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ORIGINAL ARTICLE

At the border of ecological change: status and nest sites of the Lithuanian Black Stork *Ciconia nigra* population 2000–2006 versus 1976–1992

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Abstract Recent trends in the European Black Stork *Ciconia nigra* population are geographically distinct: range expansion and adaptation to human activity dominate in western and central Europe, while declines—probably induced by landscape change—are reported in the east. We studied the large Lithuanian Black Stork population in the transition zone to explore whether, and how, the detrimental influences of recent Baltic landscape changes are balanced by the West European tendency of behavioural adaptation to human activity. Based on monitoring in sample plots, the current population was estimated at 650–950 pairs, indicating a significant decrease (possibly over 20%) during the last two decades. In comparison to the Latvian and Estonian populations, however, this decline is smaller, and the reproductive success remains at a high level [66% breeding success and 2.99 ± 0.97 (SD) fledglings per successful attempt, 2000–2006]; this north–south gradient suggests a climate-mediated impact of habitat degradation in the Baltic countries. The storks are also nesting closer to forest edges and in younger stands than 15–30 years ago, which has probably reduced the nest-tree limitation, as indicated by an increased use of large oaks. Thus, habitat degradation and adaptation seem to be taking place simultaneously in the Lithuanian Black Stork population, as was expected from its geographical location. In general, our study supports the view that, whenever possible, species conservation strategies and the use of indicator species should be geographically explicit.

Keywords *Ciconia nigra* · Geographical gradient · Habitat use · Population decline · Reproductive success

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Introduction

The Black Stork *Ciconia nigra* L. is a species attracting international concern and has been listed in Annex I of the EU Birds Directive (as well as Annex II of the Bern and Bonn Conventions), indicating that it is a bird species in need of special conservation measures to ensure its survival and reproduction in its area of distribution. The Black Stork also deserves attention due to its potential value as a landscape-scale indicator of sustainable forestry (Angelstam et al. 2004). The world population has been estimated at 10,000–15,000 pairs, over half of which breed in Europe where the recent trends are geographically distinct: range expansion and population increases dominate in the west, and declines are reported in the east (Janssen et al. 2004). To date, no satisfactory explanation has been provided for these large-scale processes, and it is also unknown whether, and how, the increases are balancing the declines in terms of total population size (Strazds 2003). However, fragmentary data indicate ecological change is occurring as well: the populations are successfully spreading to small forest patches in the agricultural landscapes of western and central Europe (Janssen et al. 2004), while the traditional preference for remote old-growth forests in the decreasing Estonian population has lost its benefit in terms of the production of young (Lõhmus et al. 2005).

The Lithuanian population of the species is of special interest due to its size (5–10% of the European Black Stork population) and its location at the transition zone—between the large declining Latvian and the increasing Polish and Byelorussian populations (Janssen et al. 2004). Data on recent trends, reproductive success and possible changes in the ecology of the species in this transition zone are, however, lacking, and earlier estimates of population size show large variations. Typical of the Baltic countries, Lithuanian landscapes have undergone marked changes following the country's independence in 1990, which could be detrimental for the species. While agricultural intensity has decreased, and many meadows and arable lands have been abandoned, timber harvesting volumes have doubled (Anonymous 2001) and housing has expanded at a rapid rate along the shores of water bodies. In contrast to these potentially detrimental changes, the last official estimate of the Black Stork population, based on expert opinion, has been the highest in history (600–800 pairs; Kurlavičius and Raudonikis 2001), while numbers below 500 (a questionnaire to foresters; Drobelis et al. 1996) or between 400 and 600 (extrapolation of local densities; Drobelis 1993) were presented in the 1990s and 1980s, respectively. It cannot be discarded, however, that methodological differences may have accounted for these different estimates.

In this paper we address the status and changes in the Lithuanian Black Stork population by estimating its size and trends based on sample-plot surveys and comparing the current characteristics of the nest stands with those documented 15–30 years ago by Drobelis (1993). We expect that the negative effects of the marked changes in landscape use (as in other Baltic countries) on the numbers and productivity of this Black Stork population may be lessened, and possibly balanced, by this species' tendency in West Europe to adapt to human activity.

Materials and methods

Assessing the population size and trend

The size of the Black Stork population was estimated from surveys of local densities in seven large sample plots (at least 200 km^2 each; a total of 2100 km^2) in different regions of Lithuania between 1999 and 2006 (Fig. 1). These data were then extrapolated over the landscapes suitable for the species in Lithuania. The landscape composition of the plots (32% forest, 60% agricultural land, 3% built-up areas and 3% water bodies) was nearly identical to the Lithuanian average; plot selection was not based on pre-known stork densities. The main field methods were winter searching of nests (a few nest locations were also obtained from local foresters or ringers) and territory mapping according to the behaviour of the birds in summer.

To assess the area of suitable landscapes for the Black Stork, we first measured the macrohabitat characteristics around 81 nests (each in a distinct breeding territory) located in 2000–2006 in 22 districts. We used circular plots of 25 km^2, i.e. 2.8-km radius, which is close to half of the average distance between neighbouring nests (author's data) and similar to the distances used previously for the species (Strazds et al. 1996; Lõhmus et al. 2005). In this part of Europe, the species is disturbance-prone, breeds only in forests and forages mainly at water bodies (Drobelis 1990; Lõhmus and Sellis 2001). Using 1:50,000 digital maps, we measured (1) the area of forest cover, (2) the area of artificial surfaces, such as towns and settlements (but not solitary farmsteads, which do not disturb the storks significantly: Drobelis 1993; Augutis and Sinkevičius 2005) and (3) the length of the hydrographical network, i.e. linear lengths of rivers and—given that the Black Stork forages wading along the shores—the perimeters of all polygons of water bodies. The most unusual nest sites (comprising 5% of the total) were omitted, and the smallest recorded area of forests, the shortest hydrographical network and the largest area of artificial surfaces around the nest were used to designate suitable cells in a 5 × 5-km grid over the whole country. Finally, the borders of the initial sample plots were corrected to include only suitable areas.

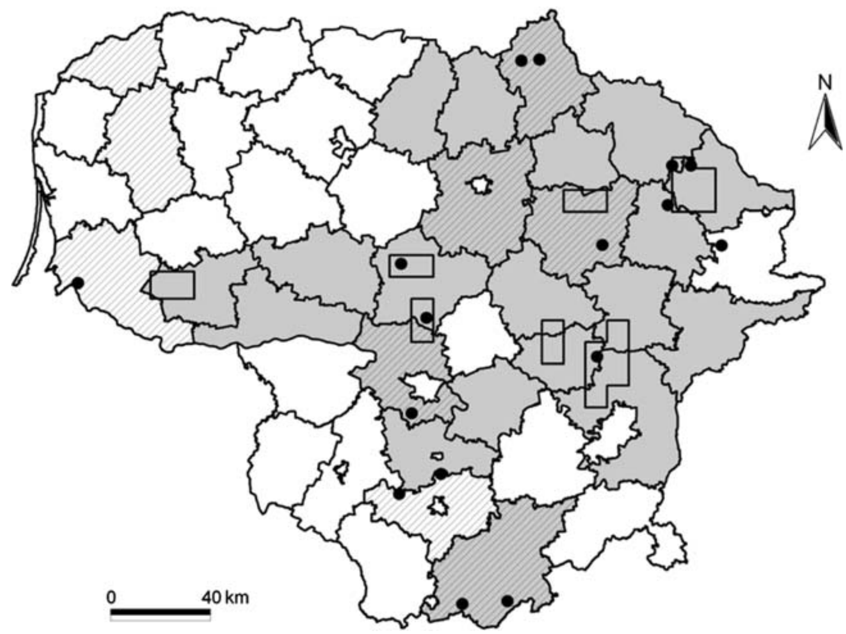

Fig. 1 Distribution of data sources: inventory plots for density estimates (*boxes*) and long-term changes (*filled circles*), regions with the nest-site descriptions from 1976 to 1992 (*hatched*) and from 2000 to 2006 (*grey*)

To establish changes in population size, we compared the local abundance of the stork in 16 sample plots, which were studied both in 1978–1996 and 2005–2006 by the same individuals using similar field methods. The sample plots were situated in different regions of the country (Fig. 1) and represented various forest types and felling intensities. In 1978–1996, the numbers of pairs present in the sample plots were established for the years of the most detailed surveys.

Estimating productivity

In 2000–2006, 8–40 nests were checked annually to record their occupancy and number of nestlings between late June and mid-July (some nests were also inspected before incubation). A nest was assessed to be occupied if it contained eggs or nestlings (or their remains), or if it had been repaired by a non-breeding pair or a single bird in the spring. At least one live nestling with well-developed plumage had to be recorded to consider the nest successful; otherwise, it was considered unsuccessful (the nest repaired but no breeding; clutch destroyed or all nestlings dead). We used three variables to measure productivity: (1) the share of successful pairs, (2) the mean number of large nestlings per occupied nest per year and (3) the mean number of large nestlings per successful nest per year. To establish trends, we compared variables (1) and (3) with the data of Drobelis (1993) and bird-ringers' records of 47 additional broods from 1979 to 1999, respectively.

Comparing nest-site characteristics

The nest site was defined as the forest stand with the nest-tree. We compared the 96 nest sites described in 1978–1992, mostly in nine administrative districts (Drobelis 1993), and 81 nest sites occupied and described in 2000–2006 in 22 administrative districts (Fig. 1). Where possible, we also used some characteristics described in the 1995 survey (Drobelis et al. 1996) and the summary statistics for all Lithuanian forests (Anonymous 2001). The following characteristics were described: (1) species and diameter of the nest-tree at breast height (1.3 m), (2) age of the stand, (3) dominating tree species, (4) relative basal area (scale 0.1–1), (5) forest type (Karazija 1988), (6) humidity (four classes), (7) site quality class (scale 1A, 1–5; larger score indicates worse conditions of tree growth) and (8) distance to the nearest external edge of the forest (i.e. to fields, lakes and other large open areas, but not to clear fellings, raised bogs and small open spaces within forests). Data on stand characteristics were obtained from the Forest Inventory Data Base of the State Forest Survey Service in 2006. The changes in nest-site characteristics were tested by comparing mean values with a t test or the frequency distributions with a chi-square test.

Results

Population status

The criteria of landscape suitability for the Black Stork, derived from the characteristics of 81 macrohabitat plots, were at least 13% forest cover and 10 km of shoreline and no more than 5.5% built-up areas. The 5 × 5-km cells classified as suitable represented approximately 60% (39,220 km^2) of Lithuania. The average population density in the seven plots was 1.95 ± 0.60 [±95% confidence interval (CI)] nesting territories per 100 km^2 of suitable landscape, ranging between 0.89 and 3.36 for different plots and years. After decreasing the probability level to restrict the density estimate within ±20% of the mean, we reached a population estimate of 610–922 pairs at 80% probability.

In the 16 sample plots, 27–31 breeding pairs of the Black Stork were found in 1978–1996 compared with 18–22 pairs in 2005–2006; the mean relative plot-scale decrease was highly variable due to the small numbers [30 ± 27% (95% CI)], but it still significantly differed from zero ($t_{15} = 2.2$, $P = 0.045$). Regionally, the decreases were from 10–11 to 5–8 pairs (38%) in the seven North-Lithuanian plots, from 10–11 to 9–10 pairs (10%) in the five plots in the central and western parts of the country and from 6–8 to 4 pairs (43%) in the four southern plots. However, the turnover of nest sites was much higher: 27% of the 48 surveyed nest sites throughout all of Lithuania were destroyed or their protection zones affected by clear fellings in 2004–2006 alone.

In contrast to densities, there was no significant change in the reproductive success: 66% of 145 occupied nests raised nestlings in 2000–2006 compared with the 71% of 85 nests in 1978–1992 ($\chi^2_1 = 0.5$; $P = 0.49$), and the annual mean brood size did not change between 1979 and 2006 (Fig. 2). Altogether, in 2000–2006, an average of 2.99 ± 0.97 (SD) nestlings fledged per successful breeding attempt ($n = 95$) and 1.96 ± 1.63 (SD) per occupied nest ($n = 145$).

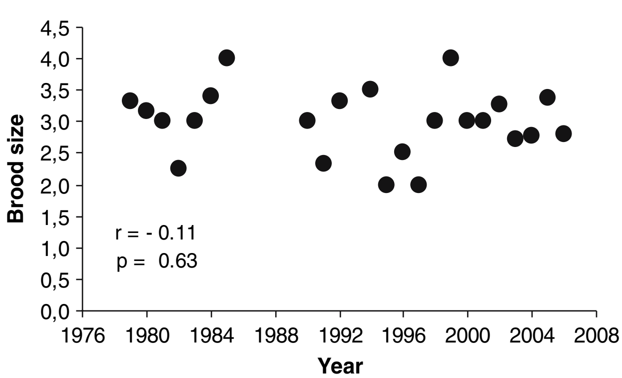

Fig. 2 Annual average brood size (large nestlings of at least ringing age) of the Black Stork in Lithuania, 1979–2006 [$n = 23$ years; 143 broods; between-year average 2.99 ± 0.22 (95% CI) young per successful nest]

Nest sites

Comparison of the current nest-site characteristics (Appendix) with historical data indicated an improvement in the mean nest-tree quality but not in the mean characteristics of nest stands. The frequency of the highly preferred oak *Quercus robur* increased from 44% of nest-trees in 1976–1992 ($n = 97$) to 51% in 1995 ($n = 253$) and 76% in 2000–2006 ($n = 82$; $\chi^2_2 = 20.2$; $P < 0.001$). These frequencies greatly exceeded the use of oak stands both in 1976–1992 (19%) and in 2000–2006 (14%; no difference between periods $\chi^2_1 = 0.9$; $P = 0.35$), which in turn, were much higher than the approximately 2% share of oak stands in Lithuania. The current 41 nest-oaks were larger [mean diameter 88.3 ± 24.1 (SD) cm] than the 33 oaks in 1978–1992 (77.2 ± 21.1 cm; $t_{72} = 2.1$; $P = 0.041$), which contrasted with the decreased age of nest stands [mean 90 ± 31 (SD) years in 1976–1992; 80 ± 30 years in 2000–2006; $t_{175} = 2.1$; $P = 0.038$]. In the last period, mid-aged forests (30–70 years) already formed 48% of the nest stands. Nest placement did not change: 47% of 36 oak-nests were situated on a side branch away from the trunk in 1976–1992, and 48% of 31 nests were in this location in 2000–2006 ($\chi^2_1 = 0.01$; $P = 0.92$).

Although the frequencies of particular forest types recorded for historical and current nest stands differed to some extent (compare Appendix and Drobelis 1993), there was no systematic change, as also indicated by the unchanged preference for the most fertile forests. Thus, the stands of quality classes 1A–2 formed 82% of the 96 nest stands in 1976–1992 and 85% of the 81 stands in 2000–2006 ($\chi^2_1 = 0.3$; $P = 0.60$), but they encompassed only 72% of all forests. However, while historical data were incomplete, it was highly probable that the current nests are situated closer to the forest edge: while in 1995 "the majority" of 253 nests were found >700 m from the forest edge (Drobelis et al. 1996), only 29% of 78 nests were still that far (median 447 m) in 2000–2006 ($\chi^2_1 > 10.3$; $P < 0.001$).

Discussion

The evidence for population decline, stable reproduction and specific nest-site changes suggest that both habitat degradation and behavioural adaptation are influencing the Lithuanian Black Stork population, as expected from its geographical location. Although our numerical estimates of population size and the extent of its change varied over a wide range due to limited samples, the declines were nevertheless reliable and appeared in different parts of the country. It is very likely that the decline in the Lithuanian Black Stork population has exceeded 20% during the last decades, which is still smaller than that found in Latvia (44%; Strazds 2005) and Estonia (50–60%; Sellis 2000). The current population size can be estimated at 650–950 nesting territories, given our calculation for the suitable landscapes and the 5% nests that were omitted to define these areas. This is close to the 600–800 pairs suggested by Kurlavičius and Raudonikis (2001), while the sample-plot or questionnaire surveys of the 1980s and 1990s (Drobelis 1993; Drobelis et al. 1996) were likely underestimates due to incomplete coverage. A probable estimate is that 1200–1700 Black Stork pairs currently inhabit the Baltic countries, while two decades ago, the numbers exceeded 2000 pairs.

The causes of the declines are probably to be found at the breeding grounds, since the migration routes and wintering areas of the declining and increasing populations overlap, and the declines are revealed in reproductive success. We found, on average and without a trend, 1.96 fledglings per occupied nest in Lithuania, which corresponds to the typical Central European values (review in Sellis 2000). During the 1990s, this figure fell to 1.05 in Estonia (Sellis 2000) and to 1.39 in Latvia, where the mean brood size declined from 3.1 to 2.5 nestlings (Strazds 2005). To understand the deeper population declines in the north, which are in contrast with the general poleward shifts of European bird ranges (Thomas and Lennon 1999; Brommer 2004), one could look to reductions in reproductive success as the potential cause of the trend. Differences in the Baltic conservation efforts are unlikely—the traditions and extent of strict protection of the species are strongest in Estonia where the population has suffered the most (Sellis 2000). However, in the 1990s, Estonia also experienced a dramatic intensification of forestry, which has been suspected to be a potential major threat to the breeding success of the Black Stork (Strazds 2003). Yet, although the species is vulnerable to disturbance and prefers stands of high timber value, forest characteristics and silvicultural activities do not provide a direct explanation for the decline (Rosenvald and Lõhmus 2003; Lõhmus et al. 2005). In support of this, the average productivity in the occupied nests of the species has not recently changed in Lithuania even though many nest sites were affected by fellings.

The most plausible explanation seems to be a climate-mediated impact of habitat degradation. In the White Stork *Ciconia ciconia* L., adverse weather conditions greatly increase chick mortality and breeding failure (Jovani and Tella 2004); annual fluctuations in the reproductive success of the Black Stork are also closely related to weather conditions (A. Lõhmus, unpublished analysis). Hence, the stronger declines in productivity and, ultimately, numbers of the Black Stork in the northern Baltic States may reflect a greater vulnerability of the birds in harsher environments to otherwise similar habitat change. For example, if nest sites near foraging grounds have been cut or forest streams have been gradually degraded due to drainage (Lõhmus and Sellis 2001, 2003), it may be increasingly difficult for the storks to balance their energy demand in the less productive northern conditions. These hypotheses should be tested in the future by, for example, radio-tracking the breeding adults in different areas (see Jiguet and Villarubias 2004).

An ability to adapt to novel habitats may allow the birds themselves to balance the loss of their traditional habitats (Sol et al. 2002). We suggest that the temporal changes in the nest sites of the Black Stork in Lithuania reveal a behavioural response to nest-tree limitation. The requirements of this species for strong nest-trees are well known, and the superiority of oak, in particular, can be explained by its ability to carry the huge nests at heights safe from predators and, whenever possible, away from the main trunk (Skuja and Budrys 1999; Lõhmus and Sellis 2003). In Lithuania, the pronounced preference for oak appeared both at the within- and between-stand scale. Hence, its more frequent use and the increased mean size of nest-oaks indicate an improvement in the mean nest-tree quality over time (even though the side-branch use remained the same). Theoretically, this might result from sequential abandonment of the worst nest sites during the population decline (e.g. Lõhmus 2001), but the simultaneous nesting closer to the forest edge and in younger stands suggests a gradual occupation of new habitats. In fact, the reduced stand age supports the finding that it has no residual effect on the incidence of Black Stork nests once the nest-tree age has been taken into account (Lõhmus et al. 2005), so the characteristic nesting of the species in old-growth (e.g. Janssen et al. 2004) may be partly related to even-aged silviculture, which restricts the old trees to old forests. As a result, the lack of suitable nest-trees has been severe enough to limit the Baltic Stork populations (Lõhmus and Sellis 2003), and the retention of large trees in felling sites, particularly near potential foraging grounds, remains a highly recommendable long-term conservation approach. However, large deciduous trees are also abundant in traditional agricultural landscapes, notably in small woods between fields, open woodlands, wooded pastures and abandoned farmsteads. Hence, the black storks could also escape the nest-tree limitation (which may be getting worse due to the increased timber harvesting) by using these man-made habitats in fragmented landscapes—a process that is clearly taking place in the western populations (Janssen et al. 2004). Therefore, this behavioural change is probably adaptive, and an important question to ponder is why the storks did not make use of these habitats any earlier.

In general terms, our study supports the view that, whenever possible, species conservation strategies and the use of indicator species for ecosystem management should be geographically explicit. Species may lose their indicative value during habitat change or adaptation (Lõhmus et al. 2005), and if this happens non-simultaneously in different areas, the resulting ecological differences would require locally adapted conservation actions (Väli et al. 2004). We therefore warn that political attempts to use common lists of indicator birds for habitat management across the whole Europe (e.g. Gregory et al. 2007) are likely to miss important details to be operative, and/or may even be misleading in certain areas.

Zusammenfassung

Im Übergangsbereich ökologischer Veränderung: Status und Neststandorte der litauischen Population des Schwarzstorchs *Ciconia nigra* 2000–2006 versus 1976–1992

Jüngere Trends in der Europäischen Population des Schwarzstorchs lassen sich geographisch differenzieren: In West- und Zentraleuropa herrscht eine Expansion und eine Anpassung an menschliche Aktivitäten vor, während im Osten ein vermutlich durch Landschaftsveränderung verursachter Rückgang zu verzeichnen ist. Um herauszufinden, ob und wie die Negativeinflüsse kürzlicher Landschaftsveränderungen im Baltikum mit der westeuropäischen Tendenz zur Verhaltensanpassung an menschliche Aktivitäten ausgeglichen werden, haben wir die große litauische Population untersucht. Auf der Grundlage einer Bestandserfassung auf ausgewählten Flächen wurde die momentane Population auf 650–950 Paare geschätzt, nachdem sie in den letzten zwei Jahrzehnten deutlich zurückgegangen war (möglicherweise um über 20%). Im Vergleich zu den lettischen und estnischen Populationen war der Rückgang jedoch geringer und der Reproduktionserfolg blieb auf einem hohen Niveau (66% Bruterfolg und 2.99 ± 0.97 SD Flügge Jungvögel pro erfolgreichem Brutversuch, 2000–2006); dieser Nord-Süd-Gradient impliziert einen klimatisch verursachten Einfluss der Habitatzerstörung in den baltischen Ländern. Zusätzlich nisten die Störche näher am Waldrand und in jüngeren Beständen als vor 15–30 Jahren, was vermutlich den Mangel an Nestbäumen, der sich durch eine verstärkte Nutzung alter Eichen abgezeichnet hatte, reduziert hat. Wie aufgrund der geographischen Lage zu erwarten war, scheinen Lebensraumzerstörung und Anpassung in litauischen Populationen des Schwarzstorchs demnach gleichzeitig von Statten zu gehen. Generell unterstützt unsere Arbeit die Ansicht, dass Strategien zur Arterhaltung und die Verwendung von Indikatorarten nach Möglichkeit klar geographisch umrissen sein sollten.

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Appendix

Table 1

Table 1 Descriptive statistics of the 81 nest sites of the Black Stork in Lithuania, 2000–2006

Variable	Summary statistics
Nest-tree species	76% *Quercus robur*, 6% *Fraxinus excelsior*, 5% *Betula* spp., 5% *Populus tremula*, 5% *Pinus sylvestris*, 2% *Picea abies*, 1% *Tilia cordata*
Dominating tree species in nest-stand	26% *Picea abies*, 23% *Betula* spp., 14% *Quercus robur*, 11% *Alnus glutinosa*, 10% *Pinus sylvestris*, 6% *Fraxinus excelsior*, 6% *Populus tremula*, 4% other
Age of nest-stand (years)	Mean 80.3 ± 30.0 (SD), range 35–160
Relative basal area	Mean 0.68 ± 0.13 (SD), range 0.3–1.0
Forest type	27% Aegopodiosa, 22% Myrtillo-Oxalidosa, 16% Hepatico-Oxalidosa, 10% Oxalidosa, 4% Oxalido-Nemorosa
Humidity of nest-stand	56% temporarily soaked, 27% normal, 10% peat bogs, 7% waterlogged
Site quality class	1A, 25%; 1, 22%; 2, 38%; 3, 14%; 5, 1%
Distance from nest to forest edge (m)	Mean 646 ± 613 (SD), range 10–3028

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