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Census methods for White stork (*Ciconia ciconia*): bias in sampling effort related to the frequency and date of nest visits

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Abstract Periodic censuses have been widely used to identify the population numbers and conservation status of many bird species. In order to be comparable, a census must be homogeneous through time. However, this requirement is not always possible. For this reason, studies addressing a possible bias in sampling efforts are very useful to correct such errors. In the present work, a standardized periodic monitoring of breeding White stork (*Ciconia ciconia*) at six Spanish colonies was conducted to estimate survey accuracy. We estimated the percentage of breeding pairs and productivity (number of chicks), i.e., accuracy, detected in each possible combination of number of visits as compared with the results obtained for the whole intensive monitoring, i.e., reality. Our results showed that single visits resulted in lower percentages of the number of breeding pairs and productivity detected compared with combinations of two or more visits. Nevertheless, one visit in a single month (April for the number of breeding pairs and June for productivity) did not show significantly lower results than the rest of the combinations of two or more visits. Early or late visits in the season might underestimate breeders by not accounting for either late-occupied or failed nests, respectively. In addition, the obvious increase in the probability of detection related with the number and the size of chicks is probably the reason why later visits in the season reported the highest value of productivity. In conclusion, the estimation bias presented in this study may be used to adjust sampling efforts in the census of the White stork.

Keywords Conservation · Monitoring · Phenology · Productivity · Survey

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Introduction

Periodic censuses have been widely used to identify population numbers (see Lowe (2006) and conservation status of many species (Tucker and Heath 1994; Schulz 1999). In many cases they have been useful to identify changes in populations (Dallinga and Shoenmakers 1987; Martí 2003). In order to be functional, a census must be homogeneous through time, since non-comparable sampling efforts might lead to misinterpretation of population values and consequently to erroneous management of the species (Laudenslayer 1988). However, sometimes this is not possible, and censuses are carried out under different conditions (e.g., different dates, frequencies, or samplers) and therefore are not comparable. For this reason, studies addressing possible bias in sampling efforts and error estimation concerning methodologies are very useful because they may allow comparing non-homogeneous censuses.

Census results are influenced by two main aspects: date and frequency of visits. Detection probability of individuals may differ within the year (Diefenbach et al. 2007). If a census takes place too early in the breeding season, most of the breeders will be missed because they have not occupied their nests yet. However, if it is too late, some might already have abandoned their nest after a breeding failure. Such errors can be overcome by several visits to the nests or colonies during the potential breeding period of species, this being especially necessary for those species with a very long breeding period (e.g., raptors; Martínez et al. 1997). Therefore, it is necessary to account for the bias due to the census date or frequency of visits to nests or colonies when interpreting data from a census with non-homogeneous methodologies.

The White stork *Ciconia ciconia* is a trans-Saharan migratory bird species that has been censused periodically during the last century from the European to the regional scale. This wide sort of census involved a great number of workers and has been carried out under different methodologies with differential monitoring frequency and effort (see reviews in Dalinga and Schoenmakers 1987; Bairlein 1991; Schulz 1999). Effort plays a key role in the detection of nests, breeding pairs, and chicks (Bernis 1981). However, these data have been used to establish the conservation status or population tendencies of this species in several countries or regions (Dalinga and Schoenmakers 1987; SEO/BirdLife (1994); Schulz 1999; Aguirre and Atienza 2002; Molina and Del Moral 2005), sometimes without accounting for whether such information was obtained in an homogeneous way or not.

This species has several advantages when taking a census of the number of breeding pairs because of the conspicuousness and size of nests and low probability of misidentification with other species. Nevertheless, factors such as date and frequency of visits to nests may strongly affect the census result (Bernis 1981). This species exhibits a broad variation in timing of arrivals and laying dates even within the same population (Kosicki et al. 2004; Tryjanowski et al. 2004; Vergara et al. 2007a, b). In the case of Spain, the breeding season may extend for over 6 months from nest defense in early February to fledging in July (Bernis 1981). Older individuals usually arrive at their nests earlier than younger ones (Vergara et al. 2007a), so a very early census in the breeding season might underestimate younger breeders that have not occupied their nests yet. On the other hand, adults spent less time in their nests as chicks grew and especially if breeding failure occured (Moritzi et al. 2001). This might produce underestimation in the number of breeding pairs if the census is achieved at the end of the breeding season.

Frequency of visits is another factor that may affect census results (Bernis 1981). It can affect the number of breeding pairs because empty nests may be censused when both parents leave the nest at the same moment. Although uncommon, this situation can occur sometimes (Cramp and Simmons 1977), mainly when chicks are less than 15 days of age (Tortosa and Villafuerte 1999). On the other hand, to see an empty nest is not a good indication of the presence of a breeding pair, because in this species, not all the constructed nests are reutilized every year (Tryjanowski et al. 2005a; Vergara and Aguirre 2006; Vergara et al. 2006, 2007b; Kosicki et al. 2007). Frequency of visits affects especially chick counts. For example, due to the big size of White stork nests, younger chicks are hard to see on top of nest platforms. Even older (and bigger) chicks are difficult to see because they usually rest laying flat on the nest platform (personal observation). Therefore, several visits are necessary to ensure the detection of chicks or fledglings, which is an important measure of productivity from a population perspective in this species (see Saether et al. 2005).

All these inconveniences place researchers in a situation of trade-off between the higher economic cost of a census lasting for several days or months and probably underestimating the population if only one or a few censuses are carried out. The white stork population currently has a favorable situation in several countries (see the world census results country by country in Schulz 1999; Molina and del Moral 2005), but not in others (Schulz 1999; Schaub et al. 2004). In Spain, the future closure of rubbish dumps (Directive 1999/31/CE), which are used by many populations as a very (or even the most) important feeding source during the breeding season, may negatively affect this species in a very short period of time (Prieto 2002; Tortosa et al 2002; Peris 2003). For these reasons, it is necessary to elaborate accurate methods to measure the census error depending on sampling effort in order to compare data between actual and future censuses. Only in this way can census data become an accurate tool for conservation and management.

Finally, a change of migratory strategy is occurring in the western European population of the White stork. Although many storks still cross the straits of Gibraltar to their wintering grounds in the African Sahel (Fernández-Cruz 2005), since the mid-1980s a growing number of individuals has been overwintering in Spain (Martínez 1994; Tortosa et al. 1995; Prieto 2002; Vergara et al. 2004), France (Archaux et al. 2004, 2008; Massemin-Challet et al. 2006), which is probably part of the dramatic advance (ca. 1 month) of arrival dates for the whole of the Iberian Peninsula (Gordo and Sanz 2006). Arrival date and laying date are strongly correlated in this species (Tryjanowski et al. 2004; Vergara et al. 2007a), and consequently the rest of the breeding phenology (hatching and fledging date) is affected by migratory schedule (Tryjanowski and Sparks 2008; Tryjanowski et al. 2004, Vergara et al. 2007a). Therefore, traditional dates for a census (at least in Spain) during the previous decades (March and June for the number of breeding pairs and productivity respectively; Bernis 1981; Lázaro et al. 1986) may not be the most accurate for the present situation.

In this paper, we calculated the number of breeding pairs and productivity according to the sampling effort (number of visits) and the date (months) by a standardized periodic census as compared with values measured as an intensive census for 5 months in six colonies throughout Spain. The objective of the present work is to report the errors associated to the frequency and date of visits in the detectability of breeding pairs and chicks produced (Martínez et al. 1997; Bernis 1981). Finally, we propose optimal calendars in terms of accuracy and resources (money, time, and personnel necessary) for future censuses of White stork at the Iberian Peninsula and discuss if the traditional dates for censuses in Spain are still adequate.

Methods

A total of 179 nests from six different White stork colonies were censused during 2003 throughout Spain: in the Central area (1) Rivas Vaciamadrid (40.18 N 3.30 W) (57 nests), (2) el Campillo (40.37 N 4.05 W) (8 nests), (3) Monesterio (40.38 N 4.02 W) (32 nests), and (4) La Granjilla (40.34 N 4.06 W) (15 nests); in the Southern area, (5) El Portal (Cádiz) (36.40 N 5.38 W) (15 nests); and in the Northern area, (6) Bustamante (Cantabria) (43.01 N 3.59 W) (52 nests). We selected these six colonies to obtain a representative range of breeding dates in Spain because this species shows a great variation in the arrival dates among zones (Gordo et al. 2007). In order to avoid disturbance of breeding birds and bias on data, a few nests randomly selected within each colony were controlled from the same point away from the colony during a fixed time (2 h) in each survey. All the visits were made in the morning. In all cases the number of nests monitored does not correspond to the total quantity of nests within the colony.

A total of ten surveys was carried out from February to June on each colony. Survey dates were 2–3 February, 5–6 March, 9–10 April, 14–15 May, and 18–19 June. All data have been grouped in months considering the two visits in 1 month as one single visit, obtaining five visits for every colony under study (one per month). We considered the presence of a breeding pair when we observed at least one individual constructing, defending, incubating, feeding chicks, or perching on the nest. We calculated the percentage of breeding pairs detected in each survey according to the number of breeding pairs detected for the selected nests in the entire season (five visits). In order to identify the best combination of visits with the higher number of occupied nests, we also calculated the percentage of breeding pairs detected for all possible combinations (in brackets) of two (10), three (10) and four (5) visits (see Table 1). *Productivity* was defined as the number of fledglings over 3 weeks of age detected for each nest in the entire season. We calculated the percentage of productivity detected in each survey according to the productivity detected for the selected nests in the entire season (three visits; in this case, only months with presence of chicks, April, May, and June, were accounted). We have also calculated the percentage of productivity detected for combinations of two visits (three possible combinations) for every colony (see Table 1).

In order to test differences in the percentage of *number of breeding pairs* and *productivity* detected among the

Table 1 Mean ± SE in the percentage of number of breeding pairs and productivity and codes for combinations

Code	Combination of months	Breeding pairs (%)	Productivity (%)	Code	Combination of months	Occupation (%)
1	Feb	78.1 ± 3.8		16	Feb-Mar-Apr	99.7 ± 0.3
2	Mar	88.7 ± 3.7		17	Feb-Mar-May	100
3	Ap	94.8 ± 1.8	14.5 ± 7.4	18	Feb-Mar-Jun	96.2 ± 1.8
4	May	92.4 ± 2.9	59.3 ± 8.5	19	Feb-Apr-May	100
5	June	67.8 ± 7.7	85.9 ± 3.1	20	Feb-Apr-Jun	99.7 ± 0.3
6	Feb-Mar	91.8 ± 2.8		21	Feb-May-Jun	99.5 ± 0.4
7	Feb-Apr	99.3 ± 0.4		22	Mar-Apr-May	98.5 ± 0.9
8	Feb-May	99.1 ± 0.5		23	Mar-Apr-Jun	98.2 ± 0.9
9	Feb-Jun	91.1 ± 4.2		24	Mar-May-Jun	98.5 ± 0.9
10	Mar-Apr	98.2 ± 0.9		25	Apr-May-Jun	96.0 ± 2.1
11	Mar-May	98.5 ± 0.9		26	Feb-Mar-Apr-May	100
12	Mar-Jun	94.3 ± 2.9		27	Feb-Mar-Apr-Jun	99.7 ± 0.3
13	Apr-May	96.0 ± 2.1	63.1 ± 9.3	28	Feb-Mar-May-Jun	100
14	Apr-Jun	95.7 ± 1.9	91.6 ± 2.5	29	Feb-Apr-May-Jun	100
15	May-Jun	93.9 ± 2.2	97.3 ± 2.7	30	Mar-Apr-May-Jun	98.5 ± 0.9

Feb February; *Mar* March; *Apr* April; *May* May; *Jun* June number of visits and combination of visits in the breeding season, we constructed a general linear mixed model (GLMM). Number of visits and combination of visits were included as fixed factors and colony as a random factor. Number of breeding pairs and productivity did not show normal distributions (K–S both $P < 0.05$). However, the use of GLMMs was suitable because residuals from models including occupation and productivity as response variables showed normal distributions (K–S all $P > 0.05$). Means ± SE are given. All tests are two-tailed.

Results

Number of breeding pairs

The number of pairs detected increased from February to April and decreased in May and June (Table 1). In addition, the percentage of breeding pairs detected was significantly different according to the number of visits (GLMM, $F_{3,171} = 37.35$, $P < 0.0001$, Fig 1). Post-hoc test revealed significant differences among the number of visits (post-hoc test, all $P < 0.01$), except in the comparison among three or four visits (post-hoc test, $P = 0.49$). However, the individual analysis of each combination showed that the single visit in April (no. 3) was not significantly lower than the rest of combinations of two, three, or four visits (Tables 2, 3).

Productivity

Productivity increases from April to June (Table 1). Overall, the percentage of productivity detected was higher with two visits than with only one (GLMM, $F_{1,29} = 10.76$, $P = 0.0027$, Fig 2). The highest percentage of productivity detected was a combination of visits in May and June (no. 13), although this percentage was not significantly different from that obtained for a single visit in June (no. 5) or two visits in April and June (no. 11; see Table 2 for more details).

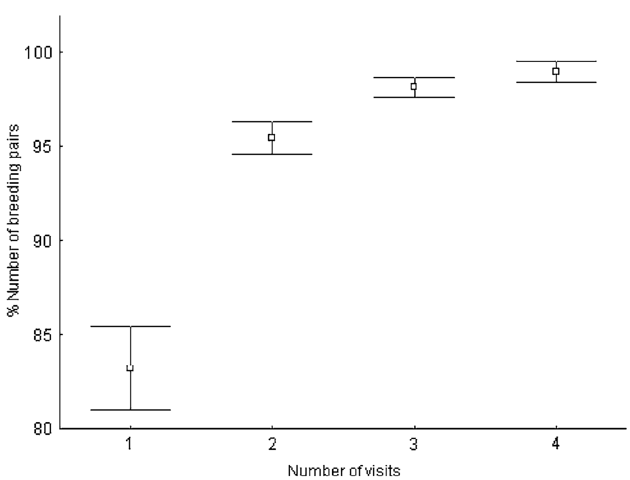

Fig. 1 Percentage of number of breeding pairs detected for the number of visits to the colonies under study

Table 2 Differences in the percentage of number of breeding pairs detected among combinations

Combination	Post-hoc test differences	Combination	Post-hoc test differences
1	All	16	1, 2, 4–6, 9
2	1, 5, 7, 8, 10, 11, 13, 14, 16–30	17	1, 2, 4–6, 9
3	1, 5	18	1, 2, 5
4	1, 5, 7, 8, 10, 11, 16, 17, 19–24, 26–30	19	1, 2, 4–6, 15
5	All	20	1, 2, 4–6, 9
6	1, 5, 7, 8, 9, 10, 16, 17, 19–24, 26–30	21	1, 2, 4–6, 9
7	1, 2, 4–6, 9	22	1, 2, 4–6, 9
8	1, 2, 4–6	23	1, 2, 4–6, 9
9	1, 6, 7, 10, 11, 16, 17, 20–24, 26–30	24	1, 2, 4–6, 9
10	1, 2, 4–6, 9	25	1, 2, 5
11	1, 2, 4, 9	26	1, 2, 4–6, 9
12	1, 5	27	1, 2, 4–6, 9
13	1, 2, 5	28	1, 2, 4–6, 9
14	1, 2, 5	29	1, 2, 4–6, 9
15	1, 5, 19, 28	30	1, 2, 4–6, 9

Significance was $P < 0.05$. Codes for combinations are given in Table 1

Table 3 Differences in the productivity detected among combinations

Combination	Post-hoc test differences
3	4, 5, 13–15
4	3, 5, 14, 15
5	3, 4, 13
13	3, 5, 14, 15
14	3, 4, 13
15	3, 4, 13

Significance was $P < 0.05$. Codes for combinations are given in Table 1

Discussion

The present study showed that the number and dates of visits to White stork colonies are key factors in order to make a correct assessment of breeding pairs and productivity, statistically corroborating the suggestions made by Bernis (1981). The number of pairs detected increases from February to April and decreases in May and June. At the

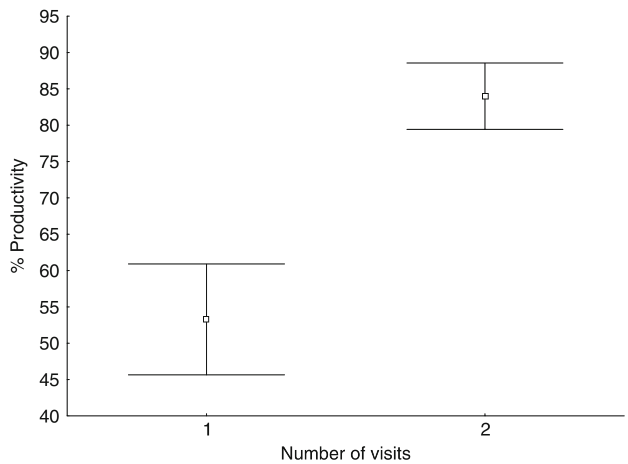

Fig. 2 Percentage of the productivity detected for the number of visits to the colonies under study

beginning of the breeding season, pairs only defend their nests against intruders (personal observation). In fact, breeders are not totally attached to their nest until egg laying. In addition, some pairs have not yet arrived in the breeding zone in February, March, and even April (Prieto 2002; Gordo et al. 2007; Vergara et al. 2007a). However, later in the breeding season, when chicks are 23 days old, they are able to thermoregulate (Tortosa and Castro 2003), and consequently parents may leave them alone in the nest while they are foraging (Tortosa and Villafuerte 1999). During this phase, nests seem empty since chicks are usually resting and still, mainly under certain conditions (early in the morning, cold or rainy days, etc., personal observation). In these cases, chicks are difficult to detect for non-experienced observers (as is sometimes the case for volunteers who collaborate in the censuses) because nests are normally at high locations that must be surveyed from a long distance. Furthermore, pairs that failed to breed early in the season abandoned their nest in the late season. The peak in the detection of occupation (April) shown in the present study coincides with the early nestling period in Spain (Cramp and Simmons 1977). Summarizing, both early and late visits might underestimate the number of breeders.

The number of detected nestlings varies throughout the season and reaches the maximum value in June. Obviously, the probability of detection increases with the number of chicks in the nest and also with the size of the nestlings. During April–May some eggs have not hatched yet, and chicks are in most cases still very small and consequently not very detectable. The number of nestlings that survive to the first 2 weeks is quite similar to the number of final fledgings because predation is very uncommon (Aguirre and Vergara 2007), and nestlings are only vulnerable to weather inclemency during the first 20 days of age (Jovani and Tella 2004, see also Denac 2006 for a study on south-eastern population). Also, food limitation is a factor that may affect nestling survival in this species (Tryjanowski and Kuzniak 2002, Tryjanowski et al. 2005b). However, this factor probably has a low effect on the Iberian population compared with the eastern ones (Tryjanowski and Kuzniak 2002, Tryjanowski et al. 2005b), due to the presence of rubbish dumps, which provide a constant and reliable source of food (Tortosa et al. 2002, 2003). In addition, episodes of big rains occurring in central Europe and having a negative impact on ecosystems (Kundzewicz et al. 2005) are unusual in the study area. These facts imply that although some chicks have only 2–3 weeks in June, at least for the Iberian populations, our estimate of the productivity is an accurate measurement of the number of chicks that finally fledged in each nest. In fact, Andrzejewska et al. (2004) monitored 205 nestling on average 34.5 days of age, and all of them lived to fledgling, suggesting that the number of chicks in the nests at that age is an accurate measurement of the number of fledglings. We did not census productivity in July in the present study because most of the chicks had fledged already (author's unpublished data), and thus productivity detected in this month must be lower than in June. During the beginning of the breeding season, many of the hatched chicks die, especially in the first 2 weeks of development (Jovani and Tella 2004). At this stage, they are still too small to be seen over the platform of the nest and therefore to be counted. For that reason, our chick counts are a good proxy of the number of fledglings, but not of the number of hatchings.

Better months to census the number of breeding pairs and productivity (in terms of detection) remain similar to the traditional dates proposed for the Iberian Peninsula 3 decades ago (Bernis 1981; Lázaro et al. 1986). These results suggest that the breeding phenology of Spanish storks has not changed in spite of their earlier arrival to the breeding grounds (ca. 1 month in the last 20 years; Gordo and Sanz 2006). In fact, we showed that April is better in terms of detection of the number of breeding pairs than the traditional month used for this census variable (i.e., March), although this difference was not statistically significant (see Table 2).

Conclusion

The present study demonstrates that the frequency and date of visits bias estimates of breeding pairs and productivity in the White stork. In addition, our results show that only one visit in one particular time of the year, April for breeding pairs and June for nestlings, might be as useful as two, three, or four visits. The combination of those months assures detection of more than the 90% of both occupation and productivity. In highly populated countries like Spain (33,217 breeding pairs, Molina and del Moral 2005), it is essential to optimize the number of visits to manage appropriately scarce money and personnel budgets for census activities. The Iberian populations of White storks represent more than 86% (70% for Spain and 16% for Portugal) of the total western population (47,132 breeding pairs) according to the preliminary results of the VI international White stork census (NABU 2006). A similar study for the Eastern populations (182,868 breeding pairs), which represent the most important fraction of the entire White stork world population (23,000 breeding pairs), is needed.

Zusammenfassung

Zählmethoden beim Weißstorch *Ciconia ciconia*: Unterschiede im Erfassungsaufwand in Bezug zu Häufigkeit und Datum der Horstkontrollen

Regelmäßige Zählungen sind bei der Bestimmung von Populationsgröße und Schutzstatus vieler Vogelarten seit langem weit verbreitet. Zur Vergleichbarkeit müssen die Erhebungen über die Zeit gleich bleiben. Diese Erforderung ist jedoch nicht immer erfüllbar. Deshalb sind Untersuchungen über mögliche Abweichungen im Erfassungsaufwand zur Korrektur solcher Fehler ausgesprochen nützlich. In der vorliegenden Arbeit wurde zur Abschätzung der Erfassungsgenauigkeit ein standardisiertes, regelmäßiges Monitoring an brütenden Weißstörchen in sechs spanischen Kolonien durchgeführt. Wir schätzten den Prozentsatz an Brutpaaren und Produktivität (Anzahl an Jungen), d.h. die Genauigkeit, die wir in jeder möglichen Kombination der Anzahl an Koloniebesuchen feststellten, verglichen mit den Ergebnissen für das gesamte intensive Monitoring, d.h. mit der Realität. Unsere Ergebnisse zeigen, dass Einzelbegehungen im Vergleich zu einer Kombination von zwei oder mehr Begehungen einen geringeren Prozentsatz an erfassten Brutpaarzahlen und Produktivität ergaben. Dennoch lagen bei einer Begehung in einem einzigen Monat (April für die Anzahl Brutpaare und Juni für die Produktivität) die Ergebnisse nicht signifikant unter denen der anderen Kombinationen aus zwei oder mehr Horstbesuchen. Frühe oder späte Besuche in der Saison könnten die Anzahl an Brutvögeln unterschätzen, weil spät besetzte beziehungsweise aufgegebene Nester nicht berücksichtigt werden. Der offensichtliche Anstieg der Feststellungswahrscheinlichkeit mit der Anzahl und der Größe der Küken ist darüber hinaus vermutlich der Grund, weshalb späte Begehungen in der Saison den höchsten Reproduktionswert liefern. Der in dieser Arbeit vorgestellte Schätzfehler könnte schließlich dazu verwendet werden, den Erfassungsaufwand bei der Weißstorchzählung zu optimieren.

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