The effects of colony size interacting with extra food supply on the breeding success of the White Stork (Ciconia ciconia)

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Abstract

In the present study, we evaluated the effect of distance to food from rubbish dumps and colony size on White Stork breeding success. Waste from poultry farms is expanding in the study area and is commonly used by the White Stork as a new food resource, which may explain the increase in the number of breeding Storks in the region. The study was carried out at 24 sites, including 88 different colonies of White Stork in northern Algeria, Sétif (36°09′N, 05°26′E; 900 m.a.s.l.); over a 4-year period (2002–2005) with considerable variation in rainfall. Nests were monitored at different distances from 30 rubbish dumps emanating largely from chicken farms. Results of the General Linear Mixed Models (GLMM) showed that breeding success of White Stork was dependent upon distance to dumps, recording the highest values in nests close to these places with food supply. There was a highly significant interaction between the year and the distance to the rubbish dumps. That is, reproductive success was higher when there was extra food in all years except in 2002, which could be due to the very low rainfall during spring 2002. Also, we found a significant interaction between colony size and distance to a rubbish dump. Results suggest that White Stork breeding success was also affected by natural food resources, since bigger colonies may deplete natural prey sooner, which is more evident in dry years.

Keywords: Anthropogenic food subsidies; White Stork; Breeding success; Colony size; Algeria.

Introduction

Despite the large amount of literature on the impact of supplemental food on birds as a single factor, Ruffino et al. (2014) recently showed a wide variability of responses of birds to food supply, suggesting that life-history traits, environmental/climatic conditions, natural food abundance or competition might explain the variable responses of birds to food supply.

Optimal foraging theory (Stephens and Krebs 1986) has proposed that animals optimize their resource acquisition by selecting the more productive patches, and accordingly we should expect that many birds breed close to any high quality spot. Currently, many of the spots providing continuous food resources have an anthropogenic origin. Dumps are considered one of the three main predictable anthropogenic food subsidies (PAFS) having the potential to sustain a large number of species and individuals, including birds (Oro et al. 2013). This predictability means a low variation in food availability in space and time that could positively affect life history traits. Therefore, extra food from garbage dumps may affect not only breeding success, but also the concentration of many birds breeding pairs around these human subsidized feeding spots (Arcese and Smith 1988; Tortosa et al. 1995a). However, an increase in breeding pair density around high quality patches may produce a decrease in the individual food intake due to resource depletion. Fretwell and Lucas (1970) proposed the concept of ideal free distributions (IFD), assuming that patches' qualities differ and that suitability declines with increasing population density in any patch. According to the IFD, we should expect a tradeoff between the attraction around garbage dumps due to their constant and abundant food availability and the limitation effect of breeding at high densities. A recent model proposed by Zurell et al. (2015) to explain the density dependence population dynamics in the White Stork emphasizes that accounting for interactive effects of individual behaviour and local environmental factors is crucial for understanding density-dependent processes within spatially structured populations.

The White Stork (*Ciconia ciconia*) is a species whose populations dramatically decreased until the mid 1980s, when it became extinct in some countries such as Belgium, Switzerland and Sweden (Zink 1967; Schüz 1980). This decrease was followed by an overall positive population development during the following 20 years (Shulz 1999). In Algeria, the population of White Stork strongly decreased between 1955 and 1974, with a loss of 75 % of breeding pairs (Thomas et al. 1975). Since 1993, a considerable increase in this population has occurred, with a total of about 80 % of breeding pairs

(Moali-Grine et al. 2004; Djerdali 2010) all over the world (Thomsen and Hötker 2006).

One main factor positively affecting the life history trait in the White Stork is additional food emanating from new prey such as the introduced invasive red swamp crayfish *Procambarus clarkii* (Negro and Garrido-Fernández 2000) or from rubbish dumps (Tortosa et al. 2002; Massemin-Challet et al. 2006; Aguirre and Vergara 2007). In fact, the presence of dumps in White Stork areas for both wintering and breeding has a positive effect on clutch size, egg volume, hatching and breeding success (Tortosa et al. 1995b, 2002; Djerdali et al. 2008b, 2016). Nevertheless, reproductive success is also known to be affected by climatic conditions (Jovani and Tella 2004; Denac 2006; Kosicki 2011; Tobolka et al. 2015); mainly by spring precipitation on the breeding ground (Nevoux et al. 2008) or by migration strategy (Massemin-Challet et al. 2006; Aguirre and Vergara 2007; Gordo et al. 2013).

However, the use of rubbish dumps as a food resource may also have a negative effect on the birds that commonly feed on them. Birds foraging in the garbage can be contaminated with a large range of pathogens dangerous not only to the fauna, but to humans and domestic animals (Monaghan et al. 1985). The lethal effect of the consumption of plastics and other dangerous material has been also documented (Peris 2003; Henry et al. 2011). For instance, in a comparative study in urban and rural White Stork colonies in

Spain, higher concentrations of some toxics, such as Polybrominated diphenyl ethers in the eggs located in urban areas, have been reported (Muñoz-Arnanz et al. 2011).

The aim of this paper is to test the effect of the abundant extra food from dumps under different climatic conditions (normal to extremely low rainfall years during breeding season), accounting for the effect of distances from garbage to the breeding sites in colonies with different sizes. We predict that the breeding success will be reduced in the driest years despite the extra food, and also predict a negative effect of colony size.

Methods

Study area

The study was conducted in the Wilaya (department) of Sétif, north-east Algeria, in an area of 6504 km^2 located between 05°00′06°00′E and 35°40′36°35′N. This is a semi-arid climatic region with a long drought period that typically lasts from mid May to the beginning of October (C.M.S. 2005). This region is characterized by the predominance of plains that are mostly used for cereal crops such as Durum Wheat *Triticum durum* L., Barley *Hordeum vulgare* L., and livestock, mainly including extensive sheep, intensive poultry farming and cattle grazing. The region is also characterized by a diversity of trees, such as Poplar *Populus alba*, Ash *Fraxinus angustifolia*, Elm *Ulmus campestris*, Holm Oaks *Quercus ilex*, and Aleppo

Pine *Pinus halepensis*, used widely by the White Stork as supports to build nests.

Survey method

The study was carried out in 88 different colonies of White Stork over a 4-year period (2002–2005) in which a great variation in precipitation occurred. We reviewed all of the study area looking for breeding colonies, and all located colonies were considered in this study. A very low rainfall in 2002 during the rearing period (months of April, May and June) was recorded (8.3 mm), in comparison with the subsequent years (51.1 mm in 2003; 49.8 mm in 2004 and 24.8 mm in 2005), the historical rainfall mean in these months during the 10-year period being 34.4 mm.

Breeding success was measured as the number of chicks still alive at 40 days or older, which is a reliable measure of the final number of fledglings, due to low mortality during the latter stages of chick development (Djerdali et al. 2008a; Kosicki 2011). Data collection was made from the 10th to the 30th of June to ensure that no chick had already fledged. Every colony was visited one or two times to ensure that nestlings were counted when they were older than 40. Counts were made during the morning when chicks are fed more frequently and they are standing in the nest, facilitating their count. Nests were monitored around 30 rubbish dumps emanating mostly from chicken farms through these years. Colonies ranged from 50 m to more than 22 km from the nearest rubbish dump. We considered the average distance from the nearest garbage to the center of every colony for all nests of colonies in our analysis.

Six hundred and one nests were monitored in 2002, 806 in 2003, 776 in 2004 and 837 nests in 2005. White Storks were observed foraging at the rubbish dumps. Chicken remains were frequently found in their nests, in about 70 % of nest inspections (Djerdali 2010). All rubbish dumps include both domestic garbage and chicken bodies from the closest chicken farms. We assume that storks find ad libitum food in the garbage, since in all cases, storks actively forage during the early morning and at the end of the day, but rest on the edges of the rubbish dumps during the rest of the day.

Data analysis

To evaluate the effect of distances to garbage on breeding success, we used General Linear Mixed Models (GLMM), the response variable being breeding success, defined as the number of chicks per nest (40 days age or older), which fitted a binomial distribution (range 0–4) with logit function. The year was included as categorical variable, the distance from the nearest dump and the colony size were used as predictor variables, and the site was included as random factor. The interactions between the three independent variables were also included in the model. Post hoc test (Fisher's LSD) within the mixed model procedure was used to assess differences in the breeding success among the years. The entire statistical analysis was performed using InfoStat software.

Results

From a descriptive point of view, the average distance to the nests from rubbish dumps was 6.88 km ± 0.123, the mean colony size was 37.6 nests ± 0.47, ranging from two up to 128 nests, and the mean breeding success was 2.2 ± 0.02 (mean ± EE are showed in all cases). The results from the GLMM showed that the breeding success was negatively associated with the distance to the nearest rubbish dump and a significant effect of the year (Fig. 1). In addition, we had a significant interaction between the year and the distance to the garbage, which means that the effect of the distance to the rubbish dumps differed among the years (Table 1). The nests located close to the garbage had higher reproductive success in the years 2003, 2004 and 2005, but in 2002, the distance to the dump did not have an evident effect, meaning that extra food from rubbish dumps did not affect White Stork breeding success in this year. The post hoc test showed that the lowest breeding success was recorded in 2002 (the driest year, 1.75 ± 0.04 SE), and the highest value in 2005 (2.46 ± 0.03), with intermediate values in 2003 (2.23 ± 0.03) and 2004 (2.22 ± 0.03). Although the colony size did not have an important effect as a single variable, its interaction with rubbish dump was significant (Table 1), the positive effect of rubbish proximity on breeding success being less evident in bigger colonies (Fig. 2). In other words, at the same distance, bigger colonies recorded lower values of breeding success than smaller ones.

Discussion

If White Storks forage according to an ideal free distribution manner, we should expect them to distribute themselves between different patches in proportion to the resource availability in such a way that individual fitness in each habitat is equal (Fretwell and Lucas 1970).

Our data show that White Storks nesting close to rubbish dumps had significantly higher breeding success than those pairs breeding further from the dumps. These results agree with previous studies in other Southern European regions (Tortosa et al. 2002; Massemin-Challet et al. 2006; Aguirre 2006) and in Central Europe (Hilgartner et al. 2014 but see Moritzi et al. 2001). The higher breeding success in nests around rubbish dumps can be explained by a constant, abundant and predictable food source. In fact, White Stork has found a new protein resource emanating from chicken farms (Djerdali et al. 2008b). These feeding places may contribute to the increase in local breeding populations around them, due to the strong philopatric behaviour found in this species in which most recruited storks breed close to their natal nests (Tortosa et al. 1995a). In contrast, Si Bachir et al. (2013), in a study on colony size and breeding success in the White Stork in north-east Algeria, reported higher breeding success in areas with high precipitation rates in slightly anthropogenic habitats than in those pairs breeding close to rubbish dumps, and they also mentioned that distance to refuse dumps affected the establishment of large colonies but didn’t affect breeding success.

However, the positive effect of rubbish dumps was not apparent in 2002, where the breeding success was very low regardless of the distance to dumps (Fig. 1). This interaction could be explained by the very low rainfall during the rearing season (months of April, May and June) in 2002 for our White Stork population, when most birds hatched in April and May (Djerdali et al. 2008b). A decrease in nestling survival when rainfall is scarce may be due to a decrease in small prey availability, since invertebrates are the main food intake during first few days after hatching. This suggests that White Stork breeding success is also affected by natural food resources, and under a natural food shortage situation, the food provided by dumps could not be enough to ensure a higher breeding success.

In Algeria, White Stork is a highly insectivorous (Boukhamza et al. 1995; Cheriak et al. 2014). Younger nestlings feed on small invertebrate prey such as insect larvae, worms, and molluscs whose activity is greatly affected in the driest years, which in turn indirectly affects potential food resources available to storks (Dallinga and Schoenmakers 1987; Tryjanowski and Kuźniak 2002). Small prey are known to be critical for young nestlings (Kosicki et al. 2006). The lack of small invertebrates could strongly affect nestling survival during the first weeks of life, as has been shown by Djerdali et al. (2008a) in Algeria, where a high mortality occurred during the first 2 weeks of life due to low rainfall.

As a general rule, a more evident effect of supplemental food on bird reproduction is found with a lower availability of natural food resources (Ruffino et al. 2014), probably due to a preference for these natural prey. However, in our case, this positive effect could not be apparent in extremely food shortage conditions, since White Stork nestlings could need a threshold value of natural food availability to cope with their nutritional requirements and evidencing a positive effect of dumps.

We also found a significant interaction between distance to rubbish dump and colony size, suggesting that the effect of rubbish dump on breeding success is also modulated by colony size. As Fig. 2 shows, the positive effect of food supply, measured as the distance to rubbish dump, was more evident in medium size colonies; that is, at the same distance, a higher number of chicks was attained in colonies of medium size, reaching the lowest value of that in the biggest ones. Regarding the decrease in breeding success in bigger colonies, it could be translated to density-dependent food depletion in both natural food and extra food, since at the same distance from dumps, bigger colonies recorded lower values of breeding success than smaller ones. Our results suggest that colony size may cause density-dependent food depletion;

most likely, through competition for food, a phenomenon that could determine breeding success. Similar conclusions were proposed by Kosicki (2010), after exploring the breeding performance of White Stork in intensively cultivated farmlands in Western Poland. This author concluded that breeding density might be one of the key factors that affect overall breeding success by depending on strong competition for food. Similar results were also found by Tryjanowski et al. (2005), who proposed that colony size and breeding success were strongly affected by access to food in the White Stork. Szostek et al. (2014) suggested that reproductive success in the Common Tern *Sterna hirundo* was related to overall colony size, as a result of resource depletion and food competition. In Magellanic Penguins, Forero et al. (2002) tested how conspecific food competition explains variability in colony size, and found that high breeding densities provoke a depletion of high-quality prey. Hence, natural prey depletion may result in lower breeding success in bigger colonies. Indeed, the fact that the distance to rubbish dumps did not have a positive effect in the driest year and the afore-mentioned density-dependent effects suggesting that food provided by rubbish dumps cannot supply the food requirements provided by natural resources in all cases, then the apparent positive effect of rubbish dumps is therefore not always evident. On the other hand, if dumps were closed due to an EU Directive (Council Directive 1999/31/EC), this could lead to population crashes in many areas where natural prey cannot support the current number of storks.

Our results show that White Stork breeding success has been conditioned by external factors such as rainfall and distance to rubbish dump, as well as population factors like colony size. However, to attain a better understanding of those factors, it is necessary take into account the interaction between them, since, as we proved in this study, the real effect of some variables depended on second ones, it thus being advisable to include these interactions in further studies to assess the factors affecting breeding success. Pairs breeding in close distance to rubbish dumps were more successful breeders than pairs of more distant nests, although this positive effect was not evident during years with very low spring rainfall, suggesting that natural food resources play an important role for breeding success. Therefore, in a scenario in which climate change may reduce precipitation in Northern Africa, natural food resources could be also reduced, which ultimately could negatively affect White Storks populations, despite the abundant extra food provided in the rubbish dumps.

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Table 1. GLMM results for analyzing independent effects on breeding success

Variable	Chi square	*df*	*p* value
Year	143.29	3	<0.0001
Colony size	0.65	1	0.4
Distance to rubbish dumps	69.64	1	<0.0001
Year × colony size	6.7	3	0.08
Year × distance to rubbish dumps	15.20	3	0.0017
Colony size × distance	10.4	3	0.0027
Colony size × distance × year	5.3	3	0.14

Breeding success as dependent variable, year as categorical variable and distance to the rubbish dumps as predictor variable. The site was included as random factor.

Figure 1. Predictive values of White Stork breeding success in relation to distance to rubbish dumps (m) during the period 2002–2005.

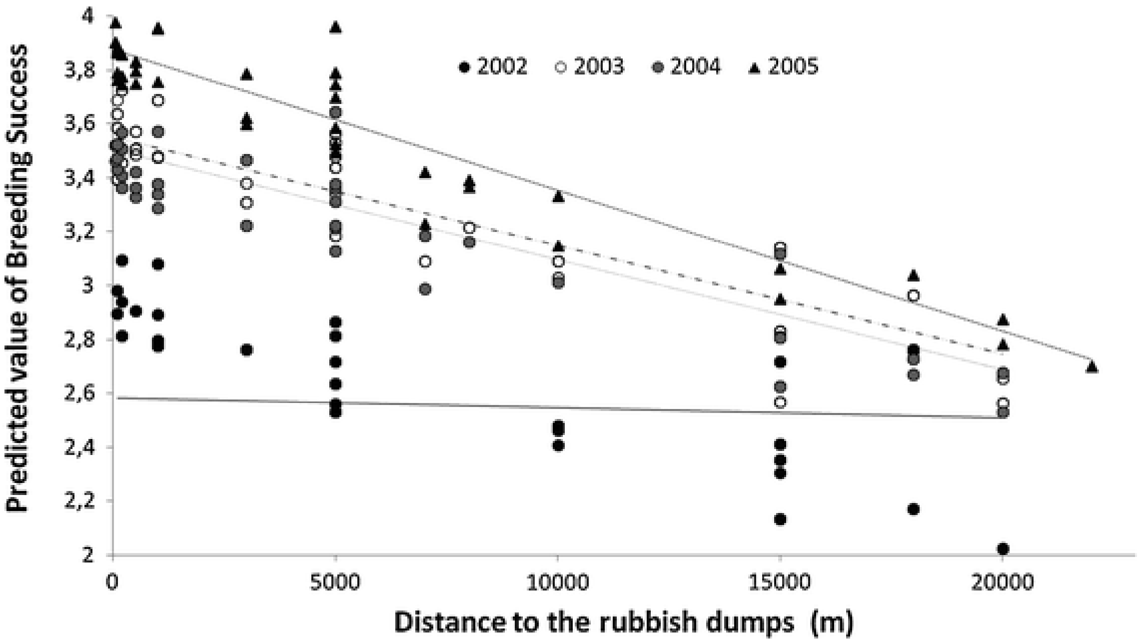

Figure 2. Breeding success (number of chicks still alive at 40 days or older) as a function of distance to rubbish dumps (m) and colony size (number of breeding pairs). Dark areas indicate higher breeding success.