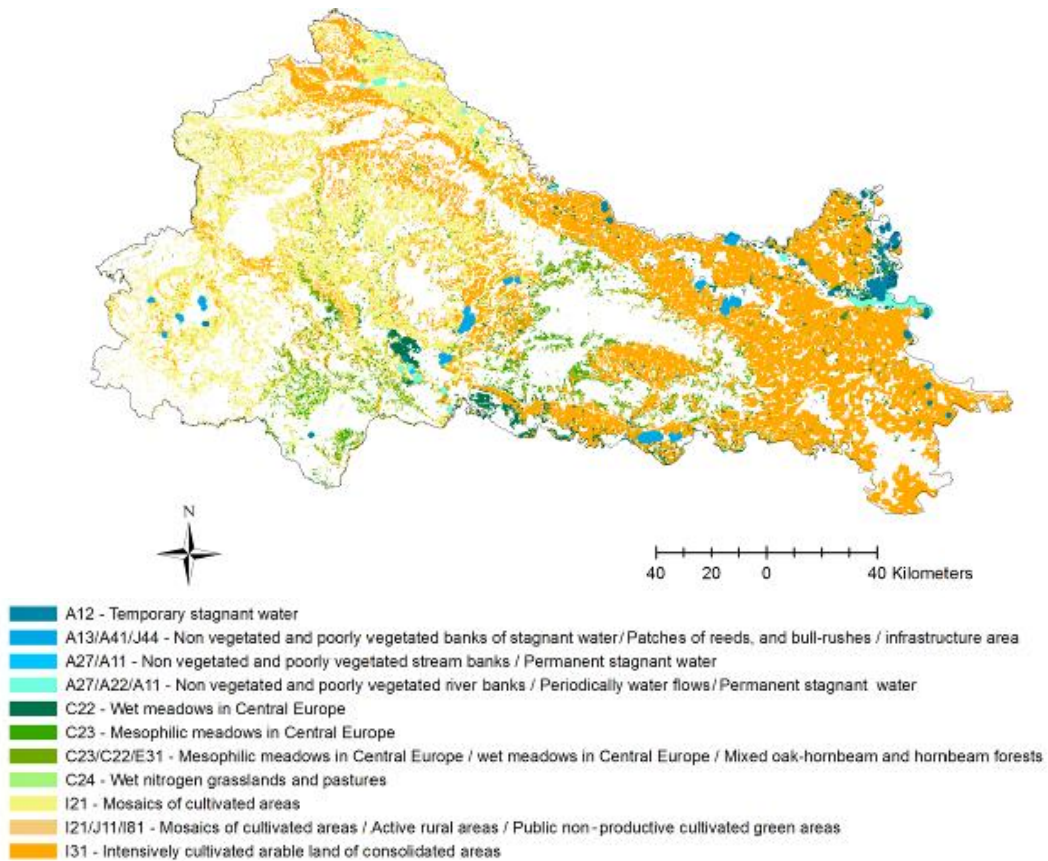


Fig. 2. Map of eleven types of white stork *Ciconia ciconia* feeding habitats in Croatia

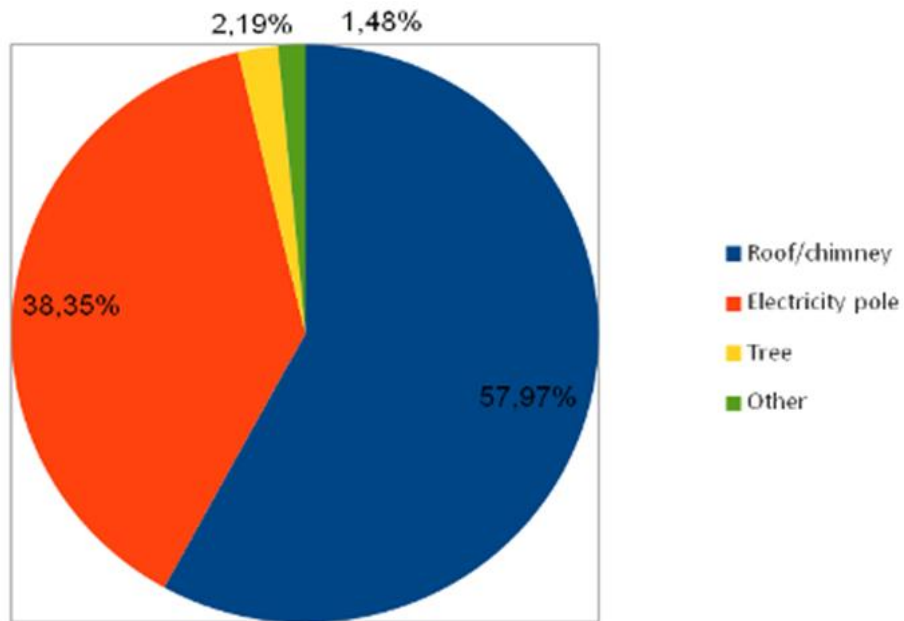


Fig. 3. Frequency of different nest locations of the white stork *Ciconia ciconia* in Croatia in 2004/2005

Table 2. Frequency of different nest position of the white stork *Ciconia ciconia* in Croatia in 2004/05

Municipality	Roof/chimney	Electric pole	Tree	Other
1. Sisak	260	45	2	0
2. Vrbovec	43	93	1	3
3. Kutina	71	10	3	0
4. Slavonski Brod	50	24	3	0
5. Nova Gradiška	66	4	4	3
6. Novska	58	6	0	0
7. Koprivnica	6	47	0	0
8. Đurđevac	14	34	4	0
9. Jastrebarsko	35	13	0	1
10. Vukovar	37	7	3	1
11. Bjelovar	15	28	1	0
12. Donji Miholjac	35	7	2	0
13. Čazma	31	9	2	0
14. Vinkovci	36	5	0	0
15. Ivanić grad	23	15	1	2
16. Županja	34	2	2	3
17. Grubišno Polje	5	34	1	0
18. Požega	26	9	2	0
19. Đakovo	20	14	0	1
20. Dugo Selo	20	13	0	1
21. Daruvar	5	26	0	0
22. Karlovac	6	22	0	0
23. Osijek	6	20	0	2
24. Ludbreg	3	24	0	0
25. Našice	11	12	1	1
26. Križevci	6	19	0	0
27. Čakovec	3	21	0	0
28. Garešnica	4	20	0	0
29. Beli Manastir	15	3	1	4
30. Valpovo	9	8	1	1
31. Virovitica	2	16	0	1
32. Velika Gorica	8	8	1	0
33. Slatina	6	8	2	0
34. Varaždin	1	10	0	0
35. Petrinja	3	4	0	0
36. Ivanec	2	5	0	0
37. Novi Marof	2	1	0	0
38. Kostajnica	1	0	0	1
39. Zabok	0	1	0	0
Total HPa = 1 687	978	647	37	25

Pokupsko basin (Karlovac municipality), as mosaic of cultivated areas with active rural areas and public non-productive cultivated green areas, shows the growth in the number of pairs reflecting the 64.71% of positive trend.

An increase of +9.09% in the number of breeding pairs had been recorded in Međimurje (NW Croatia) (municipalities of Čakovec surveyed in 2004). This area is represented by cultivated and intensively cultivated arable land with some poorly vegetated stream banks and permanent

stagnant water, and is bordering with the NE Slovenia, where the decrease of the breeding population in 2005 was found [19]. In other part of NW region bordering to Slovenia, consisting of the mosaic of cultivated and intensively cultivated area (Ivanec, Novi Marof and Varaždin municipalities) 21 breeding pairs have been recorded but its territory to the south covered by six municipalities (Krapina, Klanjec, Donja Stubica, Zaprešić, Samobor and Ozalj), being completely without breeding pairs, belongs to the territory with rarest population of White Stork in

Table 3. Rank-list of villages with 10 or more pairs (HPa) of white stork *Ciconia ciconia* and feeding habitats in 2004

Ranking place	Village/county	HPa	Types of feeding habitats in the county
1	Čigoč/SM	37	C23/C22/E31; I21; C22; I21/J11/I81; C23; I31; A27/A22/A11
2	Osekovo/SM	35	C23/C22/E31; I21; C22; I21/J11/I81; C23; I31; A27/A22/A11
3	Gušće/SM	27	C23/C22/E31; I21; C22; I21/J11/I81; C23; I31; A27/A22/A11
4	Borovo/VS	25	I31; C23
4	Donja Kupčina/Z	25	I21; I31; C23/C22/E31; I21/J11/I81; A27/A11
5	Bobovac/SM	22	C23/C22/E31; I21; C22; I21/J11/I81; C23; I31; A27/A22/A11
6	Mahovo/SM	19	C23/C22/E31; I21; C22; I21/J11/I81; C23; I31; A27/A22/A11
7	Mužilovčica/SM	18	C23/C22/E31; I21; C22; I21/J11/I81; C23; I31; A27/A22/A11
7	Jasenovac/SM	18	C23/C22/E31; I21; C22; I21/J11/I81; C23; I31; A27/A22/A11
7	Lonja/SM	18	C23/C22/E31; I21; C22; I21/J11/I81; C23; I31; A27/A22/A11
8	Orubica/BP	17	I31; C23; C22; A27/A11; C24
8	Kraljeva Velika/SM	17	C23/C22/E31; I21; C22; I21/J11/I81; C23; I31; A27/A22/A11
9	Slavonski Kobaš/BP	16	I31; C23; C22; A27/A11; C24
10	Greda/Z	13	I21; I31; C23/C22/E31; I21/J11/I81; A27/A11
10	Davor/BP	13	I31; C23; C22; A27/A11; C24
11	Sišćani/BB	12	I21; I21/J11/I81; I31; C23/C22/E31; A27/A11
11	Sunjska Greda/SM	12	C23/C22/E31; I21; C22; I21/J11/I81; C23; I31; A27/A22/A11
11	Lukavec/Z	12	I21; I31; C23/C22/E31; I21/J11/I81; A27/A11
12	Desna Martinska Ves/SM	10	C23/C22/E31; I21; C22; I21/J11/I81; C23; I31; A27/A22/A11
12	Gornja Varoš/BP	10	I31; C23; C22; A27/A11; C24

Counties: SM – Sisačko- moslavačka; VS- Vukovarsko-srijemska; Z-Zagrebačka; BP-Brodsko- posavska; BB- Bjelovarsko-bilogorska

Croatia. Last mentioned municipalities, traditionally without White Storks, are hilly area without flooded habitats, so absence of White Stork population is justified.

The area of decline in the number of pairs is in central part of the inner Croatia represented by various feeding habitats as cultivated and intensively cultivated arable land, mesophilic and wet meadows, mixed oak-hornbeam and hornbeam forest, active rural areas and public non-productive cultivated green areas (Ivanić grad, Čazma, Kutina, Garešnica, Grubišno polje and Daruvar municipalities) at 2 895 km² showing 21.67% less pairs, although the StD is still high (9 HPa/100 km²).

In total, at present, the Croatian White Stork populations are stable with the positive trend of

5.16% (Table 4). Nevertheless, between 1994/95 and 2004/05 there is no statistically significant difference in number of breeding pairs HPa ($\alpha < .05$, $P = .62$), pairs with young HPm ($\alpha < .05$, $P = .98$) and young birds JZG ($\alpha < .05$, $P = .35$).

4.2 Breeding Success

The average number of fledged young (\pm SD) JZa in 2004/2005 was 2.39 \pm 0.93 and was above 2 in all of 24 compared municipalities except 7 where it was ranging from 0.05 to 1.95 (Table 5). In comparison with JZa = 2.28 \pm 0.45 in 1994/95 (Table 5) it was positive trend accompanied by increase in total of 0.39 HPa/100 km². Bjelovar municipality with JZa and JZm = 3.57 had the highest breeding success. This is the area of mosaic of intensively cultivated arable land,

active rural areas and public non-productive cultivated green areas (Table 1a, Fig. 2).

The average breeding success of successful pairs (\pm SD) JZm was 2.86 ± 0.51 show the stability of White Stork population in Croatia and positive trend in comparison with JZm = 2.64 ± 0.52 in 1994/95 (Table 5).

4.3 Population Density

In 2004/05 the highest population density (StD) of the White Stork were found in Sisak (29.18), Vrbovec (27.24) and Dugo Selo (15.25) municipalities (Table 1). The average density related to pattern of compared area of 24 municipalities covering 14 503 km² was StD = 7.94 what is slightly more than in the years 1994/95 when StD was 7.55 HPa/100 km² (Table 5).

Foraging habitat preferences of White Stork observed in Croatia are confirmed as wider area

of alluvial wetlands of the rivers Sava, Drava and Mura with traditional agriculture landscape [20] and are very much the same as found in other European countries like Poland [21,22] and Slovenia [19]. Those alluvial wetlands in Croatia in the period 1990-2000 showed the greatest changes but mostly in forest habitat: 8% of the total area along the Danube and Drava and 5% along the Sava including Nature Park Lonjsko polje [23]. These changes seem to have no influence on White Stork population in Lonjsko polje where the increase of 52% of population is recorded.

Many aspects of biodiversity of Lonjsko polje already described [24,25,26] indicates its value for wetland depending birds especially of White Stork [27]. Benefits for survival of White Stork in Lonjsko polje are reflecting in rich diversity of its food [28] preserved through traditional agriculture and traditional building of the Posavina houses where this species can easily place their nest.

Table 4. HPa, HPm, JZG and population trend in percentage (%) of White Stork *Ciconia ciconia* in Croatia in the period from 1994/95 to 2004/05; HPa - number of breeding pairs; + positive trend; - negative trend

	Municipality	HPa		Trend	HPm		JZG	
		1994/95	2004/05	%	1994/95	2004/05	1994/95	2004/05
1	Sisak	202.0	307	+ 51.98	184.0	285	469	803
2	Kutina	102.0	84	- 17.65	88.0	70	205	232
3	Slavonski Brod	63.0	77	+ 22.22	49.5	59	119	150
4	Nova Gradiška	72.5	77	+ 6.21	54.5	72	124	183
5	Koprivnica	34.5	53	+ 53.65	28.5	52	74.5	135
6	Đurđevac	39.5	52	+ 31.65	33.0	47	88.5	114
7	Bjelovar	43.5	44	+ 1.15	41.0	44	137	157
8	Donji Miholjac	106.0	44	- 58.49	89.0	44	195	124
9	Čazma	72.5	42	- 2.07	70.5	42	252	143
10	Ivanić Grad	62.5	41	- 4.40	51.5	17	127	42
11	Županja	43.0	41	- 4.65	43.0	1	109.5	2
12	Grubišno Polje	52.5	40	- 23.81	48.5	39	125.5	134
13	Đakovo	25.0	35	+ 40.00	23.0	8	67	15
14	Daruvar	35.5	31	- 12.68	20.0	27	75.5	90
15	Karlovac	17.0	28	+ 64.71	15.0	22	36	48
16	Ludbreg	24.0	27	+12.50	21.5	27	53	74
17	Križevci	9.0	25	+177.78	6.5	15	25.5	35
18	Čakovec	22.0	24	+ 9.09	16.5	15	35.5	43
19	Garešnica	9.5	24	+152.63	9.5	24	21.5	81
20	Valpovo	25.5	19	- 25.49	25.0	16	70	43
21	Slatina	20.0	16	- 20.00	16.5	16	55.5	56
22	Varaždin	5.0	11	+120.00	4.5	11	11.5	27
23	Ivanec	6.0	7	+16.67	6.0	7	14.5	21
24	Novi Marof	3.5	3	- 14.30	3.0	3	6.5	6
	Total:	1 095.5	1 152	+ 5.16	948	963	2 498	2 758

Table 5. JZa, JZm and StD of white stork *Ciconia ciconia* in Croatia in the period from 1994/95 to 2004/2005

Municipality	JZa		JZm		StD	
	1994/95	2004/05	1994/95	2004/05	1994/95	2004/05
1 Sisak	2.32	2.61	2.55	2.81	19.20	29.18
2 Kutina	2.01	2.76	2.33	3.31	17.11	14.10
3 Slavonski Brod	1.89	1.95	2.4	2.54	5.92	7.23
4 Nova Gradiška	1.71	2.38	2.28	2.54	7.48	7.95
5 Koprivnica	2.16	2.55	2.61	2.60	4.83	7.41
6 Đurđevac	2.24	2.19	2.68	2.43	5.81	7.65
7 Bjelovar	3.15	3.57	3.34	3.57	5.94	6.01
8 Donji Miholjac	1.84	2.82	2.19	2.82	22.50	9.34
9 Čazma	3.48	3.40	3.57	3.40	15.93	9.23
10 Ivanić Grad	2.03	1.02	2.47	2.47	16.44	10.79
11 Županja	2.55	0.05	2.55	2.00	5.27	5.03
12 Grubišno Polje	2.39	3.35	2.59	3.44	12.07	9.20
13 Đakovo	2.68	0.43	2.91	1.88	3.00	4.20
14 Daruvar	2.13	2.90	3.78	3.33	5.82	5.08
15 Karlovac	2.12	1.71	2.4	2.18	2.67	4.40
16 Ludbreg	2.21	2.74	2.47	2.74	10.76	12.11
17 Križevci	2.83	1.40	3.92	2.33	1.64	4.56
18 Čakovec	1.61	1.79	2.15	2.86	3.04	3.31
19 Garešnica	2.26	3.38	2.26	3.38	2.27	5.73
20 Valpovo	2.75	2.26	2.8	2.69	7.08	5.28
21 Slatina	2.78	3.50	3.36	3.50	2.56	2.05
22 Varaždin	2.3	2.45	2.56	2.45	1.33	2.93
23 Ivanec	2.42	3.00	2.42	3.00	1.74	2.03
24 Novi Marof	1.85	2.00	2.16	2.00	1.24	1.06
Total: 14 503 km²	2.28±0.45	2.39±0.93	2.64±0.52	2.86±0.51	7.55	7.94

Positive correlation between White Stork population size and Common vole *Microtus arvalis* density were found in Poland suggesting that voles are important prey because of their high calorific value [28]. In Lonjsko polje White Storks feeds with four species of mammals of which the most frequent is the Common vole [29]. Although the fluctuation in abundance and density of this prey was not investigated, similar explanation can be applied to the population size of White Stork in Lonjsko polje with the highest HPa and StD in Croatia. Since 1990, this area is mostly included in Nature Park, as its long tradition representing the best biotope for White Stork in Croatia.

4.4 Nest Selection, Threats and Conservation

In addition to food, availability of breeding places in the vicinity of feeding habitats is the most important feature for the breeding success. Following the Čigoč, Osekovo is the village with the most breeding pairs in Croatia where 50 pairs of White Stork in 1996 was recorded [30] most of

them found on houses (Mužinić, unpublished data), showing the species evolutionary connection with human settlements.

In relation to previous period of ten years [13] in 2004/05 15.16% less nests have been located on roofs/chimneys what is statistically significant decrease ($\alpha < .05$, $P = .001$), and 96.40% more on electric poles ($\alpha < .001$, $P = .0001$). Number of nest placed on trees decreased by 26.31% (Table 6) but this is not statistically significant ($\alpha < .05$, $P = .52$). In the same time the decrease of number of nests on other positions than roof/chimney, electric poles or trees, is statistically significant ($\alpha < .05$, $P = .01$).

Shift the location of the roofs/chimneys to electric pole indicate that the species has changed its strategy of nest selection. The reason could be the disappearance of old traditional houses while a roof structure of a new built houses do not provide a satisfactory replacement so the electric poles represent for White Stork the most attractive constructional foundation for building their nests. The same trend is recorded in other

Table 6. Shift in different nest position of the white stork *Ciconia ciconia* in Croatia from 1994/95 to 2004/05

Municipality	Roof/chimney		Electric pole		Tree		Other	
	1994-95	2004-05	1994-95	2004-05	1994-95	2004-05	1994-95	2004-05
1. Sisak	192	260	5	45	2	2	3	0
2. Kutina	99	71	1	10	0	3	2	0
3. Slavonski Brod	46	50	11	24	0	3	6	0
4. Nova Gradiška	65.5	66	3	4	3	4	1	3
5. Koprivnica	10	6	24.5	47	0	0	0	0
6. Đurđevac	17.5	14	20	34	1	4	1	0
7. Bjelovar	29.5	15	13	28	0	1	1	0
8. Donji Miholjac	77	35	19	7	1	2	9	0
9. Čazma	58.5	31	4	9	9	2	1	0
10. Ivanić grad	46.5	23	11	15	2	1	3	2
11. Grubišno Polje	27	5	23	34	2	1	0	0
12. Županja	34	34	0	2	7	2	2	3
13. Đakovo	15	20	4	14	4	0	2	1
14. Daruvar	17	5	17.5	26	1	0	0	0
15. Karlovac	9	6	6	22	0	0	2	0
16. Ludbreg	7	3	17	24	0	0	0	0
17. Križevci	4	6	5	19	0	0	0	0
18. Čakovec	3	3	19	21	0	0	0	0
19. Garešnica	5.5	4	3	20	1	0	0	0
20. Valpovo	14.5	9	6	8	3	1	2	1
21. Slatina	14	6	2	8	2	2	2	0
22. Varaždin	1	1	4	10	0	0	0	0
23. Ivanec	3	2	3	5	0	0	0	0
24. Novi Marof	2.5	2	1	1	0	0	0	0
1994/1995 Total	798 (72.84%)		222.5 (20.31%)		38 (3.47%)		37 (3.38%)	
HPa: 1 095.5								
2004/2005 Total	677 (58.77%)		437 (37.93%)		28 (2.43%)		10 (0.87%)	
HPa: 1 152								

European countries whether they are West-European or East-European population: In 1994 increase in the percentage of nests on electric poles had been recorded in Portugal [31] and in Poland in the period from 1974 to 1994 birds had moved from trees and buildings to electric poles [32]. In Croatia, selection of electric poles for their nests causes a threat for the White Stork, because of electrocution but also because of removing nests by Croatian Power Company in some area. Same process has been observed in Voivodina [33] and Slovenia [19]. So, conservation measures to keep the stability of White Stork in Croatia should mainly refer to relocation of natural nests instead of being destroyed [34]. Such conservation measures should use metal frame to replace the huge White Stork nests on specially built wooden platforms [35]. Further, this would avoid the problems of regular supply of local inhabitants by

electric power while at the same time protect the birds from physical or electric shock by electric wires. In the same time the owners of new houses should allow the White Stork to build the nest on the roof helping them by setting special wooden structure situated on roofs.

5. CONCLUSION

Census of White Stork *Ciconia ciconia* in Croatia in 2004/2005 was investigated on the total breeding area and has revealed the population of 1 714 breeding pairs (HPa). The population trend is stable with increase of 5.16%. Total area of 11 feeding habitat types (14 777 km²) in comparison with total breeding area (25 481 km²) indicates that 58% of Croatian territory is suitable for White Stork feeding and breeding. The most of breeding pairs (>10/100 km²) occupied the area

of 6 type of feeding habitats represented mostly by cultivated and intensively cultivated area, mesophil and wet meadows as well as rural area. Biological density (StDBiol) is 11.56 breeding pairs/100 km². The breeding success (JZa and JZm) are above 2 respectively, showing positive trend and stability of White Stork population. Due to disappearance of old traditional houses the White Stork has been forced to change its strategy of nest selection moving from roofs/chimneys to electric poles, demonstrating 15.6% less nests on roofs/chimneys and 96.40% more on electric poles. Conservation measurements on White Stork in Croatia should be directed to Power Company, as owners of electric poles in villages, to maintain the population breeding only on chosen electric poles. But also to the owners of new houses (information, education) to allow and help building the nest using special wooden structure situated on roofs.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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