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Nest characteristics and food supply affect reproductive output of white storks *Ciconia ciconia* in semi-arid areas

Naouel Benharzallah[1] · Abdelkrim Si Bachir[2] · Christophe Barbraud[3]

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Abstract
The aim of this study was to test the influence of nest site characteristics and food supplementation from rubbish dumps on reproductive parameters of white storks breeding in semi-arid habitats. A total of 148 nests were monitored in two colonies of white storks (control colony vs. colony that benefited from high food supply in rubbish dumps) in eastern Algeria over a six-year period (2011–2016) to measure nest characteristics and reproductive parameters (clutch size, number of hatchings, number of fledglings, breeding success). Results showed that pairs breeding at proximity from rubbish dumps had larger clutch sizes (5.1 ± 0.6 *vs*. 4.6 ± 0.6), hatched more chicks (4.7 ± 0.7 *vs*. 4.3 ± 0.7) and raised more fledglings (3.0 ± 0.9 *vs*. 2.6 ± 1.0) than pairs breeding far from rubbish dumps. Results also showed that clutch size was positively related to nest surface area, and that pairs nesting on electricity poles had a lower breeding success than those nesting in trees (48.9 ± 20.4% *vs*. 64.6 ± 17.6%). Our findings suggest that breeding outputs are strongly related to selective behavior in nest placement and food availability surrounding the nesting site.

Keywords breeding success · clutch size · nest size · productivity · rubbish dumps · Algeria

Introduction

In birds, nest site selection is one of the most profound choices affecting an individual's fitness, and ultimately, a population's persistence (Li and Martin 1991). Nest site choice may represent an adaptive strategy and influence reproductive outcomes (Amundsen and Stokland 1990; Reid and Boersma 1990; Bolton 1991). As a consequence, nest site selection is under strong selective pressure and could be an indicator of individual fitness (Vergara et al. 2010). A good nesting site generally provides protection against predators and offers access to feeding areas with available and abundant food resources (Alonso et al. 1991; Ayas 2008). Birds selecting a nest site have to find the best compromise between the risk of predation, the availability of food near to the nest and microclimatic requirements (Forstmeier and Weiss 2004). Understanding nest site selection can also facilitate conservation efforts for endangered species to preserve and enhance their populations (Donázar et al. 1993; White et al. 2006).

Other environmental factors, besides nest site characteristics, that can also have a strong influence on reproductive success, include supplementary food provided by refuse dumps. For many bird species, domestic refuse dumps used as foraging sites offer an abundant and constant human made food resource (Donázar 1992; Bellebaum 2005). Most ecological studies agree that the availability of food resources have strong effects on the abundance of animal populations (White 1978; Chapman et al. 2006). In birds, food supply is an important determinant of breeding success (Watson et al. 1992; Tryjanowski and Kuzniak 2002). Existing studies show that growth patterns and chick survival can be affected by proximity to rubbish dumps (Bosch et al. 1994; Tortosa et al.1995; but see Białas et al. 2021). Supplementary feeding can also

✉ Christophe Barbraud
barbraud@cebc.cnrs.fr

1 Department of Natural and Life Sciences, Faculty of Exact Sciences and Nature and LifeSciences, University of Biskra, 07000 Biskra, Algeria

2 Department of Ecology and Environment, Faculty of Nature and Life Sciences, University Mostefa Ben Boulaïd Batna 2, 05000 Batna, Algeria

3 Centre d'Etudes Biologiques de Chizé, CNRS UMR 7372, F-79360 Villiers-en-Bois, France

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advance laying date (Aparicio and Bonal 2002; Tortosa et al. 2003), increase clutch size (Newton and Marquis 1981; Aparicio 1994; Tortosa et al. 2003; Djerdali et al. 2008) and improve breeding success (Hansen 1987; Gehlback and Roberts 1997; Wiehn and Korpimäki 1997; Si Bachir 2012; Djerdali et al. 2016). Most studies agree that food availability can reduce time and energy needed for searching food, resulting in broods not left unguarded and in breeding adults spending more time rearing their nestlings (Hamer et al. 1993).

The white stork *Ciconia ciconia* (Linnaeus, 1758) is a colonial nesting bird that often constructs its nests in the vicinity of human habitations (Cramp and Simmons 1977). This species builds large nests on a wide variety of supports including trees and human-made artificial structures such as electricity poles, roofs and other artificial nesting platforms or structures (Cramp and Simmons 1977; Tryjanowski et al. 2009). However, the effects of nest site characteristics on reproductive parameters of white storks remain relatively poorly known (Tryjanowski et al. 2009). In several regions of the world, white storks establish colonies next to rubbish dumps and studies have reported changes in foraging strategies, with white storks using more frequently rubbish dumps to feed (Schulz 1998; Tortosa et al. 2003; Kruszyk and Ciach 2010; Vergara et al. 2010). It has been shown that supplementary food provided by rubbish dumps increases the breeding success of white storks breeding in Europe (Moritzi et al. 2001; Tortosa et al. 2002; Massemin-Challet et al. 2006; Djerdali et al. 2008; but see Białas et al. 2021). Nevertheless, these combined effects of supplementary food and nest site characteristics on breeding parameters of the white stork remain poorly understood in semi-arid areas, where environmental conditions differ from those in the northern parts of the species' distributional range. The energy demands are high for breeding white storks during the chick rearing period, which generally coincides with dry conditions in semi-arid areas (May-July, Djerdali et al. 2008; Si Bachir et al. 2012; Djerdali et al. 2016; Benharzallah 2017). As a consequence, white storks breeding in semi-arid areas may use rubbish dumps as supplementary food resources, which may enhance reproductive parameters.

The aim of this study is to investigate the effects of nest characteristics and supplementary food on reproductive parameters (clutch size, number of hatchlings, productivity and breeding success) of white storks breeding in a semi-arid climate in the southern part of the species' breeding range. We studied two colonies in north-eastern Algeria. One colony was situated near rubbish dumps where birds were feeding regularly during the breeding season, and one colony had no access to rubbish dumps within the foraging range of breeding birds. We expected higher reproductive parameters for the colony situated near rubbish dumps than for the other colony.

Material and methods

Study colonies

The study was conducted during six consecutive reproductive seasons (from 2011 to 2016) in the surroundings of the Constantine city, north-eastern Algeria, North Africa (Fig. 1). This area received an average annual rainfall of 496.8 ± 120.8 mm during the last 20 years. It is located in the semi-arid Mediterranean bioclimatic stage with hot, dry summers and cool winters. February and July are the coldest and hottest months with mean temperatures of 7.4 ± 1.7°C and 26.4 ± 0.9°C, respectively. Rainfall is unevenly distributed throughout the year, mainly constituted of winter and spring rains.

Data collection was carried out in two breeding colonies. The first colony, Guigaya Achour (36°15' N, 6°27' E, altitude 624 m a.s.l.), was located southwest of the Constantine city. The breeding area was an agro-pastoral landscape surrounded by cattle farms, cereal fields and vegetable crops. This colony included a maximum of 41 nests built on electricity poles and trees including Carob tree (*Ceratonia siliqua* Linnaeus, 1753) and Aleppo pine (*Pinus halepensis* Miller, 1768). This colony was considered as a control colony (thereafter called control colony). The closest rubbish dump was situated 35 km from the colony, thus well beyond the maximum foraging range known for breeding white storks (≈5 km; Alonso et al. 1991; Johst et al. 2001; Denac 2010; Gilbert et al. 2016).

The second colony, Khennaba, was located in a village east of Constantine city (36°18' N, 6°51' E, altitude 823 m a.s.l.). In this area, arable fields are interspersed with meadows, pastures, human settlements and trees. This colony included a total of 37 nests built on electricity poles and Green oak trees (*Quercus ilex* Linnaeus, 1753). The colony was located 500 m from an urban refuse dump, thus well within the foraging range of breeding white storks (Tortosa et al. 2003). Accordingly, during our field work, we frequently observed white storks leaving nests from the Khennaba colony (thereafter called the supplementary food colony), foraging at rubbish dumps and then returning to their nests (Benharzallah 2017).

Data collection

Each year from 2011 to 2016, a sample of eight to 17 nests were selected randomly within each colony and

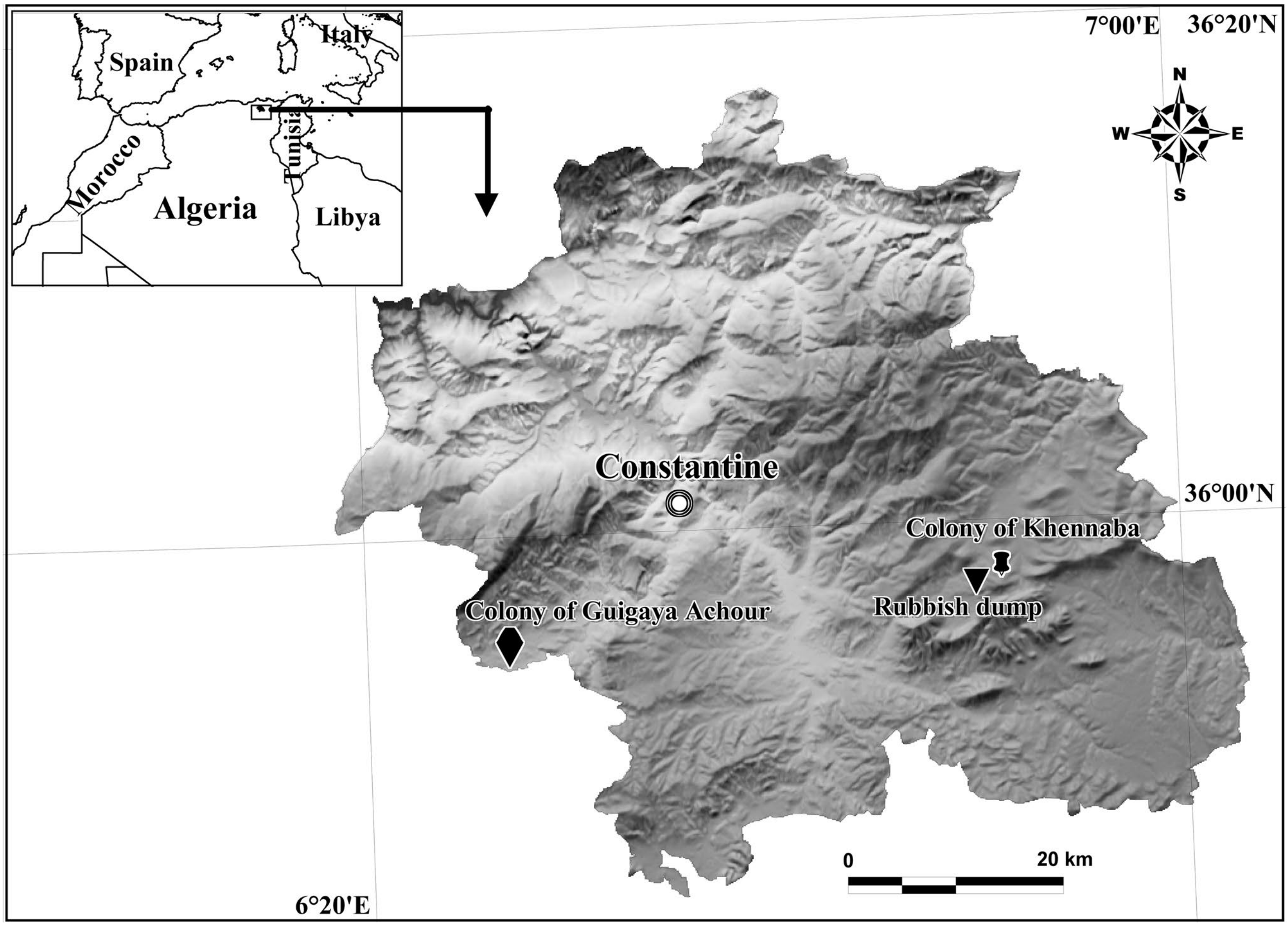

Fig. 1 Location of the study colonies Guigaya Achour (control colony) and Khennaba (supplementary food colony) and the rubbish dump in Constantine region, north-eastern Algeria

were visited regularly from March to July to estimate breeding parameters. In North Africa, first nest occupation dates by white storks are from early January to late February, egg laying starts in early March and last chicks fledge in late July (Benharzallah et al. 2015; Benharzallah 2017). Nest contents were inspected using an 8 m-long aluminum ladder. Nests situated higher than 8 m were visited using a telescopic nacelle mounted on a truck made available to us by the local authorities. Nests were marked using plastic tags numbered with a permanent marker.

We recorded the following variables for each nest: type of nest support structure, height of nest support structure (which can be higher than the height of the nest), nest height from the ground, nest surface area, clutch size, number of hatchlings, productivity and breeding success. Nests support structures were of two types (trees and electricity poles). Nest height (in meters) was measured with a Laser rangefinder. Nest surface area (in m^2) was estimated using the formula [$\pi \times$ (length/2) $\times$ (width/2)], where length was the longest measurement of the nest and width was the measurement of its corresponding perpendicular axis (Vergara et al. 2010). Clutch size was the number of eggs in the nest when the clutch was completed (Kosicki and Indykiewicz 2011). Hatchling number was the number of chicks hatched per nest where all eggs were laid (Si Bachir et al. 2008; Benharzallah et al. 2015). Productivity was estimated as the number of chicks fledged per nest. Fledged chicks were defined as nestlings older than seven weeks which were still on the nest and about to fledge (Si Bachir et al. 2012). The breeding success was expressed as the ratio of the total number of fledglings to the total number of eggs laid (Hafner 1977; Franchimont 1985).

Each nest was visited at least once a week during the nesting season. Once egg laying was initiated, nests were inspected every three days until the completion of the clutch. During the incubation period (≈ 32 days, Cramp and Simmons 1977), we only accessed to nests just before the expected hatching date based on our knowledge of laying dates to minimize disturbance. After the first young hatched, we visited the nests every two days to monitor the number of hatchlings. Number of fledglings was established by counting the number of chicks in the nests two months after hatching.

Statistical analysis

Mann-Whitney U-tests were used to examine differences in nest site characteristics (nest surface, nest support height and nest height) between the two studied colonies.

We fitted generalized linear mixed models (GLMM) to determine the effect of colony considered as a proxy of food supply due to their proximity to rubbish dumps, nest support height, nest height, nest surface area and type of nest support structure on breeding parameters (clutch size, number of hatchlings, productivity using a Poisson distribution and breeding success using a normal distribution). Because of the high correlation between nest support height and nest height from the ground (Pearson's correlation $r = 0.897$, $p < 0.001$), we choose not to include nest height as an explanatory variable. The height of nest supports and the breeding parameters were regarded as continuous variables, and the type of nest support was treated as a categorical variable (1 for trees and 2 for electricity poles). Year was not included as an explanatory variable in this analysis because our primary purpose was to determine the effect of nest site selection and supplementary food on breeding parameters. Nest identity and breeding season (year) were included as random effects, and colony, nest surface, type and height of nest support structures as fixed effect. The normality of residuals was assessed and presented a normal distribution.

Statistical analyses were performed using Rcmdr package version 2.04 (Fox 2005) for R software (R Development Core Team 2014).

Results

Nest characteristics

For all the nests studied in the two colonies, 52% were built on trees and 48% on electricity poles. The average nest surface was 2.9 ± 0.8 m^2 (minimum: 0.9 m^2, maximum: 4.5 m^2). Nest surface varied significantly between the two studied colonies (U-test = 3.64, $p = 0.0002$). Nest surface was on average larger in the control colony (3.1 ± 0.6 m^2) than in the supplementary food colony (2.6 ± 0.9 m^2, Fig. 2). There was no significant difference in nest surface between years (Kruskal–Wallis test $K^2 = 3$, $df = 5$, $p = 0.69$).

Nests support height averaged 10.8 ± 2.5 m (range: 6 to 13 m) and nest support height differed between colonies (U-test = -2.344, $p = 0.002$). Nest supports were higher in the supplementary food colony (11.3 ± 2.6 m) than in the control colony (10.5 ± 2.3 m, Fig. 2). Nests used by white storks were situated between 5 to 13 m high and

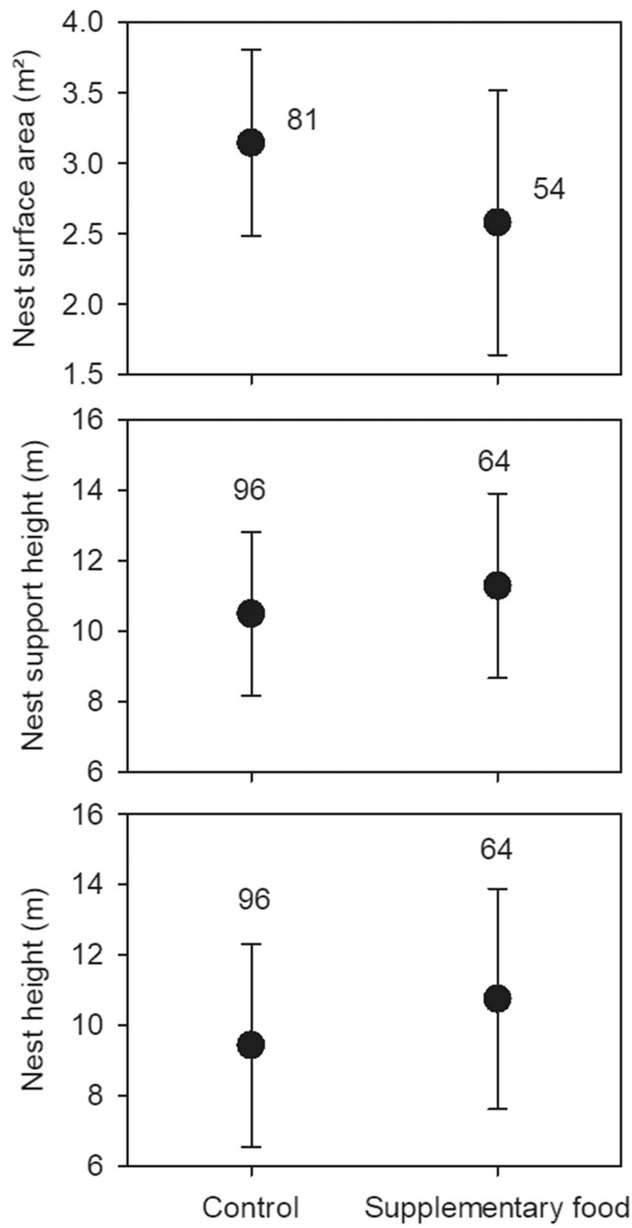

Fig. 2 Boxplots showing variation of nest surface parameters of white storks in two colonies of Constantine region (north-eastern Algeria) during six breeding seasons (from 2011 to 2016)

differed between the two colonies (U-test = -2.12, p = 0.003). Nests were higher above ground in the supplementary food colony (10.7 ± 3.1) than in the control colony (9.4 ± 2.9, Fig. 2).

A total of 148 nests were inspected during the six breeding seasons in the two colonies. Mean annual values of clutch size, number of hatched chicks, productivity and breeding success are shown in Table 1. Clutch size varied from three to six eggs and mean clutch size was 4.8 ± 0.6. Number of hatchlings ranged from 2 to 6 hatchlings per nest with an average brood size of 4.5 ± 0.7. In our study area, pairs produced on average 2.8 ± 1.0 fledglings and mean breeding success was 57.1 ± 20.5 % (Table 1).

Table 1 Breeding parameters of white storks nesting in two different colonies in Algeria during 2011-2016 (mean ± SD, sample size in parenthesis). n = total number of monitored nests

Year	Guigaya Achour (control colony)	Khennaba (supplementary food colony)
Clutch size (number of eggs)		
2011	5.0 ± 0.7 (10)	5.0 ± 0.7 (09)
2012	4.5 ± 0.7 (13)	5.0 ± 0.5 (08)
2013	4.8 ± 0.6 (11)	5.1 ± 0.3 (08)
2014	4.4 ± 0.5 (16)	5.0 ± 0.6 (13)
2015	4.6 ± 0.5 (17)	5.0 ± 0.7 (13)
2016	4.6 ± 0.5 (17)	5.4 ± 0.5 (13)
Mean (n = 148)	4.6 ± 0.6 (84)	5.1 ± 0.6 (64)
Number of hatched chicks		
2011	4.8 ± 0.8 (10)	4.5 ± 0.9 (09)
2012	4.0 ± 0.8 (13)	4.6 ± 0.9 (08)
2013	4.7 ± 0.6 (11)	5.0 ± 0.0 (08)
2014	4.2 ± 0.5 (16)	4.5 ± 0.7 (13)
2015	4.2 ± 0.6 (17)	4.5 ± 0.8 (13)
2016	4.3 ± 0.6 (17)	4.9 ± 0.3 (13)
Mean (n = 148)	4.3 ± 0.7 (84)	4.7 ± 0.7 (64)
Productivity (number of fledglings)		
2011	2.8 ± 0.9 (15)	2.9 ± 0.8 (09)
2012	2.3 ± 1.2 (15)	2.4 ± 1.6 (08)
2013	2.6 ± 1.0 (15)	3.4 ± 0.7 (08)
2014	2.8 ± 0.9 (16)	2.9 ± 0.9 (13)
2015	2.8 ± 0.7 (17)	3.0 ± 1.0 (13)
2016	2.2 ± 1.1 (17)	3.3 ± 0.7 (13)
Mean (n = 148)	2.6 ± 1.0 (84)	3.0 ± 0.9 (64)
Breeding success (%)		
2011	61.0 ± 20.6 (10)	58.9 ± 17.3 (09)
2012	47.7 ± 29.1 (13)	45.8 ± 30.3 (08)
2013	58.8 ± 19.0 (11)	66.2 ± 15.9 (08)
2014	61.6 ± 17.7 (16)	57.2 ± 16.0 (13)
2015	60.9 ± 17.9 (17)	61.0 ± 18.5 (13)
2016	46.8 ± 23.2 (17)	61.5 ± 13.1 (13)
Mean (n = 148)	55.8 ± 21.9 (84)	58.8 ± 18.6 (64)

Effect of nest site characteristics on breeding parameters

Clutch size was positively affected by nest surface area (Table 2). Large nests contained more eggs compared to smaller ones.

The type of nest support affected breeding success (Table 2). Pairs nesting on electricity poles fledged lower numbers of chicks than those nesting on trees. There was no other effect of nest characteristics on breeding parameters (Table 2).

Effect of colony on breeding parameters

The GLMM analysis indicated that pairs breeding in the supplementary food colony situated close to rubbish dumps laid more eggs, hatched larger broods and fledged more chicks than those breeding in the control colony (Table 2).

Discussion

In the present study, we investigated the effects of nest characteristics and colony on breeding parameters in two colonies of white storks in a semi-arid area in eastern Algeria. Our results showed that several breeding parameters (clutch size, number of hatched chicks, productivity) were higher in the supplementary food colony, situated close to rubbish dumps, than in the control colony. Clutch size was also larger in large nests and productivity lower in nests situated in electric poles. We also found that nests in the control colony were larger than those in the supplementary food colony, which could be due to the fact that there are more nests in the trees which provide a greater breeding platform than electric poles.

Pairs breeding in larger nests laid more eggs. These findings support earlier findings that early arriving birds occupied larger nests, started breeding earlier and laid more eggs (Djerdali 2013; Benharzallah et al. 2015). The nest surface effect found in this study might be related to parent age and/or quality. Larger nests could be indicators of the physical strength or individual quality of the male which arrives first on the nest site and influence the decision of the female when choosing a sexual partner (Moreno 2012).

Our study also suggests that nests built on electricity poles had a lower breeding success than nests built on trees. In birds, many studies have shown that nest-site characteristics can strongly influence the number and quality of young that can be successfully fledged (Rendell and Robertson 1989; Si Bachir et al. 2008; Beardsell et al. 2016).

Table 2 Results of generalized linear mixed models (GLMMs) testing for the effect of nest characteristics and colony on breeding parameters of white storks in the Constantine region. For the effect of colony the reference colony was Guigaya Achour (i.e. the control colony), for the effect of nest support type the reference type was trees

Parameter	Variables	Estimate	SD	*t*	*p*
Clutch size	Colony (Khennaba)	0.682	0.126	5.396	< 0.001
	Nest surface	0.000028	0.000007	4.031	< 0.001
	Nest support (poles)	0.129	0.210	0.614	0.544
	Nest support height	-0.048	0.043	-1.132	0.260
	Random effects	Nest:0.177 Year:0.500 Residual:0.178			
Hatched chicks	Colony (Khennaba)	0.493	0.181	2.724	0.011
	Nest surface	0.000009	0.000007	1.617	0.109
	Nest support (poles)	0.267	0.300	0.888	0.382
	Nest support height	-0.078	0.061	-1.271	0.206
	Random effects	Nest: 0.334 Year:0.578 Residual:0.225			
Productivity	Colony (Khennaba)	0.596	0.244	2.438	0.022
	Nest surface	0.000006	0.000012	0.482	0.631
	Nest support (poles)	-0.586	0.405	-1.445	0.160
	Nest support height	-0.057	0.082	-1.445	0.488
	Random effects	Nest: 7.015 Year: 18.735 Residual: 6.778			
Breeding success	Colony (Khennaba)	5.339	4.678	1.411	0.264
	Nest surface	- 0.00012	0.000251	- 0.471	0.638
	Nest support (poles)	-17.168	7.796	-2.202	0.037
	Nest support height	0.044	1.586	0.028	0.978
	Random effects	Nest: 7.671 Year: 16.769 Residual: 6.271			

Our results are in agreement with those of Vaitkuvienė and Dagys (2014) who found that electricity poles had a negative effect on white stork breeding success, and influence the orientation of incubating birds (Zbyryt et al. 2021a). Gilmer and Wiehe (1977) have reported that the number of young fledged by Ferruginous hawks (*Buteo regalis* Gray, 1844) nesting on electrical towers was lower than in nests built on natural supports. Nesting on electrical pylons may increase the risk of electrocution or collision in electric cables, and provides no protection from rain or overheating (D'Amico et al. 2018). However, Tryjanowski et al. (2009) found no difference in productivity between white storks nesting on electricity poles and those nesting on natural supports (but see Zbyryt et al. 2021b). In our study, we suspect that the lower breeding success in nests built on poles could be explained by the exposure of fledglings to electrocution. Indeed, we observed electrocution of several chicks during their flight training period just before fledging.

Our results indicated that pairs breeding in the supplementary food colony situated close to rubbish dumps laid more eggs, hatched larger broods and fledged more chicks than those breeding in the control colony with no access to a rubbish dump. In fact, clutch size and productivity measured in the supplementary food colony were among the highest of those previously reported in European populations (Table 3). Since nest surface area was larger in the control colony, and since larger nests received larger clutches, these differences were not due to differences in nest sites characteristics. Given that differences in breeding parameters between colonies were consistent across years, we suspect that they were mainly caused by food supplementation linked to the proximity of rubbish dumps in the Khennaba colony. During field work, white storks breeding at the supplementary food colony were observed feeding in rubbish dumps and food items that came from these dumps were observed in the nests (domestic chicken heads and legs, sheep's skin, fish fragments and meat, spaghettis).

Average clutch size reported for the supplementary food colony was higher than those observed in other white stork populations using supplementary food resources (Sétif, eastern Algeria: 4.8 ± 0.6, Djerdali et al. 2008; southern Spain: 4.1 ± 0.8, Tortosa et al. 2003; but see Białas et al. 2021). In bird populations, food supplementation is an important factor affecting reproductive parameters (Lack 1954; Newton and Marquis 1981; Ceballos and Donázar 1990; Donázar 1992). Lack (1967) hypothesized that available food supplies for the

Table 3 Average breeding parameters (clutch size and productivity) in European white stork populations

Parameter	Mean ± SD	Locality	Authors
Clutch size	4.3 ± 0.7	Western Poland	Tobolka et al. (2015)
	3.8	Western Poland	Kosicki and Indykiewicz (2011)
	3.8	Denmark	Skov (1992)
	4.0 ± 0.8	Southern Poland	Profus et al. (2004)
	4.1 ± 0.8	Espagne	Tortosa et al. (2003)
	4.5 ± 0.9	South West France	Barbraud et al. (unpublished data)
	4.6 ± 0.1	North East France	Massemin-Challet et al. (2006)
	4.2	Germany	Kaatz and Stachowiak (1987)
	4.1	Portugal	De Barros and Moura (1989)
	4.0	Bulgaria	Michev et al. (1989)
	3.8	Netherland	Haverschmidt (1949) in Profus (1991)
	2.7	Western Poland	Kosicki and Indykiewicz (2011)
	2.3 ± 1.3	Western Poland	Tobolka et al. (2015)
	2.7 ± 0.04	Spain	Vergara and Aguirre (2006)
	3.7	Greece	Goutner and Tsachalidis (2007)
	2.9 ± 0.05	Ukraine	Grishchenko and Yablonovska-Grishchenko (2010)
Productivity	2.5 ± 0.1	North East France	Massemin-Challet et al. (2006)
	2.7 ± 1.2	WesternTurkey	Göcek et al. (2010)
	3.8 ± 0.7	NorthernTurkey	Yavus et al. (2012)
	2.4	Germany	Kaatz (1999)
	1.8	Netherlands	Van der Have et al. (1999)
	2.6	France	Duquet (1999)
	3.2 ± 1.1	South West France	Barbraud et al. (1999)

female of Anatid species influenced clutch size. According to Tortosa et al. (2002) rubbish dumps provide an abundant and permanent food resource for white storks during the breeding period. Our results are in agreement with other studies which found that food availability had a positive effect on clutch size in this species (Gómez-Tejedor and De Lope 1993; Tryjanowski and Kuzniak 2002; Massemin-Challet et al. 2006; Djerdali et al. 2008; Si Bachir et al. 2013; but see Białas et al. 2021). The higher clutch size laid by pairs breeding in the supplementary food colony situated close to rubbish dumps could be due to the use of garbage dumps by females to feed. Females breeding close to rubbish dumps may accumulate substantial body reserves which could be invested into additional eggs and egg shell formation, as the white stork is a partial capital breeder (Tobolka et al. 2018). In birds, good correlative evidence exists between the accumulation of energy reserves in females and clutch size (Ankney and Macinnes 1978; Ankney et al. 1991). However, carry-over effects from environmental conditions encountered during the non-breeding season may also affect clutch size (Tobolka et al. 2018), although the wintering sites of the studied populations remain unknown.

Further support of the effect of food supplementation provided by rubbish dumps comes from the fact that we found higher number of hatchlings and productivity in the supplementary food colony. Other studies on white storks (Moritzi et al. 2001; Massemin-Challet et al. 2006; Djerdali et al. 2016) highlighted a higher number of fledglings for pairs breeding close to a reliable and abundant food supply, such as rubbish dumps, throughout the breeding cycle. This suggests that, in presence of nearby food resources parents do not need to move far from the nest to forage and therefore spend more time incubating eggs and caring for chicks (Bollinger et al. 1990; Grieco 2002).

In our study, number of hatchlings and productivity were positively correlated to clutch size (Spearman rank correlation, $r = 0.63$, $p < 0.001$ and $r = 0.30$, $p < 0.001$, respectively). These relationships may explain why we found that the number of hatchlings and the number of fledglings were higher in the supplementary food colony. Nevertheless, the number of fledglings was 15.4% lower in the control than in the supplementary food colony, while clutch size and number of hatched chicks were only 9-10% lower. This may suggests that brood reduction may have been slightly stronger in the control colony or that external factors such as heavy rainfall (Hilgartner et al. 2014), although no statistically significant effect was detected on breeding success, contrary to previous studies in this species which concluded that breeding success was correlated to food availability (Massemin-Challet et al. 2006). The lack of difference in breeding success between the two colonies could also be due to negative effects of feeding in the rubbish dumps for birds breeding as the supplementary food colony such as increased exposure to pathogens (Pineda-Pampliega et al. 2021). Nevertheless, estimates of breeding success obtained in our study were similar to those obtained in other populations not feeding on rubbish dumps (from 54% to 71% based on mean productivity and mean clutch size values in western France, eastern France and Germany shown in Table 3).

Our data suggest that nest characteristics and colony used here as a proxy of food supplementation play a major role in affecting the reproductive success of white storks in a semi-arid habitat. As rubbish dumps are abundant in the vicinity of many urban areas situated in semi-arid habitats in Algeria and other North African countries, this may contribute to explain the positive population growth rates of white stork populations observed during the past decades in this region (Moali-Grine et al. 2013).

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Declarations

Conflict of interest The authors declare that they have no conflict of interest.

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