Ireneusz Kaługa¹, Marcin Bocheński², Leszek Jerzak²

Factors influencing fledgling success of the White Stork *Ciconia ciconia* in Eastern Poland

**Abstract**

The paper presents the results of a study on the influence of breeding site habitat of the White Stork *Ciconia ciconia* on breeding parameters, conducted 2000 to 2014 in Eastern Poland. During that period, the average White Stork density increased from 21.4 pairs/100 km² to 38 pairs/100 km² (overall mean: 29.7 pairs/100 km²). The average number of nestlings per pair (JZa) and per successful pair (Jzm) was 2.98 and 3.00 respectively. A total of 2,711 young storks were raised, with an annual mean of 181. The productivity of the population in a particular season was significantly correlated only with the average surface water level of the Liwiec river in May. There were no significant correlations of the reproductive success of the population with the number of occupied nests, population size, cattle density, and area of land covered by agri-environmental projects in a particular breeding season or in previous years.

**Key words:** White Stork, factors, fledging success, E Poland.

**Introduction**

The White Stork *Ciconia ciconia* belongs to the wading order *Ciconiiformes* and the stork family Ciconiidae. Its breeding range stretches from Africa to southern Sweden and Denmark and from Portugal to Uzbekistan (Schulz 1998). The size of the Polish breeding population is estimated at 51,700-53,900 pairs, corresponding to 22.4% of the world population and 33.2% of the EU population (Chodkiewicz et al. 2015). The White Stork occurs all over Poland, except in woodland and mountains. Its habitats include farmland, river valleys with a significant proportion of meadows and pastures. It nests mostly in built-up areas, rarely more than 500 m away from buildings (Profus 2006).

The species chooses man-made structures as nest sites. In 2004, 59% of the Polish population nested on active electric poles. Storks also like to nest on buildings (19%) and on trees (17%) (Guziak & Jakubiec 2006).

Areas with optimal foraging sites are characterised by a high density of breeding pairs and colonies (Kalski 2006; Molewski & Jakubiec 2006; Zbyryt et al. 2014).
Breeding success of the White Stork depends on food resources. Tryjanowski & Kuźniak (2002) showed a positive correlation between the number of the Common Vole Microtus arvalis and the density and the productivity of the White Stork population in the Obra river valley, Western Poland. That study also revealed that breeding success is higher in years of a high density of the Common Vole. Furthermore, there was evidence that storks breeding closer to areas with high food supply (Tortosa et al. 2003) or foraging in company of farm animals (Tryjanowski et al. 2005) statistically raise more nestlings.

One result of the dramatic transformation of agricultural environment in some countries in Western Europe has been a significant decline of the numbers of the White Stork or even disappearance of entire populations in some areas (Bairlein 1991; Donald et al. 2001). Negative changes have also been detected in the Polish population (Chylarecki & Jawińska 2007; Chylarecki et al. 2008). Between 2005 and 2011, the number of pairs in the administrative counties of Kościan and Gostyń, western Poland, decreased by 47% and 22%, respectively, as compared to 2004 (Tobólka 2012). According to the author of that study, these changes result from an intensification in agriculture and the related decrease in biodiversity. Yet, in areas with extensive farming carried out on small plots, stork populations have maintained their size or even increased. In recent years, a significant decline in stork numbers was also reported for north-eastern Poland, where the population was thought to be the largest of the entire country, and even of the whole species’ range (Guziak & Jakubiec 2006, Molewski & Jakubiec 2006; Profus 2006). In 2013, as compared to 2004, 2008 and 2010, the number of pairs in the 17 largest breeding colonies in north-eastern Poland decreased by approximately 10% to 49% (on average 32%). The reasons for such significant declines vary for particular breeding colonies. Generally, they resulted from a loss of available foraging sites, in some areas from predation of the beech marten, and even from aggressive behaviour of other pairs in the colony (Zbyryt et al. 2014).

The results of a study in Lithuania in 2009 and 2010 (Vaitkuviene & Dagys 2015) is interesting in respect to the decline of populations of the White Stork in its numerous habitats, revealing a more than two-fold increase in the number of breeding pairs since 1994. According to the authors, such a significant increase is related to changes in agriculture which prove to be favourable for this species, namely the reduction of large farms and land privatization. They also claim that a decrease in farm size corresponds to a decreasing intensity of agricultural practices which, in turn, contributes to the increase of the White Stork population in Lithuania.

Bearing in mind the need to protect the White Stork, the most important issues are those related to the correlation of breeding parameters with habitat structure near the nest. Investigations of the above-mentioned problem are, however, rare and very little reference material is available. A study in the Kolno Upland and the Biebrza river valley shows that pairs nesting close to the edge of the river valley, i.e. in the neighbour-
hood of wet meadows, have a significantly higher breeding success than those nesting farther away (Nowakowski 2003). In central Poland nests sites located in wetlands (in river valleys and water courses valleys) are occupied earlier in the breeding season (Janiszewski et al. 2014). The number of nestlings removed from such nests by the adults is lower than in other nests and decreases with an increase of the proportion of wetlands in the nesting area. An investigation in Western Turkey shows that the area of wetlands, i.e. surface water and marshes, can be decisive in selecting a nesting site (Onmus et al. 2012). The authors state that storks choose nest sites first in river and water course valleys.

There are various activities to ensure protection of the White Stork. Reintroduction of this species in some countries of Western Europe, such as France (Schierer 1992; Duquet 1999) or Belgium (Kesteloot 1989; Boettcher-Streim & Schuz 1989) has been successful. Other measures are renaturalization of wetlands as foraging site or, e.g., protection of nest sites (Guziak & Konieczny 2006; Zbyryt 2014). Efforts are made to limit the number storks killed by electric shock when contacting power devices (Kaluga et al. 2011). In the area of the present study six power constructions were modernized (transformer stations and poles with switches) on which earlier one to seven storks were killed a year.

In terms of reviewing research on the White Stork and its protection it is crucial to learn more about the spatial arrangement of habitats in breeding areas and changes affecting them. In the future, this topic may be of key importance for conservation of the species.

The present paper aims:

– to present basic parameters characterizing the White Stork population of Eastern Mazowsze in the years 2000-2014 and to indicate influencing factors;
– to characterize reproductive parameters in Eastern Mazowsze;
– to investigate whether implementation of agri-environmental programmes for protection of ten bird species inhabiting meadows and pastures can affect reproduction of the White Stork and how it is correlated with stork protection.

The results will enable to formulate recommendations for the protection of the White Stork and will serve as a scientific support of optimal framework of agri-environmental programmes for the years 2016-2020.

**Study area**

Observations were carried out in an area of 219,893 ha covering the administrative borders of the communes Mokobody and Suchożeby, located in the county of Siedlce in the Mazowsze administrative region. Agricultural land covers 70.85%, including 61.65% of arable land and 18.2% of meadows and pastures. Forests cover 8.95% and
built-up area, orchards, ditches, and fallow land account for a total of 11.2% of the area (data from the Communal Offices of Suchożebyry and Mokobody).

According to the data presented by CORINE Land Cover project (http://www.igik.edu.pl/pl/corine-projekt, access on 4.02.2016), slightly more than half of the study area was classified as “non-irrigated arable land (2.1.1.)” and almost 20% as “pastures (2.3.1.)”. The proportion of “coniferous forests (3.1.2.)” amounted to 12%, and all other land categories combined did not exceed 5% (Table 1, Fig. 1).

<table>
<thead>
<tr>
<th>CLC code</th>
<th>Corine land cover classes</th>
<th>Total area (ha)</th>
<th>Proportion</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1.1.</td>
<td>Non-irrigated arable land</td>
<td>11,755.05</td>
<td>53.48%</td>
</tr>
<tr>
<td>2.3.1.</td>
<td>Pastures</td>
<td>4,228.76</td>
<td>19.24%</td>
</tr>
<tr>
<td>3.1.2.</td>
<td>Coniferous forests</td>
<td>2,668.41</td>
<td>12.14%</td>
</tr>
<tr>
<td>1.1.2.</td>
<td>Discontinuous urban fabric</td>
<td>887.03</td>
<td>4.04%</td>
</tr>
<tr>
<td>2.4.3.</td>
<td>Land principally occupied by agriculture</td>
<td>829.93</td>
<td>3.78%</td>
</tr>
<tr>
<td>3.1.3.</td>
<td>Mixed forests</td>
<td>502.61</td>
<td>2.29%</td>
</tr>
<tr>
<td>2.4.2.</td>
<td>Complex cultivation patterns</td>
<td>360.48</td>
<td>1.64%</td>
</tr>
<tr>
<td>3.1.1.</td>
<td>Broad-leaved forests</td>
<td>287.17</td>
<td>1.31%</td>
</tr>
<tr>
<td>2.2.2.</td>
<td>Fruit trees nad berry plantations</td>
<td>259.93</td>
<td>1.18%</td>
</tr>
<tr>
<td>1.3.1.</td>
<td>Mineral extraction areas</td>
<td>107.72</td>
<td>0.49%</td>
</tr>
<tr>
<td>3.2.4.</td>
<td>Transitional woodland shrub</td>
<td>94.36</td>
<td>0.43%</td>
</tr>
</tbody>
</table>

The main hydrological axes of the investigated area are the rivers Liwiec and Stara Rzeka, both tributaries of the river Bug. The valleys of both rivers are covered mainly by meadows and pastures. The study area includes almost a thousand stagnant water bodies, such as oxbows, ponds, field and forest waterholes, with a total area of approximately 22 ha. Large water courses, i.e. sections of the rivers Liwiec, Stara Rzeka, and Muchawka, amount to about 36 ha in total. The area of all water bodies combined accounts for 0.03% of the total study area. Nevertheless, this area also has a well-developed network of various types of smaller or bigger water courses such as tiny rivers, streams, ditches or canals, with a total length, along with the big rivers, of about 300 km. However, this water course network varies throughout the study area, most of it situated in the valleys of the Liwiec and Stara Rzeka (Fig. 2). The hydrological regime is mostly influenced by the Liwiec. The average water level in the investigated area (data from the observation post Zaliwie, located near the village Mokobody) is 164 cm. The highest mean monthly level of the river Liwiec is observed in March (about 196 cm) and the lowest in May (about 147 cm) (Fig. 3). The average water level of the Liwiec also varies from year to year (Fig. 4).

The average annual temperature during the study period was 8.3°C, and the average annual rainfall 589.7 mm. During the study there were, on average, 178 days with
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**Figure 1.** Corine land cover classes in the area of the communes of Mokobody and Suchożebrzy
Figure 2. Hydrography of the area of the communes of Mokobody and Suchożeby

Figure 3. Mean monthly water level of the Liwiec river (Zaliwie observation post) from 1998 to 2014 (data source: IMGiW)
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Rain and 62 days with snow cover per year (source: Institute of Meteorology and Water management).

Cattle breeding is an important part of the agricultural economy in the study area. From 2003 to 2014, the number of cattle increased from 11,191 to 16,281 individuals, corresponding to a density increase from 5.1 to 7.4 animals/10 ha (Fig. 5) (data from the Communal Offices of Mokobody and Suchożebry and from the Agency for Restructuring and Modernization of Agriculture).

In 2004-2006 and 2007-2013, the investigated area was subject to the implementation of EU agri-environmental programs supporting, among others, maintenance of traditional forms of meadow and pasture use. These are programs that have been implemented throughout the European Union by regional or central authorities in all member states since 1992. They are part of the Rural Development Program and carried out on a long-term basis (Kucharska 2010).

As far as the studied White Stork population is concerned, the most important program packages were:

- extensive permanent pastures (package 3)
- preservation of endangered species and natural habitats outside Natura 2000 sites (package 4)

**Figure 4.** Mean annual water level of the Liwiec river (Zaliwie observation post) from 1998 to 2014 (data source: IMGiW)
preservation of endangered species and natural habitats on Natura 2000 sites (package 5).

The first package promoted specifically cutting grass to make hay twice a year (starting 15th June), while the other two stressed protection of birds inhabiting meadows and pastures. The study area was populated by lapwing, goodwit, redshank, Eurasian curlew, and snipe. As recommended in the packages, cutting grass was postponed to a period from 1st August to 13th September, and stocking density was determined at 1 DJP/ha (a big calculation unit) (Jobda 2009).

From 2000 to 2006 only the package “Extensive permanent pastures” was implemented on the study area, and since 2007 the packages 3, 4, and 5 have been carried out with various intensity and in various versions (Source: Agency for Restructuring and Modernization of Agriculture 2014).

From 2004 until 2012 the number of evidenced plots as well as the proportion of the area covered by agri-environmental programs increased systematically, with highest values each in 2012.
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**Methods**

**Population indicators**

Fieldwork was conducted from 2000 to 2014. It started mid March, before storks arrived from their wintering areas, by making an inventory of all nests in the entire study area. Nests were then inspected for occupation by adult storks from 10\(^{th}\) to 15\(^{th}\) April, and for breeding status (clutches or not) from 10\(^{th}\) to 15\(^{th}\) May. The 4\(^{th}\) and last stage of fieldwork was inspecting each nest for breeding success from 1\(^{st}\) to 20\(^{th}\) July.

When checking breeding success, field workers also collected detailed information from local people regarding the breeding process in any particular year.

The following data for each nest were recorded:
- nest location (using GPS tracking device);
- nest site (e.g., on pole, building, or tree);
- type of nest site (e.g., wooden pole, electric pole type A, I, farm building and type of roof, tree type/species on which the nest was constructed);
- information on breeding process (if possible, date of arrival, fighting over nests, nestling number, causes of nestlings mortality);
- condition and possible threats to nest and nest site.

Since 2011, all nests were additionally visited from 15\(^{th}\) to 20\(^{th}\) June for ringing of nestlings.

Methods of calculating the reproduction parameters and their abbreviations followed the standard methodology applied in the International White Stork Census (Mrugasiewicz 1971; Profus 2006; Tryjanowski et al. 2006). The paper uses the international symbols for describing breeding success (Guziak 2006).

**Spatial data**

The basic GIS system used was QGis software, version 2.14.

A set of vector data of Corine Land Cover 2012 software could be used courtesy of the Institute of Geodesy and Cartography in Warsaw. Hydrographic data as vector layers (map of the Hydrographic Division of Poland, 1 : 10,000) were provided by courtesy of the National Water Management Authority in Warsaw. Information concerning record parcels was made available by the Head Office of Land Surveying and Cartography in Warsaw.

The area of particular land cover categories, according to Corine Land Cover, and the area covered by agri-environmental programs in respective nesting areas of the White Stork were calculated by the ArcGis 10.0 system, including Geospatial Modelling Environment (www.spatialecology.com).
QGis 2.14 software was used for computing the total number of record parcels, total length of the border of record parcels, and total length of the line of water bodies in respective nesting areas of the White Stork.

To determine whether a variable, namely the average annual fledging success in a particular breeding area, is spatially autocorrelated in the study area, the ArcGis package was used, fixing the value of the Moran “I” statistics according to Dale and Fortin (2014).

**Statistical analysis**

To determine what factors can affect the size of the White Stork population in respective years, a correlation matrix based on the following variables was created:

* dependent variable: size of the breeding population, i.e. the number of occupied nests in which pairs showed breeding activity in a particular year.

* independent variables:
  - average March water level of the Liwiec river in a particular year in (cm);
  - cattle density in the study area in a particular year (animals/10 ha);
  - cattle density in the study area in the year preceding a particular breeding season (animals/10 ha);
  - cattle density in the study area two years before a particular breeding season (animals/10 ha);
  - part of the study area (ha) covered by agri-environmental programs in a particular year;
  - part of the study area (ha) covered by agri-environmental programs in the year preceding a particular breeding season;
  - part of the study area (ha) covered by agri-environmental programs two years before a particular breeding season;
  - average fledging success per pair (Jza) in the investigated population in the season preceding a particular breeding season;
  - average fledging success per pair (Jza) in the investigated population two years before a particular breeding season;
  - average fledging success per pair (Jza) in the investigated population three years before a particular breeding season.

To determine what factors can affect fledging success in the investigated White Stork population in respective years, a correlation matrix based on the following variables was created:

* dependent variable: average number of nestlings produced by a pair starting to breed in a particular year (Jza).

* independent variables:
  - number of all occupied nests in a given year;
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- size of the breeding population in a given year;
- average Mach water level of the Liwiec river in a particular year (cm);
- average April water level of the Liwiec river in a particular year (cm);
- average May water level of the Liwiec river in a particular year (cm);
- average June water level of the Liwiec river in June in a particular year (cm);
- cattle density in the study area in a particular year (animals/10 ha);
- cattle density in the study area in the year preceding a particular breeding season (animals/10 ha);
- cattle density in the study area two years before a particular breeding season (animals/10 ha);
- part of the study area (ha) covered by agri-environmental programs in a particular year;
- part of the study area (ha) covered by agri-environmental programs in the year preceding a particular breeding season;
- part of the study area (in ha) covered by agri-environmental programs two years before a particular breeding season.

All calculations were performed with MS Excel 2013 software and the package Statistica, version 12 (StatSoft Inc. 2014), according to the assumptions and methods recommended by Zar (2013).

**Results**

**Population numbers and density**

Between 2000 and 2014 data on 124 nest sites of the White Stork was collected. In 2000, i.e. the first study year, 56 nest were present (Fig. 6). During the entire 15 years of observations, 77 completely new nests were built whereas 20 disappeared. In the last year of the study, i.e. in 2014, a total of 104 nest sites of the White Stork in the area were investigated (Fig. 7).

The number of new nests constructed in a particular breeding season varied between zero and 12, on average 4.9 (SD = 4.05) (Fig. 8). Most nest sites (12) were built in 2004, and a strong increase in the number of sites was also noted in 2009 (11) and 2011 (9). The lowest number of nests was built in 2005 (1) (Fig. 8). The increase in the number of nest sites in the following years is highly significant; Pearson R correlation, $t = 19.81$, $r^2 = 0.97$, $p < 0.001$; Fig. 9).

The increasing number of nest sites was correlated with an increase in the number and density of the breeding population. In the first year of observation, the number of breeding pairs (i.e. occupied nests in which at least one egg was laid) was 47 (StD = 21.4 p/100 km²) (Fig. 10). Taking natural fluctuations into account (the lowest number of breeding pairs (43) was found in 2003, with StD = 19.6 p/100 km²), the popu-
**Figure 6.** Nest sites of the White Stork in the year 2000 in the area of the communes of Mokobody and Suchożebry

**Figure 7.** Nest sites of the White Stork in the year 2014 in the area of the communes of Mokobody and Suchożebry
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**Figure 8.** The number of new nests constructed in a particular breeding season and nest sites which disappeared from 2000 to 2014 in the area of the communes of Mokobody and Suchożeby.

**Figure 9.** Increase of number of nests sites of the White Stork in the communes of Mokobody and Suchożeby from 2000 to 2014 (Pearson correlation, $t = 19.81$, $r^2 = 0.97$, $p < 0.001$)
Figure 10. Changes in the number of breeding population of the White Stork from 2000 to 2014 in the area of the communes of Mokobody and Suchożebry.

Figure 11. Increase of the breeding population of the White Stork from 2000 to 2014 in the area of the communes of Mokobody and Suchożebry (R Pearson correlation, t = 6.94, r² = 0.78, p < 0.001)
lation increase during the 15 study years was statistically highly significant (Pearson R correlation, $t = 6.94$, $r^2 = 0.78$, $p < 0.001$, Fig. 11).

During the entire study period, there was no breeding season when all existing nest sites were occupied. On average, 89% of the existing nests were occupied, with the lowest value noted in 2006 (78%, i.e. 61 occupied nests of 78 existing ones) and highest in 2004 (97% occupied nests of 78 existing ones) (Fig. 10).

Not in all occupied nests, birds started to breed. On average in 83% of occupied nests, birds laid at least one egg, with the highest value reported for the year 2000 (90%, i.e. 47 out of 52 occupied nests) and the lowest for 2005 (64%, i.e. 44 out of 69 occupied nests) (Fig. 10).

**Factors affecting breeding population numbers and density**

The size of the breeding population in a particular season was significantly correlated with cattle density in that year as well as one and two years earlier. It was also correlated with the proportion of the study area covered by agri-environmental programs in that particular year as well as one and two years earlier (Table 2). There was no significant correlation of population size with the average March water level in the Liwiec river in a particular year or with the average fledging success of a pair in the three previous years (Table 2).

**Table 2.** Correlation values for the White Stork breeding population numbers from 2000 to 2014 in the area of the communes of Mokobody and Suchożebry and independent variables. Significant p values (< 0.05) are marked red. The values of variables explaining most of the variance ($r^2$) are underlined.

<table>
<thead>
<tr>
<th>Independent variable</th>
<th>$r^2$</th>
<th>$t$</th>
<th>$p$</th>
<th>$n$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average annual March water level of the Liwiec river (cm)</td>
<td>0.012</td>
<td>0.40</td>
<td>0.69</td>
<td>15</td>
</tr>
<tr>
<td>Cattle density in the study area in a particular year (animals/10 ha)</td>
<td>0.67</td>
<td>4.53</td>
<td>0.001</td>
<td>12</td>
</tr>
<tr>
<td>Cattle density in the study area in the year preceding a particular breeding season (animals/10 ha)</td>
<td>0.67</td>
<td>4.24</td>
<td>0.002</td>
<td>11</td>
</tr>
<tr>
<td>Cattle density in the study area two years before a particular breeding season (animals/10 ha)</td>
<td>0.77</td>
<td>5.25</td>
<td>0.0007</td>
<td>10</td>
</tr>
<tr>
<td>Area of land (ha) covered by agro-environmental programs in the study area in a particular year</td>
<td>0.65</td>
<td>4.54</td>
<td>0.0008</td>
<td>13</td>
</tr>
<tr>
<td>Area of land (ha) covered by agro-environmental programs in the study area in the year preceding a particular breeding season</td>
<td>0.72</td>
<td>5.55</td>
<td>0.0001</td>
<td>14</td>
</tr>
<tr>
<td>Area of land (ha) covered by agro-environmental programs in the study area two years before a particular breeding season</td>
<td>0.78</td>
<td>6.88</td>
<td>0.00001</td>
<td>15</td>
</tr>
<tr>
<td>Average fledging success per pair (JZa) in the year preceding a particular breeding season</td>
<td>0.05</td>
<td>0.76</td>
<td>0.46</td>
<td>14</td>
</tr>
<tr>
<td>Average fledging success per pair (JZa) two years before a particular breeding season</td>
<td>0.07</td>
<td>0.89</td>
<td>0.39</td>
<td>13</td>
</tr>
<tr>
<td>Average fledging success per pair (JZa) three years before a particular breeding season</td>
<td>0.14</td>
<td>1.26</td>
<td>0.24</td>
<td>12</td>
</tr>
</tbody>
</table>
However, the relatively limited data for cattle counts in 2003-2014 and for the area covered by agri-environmental programs 2004-2012 did not allow for an appropriate statistical model by stepwise regression analysis, in this case the method of choice to determine the actual effect of each of the above mentioned factors on population size. Therefore, the results shown should be viewed as preliminary, indicating some tendencies.

Breeding success and fledgling productivity

Between 2000 and 2014 field workers collected data of 905 broods in the communes of Mokobody and Suchożebrzy.

Breeding success, i.e. the proportion of pairs producing at least one fledgling out of all pairs which started breeding in a particular season, was, on average, 99%. During the whole study period, only in three years (2003, 2009, and 2014) some pairs were not breeding successfully.

From 2000 to 2014 the whole population raised 2,711 young, i.e., on average, approximately 181 nestlings per year. The highest number of fledglings were produced in 2012 (255) and the least in 2003 (115). In six of the 15 breeding seasons more than 200 young birds fledged.

The average number of fledglings per breeding pair (Jza) and per successful pair (Jzm) in the period 2000 to 2014 was 2.98 and 3.0, respectively. The highest fledgling productivity parameters were noted in 2004 (Jza and Jzm = 3.51) and the lowest in 2002 (Jza and Jzm = 2.65) (Fig. 12).

During the entire study period breeding pairs raised from one to six nestlings, most frequently three or four (on average, 44% and 24% of all nests, respectively) (Fig. 13). In 48 nests (on average in 3.2 nests in a given season) five nestlings were found. Such large broods were reported frequently in 2010 (14 nests) and 2004 (9 nests) (Fig. 12). In each of the years 2010 and 2011 a single nest with six nestlings was found.

Factors affecting the breeding productivity at the population level

The size of a breeding population in a particular season was significantly correlated only with the average May water level of the Liwiec river in that year (Table 3). There was no significant correlation of reproductive success with the number of occupied nests, population size, cattle density, and proportion of land covered by agri-environmental programs in that particular breeding season or in previous years (Table 3).

However, the relatively limited data for cattle counts in 2003-2014 and for the area covered by agri-environmental programs 2004-2012 did not allow for an appropriate statistical model by stepwise regression analysis, in this case the method of choice to determine the actual effect of each of the above mentioned factors on reproductive
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**Figure 12.** The average number of fledglings per breeding pair (Jza) and per successful pair (Jzm) from 2000 to 2014 in the area of the communes of Mokobody and Suchożebry

**Figure 13.** Proportion of White Stork nest with particular fledglings production from 2000 to 2014 in the area of the communes of Mokobody and Suchożebry
success. Therefore, the results shown should be viewed as preliminary, indicating some tendencies.

**Discussion**

**Population numbers and density**

The data for the Siedlec county revealed an increase of 26% in the number of breeding pairs of the White Stork in that area (Rzępała et al. 2001). From 2000 to 2014 a more detailed investigation was carried out in the communes of Mokobody and Suchożebry (the administrative county of Siedlce). The data showed that population size and density are still increasing in contrast to the decline of the stork population often reported for many areas of the country (Chylarecki & Jawińska 2007; Chylarecki et al. 2008; Tobółka 2012; Zbyryt et al. 2014).

During the 15 years of study in the communes of Mokobody and Suchożebry 77 new nests were constructed and 20 disappeared.

Most new nests were built in 2004, a year most favorable for the White Stork populations in the entire area of Poland (Guziak & Jakubiec 2006) as well as in some specific regions of the country (Piotrowska 2006; Kalski 2006; Molewski & Jakubiec 2006; Zbyryt 2014; Zbyryt et al. 2014). For the administrative county of Kętrzyn a population increase of 25% was reported (Jakubiec & Peterson 2013). A significant increase in

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**Table 3.** Correlation values for the White Stork fledging success (JZa) from 2000 to 2014 in the communes of Mokobody and Suchożebry and independent variables. Significant p values (< 0.059 are marked red.

<table>
<thead>
<tr>
<th>Independent variable</th>
<th>r²</th>
<th>t</th>
<th>p</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of all occupied nests</td>
<td>0.11</td>
<td>1.27</td>
<td>0.23</td>
<td>15</td>
</tr>
<tr>
<td>Breeding population size</td>
<td>0.08</td>
<td>1.10</td>
<td>0.29</td>
<td>15</td>
</tr>
<tr>
<td>Average annual March water level of the Liwiec river (cm)</td>
<td>0.04</td>
<td>0.71</td>
<td>0.49</td>
<td>15</td>
</tr>
<tr>
<td>Average annual April water level of the Liwiec river (cm)</td>
<td>0.05</td>
<td>0.86</td>
<td>0.40</td>
<td>15</td>
</tr>
<tr>
<td>Average annual May water level of the Liwiec river (cm)</td>
<td>0.271</td>
<td>2.20</td>
<td>0.046</td>
<td>15</td>
</tr>
<tr>
<td>Average annual June water level of the Liwiec river (cm)</td>
<td>0.03</td>
<td>0.61</td>
<td>0.55</td>
<td>15</td>
</tr>
<tr>
<td>Cattle density in the study area in a particular year (animals/10 ha)</td>
<td>0.01</td>
<td>-0.37</td>
<td>0.72</td>
<td>12</td>
</tr>
<tr>
<td>Cattle density in the study area in the year preceding a particular breeding season (animals/10 ha)</td>
<td>0.04</td>
<td>-0.63</td>
<td>0.54</td>
<td>11</td>
</tr>
<tr>
<td>Cattle density in the study area two years before a particular breeding season (animals/10 ha)</td>
<td>0.09</td>
<td>0.91</td>
<td>0.39</td>
<td>10</td>
</tr>
<tr>
<td>Area of land (ha) covered by agro-environmental programs in the study area in a particular year</td>
<td>0.10</td>
<td>1.13</td>
<td>0.28</td>
<td>13</td>
</tr>
<tr>
<td>Area of land (ha) covered by agro-environmental programs in the study area in the year preceding a particular breeding season</td>
<td>0.08</td>
<td>1.05</td>
<td>0.32</td>
<td>14</td>
</tr>
<tr>
<td>Area of land (ha) covered by agro-environmental programs in the study area two years before a particular breeding season</td>
<td>0.04</td>
<td>0.73</td>
<td>0.48</td>
<td>15</td>
</tr>
</tbody>
</table>
the number of nesting sites in the communes of Mokobody and Suchożebry was also noted in 2009 (11) and 2011 (9).

In 2010 there were fewer new sites in the study area, yet, similarly to the other regions in Poland, this year was also favorable for the stork populations. Successful broods were reported then, e.g., in Łomża Landscape Park of the Narew Valley (Zbyryt 2014) or in Greater Poland (Tobółka et al. 2011; Tobółka 201). On the other hand, in 2005 only a one nest was built new and the highest number of nests without broods was reported (25).

2013 was regarded a catastrophic year for western Poland due to heavy rains (e.g., Chodkiewicz et al. 2013; Dolata 2013; Bocheński, Jerzak, Siekiera and Siekiera – unpublished data), but was quite successful for the White Stork population in the investigated area. In the Varmia sanctuary the number of breeding pairs in 2013 was the highest of all investigated years (2011 to 2013), and success was exceptionally high (Zbyryt 2014).

The growing number of nest sites was related to an increase in the number and density of the breeding population. In the first year of the study (2000) the general density StD was 21.4 pairs/100 km² whereas in the last year this figure was 38 pairs/100 km². These values were above the average for Poland in 2004 (16.8 pairs/100 km²) (Jakubiec & Guziak 2006), in the region of Lublin (Lubelszczyzna) with 24.8 pairs/100 km² (Piotrowska 2006), or for Greater Poland from 2005 to 2011 (6.5-9.27 pairs/100 km²) (Tobółka 2012). However, the results of the present study were lower than those reported for north-eastern Poland in 2004. In the Province of Varmia and Masuria 42.3 pairs/100 km² were reported (Molewski & Jakubiec 2006), and in the Podlaskie Province 44.9 pairs/100 km² (Kalski 2006). In the Varmia sanctuary, during seven seasons (between 2004 and 2013) the mean density was 57.1 pairs/100 km² (Zbyryt 2014).

The studied population shows a tendency to change nest sites by abandoning trees and buildings and, instead, using active electric poles. In 2000, 51% of the pairs used nests on electric poles, 25% on trees, and 24% on buildings. In the last study year (2014) as many as 86% of all pairs nested on poles, 9% on trees, and 8% on buildings. This corresponds to a trend observed all over Poland (Jakubiec and Guziak 2006), as well as in many of its regions (e.g. Kosicki & Kuźniak 2006; Rubacha & Jerzak, Wuczyński 2006; Tryjanowski et al 2009; Tobółka 2012; Zbyryt et al. 2014).

Factors affecting population numbers and density

The breeding population size in a particular season is significantly correlated with cattle density in that year, the previous year and two years before.

In the study area cattle density increased gradually (Agency for Restructuring and Modernization of Agriculture 2014), correlating with an increase in farming intensity as a result of Poland joining the European Union. The increase in cattle numbers, on the other hand, meant keeping large areas of meadows and grassland which, in turn,
ensured relatively stable food provision in the years to come and the related high reproductive success of the studied White Stork population. A similar relation was noted by Tryjanowski et al. (2005) for the valley of the Middle Odra in western Poland.

Along with changes related to cattle keeping, several negative phenomena were noted in the study area, i.e. transforming meadows and pastures into cropland or a dramatic increase of corn monoculture, as it has already been the case in western Poland (Kosicki 2010).

The population size in a particular season was also significantly correlated with the area covered by agri-environmental programs in a particular year, the previous year and two years before. In the study area the number of record parcels subject to implementation of agri-environmental programs increased greatly, and their proportion in the general landscape area grew (Table 2). At that time, the most frequently implemented program packages were numbers 3 (meadows with grass cut twice) and 4 and 5 (preservation of endangered bird species), resulting from postponing mowing grass to make hay until 1st August. This means that year by year the number of parcels on which grassland is farmed extensively increases. This lead to an increase of biodiversity due to an application of less intensive farming methods. As shown in reference books, changes of this type have a very positive effect, i.e. an increase of White Stork populations (e.g. Vaitkuviene & Dagys 2015).

There was no significant correlation of population size with the average March water level of the Liwiec river or the average reproductive success of a given pair in the previous three breeding seasons. According to Tryjanowski et al. (2005), the decision of White Storks to occupy a certain nest does not depend on the mean surface spring water level in the nesting area but rather on how the area is managed (agrotechnical works). Other authors (e.g. Creutz 1985; Schneider 1988, Dziewiaty 2002) note that years with higher spring water level of rivers correlate positively with the number of White Stork pairs and breeding success. The results of our study differ from those of other authors, which means that on extensively used agricultural lands with a high proportion of pastures, the surface water level of the existing water course network does not have a decisive impact on the size of the stork populations.

Breeding success and fledgling productivity

The average number of fledglings per pair starting to breed (Jza) and per successful pair in the period from 2000 to 2014 was 2.98 and 3.0, respectively. These values were significantly higher than those from 2004 for the Siedlec administrative county (Jza = 2.66, Jzm = 2.94), the Mazvia region (JZa = 2.51, JZm = 2.79) (Kaługa 2006) and the entire country (JZa = 2.33, JZm = 2.61) (Jakubiec & Guziak 2006).
To maintain constant population numbers, the value of Jza should be about 1.99 (Wojciechowski 1992). Therefore, the population investigated in the present study shows features of a strong population with high development potential and significant resource of fledglings to replenish the population.

The outstandingly high values of Jza and Jzm in 2004 (3.51) deserve attention. They indicate that food provision and climate conditions were exceptionally favourable in the study area in that year. 14 nests with four nestlings and nine nests with five nestlings each were noted. In just one village (Wólka Proszewska), five out of a total of eight nests had five fledglings each.

However, it should be stressed that the parameter values obtained during the entire study period were also high, indicating favourable foraging conditions which remained stable in successive breeding seasons.

**Summary and conclusions**

1. The investigated population of the White Stork *Ciconia ciconia* in the area of the communes Mokobody and Suchożebry (the administrative county of Siedlce in the Mazovia region) is characterized by a relatively high density as compared to other populations. Furthermore, the population is still increasing and its reproductive parameters are stable and high.

2. The high breeding success is positively correlated with cattle density, a result of maintaining a good proportion of meadows and pastures providing forage for farm animals and abundance of food for the White Stork.

3. Breeding parameters of a particular breeding season are neither correlated with the mean water level of the Liwiec river in March, April and June of that year nor with the mean fledgling success per pair in three years preceding the season. Therefore, on extensively used farm land with a high proportion of pastures, the surface water level of the existing water course network does not have a decisive impact on the size of a breeding population.

4. Habitat structure and quality in area of the communes of Mokobody and Suchożebry result in abundant food for the White Stork which guarantees a high long-term reproductive success. Foraging areas are relatively similar to one another and provide similar food resources to all pairs that achieve a high breeding success under such conditions.

5. Agri-environmental programs implemented in the study area contribute to an increase in biodiversity and, at the same time, have a positive effect on the numbers and density of the White Stork. However, this effect is not strong enough for a decisive impact on the reproductive success on the population level.
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Factors influencing fledgling success of the White Stork *Ciconia ciconia* in Eastern Poland


Factors influencing fledgling success of the White Stork Ciconia ciconia in Eastern Poland


