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Breeding population trends and recent changes in the nesting behaviour of the White Stork *Ciconia ciconia* L., 1758 in Navarre, north of Spain.

Tendencias de la población reproductora y cambios recientes en el comportamiento de nidificación de la cigüeña blanca *Ciconia ciconia* L., 1758 en Navarra, norte de España.

Juan M. Barbarin[1], Daniel Alonso[1], Juan Arizaga[1], Jaime Resano-Mayor[2], David Arranz[1], Diego Villanúa[1,3*]

Abstract

The white stork *Ciconia ciconia* is one of the most emblematic birds in rural habitats of Europe. Its populations showed a drastic decline during the 20th century, followed by a rapid recovery in the last decades. The population increase has led to a relaxation in the specie's monitoring effort, the last Spanish national official census having been conducted more than 15 years ago.

In order to update this knowledge, this study shows the results of a breeding population census conducted in Navarre during the spring of 2018, describing the preferences in nest location, and comparing the current breeding population size with that described in the literature published since 1960.

1 **Departamento de Ornitología. Sociedad de Ciencias Aranzadi.**
Alto Zorroaga 11. 20014 Donostia-San Sebastian. Gipuzkoa.

2 **University of Bern. Division of Conservation Biology.**
Institute of Ecology and Evolution Baltzerstrasse 6, 3012 Bern, Switzerland.

3 **Navarra Environmental Management (GAN-NIK).**
Padre Adoain 219, 31015, Pamplona-Iruña, Spain.

* Corresponding author: diegovillanua@yahoo.es

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Our results show a breeding population of 739 pairs, which is the highest value ever recorded. However, this increase in the number of pairs has not been associated with a significant expansion of the specie's distribution area, which is still limited to the southern half of Navarre. The only relevant colonisation would be the 5 pairs established in the Pamplona district.

Most pairs (86.3%) nested in colonies, with an average size of 9.2 nests. Most of the nests were located in trees (49.0%), followed by buildings (28.8%), cut trees (10.0%), pylons (6.9%) and other types of structures (antennas, chimneys, artificial nests, cranes..., 5.3%). A comparison of the current situation with previous censuses shows that there has been an annual population growth rate of 6.6%, with an important change in nesting habits, both in the percentage of pairs that nest in colonies and in the substrate selected to build the nest.

The possible causes that could explain these changes and the conservation implications for the species are discussed.

Key words: Census, conservation, landfills, reproductive habits, white stork.

Resumen

La cigüeña blanca *Ciconia ciconia* es una de las aves más emblemáticas del medio rural europeo. Su población sufrió un drástico descenso en el siglo XX, seguido de una rápida recuperación durante las últimas décadas. Este incremento ha ido acompañado de cierta relajación en la monitorización de sus poblaciones, sin que se haya publicado un censo nacional oficial en España desde hace más de 15 años.

De cara a llenar este vacío de conocimiento, el presente estudio muestra los resultados del censo de parejas reproductoras de cigüeña blanca en Navarra durante la primavera de 2018, describiendo las preferencias de ubicación de nidos y comparando la situación actual con la descrita en las publicaciones desde 1960 hasta ahora.

Nuestros resultados muestran una población reproductora constituida por 739 parejas, lo que supone el valor más alto registrado hasta el momento. Sin embargo, este incremento en el número de parejas no ha supuesto una ampliación relevante del área de distribución de la especie, que sigue circunscrita a la mitad sur de Navarra. La única colonización relevante serían las 5 parejas establecidas en la comarca de Pamplona.

La mayoría de las parejas (86,3%) nidifican formando colonias, con un tamaño medio de 9,2 nidos. El sustrato más frecuentemente elegido para ubicar el nido fueron los árboles (49,0%), seguido de los edificios (28,8%), los cortados (10,0%), los tendidos eléctricos (6,9%) y otro tipo de estructuras (antenas, chimeneas, nidales artificiales, grúas..., 5,3%).

La comparación de estos datos con los publicados anteriormente pone de manifiesto un crecimiento anual del 6,6% y un importante cambio en los hábitos de nidificación, tanto en el porcentaje de parejas que nidifican en colonias, como en el sustrato seleccionado para ubicar el nido.

Se discuten las posibles causas que podrían explicar estos cambios y las implicaciones de conservación para la especie.

Palabras clave: Censo, cigüeña blanca, conservación, hábitos reproductivos, vertederos.

Laburpena

Zikoina zuria *Ciconia ciconia* da Europako landa eremuetako ikur hegaztietako bat. XX. mendean haren populazioek beherakada gogorra jasan zuten, baina azken hamarkadetan berriz ere suspertu egin dira. Ugaritze horrek populazioen monitorizazioak nolabait gutxitzea ekarri du eta, ondorio bezala, azken 15 urteetan ez da argitaratu errolda ofizial nazionalik.

Datu hutsune horri aurre egiteko, ikerketa honek 2018ko udaberrian Nafarroan egindako zikoina zuri bikote ugaltzaileen errolda ezagutzera ematen du, habien kokapen gogokoenak deskribatzen dira eta 1960tik gaur arteko publikazioetan deskribatutakoekin alderatzen ditu.

Gure emaitzek erakusten dute 739 bikoteko populazio ugaltzailea, hain zuzen ere orain arte erregistratutako kopururik altuena. Dena den, bikoteen ugaritze honek ez du ekarri espeziearen distribuzio esparruaren hedapenik, jarraitzen baitu izaten soilik Nafarroa hegoaldea. Kolonizazio aipagarri bakarra Iruñeko arroan finkatu diren 5 bikoteak izango lirateke.

Bikote gehienek (%86,3) kolonietan egiten dituzte habiak, koloniak batez beste 9,2 habikoak direlarik (± 14,9). Habiak kokatzeko leku erabiliena zuhaitzak izan ziren (%49), eraikuntzak (%28,8), malkarrak (%10), linea elektrikoak (%6,9) eta beste mota batzuetako egituretan (antenak, tximiniak, kabi artifizialak, garabiak… %5,3).

Datu horiek lehendik argitaratutakoekin alderatuta, urtero 6,6 ± %0,2ko hazkunderako joera nabarmentzen dute. Bestetik, habia egiteko ohituren aldaketa nabarmenak ere agerian uzten ditu, bai kolonietan habia egiten duten bikote kopuruetan, bai eta habia egiteko aukeratutako kokapenetan.

Aldaketa horien guztien arrazoiak aztertzen dira, baita espeziearen kontserbaziorako izan ditzaketen inplikazioak.

Gako hitzak: zikoina zuria, errolda, ugaltze ohiturak, zabortegiak, kontserbazioa.

Introduction

The white stork *Ciconia ciconia* L., 1758 is one of the most representative and emblematic bird species of European rural landscapes. It shows a broad but discontinuous breeding distribution area, ranging north-south from Finland to Morocco, and west-east from Portugal to Kazakhstan (Del Hoyo *et al*., 1992). The global white stork population in 2015 is estimated to be composed of ca. 469000 (447000-495000)

specimens (IUCN, 2020), and the Spanish population host above 33,000 breeding pairs in 2004 (Molina & Del Moral, 2005), representing 70% of the overall European western population (NABU 2006).

During the 20th century, white stork population experienced a dramatic decline in many European countries (Dallinga & Schoenmakers, 1987; Tucker & Heath, 1994), including Spain (Molina & Del Moral, 2005). In the last decades, however, the species has undergone a very fast and good recovery (Schulz, 1999; Molina & Del Moral, 2005; Thomsen & Hötker, 2006), and nowadays it is considered a species of Least Concern (IUCN, 2020). The population recovery seems to have been possible, in part, thanks to the broad trophic niche of the species and its capacity to exploit new, super-abundant feeding sources. Particularly, the red swamp crayfish (*Procambarus clarkii*), an American crab species introduced in Europe (Negro & Garrido-Fernández, 2000), and refuse dumps (Tortosa *et al*., 2002; Massemin-Challet *et al*., 2006; Aguirre & Vergara 2007; Sanz-Aguilar *et al*., 2015; Arizaga *et al*., 2018; Bécares *et al.,* 2019), where large numbers of storks feed all year round. Furthermore, the species has been also able to adapt its nesting behaviour, evolving from an initial nest location in trees (Fasola-Matasaru *et al*., 2018) to the use of artificial substrates, including buildings or power lines' towers, among others (Molina & Del Moral, 2005; Fasola-Matasaru *et al*., 2018). Overall, this flexibility in the exploited food resources and breeding/nesting habitat type, often in close relationship with humans, seems to have been a key aspect for the fast recent population growth shown by the white stork (Bécares *et al*., 2019).

This remarkable population increase, together with the fact of being listed as a Least Concern species, has probably led to less intensive official monitoring programs. For instance, the last national census conducted in Spain was back in 2004, when it was detected a general population growth rate from the previous census in 1994 (Molina & Del Moral, 2005). In particular, the highest population growth rate was estimated in Navarre, with 621 breeding pairs in 2004 and a 550% population increase for that period (Molina & Del Moral, 2005). Since then, the white stork population continued increasing in Navarre and other regions, though the population growth rate is something that remains to be investigated. In this study, we aim to 1) update the breeding population size and the potential changes in nesting behaviour of the species in Navarre, and 2) assess its annual population growth rate based on our estimates and published census in the last decades.

Material and methods

Study area and data collection

This study was carried out in the province of Navarre, in northern Spain (Fig. 1). Situated between the western Pyrenees in the north, and the Ebro Valley in the south, Navarre

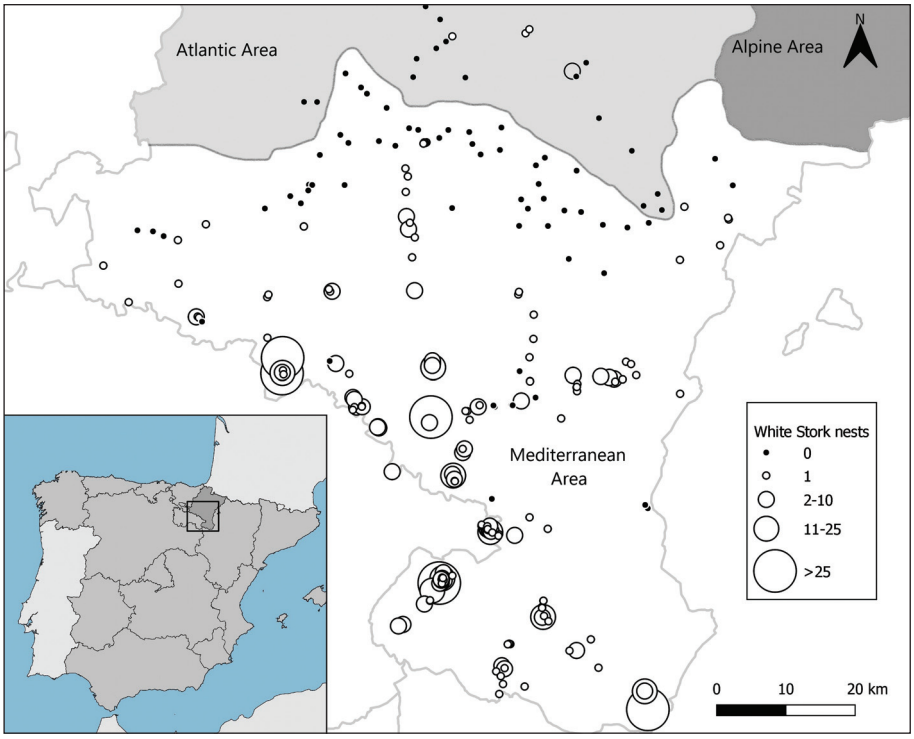

Fig. 1.- White stork distribution in Navarre in 2018 during the breeding period and size of the colonies. White circles represent occupied nest and black dots represent monitored sites where the species was absent. The different biogeographic areas are represented with different background colours.

Fig. 1.- Distribución de la Cigüeña blanca en Navarra en 2018 durante el periodo reproductivo y tamaño de las colonias. Los círculos blancos representan nidos ocupados y los puntos negros puntos muestreados donde la especie está ausente. Las distintas regiones biogeográficas están representadas con distinto color de fondo.

is divided into three biogeographical areas: the Alpine, the Atlantic and the Mediterranean (Lorda *et al*., 2011), with large differences among them (e.g. climatic, landscape, flora and fauna). The white stork occurs as a breeding species only in the Mediterranean area that occupies the southern half of Navarre (Fig. 1).

Before organizing a complete census within the region in 2018, during the autumn of 2017 we conducted a preliminary survey in order to look for nesting areas where the species had bred in previous years. We also checked other areas where, potentially, the species might have started nesting recently. This methodological approach has been widely used before (Bernis, 1981; Chozas, 1984; Pedrocchi, 1990), and it allows optimizing the subsequent fieldwork efforts (Bernis, 1981; Chozas, 1984). The formal census was carried out in April 2018, which is known to be the best time to estimate the number of breeding pairs (Aguirre & Vergara, 2009). Each colony was censured

by a single ornithologist, dedicating between 15 and 60 minutes of observation depending on the number of nests to control.

For every occupied nest, we recorded: (1) its location (coordinates), (2) substrate (building, tree, power line tower, cliff, other), (3) isolate nest/ nest in a colony. In this regard, when two or more nests were less than 500 m apart, they all were considered to form a colony (Molina & Del Moral, 2005).

Statistical analyses

To estimate the population growth rate, we compiled the data from the historical counts of breeding storks in Navarre, including our census in 2018. Overall, we collected data from 1960, 1970, 1980, 1982, 1983, 1984, 1988, 1989 (Lizarraga, 1989), 1998 (Gurelur, 1998) and 2004 (Molina & Del Moral, 2005). Then, we built a basic log-linear population growth model based on the equation: $r = (\ln N_t - \ln N_{t-1})/t$, where r is the annual growth rate, N is the population size and t is the year. All the analyses were done with the package 'rtrim' for R (R Core Team, 2014).

We also run a chi-square test on a contingency table on years by type of nest (isolated/in a colony) in order to see whether the proportion of nests found in colonies varied significantly among years. A significant result of this test was considered as evidence supporting that one/more year had a proportionally higher (or smaller) number of nests in colonies. To detect exactly which years caused significant differences, we looked at the standardized residual values from this contingency table; values >3 were considered to deviate from the mean, overall distribution pattern (Agresti, 2002). This analysis was run in the software PAST (Hammer *et al.*, 2001).

Results

The number of white stork breeding pairs in Navarre in 2018 was estimated to be 739, the highest number ever recorded (Table 1). The models showed a positive annual population growth rate (± SE) of 6.6 ± 0.2%/year (Fig. 2).

Most pairs (n = 638; 86.3%) placed their nests in colonies, and the mean (± SD) size of the colony were 9.2 (± 14.9) pairs (range: 2-97). The proportion of nests found in colonies varied between 1960 and 2010 ($\chi^2_{10} = 642.6$, $P < 0.001$). The standardized residual values of such ratios showed that there were proportionally more nests in colonies in 2004 and 2018 compared to the period from 1960 to 1998 (Table 1).

In 2018, most (49.0%) nests were found in trees, followed by buildings (28.8%), cliffs (10.0%), electric towers (6.9%) and other types of structures (such as antennas, chimneys, specific pylons for nesting, train overhead catenary or cranes; 5.3%).

Year	Occupied nests	Isolated	Colony
1960	79	51.9% (+4.4)	48.1% (-2.7)
1970	59	55.9% (+4.4)	44.1% (-2.7)
1980	47	70.2% (+5.9)	29.8% (-3.5)
1982	44	72.7% (+6.0)	27.3% (-3.6)
1983	42	76.2% (+6.3)	23.8% (-3.8)
1984	39	79.5% (+6.5)	20.5% (-3.9)
1988	42	81.0% (+6.9)	19.0% (-4.1)
1989	42	85.7% (+7.5)	14.3% (-4.5)
1998	261	45.6% (+6.1)	54.4% (-3.6)
2004	621	6.1% (-9.8)	93.9% (+5.9)
2018	739	13.7% (-6.7)	86.3% (+4.0)

Table 1.- Number of occupied nests found either isolated (isolate nest) or in a colony (more than one nest) during the different censuses of breeding white storks conducted in Navarre since 1960. In parenthesis, we show the standardised residual values obtained from a chi-square test used to assess if a percentage deviated from a mean global ratio with years pooled. Residual values >3 (or <3) indicate significant deviations.

Tabla 1.- Número de nidos ocupados aislados o formando colonias (más de un nido) durante los distintos censos de reproductores realizados en Navarra desde 1960. Entre paréntesis, se muestra el valor residual estandarizado obtenido del test de Chi cuadrado usado para evaluar si el porcentaje se desviaba de la media de los años agrupados. Valor del residual >3 o <3 indican una desviación significativa.

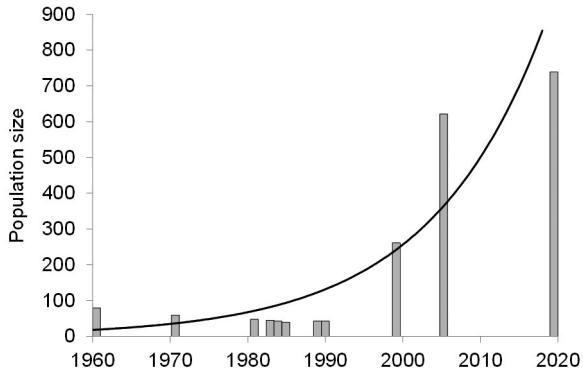

Fig. 2.- Fitted (line) and observed (bars) values of the Navarre white stork population size as obtained from a log-linear population growth model.

Fig. 2.- Valores ajustados (línea) y observados (barras) del tamaño de la población de cigüeña blanca de Navarra obtenidos de un modelo de crecimiento poblacional log-lineal.

Again, this proportion varied significantly among years since the first census of 1960 (χ^2_{20} = 773.7, $P < 0.001$; Table 2). Overall, it can be seen that up to 2004 (note, however, that there were no data for the period 1970-1988), most nests were situated in buildings (mean: 94.5%), but this circumstance showed a dramatic change in 2018, when there were a remarkably lower proportion of nests in buildings compared to other types of substrates, notably trees (see Table 2).

Despite the important population increase, the geographical distribution of the white stork in Navarre has hardly changed since 1960, mainly covering the southern half of this region (Fig. 1). The 5 nests found in the Pamplona district, at the northern part of its distribution, is the only recent colonization.

	1960 (79 nest)	1989 (42 nest)	1998 (261 nest)	2004 (621 nest)	2010 (713 nest)	2018 (739 nest)
Tree	1.3% (-4.3)	2.4% (-3.0)	1.5% (-7.6)	5.5% (-9.8)	30.9% (+2.9)	49.0% (+12.8)
Buildings	98.7% (+4.6)	97.6% (+3.3)	96.9% (+8.0)	84.9% (+8.5)	46.4% (-4.3)	28.8% (-10.6)
Cliffs	- (-2.3)	- (-1.7)	- (-4.2)	4.0% (-2.6)	9.3% (+2.6)	10.0% (+3.5)
Electric towers	- (-2.0)	- (-1.4)	1.1% (-2.8)	4.2% (-0.8)	5.8% (+1.0)	6.9% (+2.4)
Others	- (-1.8)	- (-1.3)	0.4% (-3.0)	1.4% (-3.4)	7.7% (+4.5)	5.3% (+1.4)

Table 2.- Percentage of white stork nests recorded in each type of substrate in the different years in which these data were recorded. In parenthesis, we show the standardized residual values obtained from a chi-square test used to assess if a percentage deviated from a mean global ratio with years pooled. Residual values >3 (or <3) indicate significant deviations.

Tabla 2.- Porcentaje de nidos de Cigüeña blanca registrados en cada tipo de soporte en los diferentes años en los que se recogió esa información. En paréntesis, se muestra el valor residual estandarizado obtenido del test de Chi cuadrado usado para evaluar si el porcentaje de desviaba de la media de los años agrupados. Valor del residual >3 o <3 indican una desviación significativa.

Discussion

The white stork population in Navarre has nowadays its maximum size ever recorded. With around 740 breeding pairs, this population has experienced a significant increase during the last decades, following the same positive trend occurred both in Spain (Molina & Del Moral, 2005; Vergara *et al*., 2007, 2010; Cuadrado *et al*., 2016; Bécares *et al*., 2019) and in Europe in general (Thomsen & Hötker, 2006; EBCC, 2020). This increase has not been constant, but has shown a first phase with little growth or even

a slight decrease between 1960 and the early 90s, followed by an exponential increase in the first years of the 21st century, and an apparent stabilization in the last years, a situation similar to that observed in other populations (Molina & Del Moral, 2005; Cuadrado *et al.,* 2016).

The overall increase in the proportion of nests located in colonies during the 21st century may explain in part the increase of the white stork population in Navarre. Colonial breeding can decrease predation (Burger, 1981; Serrano *et al*., 2005), increase foraging efficiency (Krebs, 1978), and help to communicate information about the location of optimal food patches (Wittenberger & Hunt, 1985). However, colonial birds are often very vulnerable to density-dependent processes (Newton, 2013), since colonies exist if the ecosystem has a relatively high carrying capacity, allowing all birds to breed and survive. Thus, the increasing size of white stork colonies in Navarre suggests that the region has a sufficient amount of suitable habitat for nesting and foraging, with enough trophic sources to sustain a population that could still be growing. This scenario has been in part promoted by food contributions of anthropic origin, like the huge amount of refuse dumps in the Culebrete landfill located in southern Navarre. In fact, this landfill is visited all year round by thousands of storks belonging to the local breeding population, but also by many other storks in passage, that use this landfill as an important stopover area both during the autumn and spring migrations (Resano-Mayor *et al.*, 2016, Arizaga *et al.*, 2018; Bécares *et al*., 2019). Apart from refuse dumps, many storks in Navarre also benefit from other, relatively new habitats, like the rice fields cultivated around the Arguedas area which seem to provide good foraging sites for the species.

In accordance with the European Landfill Directive, the use of open-air landfills should be gradually reduced to a minimum in all Member States (European Union Parlament, 2018). This new policy can cause important changes in the abundance and distribution of white stork populations that nowadays make a frequent use of the refuse dumps, such as the studied population in Navarre or other populations in southern Spain (Cuadrado *et al.*, 2016) and south-central Portugal (Gilbert *et al.*, 2016). If such an abundant food resource suddenly is cut off or even disappear, many birds will be forced to search and compete for alternative and less abundant food, with the associated consequences on their spatial ecology (Arizaga *et al.*, 2014; Gilbert *et al.*, 2016) or demography (Tortosa *et al.*, 2002; Massemin-Challet *et al.*, 2006; Hilgartner *et al.*, 2014). Under such a scenario, the carrying capacity of the system might considerably decrease and, hypothetically, many colonies could decrease in size or even disappear (Newton, 1998, 2013). To what extent the affected individuals could be able to adapt or forced to move is an open question that would deserve further investigation both during breeding and non-breeding seasons.

In respect of the substrate selected to build the nests, the results found in the present study have been radically different from the situation described for Navarre by the

end of the last century, when practically all the nests were located in buildings and nesting in trees was quite anecdotal (Lizarraga, 1989). This change could have been influenced by multiple factors, and one of the most important would be the elimination of nests and the installation of systems to drive away the storks during the restoration of the churches. Stork nests are very bulky and heavy structures (Tryjanowski *et al*., 2009; Vergara *et al*. 2010), which can endanger and damage the integrity of historic buildings such as churches or cathedrals. Therefore nest removal has been a common practice for the last few decades (SEO/Birdlife, 2016). As these management actions require the permission of the competent environmental authority, it has been usually demanded that these nest withdrawals had to be accompanied by the installation of artificial pole nests in the vicinity of riparian forests or poplar plantations, which could have encouraged the colonization of this type of habitat (Cuadrado *et al.,* 2016). This situation is common all over Spain, as shown in the last national census, where trees were the most used substrate (around 40%) for nesting, relegating buildings (around 30%) to a second place (Molina & Del Moral, 2005). However, one peculiarity of the breeding population in Navarre is the relatively common use of cliffs for nesting (10%, the third most frequent substrate), which are rarely used in the rest of Spain (Molina & Del Moral, 2005). This could be partly due to the fact that these cliffs are adjacent to large rivers that are an important source of food (Janiszewski *et al*., 2014; Fasola-Matasaru *et al*., 2018). Therefore, the location of the nests on the cliffs could actually be related with the selection of important foraging grounds that provide good food resources such as those large rivers (Bécares *et al*., 2019). It is also remarkable the low percentage of nests located in power lines detected in Navarre (6.9%) compared to the situation in other European regions, where this substrate is one of the most frequently used by white storks to nest (Tucakov, 2006; Tryjanowski *et al*., 2009; Gyalus *et al*., 2018). The same applies if compared with neighbour regions like Aragón, where power lines are the second most frequently used substrate, with 28.6% of the nests (Pinzolas, 2005). The selection of power lines as a point to locate the nest seems to be related to the scarcity of other suitable supports such as trees in environments with high food availability, such as flat areas intended for intensive agriculture (Infante & Peris, 2003). Navarre has a large river network made up of rivers with reasonably well-preserved riparian forests containing large trees (e.g. Special Conservation Areas ES2200024, ES2200035, ES2200040), where storks can install their nests. Regardless the reason behind, the fact that storks hardly use power lines to nest in Navarre is a very good fact, since the use of this type of structures entails significant costs both economic, due to maintenance problems of the power lines themselves (Negro, 1999; Tryjanowski *et al*., 2009), but also environmental, in the form of stork deaths by electrocution (Garrido & Fernández-Cruz, 2003; Tryjanowski *et al*., 2009).

Finally, the specie's breeding distribution area in Navarre has remained more or less unchanged for the last decades, which agrees with the general unaltered range reg-

istered in Europe, with only a slight expansion (Molina & Del Moral, 2005). This could probably be due to the specie's philopatry and high site-fidelity (Chernetsov *et al*., 2006; Vergara *et al*., 2010; Galarza & García, 2012; Cuadrado *et al*., 2016). In addition, it is well known that the species avoids the forested areas (Carrascal *et al*., 1993; Bécares *et al*., 2019), the mountain habitats (Bécares *et al*., 2019) and Atlantic climate (Molina & Del Moral, 2005). Therefore, the northern half of Navarre would not offer either an adequate bioclimatic zone or an appropriate ecological niche for the species.

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