

Article

First Report on a Cliff-Nesting Pair of Black Storks (*Ciconia nigra* Linnaeus, 1758) and Their Nestlings

Pierangelo Freschi ¹, Carlo Cosentino ^{1,*}, Fabio Napolitano ¹, Corrado Pacelli ¹, Danilo Manicone ¹, Egidio Mallia ², Marco Ragni ³, Rosanna Paolino ¹ and Ada Braghieri ¹

¹ School of Agricultural, Forestry, Food and Environmental Sciences (SAFE), University of Basilicata, 85100 Potenza, Italy; pierangelo.freschi@unibas.it (P.F.); fabio.napolitano@unibas.it (F.N.); corrado.pacelli@unibas.it (C.P.); danilomanicone@libero.it (D.M.); rosannapaol@gmail.com (R.P.); ada.braghieri@unibas.it (A.B.)

² Regional Park of “Gallipoli Cognato Piccole Dolomiti Lucane”, 75011 Accettura, Italy; egidiomallia2@gmail.com

³ Department of Soil, Plant and Food Science, University of Bari Aldo Moro, 70125 Bari, Italy; marco.ragni@uniba.it

* Correspondence: carlo.cosentino@unibas.it; Tel.: +39-0971-295044

Abstract: The black stork is an endangered species in many countries, due to its low adaptability to environmental changes and its sensitivity to anthropogenic disturbances. In Italy, the most recent report on the species' nesting sites lists only 36 pairs, of which 16 are in Basilicata, 7 are in Calabria, 4 are in Piedmont and Molise and 1 is in Campania. This study focuses for the first time on the behavior of a *Ciconia nigra* pair in the Basilicata region, where the species nests exclusively on cliffs rather than in trees, as is more frequent elsewhere. The video recordings were used to observe the species during the pre- and post-hatching periods and to refer to the 2012 nesting season, as in that year, the video recordings covered the entire reproductive period. In the pre-hatching phase, the activity for which most time is spent is brooding, which lasts on average 43' in the morning and in evening and more than 49' at midday. In the post-hatching phase, a large part of the recording period is spent on activities related to parental care. There were no moments of inactivity during this phase, the parents were frequently observed setting up the nest and preening themselves, while they were rarely seen in a huddled position. The alert activity was also very frequent, especially at midday. Our study has shown that the black stork, a shy and cautious species, may return to nest in increasing numbers given the development of the promising Lucanian nucleus, if attention is paid to the habitat quality and feeding areas, where human activities should be avoided unless absolutely necessary.

Keywords: black stork; cliff nesting; parental behavior; nestling behavior; surveillance camera



Citation: Freschi, P.; Cosentino, C.; Napolitano, F.; Pacelli, C.; Manicone, D.; Mallia, E.; Ragni, M.; Paolino, R.; Braghieri, A. First Report on a Cliff-Nesting Pair of Black Storks (*Ciconia nigra* Linnaeus, 1758) and Their Nestlings. *Forests* **2023**, *14*, 1941. <https://doi.org/10.3390/f14101941>

Academic Editor: Linas Balčiauskas

Received: 5 September 2023

Revised: 20 September 2023

Accepted: 22 September 2023

Published: 24 September 2023



Copyright: © 2023 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

1. Introduction

The black stork (*Ciconia nigra* Linnaeus, 1758) is an endangered species in many countries due to its low adaptability to environmental changes and its sensitivity to anthropogenic disturbance. This species occurs in over a hundred countries in Europe, Asia and Africa; its areal is the largest of all stork species. In Europe, its population is distributed across 35 countries [1]. Breeding sites are observed from Spain to Sakhalin Island, although its ideal habitat is the flood plains of the central continental regions [2]. This species has an extremely large range and therefore does not approach the thresholds for ‘Vulnerable’ according to the range size criterion, established by both the International Union for Conservation and BirdLife International, and is classified as ‘Least Concern’ [3]. Only in recent years, it has nested again in Western Europe, after suffering a drastic decline in the twentieth century until it disappeared from Belgium, Germany, Denmark and Sweden. Adults come to the nesting sites in February–March and usually return to the areas they left the previous year [4]. However, disturbance by humans or some predators or the fall

and destruction of the nest could cause the storks to change nesting sites over the years. Studies conducted in Estonia [5], Poland [6,7] and Greece [8] concerned the preferred tree species for building the stork's nest. It was found that *C. nigra* prefers to nest on oaks, poplars and pines, while it avoids spruce. It has also been observed that the trees selected for nesting are on average over 25 m high, about 120 years old and have a diameter of at least 50 cm at 1.30 m height [9,10]. In Central European regions, the nests are mainly built on large branches of large, dominant trees or in planitial forests or on wooded hills in the middle of large valleys crossed by streams rich in fish [11]. However, in the Iberian Peninsula [2,12], the Carpathians, Russia, Austria [13] and southern Africa [14], nests may be built in ravines or on rocky ledges, in river gorges or in mountainous areas, on steep rocky slopes and in shallow caves. In Italy, *C. nigra* is a migratory species that nests and occasionally hibernates [15]. The Italian peninsula was certainly part of the species' ancient nesting range until 1000 years ago. There is visual evidence of its presence in the treatise on falconry, *De arte venandi cum avibus*, by Frederick II of Swabia (1194–1259 AD), in which he describes the species nesting in northern Apulia in the thirteenth century. Later, from the Renaissance onwards, there is no evidence of nesting sites in Italy, while it was likely that black storks were present during their migrations towards African wintering grounds or Central European breeding areas. The probable disappearance of a nesting bird could be attributed to intensive persecution for food purposes due to trophic competition with humans in fisheries and to increasing deforestation [16]. Fraissinet et al. [17] stated that the black stork has been nesting in Italy in modern times since 1994, while the most recent report from 2022 [18] on the species' nesting sites in Italy records the presence of 36 pairs, of which 16 are in Basilicata, 7 are in Calabria, 4 are in Piedmont and in Apulia, 2 are in Molise and in Latium, and 1 is in Campania. Moreover, in the same year, 36 of the 79 fledged juveniles in Italy came from the Basilicata region. Compared to the 2021 season, there was an increase of six territorial pairs, the highest number found so far; the new pairs were found in Lazio, Molise, Basilicata and Calabria. In the province of Potenza, the first documented nesting was observed in 2000. The increasing presence of the species during the migration and breeding season in Basilicata, especially in the province of Potenza, is due to the good availability of suitable and little anthropized areas for the species. It is noteworthy that in Basilicata, the species nests everywhere on cliffs and no nest has yet been found in trees. As for trophic areas, empirical observations report regular use of the banks of rivers and lakes, especially those of artificial origin. The few studies available in the literature on this species refer exclusively to the more common tree nesting [17]. Our study focuses instead, for the first time, on the behavior of *C. nigra* in a nest located on a cliff. The exclusive nesting of this species in Basilicata on rocky surfaces is all the more particular because the region includes large forested areas with many tall trees suitable for nesting by the species. This aspect has also led us to better understand the behavior of parents in the phase before and after hatching and of the nestlings until fledging.

2. Materials and Methods

2.1. Study Area

The Regional Park "Gallipoli Cognato Piccole Dolomiti Lucane" (40°30'49.65" N, 16°8'35.70" E) covers about 27,000 ha and lies between 200 and 1367 m a.s.l. Within the park, the Gallipoli Cognato Forest (4200 ha), together with the Montepiano forest (522 ha), forms the most important wooded area. This area is characterized by oak woods with *Quercus cerris*, *Quercus frainetto*, *Quercus petraea* and *Quercus pubescens*, as well as other tree species such as *Carpinus betulus*, *Tilia cordata*, *Fraxinus oxyphyllus*, *Fraxinus ornus* and *Alnus glutinosa* [19,20]. The small pure groves of *Ilex aquifolium* are also noteworthy. Another key element of the park is the rocky outcrops and the cliffs of the "Piccole Dolomiti Lucane", a chain of sandstone cliffs crossed by the Caperrino stream (Figure A1); *C. nigra* nests here. Around these peaks, mesophilic forests survive with *Castanea sativa*, *Acer campestre*, *Acer monspessulanum* and *Tilia cordata*, and deciduous forests of *Carpinus orientalis* covering the driest sites [21–23]. The rich biodiversity of the park is also contributed by

the presence of wildlife, characterized by several species that are particularly important from a conservational point of view. Among these, we mention *Capreolus capreolus italicus*, recently reintroduced in the park, and *Lepus corsicanus*, two endemic species found only in limited areas in central and southern Italy [22,24,25]; *Lutra lutra* and the wintering species *Ardea cinerea*, *Ardea alba* and *Egretta garzetta*, which together with *C. nigra*, colonize shallow feeding grounds rich in fish. Nesting raptors such as *Milvus milvus*, *Milvus migrans* and *Circus gallicus* and rare sparrow species such as *Phoenicurus phoenicurus*, *Ficedula albicollis* and *Dendrocopos medius*, which nest almost exclusively in undisturbed forest areas, also occur [21].

2.2. Animals

The black stork is a very rare species in Italy and in 2012, the year referred to in this study, only 12 breeding pairs were counted nationwide. We have chosen this year and not the following ones as the video recordings covered the entire reproductive period. In our study, a nesting site on a cliff was investigated, which is very unusual for this species, which normally nests on high trees. To install the video recording system on the cliff face, a team of free climbers had to intervene. The objective operational difficulties allowed the installation of a single system and thus the observation of a single nesting pair.

2.3. Video Recording System

An Arecont Vision AV2825IR IP camera (AV Costar, Clovis, CA, USA) with a resolution of 1920 × 1080 and a recording speed of 24 FPS was used. The images were transmitted via the Alvarion BreezeNET B-14 wireless system (Alvarion, Herzlyia, Israel). The unit was equipped with an antenna with a frequency range of 4.9–6.1 GHz and a stand-alone photovoltaic kit (980 V 12 W) with four 70Ah batteries, a charge controller 12v/24v, 3 PV modules of 250 Wp and an AC inverter 24 V/500 Watt. The video recording was carried out with the VioStor-2004L digital video recorder surveillance system (QNAP, Taipei, Taiwan). The videos were taken from the beginning of the breeding season until the nestlings fledged. Considering the large number of images, we analyzed shots of a whole day every four days from 27 March to 17 July, i.e., 29 days in total. The average duration per day of the film shot was 13 h. The video recording system produced video files with a duration of 5' at a time. Then, for each observation day, the 12 video files of each hour were converted to AVI format using Any Video Converter software (Anvsoft Inc., Shenzhen, China) and merged into a single file of 1 h duration. This was necessary because we used a time frame of 1 h for the behavioral observations. The observation period was divided into 2 phases:

Pre-hatching from 27 March to 6 May;

Post-hatching from 10 May to 17 July.

The videos were observed and analyzed using the continuous recording technique [26], which detects each observed event and records the timing and duration of the different behavioral activities. Behavioral observations were conducted using Observer XT 8.0 software (Noldus Information Technology, Wageningen, The Netherlands). Preliminary observation of video sequences (*ad libitum* sampling) allowed the identification of the main behavioral categories, postures and presence/absence of partners, for each of which the duration (min per h) and/or hourly frequency were recorded. Behavioral activities were divided into (a) exclusively in the pre-hatching phase (parents only); (b) exclusively in the post-hatching phase (both parents and nestlings); and (c) in both phases (parents only). All the activities considered are shown in Table 1.

Table 1. Duration and/or frequency of the observed activities during the pre- and post-hatching phases.

Nest Composition	Measure	Activity/Status
		Pre-hatching
	Duration and frequency	Courtship, Mating, Nest building, Incubation
	Frequency	Incubation shift, Body orientation shift during incubation, Egg turning
		Pre- and Post-hatching
Only parents	Duration and frequency	Standing, Self-preening, Allopreening, Exploration, Alert, Inactivity, Nest maintenance, Nest uncovered, Presence of two parents, Presence of one parent, Absence of parents
		Post-hatching
Parents with nestlings	Duration and frequency	Brooding, Nestling feeding, Nestling preening, Nestlings peck parents, Contact with dead nestlings, Empty nest
	Frequency	Change of body orientation in brooding, Brooding switch, Nestling feeding, Nestling pecking parents
Only nestlings	Duration and frequency	Rest, Interaction among nestlings, Exploration, Self-preening, Alert, Down, Flight attempts
	Frequency	Wings spread

The post-hatching observations concerned both the behavior of the pair and that of the nestlings from birth to fledging. Due to the low sexual dimorphism, it was not possible to distinguish the sex of the parents. Furthermore, due to the limited field of observation of the camera, it was not possible to check whether the animals were outside the nest in the case of an empty nest or near the nest but out of range of the camera (Figures A2–A8 and Video S1). Three observation periods were considered: morning, from the beginning of the day to 10:59; midday, from 11:00 to 15:59; and evening, from 16:00 to the end of the day, depending on natural light.

2.4. Statistical Analysis

Duration and frequency of patterns were analyzed with the GLM procedure using a bi-factorial linear model that included the effects of the diurnal period (morning, midday and night), phase (for activities expressed in both phases of pre- and post-hatching) and their interaction. Since the interactive effect of the factors was not significant, a bifactorial model without interaction was then used. Data on activities observed in only one phase were analyzed by a mono-factorial model that included only the effect of the diurnal period. Differences between means were determined using the Tukey HSD test. Data were analyzed using R software (R Core Team, Vienna, Austria) [27].

3. Results and Discussion

3.1. Exclusive Patterns in the Pre-Hatching Phase

3.1.1. Duration

Among the activities analyzed in the pre-hatching phase (Figures A2–A5), only courtship had a duration that differed significantly ($p < 0.05$) between periods (Figure 1); in particular, it was shorter at midday (12.13') than in the evening (23.37'). The activity on which the most time was spent was incubation, which lasted on average 43' in periods 1 and 3 and more than 49' in period 2. The time spent on nesting was 7.39' in the morning 5.15' at midday and 4.07' in the evening.

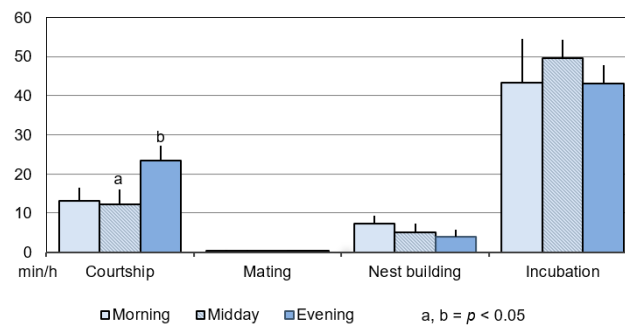


Figure 1. Duration (min/h; $\bar{x} \pm SE$) of activities in the pre-hatching phase in the three daily periods.

This is probably due to the better microecological conditions at this site, which is cooler in the early morning hours as it is still in the shade. Nest building is one of the many activities performed by the species in pairs. In relation to other species, Soler et al. [28] have shown in passerine birds that nests built by both parents are larger compared to the body size of the species than those built by a single parent. In addition, species in which both parents are actively involved in nest building invest more in reproduction because each has the opportunity to evaluate the reliability of the other sex than species in which only one parent is involved in nest building.

3.1.2. Frequency

The only significant difference ($p < 0.01$) was found for courtship between the morning (1.57) and evening (3.86) (Figure 2).

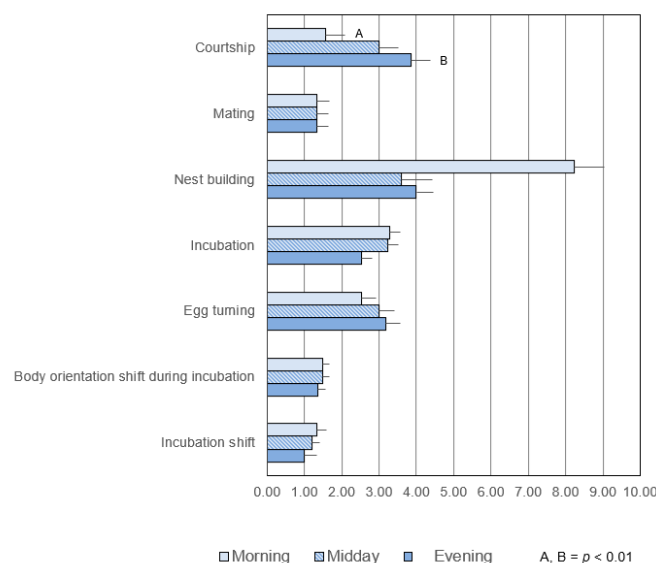


Figure 2. Hourly frequency ($\bar{x} \pm SE$) of activities in the pre-hatching phase in the three daily periods.

Instead, the frequency of mating was the same (1.33) in the three daily periods considered. Behavior during mating is described by Kahl [29] in 2 phases: (1) the male moves carefully behind the female, climbs onto her shoulders and hooks on, bending his legs to come into contact with her cloaca, and the female partially opens her wings; (2) the male strokes the female's neck quickly and gently with his beak and shakes his head restlessly back and forth. Mating behavior is similar in *C. nigra*, *C. ciconia* and *C. abdmii*. The males of the latter species seem to shake their heads faster during mating than the two European species. In all storks, mating takes place on the nest and with little foreplay, although in the present study, similar behavior such as long preening before mating was observed. Before each mating, the male chases the female for a few seconds and sometimes stretches his neck on the female's back, who, when ready to mate, bends forward and brings the body axis into a horizontal position. Normally, mating takes place when the female is standing, but Kahl [29] observed a male climbing onto a sitting female in the nest as if she were incubating, and this mating appears to have been successful. It is interesting to note how the activities associated with the presence of the eggs and their care occur at not dissimilar intervals during the day: the incubation shift occurs at least once per hour and ranges from 1.33 in the morning to 1 in the evening; eggs are turned 2.5, 3 and 2.8 times per hour in the morning, midday and evening, respectively; and the frequency of the hourly change of body orientation during incubation is 1.5 in the morning and midday and 1.36 in the evening. In the white stork *C. ciconia*, wind direction and wind strength are the most important factors affecting the body orientation of incubating birds [30,31]. Poussart et al. [32] evidenced that Snow geese *Chen caerulescens atlanticus* can reduce both air resistance and the energy costs of incubation by turning their heads and bodies.

3.2. Common Activities in the Pre- and Post-Hatching Phases

3.2.1. Duration

In the pre-hatching phase, the comparison of activities among diurnal periods (Table 2) showed a significant difference ($p < 0.05$) in allopreening, mainly due to the pair having longer contact in the evening (12.26') than at midday (1.56'). The average hourly duration of standing was over 16' in the morning and evening and 12' at midday. The alert status decreased from about 7' in the morning to 1.30' at midday, while it was absent in the last period of the day. In the post-hatching phase, most of the time was spent brooding and usually only one parent was present (Table 2) (Figures A6 and A7).

Table 2. Average duration ($\bar{x} \pm SE$; min/h) ⁽¹⁾ of activities in the pre- and post-hatching phases in the three daily periods.

Activity/Status	Pre-Hatching			Post-Hatching		
	Morning	Midday	Evening	Morning	Midday	Evening
Self-preening	5.27 ± 1.30	2.46 ± 1.30	2.19 ± 1.30	9.02 ± 1.02 ^a	7.11 ± 1.15	5.37 ± 1.08 ^b
Allopreening	5.23 ± 2.33	1.56 ± 0.16 ^a	12.26 ± 3.29 ^b	0.97 ± 0.10	0.00 ± 0.00	0.00 ± 0.00
Exploration	5.07 ± 1.62	5.30 ± 0.38	5.04 ± 0.32	7.31 ± 1.30	3.19 ± 1.54	7.59 ± 1.40
Inactivity	7.38 ± 3.02	8.00 ± 2.09	3.14 ± 0.35	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Alert	7.06 ± 1.01	1.27 ± 0.11	0.00 ± 0.00	5.15 ± 1.01	11.37 ± 4.51	0.00 ± 0.00
Standing	16.39 ± 5.12	12.00 ± 2.03	16.10 ± 5.03	34.33 ± 3.31	30.03 ± 4.01	30.41 ± 3.34
Nest maintenance	4.48 ± 1.33	5.12 ± 0.88	4.21 ± 0.43	7.48 ± 1.05 ^{Aa}	4.28 ± 0.42 ^B	5.20 ± 0.42 ^b
Presence of two parents	18.29 ± 3.14	17.52 ± 4.09	19.23 ± 4.09	2.48 ± 0.30	1.18 ± 0.15	0.31 ± 0.05
Presence of one parent	18.13 ± 5.08	16.32 ± 5.19	13.42 ± 5.29	42.29 ± 3.27	43.16 ± 3.58	38.51 ± 3.24
Absence of parents	11.36 ± 10.5	9.50 ± 1.35	23.45 ± 15.26	17.34 ± 9.40	39.49 ± 7.04	39.07 ± 8.34

⁽¹⁾ a, b = $p < 0.05$; A, B = $p < 0.01$.

It is likely that one parent was concerned with guarding and protecting the nest while the other took care of foraging for the offspring. Conversely, the parents spent little time on inactivity, exploration and allopreening. There were also significant differences in the time spent by the pair in the nest maintenance, longer in the morning (7.48') than at midday

(4.28'; $p < 0.01$) and in the evening (5.20'; $p < 0.05$), and in self-preening ($p < 0.05$) when comparing morning (9.02) with evening (5.37'). Cotgreave and Clayton [33], who collected data from 62 bird species, found that birds spend about 9% of their time on grooming activities, with over 92% of the main activities being preening and scratching. As for the alert status, it increased from morning (5.15') to midday (11.37') and was absent in the evening, similar to during the pre-hatching phase. The most frequent and at the same time very different alarm behavior among the different stork species is the "up-down", a kind of dance on the nest. This behavior is more intense and frequent in males and was defined by Kahl [29] as a kind of greeting to the female. The same author observed this behavior closely in the black stork and described it in three phases: (1) the bird carries its body horizontally, stretches its neck partly forward and bends downwards; (2) the head and beak bob rhythmically up and down in synchrony with a series of two-syllable whistles, and the neck is moved sinuously from side to side; and (3) the white feathers of the lower tail stand out conspicuously below the black feathers, the tail and lower tail are carried at an angle of 45° to the body axis and occasionally raised horizontally, and the wing tips are slightly raised. This behavior, which was also described in the study by Schuz [34] and defined by the term hissing chatter, was observed in the present study during states of excitement in both adult and young birds. When a stork is alone in its nest and an intruder approaches, it emits a hiss that is distinguished by its long duration. In addition, the alert stork orients itself in the direction of the intruder, the tail is strongly folded and the wings are partially spread and rhythmically moved up and down. This threatening behavior is a territorial defense behavior and stops when the alien stork moves away. When analyzing the data grouped exclusively by phase (Figure 3) we observed a significantly ($p < 0.01$) higher presence of both parents in the pre-hatching phase (18.21') compared to the post-hatching phase (1.33').

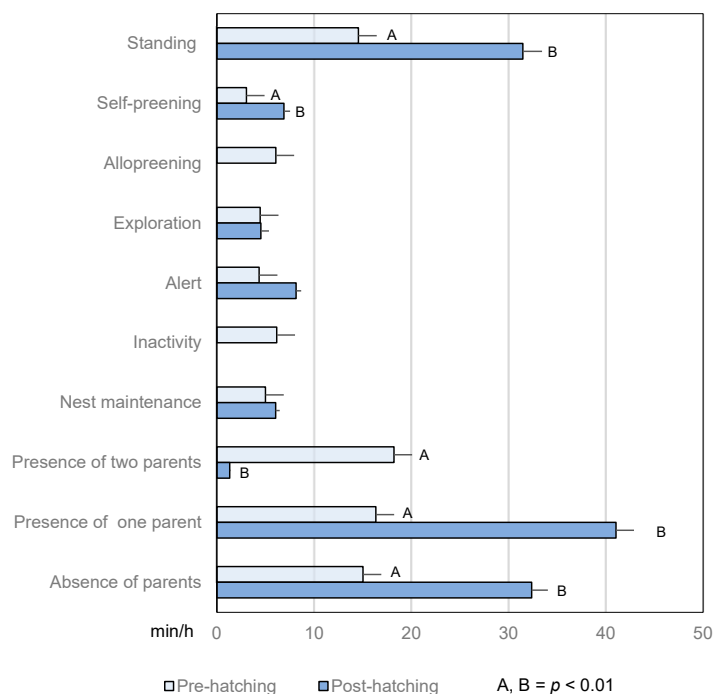


Figure 3. Average duration (min/h; $\bar{x} \pm SE$) of common activities of the pair in the pre- and post-hatching phases.

Conversely, we observed longer periods with only one adult after hatching (41.05' vs. 16.35'; $p < 0.01$), which also explains the low signs of parental interaction, inactivity and exploration. The difference ($p < 0.01$) in standing with twice as long duration in the second phase compared to the first phase is explained by the time adults spend incubating. The

time spent on self-preening also showed a significant difference ($p < 0.01$) and was more than twice as high in the second phase (6.9') as in the first (3.04'). Grooming behavior, defined by Clayton and Cotgreave [35] as a combination of preening and scratching, is the most common defensive behavior of birds against ectoparasites. These authors also reported that long-billed species spend an average of 16.2% of their grooming time scratching, compared to 2.3% for short-billed species. The energetic cost of this activity is estimated to be twice the metabolic rate in some bird species [36,37].

3.2.2. Frequency

The activities that had a higher average hourly frequency in the pre-hatching phase were self-preening and nest maintenance. A high frequency was also recorded when the parents were fully present to satisfy the need to incubate and take care of the nest (Table 3).

Table 3. Average hourly frequency ($\bar{x} \pm SE$)⁽¹⁾ of pre- and post-breeding activities of the pair in the three daily periods (min/h).

Activity/Status	Pre-Hatching			Post-Hatching		
	Morning	Midday	Evening	Morning	Midday	Evening
Self-preening	6.30 ± 1.09 ^a	4.27 ± 1.09 ^b	4.45 ± 1.09	2.33 ± 0.54	2.21 ± 1.01	2.34 ± 0.57
Allopreening	2.25 ± 0.53	2.15 ± 0.53	3.10 ± 1.16	1.00 ± 0.07	0.00 ± 0.00	0.00 ± 0.00
Exploration	5.3 ± 0.51	4.32 ± 1.03	4.26 ± 0.54	2.57 ± 0.41	1.50 ± 0.49	3.32 ± 0.44
Inactivity	2.38 ± 0.32	2.25 ± 0.37	2.33 ± 0.44	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Alert	2.00 ± 1.44	1.00 ± 1.12	0.00 ± 0.00	3.00 ± 1.44	4.50 ± 1.12	0.00 ± 0.00
Standing	3.02 ± 0.25 ^A	2.07 ± 0.26 ^B	2.20 ± 0.26 ^C	1.49 ± 0.17	2.25 ± 0.19	2.13 ± 0.17
Nest maintenance	6.56 ± 1.06 ^a	7.18 ± 0.62 ^A	4.53 ± 1.06 ^{Bb}	3.03 ± 0.46	3.22 ± 0.58	2.30 ± 0.51
Presence of two parents	5.18 ± 1.15 ^A	2.28 ± 1.27 ^B	2.28 ± 1.27 ^B	3.33 ± 0.36 ^a	1.36 ± 0.66	1.00 ± 1.09 ^b
Presence of one parent	3.50 ± 0.37 ^A	1.59 ± 0.38 ^B	1.59 ± 0.38 ^B	2.26 ± 0.26	1.54 ± 0.28	1.32 ± 0.25
Absence of parents	3.25 ± 1.15	1.00 ± 1.26	1.50 ± 1.06	1.20 ± 1.07	2.00 ± 0.47	1.29 ± 0.57

⁽¹⁾ a, b = $p < 0.05$; A, B, C = $p < 0.01$.

On the other hand, it was much less frequent for parents to explore the nest or leave it uncovered. When comparing the activities observed during the different periods of the day in the pre-hatching phase, some significant differences emerged. In the morning, it was more common than during the rest of the day to observe one or both parents at the nest, in a standing posture and busy tending. In the post-hatching phase, there were no moments of inactivity; rather, parents were frequently observed setting up the nest and self-preening, while they were less frequently seen in a huddled position. Alert behavior was also frequent, especially at midday (4.50 times per hour) (Table 3). In the Iberian Peninsula, Cano-Alonso and Tellería [12] have shown that nesting pairs on cliffs are more frequently detected than nesting pairs in forests [38,39]. Hence, the former elicit more behavioral alert responses when they are in openly accessible areas, caused not only by predators but also by observers [40] and climbers [41]. The only significant difference ($p < 0.05$) observed between periods in the post-hatching phase concerned the presence of both parents in the nest, which was more frequent in the morning than in the evening (3.33 vs. 1.00), as this phase of the day was probably dedicated to searching for the last food resources of the day to feed the nestlings. Comparisons of frequencies between phases are depicted in Figure 4.

Significant differences ($p < 0.01$) were found in the frequency of self-preening and activities devoted to the nest maintenance, which are more than twice as high in the pre-hatching phase. Allopreening and inactivity were absent in the post-hatching phase.

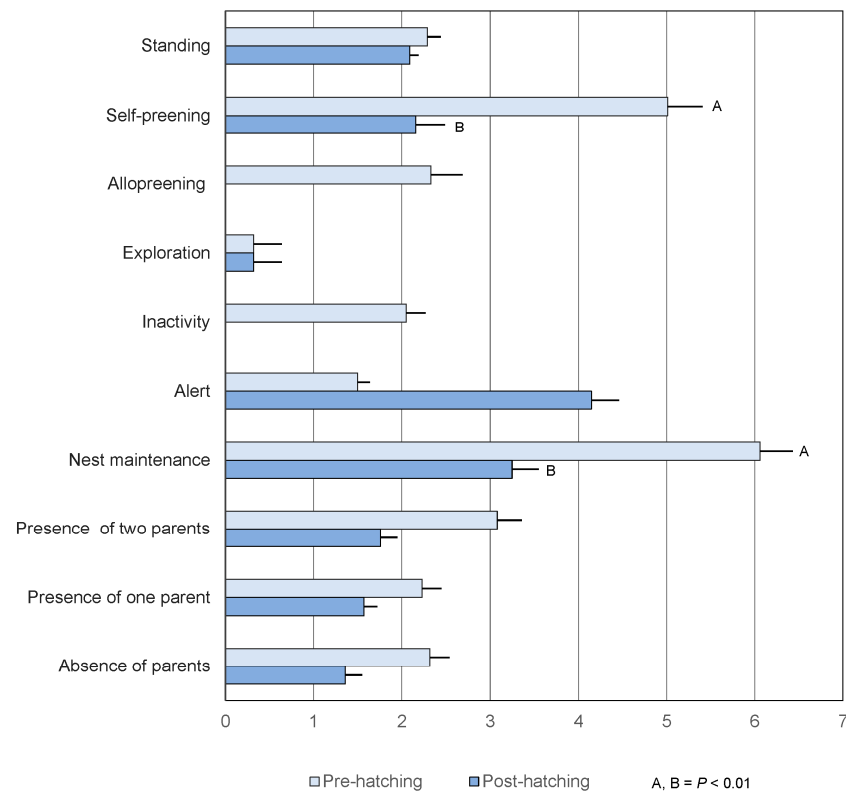


Figure 4. Hourly frequency ($\bar{x} \pm SE$) of the common activities in the pre- and post-hatching phases.

3.3. Exclusive Activities in the Post-Hatching Phase

3.3.1. Duration

In the post-hatching phase, the parents were very busy in caring for the nestlings (Figures A6 and A7) (Video S1). The time spent brooding was over 40 min/h in the morning and over 45 min/h at midday and in the evening (Figure 5); this time seems to decrease with the growth of the offspring.

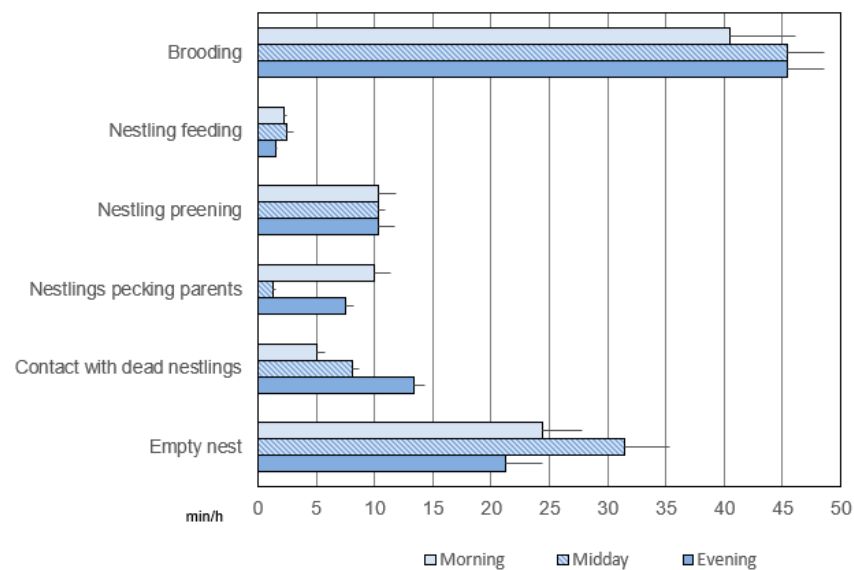


Figure 5. Interaction among parents and nestlings: average duration (min/h; $\bar{x} \pm SE$) of activities in the three daily periods.

The time spent by the parents feeding the nestlings was similar in the morning and at midday (2.18' and 2.52'), while it decreased in the evening (1.5'). The administration of food by the parents is a response to a typical behavior of the nestlings, called “begging” by Kahl [29]; this behavior can be divided into three phases: (1) the nestlings lean on the tarsi (in our study, when only the two survivors are present, they place one in front of the other), partially open and lift the wings and raise the tail above the dorsal line; (2) they nod rhythmically; and (3) they emit high-pitched, shrill cries synchronous with their head movements. In our study, this behavior occurred intermittently as long as the parent was in the nest, even after it had been fed, because the nestlings rarely seemed to get enough food to become full. The nest remains mostly uncovered (Figure 5) at midday, although not significantly, when this condition exceeded 30', while it showed lower values in the morning (24.39') and evening (21.19'). The nestlings spent a large part of their time resting in the nest, 24.14', 34.09' and 31.04' in the morning, midday and evening, respectively (Figure 6).

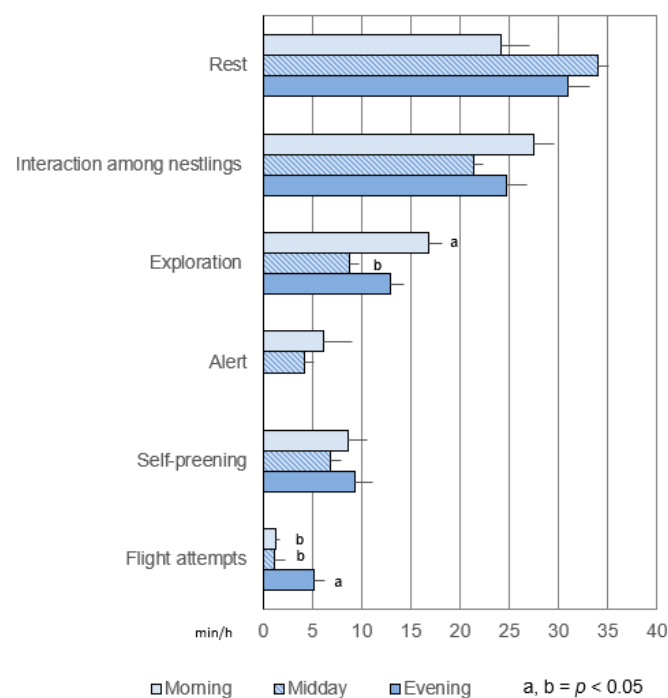


Figure 6. Nestling activity: average hourly duration (min/h; $\bar{x} \pm SE$) in the three daily periods.

The timing of interaction among nestlings was significantly higher ($p < 0.05$) in the morning (27.51') than at midday (21.45'). The hourly alert status was observed for 6.17' in the evening and for 4.17' at midday, while it was absent in the evening. In the last ten days before fledging, the two surviving nestlings (Figure A8) spent more than 5' in the evening and only about 1' in the morning and at midday during their flight attempts. The walking and exploration times were very similar, as these two activities are interrelated.

3.3.2. Frequency

The activities with the highest hourly frequency of parents towards nestlings were allopreening and feeding, followed by contact with dead young birds. For these and the other activities shown in Figure 7, there was no significant difference among the three daily periods.

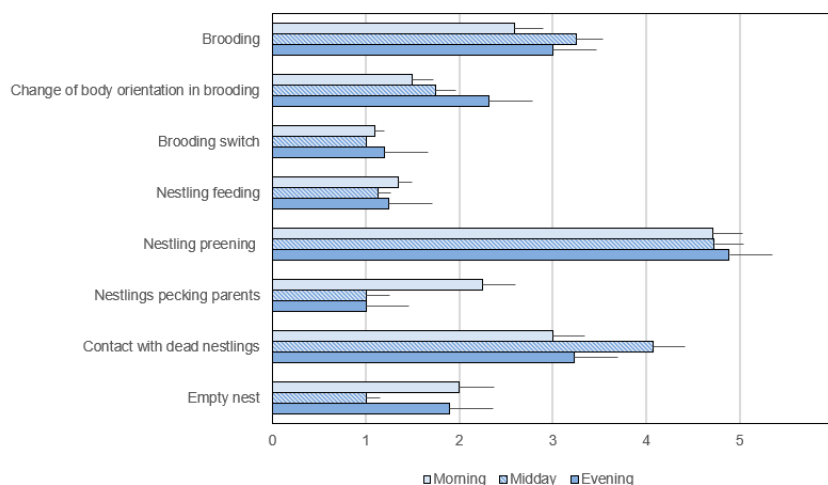


Figure 7. Hourly frequency ($\bar{x} \pm SE$) of the parents nestling activities.

The only significant difference ($p < 0.01$) in Figure 8 referred to the hourly frequency of the standing posture of the nestlings, which was higher in the evening (5.19) than in the morning (4.37).

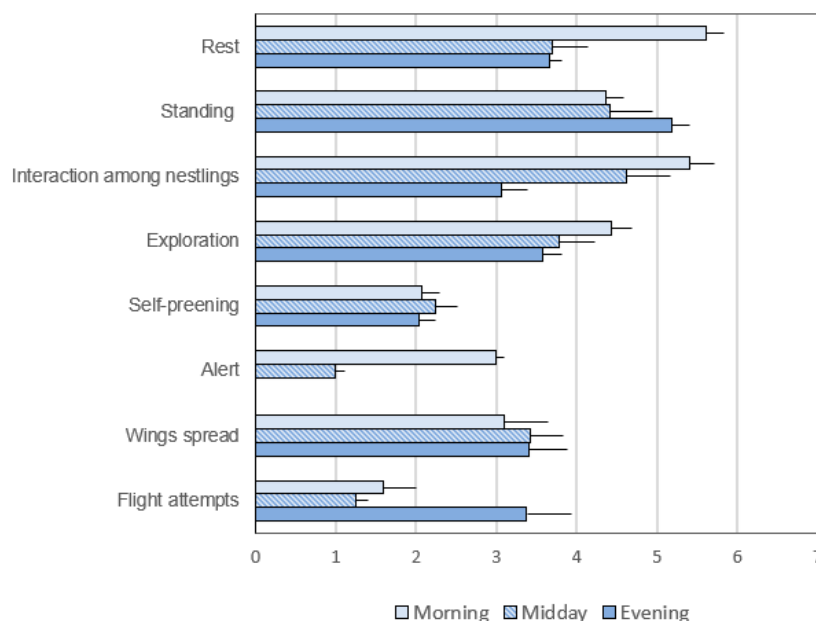


Figure 8. Hourly frequency ($\bar{x} \pm SE$) of the nestling activities.

Also noteworthy was the frequency of flight attempts at the nest site, which was higher in the third period and especially at dusk. The other activities, both those related to the interaction between parents and offspring and those of the nestlings, showed an almost constant frequency in all three periods of the day (Figure 8). As is usual for this species, of the five nestlings born, only two managed to fly away, while the other three died about a month after birth for unknown reasons. The reasons for the death of the nestlings were probably due to the fact that the eggs were laid about two days apart and hatching occurred asynchronously, so that there were nestlings of different ages and weights (Appendix A Figure A7, Video S1). There is strong competition for food among nestlings, and it is a great advantage to be larger. As a result, the young only get a full meal when the older ones are full. In times of food scarcity, the juveniles are therefore undernourished and at risk of starvation. [29]. Juvenile mortality in the black Stork is also

related to cases of infanticide. One case was observed in Poland, in the Łochowskie Forest, where a parent grabbed the head of one of the five nestlings of its brood with its beak and threw it out of the nest. The causes of infanticide may be the overproduction of offspring, which leads parents to eliminate animals with lower life expectancy [42–45]. Tortosa and Redondo [46], in their study of infanticide cases in the white stork, found that parents sacrificed the youngest nestlings, which grew more slowly than their siblings. However, no cases of infanticide were observed in the present study. Mock and Forbes [44] noted that by producing marginal young, parents benefit from unpredictable resources that turn out to be unusually abundant; provide food or servants for the main brood members; and/or keep a supply of replacements for the core offspring that either do not survive or develop poorly.

4. Conclusions

Among the greatest threats to the biodiversity of many European agro-ecosystems today, such as the Basilicata region, is the rapid change in agricultural practices; semi-natural grasslands, heathlands, arable steppes and agroforestry systems are affected by a significant loss of biodiversity. Nevertheless, the establishment of the Natura 2000 network in application of Council Directives 79/409/EEC on the conservation of wild birds and 92/43/EEC on the conservation of natural habitats and of wild fauna and flora could be a promising strategy to revive these traditional practices. Once fully operational, this ecological network will consist of a system of protected areas [i.e., Special Areas of Conservation (SACs) and Special Protection Areas (SPAs)] designed to ensure the long-term survival of Europe's most valuable and threatened species and habitats. Given the development of the promising black stork nucleus in the Basilicata region, it is advisable to plan for various human activities, starting with tourist attractions (the “flight of the angel” *in primis*), which at certain times of the year clash with the necessary quiet that this species needs to survive. As previously reported, the black stork has proven to be a shy and cautious species that does not interact much with humans. It is therefore advisable to focus on the quality of habitats and feeding areas, i.e., riverine areas within a radius of up to 20 km from the nesting sites where the species finds food, but also on improving food sources by creating shallow artificial pools near the spawning sites. It is possible that, if it finds suitable conditions and little disturbance, this species can also establish itself in Italy with stable populations; at the moment, the most ‘promising’ nucleus seems to be that in Basilicata. Our study is a first contribution to the knowledge about nesting behavior on cliffs. Only an extension of the study to several pairs and in more than one reproductive cycle will perhaps help to (a) understand this species’ unusual choice to nest on cliffs in Basilicata and in some other continental areas, rather than on tall trees as is usually the case; and (b) define more precisely the behavioral response of the species to anthropogenic and natural stressors, in particular to the presence of nest predators, birds (*Bubo bubo*, *Corvus corax*, *Buteo buteo*, *Milvus milvus*) and mammals (*Martes foina*, *Martes martes*).

Supplementary Materials: The following supporting information can be downloaded at: Video S1: Nestlings with one parent, <https://zenodo.org/record/7763461> (accessed on 24 February 2023).

Author Contributions: Conceptualization, P.F., M.R. and A.B.; methodology, F.N.; software, R.P.; validation, P.F., C.C. and A.B.; formal analysis, C.P.; investigation, E.M.; resources, P.F.; data curation, D.M.; writing—original draft preparation, D.M.; writing—review and editing, D.M.; visualization, A.B.; supervision, C.P. and M.R.; project administration, C.C.; funding acquisition, P.F. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Data Availability Statement: Data are available on request.

Acknowledgments: We are grateful to the Direction of the Regional Park “Gallipoli Cognato Piccole Dolomiti Lucane” for providing the video material used for the study.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A



Figure A1. The sandstone cliffs of the “Piccole Dolomiti Lucane” in the background and the Caperrino stream.



Figure A2. Courtship.



Figure A3. Mating.



Figure A4. Nest building.



Figure A5. Incubation.



Figure A6. Nestling care.



Figure A7. Full brood.



Figure A8. Nestlings almost ready for fledging.

References

1. Tamas, E.A. Breeding and Migration of the Black Stork (*Ciconia nigra*), with Special Regard to a Central European Population and the Impact of Hydro-Meteorological Factors and Wetland Status. Ph.D. Thesis, University of Debrecen, Debrecen, Hungary, December 2012.
2. Elliot, A. Family Ciconiidae. In *Handbook of the Birds of the World—Ostrich to Ducks*; Del Hoyo, J., Elliot, A., Sargatal, J., Eds.; Lynx Edicions: Barcelona, Spain, 1992; Volume 1, pp. 436–465. ISBN 978-84-87334-10-8.
3. BirdLife International 2012. *Ciconia nigra*. The IUCN Red List of Threatened Species. Available online: www.iucnredlist.org (accessed on 14 December 2022).
4. Bobek, M.; Hampl, R.; Peske, L.; Pojer, F.; Simek, J.; Bures, S. African Odyssey project—Satellite tracking of black storks *Ciconia nigra* breeding at a migratory divide. *J. Avian Biol.* **2008**, *39*, 500–506. [[CrossRef](#)]
5. Löhmus, A.; Sellis, U. Nest trees—A limiting factor for the Black Stork (*Ciconia nigra*) population in Estonia. *Aves* **2003**, *40*, 84–91.
6. Zawadzki, G.; Zawadzka, D. Wybór drzew gniazdowych myszółowa, jastrzębia i kruka w Puszczy Augustowskiej. *Sylvan* **2017**, *161*, 669–676.
7. Zawadzki, G.; Zawadzka, D.; Soltys, A.; Drozdowski, S. Nest-site selection by the white-tailed eagle and black stork—implications for conservation practice. *For. Ecosyst.* **2020**, *7*, 59. [[CrossRef](#)]
8. Poirazidis, K.; Bontzorlos, V. Population trends and multi-scale breeding habitat analysis for the black stork (*Ciconia nigra*) in Dadia-Lefkimi-Soufli National Park, north eastern Greece. *Annu. Res. Rev. Biol.* **2017**, *19*, 1–12. [[CrossRef](#)]
9. Banas, J.; Zieba, S.; Bujoczek, M.; Bujoczek, L. The Impact of Different Management Scenarios on the Availability of Potential Forest Habitats for Wildlife on a Landscape Level: The Case of the Black Stork *Ciconia nigra* (Linnaeus, 1758). *Forests* **2019**, *10*, 362. [[CrossRef](#)]
10. Vlachos, C.G.; Bakaloudis, D.E.; Alexandrou, O.G.; Bontzorlos, V.A.; Papakosta, M.A. Factors affecting the nest site selection of the black stork *Ciconia nigra* in the Dadia-Lefkimi-Soufli National Park, north eastern Greece. *Folia Zool.* **2008**, *57*, 2512–2557.
11. Jiguet, F.; Villarubias, S. Satellite tracking of breeding black storks *Ciconia nigra*: New incomes for spatial conservation issues. *Biol. Conserv.* **2004**, *120*, 153–160. [[CrossRef](#)]

12. Cano-Alonso, L.S.; Tellería, J.L. Breeding productivity in relation to nesting substrate and nest site accessibility to humans in the black stork *Ciconia nigra*. *Ardeola* **2013**, *60*, 357–363. [[CrossRef](#)]
13. von Puhringer, N. Bestandserfassung des schwarzstorchs (*Ciconia nigra*) in Oberösterreich 2020/21 im kontext der bestandsentwicklung—von der erfolgsgeschichte zum sorgenkind? *Vogelkdl. Nachr. OÖ. Naturschutz aktuell* **2022**, *28/29*, 3–61. Available online: https://www.zobodat.at/pdf/VNO_028-029_0003-0061.pdf (accessed on 24 February 2023).
14. Lee, A.T.K.; Whitecross, M.A.; Smit-Robinson, H.A.; Allan, D.G.; Van den Heever, L.; Jenkins, A.; Retief, E.F.; Colyn, R.B.; Tarboton, W.; Chetty, K.; et al. A review of the conservation status of Black Stork *Ciconia nigra* in South Africa, Lesotho, and Eswatini. *Bird Conserv. Int.* **2023**, *33*, e56. [[CrossRef](#)]
15. Spina, F.; Volponi, S. *Atlante della Migrazione degli Uccelli in Italia—Non Passeriformi*; ISPRA: Rome, Italy, 2008; pp. 127–129. ISBN 9788844803780.
16. Caldarella, M.; Bordignon, L.; Brunelli, M.; Cripezzi, E.; Fraissinet, M.; Mallia, E.; Marrese, M.; Norante, N.; Urso, S.; Visceglia, M. *Status della Cicogna nera (Ciconia nigra) e Linee Guida per la Conservazione della Specie in Italia*; Parco regionale Gallipoli Cognato–Dolomiti Lucane: Accettura, Italy, 2018.
17. Fraissinet, M.; Bordignon, L.; Brunelli, M.; Caldarella, M.; Cripezzi, E.; Giustino, S.; Mallia, E.; Marrese, M.; Norante, N.; Urso, S.; et al. Breeding population of Black Stork, *Ciconia nigra*, in Italy between 1994 and 2016. *Riv. Ital. Ornitol.* **2018**, *88*, 15–22. [[CrossRef](#)]
18. Brunelli, M.; Bordignon, L.; Caldarella, M.; Cripezzi, E.; Dove, B.; Fraissinet, M.; Mallia, E.; Marrese, M.; Norante, N.; Urso, S.; et al. Rapporto sulla nidificazione della Cicogna nera *Ciconia nigra* in Italia. *Alula* **2022**, *29*, 118–119.
19. Freschi, P.; Fascetti, S.; Musto, M.; Mallia, E.; Blasi, A.C.; Cosentino, C.; Paolino, R. Diet of the Apennine hare in a southern Italy Regional Park. *Eur. J. Wildl. Res.* **2014**, *60*, 423–430. [[CrossRef](#)]
20. Freschi, P.; Fascetti, S.; Musto, M.; Mallia, E.; Cosentino, C.; Paolino, R. Diet of the Italian hare (*Lepus corsicanus*) in a semi-natural landscape of southern Italy. *Mammalia* **2014**, *79*, 51–59. [[CrossRef](#)]
21. Freschi, P.; Musto, M.; Paolino, R.; Cosentino, C. Grazing and biodiversity conservation: Highlights on a Natura 2000 Network site. In *The Sustainability of Agro-Food and Natural Resource Systems in the Mediterranean Basin*; Vastola, A., Ed.; Springer International Publishing AG: Basel, Switzerland, 2015; pp. 271–288. [[CrossRef](#)]
22. Freschi, P.; Fascetti, S.; Musto, M.; Cosentino, C.; Paolino, R.; Valentini, V. Seasonal variation in food habits of the Italian hare in a south Apennine semi-natural landscape. *Ethol. Ecol. Evol.* **2016**, *28*, 148–162. [[CrossRef](#)]
23. Freschi, P.; Fascetti, S.; Riga, F.; Cosentino, C.; Rizzardini, G.; Musto, M. Diet composition of the Italian roe deer (*Capreolus capreolus italicus*) (Mammalia: Cervidae) from two protected areas. *Eur. Zool. J.* **2017**, *84*, 34–42. [[CrossRef](#)]
24. Freschi, P.; Fascetti, S.; Riga, F.; Rizzardini, G.; Musto, M.; Cosentino, C. Feeding Preferences of the Italian Roe Deer (*Capreolus capreolus italicus* Festa, 1925) in a Coastal Mediterranean Environment. *Animals* **2021**, *11*, 308. [[CrossRef](#)]
25. Rizzardini, G.; Fascetti, S.; Pietri, C.; Riga, F.; Cosentino, C.; Freschi, P. Feeding preferences in dry season of the Italian hare (*Lepus corsicanus*) in two sites of Corsica. *Eur. J. Wildl. Res.* **2019**, *65*, 43. [[CrossRef](#)]
26. Martin, P.; Bateson, P. *Measuring behaviour*, 4th ed.; Cambridge University Press: Cambridge, UK, 2021; pp. 79–132. ISBN 978-1-108-47831-1.
27. R Core Version 3.6.1. Available online: <https://www.r-project.org> (accessed on 24 February 2023).
28. Soler, J.J.; Moller, A.P.; Soler, M. Nest building, sexual selection and parental investment. *Evol. Ecol.* **1998**, *12*, 427–441. [[CrossRef](#)]
29. Kahl, M.P. Comparative ethology of the Ciconiidae. Part 4. The “Typical” Storks (Genera *Ciconia*, *Sphenorhynchus*, *Dissoura* and *Euxenura*). *Z. Tierpsychol.* **1972**, *30*, 225–252. [[CrossRef](#)]
30. Baoqing, L.; Jun, Z.; Ainan, Q. Studies on incubation and raising of oriental White Stork (*Ciconia boyciana*). *Chin. J. Zool.* **2004**, *39*, 45–47.
31. Zbyryt, A.; Jankowia, L.; Jerzak, L.; Tryjanowski, P. Head and body orientation of the White Stork *Ciconia ciconia* during incubation: Effect of wind, apex predators and power lines. *J. Ornitol.* **2002**, *163*, 181–189. [[CrossRef](#)]
32. Poussart, C.; Gauthier, G.; Laroche, J. Incubation behaviour of greater snow geese in relation to weather conditions. *Can. J. Zool.* **2001**, *79*, 671–678. [[CrossRef](#)]
33. Cotgreave, D.H.; Clayton, P. Comparative analysis of time spent grooming by birds in relation to parasite load. *Behaviour* **1994**, *131*, 171–187. [[CrossRef](#)]
34. Schuz, E. Bewegungsnormen des Weißen Storchs. *Z. Tierpsychol.* **1942**, *5*, 31. [[CrossRef](#)]
35. Clayton, D.H.; Cotgreave, P. Relationship of bill morphology to grooming behaviour in birds. *Anim. Behav.* **1994**, *47*, 195–201. [[CrossRef](#)]
36. Goldstein, D.L. Estimates of daily energy expenditure in birds: The time-energy budget as an integrator of laboratory and field studies. *Am. Zool.* **1988**, *28*, 829–844. [[CrossRef](#)]
37. Clayton, D.H.; Koop, J.A.H.; Harbison, C.W.; Moyer, B.R.; Bush, S.E. How Birds Combat Ectoparasites. *Open Ornitol. J.* **2010**, *3*, 41–71. [[CrossRef](#)]
38. Ferrero, J.J.; Román, J.A. Estudio sobre la cigüeña negra en Extremadura II: Nidotópica y hábitat de nidificación. *Alytes* **1991**, *5*, 19–46.
39. del Moral, J.C. Cigüeña negra *Ciconia nigra*. In *III Atlas de las Aves en época de Reproducción en España*; Molina, B., Nebreda, A., Muñoz, A.R., Seoane, J., Real, R., Bustamante, J., del Moral, J.C., Eds.; SEO/BirdLife: Madrid, Spain, 2022; pp. 1–8. Available online: <https://atlasaves.seo.org/ave/ciguena-negra/> (accessed on 13 June 2023).

40. Prieta, J.; Traverso, J.M. Appropriación de nidos de cigüeña negra por rapaces rupícolas. *Quercus* **2000**, *172*, 24–28.
41. Brambilla, M.; Rubolini, D.; Guidali, F. Rock climbing and raven *Corvus corax* occurrence depress breeding success of cliff-nesting peregrines *Falco peregrinus*. *Ardeola* **2004**, *51*, 425–430.
42. Kłosowski, G.; Kłosowski, T.; Zieliński, P. A case of parental infanticide in the black stork *Ciconia nigra*. *Avian Sci.* **2002**, *2*, 59–62.
43. Konarzewski, M. The evolution of clutch size and hatching asynchrony in altricial birds: The effect of environmental variability, egg failure and predation. *Oikos* **1993**, *67*, 97–106. [[CrossRef](#)]
44. Mock, D.W.; Forbes, L.S. The evolution of parental optimism. *Trends Ecol. Evol.* **1995**, *10*, 130–134. [[CrossRef](#)]
45. Zielinski, P. Brood reduction and parental infanticide—Are the White Stork *Ciconia ciconia* and the Black Stork *C. nigra* exceptional? *Acta Ornithol.* **2002**, *37*, 113–119. [[CrossRef](#)]
46. Tortosa, F.S.; Redondo, T. Motives for parental infanticide in White Storks *Ciconia ciconia*. *Ornis Scand.* **1992**, *23*, 185–189. [[CrossRef](#)]

Disclaimer/Publisher’s Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.