

Life History of the Andean Condor in Ecuador

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Source: Tropical Conservation Science, 17(1)

Published By: SAGE Publishing

URL: <https://doi.org/10.1177/19400829241238005>

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Tropical Conservation Science
Volume 17: 1–8
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DOI: 10.1177/19400829241238005
journals.sagepub.com/home/trc



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Abstract

Background and Research Aims: Little information exists on the breeding behavior of the Andean Condor (*Vultur gryphus*). Its global population, estimated at 6700 adult individuals, is declining throughout its distribution range. With less than 150 condors, the Endangered condor population in Ecuador is of conservation concern. This study aimed to analyze the breeding behavior of wild-born Andean Condors in Ecuador. **Methods:** Between 2009 and 2021, we monitored 22 egg-laying attempts in eight Andean Condor nests, evaluated the parental care of three breeding pairs of condors and recorded the species' interactions with other raptors and mammals during the nestling-rearing season, and examined the breeding success of an Andean Condor pair during a decade of monitoring. **Results:** Our breeding records indicated that Andean Condor lay eggs throughout the year, and 16 nestlings spent between six and 10 months in the nest before making their first flights. We found differences in the length of time that the parents remain with the nestling, and described agonistic encounters between condors and other raptors and a Spectacled Bear (*Tremarctos ornatus*) in the condor nesting areas. The breeding success of the monitored condor pair was 0.88 nestlings per clutch, and the female laid an egg on average every 15 months. **Conclusion:** Considering the small size of the Andean Condor population in Ecuador, studies on the breeding behavior of wild-born condors are a high research priority to assess population trends and prevent extinction. Specifically, we recommend further research on parental care, breeding success, nestling survivorship, and nesting phenology. **Implications for Conservation:** Beyond the importance of the protected area system, strategic planning of key areas for the maintenance of condor populations in the northern Andes must encompass the evaluation of new potential protected areas that offer direct benefits to these birds. These should include nesting sites in human-dominated landscapes such as rural Andean areas.

Keywords

parental care, breeding success, agonistic encounter, egg-laying, vultures

Introduction

Little information is available on the breeding biology of New World vultures (Cathartidae), which restricts the development of efficient conservation actions (Santangeli et al., 2022). One such species is the Andean Condor (*Vultur gryphus*), inhabiting paramos and montane forests throughout the Andes (Ferguson-Lees & Christie 2001; Lambertucci, 2007; Plaza & Lambertucci 2020). Its global population does not exceed 6700 adult individuals, and it is in decline throughout its distribution range and, therefore listed as Vulnerable (Birdlife International, 2023). However, its conservation status is of most concern in Ecuador, where its total population is less than 150 individuals (Naveda-Rodríguez et al., 2016; Vargas et al., 2018a) and isolated from the populations in Colombia

and Perú (Padró et al., 2023). The species is listed as Endangered at the national level (Freile et al., 2019).

The Andean Condor is the only vulture species displaying sexual dimorphism, allowing reliable comparisons of males

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Received: 4 September 2023; accepted: 13 February 2024

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and females providing parental care (Lambertucci & Mastrantuoni 2008). Male Andean Condors are larger than females. Males also have a large comb which increases in size with age, whereas females completely lack a crest (Houston et al., 2020). The information available about its breeding behavior comes from observations of a few pairs of Andean Condors in their nests, mostly in the south of their range (e.g., Lambertucci & Mastrantuoni 2008; Sáenz-Jiménez et al., 2016; Restrepo-Cardona et al., 2018). The species nests in rocky escarpments, although nests are also found in cliffs over water and caves at ground level (Lambertucci, 2007; Lambertucci & Speziale 2009). Females of Andean Condors lay a single egg, an event that may occur every two years. Both adults incubate the egg for approximately 60 days and then feed the nestling for many months. The nestlings remain in or near the nests for approximately 15 months (Lambertucci & Mastrantuoni 2008).

Because of the latitudinal extent of the Andean Condor's range, egg-laying dates can vary markedly from Colombia to southern Chile (McGahan, 1972). In the northern Andes, egg-laying was reported between January and February (Köster, 1997) in Ecuador, between February and April by Sáenz-Jiménez et al. (2016), and between October and December by Restrepo-Cardona et al. (2018) in Colombia. However, towards the southern Andes in Argentina and Chile, the egg-laying of condors occurs between August and December (McGahan, 1972; Lambertucci & Mastrantuoni 2008; Gargiulo, 2014). Furthermore, there are seasonal differences in the use of communal roosts by Andean Condor populations in Tropical and subtropical Andean areas (Lambertucci, 2010; Márquez-Alvis et al., 2023), and the feeding habits of the species vary along a ~2500 km latitudinal gradient of human-modified habitats and more pristine ecosystems (Duclos et al. 2020).

Although there has been a recent increase in the availability of scientific information on the population biology of the Andean Condor, specific knowledge of its breeding behavior remains scarce (Plaza & Lambertucci 2020). This study aimed to (1) analyze the timing of egg-laying in wild-born Andean Condors, (2) evaluate the parental care of three pairs of condors and provide a record of the species' interactions with other raptors and mammals during the nestling-rearing season, and (3) examine the breeding success of an Andean Condor pair in a 10-year period in Ecuador.

Materials and Methods

Study Area

The study was carried out in eight wild-born Andean Condor nests located on rocky escarpments in the Andean region of Ecuador. Six nests were located in the province of Pichincha, in Itulcachi at 2,999 m a.s.l. (0°18'S, 78°18'W) in the middle basin of the Río Itulcachi and El Tablón at 3,020 m a.s.l. (0°16'S, 78°18'W). In the Peñón del Isco at 3,575 m a.s.l.

(0°27'S, 78°19'W) and Peñón del Cóndor at 3,934 m a.s.l. (0°27'S, 78°16'W). Both sites are in the Reserva Ecológica Chakana of the Fundación Jocotoco. In Chitachaca at 3,306 m a.s.l. (0°2'S, 78°6'W) and Caleras at 3,312 m a.s.l. (0°3'S, 78°4'W), located in the middle and upper basins of the Río Chitachaca, respectively. One nest was located in Cotopaxi province, in Barrancas at 4,180 m a.s.l. (0°44'S, 78°24'W), and another was in the Azuay province, in the Reserva Municipal Cóndor Sur at 1,637 m a.s.l. (3°26'S, 79°11'W), located in the middle basin of the Río León. The distance between the nests in Itulcachi and El Tablón is 2.94 km, between the nests in Peñón del Isco and Peñón del Cóndor is 4.52 km, and between the nests in Chitachaca and Caleras is 3.12 km (Figure 1).

The nest areas comprised various landscapes of Andean paramos and Andean Mountain Forests. Nests in Caleras, Barrancas, Peñón del Isco, and Peñón del Cóndor were located in the paramo ecosystem. Paramo is a grassland-shrubland ecosystem found above 3000 m a.s.l. in areas that are humid year-round, with > 3000 mm of annual precipitation (Rundel, 1994). Nests in El Tablón, Itulcachi, Chitachaca, and Río León were located in the ecotone between the upper limit of the Andean Mountain Forests and the paramo. The Andean Mountain Forests in Ecuador have been extensively degraded due to human disturbance such as cattle ranching and agriculture (Sierra et al., 2021).

Methodology

To understand the timing of the breeding of wild-born Andean Condors in Ecuador, we gathered information about egg-laying, incubation, and nestling-rearing attempts. This information was compiled from non-systematic observations of condor nests that the authors and collaborators of this study monitored between 2009 and 2021.

To describe the Andean Condor parental care, each nest site was considered as the central point within an area of 1 km² surrounding it, and we recorded the time that each breeding adult remained within this area. Upon detection of an egg in a nest, the time each adult spent incubating was recorded. When a nestling was detected, the time each adult spent with the nestling and time spent feeding the nestling were recorded. Additionally, agonistic encounters between condors, other raptor species, and large mammals were recorded (Lambertucci & Mastrantuoni 2008; Restrepo-Cardona et al., 2018).

Between November and December 2017 and between June 2021 and February 2022 at El Tablón, between January and March 2021 at Itulcachi, and between July and September 2021 at Chitachaca, we conducted systematic observations at the three nests. Nests were observed between 0600 and 1814 h at El Tablón in 2017 (five visits/month) and between 0800 and 1630 h between 2021 and 2022 (three visits/month), between 0555 and 1825 h at Itulcachi (six visits/month), and between 0800 and 1630 h at Chitachaca

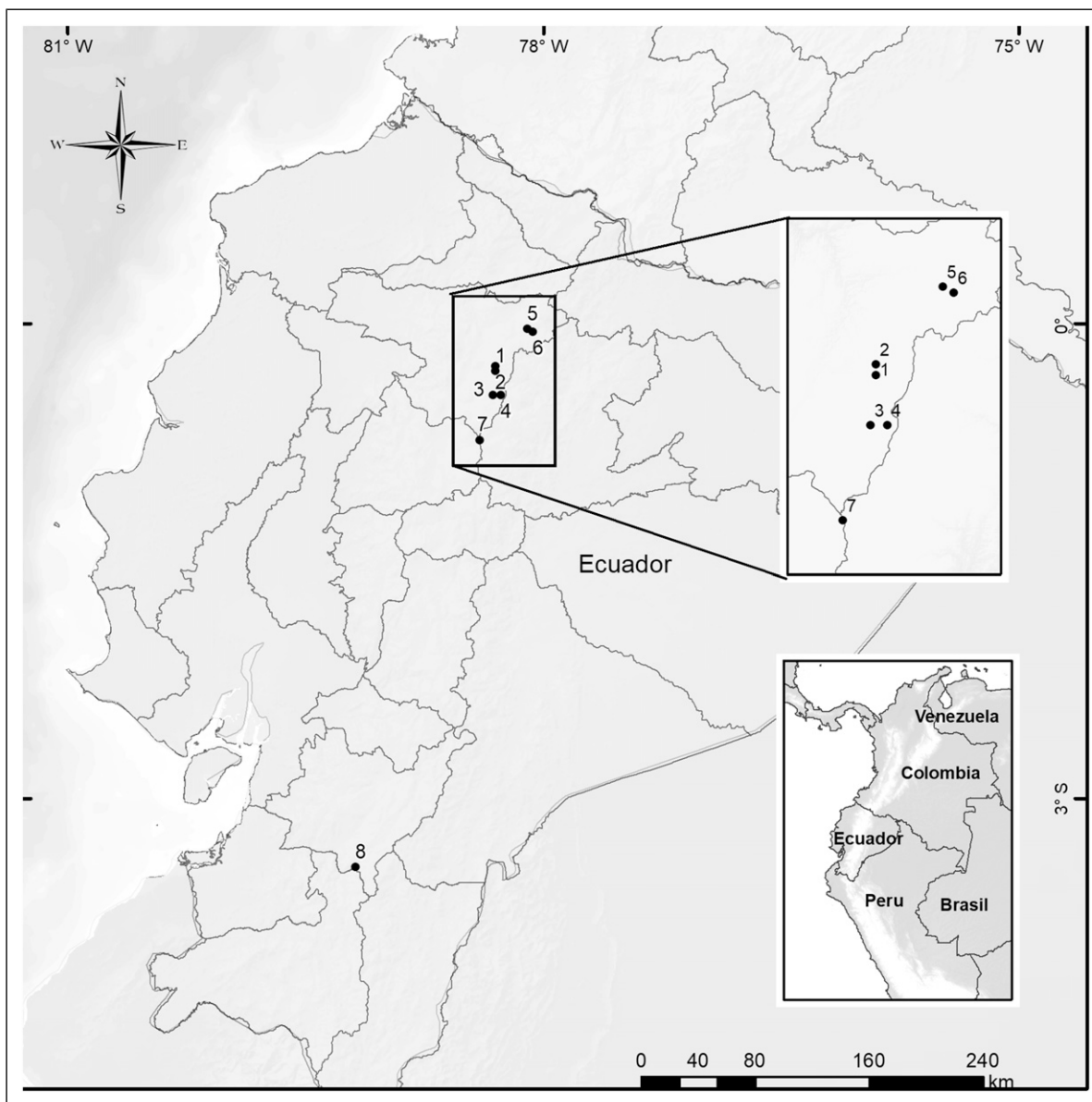


Figure 1. Map of the locations of eight wild-born Andean Condor (*Vultur gryphus*) nests in the Andean region of Ecuador. (1) Itulcachi, (2) El Tablón, (3) Peñón del Isco, (4) Peñón del Cóndor, (5) Chitachaca, (6) Caleras, (7) Barrancas, and (8) Río León.

(five visits/month). We used binoculars (10 x 42 and 10 x 50), telescopes (20-60 x 60 and 20-60 x 65), and cameras to observe from elevated points between 50 and 300 m horizontal distance from each nest.

To analyze the breeding success of the Andean Condor pair at Peñón del Isco, the nest was monitored by direct observations over 10 nesting attempts from November 2011 to November 2021. The nest was visited two days every week and observed for 12 hours. We calculated the breeding success (number of nestlings hatched/total number of eggs laid), the total number of nestlings that fledged, and the permanence in the nest of these nestlings before making their first flights (Villegas-Davies et al., 2018). We did not record

behaviors such as mating, courtship displays, and feather cleaning.

Data Analysis

To assess whether there were significant differences in the number of hours each adult Andean Condor remained in the nest incubating the egg, or accompanying or feeding the nestling, we performed Chi-square tests of independence using R Project version 2.1 (R Core Team, 2020). Statistical significance across all analyses was considered when $P < 0.05$. We did not perform quantitative analyses of egg-laying, incubation, and nestling-rearing dates in the nest, nor did we

make comparisons of parental care between condor pairs due to a lack of systematic data.

Results

Nesting Attempts and Timing of Egg-Laying

Between 2009 and 2021, we compiled records of 22 condor nesting attempts in eight sites in Ecuador. We found that wild-born Andean Condors laid eggs throughout the year. Our data show the rearing of 19 Andean Condor nestlings in eight nests. Of these, 16 nestlings remained in the nests between six and 10 months before making their first flights. One nestling fell from the nest and died. Another nestling fell from the nest and lost its tail to an attack by free-ranging dogs, and another fell from the nest and broke its leg. In addition, three eggs failed to hatch. We found that nine male nestlings remained in the nest for between seven and 10 months and seven female nestlings were in the nest between six and eight months before making their first flights (Table 1).

Incubation and Rearing of the Nestling

We recorded the presence of a single egg when we began observations at the Itulcachi nest in January 2017, and at El Tablón nest in November 2017 and June 2021. At Chitachaca, in July 2021, we observed a female nestling of approximately five months of age.

At the Itulcachi nest, in 2017, in over 211.48 h of observations carried out between January 31st and March 23rd, the female remained in the nest incubating the egg 35.97% of the time (76.07 h), while the male did so for 32.89% of the time (69.56 h) ($\chi^2 = 0.29$, $df = 1$, $P = 0.59$). After March, the condors did not continue incubation and the egg did not hatch.

At El Tablón nest, in 2017, during 11.01 h of observation between November 7th and 15th, the female incubated the egg for 31.51% of the time (3.47 h), while the male did so for 28.51% of the time (3.14 h) ($\chi^2 = 0.01$, $df = 1$, $P = 0.90$). On November 15th, we observed the hatching of a male nestling. During 81.48 h of observation between November 15th and December 9th, the female was with the nestling in the nest for 39.88% of the time (32.50 h) and the male for 29.55% of the time (24.08 h) ($\chi^2 = 1.27$, $df = 1$, $P = 0.25$). The female fed the nestling for 0.62% of the time (0.51 h), while the male fed the nestling for 0.55% of the time (0.45 h) ($\chi^2 = 0.01$, $df = 1$, $P = 0.91$). On December 10th, the nestling fell out of the nest and died.

Again at El Tablón nest, in 2021, during 28.12 h of observation between June 18th and July 9th, the male incubated the egg for 40.29% of the time (11.33 h) and the female for 35.63% of the time (10.02 h) ($\chi^2 = 0.07$, $df = 1$, $P = 0.77$). Whereas, during 90.19 h of observation between July 23rd, 2021, and January 7th, 2022, the male stayed for longer with the nestling in the nest (11.47 h, 12.71%) compared to the

female (3.41 h, 3.78%) ($\chi^2 = 4.32$, $df = 1$, $P = 0.03$). The male fed the nestling for 0.58% of the time (0.53 h) and the female for 0.05% of the time (0.05 h) ($\chi^2 = 0.39$, $df = 1$, $P = 0.52$).

At the Chitachaca nest, in 2021, over 78.10 h of observation between July 19th and September 1st, the female was in the nest for 10.38% of the time (8.11 h), and the male was in the nest for 5.59% of the time (4.37 h) ($\chi^2 = 1.12$, $df = 1$, $P = 0.28$). The female fed the nestling for 0.51% of the time (0.40 h), while the male was not observed feeding the nestling.

Territorial Defense

At El Tablón, in 2021, when the nest had an egg, on one occasion the female displaced a pair of Black Vultures (*Coragyps atratus*), and on another occasion, it displaced a juvenile male condor from the vicinity. In 2017, when there was a nestling in the nest, on one occasion the condor pair displaced a Black-Chested Buzzard-Eagle (*Geranoaetus melanoleucus*). Whereas between 2021 and 2022, during the nestling period, the female displaced an adult female condor, a Black Vulture pair and a Spectacled Bear (*Tremarctos ornatus*) on one occasion, respectively. The Spectacled Bear came within three meters of the nest entrance. While on one occasion, the male displaced another adult female condor from the vicinity. At the Itulcachi and Chitachaca nests, no agonistic encounters were recorded between the condors and other species entering the 1km² nesting area.

Breeding Success

The breeding success of the Andean Condor pair at Peñón del Isco was 0.88 nestlings per clutch. The female laid an egg on average every 15 months. Three nests were reused two times and two other nests were used once. All the nestlings (seven birds) fledged from the nest and an egg failed to hatch. However, the nestling that hatched in 2015 fell from the nest while attempting its first flight. It was rescued, marked with wing band No. 12 and a satellite transmitter, and was recorded surviving, subsequently. This nestling returned to the natal site on one occasion in March 2017, and there it was fed by the parents that were rearing another nestling inside the nest. Furthermore, the time that Andean Condor nestlings remained in the nest before making their first flight ranged from six to eight months (Table 1).

Discussion

We present records of 22 Andean Condor egg-laying attempts between 2009 and 2021 in eight nests, which indicate that wild-born condor egg-laying occurs throughout the year in Ecuador. Our data on the breeding behavior of condors show that there could be differences in the lengths of time that the parents remain with the nestling in the nest, as well as evidence presented of agonistic encounters between condors and

Table 1. Records of egg-laying, incubation, and rearing of nestlings in eight wild-born Andean Condor (*Vultur gryphus*) nests in Ecuador, chronologically ordered between 2009 and 2021.

Locality	Egg-laying/ Incubation	Rearing of nestling in the nest	Sex of nestling	Observations/Source
Chitachaca	Oct. – Dec. 2009	Jan. – Aug. 2010	Male	Nestling fledged
El Tablón	Feb. – Apr. 2011	May. – Nov. 2011	Female	Nestling fledged
Caleras	Feb. – Apr. 2011	Apr. – Dec. 2011	Male	Nestling fledged (Narváez, 2012)
Río León	Oct. – Dec. 2011	Jan. – Sep. 2012	Male	Nestling fledged (Vargas et al., 2017)
Peñón del Isco	Nov. – Dec. 2011	Jan. – Oct. 2012	Male	Nestling fledged (Vargas, 2012)
Peñón del Isco	Apr. – Jun. 2013	Jun. – Dec. 2013	Male	Nestling Fledged (Vargas et al., 2013)
Peñón del Cónдор	Sep. – Nov. 2013	Mar. – Sep. 2014	Female	Nestling Fledged (Vargas et al., 2017)
Peñón del Isco	Jul. – Aug. 2014	Sep. 2014 – Feb. 2015	Female	Nestling fledged (Vargas et al., 2017)
Barrancas	Oct. 2014			The egg failed to hatch
Peñón del Isco	Aug. – Oct. 2015	Oct. 2015 – Apr 2016	Female	The nestling fell from the nest while attempting its first flight. It was rescued, marked with wing tag No. 12 and a satellite transmitter, and left in the natal site (Vargas et al., 2017)
Peñón del Isco	Nov. – Dec. 2016	Jan. – Aug. 2017	Female	Nestling fledged (Vargas et al., 2017)
Itulcachi	Jan. – Mar. 2017			The egg failed to hatch (Vargas et al., 2018b)
El Tablón	Sep. – Nov. 2017	Nov. – Dec. 2017	Male	The male nestling fell from the nest and died 27 days after hatching
Peñón del Isco	Jan. 2018			The egg failed to hatch (Vargas et al., 2018b)
Peñón del Isco	Apr. – Jun. 2018	Jun. 2018 – Jan. 2019	Female	Nestling fledged and marked with wing tag No. 14 and a satellite transmitter (Vargas et al., 2018b)
El Tablón	Oct. - Dec. 2018	Jan. – Jul. 2019	Male	Nestling fledged (Vargas et al., 2018b)
Peñón del Isco	Aug. – Oct. 2020	Nov. 2020 – Jun. 2021	Male	The nestling fell from the nest while attempting its first flight, it could subsequently fly with no problems
Chitachaca	Oct. – Dec. 2018	Jan. – Jul. 2019	Male	The nestling fell from the nest and lost its tail in an attack by free-ranging dogs. The bird is now in captivity
Chitachaca	Sep.- Nov. 2019	Dec. 2019 – Jun. 2020	Female	The nestling fell from the nest and broke a leg. The bird is now in captivity
Itulcachi	Jan. – Mar. 2019	Apr – Nov.- 2019	Male	Nestling Fledged. Marked as nestling with wing tag No. 15 and a satellite transmitter (Vargas et al., 2019)
El Tablón	May. – Jul. 2021	Jul. 2021 – Jan. 2022	Male	The last time the juvenile was observed in the nest vicinity was September 22th, 2022
Chitachaca	Dec. 2020 – Feb. 2021	Feb. 2021 – Sep. 2021	Female	The nestling was marked with wing tag No. 18 and a satellite transmitter, and left in the nest

other condors, raptor species, and a Spectacled Bear in the nesting areas. We also highlight that the breeding success of the Andean Condor pair at Peñón del Isco was 0.88 nestlings per clutch and that the female laid an egg on average every 15 months (Table 1).

Our breeding records indicate that Andean Condor lay eggs throughout the year (Table 1), in both rainy (between March and April and between October and November) and dry (between December and February and between May and September) periods (Albuja et al., 2012). There is evidence of egg-laying and incubation in subtropical Andes occurring between August and December (McGahan, 1972;

Lambertucci & Mastrantuoni 2008; Gargiulo, 2014). Therefore, we assume that latitude affects Andean Condor egg-laying and hatching time through the species' distribution range. Harsh winter conditions that might harm an egg or nestling are absent in equatorial areas, but local variation in food availability may affect the timing of reproduction (McGahan, 1972; Wallace & Temple 1988). Furthermore, climatic factors, such as precipitation, temperature, and humidity, can influence the nesting phenology of birds (Cooper et al., 2005). Precipitation, temperature, and seasonality may affect the use of communal roost by Andean Condors in Tropical and subtropical areas (Lambertucci, 2010;

Márquez-Alvis et al., 2023). All of these are factors that we did not measure in our study. It is therefore important to conduct research to evaluate the influence of climate variability and food availability on the nesting phenology and feeding habits of the Ecuadorian Andean Condor population and thus contribute to the knowledge about the species' life history.

We found that, at El Tablón in November 2017 and between June and July 2021, at Itulcachi between January and March 2017, and at Chitachaca between July and September 2021, both Andean Condor parents incubated the eggs, or cared for or fed the nestling for a similar amount of time. However, at El Tablón between July 2021 and January 2022, the male remained in the nest with the nestling for more time than the female. Similarly, in Argentina, during the nesting period, the male visited the nest site more often, stayed for longer periods, interacted with the nestling, and brought food more frequently than the female (Lambertucci & Mastrantuoni 2008). Observations at a condor nest in Pa-pallacta, Napo province in Ecuador, revealed that the male fed the chick more often than the female (Köster 1997). The social hierarchies that structure Andean Condor populations may affect patterns of breeding behavior. Adult male condors are known to restrict access of females and juveniles to food but also may displace females to conduct incubation (Pavez & Tala 1995; Donázar et al., 1999; Lambertucci & Mastrantuoni 2008).

Our observations provide evidence of interspecific interactions between wild-born Andean Condors and other raptor and mammal species in their nesting areas in Ecuador. Similarly, in Argentina, wild-born Andean Condors defended their territory against condors and other raptors such as the Black Vulture, Turkey Vulture (*Cathartes aura*), and Peregrine Falcon (*Falco peregrinus*) (Lambertucci & Mastrantuoni 2008). Furthermore, in a nest of captive-born and reintroduced condors in Colombia, interactions between condors, Black-chested Buzzard-Eagles, and Black Vultures were reported by Restrepo-Cardona et al. (2018). However, we highlight our observation of a female Andean Condor displacing a Spectacled Bear near the nest at El Tablón in 2021. To our knowledge, this is the first documented record of such an agonistic encounter between these two threatened species. The lack of records of agonistic interaction between Andean Condors and other species at the Itulcachi and Chitachaca nests could be due to the lower sampling effort or to their acceptance of the presence of these species.

The time that 16 Andean Condor nestlings remained in the nests before making their first flight ranged from six to 10 months (Table 1). This finding supports those of Lambertucci and Mastrantuoni (2008) and Gargiulo (2014) in Argentina, suggesting that it may be a typical parameter of the life history of the species. Furthermore, the breeding success of a condor pair during a decade of monitoring at Peñón del Isco was 0.88 nestlings per clutch. There is limited information documented about wild-born Andean Condors

breeding success (Houston et al., 2020; Santangeli et al., 2022). Similar to our results, in the provinces of Cotopaxi, Napo, and Pichincha, condor breeding success was 0.75 chicks per nest where there were three successes and one failure in both 2018 and 2019 (Sánchez & Gallo-Viracocha 2023); however, these authors do not provide information about the specific sites where these breeding events were recorded or data on the dates these cases occurred. Likewise, we did not include in our analysis nine breeding events reported by Sánchez & Gallo-Viracocha (2023) because these data were obtained through interviews with people, and our records are derived from direct observation between 2009 and 2021.

Implications for Conservation

It is of concern that, of the eight Andean Condor nests analyzed in this study, none are located within the National System of Protected Areas of Ecuador, and only three nests are located within private or local protected areas. The nests at Peñón del Isco and Peñón del Cóndor are in the Reserva Ecológica Chakana, and the nest in the middle basin of the Río León is located within the Municipal Reserve Cóndor Sur. We observed that a nestling fell out of the nest and lost its tail after being attacked by free-ranging dogs; the bird is now in captivity (Restrepo-Cardona et al., 2022). Furthermore, between 2018 and 2019, at El Tablón, the parents raised the nestling while heavy machinery was being used to construct a road close to the nest (<40 m). The assessment of human threats during the breeding period is a fundamental component of Andean Condor conservation (Lambertucci & Speziale 2009). Beyond the importance of the protected area system, strategic planning of key areas for the maintenance of condor populations in the northern Andes must encompass the evaluation of new potential protected areas that offer direct benefits to these birds. These should include nesting and breeding sites in human-dominated landscapes such as the rural Andean areas (Restrepo-Cardona et al., 2018).

Necessary measures for Andean Condor conservation must comprise the development of systematic studies of a higher number of nests and should, in the long term, include the parental care, breeding success, nestling survivorship, and nesting phenology of the species in the northern Andes, where its reduced populations are more vulnerable to local extinction due to anthropogenic threats (Naveda-Rodríguez et al., 2016; Vargas et al. 2018a; Restrepo-Cardona et al., 2022; Padró et al., 2023). Studies of the breeding behavior of wild-born Andean Condors are a high research priority to assess population trends and prevent extinction. A better understanding of the patterns of Andean Condor breeding behavior and population demography will inform the implementation of effective actions for the conservation of this iconic species.

Acknowledgments

We thank the Fundación Jocotoco, the companies SUDINCO and NOVOPAN, and P. Escobar, for granting access to their respective properties to study the pairs of condors. We also thank V. Ushiña and V. Amoguimba for their help with the fieldwork, F. Cardozo for sharing information about the condors of the Río León. We thank the Ministerio del Ambiente de Ecuador (MAE/MAATE) for granting Research permits: 005-12- IC-FAU-DNB/MA; MAE-DNB-CM-2015-0010; 012-18-IC-FAU-DNB/MA; 022-19-IC-FAU-DNB/MA; MAAE-ARSFC-2020-0765, MAAE-ARSFC-2022-2093. This research was funded by The Peregrine Fund, Fundación Condor Andino – Ecuador, FLORSANI, Parque Cóndor, The Butler Foundation, Barbara Butler, Virginia Safari Parks, Wolf Creek Charitable Foundation, and G. García. We also thank the useful comments by Associate Editor and two anonymous reviewers whose contributions improved content of this paper.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

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