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Strong declines of the White Stork *Ciconia ciconia* population in south-western Poland: a differentiated importance of altitude and land use changes

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Abstract. Studies of long-term trends in avian populations require large-scale data not available for most bird species. The White Stork *Ciconia ciconia* is unique being monitored for over a century and well-reflecting modern environmental changes. Its worldwide and national populations are estimated every 10 years thanks to the International White Stork Censuses (IWSC). We present the yet unpublished data of the last IWSC 2014 from the main species stronghold, Poland. We assessed the population size and compared its changes with the previous IWSC 2004 in 23% of the country area, including mountains. We looked for potential drivers of trends among land use transformations, checked population changes along altitudinal gradient, and compared the long-term trends in the global, national and regional populations. In 2014, 2560 pairs (3.61 pairs/100 km^2) bred in south-western Poland, a decline by 35.5% compared to 2004. Decreases were strongly inversely related to the altitude, i.e. declines in lowlands were twice as high as in the mountains. Changes in area of grasslands, croplands, forests, and built-up areas were all weak predictors of the decline. Stork decrease in south-western Poland contradicts a stable country-wide trend in 2004–2014 (although the latest country-wide data also suggest a decline), which is inconsistent with the increase of the global population. Heterogeneity in trends indicates that Poland could be currently viewed as a transitional area, lying between large breeding areas inhabited by increasing stork populations. Notably, the western border between areas of increases and decreases coincides with the division into two migratory populations suggesting that the heterogeneity of trends may be related to migration paths and wintering grounds. Overall, our data confirm recent range shift of the species, and show difficulties in drawing general conclusions on stork demography based on regional data.

Key words: population ecology, long-term trends, altitudinal gradient, land use, census, Central Europe

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INTRODUCTION

Recent synergic effects of changes in climate and land use caused by increasing food and space demands of the growing human population negatively affect birds worldwide (Jerrentrup et al. 2017, Northrup et al. 2019). Agricultural lands that cover approximately half of the world land surface (World Resources Institute 2020) are under increasing human pressure due to gradual increasing productivity, agriculture intensification (Rockström et al. 2017), and transformations or/and disconnectivity of semi-natural habitats (Hooftman & Bullock 2012). Changes in agriculture are known to drive farmland birds decline (e.g. Lemoine et al. 2007, Wretenberg et al. 2010, Jerrentrup et al. 2017), however the statement is supported mostly by data collected in short- or medium-term periods. Results obtained from long-term monitoring of bird populations (i.e. several decades) are still scarce and apply only to a few farmland species.

The White Stork *Ciconia ciconia* is the most cherished of European birds and a classical model in population studies (Lack 1966, Bairlein 1991, Newton 2013). It represents a farmland indicator species (Tobolka et al. 2012), particularly suitable for understanding human impact on biodiversity. The White Stork has benefited from past land changes (e.g. deforestation) but subsequently suffered from land use intensification. The loss of habitats by drainage of wetlands, domination of high-input crops, industrialization and the extension of residential areas have degraded its former breeding areas on an important scale, especially in Western Europe (Schulz 2004). In turn, in eastern Central Europe a large-scale improvement of stork habitats following the collapse of the socialist economic system resulted in prominent recovery of the White Stork population (Vaitkuviene & Dagys 2015). Apart from changes in land use, a multitude of other factors in both the breeding and wintering areas and on the migration routes are considered responsible for the global and regional variations in stork numbers (Wuczyński et al. 2021). The knowledge of its population size and trends is based on The International White Stork Censuses (IWSC), a large ornithological undertaking carried out in the entire species range and organized seven times to date. That makes an opportunity to follow the species changes over a long time and observe the population response to changing environment. As many as 41 countries participated in the last IWSC in 2014, including Poland (Thomsen et al. 2017). Although the complete census data are still not yet available and the worldwide population size of the White Stork remains unknown, an increasing overall trend is evident (EBCC 2021).

Poland (312,679 km^2) is a key part of the species' geographical range, hosting the world's largest population assessed at 52500 breeding pairs in the 6th IWSC in 2004 (Jakubiec & Guziak 2006). The last census in 2014 is still not summarized at the country level, and the lack of data from the Polish stronghold made it challenging to assess the development of the White Stork numbers on a broader scale. Surprisingly, the direction of current changes in the Polish stork population is also unclear. The data obtained from several sample plots (Janiszewski et al. 2014, Zbyryt 2014, Zbyryt et al. 2014, Dylik 2018) indicate a stability, whereas other regional data (Kuźniak & Tobółka 2010, Pietrowiak 2012, Peterson & Jakubiec 2016, Sikora 2017) and the nationwide Monitoring of Birds of Poland (Wardecki et al. 2021) show a downward trend. On the other hand, Tryjanowski et al. (2005a) showed that trends might differ strongly, even between relatively close areas. Geomorphological variables (e.g. altitude) may also be important, particularly while warmer lowlands are under higher agricultural intensification and urbanization than adjacent highlands (Koleček et al. 2014). In the face of that, there is a noticeable lack of quantitative results from large compact parts of the country that could shed light on current processes in stork demography.

In this paper, we present the results of the 7th IWSC concerning a compact area of 23% of the country area, i.e. five out of 16 Polish provinces. The provinces adjoin the southern and western state border and are distinctive in terms of the stork population. They are characterized by the country-lowest large-scale stork densities, shown in all censuses to date (Wuczyński et al. 2021). Stork distribution is also extremely uneven due to unsuitable mountain ranges in the south, extensive forests in the west, and attractive meadow and pond areas in the north. It is also an area of the most dynamic population changes, resulting from long-term altitudinal shifts and colonization of the upland regions (Tryjanowski et al. 2005b, Wuczyński 2006a). It is even more important considering that the farming areas in the mountains and lowlands are under opposite pressure of agricultural intensification (Plieninger et al. 2016), which makes it difficult to draw conclusions that are common to the entire region. Finally, it is an area having the longest tradition of large-scale stork counts in the world (Janota 1876), producing the longest series of data in Poland (Mrugasiewicz 1972, Profus 2006a), with large areas covered by annual monitoring, which facilitates the counts. As a result, during all the censuses to date, the southern region of Poland was one of the most thoroughly researched, and also in 2014 the region was largely inspected. Partial results, i.e. reporting reproduction, location of nests and local densities in 2014, have already been published (Sztwiertnia et al. 2018). However, the publication did not contain an overall population assessment, neither did it provide temporal trends, which are the focus here.

The first goal of this paper is to provide the first large-scale results of the 7th IWSC from Poland. We assessed the size of the White Stork population in nearly a quarter of the country area and then compared the results of 2014 with the numbers obtained a decade earlier, during the 6th IWSC 2004. This way, we aim to shed light on the discrepancies regarding recent population trends in Poland based on sound quantitative data. Secondly, to look for potential drivers for the observed trends in the White Stork population, we investigated parallel changes in landscape composition, especially changes in agricultural land use types that are of primary importance for the species. In the modelling approach applied, we also incorporated an elevational aspect since our area covered most of the mountainous terrains of Poland, including the adjacent foothills and lowlands. Thus, the next aim was to check whether the revealed population changes are related to the altitudinal gradient. Earlier evidence showed a long-term increase in the elevational range of the White Stork both in the Sudetes (Wuczyński 2006a) and in Carpathians (Mielczarek & Profus 2016). Finally, to show our new results in a broader spatiotemporal context, we collated stork numbers obtained from all consecutive IWSCs and compiled the long-term population changes on different geographical scales: in the research region, Poland and the world. In doing so, we intend to deliver long-term quantitative data on stork numbers obtained from all IWSCs in a condensed, tabular form. Until now, such data has been scattered in multilingual literature, difficult to obtain, and often inconsistent.

METHODS

Census methods

Contrary to all previous IWSCs in Poland, which were based on country-wide surveys merely supplemented with local field inspections, the 7th IWSC was conducted using only direct field inspections supposed to cover the entire territory of Poland. The action was planned based on the administrative division of the country on provinces (voivodship), counties (powiat) and communes (gmina). This study concerns the area of five provinces situated in south-western Poland: from west to east, they were Lubuskie, Dolnośląskie, Opolskie, Śląskie, and Małopolskie Provinces (Fig. 1). They cover an area of 70,863 km^2 (22.7% of the country) and are divided into 113 counties (including 28 cities with county rights) and 670 communes (Table 1). In each province, 1 or 2 coordinators (the authors) were appointed, responsible for building a network of collaborators to collect and submit the data. The collaborators (> 100 volunteers) supplied with an instruction and data form carried out the field controls within the smallest administrative units, the communes. They were obliged to check all villages within the commune and other places suitable for nesting by White Storks and to detect all nests. Each nest was described with several parameters used as a standard in the White Stork studies (Guziak 2006). In particular, the number of nests occupied by breeding pairs had to be counted. Field inspections took place in the first half of July 2014, i.e. during the late fledging period, and in the case of delayed broods, the inspections were repeated. Most field data were recorded in a special database administered by the Institute of Nature Conservation PAS. The five provinces under this study were well researched, as 90.1% of

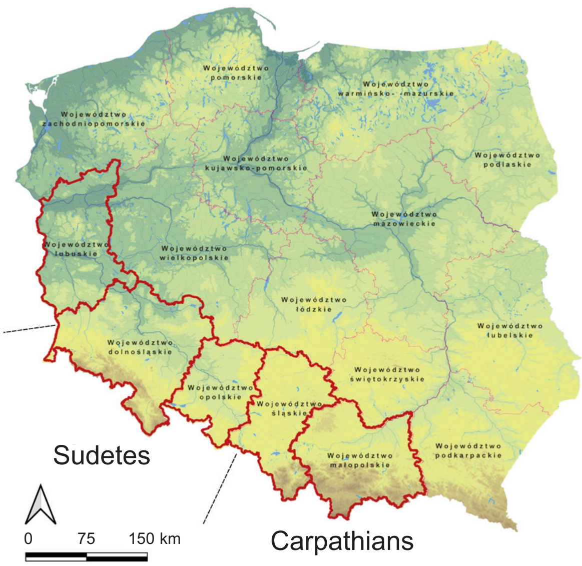

Fig. 1. Location of the five provinces under study (outlined in red) against the topographic map of Poland and the distribution of other provinces. Dashed lines show the approximate borders between the mountain ranges of the Sudetes and the Carpathians and between the Sudetes and adjoining lowlands.

Table 1. Characteristics of the five provinces of south-western Poland including administrative division, altitude and unsurveyed areas during the 7th International White Stork Census.

Province (voivodship)	Total area (km^2)	Unsurveyed area (km^2/%)	No of counties (incl. unsurveyed)	No of communes (incl. unsurveyed)	County altitude (m asl) mean (min–max)
Dolnośląskie	19946.7	768.4 (3.9)	29 (1)	168 (9)	248.9 (95.7–587.6)
Małopolskie	15182.9	535.7 (3.5)	22 (1)	182 (7)	384.3 (180.0–1089.3)
Lubuskie	13987.9	5253.7 (37.6)	14 (5)	82 (37)	78.1 (46.1–132.8)
Śląskie	12333.1	471.0 (3.8)	36 (8)	167 (8)	291.9 (216.6–654.4)
Opolskie	9411.9	0 (0.0)	12 (0)	71 (0)	202.3 (157.1–283.3)
Total	70862.5	7028.8 (9.9)	113 (15)	670 (61)	262.9 (46.1–1089.3)

the area was covered with inspections (Table 1). The best explored was the Opolskie Province (fully controlled), the worst was the Lubuskie Province (62.4%). In total, 98 out of 113 counties were accurately inspected, whereas 15 counties from which sparse data were obtained were considered unsurveyed (Appendix 1). It should be explained, however, that the nine counties in the Dolnośląskie and Śląskie Provinces marked as unsurveyed are all cities with county rights (e.g. Legnica, Chorzów, Sosnowiec) almost devoid of breeding White Storks: a total of 3 pairs in 2004.

Estimation of population size

The size of the stork population in the examined areas was determined by summing up the detected breeding pairs in administrative units. To estimate the numbers in the unsurveyed units, the results of the 6th census in 2004 in these fragments were used, corrected for the change index calculated for the areas examined in 2014 census. We took advantage of the fact that the data from 2004 were compiled in detail at the scale of communes, counties and provinces (Guziak & Jakubiec 2006), so it was possible to compare them within any units with the results obtained in 2014. Therefore, we first calculated the rate of change for each province, which is the quotient of the number of breeding pairs in 2014 and 2004 in the examined areas. Then, for each commune or county not examined in 2014, appropriate stork numbers from 2004 were assigned, multiplied by the change index and rounded to the nearest whole numbers. Finally, based on the summary results for individual counties, provinces and the entire area, we calculated the percentage rate of change (RC) for the decade according to the formula: RC = (BP2014 * 100/BP2004) - 100, where BP is the number of breeding pairs in the given year. RC was then used to present recent trends in the regional stork population, it was also a response variable in the statistical models (see below).

The index was also used to show the development of the regional population on a broader temporal scale, based on the previous IWSCs. RC indices for previous counts were calculated using the above formula, substituting the values of the number of breeding pairs for two neighbouring counts. These data were also compared with the number of storks in Poland and the entire range of the species, obtained on the basis of literature data. For this comparison, the lack of the national assessment from the 2014 census was replaced with the results of the Monitoring of Birds of Poland (hereafter MBP)(Wardecki et al. 2021, Wuczyński et al. 2021).

Statistical approach and data sources

Multiple regression models were used to evaluate the response of RC indices in counties to six explanatory variables. Four predictors represented percentage changes in: arable lands (croplands_change), meadows and pastures (grasslands_change), forests (forests_change), built-up and urbanized lands (urban_change). The other two variables were the mean altitude of the county (alt_mean) and the mountain range (mountain_range — a binary variable: the Carpathians/Sudetes; see below for assigning counties to mountain ranges). None of the predictors was highly collinear with another, as all absolute values of correlation coefficients were below 0.5. Five correlations were stronger than 0.3: alt_mean × forests_change = -0.46, mountain_range × urban_change = -0.39, alt_mean × mountain_range = -0.39, croplands_change × grassland_change = 0.38 and mountain_range ×forests_change = 0.47.

Models containing all possible combinations of variables and their interactions were fitted and ranked using corrected Akaike Information Criterion (AICc) (Burnham & Anderson 2002). The subset of top-supported models — with ΔAICc $\leq$ 2 — was considered in further steps. For each model the Akaike weight (ωAIC) was also calculated to assess the relative importance (RVI) of explanatory variables (Burnham & Anderson 2002). To avoid overfitting, we calculated the Variance Inflation Factor (VIF) for each predictor and excluded all models having at least one variable with VIF > 2. Since the model weights were balanced, model averaging and model-averaged prediction was applied. Diagnostic analyses showed that the assumptions of linear regression were met. The models were fitted with R (R Core Team 2021) using MuMIn package (Bartoń 2020) to rank and average models.

Data on land use changes at the county level were downloaded from https://bdl.stat.gov.pl/BDL/dane/podgrup/temat. These are data from the Agricultural Censuses, conducted using a uniform, nationwide methodology and collected by the Central Statistical Office. To calculate changes in land use types we used available data from the years closest to years of the IWSCs, i.e. 2004 and 2014 for forest area, 2002 and 2010 for croplands and grasslands, and 2012 and 2014 for urban and built-up areas. Percentage changes in land use types among counties are presented in Appendix 1 and they are generalized in Appendix 2. In the total area, the magnitude of change in the years under comparison was low (medians between -0.01 and 7.41%, the highest in the forested areas). Area of croplands was rather stable, grasslands decreased in most counties, while forests and developed areas (urbanized and built-up lands) clearly increased (Appendix 2). Note that the urban_change could be derived from only a three-year time span so one may expect more volatility due to this variable. Also note that in several counties the changes in land use types were unavailable and these counties were excluded during modelling. Moreover, in one county (Katowice) the RC index could not be calculated due to zero value in 2004, and also one outlier county (Tatrzański) was excluded, since the county covers the highest areas of Poland, mostly unsuitable for the White Stork (average county altitude 1089 m asl). Therefore, the regression models were built on data from 94 counties, i.e. all inspected, non-zero and non-outlier counties having full land use data.

The mean altitude of each county was obtained using the "Raster statistics for polygons" tool within the SAGA module in the QuantumGIS program (QGIS.org 2021). To visualise the association of the White Stork with elevational gradient, we compared the rates of change predicted by the averaged regression models in three types of counties separated according to the mean county altitude, i.e. lowland, foothill and mountain counties (Appendix 1). The comparison was made for the entire set of 94 counties, and separately for the Sudetes (46 counties situated in the Lubuskie, Dolnośląskie and Opolskie Provinces) and Carpathians (48 counties situated in Śląskie and Małopolskie Provinces). In the Sudetes region, the altitude thresholds for lowland, foothill and mountain counties were up to 200 m, 200–400 m and over 400 m, respectively, while in the Carpathians, the thresholds were up to 300 m, 300–500 m and over 500 m. Uneven thresholds reflected physico-geographical differences between the mountain ranges and made similar the intra-group conditions for the stork occurrences. The Sudetes, with the highest peak at 1602 m asl, are much lower mountains than the Carpathians (2499 m asl) and have the altitudinal ecological zonation shifted down (Hess et al. 1980, Kondracki 2000). Finally, using the raw data, we calculated the percentage rates of change (RC) in three types of counties to provide quantitative information of stork trends within the elevational belts (Appendix 3).

RESULTS

Based on 2307 breeding pairs really recorded during the 7th IWSC in 2014, the White Stork population in five provinces of SW Poland was estimated at 2560 pairs (Table 2). The mean density amounted to 3.61 pairs/100 km^2 and was relatively even among the entire area, lower only in the Dolnośląskie Province (2.66 pairs/100 km^2). Compared to the results of the 2004 census, a substantial population decline was found, amounting to 35.5% in the entire area (range 30–42% in individual provinces), being higher in the west (Fig. 2). In each of the five provinces, the decrease in numbers between 2004 and 2014 was significant (Table 2), i.e. from among 98 counties covered with counts, only six counties had higher numbers in 2014.

Seven models explaining changes in the White Stork population had high support (Table 3). None of the models was clearly superior to the others, with the top-supported model weight of 0.27, and the variance explained between 9% and 13%. The most important variables were associated with the county location relative to mountains: the mean county altitude was present in all top models (RVI = 1), while the mountain_range — in four models (RVI = 0.63). Predictors related to

Table 2. Number of breeding pairs (BP) and density of the White Stork in five provinces of south-western Poland in 2014 and 2004. The differences in breeding pairs were tested with the Wilcoxon test, based on county data. The provinces ordered by the decreasing number of pairs in 2014.

Province	2014		2004		N	Z	p
	BP (no of pairs from estimation)	Density (pairs/ 100 km^2)	BP	Density (pairs/) 100 km^2	(no of counties)		
Lubuskie	595 (197)	4.25	942	6.73	12	3.06	0.0022
Małopolskie	534 (16)	3.52	812	5.35	22	3.43	0.0006
Dolnośląskie	531 (38)	2.66	915	4.59	27	4.40	0.0000
Śląskie	504 (2)	4.09	724	5.87	28	4.38	0.0000
Opolskie	396 (0)	4.21	577	6.13	12	3.06	0.0022
Total	2560 (253)	3.61	3970	5.60	101	8.32	0.0000

changes in land use had lower importance: croplands_change and urban_change appeared in two models, with RVI equaling to 0.23 and 0.21, respectively, and grasslands_change was included in only one model (RVI = 0.14). As expected, changes in the White Stork population were positively related to increases in croplands and grasslands, and negatively to the growth of urbanized areas. Changes in forest areas and the interaction terms were absent from all top-supported models.

Model-averaged coefficients confirmed the importance of elevation for the stork demography, the county altitude turned out to be the only significant variable (Table 4). Specifically, population declines were inversely related to the county altitudes, meaning that higher drops were recorded in lowlands (Fig. 3). Mountain_range was not significant and indeed the relationship concerned both the Sudetes and Carpathians, although it was more pronounced in the Sudetes. Based on raw data, in the mountain counties of the Sudetes the changes had a particularly low average rate of decrease (-0.14%), compared to adjoining foothills (-32%) and lowlands (-39%) (Appendix 3). Overall, population declines in lowland counties of SW Poland were over two times higher than in mountain counties, while the foothills showed intermediate values of stork decrease (Fig. 3).

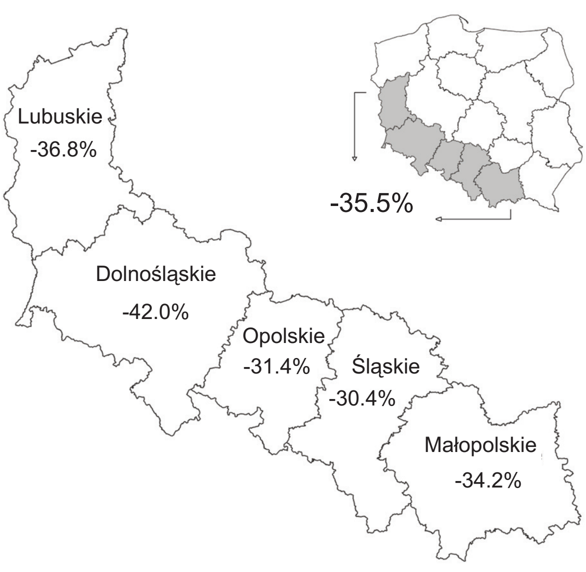

Fig. 2. The percentage rates of change in the White Stork population between 2004 and 2014 in five provinces of SW Poland.

Long-term data available for three provinces indicate that a sharp population drop observed in the last two decades in SW Poland contrasts with the country-wide population's upward or stable trend over most of this time (Fig. 4). Moreover, during the last half-century, when data from both populations are available, only in 1984–2004 the trend in SW Poland was consistent with the nationwide population. It should be noted, however, that recently (after 2014), the trend of the nationwide population has also reversed and is now declining (Wardecki et al. 2021), which is in line with the situation in SW Poland. In turn, the stable trend of the Polish stork population between 2004 and 2014 was inconsistent with spectacular, yet so far unquantified, the upward trend of the global population (Table 5).

DISCUSSION

Diversity of population trends across Europe

We showed that between the 6th and 7th IWSC (2004–2014), the population of the White Stork in south-western Poland was subject to a strong decline, contradicting a stable nationwide trend and increasing trend of the whole world population (Jakubiec & Guziak 2006, Thomsen &

Table 3. Models describing the rate of change of the White Stork population in relation to the following explanatory variables: alt_mean (mean altitude of the county), mountain_range (either Sudetes or Carpathians), forests_change (% change of forest area between 2004 and 2014), croplands_change (% change of arable lands between 2002 and 2010), grasslands_change (% change of meadows and pastures between 2002 and 2010), urban_change (% change of built-up and urbanized lands between 2012 and 2014). K — the number of estimated parameters, including the intercept. Corrected Akaike Information Criterion (AICc) was used to compare the models. Delta (ΔAIC) shows the difference in AICc between each model and the best-supported model. Weight (ωAIC) shows the relative importance of the model, with all weights summing up to 1. R-squared metrics were additionally provided as a measure of fit. Only models with ΔAIC ≤ 2 are presented.

Model	Formula	K	AICc	ΔAIC	ωAIC	R-squared	adjusted R-squared
1	alt_mean + mountain_range	3	845.95	0	0.27	0.12	0.10
2	alt_mean	2	846.99	1.04	0.16	0.09	0.08
3	alt_mean + mountain_range + grasslands_change	4	847.27	1.32	0.14	0.13	0.10
4	alt_mean + mountain_range + croplands_change	4	847.52	1.57	0.12	0.13	0.10
5	alt_mean + urban_change	3	847.69	1.74	0.11	0.11	0.09
6	alt_mean + croplands_change	3	847.84	1.89	0.10	0.11	0.09
7	alt_mean + mountain_range + urban_change	4	847.89	1.94	0.10	0.13	0.10

Lachmann 2013, Wardecki et al. 2021). Our data also show that the stork can undergo rapid changes in abundance and that these changes can vary greatly in nearby regional populations. These aspects have previously been addressed in the literature on the White Stork (e.g. Tryjanowski et al. 2005b), but few empirical studies capable of demonstrating this have been conducted in recent years, at a broad spatial scale and in key areas of species distribution. Our new data fulfil these requirements and illustrate the phenomena in stork demography observed across Europe in recent decades.

The downward trend was not a surprise since the observations from several study plots in the region have clearly indicated a long-lasting disappearance of the stork in SW Poland (Kuźniak & Tobółka 2010, Sztwiertnia et al. 2018). For example, in the Milicz district having the longest (starting 1959) series of counts in Poland (Mrugasiewicz 1972), the population of 53 pairs in 2015 almost halved compared to 2004 (98 pairs) and was substantially lower than in peak level of 181 pairs in 1962 (Lenkiewicz et al. 2021). However, the rate of change revealed in our study, higher than elsewhere, and its uniformity among our areas was surprising. A 35% decline over ten years is a reasonably high figure for a long-lived, single-brooded bird species with a relatively slow reproduction rate, albeit it is not exceptional. Indeed, in the same period, populations in the Netherlands and Sweden increased by 51%, in Switzerland by 90%, in France by 129%, and in 16 German federal states, the amplitude of changes ranged from –25 to 1430% (Thomsen et al. 2017). These numbers should be considered carefully, while some local populations started from very low numbers, i.e. just several breeding pairs. Notably, however, most of these figures relate to increases, whereas we are not aware of any large areas with current decreases at the magnitude of the one revealed in south-western Poland (accounting areas with a sound population size). Although such a significant decline could have been influenced by a high stork abundance in 2004, the abundance was nevertheless the result of long-term population

Table 4. Model-averaged parameter estimates, their standard errors (SE) and significance, based on top-supported linear models, explaining the rate of change of the White Stork population in relation to the mean altitude of the county, the mountain range and land use changes of the county. Values of the relative importance (RVI) of explanatory variables are also presented. For further abbreviations, see Table 3.

Parameter	Estimate	SE	z	p	N models	RVI
Intercept	-51.13	6.84	7.392	< 0.001	-	-
alt_mean	0.06	0.02	3.198	0.001	7	1.00
mountain_range	5.06	5.48	0.917	0.359	4	0.63
grasslands_change	0.94	3.60	0.260	0.795	2	0.23
croplands_change	1.64	4.76	0.341	0.733	2	0.21
urban_change	-0.10	0.33	0.305	0.760	1	0.14
forests_change	-	-	-	-	0	0

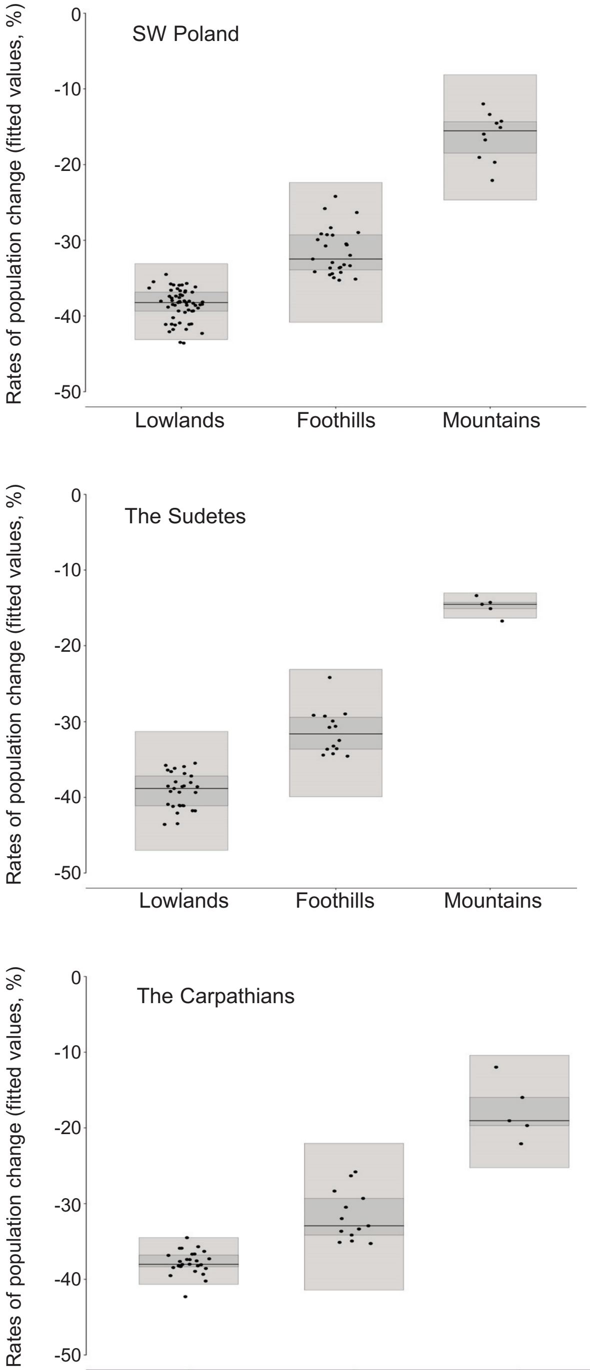

Fig. 3. Percentage rates of change (RC) in population size of the White Stork between 2004 and 2014 in lowland, foothill, and mountain counties of SW Poland. Result obtained from the averaged model based on the subset of top-supported models (Tables 3 and 4). Separate figures present comparisons of RC in counties from the entire area of SW Poland (N = 94), in counties lying in or adjacent to the Sudetes (N = 46), and the Carpathians (N = 48). The boxplots show medians as horizontal lines, and the interquartile and non-outlier ranges as the inner and outer boxes. Dots show RC values in individual counties.

growth occurring both globally and in the eastern core population (Table 5), and not a single spike concerning 2004.

On a wider geographic scale, decreasing trends are now rare. After strong declines in the 20th century (Profus 2006a), the worldwide population of the White Stork is currently on a strong upward trend (EBCC 2021). The increases concern most of the European range — from the Iberia region to East Germany and the east of Poland. Meanwhile, a relatively small area of Central Europe is an island dominated by downward or stable trends. Specifically, in Germany, in four federal states adjacent to Poland, a decrease of 10% was recorded in 2004–2014, compared to an increase of 99% in the rest of the country. Changes in the Czech Republic and Slovakia amounted to -2.7% and 1.6%, respectively (Fulin 2016, Nyklová-Ondorová & Hanley 2016), Austria -5.6%, and Hungary -6.6% (Thomsen et al. 2017). In contrast, beyond the eastern border of Poland, data from the same period invariably indicate increases in stork numbers: e.g. by 32% in Latvia (Janaus 2016), 7.7% in Belarus, 25% in Ukraine (Thomsen et al. 2017).

The outlined national assessments should also be seen considering the migration system of the White Stork. In Central Europe, the border between areas with overall population increases and decreases (or stability) coincides with the division into western and eastern stork migration pools, occurring longitudinally across Germany (Kania 2006). Thus, the declines mainly affect the western edge of the eastern migratory population. Reports from the western population clearly indicate that shortening migration, overwintering in Europe and using landfills as foraging grounds are profitable for the White Storks (Tortosa et al. 2002, Gilbert et al. 2016, Cheng et al. 2019). In contrast, the eastern migrants that overwinter south of the Sahara all the way down to South Africa are disadvantaged, because of bearing much higher migration costs. It is known that juvenile storks originating from eastern migratory population invest much higher amount of energy than western migrants because of longer overall journey and also longer daily foraging trips in African rural areas compared to overwintering regions of Europe (Flack et al. 2016). Higher energy expenditure may result in lower survival and fitness, potentially leading to the population declines observed in Central Europe. However, this does not justify diverse trends occurring within the same migration pool. It is still unclear whether

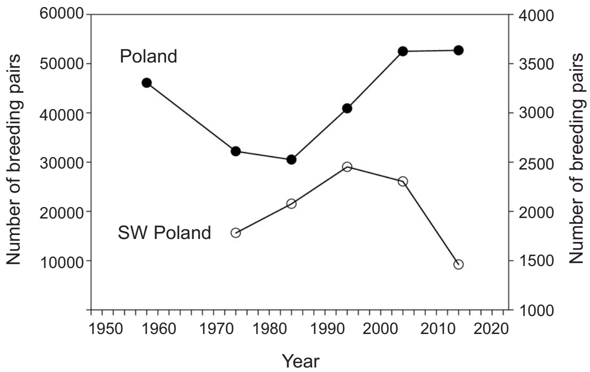

Fig. 4. Development of the White Stork populations in Poland (nationwide data) and in three provinces of SW Poland (Dolnośląskie, Opolskie and Małopolskie) as obtained from consecutive International White Stork Censuses 1958–2014. Size of the Polish population in 2014 revealed by the Monitoring of Birds of Poland. Scale on the right axis moved in order to better visualise the trends. See Table 5 for further details.

opposite trends within parts of the eastern core population can be associated with migration habits, and if so, what mechanisms are responsible for the observed spatial arrangement.

Drivers of the population decrease in SW Poland

Although the causes of the observed transformations in stork demography are complex (Schulz 2004, Krogulec 2020), global climate and land use changes are usually presented as the most important driving factors (Sæther et al. 2006, Huntley et al. 2008). Specifically, in Eastern Europe, the growth in breeding numbers is accompanied by east- and northward range expansion, i.e. towards colder areas compared to the existing central areas of distribution (Keller et al. 2020). In consequence, the latter are expected to become less populated by storks. Our study could serve as a quantitative illustration of these processes. In accordance with the north-eastern direction of the range shift and with thermal gradients in Central Europe, the warmest south-western part of Poland should experience decreases in population size (Huntley et al. 2007), as confirmed by our data. We also searched for the sources of stork decline in contemporary land use changes in Poland, i.e. the extension of residential areas, afforestation and decrease in surface area of agricultural land (Poławski 2009). Since the changes coincide with trends in other Central European countries (Munteanu et al. 2014, Cegielska et al. 2018), they can potentially explain the stork demography in a wider, regional scale. Indeed, changes in area of grasslands, croplands and urbanized lands appeared in the set of best AIC models, so they could contribute to the observed decreases in stork numbers. Nevertheless, the importance of land use variables should not be overestimated. None of them appeared in the top models (containing only variables associated with the altitude), the variables had relatively low values of importance index, and the explained variance was low. It has then to be concluded that we found only modest support for the significance of land use changes in explaining the White Stork decline in SW Poland. Thereby, other external factors may have higher importance, such as mortality during migration, changes in wintering grounds and stop-over sites, or source-sink dynamics across neighbouring populations.

Importance of the altitude

A novel outcome of our study is the relationship between population change and the altitudinal gradient: stork declines in the uplands were smaller than in the lowlands. Elevational gradients are believed to constitute a fine-scale substitute for latitudinal gradients, although there is not a strict homology of both patterns (Popy et al. 2010, Sanders & Rahbek 2012). In any case, the revealed differences would again imply a sensitivity of the White Stork to climate-driven factors, which in higher elevations may currently be more favourable for the stork than in lowlands. Indeed, the results of the 6th IWSC 2004 from the Sudetes indicated significantly higher stork productivity at higher elevations compared to lowlands and foothills (Wuczyński 2006a). This could directly translate into further smaller population declines in the mountain and foothill counties. However, the mechanism underlying this relationship remains unclear. While differences in temperature or precipitation may directly influence the differences in trophic conditions along the elevational belts (McCain & Grytnes 2010), the importance of altitude-dependent external forces such as environmental transformations and human land use intensity, seems more likely. Noncrop matrix habitats, meadows and pastures are still much more available in montane regions compared to lowlands in Poland and elsewhere (Becker et al. 2007), whereas the reforestation is more intensive in lowlands (Appendix 1). Different scales of habitat deterioration may then be responsible for the observed differences in population performance of the White Stork along the elevational gradient.

Table 5. Number of pairs of the White Stork breeding worldwide, in Poland, and in three southern provinces in the years of consecutive international censuses (Wuczyński et al. 2021, modified). Growth rates related to the previous census, percentage of the Polish population in the global population, and percentage of the population in three provinces in the Polish population are also presented.

Year	Worldwide population	Growth rate (%)	Sources	Polish population (% of the global population)	Growth rate (%)	Sources	Population in Dolnośląskie, Opolskie and Małopolskie provinces (% of the Polish population)	Growth rate (%)	Sources
1958	147 400 (underestimated)		Wuczyński et al. 2021	46 100 (31.3) (underestimated)		Wuczyński et al. 2021			
1974	146 000		Dornbusch 1982	32 200 (22.1)	-30.2	Jakubiec 1985	1781 (5.5)		Mielczarek 2006, Profus 2006a, Wuczyński 2006b
1984	140 300	-3.9	Schulz 2004	30 500 (21.7)	-5.3	Profus et al. 1989	2077 (6.8)	16.6	Mielczarek 2006, Profus 2006a, Wuczyński 2006b
1994	168 000	19.7	Schulz 2004	40 900 (24.3)	34.1	Jakubiec & Guziak 1998	2452 (6.0)	18.1	Mielczarek 2006, Profus 2006a, Wuczyński 2006b
2004	233 000	38.7	Thomsen & Lachmann 2013	52 500 (22.5)	28.4	Jakubiec & Guziak 2006	2304 (4.4)	-6.0	Mielczarek 2006, Profus 2006b, Wuczyński 2006b
2014				52 700	0.4	Monitoring of Birds of Poland (Wardecki et al. 2021)	1461 (2.8)	-36.6	this study

Finally, it should be noted that despite more favourable population trends in higher elevations, declines in stork numbers prevailed there as well. This outcome was not obvious in light of the previous long-term, prominent influx of the White Stork to higher altitudes (Tryjanowski et al. 2005b, Wuczyński 2006a). We rather expected a stable situation or even increases in uplands. Contradictory results suggest that the earlier influx of storks into the mountains in Poland has stopped and that the large-scale shift of the species range has a stronger impact on population dynamics than local factors (Jørgensen et al. 2016).

Trends in the nationwide stork population in Poland

As a final point, it is worth considering to what extent the presented data from 23% of Poland inform about the situation of the stork in the whole country, which is still one of the most important strongholds of the species. Considering only two points in time compared in this study, 2004 and 2014, the downward trends in south-western Poland do not correspond to the stable situation in the national population, which would result from the MBP. Also, Chylarecki et al. (2018) previously showed that in 2001–2016, predominantly downward trends in western Poland differed from the relatively stable ones in eastern Poland, although significant fluctuations characterized the entire period. Notably, the largest year-to-year decline was identified just between 2004 and 2005. The national population has not fully recovered after this drop (Wuczyński et al. 2021), which corresponds to the results presented in this paper. Moreover, just recently, the updated MBP data have been made available, which also indicate an apparent decrease in the nationwide population: in the years 2014–2019, the decline amounted to 10.2% (from 52.7 to 47.3 thousand pairs) (Wardecki et al. 2021, Wuczyński et al. 2021). The following years will indicate whether it is a temporary fluctuation or a long-term trend. However, in a long-lived bird species, even a short-term 10% decrease may have long-lasting effects on population viability (Sæther et al. 2005). When looking for general conclusions from the puzzled Polish data, it can be stressed that, first, Poland now seems to be a transitional area, lying between Western and North-Eastern Europe, two large areas inhabited by increasing populations of the White Stork. Such a location may cause population heterogeneity and rapid changes at the local level, similar to those presented in this paper. Second, it is essential to note that neither of the Polish data points to an upward trend observed in the global population. The trends are stable at most, while the recent post-2014 nationwide data indicate a decline. This means that the arguments indicating a downward trend in the Polish stork population are currently prevailing. Results obtained in the south-western part, presented in this paper, are a meaningful example of current nationwide declines.

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STRESZCZENIE

[Silny spadek liczebności bociana białego w południowo-zachodniej Polsce zależny od gradientu wysokościowego i zmian użytkowania terenu]

Bocian biały jako jeden z najlepiej i najdłużej badanych gatunków ptaków stał się modelowym obiektem badań populacyjnych. Ocena wielkości jego populacji wydaje się względnie łatwa z racji cech biologii lęgowej, napotyka jednak na poważne trudności, jeśli jest dokonywana w dużej skali przestrzennej i czasowej. Wielkość światowej populacji jest oceniana w trakcie cyklicznych Międzynarodowych Cenzusów Bociana Białego, organizowanych co 10 lat, co ostatnio miało miejsce w roku 2014. W niniejszej pracy przedstawiamy pierwsze wielkoskalowe wyniki tego cenzusu pochodzące z Polski. Dotyczą one zwartego i dobrze zbadanego fragmentu obejmu-

jącego pięć południowo-zachodnich województw, od lubuskiego do małopolskiego, stanowiące 23% powierzchni kraju (Tab. 1, Fig. 1). Celem badań była ocena regionalnej liczebności bociana i jej zmian w porównaniu z poprzednim cenzusem z 2004 r. oraz poszukiwanie czynników mogących te zmiany wywoływać. Sprawdziliśmy trendy populacji bociana wzdłuż gradientu wysokościowego, ponieważ obszar badań obejmował znaczącą część wyżynnych terenów Polski. Ponadto, dzięki zestawieniu wyników wszystkich siedmiu dotychczasowych cenzusów, porównaliśmy długoterminowe trendy w populacji bociana ocenianej w skali regionalnej, krajowej i globalnej.

Liczebność bociana białego w południowo-zachodniej Polsce w 2014 r. oszacowano na 2560 par lęgowych, gniazdujących w średnim zagęszczeniu 3,61 pary/100 km^2, najniższym w województwie dolnośląskim i porównywalnym na pozostałym obszarze (Tab. 2). W stosunku do roku 2004 odnotowano silną redukcję liczebności wynoszącą 35,5% w skali regionu i od 30 do 42% w poszczególnych województwach (Fig. 2). Przyczyn spadku szukano z pomocą modeli liniowych, korzystając z danych geodezyjnych o użytkowaniu terenu i wysokości bezwzględnej 113 powiatów znajdujących się na obszarze badań (Apendyks 1 i 2). Wykryto wyraźne powiązanie zmian liczebności bociana ze zmiennymi opisującymi kontekst wysokościowy, zaś słabe w przypadku miar użytkowania terenu (Tab. 3 i 4). Spadki liczebności były odwrotnie proporcjonalne do wysokości bezwzględnej — w powiatach nizinnych okazały się ponad dwukrotnie większe niż w górskich, zaś pośrednie były na pogórzach. Zależność ta dotyczyła rejonu Sudetów i Karpat, lecz w Karpatach była mniej wyraźna (Fig. 3, Apendyks 3). Wyniki te sugerują, że tereny wyżynne są obecnie bardziej sprzyjające dla lęgowej populacji bociana — być może ze względu na korzystniejsze warunki mikroklimatyczne i troficzne, a także większą dostępność preferowanych siedlisk niż niziny, zdominowane przez intensywne agrocenozy. Zgodnie z oczekiwaniami, spadek udziału trwałych użytków zielonych i gruntów ornych oraz poszerzanie terenów zabudowanych w powierzchni powiatu wiązały się z większymi spadkami liczebności, nie były to jednak silne zależności

Porównanie zmian populacyjnych w różnych skalach przestrzennych okazało się niespójne (Tab. 5, Fig. 3): silne spadki w południowo-zachodnich województwach w okresie 2004–2014 przeczą raczej stabilnej sytuacji ogólnokrajowej, artykułowanej wówczas w Monitoringu Ptaków Polski, choć należy podkreślić, że nowsze (po 2014) dane ogólnokrajowe również wskazują na spadek liczebności. Z kolei dane krajowe są sprzeczne ze spektakularnym wzrostem obserwowanym w ostatnich dekadach w światowej populacji bociana białego. W dyskusji przedstawione zostały fluktuacje liczebności w innych krajach Europy, wskazujące na dużą rozpiętość skal i kierunków trendów. Utrudnia to interpretację obecnych i przyszłych zmian liczebności. W konkluzji stwierdzono, że Polskę, lub szerzej, Europę Środkową, należy obecnie traktować jako obszar przejściowy, nacechowany zmniejszaniem liczebności bociana białego, leżący pomiędzy rozległymi częściami areału lęgowego o rosnących populacjach.

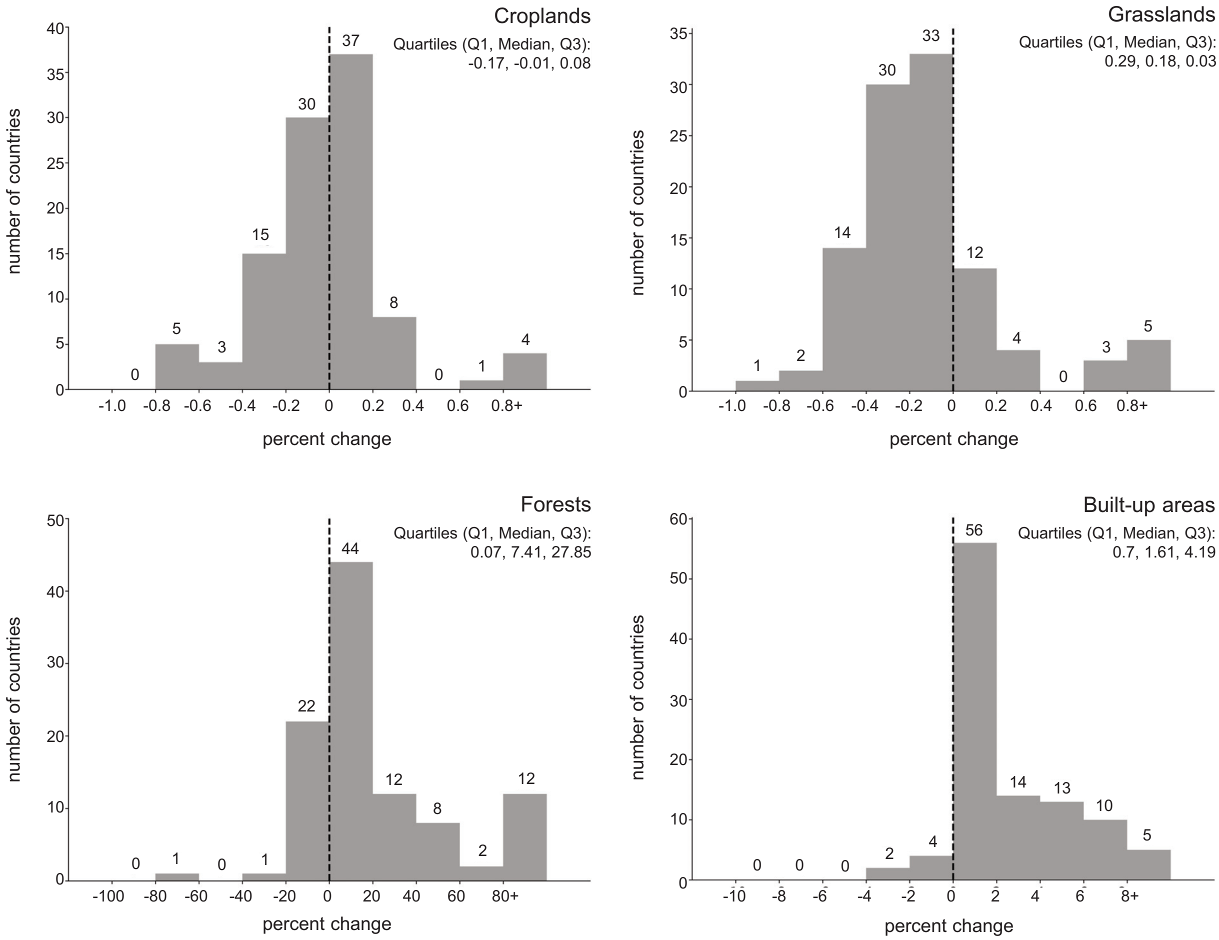
Appendix 1. List of counties in five provinces of SW Poland with data on altitude (L — lowland, F — foothills, M — mountain), percentage change in four land use types between 2002 and 2010 (croplands and grasslands), 2004 and 2014 (forests) or between 2012 and 2014 (urban and built-up areas), numbers of the White Stork in 2004 and 2014, and percentage rate of population change between these years. Counties are arranged according to number of breeding pairs in 2014 within provinces. Empty cells indicate no data available. Stars indicate unsurveyed counties for which number of pairs in 2014 was derived from estimation (see Methods).

Province (voivodship)	County (powiat)	County type	Mean altitude (m asl)	Crop-lands change (%)	Grass-lands change (%)	Forest change (%)	Urban/ Built-up change (%)	No of pairs in 2004	No of pairs in 2014	Rate of change (%)
Lubuskie	gorzowski	L	46.1	0.1	-0.1	93.1	1.3	159	102	-35.8
	strzelecko-drezdenecki	L	58.3	0.7	-0.1	218.3	0.5	149	82	-45.0
	słubicki	L	55.7	0.2	-0.5	124.9	4.7	69	66	-4.3
	sulęciński	L	78.8	0.1	0.6	103.2	1.7	78	51	-34.6
	zielonogórski	L	77.3	0.1	-0.2	26.4	3.5	106	49	-53.8
	międzyrzecki	L	60.0	0.1	-0.3	25.7	1.1	76	48*	-36.8
	wschowski	L	83.8	-0.1	-0.1	29.8	1.5	45	37	-17.8
	krośnieński	L	64.2	0.3	0.9	80.5	0.4	51	36	-29.4
	żagański	L	132.8	0.2	-0.2	45.9	1.3	55	35*	-36.4
	żarski	L	117.6	0.2	-0.3	2.1	1.8	51	32*	-37.3
	nowosolski	L	84.7	0.1	-0.5	77.7	1.4	48	30*	-37.5
	świebodziński	L	93.1	-0.1	-0.1	21.9	1.4	54	26	-51.9
	Gorzów Wielkopolski	L	46.9	2.0	2.6	-3.7	1.3	1	1*	0.0
	Zielona Góra	L	94.6	7.5	4.6	0.0		0	0	0.0
Dolnośląskie	legnicki	L	140.6	0.0	-0.3	58.1	0.4	88	64	-27.3
	górowski	L	95.7	0.1	-0.4	98.9	1.1	52	43	-17.3
	trzebnicki	L	128.4	0.1	-0.1	55.0	0.5	94	43	-54.3
	milicki	L	126.3	-0.1	-0.1	26.2	1.7	67	37	-44.8
	wrocławski	L	148.4	0.0	-0.2	-4.5	6.1	55	36	-34.5
	oleśnicki	L	170.5	0.1	-0.2	49.5	0.4	74	32	-56.8
	polkowicki	L	141.1	0.1	0.1	107.2	0.8	59	30	-49.2
	lubiński	L	127.5	-0.1	0.0	139.8	1.6	47	24	-48.9
	średzki	L	139.9	0.0	-0.2	14.3	1.9	36	24	-33.3
	świdnicki	F	251.3	0.0	-0.2	-1.5	4.5	26	22	-15.4
	głogowski	L	96.4	0.0	-0.2	291.7	0.5	44	21	-52.3
	wołowski	L	118.5	0.1	0.0	89.0	0.9	29	16	-44.8
	oławski	L	136.8	0.1	-0.2	18.9	1.6	31	14	-54.8
	jaworski	F	286.6	0.1	-0.1	27.7	0.3	17	13	-23.5
	strzeliński	L	179.6	0.0	-0.5	-7.5	0.4	36	12	-66.7
	ząbkowicki	F	311.1	-0.2	-0.3	27.9	1.2	22	12	-45.5
	zgorzelecki	F	210.7	0.2	-0.2	87.3	1.8	12	12	0.0
	dzierżoniowski	F	303.3	0.1	-0.1	10.4	0.8	13	9	-30.8
	kamiennogórski	M	560.4	0.1	0.2	19.8	1.5	7	9	28.6
	lwówecki	F	388.7	0.0	-0.1	43.4	-0.7	20	9	-55.0
	bolesławiecki	L	181.4	0.0	-0.2	36.7	-2.4	13	8	-38.5
	złotoryjski	F	275.1	0.1	-0.2	22.6	1.0	16	8	-50.0
	Wrocław	L	118.7	-0.1	-0.9	12.5	6.2	20	8	-60.0
	kłodzki	M	549.8	0.3	0.1	14.9	-0.1	9	7	-22.2
	lubański	F	300.4	0.1	-0.3	54.7	0.5	14	7	-50.0
	jeleniogórski	M	587.6	0.0	-0.2	8.6	2.7	4	6	50.0
	wałbrzyski	M	546.5	0.1	0.1	-27.7	0.7	7	3	-57.1
	Jelenia Góra	M	470.2	1.4	0.7	15.4	0.4	1	1	0.0
	Legnica	L	127.4	-0.7	37.9		1.1	2	1*	-50.0
Opolskie	oleski	F	230.0	0.0	-0.1	4.6	3.2	80	53	-33.8
	opolski	L	170.2	0.0	-0.3	11.3	1.0	62	53	-14.5
	nyski	F	234.0	0.0	-0.4	5.8	-0.1	80	44	-45.0
	prudnicki	F	232.6	0.0	-0.7	-18.7	7.6	50	39	-22.0
	brzeski	L	158.0	0.1	-0.5	61.1	4.1	61	36	-41.0
	kluczborski	L	191.8	0.0	-0.2	38.3	0.4	49	35	-28.6
	kędzierzyńsko-kozielski	F	203.7	-0.1	-0.2	7.1	-3.0	41	32	-22.0
	głubczycki	F	283.3	0.0	-0.5	9.1	0.3	37	28	-24.3
	namysłowski	L	160.7	0.0	-0.2	95.0	0.0	51	28	-45.1

Continued on the next page

Province (voivodship)	County (powiat)	County type	Mean altitude (m asl)	Crop-lands change (%)	Grass-lands change (%)	Forest change (%)	Urban/ Built-up change (%)	No of pairs in 2004	No of pairs in 2014	Rate of change (%)
	strzelecki	F	222.8	0.0	0.0	5.4	1.4	34	23	-32.4
	krapkowicki	L	183.3	-0.1	-0.3	47.8	0.4	27	22	-18.5
	Opole	L	157.1	0.4	0.8	20.3	0.4	5	3	-40.0
Śląskie	częstochowski	L	255.6	-0.1	-0.3	5.7	1.0	130	97	-25.4
	zawierciański	F	331.0	0.1	-0.4	0.8	1.3	60	56	-6.7
	bielski	F	397.1	-0.2	0.0	-0.9	2.7	43	40	-7.0
	lubliniecki	L	269.7	0.0	-0.2	7.7	1.3	53	40	-24.5
	kłobucki	L	238.5	0.0	-0.3	1.5	2.8	63	39	-38.1
	raciborski	L	216.6	0.0	-0.3	-17.9	0.5	46	33	-28.3
	cieszyński	F	449.7	-0.2	0.0	1.7	2.0	41	32	-22.0
	pszczyński	L	256.7	0.0	-0.2	-0.6	5.0	47	28	-40.4
	gliwicki	L	236.9	0.3	-0.1	10.8	2.8	45	27	-40.0
	myszkowski	F	325.4	0.1	-0.2	6.8	4.7	25	20	-20.0
	tarnogórski	L	275.6	0.4	-0.4	-2.3	5.1	36	16	-55.6
	wodzisławski	L	243.0	-0.2	-0.4	-1.4	7.8	20	13	-35.0
	bieruńsko-lędziński	L	244.3	-0.1	-0.3	4.0	5.1	13	9	-30.8
	będziński	F	302.3	-0.3	-0.2	-1.7	2.6	16	8	-50.0
	rybnicki	L	256.1	-0.2	-0.5	0.5	7.4	23	7	-69.6
	żywiecki	M	654.4	-0.6	-0.4	0.0	3.1	12	7	-41.7
	mikołowski	L	279.1	0.0	-0.2	11.9	3.7	11	5	-54.5
	Dąbrowa Górnicza	F	307.3	-0.5	-0.3	-0.7	2.6	6	4	-33.3
	Jastrzębie-Zdrój	L	262.6	-0.1	-0.2	-9.2	1.5	3	4	33.3
	Tychy	L	254.4	0.0	0.1	-1.1	0.8	5	4	-20.0
	Częstochowa	L	259.8	0.0	-0.2	43.4	0.7	6	3	-50.0
	Katowice	L	276.5	0.0	-0.6	-18.6	0.3	0	2	
	Mysłowice	L	268.5	-0.3	-0.4	0.0	0.7	3	2*	-33.3
	Rybnik	L	248.1	-0.2	-0.5	19.9	0.7	4	2	-50.0
	Zabrze	L	254.0	1.3	0.3	-63.3	0.7	3	2	-33.3
	Bytom	L	287.3	0.1	1.0		5.0	1	1	0.0
	Gliwice	L	240.1	0.2	0.4	21.3	31.8	2	1	-50.0
	Jaworzno	L	276.4	0.4	-0.6	18.8	1.9	3	1	-66.7
	Żory	L	262.1	-0.2	-0.3	0.2	10.2	4	1	-75.0
	Bielsko-Biała	F	413.0	-0.4	-0.3	-2.8	2.8	0	0*	0.0
	Chorzów	L	287.3	-0.3	0.0		0.9	0	0*	0.0
	Piekary Śląskie	L	285.5	0.4	-0.5	-19.5	6.2	0	0*	0.0
	Ruda Śląska	L	267.0	-0.3	-0.4	23.9	0.8	0	0*	0.0
	Siemianowice Śląskie	L	277.3	0.4	-0.4		0.2	0	0*	0.0
	Sosnowiec	L	264.5	0.7	-0.1	-14.0	1.3	0	0*	0.0
	Świętochłowice	L	284.3	0.6	-0.1		-0.8	0	0*	0.0
Małopolskie	nowotarski	M	705.5	-0.4	0.3	0.0	2.7	86	83	-3.5
	tarnowski	L	265.5	-0.2	-0.1	3.1	8.0	94	68	-27.7
	bocheński	L	263.0	-0.3	-0.1	0.1	6.1	90	51	-43.3
	dąbrowski	L	180.0	-0.3	-0.1	3.2	7.6	47	51	8.5
	brzeski	L	242.3	-0.3	0.0	2.6	4.5	113	46	-59.3
	gorlicki	F	460.4	-0.3	0.0	1.9	2.0	29	36	24.1
	wielicki	L	243.4	-0.3	-0.3	4.6	13.7	52	34	-34.6
	oświęcimski	L	253.5	-0.1	-0.3	1.9	8.7	65	27	-58.5
	nowosądecki	M	529.8	-0.4	0.0	1.5	1.9	36	26	-27.8
	krakowski	F	302.8	-0.2	-0.2	-6.0	7.0	41	21	-48.8
	proszowicki	L	234.9	0.0	-0.3	11.2	0.0	36	21	-41.7
	chrzanowski	L	293.7	-0.6	-0.3	-1.4	1.6	20	12*	-40.0
	limanowski	M	582.2	-0.4	0.1	0.0	7.2	13	10	-23.1
	wadowicki	F	345.5	-0.2	0.2	2.2	0.7	29	10	-65.5
	miechowski	F	313.0	0.0	-0.1	16.4	5.1	13	9	-30.8
	myślenicki	F	425.7	-0.5	0.0	-0.9	4.8	12	8	-33.3
	Kraków	L	222.5	0.1	0.1	0.4	3.1	14	7	-50.0
	olkuski	F	374.5	-0.1	0.3	5.4	5.6	7	6	-14.3
	tatrzański	M	1089.3	-0.8	-0.3	5.0	4.1	5	3	-40.0
	Tarnów	L	210.7	1.0	0.9	-2.0	11.0	6	3	-50.0
	suski	M	596.2	-0.6	-0.2	0.0	3.0	2	1	-50.0
	Nowy Sącz	F	321.1	-0.3	0.1	-1.1	2.3	2	1	-50.0

Appendix 2. Distribution of changes in four land use types in counties of SW Poland. Numbers above bars indicate the number of counties with percentage change category shown in horizontal axis. Dashed lines separate decreases (left side) and increases (right side) in shares of land use types. Medians and quartiles of the total data within each type are also presented. The last bin of each histogram is unbounded from the right side, due to the presence of several outlying values of increase (see Appendix 1).



Appendix 3. Population size and the mean rate of change in the number of breeding pairs of the White Stork between 2004 and 2014 in three types of counties separated according to altitude. Result from the Sudetes and Carpathians are shown separately, counties devoid of storks and those unsurveyed in 2014 are excluded.

County type	No of counties	Mean altitude (m asl)	No of breeding pairs in 2004	No of breeding pairs in 2014	Rate of change (%)
Sudetes + Carpathians					
mountain	11	624.7	182	156	-16.98
foothills	27	310.7	786	562	-29.90
lowland	58	187.3	2746	1679	-38.87
Total	96	272.1	3714	2397	-33.84
The Sudetes					
mountain	5	542.9	28	26	-0.14
foothills	14	266.7	462	311	-32.12
lowland	29	125.1	1711	1038	-39.44
Total	48	209.9	2201	1375	-33.21
The Carpathians					
mountain	6	692.9	154	130	-31.02
foothills	13	358.1	324	251	-27.50
lowland	29	249.4	1035	641	-38.29
Total	48	334.3	1513	1022	-34.46