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OPINION

The White Stork in Poland – long-term trends and an uncertain future for a mighty population

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Figure 1. In Poland, the White Stork is regarded as a symbol of the agricultural landscape and an element of the national heritage. Traditional nest location on the roof of the farm building, Budzów, SW Poland, 2019. Photo by Andrzej Wuczyński.

Every fourth stork is Polish. Such a saying has been used for decades in popular literature and the media, accurately reflecting the importance of Poland in maintaining the population of the White Stork *Ciconia ciconia*. Indeed, the country is of global importance for the species, hosting the world's largest number of breeding pairs. However, the latest data documenting surprisingly dynamic changes of stork abundance in various parts of the distribution indicate that Poland is losing its privileged position. More broadly, Central Europe, traditionally considered to be the center of the species range, is currently characterized by declining trends, inconsistent with the impressive increases in the global population. These discrepancies are illustrated by recent studies from Poland, showing the specificity of the Polish population, as well as its long-term trends against the background of global changes in stork numbers and distribution (Figure 1).

The world's first large-scale White Stork census was made in 1876 in the North Carpathians region (southern Poland). It was based on questionnaire forms advertised in two school journals and addressed to teachers of rural schools (Janota, 1876). Feedback was obtained about 1919 nests, mostly occupied by storks, and the detailed list of localities has been published. This allowed, inter alia, for the later reconstruction of the White Stork expansion in the area of the Polish Carpathians (Profus 2006). In modern times, the most important source of information on stork abundance is The International White Stork Census (IWSC) which provides an overview of the regional and worldwide population dynamics of the species. To date, the censuses have been carried out seven times, in 1934, 1958, 1974, 1984, 1994/95, 2004/05 and 2014, setting milestones for all studies on stork demography. Unfortunately,

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despite adequate methodology, thousands of participants and institutions involved as well as substantial financial resources, the national counts were incomplete at times, and since 1974, the global population size could only be assessed four times. Interestingly, the last IWSC in 2014 also was not completed, so the current size of the global stork population remains unknown, although an increase is evident (Thomsen *et al*. 2017).

Poland has participated in each of the IWSC, but the census of 1934 contained data covering only a part of the current Polish territory, which did not allow a comprehensive population assessment. The next census in 1958 was carried out throughout the territory of Poland, however the results were not published at the time (except for a one-page note in a popular school journal), whereas the last census in 2014 is still not summarized at the country level. As a result, the IWSCs allowed to assess the size of the Polish stork population four times – in 1974, 1984, 1994 and 2004 – whereas numbers both in the mid-20th century and recently remained uncertain, making it difficult to assess the development of population in Poland but also on wider, regional and global scales. Fortunately, as a remedy against the lack of 2014 data from IWCS, it can be the national program, Monitoring of Birds of Poland (hereafter MBP), implemented annually since 2000 (https://monitoringptakow.gios.gov.pl). Although not fully comparable with the IWSC, the MBP is based on a consistent methodology of field research and analysis, and is the only source of information about the current nationwide population size of the White Stork and many other bird species.

Reconstruction of the long-term dynamics in Poland

In order to comprehensively present the development of the stork population, we first used the oldest existing nationwide dataset in Poland, i.e. the original survey data collected during the 2nd IWCS in 1958, and compared them with the results of the next, complete census of 1974. The preserved questionnaires from 1958 constitute large and unique materials regarding stork numbers in Poland, sent at that time by teachers of rural schools. Using a representative sample of these data and advanced statistical methods, we were able to shift the knowledge about the White Stork abundance in the Polish stronghold backwards by 16 years (Wuczyński *et al*. 2021). Average population was estimated at about 46,100 breeding pairs and the nationwide density at 14.7 pairs/100 km^2. The contribution of the Polish population to the world population was indeed significant, constituting approx. 1/4, as in later years. Interestingly, a strong decreasing trend (28% or 1.75% per year) has been noted between 1958 and 1974 indicating that the population experienced a massive decline during 1960s-1980s, comparable with the declines of the western population. This finding contradicts a well-established presumption that the core central-eastern population was stable in this period and brings a new perspective on the causes of population changes in the White Stork.

The dynamics in further decades could be reconstructed from consecutive IWCSs and, most recently, from the MBP data. After drop in the 1980s the population steadily increased to stabilize at a level of 52,500 pairs in 2004 (acc. to the 6th IWCS) and 52,700 pairs in 2014 (according to the MBP). In the last few years, however, an apparent decrease in the nationwide population is noted (see below). The increases in Poland between 1984 and 2004 mirrored the growth of the global population, while the post-2004 data indicate a divergence of trends: the number of storks in Poland was stable at most, inconsistently with spectacular, yet so far unquantified, the upward trend of the global

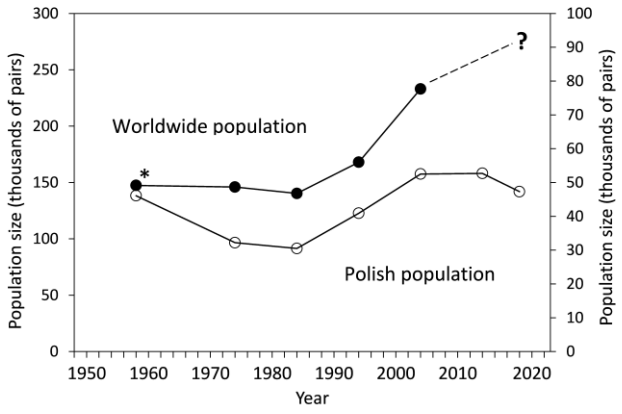

Figure 2. Development of the White Stork populations based on worldwide and nationwide Polish data. The most recent (2019) worldwide trend is approximate. Star indicates an incomplete census at the global scale in 1958.

population (Figure 2).

Intricacies of the recent trends in the Polish population

Tracking the latest population changes in Poland has proved to be a challenge again due to the lack of complete 2014 results and divergence in trends within the national data. To unravel the puzzle, we looked at the IWCS 2014 results from the best-studied, SW part of Poland and compared them with the results of previous censuses and the MBP data (Wuczyński *et al*. 2021a).

Against the rest of the country, five out of 16 Polish provinces adjoining the southern and western state border, including mountains, can hardly be considered an optimal area for the White Stork. They occupy 23% of the country (70,863 km^2), are characterized by relatively strong industrialization and intensive agriculture. As a result, the region is characterized by the country-lowest stork densities, evident in all censuses to date, and an uneven distribution of nesting sites. However, it is an area with the longest tradition of the large-scale stork counts in the world, producing the longest series of data in Poland, and with large areas covered by annual monitoring. For all these reasons, this area was also properly surveyed during the IWCS 2014 – and as such, well suited for checking population changes.

In 2014 the stork numbers in the five provinces was assessed at 2560 pairs breeding in a density of 3.61 pairs/100 km^2. Regarding the trends it was telling that, firstly, compared to the previous census in 2004, a substantial population decline of 35.5% was found. The declines were quite uniform within the region, slightly higher in the west. We are not aware of any large areas within the White Stork range with current decreases at the magnitude of the revealed in south-western Poland. This decline could not be explained by changes in land use over the period compared, so its causes remain unknown, but we see it as a result of large-scale rather than local processes. Secondly, decreases were strongly inversely related to the altitude, i.e. declines in lowlands were twice as high as in the mountains. This finding suggests that the uplands are currently more favorable to the breeding storks than the lowlands, perhaps due to more favorable microclimatic and trophic conditions, as well as greater availability of preferred habitats (Tryjanowski *et al*. 2005a, Martin *et al*. 2021). This is also confirmed by earlier results of the 6th IWSC 2004 from the Sudetes, which indicated significantly higher stork productivity at higher elevations compared to lowlands and foothills (Wuczyński 2006).

Thirdly, a troublesome temporal mismatch was noticed in the trends of both SW Poland and the entire country. Considering only two points in time compared in our study, 2004 and 2014, the strong downward trends in south-western Poland did not correspond to the stable situation of the national population (Chylarecki *et al*. 2018). However, the most recent MBP data 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), or even more considering a different representation of the sample plots. Seemingly, this corresponds to the declines in SW Poland, but the problem is that there are no recent data covering the entire region. On the contrary, the results from sample areas inspected annually, suggest some stabilization in the last five years in SW Poland, and even signs of an increase have appeared (unpublished data). It is worth adding that similar discrepancies in the directions of trends also applied to the past: during the last half-century, when data from both SW Poland and the entire country were available, only in 1984–2004 the trend of the two populations was similar. Thus, the current mismatch confirms the long-term rule, at which the turnaround in SW Poland by about a decade precedes the change observed on a national scale. Therefore, an intriguing question arises whether the recent data from SW Poland does not reveal an upward trend that is just beginning, which may raise again the Polish and Central European population. Such a return is possible thanks to extremely thriving neighboring populations: currently the increases concern most of the European range of the White Stork – 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 (Wuczyński *et al*. 2021a).

Final remarks

What can be gleaned from the Polish data on the White Stork dynamics? Long-term look revealed a sine wave pattern in population changes, known from other studies and regions. What may be surprising is the high rate of these changes. A 35% decline over ten years or 10% over five years are reasonably high figures as for a long-lived, single-brooded bird species with a relatively low reproduction rate. This implies the need for caution when drawing conclusions based on, say, data from a decade ago, because even during this relatively short period of time, a lot could have changed.

Rapid changes occur at large spatial scales covering countries and the entire species range. Interestingly, the rate and directions of trends may differ between neighbouring populations, which is one of the exciting issues in stork population ecology (Tryjanowski *et al*. 2005b). In this context we note that Poland, characterized by stork declines, now seems to be a transitional area between Western and North-Eastern Europe – two large areas inhabited by increasing populations of the White Stork. Perhaps such a location affects the population heterogeneity and accelerates the fast changes in abundance (Figure. 3).

To show the Polish data in a broader context, we tabulated long-term quantitative data on the White Storks numbers in Poland and some other countries (Wuczyński *et al*. 2021). This was not an easy task, as former estimates of the population in individual countries, if available, were scattered in multilingual literature, difficult to obtain and often inconsistent. A particular nuisance when compiling these results was the multiplicity of national assessments in a given year, particularly intractable in the case of old and foreign assessments. This problem has also affected Poland. While the last census of 2014 is still pending, there are already at least three different published estimates of the size of the nationwide population for 2014. There is a concern that this may lead to further ambiguities and interpretation problems in the future. Researchers are well aware of a number of pitfalls of counting the White Storks, especially at high densities, therefore some restraint is called for when presenting results based on intuition rather than clear methodological foundations.

Although the White Stork is one of the best-studied animal species, understanding the processes underlying population trends remains a challenge. Trends in Poland and Central Europe may certainly depend on a multitude of factors, however their individual impacts are difficult to disentangle. Since the outlined changes occur at large spatial scales it seems likely that they are shaped by large-scale processes rather than local ones. In particular, these include eastward range shift of the White Stork, possibly facilitated by global warming, grasslands and wetlands losses, alterations in agricultural practices and land use intensification, all interacting with intra-specific mechanisms that regulate the population dynamics. When looking for reasons outside the breeding areas, it should be noted that in Central Europe, the border between areas with overall population increases and decreases/stability coincides with the division into western and eastern stork migration pools, occurring longitudinally across Germany.

Figure 3. Diverse trends in the White Stork populations may be driven by differences in the reproduction rate. A brood of five young in Stańczyki, NE Poland, 2013. Photo by Andrzej Wuczyński.

This means that the heterogeneity of trends may also be related to migration paths and wintering grounds, leading to different costs for western and eastern migrants. However, this does not explain diverse trends occurring within the same migration pool, what we observe within the eastern White Stork population.

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