Reproductive data and analysis of recoveries in a population of white stork, *Ciconia ciconia*, in southern Spain: a 24–year study

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Abstract

Reproductive data and analysis of recoveries in a population of white stork, Ciconia ciconia*, in southern Spain: a 24–year study.*— Changes in nest density and reproductive success of a free–ranging population of white stork, *Ciconia ciconia*, in the Gardens of ZooBotánico Jerez (Cádiz) were studied from 1990 to 2013. Reproductive data (number of nests and number of chicks per nest) and the effect of rainfall on the reproductive success were analyzed. In addition, a number of chicks were colour–ringed each year and the recovery data were also analyzed. The number of nests found in the area steadily increased during the study period and varied greatly from year to year from 2001 onwards (mean 19, range = 4–35, N = 22 years). Reproductive success also varied greatly among years. Overall, the mean number of chicks per nest was 1.78 ± 1.2 (range = 0–5, N = 439 nests). Reproductive success was strongly influenced by rainfall. It was highest (1.88) in years classified as rainy, medium (1.62) in years classified as normal, and lowest (1.24) in dry years. A total of 404 white storks were ringed, 110 of which were observed a total of 308 times (2.8 + 2.8 times per bird, range 1–12, all year data pooled). Recovery data show that with one exception, all ringed birds were recorded at different habitats of S Spain throughout the year. Remarkably, none was observed at traditional wintering quarters, south of the Sahara in Africa. Juveniles remained in the area (from July to October) soon after leaving our colony, and virtually all of them disappeared from November to January (their first winter) but were recorded again during their first breeding season. On the contrary, adults were repeatedly recorded at different sites in Cádiz, Sevilla and Huelva all year round. These birds showed a strong philopatry as some of them were recorded as breeders in our colony, up to 11 years after ringing. Our data emphasize the importance of both refuse damp and wetland areas for the species, especially in winter, and a shift in the timing of the reproductive season as birds were recorded from November to July each year. Our study provides evidence of the increase in the population, a significant effect of rainfall on their reproductive success, and the non–migratory habits of adult white storks in our colony. To our knowledge, this is the first time that such long–term reproductive data for a Mediterranean population of white storks is shown.

Key words: Long–term, Nest density, Recovery data, Reproduction, Breeding success, *Ciconia ciconia*

Resumen

Historial reproductivo y análisis de las recapturas de una población de cigüeñas blanca, Ciconia ciconia*, del sur de España: un estudio de 24 años*.— Entre 1990 y 2013 se estudiaron los cambios en la densidad de nidos y el éxito reproductor de una población de cigüeñas blancas, *Ciconia ciconia*, que viven en libertad en los jardines del Zoobotánico de Jerez (Cádiz). Se analizaron datos relativos a la reproducción (número de nidos y número de pollos volantones por nido) y el efecto de la pluviometría en el éxito reproductor. Asimismo, cada año se marcaron con anillas de colores varios pollos y también se analizaron los datos de recaptura. El número de nidos hallados en la zona aumentó de forma constante durante el periodo de estudio y varió notablemente entre años a partir de 2001 (media = 19; intervalo = 4–35; N = 22 años). El éxito reproductor también varió considerablemente entre años. En total, la media de pollos volantones por nido fue de 1,78 ± 1,2 (intervalo = 0–5; N = 439 nidos). La precipitación influyó en gran medida en el éxito reproductor, que fue máximo (1,88) en los años clasificados como lluviosos, medio (1,62) en los años clasificados como normales y mínimo (1,24) en los años secos. Se anillaron un total de 404 cigüeñas blancas de las cuales 110 se observaron en 308 ocasiones (2,8 + 2,8 veces por ave; intervalo = 1–12,

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datos de todos los años). Los datos de recaptura mostraron, con una única excepción, que todas las aves anilladas se habían registrado en distintos hábitats del sur de España durante todo el año. Cabe resaltar que no se observó ningún ave en las tradicionales zonas de invernada del Sáhara meridional, en África. Los jóvenes permanecieron en zonas próximas a su lugar de nacimiento (entre julio y octubre) poco después de abandonar nuestra colonia y la inmensa mayoría de ellos desaparecieron entre noviembre y enero (su primer invierno); sin embargo, se registraron de nuevo durante la primera estación reproductora. Por el contrario, los adultos se siguieron registrando en distintos lugares de Cádiz, Sevilla y Huelva durante todo el año. Estas aves mostraron una gran filopatria, ya que algunas de ellas se registraron como reproductoras en nuestra colonia (hasta 11 años después del anillamiento). Nuestros datos ponen de relieve la importancia de los vertederos y los humedales para la especie, especialmente en invierno, y el cambio en la fenología reproductora, puesto que las aves se registraron entre noviembre y julio de todos los años. En resumen, en este trabajo se aportan datos que respaldan el incremento de la población, el efecto significativo de la precipitación en el éxito reproductivo y el comportamiento no migratorio de los adultos de cigüeña blanca en nuestra colonia. Que sepamos, es la primera vez que se aportan datos a tan largo plazo sobre la reproducción de esta especie para una localidad mediterránea del sur de Europa.

Palabras clave: Largo plazo, Densidad de nidos, Datos de recaptura, Reproducción, Éxito reproductor, *Ciconia ciconia*

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Introduction

The study of the number of breeding pairs per unit area and the reproductive traits for a species in a given season is a basic issue in ornithology. In most cases, studies search for correlations across seasons or differences between years in an attempt to correlate either the density of nests or reproductive traits with a number of environmental variables such as rainfall (*e.g.,* Green, 1988; Steenhof et al., 1997; Chase et al., 2005). Most studies consider a relatively low number of breeding seasons (< 5 yrs), with long–term studies (> 10 yrs) being scarce (but see Holmes et al., 1986; Dallinga & Schoenmakers, 1989; Clark & Mednis, 2002; Chase et al., 2005; Wilkin et al., 2006; see Woller et al., 1992 for a review). The analyses of long–term data sets have allowed the development of a number of disciplines such as demography, population dynamics and ecology, of much concern in the current scenario of climatic change (Brereton et al., 1995; Root et al., 2003; Parmesan, 2006).

The white stork, *Ciconia ciconia*, is, perhaps, one of the most studied bird species. Many aspects of its distribution range, migratory habits, and reproductive traits are remarkably well known (Schulz, 1998, see del Hoyo et al., 1992 for a review). Undoubtedly, its preference to reproduce at human–made habitats has favored this knowledge. In the Iberian peninsula, the population of white storks has been monitored since the middle of the last century (Bernis, 1995). In 2004, SEO Birdlife performed the first Spanish population census as part of the VI International Census of the species (Molina & del Moral, 2005). The Spanish population has notably increased in the last decades (Molina & del Moral, 2005). Some authors have hypothesized that such an increase is linked to a change in both feeding habits (by using new resources such as refuse rubbish dumps or crayfishes on rice fields, Purroy, 1997; Tortosa et al., 2002; Sanz–Aguilar et al., 2015) and a shift in their migratory habits (now many birds do not migrate to overwinter in Africa but remain in southern Spain during the winter months (Máñez et al., 1994; Sanz–Aguilar et al., 2015). According to available information, this shift in migratory habits started about 1985 (Máñez et al., 1994; Purroy, 1997; Barjola, 2001).

In this note, we present reproductive data (both number of nests and breeding success) of a free–living white stork population settled at the gardens of ZooBotánico Jerez (Cádiz, S Spain) from 1990 to 2013 (N = 24 years). We analyzed the influence of rainfall in the reproductive success (number of chicks per nest), predicting that breeding success would be higher in wet years when feeding opportunities are presumably better (Dallinga & Schoenmakers, 1987; Carrascal et al., 1993, Tortosa et al., 2003; Jovani & Tella, 2004). Finally, as a number of chicks were colour–ringed at our colony each year, we analyzed the ringing recovery data in order to clarify the migratory status of this population. Specifically, we analyzed whether white storks spent the winter in the area and the extent of breeding philopatry, a pattern common to this species (del Hoyo et al., 1992). Although several studies have analyzed the variation in the number of pairs and their reproductive traits for remarkably long–term data sets in white stork (Dallinga & Schoenmakers, 1989; Tryjanowski et al., 2005; Gordo et al., 2013), to our knowledge, this is the first time that such long–term reproductive and ringing recovery data are reported for a population in the Mediterranean area.

Material and methods

Study site

A wild population of white storks reproduces at the gardens of ZooBotánico Jerez every year. The gardens of ZooBotánico Jerez cover an area of 6.5 has, located in the western part of the city of Jerez de la Frontera (Cádiz, S Spain, coordinates: 36.689009º N, –6.150112º W). The gardens are characterized by a dense canopy composed of many species of trees (some over 140 years old and higher than 30 metres). Each year, white stork locate their nests in large trees to and on artificial platforms erected above some animal enclosures to facilitate their reproduction.

Field work

This colony was studied from 1990 to 2013. Each year, the whole area was prospected for nests at least once a week during the reproductive season (from February to July) to assess the reproductive activity of white stork in the colony. In each survey, we followed a fixed route (ca. 2 km in length) on days with good weather (no wind and no rain). We used standard 10 x 40 binoculars to observe of the nests. All nests found were noted on a scaled map. We also noted the presence of adults (and their identification number if ringed) and the number of chicks found at each nest. Clutch size or hatchling date were not recorded as many nests were too high to effectively record these variables. We measured reproductive success as the number of fledglings (juveniles that completed the reproduction and abandoned the nests), the procedure used in other studies (*e.g.,* Lázaro et al., 1986). Only those nests for which information was accurately recorded were included in the reproductive success analyses. Reproductive data of years 2004 and 2007 were not available.

Climatologic data

Rainfall data was obtained from Jerez Airport Station (AEMET, Spanish Meteorological Agency, sequence 1974–2013). For the analyses, we used the rainfall of the period October (year n–1) to April (year n) for a reproductive season (year n). The rainfall accumulated during this period is likely to influence feeding opportunities and hence influence the reproduction of white stork during a reproductive season. According to the rainfall data, the reproductive season (year n) was classified as dry (< 400 mm of rainfall), normal (400–600 mm) or wet (> 600 mm).

Ringing of chicks and the analysis of recovery data

In May–June each year, we visited several of the more accessible nests and ringed all the chicks. Each chick received a metallic ring and a standard colored plastic ring with an alphanumerical code for identification at a distance. First, we analyzed the recoveries of juveniles during their first year of life. For our convenience, this period was considered from July (the month when most juveniles leave the colony, year n) to October (year n+1). Three periods were considered: the post–fledging period (from July to October, year n), the winter period (from November to January, year n+1) and the breeding season (from February to October, year n+1). Second, we analyzed the recoveries of adult white storks (*i.e.,* those that occurred during the second reproductive season or more). Again, we considered winter (between November to January) and breeding (from February to October) recoveries. A total of 404 chicks were ringed from 1996 to 2011. The Spanish Ringing Office at Estación Biológica Doñana–CSIC, provided white stork (period 1994–2011) recovery data.

Statistical analyses

We used standard parametric statistics according to Sokal & Rohlf (2005). We analyzed the hypothesis that reproductive success was influenced by type of year. To achieve this, we introduced the number of fledglings per nest as the dependent variable and the type of year (humid, normal or dry) as a factor in an ANOVA analysis. Data from all years were pooled for the analyses. Statistics were performed using SPSS *vs.* 15.0. The results are reported as mean ± SE. The significance was set a $P < 0.05$.

Results

Number of nests and reproductive success

The white stork colony at ZooBotánico de Jerez increased during the study period (table 1). The number of nests varied greatly among years from 4 (in 1990) to 35 nests (in 2006). A single nest was recorded in Jerez city in 1985 (before this study started) and this nest was located in the gardens of ZooBotánico Jerez (own data). The colony grew exponentially until 2001 when a total of 32 nests were recorded. From 2002 to 2013, the size of the colony was also high but with great variations between years (table 1). Overall, the mean number of nests per year was 19 (range = 4–35, N = 22 yr).

Reproductive success also varied greatly between years (table 1). It was low (< 1 chick/nest, in 1999, 2005, and 2012), medium (ca. 1.5 chicks/nest in 1992, 1993, 2002, and 2003) and high (> 2 chicks/nest in 1991, 1996, 2001, and 2003). The mean number of chicks was minimum in 2012 (0.7 + 0.9, range = 0–2, N = 17) and maximum in 2001 (2.4 + 1.1, range = 0–5, N = 32). Overall, reproductive success was 1.78 ± 1.20 (range = 0–5, N = 439). Colony size had little effect on mean reproductive success as the correlation between total number of nests and the mean number of fledglings per nest did not reach statistical significance (Pearson product–moment correlation, $r_p = -0.18$, $P = 0.43$, N = 22).

The effect of rainfall

Reproductive success was significantly influenced by rainfall (one factor ANOVA, $F_{2, 437} = 10.7$, $P < 0.001$). The mean number of fledglings recorded per nest was low in dry years (1.24 ± 1.18, N = 199), medium in years considered to have a normal rainfall (1.62 ± 1.17, N = 116), and high in wet years (1.88 ± 1.39, N = 94). The effect of rain on fledgling success was highly significant as rain and the mean number of fledglings per nest (mean values of all nests in a year) were highly correlated (Pearson product moment, $r_p = 0.50$, $P = 0.017$, N = 22).

Analysis of recoveries

A total of 404 chicks were ringed during the study period. Of these 110 white storks were observed a total of 308 times (2.8 + 2.8 times per bird, range = 1–12, N = 110, data of all years pooled). With one exception (code RU2, ringed in May 1997 was recorded 12 months later in Algeria), all these recoveries occurred in Cádiz, Huelva or Sevilla (all in S Spain). The analysis of recoveries classified as juveniles (see methods) showed that: (1) a total of 33 birds (or 30%) were observed 1.2 + 0.5 times (range = 1–3, N = 33, all year data pooled) soon after leaving our colony (from July to October in the same year as ringing). Most of these birds (N = 24) were consistently observed at Miramundo (a well known urban dumping site in Medina Sidonia, Cádiz, ca. 25 km SE of our colony), suggesting that many post–fledgling white storks remained in Cádiz province for a few months after leaving our colony; (2) nearly all juveniles abandoned the study area in their first winter as only two birds (or 1.8%) were recorded during this period; and (3) 46 birds (or 41.8%) were recorded during their first breeding season (from February to October year n+1) in the area. Similarly, the analysis of recoveries of birds classified as adults (see methods) showed that: (1) 27 white storks (or 24%) were recorded in winter (from November to January). These birds were consistently observed at wetland habitats in S Spain (especially Doñana National Park and wetland areas of Sevilla and Cádiz) and various dumping sites in Cádiz (especially Miramundo and Los Barrios); and (2) a total of 57 white storks (or 51%) were recorded during the second breeding season (year n+2 or more). Overall, the number of years elapsed between the year of ringing and breeding was 3.6 + 2.5 years (range = 1–11, N = 81, all years pooled). As expected, a few ringed birds showed a strong philopatry as 10 white storks (or 9%) were recorded breeding again in our colony in the following season. The number of years elapsed between breeding and first ringing of these birds was 4.4 + 3.6 years (range = 1–11, N = 10).

Table 1. Colony size and reproductive data of the white stork colony at ZooBotánico Jerez per year in relation to type of climatic year. Years were classified as: rainy (> 600 mm of rainfall), normal (between 400 and 600 mm), or dry (< 400 mm). Data include the number of nests (Nn) found each year and the number of fledglings (Nf, mean ± SD and range). Rainfall was measured as the total monthly data from September to April of the following year: [(a)] Data not available.

Tabla 1. Datos sobre el tamaño y la reproducción de la colonia de cigüeña blanca del Zoobotánico de Jerez por año en relación con el tipo de año climático. Los años se clasificaron en: lluviosos (> 600 mm de precipitación), normales (entre 400 y 600 mm) y secos (< 400 mm). Los datos comprenden el número de nidos (Nn) encontrados cada año y el número de pollos volantones (Nf, media ± DE e intérvalo). La precipitación se midió como el valor mensual total entre septiembre y abril del año siguiente: [(a)] Datos no disponibles.

Year	Nn	Nf (mean ± SD)	Range	Rainfall (mm)	Type of climatic year
1990	4	1.75 ± 1.25	0–3	639.0	Rainy
1991	5	2.2 ± 1.30	0–4	494.9	Normal
1992	7	1.57 ± 1.27	0–3	291.8	Dry
1993	7	1.57 ± 0.97	0–3	369.4	Dry
1994	10	1.30 ± 1.06	0–3	311.8	Dry
1995	11	1.45 ± 1.21	0–4	220.6	Dry
1996	14	2.00 ± 1.62	0–4	752.2	Rainy
1997	16	1.19 ± 1.11	0–3	881.7	Rainy
1998	17	1.59 ± 1.54	0–5	513.6	Normal
1999	23	0.74 ± 0.96	0–3	92.4	Dry
2000	26	1.07 ± 0.93	0–3	402.2	Normal
2001	32	2.47 ± 1.19	0–5	680.3	Rainy
2002	21	1.43 ± 0.89	0–3	368.9	Dry
2003	13	2.69 ± 1.03	0–4	534.0	Normal
2004	(a)	(a)			
2005	34	0.88 ± 0.81	0–3	155.0	Dry
2006	35	1.80 ± 1.51	0–4	331.4	Dry
2007	(a)	(a)			
2008	34	1.38 ± 1.30	0–4	270.9	Dry
2009	29	1.52 ± 1.09	0–4	499.2	Normal
2010	28	1.57 ± 1.45	0–4	815.1	Rainy
2011	26	1.65 ± 0.94	0–4	575.9	Normal
2012	17	0.70 ± 0.92	0–2	257.4	Dry
2013	30	1.96 ± 1.09	0–4	495.0	Normal
Total	439	1.78 ± 1.20	0–5		

Discussion

Our study provides some interesting results. First, the number of white stork nests in our colony increased between 1990 and 2013. In fact, this increase started earlier as only one nest (located at ZooBotánico Jerez) was found in Jerez city in 1985 (own data). White stork populations in other parts of Spain have undergone a similar increment in the last decades. The VI International Census performed by SEO–BirdLife (Molina & del Moral, 2005) showed a decline from 1948 to 1984 (from 14,503 to 6,753 nests,) and a notable increase from 1994 to 2004 (from 16,643 to 33,217 nests, respectively). In addition, a number of local studies have reported the same trend (Lázaro et al., 1986; Pedrochi, 1993; Bernis, 1995; García García, 1997;

Nalda et al., 1994; Prieto Martín, 2002). Interestingly, several authors noted that this shift in the density of the population trend occurred in 1985 (Purroy, 1997; Prieto Martin, 2002; Molina & del Moral, 2005). Our data strengthen this idea and report a steady increment in white stork populations from 1985 onwards, a finding similar to that reported in many other white stork breeding populations in the Iberian peninsula.

Second, reproductive success varied greatly between years and was significantly influenced by rainfall. As reported for many bird species, weather conditions (especially rainfall) are known to have a significant impact on the reproductive success of white storks (Dallinga & Schoenmakers, 1987; Tortosa et al., 2003; Jovani & Tella, 2004; Massemin–Chalet et al., 2006). Another study, however, suggested that local livestock farming, rather than the water level, was the most significant variable (*cf.* Tryjanowski et al., 2005). In our case, rainfall —and consequently, the availability of wetlands— seemed to increase feeding opportunities for white storks because the species prefer wetlands and pastures to forage (del Hoyo et al., 1992; Carrascal et al., 1993; pers. obs.)

Third, the recovery data provide some clues about the non–migratory habits of the species in our colony. Remarkably, none of the ringed birds were observed in Africa, south of the Sahara, a traditional overwintering area for the species (*cf*. del Hoyo et al., 1992). However, we do not exclude the possibility that the absence of recoveries in Africa was simply due to the low number of birds ringed in our study site. Juveniles, however, disappeared during their first winter but returned to their breeding grounds within their first year of life. Adults, on the contrary, were resident in the area and were frequently recorded in the area all year round. It has been suggested that white stork populations breeding in the Iberian peninsula have changed their migratory habits over recent decades (Máñez et al., 1994; Purroy, 1997; Barjola, 2001; Archaux et al., 2004). Our recovery data clearly support this notion in the the case of adult white storks. Other studies have also reported a change in the migratory habits of white stork breeding populations (Máñez et al., 1994; Purroy, 1997; Barjola, 2001; Molina & del Moral, 2005; Manuel Fernández Cruz, pers. comm.; see also Archaux et al., 2004 for a similar case reported in France). Available information on more than 60 radio–tagged white storks controlled by satellites, a new method extensively used today, provides similar results (see MIGRA Program, developed by SEO–BirdLife; Anonimous, 2015).

And fourth, breeding philopatry seems to be the general trend, as a few white storks were recorded at our colony in a subsequent breeding season, a pattern similar to that observed in many other white stork colonies (del Hoyo et al., 1992; see Prieto Martín, 2002 for a similar case in another Spanish population).

There are a number of reasons for this change in the migratory habitats of white stork. First of all, the species became strictly protected by Spanish law in 1975 (*cf.* R. D. 2573 from BOE, dated 5 November 1973), favoring the conservation of both individuals and their nests. The second reason is the shift in their feeding habits, with an increment in the use of urban waste dumps (Tortosa et al., 2002; Peris, 2003; Ciach & Kruszyk, 2010; this study; see also Purroy, 1997 and references therein). Interestingly, some studies suggest that the shift in migratory behavior occurred from 1985 onwards. Our recovery data (performed from 1995 onwards) also support this view. And third, the introduction of the exotic crayfish, *Procambarus clarkii*, at many wetland habitats of southern Spain occurred in 1974. This species has become the base of the diet of many mammals and bird species including white storks (Machamalo de Blas, 1995; Tablado et al., 2010). Our recovery data analysis also highlight the relevance that some refuse damps (especially Miramundo and Los Barrios, both in Cádiz) and wetland areas (all located around Doñana National Park both in Huelva and Sevilla and Cádiz Bay area) have for white storks, especially for post–fledgling juveniles and adult birds in winter. The importance of these habitats has been reported in many other studies (Purroy, 1997; Tortosa et al., 2002; Molina & del Moral, 2005; Sanz–Aguilar et al., 2015). Another point of note is that white storks have also changed the timing of their reproductive season; both juveniles and adults leave our colony in early July and return to their same breeding quarters early in November (own data), similar to observations in other white stork colonies (Barjola, 2001; Prieto Martín, 2002; Gordo & Sanz, 2006).

In conclusion, our study provides evidence of the steady increase in the population and non–migratory habits of adult white storks in our colony and emphasized the impact urban waste sites and and wetlands in the maintenance of their populations, especially in non–breeding periods. White storks seem to be a plastic, highly adaptable species that exhibits relatively rapid changes in migratory habits. To our knowledge, this is the first study to provide such long–term reproductive data for a white stork population in a Mediterranean habitat.

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