Tryjanowski P., Sparks T.H. & Jerzak L. (eds.)
The White Stork in Poland: studies in biology, ecology and conservation
Bogucki Wydawnictwo Naukowe, Poznań 2006

Colonization of new territories: the White Stork *Ciconia ciconia* distribution and population changes in the Sudeten Mountains (Poland)

Andrzej Wuczyński

Institute of Nature Conservation, Polish Academy of Sciences, Lower-Silesian Field Station, Podwale 75, PL-50-449 Wrocław, Poland, e-mail: a.wuczynski@pwr.wroc.pl

ABSTRACT: Colonization of mountain areas by the White Stork is a new and poorly documented phenomenon, started in the first half of the last century. In this paper I present the course of expansion and the current distribution of this species in the range of the Sudeten Mountains, SW Poland (max. altitude 1602 m, habitats available for stork up to 600 m asl). Results are based on the White Stork censuses started here as early as 1907. Before 1950 the White Stork occurred almost exclusively in the foothill zone of Sudeten, and fluctuated in numbers. The number of occupied nests grew fourfold between 1934 (38) and 2004 (169), and the altitude of nests increased by 200 m (max. 560 m asl). In this period, mountain valleys became inhabited and changes in the frequency of nest types were noted. However, during the last decade the colonization stopped in terms of numbers and altitudinal expansion but the reasons remain unclear. The stork density in the inner mountain area (0.85 pairs/100 km^2) was only a third that in the foothills, but the breeding performances were better. Long-term yearly data from two sample plots showed a significant increase in chick productivity per pair (JZa) in the plot lying inside the mountains (1643 m^2), but a decrease in chick productivity per successful pair (JZm) in the plot lying in the foothills (793 km^2). Comparison with two other populations colonizing the Carpathians revealed a dissimilarity with the Sudeten population, e.g. higher rate and different periods of expansion. Treating the White Stork as a model species entering new, previously unoccupied areas it was shown that the course of this process can change in time, and differences can be seen both within the given population and between populations colonizing different (upland) areas.

KEY WORDS: population changes, colonization, breeding success, altitudinal gradient, mountains, White Stork

Introduction

The White Stork is regarded as a lowland species, originally connected mainly with open rivers valleys, and recently inhabiting the agricultural landscape, of which it has became the symbol (Creutz 1988, Schulz 1998). The highest densities (20–45 pairs/100 km^2) and the centre of its geographical range, are found in lowlands in the north and east of Poland and in adjacent areas of neighboring countries. However, many examples show that the stork has the biological potential to nest also in high, mountainous areas. Breeding attempts in Morocco reach an altitude of 2500 m asl, in Turkey 2300 m, in Armenia 2000 m (Schulz 1998), and in Georgia the entire population (but only 53–61 pairs in 1996) breeds in environments of 1900–2100 m (Gavashelishvili 1999). The highest localities in Europe are met on the Iberian Peninsula (1350 m) and in the Balkans (1300 m), and in the centre of the continent in the Polish and Slovak Tatra mountains at an altitude of 800–900 m asl (Profus 2006). The highest elevation of a breeding attempt in Poland was 890 m asl in Zakopane-Pardałówka in 1998 (Profus & Cichocki 2002).

Uphill shift in distribution of the White Stork is a new phenomenon, started in the first half of the last century. It is believed to be the consequence of anthropogenic changes of habitats resulting in the improvement of food supply (Profus 2006), and possibly also an effect of climate warming (Tryjanowski et al. 2005b). The process is poorly documented, and most data come from the Polish Carpathians (Profus & Mielczarek 1981, Ćwikowski & Profus 2000, Profus & Cichocki 2002, Tryjanowski et al. 2005b, Jakubiec 2006, Profus 2006). The population increase was described also in the Slovak Tatra Mountains (Stollmann 1988, 1989), in the Polish Sudeten Mountains (Wuczyński 1997, 2006, Mikusek & Wuczyński 2005), in the Czech Upland (Rejman 1989, Hladik 1989), and in the Sakson Rudawy Mountains (Bäßler et al. 2000). Data from other mountainous areas are lacking, making it impossible to determine whether the process of altitudinal expansion of the White Stork is widespread within its geographical range or rather is a unique feature of the Central-European population.

The Sudetens is a mountain range of average size located on the Polish-Czech border, with the most westernly part located in Germany. There was evidence of the stork expansion in these mountains in the 20th century, both on the Polish side (Wuczyński 1997, Jakubiec 1991, Wuczyński 2006, Mikusek & Wuczyński 2005) and on the Czech side (Rejman 1989). However, comprehensive and new data are missing. It is not known whether the colonization in these mountains is still ongoing and what is its rate. There is limited information coming from the main, interior part of the mountains, and the ecology of the "mountainous" populations of the White Stork is weakly recognized. The aim of this study was to present the course and rate of colonizing of the Polish Sudeten Mountains, and to describe the numbers, distribution and breeding performance of White Storks in this area.

Study area

The study was carried out across most of the Sudeten Mountains located within the borders of Poland (8446 km^2). In a physico-geographical division the study area coincided with the sub-province Sudeten Mountains and the Sudeten Foreland (Kondracki 1998, Żurawek 2005). Detailed borders were outlined by the administrative units – 12 districts (Polish: powiat) located within the Dolnośląskie province (Polish: województwo) (Fig. 1). Since the administrative and physico-geographical borders did not coincide, small fragments of the Sudeten region remained outside the study area (mainly the Opawskie Mountains, E part of the Sudeten Foreland, the Ślęża Massif and N part of the Izerskie Foothills, less than 10% in total), whereas two rather lowland parts were included (N parts of Zgorzelec and Jawor counties).

The Sudeten Mountains stretch from SE (Moravian Gateway) to NW (Łużyckie Mountains). They are an example of block mountains, belong to the oldest ranges in Europe and are very diverse in structure. The massif is approx. 300 km long and 50 km wide, and is split into five parts: Eastern, Central, Western Sudeten, the Sudeten Foreland and Western Sudeten Foothills. These are divided into a dozen or so smaller mountain groups, mostly forested, like the Karkonosze Mountains (1602 m – the highest peak for Sudeten), Kaczawskie Mountains (724 m), Sowie Mountains (1015 m), Śnieżnik Massif (1425 m). These groups are separated by subsidence basins, of which the biggest are the Basins Jeleniogórska (altitude 330–400 m), Kamiennogórska (410–560 m) and Kłodzka (360–450 m). Basins are covered by agriculture and along with the foothills zone are the most important areas available for the White Stork as breeding grounds in the Sudeten region.

From the north the main massif of Sudetes is adjoined by: a) the Western Sudeten Foothills, which is an upland region (300–500 m) furrowed by long gorges of rivers, b) the Sudeten Foreland (200–300 m), which is a rolling landscape with scattered hills, mostly wooded and isolated. A distinctive, tectonic feature, which sharply marks the boundary between the Sudeten and the Foreland is the Sudeten Marginal Fault, nearly 100 km long, where agricultural, lowland-like areas directly border the steeply elevated, wooded mountain slopes. Further north the Sudeten Foothills and Foreland gently turn into a vast area of lowlands, not included in this study.

The Sudeten region has a rich river network, the main western tributaries of the Oder river flow out of here, they go longitudinally and are termed mountain-lowland rivers (from the west these are Nysa Łużycka, Bóbr, Kaczawa, Bystrzyca, Ślęża, Oława and Nysa Kłodzka). The main Sudeten ridge is a watershed between the Baltic Sea basin in the north, the North Sea in the west and the Black Sea in the south. The Sudeten has a mountain climate with oceanic influences, the mean temperature at an altitude of 600 m is 15°C in July and –3°C in January, precipitation amounts to 800 mm at the foot of the mountains and 1200 mm on the ridges. The proportions of different habitats in the studied area in 2004 averaged: arable fields 39%, forests 33%, meadows and pastures 17%, and 11% other habitats (inhabited areas, roads, waters etc.) (Appendix). Population density in 2004 was 142 people/km^2.

Material and methods

The main sources of information were the results of the consecutive regional and international White Stork censuses, carried out on this area in 1907, 1922, 1933/34, 1974, 1984, 1995 and 2004. Questionnaires and, in selected areas, direct field observations were the standard methods used. The detailed methodology of data collecting and analysis have been described in the studies summing up the results of the consecutive censuses: 1907 and 1922 – Pax (1925), 1934 – Brinkmann (1935), 1974 – Jakubiec (1985), 1985 – Profus et al. (1989), 1995 – Jakubiec and Guziak (1998), 2004 – Guziak (2006). The distribution of the White Stork in the first half of the last century was taken from the publications of Pax (1925) and Brinkmann (1935). Results of the 3rd and 4th counts (1974 and 1984) were taken directly from the national survey materials archived in the Lower Silesian Station of the Institute of Nature Conservation PAS. Results of the 5th and 6th counts were obtained from the White Stork database, led by PTPP "pro Natura" (Wrocław). Moreover, my own unpublished materials were used, as well as data from two sample plots lying within the studied area and covered by a long-term monitoring of the White Stork – Sudeten Foreland, covering 793 km^2 (nine communes) of the foothills zone (for more details see Wuczyński 1997), and Kłodzko Region covering the mountainous county of Kłodzko, 1643 km^2 (Mikusek & Wuczyński 2005).

Population size was assessed based on the number of nests occupied by breeding pairs only (HPa), with extrapolation for poorly recorded areas (less than 10% of the total area in different counts). Frequency of nest types was calculated for all nests found in particular censuses. During analysis standard population indices were used (Mrugasiewicz 1971, Jakubiec 1985). The altitude of each nest was recorded from detailed maps, for nests of unknown precise position the midpoint of the village with the nest was used. Data were analyzed for the whole Sudeten region, as well as for two groups of districts:

a) mountainous counties, where the altitude is totally above 300 m asl: Jelenia Góra (including the county of the city Jelenia Góra), Kamienna Góra, Wałbrzych and Kłodzko (totally 3290 km^2),
b) foothill counties, covering the great, wavy sweep of mosaic habitats adjoining the main massif of the Sudeten Mountains: Zgorzelec, Lubań, Lwówek Śląski, Złotoryja, Jawor, Świdnica, Dzierżoniów, Ząbkowice Śląskie (totally 5156 km^2).

Additionally, data for 2004 were compared with the results obtained in the remaining, lowland counties of the Dolnośląskie Province (14 districts, 11502 km^2), collected with the same methodology as in the Sudeten Mountains

Results

Recent numbers and distribution

Based on 157 recorded breeding pairs, the population of the White Stork in the Sudeten Mountains in 2004 was estimated at 168 pairs, and the total density amounted to 1.99 pairs/100 km^2. The distribution was very uneven, in the moun-

tainous districts the density was a third that in the foothill zone (0.85 and 2.72 pairs/100 km^2, respectively), also when forested areas were excluded (1.48 and 3.68 pairs/100 km^2 respectively). Nevertheless, these densities were much lower than in the adjoining lowland part of the Dolnośląskie Province (6.49 pairs/100 km^2, HPa=747). Among the main Sudeten massif only some intermontane basins and river valleys were occupied, and everywhere nests were sparse (Fig. 1). Among 48 nests recorded in mountain districts and with at least one breeding attempt during the last four censuses, as many as 73% concentrated in the three biggest Sudeten basins: Jelenia Góra Basin (14 nests), Kamienna Góra Basin (including its two smaller parts – Krzeszów Basin and Lubawka Gateway) (12 nests), and Kłodzko Basin (including Upper Nysa Trench) (10 nests). Distribution of nests in foothill districts was more even, but also sparse. No regions of nest concentrations were noted, and two occupied nests in one village were exceptional (Appendix).

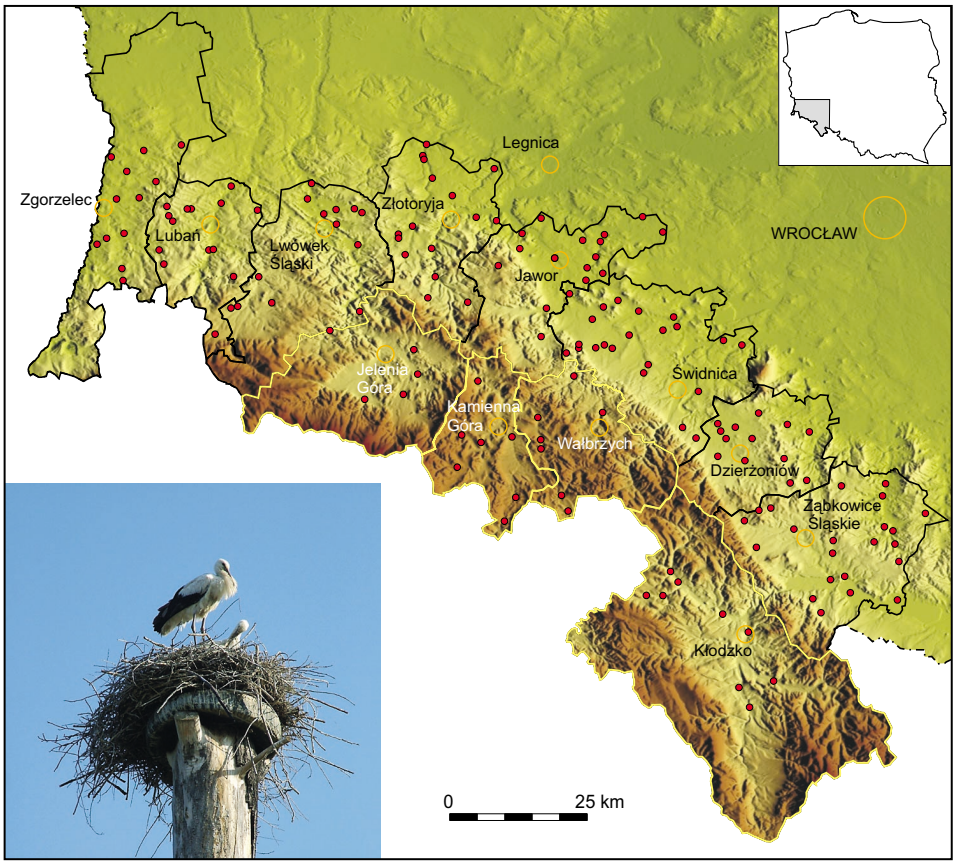

Fig. 1. Distribution of White Stork in the Sudeten region in 2004. Each dot represents one occupied nest (N=157, see Appendix for details). Borders of mountainous districts are marked with yellow line

Population dynamics

The first complete counts of the White Stork in Silesia were conducted in 1907, 1922 (Pax 1925), and 1933–1934 (Brinkmann 1935). In comparison with later censuses the population assessment was probably slightly overestimated, especially in 1907. In this count only the total number of nests was revealed, without division into occupied and unoccupied classes. Such division was done in the next two counts, however nests irregularly visited by non-breeding birds (determined today as HB) were probably counted among occupied nests. In this period the characteristic feature of the Sudeten region was the lack of breeding sites in the area of mountainous counties (Table 1, Fig. 2). An exception was one nest in a complex of ponds in Podgórzyn near Jelenia Góra – recorded at the beginning of the 20th century, absent in 1922 and found again in 1934. The population in the foothill dis-

Table 1. Number of breeding pairs of White Stork in mountainous and foothill districts of the Sudeten Mountains revealed in consecutive censuses (% in parenthesis)

	Mountainous	Foothill	Total
1907	1 (1.3)	79 (98.8)	80
1922	0 (0.0)	11 (100.0)	11
1934	1 (2.6)	37 (97.4)	38
1974	11 (10.2)	97 (89.8)	108
1984	25 (17.2)	120 (82.8)	145
1995	22 (12.1)	160 (87.9)	182
2004	28 (16.7)	140 (83.3)	168

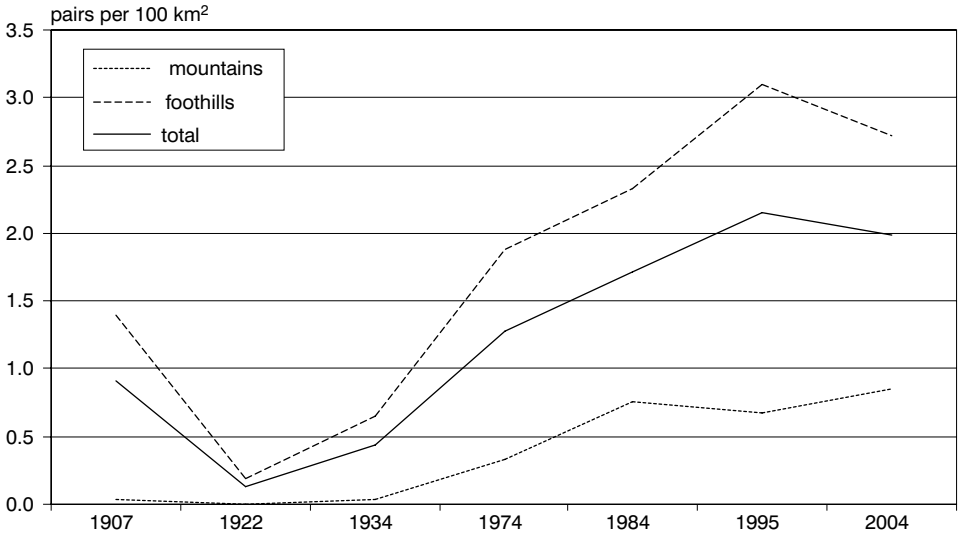

Fig. 2. Changes in density of the White Stork in the Sudeten region

tricts fluctuated in accordance with changes observed in a wider, Central European scale – the highest number at the beginning of the century, the collapse in the 1920s (to 11 breeding pairs only), and then recovery up to half of the 1907 level in 1934.

Subsequent censuses showed a slow, and rather stable increase in population size, with the maximum in the middle of the 1990s. For example, in the former Wałbrzych Province (4178 km^2) the number of pairs increased from 4 to 102 between 1922 and 1995 (Wuczyński 1997). The expansion concerned not only the foothill zone, but also the mountainous counties, where already 17% of the population nested in 1984 and 2004. The precise years of colonising the mountains remain unknown, but for example in the Kłodzko Region 3–4 pairs of the White Stork bred by the mid-1950s (Mikusek & Wuczyński 2005). The data from the last decade are not consistent, they show further population increases (27%) in mountain counties, but a decrease in the more densely inhabited foothill zone. Similar tendencies can be seen in the two sample plots studied annually. In the Sudeten Foreland the population decreased between 1995 (32 pairs) and 2005 (20 pairs), whereas in the Kłodzko Region between 1995 and 2004 a minimal increase from 8 to 9 pairs was noted (Wuczyński 2006 and unpubl. data).

Nest location

In the first half of the 20th century there were almost exclusively two types of nests – in trees and on buildings. In 1922 in the whole area of Lower and Upper Silesia respectively 271 and 257 such nests were recorded (Pax 1925), and the figures for 1934 were 731 and 523 (Brinkmann 1935). Similar proportions concerned also the Sudeten Mountains (Fig. 3). Later, the importance of nests on poles gradually grew

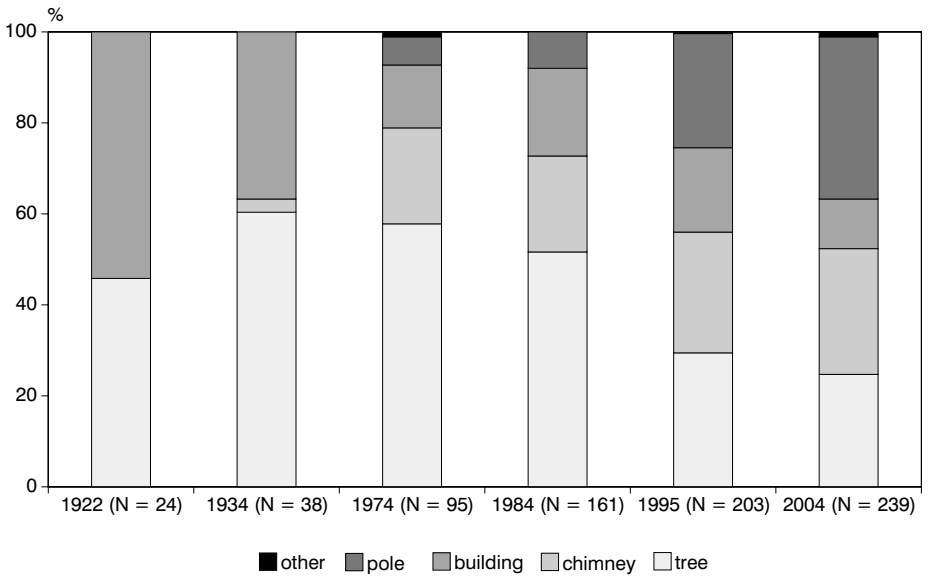

Fig. 3. Changes in proportion of nest localisation in the Sudeten region

and in 2004 they accounted for 36% of all nests. A new phenomenon during the post war period was also a relatively high and stable percentage of nests on chimneys (28% in 2004), whereas the share of nests in trees and on buildings decreased. The percentage of nest types varied in the two groups of districts – in 2004 in mountain areas nests on chimneys dominated (47%) and nests on poles were noted exceptionally, whereas in foothill counties the latter type predominated (41%). These differences may be connected with changes in the density of the White Stork. In Dolnośląskie province in 2004 the density was positively correlated with the percentage of nests on poles (r_s = 0.746; N = 26 districts; P < 0.001), and negatively with percentage of nests on chimneys (r_s = –0.622; N = 26 districts; P < 0.001) (Wuczyński 2006).

Altitudinal distribution

In 1922, breeding sites of the White Stork in the Sudeten Mountains were restricted to altitudes below 250 m, and in 1907 and 1934 below 360 m (Pax 1925, Brinkmann 1935). Recently the species has bred at 150–560 m asl (median 245 m), but still most nests are situated at relatively low altitudes (Table 2). In 2004 only 45 nests (28.7%) were located above 300 m. During the last four counts no increase occurred in mean, maximum nor upper quartile altitudes of nests (Fig. 4). Altitudes calculated for the mountainous counties only did not change significantly either (Kruskal-Wallis test $H_{3, 82}$ = 1.266; P = 0.737). Moreover, the altitude of the lowest nests did not decrease between 1974–2004. Established between 1974–1984 the nest with the highest elevation in 2004 was situated at 560 m asl at Miszkowice in the Kamienna Góra Basin. Recently the figure increased to 580 m, as in 2006 a new occupied nest (HPo) appeared in Unisław (Wałbrzych district) (pers. comm. P. Wasiak). Moreover, in 2005 the stork pair started to build new nest (not finished) at 650 m asl in Rzeczka in the same district (pers. comm. C. Dziuba). It is worthy of note that in 1955–1957 one successful nest situated at 550 m was already reported from the Kłodzko Region (Mikusek & Wuczyński 2005).

Table 2. Altitude of the occupied nests by White Stork in the Sudeten Mountains in 2004

Altitude (m asl)	N nests	%
150–200	32	20.4
201–250	57	36.3
251–300	23	14.6
301–350	21	13.4
351–400	10	6.4
401–450	2	1.3
451–500	7	4.5
501–550	4	2.5
551–600	1	0.6
Total	157	100.0

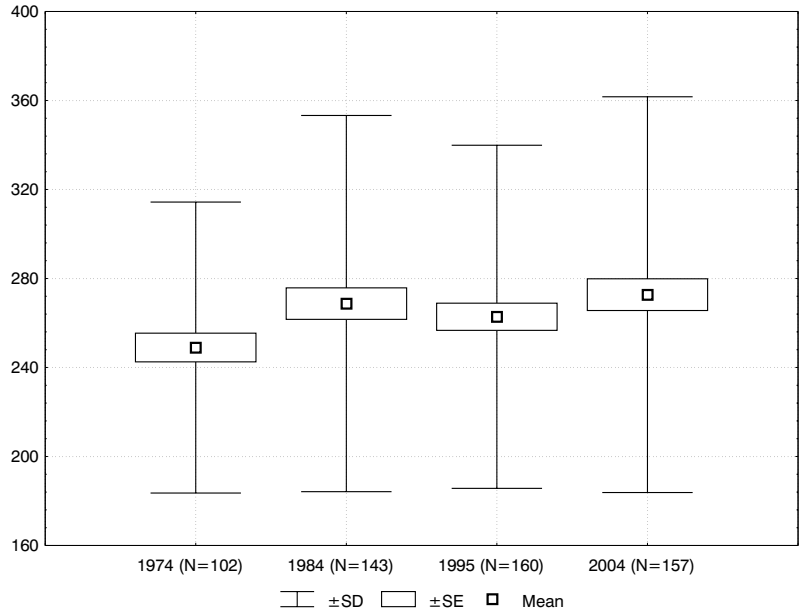

Fig. 4. Mean altitude of White Stork nests in the Sudeten region. Kruskal-Wallis test $H_{3,562} = 3.019$; $P = 0.389$

Breeding performances

Among 155 pairs with a known outcome of breeding in 2004, 88.4% were successful and raised a total of 316 fledglings. The average pair raised 2.17 young (JZa index), and the average brood size was 2.45 (JZm index). Storks in mountainous districts had better chick productivity than those in foothill districts (significant differences in JZa and JZm indexes, but not in percentage of unsuccessful broods – %HPo index) (Table 3). When data from the whole Dolnośląskie Province were compared, storks in mountainous districts still had higher productivity than those in the foothill and lowland districts (Kruskal-Wallis test $H_{2, 837} = 8.033$; $P = 0.018$ for JZa, and $H_{2, 720} = 6.445$; $P = 0.040$ for JZm). In 1974, 1984 and 1995 the demographic parameters did not differ between storks breeding in mountain and foothill districts. When nests were divided into two altitudinal groups – below and above the altitude of 300 m – the reproductive indices JZa and JZm had higher values in the latter group in 1974, 1984 (only JZm), 1995 and 2004, but the differences were not significant (Mann-Whitney U test). In 2004 a positive but non significant relationship between chick productivity and altitude was revealed (Fig. 5).

In four consecutive censuses, interseasonal comparisons demonstrated significant decrease in brood size (JZm) in foothill districts (Kruskal-Wallis test $H_{3,293} = 9.560$; $P = 0.023$), and a marginally significant increase in JZa index in mountain districts (Kruskal-Wallis test $H_{3,73} = 7.496$; $P = 0.058$) (Table 3). These trends were confirmed in sample plots studied annually. In the Sudeten Foreland during 1989–2005 the JZm index decreased significantly ($r = –0.561$, $P = 0.019$),

Table 3. Reproduction indices of White Stork in mountainous and foothill districts in consecutive censuses (Mann-Whitney U test and chi-square with Yates correction, sample sizes in parentheses – HPa)

JZa				
Year	Mountainous	Foothill	Z	P
1974	1.60 (5)	2.26 (50)	–0.92	0.356
1984	1.74 (23)	1.84 (76)	–0.28	0.781
1995	2.12 (17)	1.96 (120)	0.33	0.744
2004	2.71 (28)	2.01 (119)	2.64	0.008
JZm				
Year	Mountainous	Foothill	Z	P
1974	2.67 (3)	2.82 (40)	–0.31	0.757
1984	2.50 (16)	2.50 (56)	0.03	0.973
1995	2.25 (16)	2.47 (95)	–0.86	0.389
2004	2.81 (27)	2.35 (102)	2.06	0.039
%HPo				
Year	Mountainous	Foothill	χ^2	P
1974	20.0 (10)	11.2 (89)	0.09	0.769
1984	28.0 (25)	16.7 (120)	1.09	0.298
1995	4.5 (22)	17.4 (144)	1.50	0.220
2004	3.6 (28)	13.4 (127)	1.30	0.254

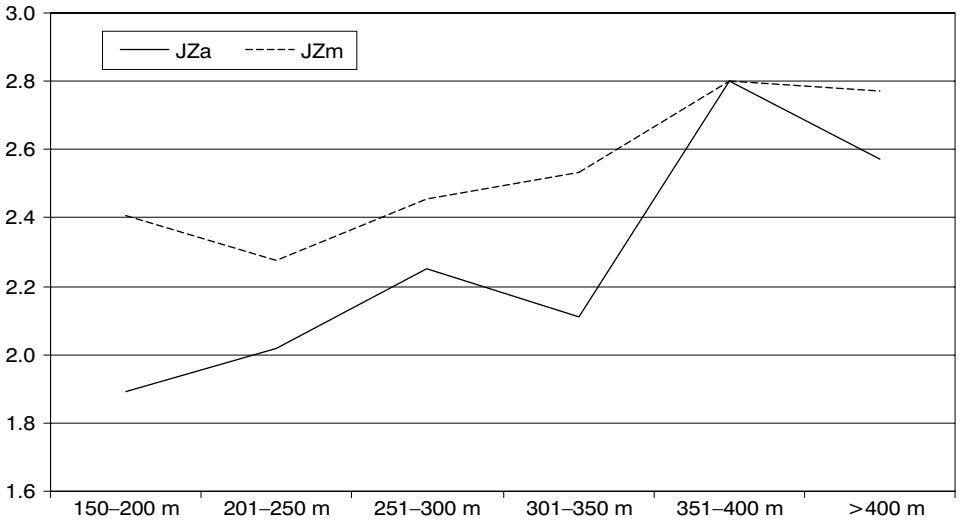

Fig. 5. Productivity of the White Stork in the Sudeten Mountains in 2004 in relation to the elevation of nests

while the decrease in JZa was nonsignificant (r = –0.306, P = 0.233) (Wuczyński 1997 and unpubl. data). In contrast, in the mountainous Kłodzko Region in 1974, 1984–1995 and 2004 the JZa index increased significantly (r = 0.570, P = 0.033), but the JZm index remained stable (r = 0.073, P = 0.804) (Mikusek & Wuczyński 2005).

Discussion

The last century was the period of colonising the mountainous areas and foothills of Sudeten by the White Stork. Recently the numbers of this species doubled in comparison with the beginning of the 20th century, and in relation to 1934, it increased fourfold. At the same time the altitudinal breeding range increased by about 200 m. Even though the colonization of these mountains is an established fact, the results, especially from the last decade are not consistent. The increase in altitude of nests could be observed only when compared with the pre-war period, and during the last 30 years neither the maximum elevation nor the percentage of nests from the highest elevations changed noticeably. In the case of population dynamics, in the more densely inhabited zone of the foothills, and consequently in the whole Sudeten region, a decrease during the last decade was recorded. The increase was maintained in mountainous districts, however the rate was very slight (approx. 0.4 new nests per year during 1934–2004, in comparison to 1.5 in the foothills), and since 1984 the numbers increased by only three pairs. These facts suggest rather the inhibition of the stork colonization process in the Sudeten region, and the reasons remain unclear.

Firstly, the Sudeten White Storks depend on wider population processes. Although the population size in Poland increased by 28% between 1995 and 2004, in the SW part of the country the number of pairs decreased (by 20% in Dolnośląskie province, which remained the area of the lowest density in Poland with 915 breeding pairs) (Jakubiec & Guziak 2006). This decrease could also stop the storks from further colonizing the highlands. Secondly, the stork distribution depends principally on topographic features and afforestation of the Sudeten Mountains. The small percentage of nests above 300 m altitude is due to a lack of extensive and unwooded uplands. Areas located above 300–400 m are sparse, wooded hills and ridges, not suitable for the White Stork. An altitudinal contrast is particularly visible along the Sudeten Marginal Fault (see description of the study area). An untypical area only exists in the Kamiennogórska Basin – agricultural, wide and of relatively high elevation (410–550 m) – in which are concentrated nests of the highest altitudes in the Polish Sudeten.

Contrary to expectations, demographic parameters were better in areas of higher altitudes, which could seem suboptimal for breeding (Tryjanowski et al. 2005b). Moreover, differences between the indices of productivity were bigger after the area-based division of nests (into mountainous and foothill districts), than after the altitude-based division (nests located below or above 300 m altitude). This suggests that in regions with relatively low and level altitudes, like the Sudeten, the elevation itself is not a good measure of breeding conditions, but

rather a complex of features must be considered (habitat, climate, edaphic conditions). The climate influence seems particularly important in the Sudeten Mountains. In mountainous districts the climate is clearly harsher than in foothills, however such conditions may be more favourable for the White Stork, possibly thanks to a complex of related aspects (higher humidity, better proportion of good foraging grounds (pastures, rivers), better food supply and availability etc.). Moreover, a long-term increase of the productivity indices observed in the mountains (but not in the foothills) suggests the improvement of these conditions. Indicative are also the average values of these indices. In the Kłodzko Region the long-term mean JZa value amounted to 2.41 fledglings per statistical pair (Mikusek & Wuczyński 2005), and in the Sudeten Foreland it was only 1.67 (Wuczyński 2006). According to the figure suggested by Wojciechowski (1992), to keep a stable level of population, a statistical pair of the White Stork should produce at least 1.99 fledgling in each season (a very similar figure of 2.02 was earlier obtained in Bavaria by Burnhauser (1983, after Profus 2006)). A low value recorded in storks from the Sudeten foothills suggests that they are particularly dependent on the immigration of birds from areas of higher reproductive rate. In contrast, high productivity of the mountainous population confirms that this part of Sudeten has suitable conditions to maintain or develop this population. The great subsidence basins play a significant role, which seem to be able to maintain a much denser population of the White Stork and possibly its increase will be noted here in future.

A feature of the mountainous districts supporting the stork population used to be a high proportion of permanent grassland. Recently they still amount to 50% of farmland areas (21% in foothill counties) and this is the highest figure among all districts of the Dolnośląskie province (Grykień 2005). However, a worrying trend in the last decade has been the conversion of these habitats into recreational areas, forests and other, non-agricultural uses (Bogda et al. 2005). As a result, in 2004 the mountainous counties created a compact belt with the highest percentage of fallow lands in the Dolnośląskie province, which accounted for 35–40% of farmland areas (Grykień 2005). Therefore, in contrast to previous statements another perspective is possible, i.e. the worsening the conditions for the White Stork in the Polish Sudeten Mountains.

It was possible to compare the colonization in the Sudeten Mountains with similar processes described in two regions of the Carpathians: Podhale in the uphill Tatra Mountains (950 km^2) (Profus & Cichocki 2002, Tryjanowski et al. 2005b, Profus 2006), and Bieszczady and Góry Sanocko-Turczańskie Mountains (2486 km^2) (Ćwikowski & Profus 2000). The comparison revealed that the Sudeten population of the White Stork and the process of colonising these mountains are characterized by a distinct identity:

a. density is much lower in the Sudeten (1.99 pairs/100 km^2 in 2004), than in Podhale (7.3 pairs/100 km^2 in 2002), and in Bieszczady (3.4 pairs/100 km^2, average for 1996–1998). The recent inhibition of the stork colonization process, recorded in Sudeten, wasn't observed in Podhale (analogous data from Bieszczady are missing).

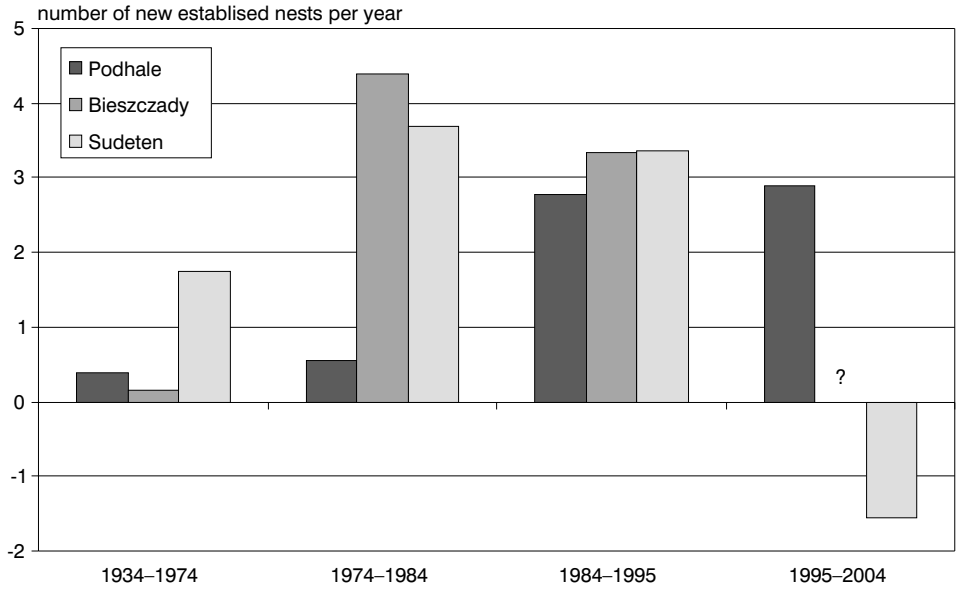

Fig. 6. Rate of expansion of White Stork in three mountainous regions of Poland

b. in the Sudeten the altitude of breeding sites is lower. In Podhale the whole population nests between 450 and 800 m asl, and in Bieszczady the maximum altitude is similar (500–600 m), but the percentage of nests on high elevation is higher.
c. the populations differ in their rate of expansion (Fig. 6). In the Sudeten it was more stable and relatively intensive already in 1934–1974, whereas in Bieszczady the rate intensified after 1974, and in Podhale only about 10 years later. Taking into account the longest period for which the data exist and assuming a constant rate of increase in nest numbers, the rate in Sudeten was the highest (1.9 new nests per year, 1934–2004), lower in the population in Bieszczady (1.5; 1934–1996), and the lowest in Podhale (1.1; 1931–2004). However, the colonization in Sudeten concerned mainly the foothill areas, considering the mountainous districts only, the rate of increase in nest numbers was only 0.4 per year for the last 70 years.
d. comparison of the population's productivity is difficult as data come from different periods. In Podhale there is recorded an increasing long-term trend in stork productivity, which resembles the mountainous population in the Sudeten. However, in Podhale more chicks were produced in the lowest altitudinal belts, which is in contrast to Sudeten, but can be connected with the big difference in mean elevation of both regions. In Bieszczady the level of productivity was low (JZa = 1.66; 1996–1998), which makes this population more similar to storks from the foothill zone of Sudeten.
e. another difference concerns types of nests – the proportion of nests on chimneys in the Carpathians is much lower than in Sudeten, and in Bieszczady there is much stronger predominance of nests on poles (70% in 1998).

Published data concerning the stork population in Czech Sudeten Mountains indicate some similarities to that in the Polish part. The species breeds here in very low densities – 0.1–1.9 pairs/100 km^2 (mean 1.2) in eight counties neighboring Poland in 2000 (Rejman 2000). Even though the area of the Sudeten is bigger than in Poland, the highest altitudes of nests are similar, e.g. 440 m in the Karkonosze Mountains (earlier a breeding attempt at 610 m) (Flousek & Gramsz 1999), or 600 m in the Orlickie Mountains (Hromadko et al. 2005). In the whole area of the Czech Republic the stork population was stable in the last decade (Kaatz 2006), but grew nearly eightfold between 1934 and 2000 (Rejman & Lacina 2002). The proportion of nests located above 300 m altitude increased from 41% to 52% between 1934 and 1994/95, but a more distinct increase concerned the nests above 500 m: from 5% to 15%, respectively (Rejman 1989, 1999).

To conclude, the presented data document an internal diversity of the Sudeten population of the White Stork, but also inconsistency of the reported colonization process. Also, it was shown to follow a different course to that of other mountain populations (Tryjanowski et al. 2005a). The data on the White Stork confirmed the significance of the Sudeten subsidence basins in shaping the biodiversity of these mountains. The reasons for the low population size of the stork in Sudeten remain unknown, however both mountainous and foothill areas are still not filled with this species. Since the European stork population is increasing, it will be interesting to monitor the further changes of the local Sudeten population, as well as the occurrence of this species in other upland areas within its range.

Acknowledgements

I am grateful to Bogusław Przybylski (Polish Geological Institute) for preparing the map of the stork distribution in Sudeten and referees for helpful comments and for linguistic revision of the text. I also thank the Polish Society of Wildlife Friends "pro Natura" for access to results of the 5th and 6th censuses of the White Stork.

References

Bäßler R., Schimkat J., Ulbricht J. 2000. Artenschutzprogramm Weißstorch in Sachsen. Sächsisches Landesamt für Umwelt und Geologie, Dresden.

Bogda A., Kabała C., Karczewska A. 2005. Biotic components of the environment. In: Blachowski J., Markowicz-Judycka E., Zięba D. (eds.) Ecophysiographical study for Dolnośląskie Province. Woj. Biuro Urbanistyczne, Wrocław: 93–107.

Brinkmann M. 1935. Der Bestand des weißen Storches (*Ciconia c. ciconia* L.) in Ober- und Niederschlesien nach der Zählung von 1934. Ber. Ver. schles. Orn. 20, 3–4: 33–58.

Creutz G. 1985. Der Weißstorch *Ciconia ciconia*. A. Ziemsen Verlag, Wittenberg Lutherstadt.

Ćwikowski C., Profus P. 2000. The breeding population of White Stork *Ciconia ciconia* in Polish Carpathians. Part I. The history of colonization of the Bieszczady and Góry Sanocko-Turczańskie Mountains by White Stork and its breeding success. Chrońmy Przyr. Ojcz. 56, 3: 7–41.

Flousek J., Gramsz B. 1999. Atlas of breeding birds in the Krkonoše Mts. (Czech Republic/Poland) in 1991–1994. Správa Karkonošskeho národního parku, Vrchlabí.

Gavashelishvili A. 1999. Bestandserfassung des Weißstorch (*Ciconia ciconia*) in Georgien im Jahr 1996. In: Schulz H. (ed.) White Strok on the up? Proc. Internat. Symp. White Stork, Hamburg 1996. NABU, Bonn: 323–325.

Grykień S. 2005. Structure of land use. In: Blachowski J., Markowicz-Judycka E., Zięba D. (eds.) Ecophysiographical study for Dolnośląskie Province. Zarząd Woj. Dolnośląskiego, Woj. Biuro Urbanistyczne, Wrocław: 219–229.

Guziak R., Jakubiec Z. (eds.) 2006. White Stork *Ciconia ciconia* (L.) in Poland in 2004. Results of the VIth International White Stork Census. PTPP "pro Natura", Wrocław.

Hladik B. 1989. Bestandsänderungen des Weißstorchs im Nordosten des Böhmisch-Mährischen Hügellandes. In: Rheinwald G., Ogden J., Schulz H. (eds.) Weißstorch – White Stork. Proc. I Int. Stork Conserv. Symp. Schriftenreihe des DDA 10, Bonn: 77–80.

Hromadko M., Cihak K., Hromadkova V., Pokert J. 2005. Ptaci Orlickych hor. OS Libri, Dobre.

Jakubiec Z. 1985. Number and density of White Stork in Poland in 1974. Studia Nat. A 28: 233–252.

Jakubiec Z. 1991. White Stork – *Ciconia ciconia* (L. 1758). In: Dyrcz A., Grabiński W., Stawarczyk T., Witkowski J. Birds of Silesia. The faunistic monograph. Uniwersytet Wrocławski, Zakład Ekologii Ptaków, Wrocław: 69–77.

Jakubiec Z. 2006. White Stork in Podkarpackie Province in 2004. Guziak R., Jakubiec Z. (eds.) White Stork *Ciconia ciconia* (L.) in Poland in 2004. Results of the VIth International White Stork Census. PTPP "pro Natura", Wrocław: 201–222.

Jakubiec Z., Guziak R. 1998. White Stork *Ciconia ciconia* in Poland in 1995 – distribution, numbers, conservation problems. Not. Orn. 39: 195–209.

Jakubiec Z., Guziak R. 2006. The White Stork in Poland in 2004. In: Guziak R., Jakubiec Z. (eds.) White Stork *Ciconia ciconia* (L.) in Poland in 2004. Results of the VIth International White Stork Census. PTPP "pro Natura", Wrocław: 377-394.

Kaatz C. 2006. Mitteilungsblatt 98/2006 der BAG Weißstorchschutz. NABU.

Kondracki J. 1998. Regional geography of Poland. PWN, Warszawa.

Mikusek R., Wuczyński A. 2005. White Stork *Ciconia ciconia* (L.) in Kłodzko Region. Przyroda Sudetów 8: 105–116.

Pax F. 1925. Wirbeltierfauna von Schlesien. Gebrüder Borntraeger, Berlin.

Profus P. 2006. Population changes and breeding ecology of the White Stork *Ciconia ciconia* L. in Poland against a background of the European population. Synthesis. Studia Nat. 50: 1-155.

Profus P., Cichocki W. 2002. Effect of the rainfall and floods on the reproduction and numbers of White Stork *Ciconia ciconia* in the Podhale and in the Gorce Mountains in the years 1997–2002. In: Denisiuk Z. (ed.) A strategy of landscape and biological diversity conservation in valuable nature areas, affected by flood disaster. IOP PAN, Kraków: 115–127.

Profus P., Jakubiec Z., Mielczarek P. 1989. Zur Situation des Weißstorchs, *Ciconia ciconia* L., in Polen, Stand 1984. In: Rheinwald G., Ogden J., Schulz H. (eds.) Weißstorch – White Stork. Proc. I Int. Stork Conserv. Symp. Schriftenreihe des DDA 10, Bonn: 81–98.

Profus P., Mielczarek P. 1981. Changes in numbers of White Stork's *Ciconia ciconia* (Linnaeus, 1758) in Southern Poland. Acta Zool. Cracov. 25: 139–218.

Rejman B. 1989. Der Weißstorch in der Tschechei 1934–1984. In: Rheinwald G., Ogden J., Schulz H. (eds.) Weißstorch – White Stork. Proc. I Int. Stork Conserv. Symp. Schriftenreihe des DDA 10, Bonn: 69–72.

Rejman B. 1999. Der Bestand des Weißstorchs *Ciconia ciconia* in der Tschechischen Republik in den Jahren 1994 und 1995. In: Schulz H. (ed.) White Strok on the up? Proc. Internat. Symp. White Stork, Hamburg 1996. NABU, Bonn: 69–72.

Rejman B. 2000. Výsledky 20. celostatniho scitani hnízdìnícich paru capa bílého v Ceske republice v roce 2000. Ceska spolecnost ornitologicka. Prosinec.
Rejman B., Lacina D. 2002. Výsledky monitoringu hnízdìní capa bílého (*Ciconia ciconia*) v Ceské republice. Sylvia 38: 103–111
Schulz H. 1998. *Ciconia ciconia* White Stork. BWP Update 2: 69-105.
Stollmann A. 1988. Population dynamism of the White Stork (*Ciconia ciconia* L.) in the subtatran area over the past fifty years. Zb. Pr. Tatra. Nar. Parku 28: 137–148.
Stollmann A. 1989. Der Weißstorch (*Ciconia ciconia*) in der Slowakischen Sozialistischen Republik (SSR). In: Rheinwald G., Ogden J., Schulz H. (eds.) Weißstorch – White Stork. Proc. I Int. Stork Conserv. Symp. Schriftenreihe des DDA 10, Bonn: 73-78.
Tryjanowski P., Sparks T.H., Jakubiec Z., Jerzak L., Kosicki J.Z., Kuźniak S., Profus P., Ptaszyk J., Wuczyński A. 2005a. The relationship between population means and variances of reproduction success differs between local population of White Stork (*Ciconia ciconia*). Popul. Ecol. 47: 119–125.
Tryjanowski P., Sparks T.H., Profus P. 2005b. Uphill shifts in the distribution of the White Stork *Ciconia ciconia* in southern Poland: the importance of nest quality. Diver. Distrib. 11: 219–223.
Wojciechowski Z. 1992. White Stork (*Ciconia ciconia*) in the Łowicz District. Acta Univ. Lodz. Folia Zool. Anthrop. 1: 5–28.
Wuczyński A. 1997. The history and breeding of the White Stork population in the Sudetic Foreland. Chrońmy Przyr. Ojcz. 53: 28–44.
Wuczyński A. 2006. White Stork in dolnośląskie province in 2004. In: Guziak R., Jakubiec Z. (eds.) White Stork *Ciconia ciconia* (L.) in Poland in 2004. Results of the VIth International White Stork Census. PTPP "pro Natura", Wrocław: 27-52.
Żurawek R. 2005. Physico-geographical divisions. In: Blachowski J., Markowicz-Judycka E., Zięba D. (eds.) Ecophysiographical study for Dolnośląskie Province. Zarząd Woj. Dolnośląskiego, Woj. Biuro Urbanistyczne, Wrocław: 11–20.

Appendix

List of villages/towns with occupied nests (HPa) by the White Stork in 1974, 1984, 1995 and 2004 in mountainous (M) and foothill (F) districts of the Sudeten region

District	Type	Area in km^2	% of forests 2004	% of grasslands 2004	Number of pairs in 2004	List of nests split into communes (underlined names)
1	2	3	4	5	6	7
Jelenia Góra	M	737	46.9	22.7	5	Jelenia Góra: Cieplice Śl. (bc; t), Maciejowa (cd; 3; h), Raszyce (b; u), Sobieszów (ab; u), Mysłakowice: Bukowiec (a), Karpniki (a; t), Mysłakowice (bcd; 3; o), Wojanów (bd; 3; h), Podgórzyn: Marczyce (a; t), Podgórzyn (abcd; 4; t), (b; t), Stara Kamienica: Barcinek (cd; 4; t), Sosnka (c; t), Stara Kamienica (abc; t)
Kamienna Góra	M	396	36.8	32.4	7	Kamienna Góra: Czadrów (bd; 3; t), Janiszów (cd; 4; p), Szarocin (cd; 3; h), Lubawka: Bukówka (a), (b; t), Chełmsko Śl. (cd; 4; h), Lubawka (b), Miszkowice (bcd; 4; h), (b; t), (bc; t), Świdnik (c; t), Uniemyśl (d; 2; h), Marciszów: Ciechanowice (d; 3; p), Świdnik (b; t)
Wałbrzych	M	514	39.1	25.0	7	Czarny Bór: Czarny Bór (d; 5; h), Grzędy (d; 1), Witków (d; 2), Mieroszów: Golińsk (d; 2; h), Mieroszów (bcd; 1; h), Stare Bogaczowice: Chwaliszów (d; 2; t), Wałbrzych: Poniatów (d; 0; h)
Kłodzko	M	1643	43.2	20.5	9	Bystrzyca Kłodzka: Bystrzyca Kł. (b; h), Gorzanów (bcd; 2; u), (a; h), Zabłocie (d; 2; u), Kłodzko: Kłodzko (bd; 3; h), (abc; u), (c; u), Ławica (b; t), Ołdrzychowice Kł. (bcd; 2; h), Piszkowice (abcd; 4; h), Radków: Radków (cd; 3; h), Ratno Dln. (d; 2; h), Ścinawka Grn. (bcd; 4; u), Ścinawka Śr. (bcd; 1; u),
Zgorzelec	F	838	47.7	12.1	12	Bogatynia: Rybarzowice (ab), Pieńsk: Dłużyna Dln. (abcd; 3; h), Dłużyna Grn. (c; h), Lasów (c; u), (acd; 0; p), Żarki Śr. (abc; u), Sulików: Radzimów Grn. (d; 2; h), Studniska Dln. (ad; 2; p), Studniska Grn. (abc; t), Sulików (a; t), Wrociszów Grn. (d; x; t), Węgliniec: Czerwona Woda (d; 2; h), Ruszów (c; u), Zawidów: Zawidów (d; 2; h), (c; h), Zgorzelec: Gronów (cd; 2; p), Jerzmanki (a), (a), Koźmin (d; 3; t), Kunów (bc; u), (c; u), Łagów (cd; x; t), Osiek Łużycki (abcd; 3; h), Ręczyn (abc; t), Trójca (d; 1; p), Żarska Wieś (ab; t)

1	2	3	4	5	6	7
Lubań	F	428	24.0	21.6	14	Leśna: Pobiedna (d; 2; h), Szyszkowa (b; u), Lubań: Henryków Lub. (c; p), Jałowiec (abc; p), Kościelnik (bcd; 2; h), Kościelniki Dln. (cd; h), Mściszów (bcd; 2; p), Nawojów Łużycki (cd; 2; p), (b; p), Nawojów Śląski (ab; t), Pisarzowice (abcd; 2; h), (ab; t), (d; 2; t), Radogoszcz (d; 2; h), Radostów Dln. (ab; t), Radostów Śr. (c; p), Olszyna: Olszyna Dln. (bc; p), Zapusta (d; 0; p), Platerówka: Platerówka (d; 1; t), Włosień (d; 2; p), Zalipie (c; h), Siekierczyn: Nowa Karczma (d; 2; t), Siekierczyn (d; 0; t), (d; 1; p), (c; h), Zaręba (abc; u)
Lwówek Śląski	F	710	35.1	24.6	13	Gryfów Śląski: Gryfów Śl. (d; 2; t), Młyńsko (abcd; 3; t), Ubocze (bc; t), Wieża (ab; t), Lubomierz: Lubomierz (b; t), Oleszna (bc; t), Oleszna Podgórska (c; u), Wojciechów (bc; p), Lwówek Śl.: Bielanka (b; t), Brunów (cd; 3; t), Chmielno (abcd; x; t), (c; t), Gradówek (b; t), Niwnice (a; t), Płakowice (bd; 2; h), (b; h), Rakowice Mł. (bcd; 0; p), Rakowice Wlk. (abc; u), Skorzynice (abd; 0; p), Sobota (abcd; 3; u), (c; h), Włodzice Wlk. (bd; 3; h), Zbylutów (abcd; 2; p), (a; t), Żerkowice (ab; t), Mirsk: Brzeziniec (b; t), Giebułtów (c; u), (d; 2; p), Karłowiec (d; 3; p), Mroczkowice (b; t), Rębiszów (bc; t), Wleń: Strzyżowiec (cd; 3; h)
Złotoryja	F	575	20.6	11.8	16	Pielgrzymka: Nowa Wieś Grodziska (c; t), Pielgrzymka (abcd; 3; p), Proboszczów (cd; 3; h), (c; t), Twardocice (abcd; 1; t), (bcd; 3; u), Świerzawa: Dobków (bcd; 3; p), Lubiechowa (d; 0; u), Nowy Kościół (bcd; x; h), Rzeszówek (a; t), Sędziszowa (d; 3; o), Zagrodno: Brochocin (b; t), Grodziec (c; p), Jadwisin (c; p), (cd; 1; p), Łukaszów (c; t), Modlikowice (d; x; p), (abc; t), (cd; x; t), Olszanica (abc; t), (b; t), Radziechów (ab; t), Uniejowice (c; p), Wojciechów (c; p), Zagrodno (cd; 3; p), (c; p), Złotoryja: Kopacz (b; t), Lubiatów (d; 2; p), Łaźniki (abd; 2; t), Nowa Wieś Złotoryjska (cd; 2; u), Rokitnica (d; 2; u), Rzymówka (ab; t), Wilków (a, h)
Jawor	F	581	21.9	10.2	17	Bolków: Lipa (bc; h), Wierzchosławice (bc; p), (a), Wolbromek (abcd; 2; p), Jawor (cd; 2; h), (c; p), Męcinka: Kondratów (c; t), Małuszów (bcd; 1; p), Męcinka (bcd; 2; p), Muchów (c; t), Piotrowice (bc; h), Pomocne (abcd; 2; t), Przybyłowice (ad; 2; p), Słup (abcd; 3; t), Mściwojów: Barycz (c; t), Luboradz (d; 2; u), (c; t), Mściwojów (d; 2; p), (c; t), Niedaszów (abcd; 3; t), Siekierzyce (b; u), Snowidza (cd; 0; p), Targoszyn (d; 0, t), Paszowice: Paszowice (ab; t), Sokola (d; 2; h), Wiadrów (b; t), Wądroże Wielkie: Biernatki (ab; t), Budziszów Mł. (d; 3; p), Budziszów Wlk. (a), Granowice (a; t), Kosiska (ad; 3; p), Mierczyce (abd; 2; h), Skała (ad; 2; p),

1	2	3	4	5	6	7
Świdnica	F	743	13.7	8.9	22	Dobromierz: Dobromierz (cd; 0; h), (d; 3; h), Dzierzków (b; t), Gniewków (abcd; 2; h), Pietrzyków (d; 1; t), Roztoka (a; t), Siodłkowice (c; t), Szymanów (d; 2; h), Jaworzyna Śląska: Bolesławice (b; t), Milikowice (a), (cd; 2; p), Piotrowice Świdn. (d; 3; p), Witków (cd; 3; h), Marcinowice: Chwałków (bc; h), Gola Świdn. (cd; 0; h), Kątki (bc; h), Klecin (b; u), Strzelce (d; 0; t), Szczepanów (abc; p), Strzegom: Godzieszówek (abd; 0; p), Granica (b; t), Graniczna (d; 3; p), Modlęcin (ad; 2; t), Morawa (d; 2; p), Olszany (abd; 2; t), Stanowice (abc; t), (d; 2; t), Żółkiewka (bd; 3; h), (b; t), Świdnica: Bojanice (cd; 2; p), Grodziszcze (abc; h), Jagodnik (b; t), Komorów (c; p), Lutomia Dln. (abcd; 3; h), (c; h), Makowice (b; h), Miłochów (d; 2; p), Niegoszów (b; u), Opoczka (b; h), Pszenno (b; t), Słotwina (bc; p), Zawiszów (c; h), Żarów: Bożanów (ac; p), Gołaszyce (ab; t), Imbramowice (abc; p), Łażany (cd; 3; p), Mrowiny (ab; u), (c; p), Przyłęgów (abc; t), Żarów (cd; p)
Dzierżoniów	F	479	20.8	9.2	13	Dzierżoniów: Dzierżoniów (d; 3; p), Dobrocin (abc; h), Mościsko (abcd; 3; h), (c; h), (d; 1; t), Nowizna (bcd; 0; u), Ostroszowice (a; t), (b; t), Tuszyn (ab; t), Uciechów (cd; 3; p), Włóki (d; 2; h), Łagiewniki: Jaźwina (abcd; 4; u), Łagiewniki (bc; t), Oleszna (b; u), Przystronie (abcd; 0; h), Sieniawka (cd; 2; p), Sienice (c; u), Stoszów (b; p), Niemcza: Gilów (cd; 2; p), Gola Dzierż. (c; u), Ligota Mł. (c; u), Przerzeczyn Zdr. (d; 0; h), Pieszyce: Pieszyce (c; t), (abcd; 3; h), Piława Górna: Piława Górna (bcd; 0; h)
Ząbkowice Śląskie	F	802	19.9	8.8	22	Bardo: Brzeźnica (a; u), Przyłęk (ab; u), (bc; u), Ciepłowody: Ciepłowody (ab; u), (cd; 3; p), Kamieniec Ząbk.: Byczeń (abcd; 3; p), Chałupki (abc; h), Doboszowice (a; h), Kamieniec Ząbk. (d; 2; h), (c; p), Ożary (acd; 3; h), Pilce (ac; k), (ac; u), Pomianów Dln. (a), Sosnowa (a; u), (a; u), Topola (ad; 2; t), Stoszowice: Budzów (acd; 4; u), Grodziszcze (cd; 2; t), Lutomierz (bc; u), Przedborowa (cd; 0; p), Różana (bcd; 3; u), Ząbkowice Śl.: Bobolice (c; u), (b; u), Olbrachcice Wlk. (abcd; 2; u), Stolec (acd, x; h), Strąkowa (abcd; 3; u), Tarnów (a; t), Ząbkowice Śl. (b; h), Ziębice: Głęboka (c; p), Henryków (bc; p), (d; 2; h), Kalinowice Dln. (b; h), Krzelków (c; u), Lipa (abcd; 3; p), Lubnów (c; h), Osina Mł. (bcd; 2; h), Pomianów Dln. (d; 3; t), Służejów (d; x; p), Starczówek (cd; 2; h), Wadochowice (cd; 4; p), Wigancice (acd; 3; h), Ziębice (d; 2; p), (c; h), Złoty Stok: Mąkolno (cd; 2; h)
Total		8446	32.7	17.0	157*	

Abbreviations:
a, b, c, d – nest occupied in 1974, 1984, 1995 and 2004 (respectively)
0–5 digits, x – number of fledglings in 2004. Breeding results from the other years are not shown.
h – chimney, o – other, p – pole, t – tree, u – building – nest location in the last year when the nest was occupied
Example: notation (acd; 3; h) means that the nest was occupied in 1974, 1995 and 2004, the pair raised 3 young in 2004 and in that year the nest was located on chimney
*final population size in 2004 (168 pairs) was achieved by adding 7 and 4 pairs in districts Lwówek Śląski and Świdnica, respectively, treated like poorer controlled