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Breeding density, spacing of nest-sites and breeding performance of black storks *Ciconia nigra* in Dadia-Lefkimi-Soufli Forest National Park, north-eastern Greece

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Abstract. Breeding densities and the breeding biology of the black stork *Ciconia nigra* were studied in Dadia – Lefkimi – Soufli Forest National Park, north-eastern Greece, during 2006–2008. One hundred and one breeding attempts were monitored during the 3-year study period. In total 271 fledglings were successfully raised during that period. Black storks arrived in the study area between the last days of February and mid-March. Mean fledging date was 16 July. An average of 3.26 fledglings per successful pair (n = 83) were produced. The mean nearest neighbour distance between occupied nests was 1.09 km (1SD: 0.94, n = 33). Nests containing fledglings were recorded as close as 228 m. The population density was calculated at 8.1 pairs/100 km² for the whole study area. The steady increase of the black stork population in the study area during the last few decades is partially attributed to the intensification of agriculture at small scale, which has created ideal feeding grounds for the species. The establishment of shallow artificial ponds in grasslands or along streams within the protected area may improve the availability of food resources for the species.

Key words: Black stork, *Ciconia nigra*, breeding success, breeding density, breeding phenology.

Introduction

The black stork *Ciconia nigra* is a bird with an extensive breeding range, which extends across Europe to northeastern China, including a small breeding population in southern Africa. Nevertheless, the species requires special conservation measures in Europe. During the 19th and first half of the 20th century the European population suffered a considerable decrease and disappeared from most of its western European breeding range (cf. Sackl 1985). After an increase of breeding numbers, followed by the expansion of its range since the 1970s, the European population is currently considered to be stable (Birdlife International 2004). As a migratory bird the long-term maintenance of the population depends on the availability of suitable habitats on the breeding and wintering grounds (Newton 1998, Chevallier et al. 2010, Cano et al. 2013). Within its breeding areas, forest destruction and, particularly, the lack of availability of old mature trees adequate for nest construction, have been reported as the main threats (Lõhmus & Sellis 2003, Rosenvald & Lõhmus 2003). In addition, the degradation of feeding habitats and especially the drainage of permanent water courses contributes to the population decline (Lõhmus & Sellis 2001). The later could be accelerated under global climate change which might have important consequences on nesting success and survival rates of the species (Both et al. 2006). The species has declined in Greece, and was recently listed as "Endangered" in the Red Data Book of threatened vertebrates in Greece (Legakis & Maragou 2009).

Black storks inhabit old undisturbed forest areas, interspersed with shallow lakes, marshes, ponds and streams (Sackl 1985, Mériaux et al. 1991, Vlachos et al. 1996). The province of Evros, where the present study was conducted, offers optimal habitat conditions such as well-wooded areas for nesting and shallow wetlands for foraging (Hancock et al. 1992). It constitutes the most important breeding area of the species in Greece, hosting more than 40 breeding pairs every year (O. Alexandrou, pers. comm.), and is one of the species' southernmost nesting areas in Europe. The present study was carried out in the Dadia – Lefkimi – Soufli Forest National Park during 2006–2008, and aimed to (1) determine the breeding chronology and nesting success and (2) to estimate the breeding density and dispersion of nest-sites in the area.

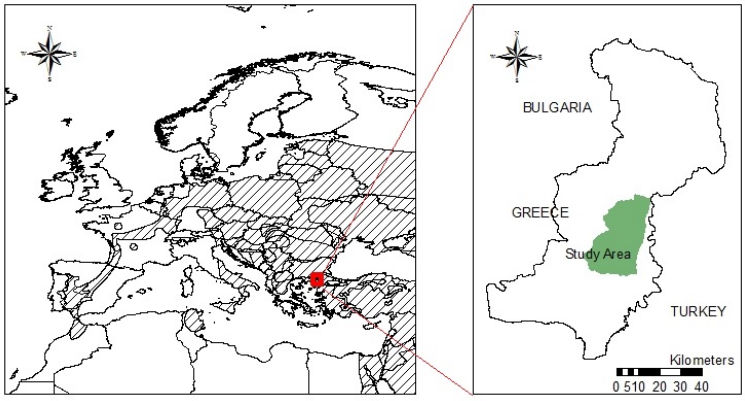

Figure 1. Distribution range (hatched area) of black stork in Europe and study area (green) in northeastern Greece. Distribution range was extracted from the NatureServe database (Ridgely et al. 2005).

Materials and methods

Study area

The Dadia – Lefkimi – Soufli Forest National Park (hereafter DLS NP) is located in the central part of Evros Prefecture, north-eastern Greece (40° 59′ to 41°15′ N, 26° 00′ to 26° 19′ E) (Fig. 1). DLS NP encompasses a part of the south-eastern tip of the Rhodope mountain range, with altitudes between 10 and 654 m a.s.l. The area is widely known for its rich biodiversity, as it supports one of the most diverse populations of raptor species in Europe, where 90% of European raptor species have been observed (Dennis 1989). Besides black vulture *Aegypius monachus*, imperial- *Aquila heliaca* and white-tailed eagle *Haliaeetus albicilla*, golden eagle *Aquila chrysaetos*, short-toed eagle *Circaetus gallicus*, lesser spotted eagle *Aquila pomarina*, booted eagle *Aquila pennata*, honey buzzard *Pernis apivorus*, long-legged buzzard *Buteo rufinus*, common buzzard *Buteo buteo* and goshawk *Accipiter gentilis* breed regularly (Poirazidis et al. 2011). In order to protect this remarkable diversity of raptors, especially the black vulture population, the area was declared a nature reserve in 1980 and a national park in 2003.

The area is characterized by numerous small and large valleys, bordered by steep and gentle slopes, as well as an intricate network of smaller and larger water courses. The climate with dry summers and cold winters is sub-Mediterranean with a strong continental influence. Mean monthly temperatures range from 25°C in July to 4°C in January, while the mean annual precipitation is 664 mm. Precipitation is concentrated in the cold season from autumn to spring, whilst summers are dry and last from mid-June to the end of September. During summer reduced rainfall leads to a recession of surface waters, a process accelerated by water manipulation for irrigation purposes.

The study area extends over 432.86 km², of which approximately 17% (73 km²) consist of two zones (core areas) of strict protection. Forests dominated by Calabrian pine *Pinus brutia* and black pine *P. nigra*, oaks (*Quercus fraineto*, *Q. pubescens*, *Q. sessiliflora* and *Q. cerris*) or mixed woodlands cover 75% of the national park, followed by agricultural lands (16%), shrubs (5%), and open areas consisting of grasslands and heaths (4%) (Bakaloudis et al. 1998). Riparian forests are dominated by willows *Salix* spp., poplars *Populus* spp. and black alders *Alnus glutinosa*.

Field procedures

Black stork territories were located through standard methods (Andersen 2007), i.e. (a) historical descriptions of traditional nesting sites, (b) territorial and breeding behavior of pairs in the early breeding season such as copulation clattering, vocalizations and nest material deliveries (Sackl 2000) and (c) during extensive exploratory surveys on foot.

All nests were visited repeatedly every three or four days to estimate the onset of incubation by the presence of at least one adult bird for nest guarding. The first date of incubation was estimated with the mid-date between two consecutive visits without and the first observation of nest guarding. A mirror attached to a telescopic pole was used to count eggs (Parker 1972), avoiding days of inclement weather. During late incubation and the late brooding period each nest was visited every two or three days for determining hatching and fledging dates. To minimize disturbances, nesting performance was checked with binoculars (10 × 40) or a telescope (60×) from a safe distance. Remote observations largely benefited from area's mountainous relief and the location of many nesting-trees mainly on steep slopes.

The geographic locations of all nests were obtained with a GPS. Nearest neighbour distances between nest-sites were calculated in ArcView 3.2. For 3 pairs that changed nesting sites between years the central point of the nest cluster was used to measure nearest neighbour distance (Dare & Barry 1990).

Breeding pairs (hereafter bp.) were defined as pairs that laid eggs and successful pairs as nesting birds that fledged at least one young. Hatching success (%) was cal-

culated by the total number of eggs hatched divided by the number of eggs laid. Fledging success (%) was estimated by the total number of young fledged divided by the number of eggs hatched and breeding success (%) was defined as the total number of young fledged divided by the number of eggs laid. Mean brood size at hatching was defined as the total number of eggs hatching over the number of pairs that hatched at least one egg. Mean brood size at fledging per bp. was defined as the total number of fledglings over the total number of bp., and mean brood size at fledging per successful pair (s.p.) was defined as the total number of fledglings over the total number of pairs that successfully fledged at least one young. Nesting density (number of pairs/100 km^2) was calculated by including all bp. found in early spring, whereas mean nearest neighbour distances were estimated for all nests, irrespective of breeding success.

In order to calculate mean water depth at the main stream which crosses the study area, four water level measurements per month were obtained at the Diavolorema stream from January to August, during 2006–2008.

Statistical analyses

Breeding variables (laying, hatching and fledging dates) were tested for homogeneity of variance and normality using Bartlett's and Anderson-Darling tests, respectively. One-way ANOVA was applied to compare breeding variables, but when variables did not meet the above assumptions after transformations then the equivalent non-parametric Kruskal-Wallis test was used (Zar 1996). Chi-square test was used to compare breeding parameters (hatching success, fledging success and breeding success) between years.

All statistical analyses were performed using the Minitab (version 15) statistical package and differences were considered significant with $a \leq 0.05$.

Results

Breeding density

Between 2006 and 2008, 35 nesting territories, i.e. clusters of nests which we assigned to single breeding pair, were located in the study area. Mean nearest neighbour distances was calculated at 1.09 km (SD: 0.94, n = 33). The shortest distance between two successful nests was 228 m, while the greatest distance was amounted to 4,947 m. Sixty per cent of the occupied nests were found within 1,000 m and 86% within ≤ 2,000 m of their closest neighbour. Breeding density in the study area was 8.1 pairs/100 km^2 for total area and 10.8 pairs/100 km2 for the area of woodlands.

Breeding chronology

In spring black storks arrived at the study area between the last days of February and mid-March. The mean date of egg-laying was 8 April (SD: 9.8 days); mean date of hatching was 14 May (SD: 10.5 days) and mean fledging date was 16 July (SD: 11 days). No statistically significant differences were detected between years for mean dates of egg-laying ($F_{2,89} = 0.79$, $P = 0.459$) and mean dates of hatching ($F_{2,83} = 0.48$, $P = 0.622$) or fledging ($F_{2,81} = 0.4$, $P = 0.669$). Most of the birds left the area in September and the last individuals were seen on 11th of October 2008 in the area.

Breeding success

Of 101 black stork breeding attempts monitored during the study period, in 92 cases eggs were laid and fledglings were successfully raised in 83 occupied nests, accounting for 97% of all broods (Table 1). Nine breeding attempts were unsuccessful, of which 67% of failures occurred at the egg stage and 33% at nestling stage. Overall, in 90% of nests at least one chick fledged. In total, 271 fledglings were successfully raised during the 3-year study period. Mean clutch size was 3.90 eggs (n = 92) and mean brood size at hatching – 3.55 nestlings (n =86). Black storks produced an average of 3.27 fledglings per successful pair (n = 83). Broods of three chicks at fledging were most frequent (39.7%), closely followed by broods of four young (37.3%), while 15.7% of broods consisted of two fledglings, 4.8% had five and only two nests (2.4%) with a single fledgling were recorded.

Breeding performance did not vary significantly among years ($P > 0.05$). Breeding success was 71% in 2007, 78% in 2006 and 79% in 2008 (Table 1). Hatching success was highest in 2008, but again no significant differences were found between years ($P = 0.909$). In the same way, no significant differences were detected between years for fledging ($P = 0.871$) and breeding success ($P = 0.840$) (Table 1).

Chick mortality was recorded both in the early and the late stages of breeding. In one case, chicks less than two weeks old were predated, possibly by common buzzards. The event was not directly observed, however, numerous down feathers were found scattered in the nest, the chicks were missing and some days later the nest was occupied by a buzzard. Five chicks from three different broods fell off their nests shortly before fledging and were found in the vicinity of the nest-site half-eaten, possibly by dogs or foxes. In one case, a young bird was observed falling out of the nest when a herd of goats passed directly below the nest-tree.

Table 1. Breeding parameters of black storks in Dadia – Lefkimi – Soufli Forest National Park, northeastern Greece, during 2006–2008. bp.: breeding pairs, s.p.: successful pairs.

Parameter	Year				Statistic	P-value
	2006	2007	2008	All		
Number of territorial pairs	32	35	34	101		
Pairs laying eggs (%)	28 (87)	33 (94)	31 (91)	92 (91)		
Pairs hatching eggs (%)	26 (93)	30 (91)	30 (97)	86 (93)		
Pairs fledging young (%)	26 (100)	29 (97)	28 (93)	83 (97)		
Successful breeding pairs (%)	26 (93)	29 (88)	28 (90)	83 (90)		
Hatching success %	85	82	88	85	$\chi^2 = 0.19$	0.909
Fledging success %	91	87	89	89	$\chi^2 = 0.06$	0.871
Breeding success %	78	71	79	76	$\chi^2 = 0.34$	0.840
Mean (1SD) clutch size	3.86 (1.00)	3.94 (1.10)	3.90 (0.79)	3.90 (0.98)	H = 0.22	0.898
Mean (1SD) brood size at hatching	3.54 (0.86)	3.53 (0.82)	3.57 (0.68)	3.55 (0.78)	H = 0.11	0.948
Mean (1SD) brood size at fledging/bp.	3.00 (1.22)	2.79 (1.39)	3.06 (1.24)	2.95 (1.28)	H = 0.63	0.279
Mean (1SD) brood size at fledging/s.p.	3.23 (0.91)	3.17 (0.97)	3.39 (0.74)	3.27 (0.87)	H = 0.66	0.718

Table 2. Density of black storks in different breeding grounds (p: pairs, bp.: breeding pairs).

Country / Region	Breeding Density (/100 km²)	Source
Eastern Austria	1.34 p	Sackl 1985
Central Poland	1.79 bp.	Zieliński 2008
Croatia / Sava	5.00 p	Schneider-Jacoby 1999
Poland / Bialoweza Forest	5.50 p	Czuchnowski & Profus 1996
Poland / Sobiborski Landscape Park	8.30 bp.	Czuchnowski & Profus 1996
Greece / DLS NP	10.80 bp.	present study

Discussion

Following to the present study current population size of black stork in DLS NP was estimated at 32–35 pairs. There seems to be a steady increase during the last 3 decades: in an earlier study from 1992–1995, Vlachos et al. (1996) recorded 16 breeding pairs in the area, while in a territorial analysis during breeding surveys in 2001–2005, an annual mean of 28.4 breeding pairs (25–33 pairs) was recorded in the national park (Poirazidis et al. 2006).

Throughout its range the breeding success of Black Storks varies considerably. In DLS NP high reproduction rate, combined with low proportion of unsuccessful bp. and high hatching and fledging success, obviously promoted the population increase of the species. Black storks' productivity in the study area (3.26 fledglings per successful bp.) is one of the highest recorded in Europe. For example, in Latvia Strazds (2011) found that the average number of young reared per reproductive pair was 2.66 (1SD: 0.85), and Tamás (2012) reported that black storks in Gemenc region in southern Hungary produced an average of 2.63 (1SD: 0.61) fledged young per pair. Overall breeding success in our study area reaches almost 80%. Although the area hosts a large number of raptor species, comparably few cases of nest predation were observed during the present study. In Latvia, the main predators affecting the breeding success of black storks are pine marten *Martes martes* as well as white-tailed eagle (Ķuze et al. 2008, Strazds 2008, 2011). In our study area we found no evidence for nest predation by mammals, while the area thrives with large birds of prey. Based on the low frequency of nest predation in DSL NP, effects of avian predators on black stork's breeding success appear to be insignificant.

Breeding density in the study area is one of the highest reported for the species in Europe (Table 2). Mean nearest neighbour distance of the 33 nesting territories located in the DLS NP during this study (1.09 km) is considerably smaller than that found in Poland (2.5–5.8 km; Czuchnowski et al. 1996), Lithuania (4.45 km; Stončius et al. 2008) and Spain (17–22 km; Hernández & Fernández 1996). The location of nest-sites and nesting densities of black storks depend on the availability of mature trees (Bakaloudis et al. 2005) in the proximity of adequate feeding habitats (Vlachos et al. 2008). Consequently, in DSL NP nests are concentrated along main streams.

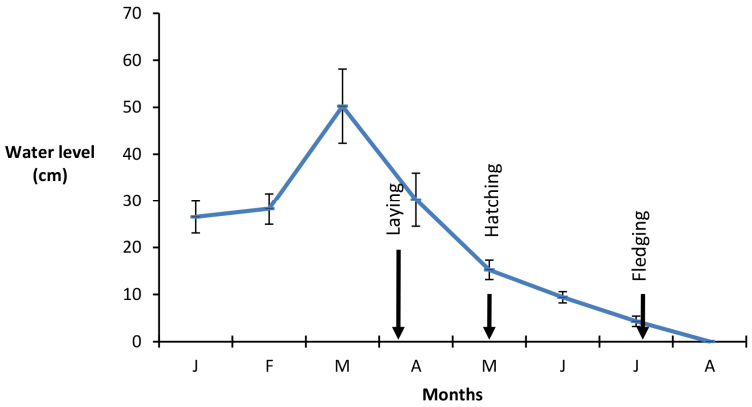

Figure 2. Water level (mean depth, 1SD) of main feeding habitats and breeding phenology of black storks in Dadia – Lefkimi – Soufli Forest National Park.

In our study area most streams dry out during the summer, sufficient water remains in streams and marshy ponds only in lowland areas. During the late breeding season black storks aggregate in isolated pools for feeding, which constitute the main feeding habitats in summer (Lõhmus & Sellis 2001). According to Tucakov et al. (2006), in the central Danube floodplains high breeding concentrations of black storks indicate temporarily favorable feeding conditions. Similarly to DLS NP, their study area offered shallow depressions, suitable for feeding, close to mature and undisturbed forest stands.

High reproduction rate (and probably stable population numbers) in our study area indicate good food availability and prey accessibility (Bakaloudis 2009, 2010). In DLS NP high concentrations of fish are available in main streams in the late breeding season when water levels are low. Because prey is more easily caught when large numbers of fish are concentrated in shallow water (Kahl 1964, Kushlan et al. 1975), feeding conditions are almost optimal in DSL NP in the summer. In our study area the breeding period largely coincides with the lowest water level in main streams (Fig. 2).

In Greece agriculture has intensified significantly since the 1980s by the cultivation of plants (cotton, sugar beets and corn) which demand high water input. The most food-demanding period during the breeding cycle of black storks after hatching, coincides with the xerothermic period in Greece and in other Mediterranean countries, when evaporation is very high. Currently, during the summer large quantities of water are used for irrigation of agricultural lands. For black storks these practices apparently have cascade consequences on food availability: a) ceasing of permanent water flow in small streams and the creation of ponds, b) the gradual fall of water levels in these ponds, c) "trapping" and aggregation of large quantities of fish in small and shallow ponds and subsequently, d) the good availability of large quantities of fish.

However, in the spring, during the early stages of the breeding cycle when irrigation has not yet started and ponds have not yet been formed, black storks move from DSL NP as far as the flooded rice fields on the Greek–Turkish border for feeding (6 to 10 km, pers. obs.). In this period, rice fields are probably the only foraging habitat available for black storks from DLS NP (Fasola et al. 1996, Toral & Figuerola 2010), due to elevated water depth making streams and rivers unsuitable foraging habitats. Given that black storks forage over large areas (Jiguet & Villarubias 2004), the formation of shallow artificial pools in grasslands (like in rice fields) or along streams within the national park apparently improves the accessibility to food resources in summer (Tucker & Heath 1994, Moreno-Opo et al. 2011).

The present study indicates that high nesting densities and the high breeding success of black storks in DLS NP derives from high food accessibility in ephemeral ponds in streams, due to intensive water utilization in summer. However, mean water levels are expected to fall substantially in the future due to climate change and human-induced activities, such as changing land use and increasing water demand for irrigation (Ewert et

al. 2005, Milly et al. 2005). Hence, future degradation of feeding habitats may heavily impair the feeding conditions and food availability for black storks in DSL NP (south-eastern Europe) during the summer months. In addition, frequently feeding in ponds in intensively cultivated agricultural lands may cause concerns for the long-term exposure of black storks to toxic chemicals. Therefore, a monitoring scheme of biological, environmental and human-induced factors is needed to allow managers to take appropriate actions for maintaining the population of black storks and other bird species in DSL NP, like lesser spotted eagle and herons, which depend on ephemeral water ponds for feeding.

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