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Longevity and survival of the black stork *Ciconia nigra* based on ring recoveries

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Abstract: To understand population dynamics, the determination of survival rates is very important. For the black stork *Ciconia nigra* no survival rate determination has been published to date. This might be due to the fact that ringing activity and recovery numbers in general are still relatively low for the species. The international black stork colour ringing programme is taking place with the participation of 25 countries including Hungary. Altogether more than 7,000 black storks have been colour ringed worldwide, of which 1,069 individuals were marked in Hungary. This article's objective is the determination of the survival rates for the black stork, as well as to estimate the longevity of the species based on live encounters of ringed individuals. The conclusions are that longevity can be estimated based on the data, and is in agreement with previous knowledge; and that the survival rate of the species, with our present knowledge, shows a significant difference between first year (0.1696, 0.1297–0.219) and older birds (0.838, 0.773–0.887).

Key words: black stork; colour ringing; Hungary; encounter; survival; longevity

Introduction

In order to understand population dynamics, there is a need to assess how much variation in survival, reproduction or dispersal contributes to population change (Krebs 2009). The need to understand the limitations of bird populations and the factors influencing these arose with the knowledge on declines in the abundances of many species (Robbins et al. 1989). Thus, to be aware of survival rates are crucial for the understanding of the processes of population dynamics, and is very important for the development of an effective protection strategy especially in long-lived species (Sæther et al. 2005). Survival may be influenced by numerous factors, among which breeding success, the status of the habitat used during migration and wintering situations all play important roles, as shown for some long-distance migrant species (e.g., Boyd & Piersma 2001).

For the black stork *Ciconia nigra* (L. 1758) no survival rate determination has been published to date. This might be due to the fact that ringing activity and recovery numbers in general are still relatively low for this species. It has been reported by different authors (Sellis 2003; Strazds 2003; Tamás et al. 2006) that the population of the species in the Baltic countries is decreasing, concluding that the deterioration of habitats and human impacts in the breeding territories and feeding areas caused the decline. Over the same period in Germany and France (Villarubias et al. 2003; Janssen et al. 2004) an increase of the population is reported, and in the 1980's the species started to re-colonise territories in Belgium, Luxembourg and Denmark, from where it had previously been lost (Janssen et al. 2004). So far, we haven't examined population changes in detail, we have only given estimates based on the census of breeding pairs which is highly influenced by the activity of volunteers in certain areas (Kalocsa & Tamás 2010). For an effective population study survival rate determination is vital.

The international black stork colour ringing programme is taking place with the participation of 25 countries. In Central Europe, particularly in the Czech Republic, Poland and Hungary, the intensity of ringing of this species is high. Altogether more than 7,000 black storks have been colour ringed worldwide (pers. comm., van den Bossche 2010), of which 1069 individuals were marked in Hungary (∼15%), which fits with the criterion of the minimal sample size according to Krejcie & Morgan (1970). The number of recoveries is the highest in Hungary among all European countries, ostensibly because of the high level of volunteer activity and the favourable geographical location of this country, with lots of black storks migrating through it, and many migration stopover places identified within the Carpathian Basin. One of the goals that was established in 1994, at the start of the colour ringing programme, was to determine how long black storks live (Kalocsa & Tamás 2002). I set two objectives in the present study: to determine longevity and survival rate based on ringing recoveries.

Table 1. Live encounter matrix of black storks colour-ringed in Hungary, 1994–2009.

Year	n_{ri}	n_{re}																
	Ringed	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	TOTAL
1994	13	1	0	2	1	0	0	0	0	0	0	1	0	0	1	1	1	8
1995	33		5	3	1	0	0	1	0	0	0	0	1	1	0	0	0	12
1996	53			5	3	0	1	0	0	0	1	1	2	0	0	0	0	13
1997	52				2	0	1	1	0	1	2	0	0	1	1	0	0	9
1998	33					0	0	0	0	0	0	2	1	1	0	0	0	4
1999	67						11	6	2	1	0	0	0	2	1	1	1	25
2000	46							1	0	0	0	0	0	0	0	0	0	1
2001	71								1	1	2	1	1	1	0	1	0	8
2002	76									3	1	1	1	1	0	1	2	10
2003	53										0	1	3	0	0	3	2	9
2004	76											3	4	3	3	5	2	20
2005	93												8	6	4	4	1	23
2006	65													11	2	4	5	22
2007	164														14	10	12	36
2008	72															3	1	4
2009	102																31	31
TOTAL	1069	1	5	10	7	0	13	9	3	6	6	10	21	27	26	33	58	235

Explanations: n_{ri} – number of ringed individuals yearly and n_{re} – number of live encounters, i.e., the number of birds ringed in certain years identified in the respective year.

Material and methods

Data

In the present study I used the databases of EURING (all black stork recovery data until November 2009) and the Hungarian Bird Ringing Centre (all black stork ringing and recovery data until November 2009).

Methods

Current methods for estimating age-specific survival rates from the ring recoveries of birds depend critically on a number of assumptions. Even if these assumptions hold, current estimating procedures require the imposition of a constraint. The need for the limitation arises, in the first place, because the generally used design of field observations is inadequate to provide sufficient biological information to estimate the parameters of interest. Because survival probabilities of birds are believed to become "constant" with increasing age, a commonly used constraint is that the survival probabilities in successive age-groups of older birds are equal. The limitation achieves mathematical expediency but does not necessarily give reliable survival estimates, no matter how many birds are ringed (Lakhani & Newton 1983). Ideally, to estimate age-specific survival rates, the age of every ringed bird should be known (Lakhani 1987), but previous analyses have also shown that models for birds ringed as young can be used to test even complex variation in survival rates, provided that recovery rates do not vary with age (Francis 1995).

I analysed the recoveries of black storks colour ringed in Hungary, determining their recovery rate, the changes in recovery rate over time and, furthermore, the survival rates based on recoveries of ringed individuals (Lebreton et al. 1992). The model computations are based on the encounter matrix (Table 1). I used MS Excel 2007, U-CARE (Choquet et al. 2005) and M-SURGE (Choquet et al. 2004) to perform the analysis. In the models the animals are released live at encounter no. 1 (ringing) as pulli. Marked animals are encountered live (ring identification) in specific years (1 to 16). Encounter histories of birds are defined in the input file as single records for identical cases. I used a single grouping, as it is not possible to differentiate between the sexes, and, additionally, the number of birds reported dead was so low compared to the number of colour ring readings that I excluded them from the dataset. For the analysis of survival, only the Hungarian database was used, because the total number of individuals ringed annually is not accurately known for the other schemes.

Results

Out of 1,378 ringed individuals with at least one recovery in the EURING database, except for 20 individuals, all were ringed as pulli. As the number 20 is too low to draw conclusions for birds ringed at an age different from pullus, I excluded these. The oldest known age black stork recovered was an individual from Poland – found dead 19 years after ringing. The second oldest individual was also Polish, found dead at age 18 calendar years (cy). The oldest live encountered black storks were 2 individuals encountered at 17 cy, one from Poland and one from Hungary. In the Hungarian database, there are 1,069 individuals ringed as pulli. Summarizing the recoveries of all individuals at specific ages, and plotting these against the number of ringed individuals as a percentage, a survival curve can be drawn (Fig. 1).

The encounter matrix of black storks based on the database of the Hungarian Bird Ringing Centre is given in Table 1, indicating the number of individuals ringed annually, and showing how many of these were seen in the same year and the following years.

U-CARE (Choquet et al. 2005) goodness of fit test indicated age effect on survival in the case of black storks marked as pulli ($chi^2 = 92.972$, $df = 12$, $P < 0.001$, TEST3.SR). The $Sa2{*}t$, $P{*}t$ model (which expects different survival for 1 cy and older birds, and the survival of these two age classes as well as encounter

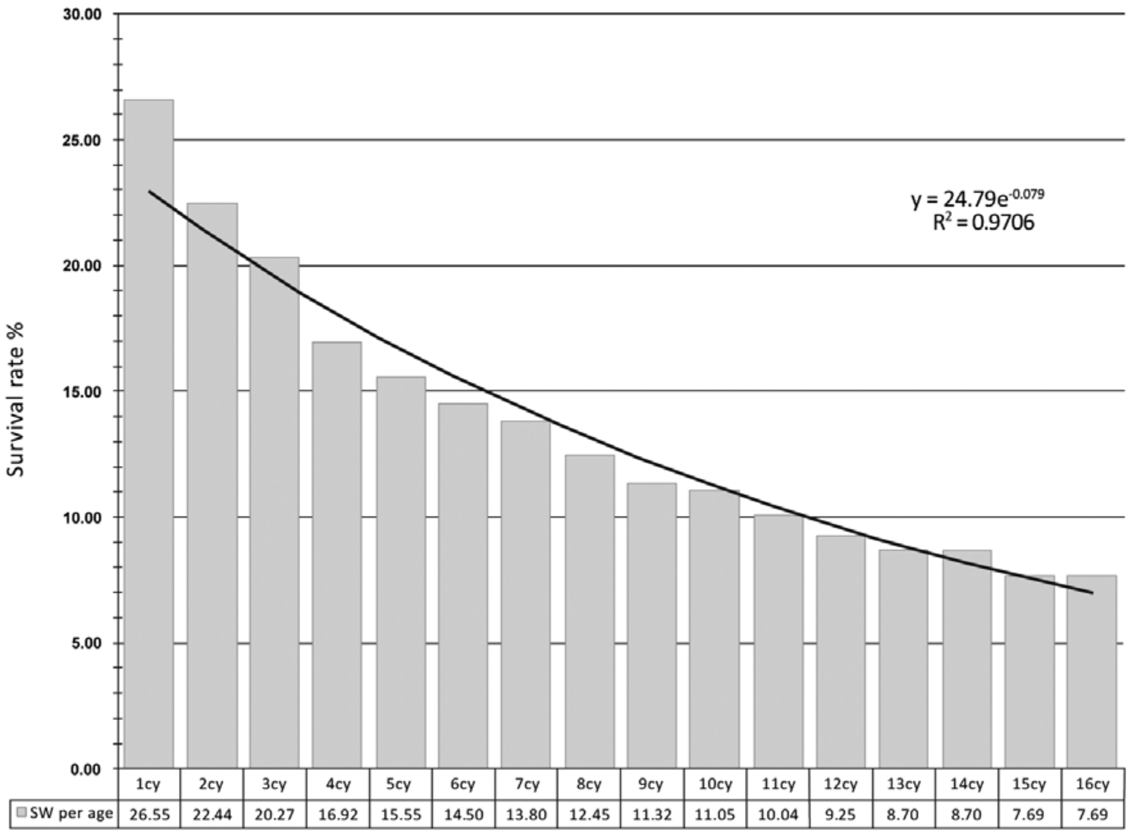

Fig. 1. Survival curve of black storks calculated directly from ring recoveries, 1994–2009. On the horizontal axis age is shown in calendar years (cy).

Table 2. Results of the model selection for the survival of the black stork.

Model	*S*	*P*	*Dev*	*np*	*AICc*
m1	a(1,2)*t	t	1032.9396	42	1116.94
m2	a(1,2)*t	.	1064.7231	30	1124.72
m3	a(1,2)+t	t	1038.8053	31	1100.81
m4	**a(1,2)**	**t**	**1060.9373**	**17**	**1094.94**
m5	t	t	1129.9217	29	1187.92
m6	.	t	1142.0576	16	1174.06

Explanations: *S* – survival rate, *P* – encounter rate, *Dev* – deviance, *np* – number of identifiable parameters, *AICc* – Akaike value. Models which expect age effect on survival are indicated with *a* (1,2); *t* – time effect; * interaction between age and survival; + no interaction between age and time; . constant value. Model **m4** (in bold) has the best fit value.

rate varies with years) fit the data ($chi^2 = 28.742$, $df = 34$, $P = 0.723$) so this was used as basic general model.

On the basis of the model selection, program M-SURGE (Choquet et al. 2004) showed that *S a*(1,2), *Pt* model has the lowest Akaike criterion value (Anderson & Burnham 1999). This model expects that the survival rate is constant over the years but different for 1 cy birds compared to older individuals, and encounter rate varies over the years. According to the model, there is a significant difference between 1 cy (survival rate: 0.1696, 0.1297–0.219) and older birds (survival rate: 0.838, 0.773–0.887).

Discussion

The longevity of the black storks can be estimated based on colour ringing activities: the age distribution of live encounters. According to this; more than 20% reach adulthood (3 cy) and may start breeding; approximately 10% may live longer than 10 years, and some may reach more than 20 (approximately 5%). In literature (Janssen et al. 2004) the oldest ringed recovery in the natural population was 18 cy, but in captivity a few individuals lived as long as 30 and 36 cy. This age (36) may be reached by 1.44% of the population in wild according to the estimate produced from recoveries.

The relatively high encounter rate is a result of the use of colour rings which can be easily identified, however, the differences between encounter rates between years could suggest (1) the differences in effort in order to identify ringed individuals; (2) the changes in conditions at feeding sites and stopover roosts.

The age distribution, the longevity estimates, the recovery rates and the survival of ringed individuals suggest that the population from which the sample was taken must be at least stable or even increasing. However, this is not a strong argument and more effort needs to be invested in order to support these results.

The significant difference found between 1 cy and older birds can be caused by a real difference in survival, however, higher permanent emigration of young birds might also have a role in it.

Comparing the results with the other European breeding stork, the white stork *C. ciconia* (L. 1758), we can conclude that both species are relatively long-lived, but for the white stork even 34 and 39 years in wild are reported (EURING Longevity List). We have to admit that the ringing of white storks has traditionally been intense and there are much larger numbers of white storks ringed and identified yearly, so the difference in the age of recovered birds does not essentially mean a real difference in the lifespan. We see that survival patterns are similar, despite the fact that habitat types used by the two species can be very different during the breeding season, as well as on migration and during wintering. Similarities in low survival of young might be due to similar main threatening factors – or causes of death – for the two species; for example, electrocution by and collision with power lines are reported as very serious for both species, especially in first-year birds (Schaub & Pradel 2004).

The annual survival rate of white stork juveniles and adults was comparable both in Switzerland (Schaub & Pradel 2004) and in other countries, but in white stork differences in survival rates were observed both within western populations and between western and eastern populations (Kanyamibwa et al. 1993), which could also hold for the black stork, but our data are insufficient to look at this.

In white stork, an effect of age was only noted as significant in the Alsacian population (Kanyamibwa et al. 1993). For the analysed black stork dataset, age effect turned out to be pre-eminent. It is a task for future research to confirm differences within and between populations, if any, for this species. All the above results indicate a compelling need to intensify the colour ringing programme and ring reading activities.

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