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BREEDING ECOLOGY, NESTING HABITAT AND THREATS TO A BLACK-AND-CHESTNUT EAGLE *SPIZAETUS ISIDORI* POPULATION IN THE MONTANE FORESTS OF CENTRAL PERU

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Abstract · The Black-and-chestnut Eagle *Spizaetus isidori* is an endangered and little-known top predator of South American montane forests. To better understand the breeding ecology and threats of this eagle, we studied several pairs between 2017 and 2022 in the central Andes of Peru. We recorded 62 adults, one immature, and 36 juveniles in 36 territories. These territories were in mountainous areas (altitudinal range 690–3,810 m a.s.l.), widely covered by montane forests (43.8–99.7% cover), and secondarily by open land (0.3–56.2% cover), far from urban settlements (1.3–27.1 km). Nesting sites (N = 15) were at medium altitudes (1,330–2,330 m a.s.l.) in steep hillsides or ravines (15–55°), having no preferential cardinal orientation, and relatively close to permanent water courses (20–800 m), open areas (30–930 m) and sites with human activity (120–2,200 m). Nests (N = 15) were placed at the top of tall (28–40 m) and thick-stemmed (DBH range 0.53–1.52 m) emergent trees of nine genera, with *Ficus* and *Juglans* being the most used. Incubation and brood-rearing occurred during the dry season (Mar–Nov). The wooded slopes where the eagles nested are being replaced by crops and livestock pastures, causing an estimated loss of 218.2 km^2 of forest cover in our study area (5,056 km^2) during the last 20 years. We detected human persecution in 55.5% of the territories, resulting in 26 juveniles, four adults, two immatures, and nine unaged eagles killed. Preventing the local extinctions of these eagles will require long-term population monitoring, improving knowledge of its ecology, mitigation of human-eagle conflict, development of education programs, and strengthening of land use inspection.

Resumen · Ecología reproductiva, hábitat de anidación y amenazas a una población de águila inca *Spizaetus isidori* en los bosques montanos del centro de Perú.

El águila inca *Spizaetus isidori* es un depredador tope amenazado poco conocido de los bosques montanos de Sudamérica. Para entender mejor su ecología reproductiva y amenazas, entre 2017 y 2022 estudiamos a varias parejas en los Andes del centro de Perú. Registramos 62 adultos, un inmaduro y 36 juveniles en 36 territorios. Estos territorios se localizaron en áreas montañosas (690–3.810 m s.n.m), cubiertas por bosque montano (43,8–99,7%) y algunas áreas abiertas (0,3–56,2%), lejos de áreas urbanas (1,3–27,1 km). Los sitios de anidación (N = 15) estuvieron a elevaciones medias (1.330– 2.330 m s.n.m.) en laderas o quebradas con pendientes moderadas a fuertes (15–55°), en cualquier orientación cardinal, relativamente cerca de cursos de agua (20–800 m), áreas abiertas (30–930 m), y sitios con actividad humana (120–2.200 m). Los nidos (N = 15) estuvieron en la parte superior de árboles emergentes (28–40 m) de tronco grueso (rango DAP 0,53–1,52 m) pertenecientes a nueve géneros, siendo *Ficus* y *Juglans* los más utilizados. La incubación y crianza se desarrollaron durante la estación seca (mar.-nov.). Los bosques donde anidan las águilas están siendo talados para expandir campos de cultivo y pastizales ganaderos, perdiéndose un estimado de 218,2 km^2 de cobertura boscosa en el área de estudio (5.056 km^2) durante los últimos 20 años. Detectamos persecución humana en 55,5% de los territorios, resultando en 26 juveniles, 4 adultos, 2 inmaduros y otras 9 águilas muertas de edad indeterminada. Para evitar extinciones locales de estas águilas, se requiere monitorear sus poblaciones a largo plazo, mejorar el conocimiento sobre su ecología, mitigar el conflicto humano-águila, desarrollar programas de educación, y una mayor fiscalización del uso de suelo.

Keywords: *Accipitridae · Endangered Raptor · Habitat Loss · Human-wildlife Conflict · Yunga Forest*

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INTRODUCTION

Raptors (birds of prey) play a role in determining ecosystem balance, structuring biological communities, promoting biodiversity, and serving as environmental barometers (Sergio et al. 2008, Donázar et al. 2016). Despite their importance, human activities have caused the extinction of several species and the population decline of many others on a global scale (Sarasola et al. 2018). Large raptors are especially vulnerable to extinction because they need vast areas of suitable habitat to meet their ecological requirements (Newton 1979). Apart from scavengers, raptor species most likely to be threatened are larger species that live in forests, have small distributional ranges, and long generation times. These species are considered a high priority for research and conservation (McClure et al. 2018, Buechley et al. 2019). Thus, accurate knowledge of their breeding ecology and documenting their main threats play a central role in effective conservation of large forest-dwelling raptors (McClure et al. 2018). For most Neotropical species, these parameters are poorly known, mostly because many live in structurally complex habitats in developing countries, which represents a great challenge for their study due to difficulty accessing the remote areas where they live (Thiollay 1989, Buechley et al. 2019).

The Black-and-chestnut Eagle *Spizaetus isidori* Des Murs 1845, is a large top avian predator (63–74 cm; 2–3.5 kg) endemic to South American montane cloud forests, distributed along wooded slopes of the Andes and nearby mountain ranges (1,000–3,500 m a.s.l.) of Venezuela, Colombia, Ecuador, Peru, Bolivia and northern Argentina (11°N–28°S; Fjeldså & Krabbe 1990, Thiollay 1994, Ferguson-Less & Christie 2001, Rivas-Fuenzalida et al. 2022a). Despite its wide yet narrow continental distribution, this species is one of the more poorly known Neotropical raptors (Monsalvo et al. 2018). It has been affected by intense deforestation throughout much of its range; it is estimated that current habitat loss in countries such as Colombia could reach up to 60% (Renjifo et al. 2014). Another threat in several countries is human persecution in retaliation to poultry predation (Lehmann 1959, Márquez & Delgado 2010, Zuluaga & Echeverry-Galvis 2016, Aráoz et al. 2017, Restrepo-Cardona et al. 2019, Zuluaga et al. 2022). Due to these anthropogenic pressures, it is currently estimated that the global population of Black-and-chestnut Eagles is less than 1,000 mature individuals, and thus are classified as Endangered by the IUCN (BirdLife International 2022). The better-known aspect of the species' biology is its feeding ecology, along with anecdotal reports of nests in Colombia, Ecuador, Bolivia, and Argentina (Lehmann 1959, Hilty & Brown 1986, Strewe 1999, Márquez & Rengifo 2002, Zuluaga & Echeverry-Galvis 2016, Aráoz et al. 2017, Zuluaga et al. 2018a, Restrepo-Cardona et al. 2019).

In Peru, the Black-and-chestnut Eagle occupies a forest strip of more than 1,600 km long between 900-3,500 m a.s.l. (Valdez & Osborn 2004, Walker et al. 2006, Schulenberg et al. 2010). Despite this, very little is known about the species in the country, and there are only a few behavioral observations of two pairs of eagles (Valdez & Osborn 2004). Here we provide new information on the Black-and-chestnut Eagle based on observations of several nesting territories found in the Andean montane forests of central Peru. Our general objectives were to describe its breeding ecology, nesting habitat, and main threats.

METHODS

Study area. We worked in the montane regions (1,000–3,000 m a.s.l.) of Junín and Pasco Departments in the eastern Andes of central Peru. The general study area covers approximately 5,056 km^2 and is located in the interior of the Selva Central (10°09'S – 11°24'S; 75°16'O – 75°30'O, Figure 1), within the Yunga vegetation zone, which is divided into three ecosystems located at different altitudinal ranges: 1) The Yunga basimontane forest (between 600–1,800 m a.s.l.), 2) The Yunga montane forest (1,800–2,500 m a.s.l.), and 3) the Yunga high montane (pluvial) forest (2,500–3,800 m a.s.l.). The Yunga basimontane forest ecosystem is a transitional complex with botanical species belonging to both the low Amazon basin and Yunga, with tall emergent trees reaching 35 m in height. With increasing altitude, the Yunga montane forest emerges. This ecosystem is consistently covered by mist and hosts abundant epiphytes, lichens, bromeliads and orchids, emergent trees, and tree ferns 10–20 m height. Finally, above 2,500 m a.s.l. the Yunga high montane forest reaches the top of the mountains, has low trees, and a great abundance of epiphytes. Above the high montane forest lies the páramo grasslands and dwarf forest, represented by plants of the families Ericaceae, Solanaceae, Asteraceae, Polemoniaceae, Rosaceae, among others (MINAM 2018). The two main protected areas within the study area are the Yanachaga-Chemillén National Park and the Pui Pui Protected Forest, together harboring c. 180,000 ha of montane forests and páramo.

Extensive human-caused forest degradation has occurred during the last 60 years in Peru's humid eastern montane forest due to timber extraction, often followed by conversion to low-quality rangeland. Most of this impact occurs through several kilometers of roads associated with recent colonists or illegal loggers, which extract resources from state-owned lands (Young & León 1999). In the study area, deforestation pressure is high outside of protected areas. However, there are still relatively large fragments or relicts of intact to nearly intact forest (c. 3,840 km^2) above 1,200 m a.s.l., resulting in lower levels of anthropogenic impact as the distance from populated centers increases (Antón & Reynel 2004). On the slopes and foothills, large forest areas have been replaced by plantations, including granadilla *Passiflora edulis*, rocoto *Capsicum pubescens*, banana *Musa paradisiaca*, pineapple *Ananas comosus*, avocado *Persea americana*, and coffee *Coffea arabica*, as well as grazing areas for cattle-raising (Authors pers. observ.).

Bird sampling. Between May 2017 and October 2022, we monitored 36 presumed or confirmed nesting territories and 15 nests (within confirmed nesting territories) in our study area.

Habitat around nesting territories. A nesting territory was

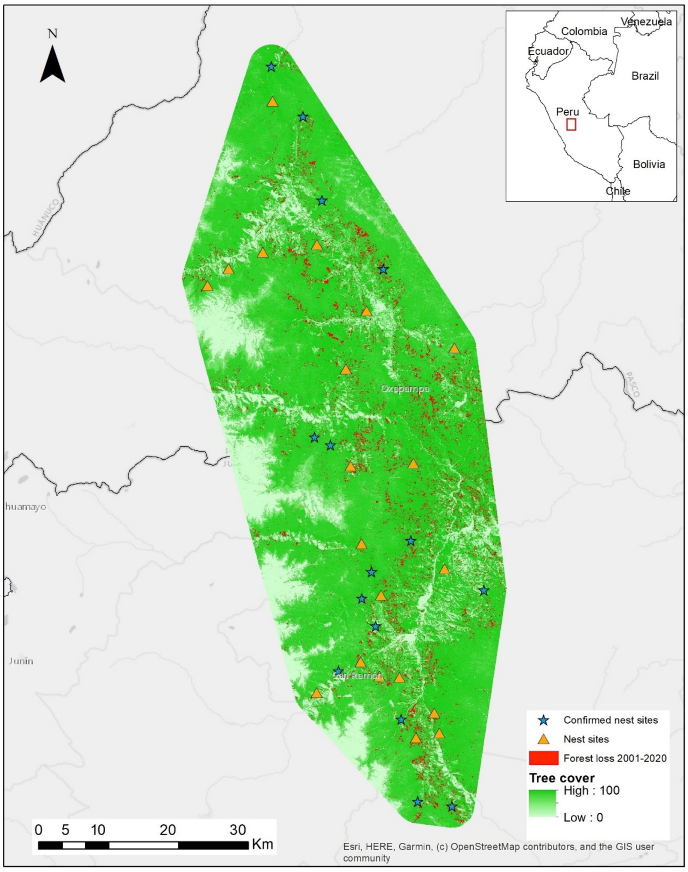

Figure 1. General study area, with confirmed nests (stars) and suspected nest site locations (triangles) of the Black-and-chestnut Eagle *Spizaetus isidori* in the central Andes of Peru. Current tree cover and forest loss from 2001 to 2020, within a 5,056 km^2 area surrounding the nesting sites.

defined as "an area that contains, or historically contained, one or more nests within the home range of a mated pair" or "a confined locality where nests were found, usually in successive years, and where no more than one pair was known to have bred at one time" (Steenhof & Newton 2007). For our study, we also considered nesting territories, the sites where we did not find a nest, but the pair actively occupied the area. In locations where we observed adults or dependent juveniles (<1 year of age, vocally requesting food) in suitable habitat for nesting more than twice throughout the breeding season, we considered the center of the post-fledging family area (PFA, defined as "areas occupied by the family group, from the time the fledgling leaves the nest until it stops depending on adults to eat"; Tapia et al. 2007) as the nest site. On the other hand, considering that territorial adults have predictable daily activity patterns (e.g., usually soaring with mid-morning thermals over nesting sites; Valdez & Osborn 2004, Rivas-Fuenzalida pers. observ.), we assume that solitary adults repeatedly soaring at these hours in sites with suitable habitat were within their nesting territory, even though we were unable to find their nests due to difficult access.

To characterize the habitat around each breeding territory, we established circular buffers of 4 km in radius (c. 5,000 ha, the approximate home range of a nesting pair in the study area; Rivas-Fuenzalida et al. 2022a) around nests and nest sites locations (N = 36). We then measured the surface-area of two habitat types: 1) forest areas and 2) open areas (including grasslands, cultivated fields, paramo, landslides, and water bodies) using ArcGIS 10.3.

Characteristics of nest sites. To determine elevation at the nest sites, we used locations taken under nest trees by GPS (GARMIN 64S). We measured the distances from nest trees to water courses, open areas, and inhabited places using ArgGIS. The slope of every nest site was calculated from a digital elevation model (DEM) in ArcGIS.

Characteristics of nest trees and nests. We used a clinometer to estimate tree height and nest height above the ground. Using a measuring tape, we measured the Diameter at Breath Height (DBH). To identify tree genera and species, we relied on our knowledge. In some cases, when possible, we took photos and samples of leaves and flowers, for identification by Peruvian botanists. We recorded the number of branches supporting the nest, whether the nest was built on epiphytes, nest location within the tree crown, nest shape (estimated by direct measurement or drone photos), and composition (e.g., branches, green leaves, prey remains). We climbed the tree with arborist equipment to accurately measure the nest and used a measuring tape.

Productivity and breeding phenology. To estimate breeding phenology, we made observations of courtship behavior, eggs, and morphological development stages of chicks at 10 nests, visiting each nest at least four times per season and considering: 1) a courtship period of three months, 2) incubation period of 51 days (Juan Manuel Grande pers. com.), 3) chick-rearing period of 60 days (until the age at which the young abandon the nest, but remain on the nest tree), 4) the first flight out of the nest tree at 92 days after hatching, and 5) post-fledging period of 4.5 months until juvenile dispersal (Aráoz et al. 2017, Zuluaga et al. 2018b, Rivas-Fuenzalida et al. 2022a). We estimated productivity as a successful attempt being a breeding pair producing a fledging.

Threats: human persecution and habitat loss. To obtain information on the attitudes of local people towards the eagles, we conducted informal interviews with villagers familiar with the species, located ≤ 4 km from a nesting site. We interviewed every poultry owner who agreed to talk with us (N = 22), asking them two questions: 1) Do you have a conflict with the species due to poultry predation? and 2) How many eagles have you killed to defend your poultry? In many cases, we only obtained information about killed eagles by the villager´s descriptions. However, in a few cases, we also obtain physical evidence (e.g., talons, heads, feathers, embalmed birds, entire bodies) or photographic evidence of kills. To determine the age classes of killed eagles in cases with no physical or photographic evidence, we showed photos of juvenile, immature, and adult eagles to the villagers. We assume that each killed eagle belonged to the nearest nesting site. To evaluate habitat loss, we also measured the forest cover change derived from Global Forest Watch (Hansen et al. 2013) between 2001 and 2020 as a proxy for habitat conversion in an area of 5,056 km^2, corresponding to a polygon that enclosed all the 4 km buffers around the territories.

RESULTS

We monitored 36 breeding territories, 14 in the Pasco region and 22 in the Junín region (Figure 1). Three territories were found in 2017, 9 in 2018, 1 in 2019, 8 in 2020, 14 in 2021, and 1 in 2022. We found nests in 15 territories, while in the remaining 21, we assumed the existence of nests. In these territories, we observed 62 adults, one immature, and 36 juveniles (Figure 2). The 16 territories observed for more than one season were considered as independent breeding events.

Habitat around nesting territories. The territories (N = 36, Table 1) were located in areas of very rugged terrain, with numerous ravines and steep slopes. Within the area limited by a radius of 4 km around the nest locations, the minimum altitude ranged between 690–2,080 m a.s.l. (mean ± SD = 1,329.4 ± 397.7 m a.s.l.), and the maximum altitude varied between 1,710–3,810 m a.s.l. (mean ± SD = 2,915.6 ± 530 m a.s.l.). In this same area, the proportion of forested area within breeding territories ranged from 43.8–99.7% (mean ± SD = 90.4 ± 11.5%), while open areas ranged from 0.3–56.2% (mean ± SD = 9.6 ± 11.5%). The linear distance from the nest location to the edge of the nearest urban area ranged from 1.3–27.1 km (mean ± SD = 9.1 ± 6.7 km).

Characteristics of nest sites. Breeding territories with located nests (N = 15, Table 2) were in ravines or hillsides with a moderate to steep slope (range = 15–55°, mean ± SD = 36.2 ± 12.8°), and nest sites were located at an elevation ranging 1,330–2,330 m a.s.l. (mean ± SD = 1,821.3 ± 335.6 m a.s.l.). Nest sites were located relatively close to water courses (range = 20–800 m; mean ± SD = 381.3 ± 250 m) and open areas (range = 30–930 m; mean ± SD = 286 ± 299.5 m), and from inhabited places (range = 120–2,200 m; mean ± SD = 822 ± 698 m). The slopes where the nests were located did not show any trend in terms of cardinal orientation, being oriented: N (N = 1), NE (N = 2), S (N = 2), SW (N = 4), SE (N = 2), E (N = 2), and W (N = 2).

Characteristics of nest trees and nests. Black-and-chestnut Eagles built their nests (N = 15, Table 3) in the upper portion

Figure 2. Chick and adult female Black-and-chestnut Eagle *Spizaetus isidori* in the nest, Pampa Seca site, Junín, Peru. Photo: Tomás Rivas-Fuenzalida

Table 1. Characteristics of the breeding territories (N = 36) of the Black-and-chestnut Eagle *Spizaetus isidori* in the Andean montane forests of central Peru. All measurements, except distance to the urban area, were calculated within a 4 km radius (5,000 ha) around the nest location.

Variable	Mean ± SD	Range
Minimum altitude (m a.s.l.)	1,329.4 ± 397.7	690 – 2,080
Maximum altitude (m a.s.l.)	2,915.6 ± 530	1,710 – 3,810
Forested area (%)	90.4 ± 11.5	43.8 – 99.7
Open area (%)	9.6 ± 11.5	0.3 – 56.2
Distance to urban area (km)	9.1 ± 6.7	1.3 – 27.1

Table 2. Characteristics of nest-sites (N = 15) of the Black-and-chestnut Eagle *Spizaetus isidori* in the Andean montane forests of central Peru (see methods).

Variable	Mean ± SD	Range
Altitude (m a.s.l.)	1,821.3 ± 335.6	1,330 – 2,330
Distance to nearest water course (m)	381.3 ± 250	20 – 800
Distance to nearest open area (m)	286 ± 299.5	30 – 930
Distance to nearest human activity (m)	822 ± 698	120 – 2,200
Slope inclination (°)	36.2 ± 12.8	15 – 55

(range = 26–38 m, mean ± SD = 31.9 ± 3.8 m) of tall emergent (height range = 28–40 m, mean ± SD = 34.5 ± 4.2 m), and thick-stemmed trees (DBH range = 0.53–1.32 m, mean ± SD = 1.01 ± 0.27 m), belonging to nine genera, with *Ficus* and *Juglans* being the most frequently used (N = 3). The number of branches that supported the nests varied between two and four, and several nests were built on epiphytic plants. Nine nests were on the side of a treetop, three in the middle of the crown and three in the main top. Three nests had oval, and 10 had circular shapes. The only nest measured (Huatziroqui) had the following dimensions: 130 cm wide, 140 cm long, and 50 cm high. However, some large branches in the base of the nest reached up to 2 m. Before egg laying, the nest cup was approximately 15 cm deep. As the chick-rearing period progressed, the female filled the cup with twigs until it was practically a flat platform. Unmeasured nests had similar dimensions (c. 1.4 m diameter) as estimated by comparison with the size of adults perched. The nests were built with dry branches, twigs with green leaves, lichens, and bark, and contained pellets and prey remains such as feathers, hair, and bones.

Productivity and breeding phenology. In all the nests where we found eggs (N = 7), only one egg was laid per pair/season. In the sites where we corroborated successful reproduction (N = 28), a single juvenile was fledged per pair/season. We confirmed that at least six pairs produced one juvenile every year, and three pairs produced only one fledging every 1.5 to 2 years. The incubation and chick-rearing periods were concentrated in the driest months of the year. The earliest laying occurred in mid-March, but most occurred between late April and mid-July (Figure 3). The earliest hatching occurred in early May and from mid-June to early September in the remaining nests. Fledglings made their first jumps out of the nest between the end of July and the end of November, while the first flights out of the nest tree occurred between the beginning of August and the beginning of December. The post-fledging period extended between August and May, mainly during the rainy season. However, at one site, we observed a juvenile still feeding at the nest (although it was already flying within 500 m of the nest) in early May, which probably dispersed in June or July.

Threats: human persecution and habitat loss. In 55.5% of the nesting territories (N = 36), we recorded human persecution towards Black-and-chestnut Eagles in retaliation to poultry predation, resulting in 41 individuals killed between 1999

Table 3. Characteristics of nest trees (N = 15) of Black-and-chestnut Eagles *Spizaetus isidori* in the Andean montane forests of central Peru.

Territory	Nest trees			Nests				
	Species	Height (m)	DBH[1] (m)	Height[2] (m)	N° of supporting branches	Position at the tree crown	Shape	Composition[4]
Huampal	*Eriotheca macrophilla*	30	0.83	26	4	Side top	Oval	Br, Li, Gr
Alto Tunqui	*Juglans neotropica*	32	0.86	30	3[3]	Side top	Circular	Br, Li, Gr
Prosoya	*Ficus* sp.	40	1.20	35	3[3]	Side top	–	Br
Acuzazú	*Ficus* sp.	40	0.93	35	4	Inside crown	Circular	Br, Li, Gr, Pr
Pampa Seca	*Erythrina velutina*	28	0.53	26	4	Inside crown	Oval	Br, Gr, Pr, Pe
Río Blanco	*Juglans neotropica*	36	–	35	3	Side top	Circular	Br
La Alianza	*Chorisia insignis*	35	–	33	3	Inside crown	Circular	Br, Gr, Pr
Huatziroqui	*Brosium alicastrum*	38	1.32	35	3	Main top	Circular	Br, Li, Gr, Pr, Pe
Nueva Italia	*Juglans neotropica*	34	–	29	4[3]	Side top	Circular	Br, Gr, Pr
La Promisora	*Ceiba pentandra*	30	–	32	4	Side top	Circular	Br, Li
La Lora	–	34	–	30	2	Side top	–	Br
S. J. de Utcuyacu	*Cedrela angustigolia*	40	–	36	3	Side top	Circular	Br, Li
Unión Mantus	*Ocotea sp.*	32	1.15	32	4	Main top	Oval	Br, Li
Huayainay	–	40	–	38	2[3]	Main top	Circular	Br, Gr
Chacaybamba	*Ficus sp.*	28	1.23	27	4	Side top	Circular	Br, Li, Gr
Mean ± SD		34.78 ± 4.40	1.00 ± 0.26	31.92 ± 3.95	3.28 ± 0.72			

[1] Diameter at breast height. [2] Distance from the ground at the base of the tree to the base of the nest platform. [3] The nest was also supported by epiphytic plants
[4] Br = large dry sticks, Li = lichen, Gr = Green sticks/leaves, Co = cortex, Pr = prey remains (bones, hairs y feathers), Pe = pellets.

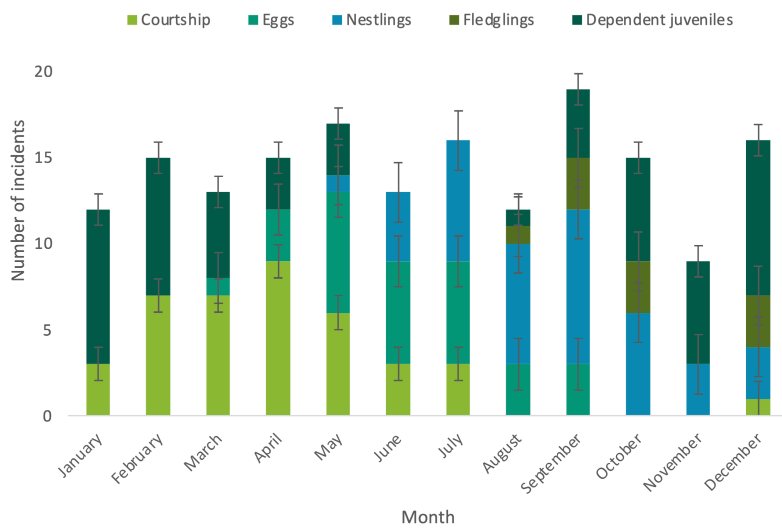

Figure 3. Breeding phenology of the Black-and-chestnut Eagle *Spizaetus isidori* in the montane forests of central Peru.

and 2019, according to the information of local villagers. Deaths corresponded to four adults, two immatures (Figure 4A), 26 juveniles (Figure 4B), and nine individuals of undetermined age.

In our study area (5,056 km²), the loss of forest cover around nesting territories reached an estimated 21,822 ha between 2001 and 2020 (Figure 1), averaging 1,091 ha per year. However, forest loss rates have been increasing, especially during the last five years, in which 9,794 ha were lost, averaging 1,959 ha per year.

DISCUSSION

Given that dependent juveniles we observed in Peru and by others observed in Colombia (Zuluaga et al. 2018b) concentrate their movements within a 500 m radius around the nest, we believe that our location estimates of unfound nests were accurate enough. In general, the characteristics of the nesting territories, nest sites, nest trees, and nests found in Peru coincided with those reported in other countries such as Venezuela (Hilty & Brown 1986), Colombia (Lehmann 1959, Strewe 1999, Márquez & Delgado 2010, Zuluaga & Echeverry-Galvis 2016), Ecuador (Zuluaga et al. 2018a), Bolivia (Hilty & Brown 1986) and Argentina (Aráoz et al. 2017). The observation of a nest in the Yanachaga-Chemillén National Park (Huampal) is the lowest altitude record for the species (1,330 m a.s.l.). Based on observations of a pair with an unlocated nest but confirmed reproduction, we estimate that some nests can be located above 2,500 m a.s.l.

Black-and-chestnut Eagles showed lower productivity than most raptors (Newton 1979), with a maximum of one juvenile produced per season. However, compared with other *Spizaetus*, including the Ornate Hawk-Eagle *S. ornatus*, the Black-and-white Hawk-Eagle *S. melanoleucus*, and the Black Hawk-Eagle *S. tyrannus*, which produce only one juvenile every 1.5 or 2 years (Canuto et al. 2012; Whitacre et al. 2012a, 2012b), Black-and-chestnut Eagles showed higher productivity. This is likely related to the relatively short duration of the post-fledging period (4.5 months; Zuluaga et al. 2018b).

Their breeding phenology was similar to that observed in other countries, with incubation and chick-rearing periods concentrated during the dry season (Aráoz et al. 2017; Zuluaga et al. 2018a, 2018b). This permits tropical raptors to minimize the adverse effects of storms on their eggs and chicks, and increases the chances of juvenile survival during the rainy season when prey is more abundant (Whitacre & Burnham 2012).

The human-eagle conflict has been known along virtually the entire Black-and-chestnut Eagle's distributional range for a long time. In Colombia, several studies revealed the occurrence of human persecution since the early 20th century (Lehmann 1959, Córdoba-Córdoba et al. 2008, Zuluaga & Echeverry-Galvis 2016; Restrepo-Cardona et al. 2019, 2020), and several shot individuals have been received in rescue centers of Colombia, Ecuador, and Peru (Alex Ospina, Joep Hendrix, Ernesto Arbelaez, and José Antonio Otero pers. com.). Some dietary studies found that poultry consumption can occasionally be greater than the consumption of natural prey (Márquez & Delgado 2010, Zuluaga & Echeverry-Galvis 2016, Restrepo-Cardona et al. 2019). In Argentina, the presence of domestic fowl in these eagles' diet presumes that conflict with humans can occur (Aráoz et al. 2017).

At a global scale, human-raptor conflict derived from domestic animal predation by large raptors has caused significant population declines due to direct human persecution, being one of the main threats for many species (Newton 1979). This conflict has been recorded for several medium to large-sized raptors which inhabit forest habitats in South America, including the three lowland *Spizaetus*: Black-and-white Hawk-Eagle (TRF pers. observ., Alex Ospina pers. com.), Ornate Hawk-Eagle (Ffrench 1973, Friedmann & Smith 1955, Alex Ospina pers. com.) and Black Hawk-Eagle (Whitacre et al. 2012b, TRF pers. observ.). In the austral temperate forest ecoregion (southern Chile and Argentina), the Rufous-tailed Hawk *Buteo ventralis* —an ecological equivalent of the Black-and-chestnut Eagle in southern South America— also suffers intense persecution by villagers in retaliation to poultry predation; together with habitat loss, such persecution is responsible for local extinctions within some areas of its distribution (Rivas-Fuenzali-

Figure 4. Immature (A) and juvenile (B) Black-and-chestnut Eagle *Spizaetus isidori* killed in retaliation to poultry predation in the eastern Andean slopes of central Peru. Photos: Fundación Ñankulafkén archive.

da & Figueroa 2019).

Montane forest loss and degradation represent the main threat to the Black-and-chestnut Eagle in the long-term (Thiollay 1991, Echeverry-Galvis et al. 2014), since structure and function recuperation of old-growth forests may take centuries (Newton 1979). If we estimate a loss rate of 1,959 ha per year, in 55.5 years —or three generations— of the Black-and-chestnut Eagle (generation length = 18.5 years; BirdLife International 2022) the total forest cover loss will be 108,724 ha (i.e., the area that covers the needs of c. 22 breeding pairs, 61% of the currently known breeding pairs in the area). However, with increasing rates every year, this amount of forest loss and its impact on Black-and-chestnut Eagle populations could be much higher.

At a finer scale, deforestation may reduce the reproductive viability and habitat suitability for large eagles due to decreasing prey availability (Miranda et al. 2021). In the case of Black-and-chestnut Eagle, this makes them more prone to hunt domestic fowl, increasing the conflict with humans (Restrepo-Cardona et al. 2020). In Chile, it has been observed that forest loss can increase the vulnerability of Rufous-tailed Hawks to human persecution since they are more visually exposed, and even the fledglings are killed by domestic dogs when they fall to the ground during their first flights (Rivas-Fuenzalida et al. 2011, Rivas-Fuenzalida & Figueroa 2019). Furthermore, forest-dwelling raptors can face increasing interspecific competition when forests are replaced with cultivated land since these sites are rapidly colonized by open-habitat raptor species which are typically more aggressive (Rivas-Fuenzalida & Figueroa 2019). In Ecuador and Peru, for example, territorial pairs of Black-chested Buzzard-Eagles *Geranoaetus melanoleucus* and White-tailed Hawks *G. albicaudatus* have been observed displacing Black-and-chestnut Eagles from areas they have recently colonized due to deforestation (Rivas-Fuenzalida et al. 2022a, 2022b; Fernando Andrade pers. com.). Finally, it has been shown that climate change and habitat loss may result in substantial reductions in distributional ranges for large forest-dwelling raptors (Sutton et al. 2022).

Recommendations. To halt the local extinction of this species, we recommend to: 1) carry out long-term monitoring of breeding populations, 2) improve knowledge of its natural history (e.g., diet, habitat use, home range, juvenile dispersal, population densities), 3) promote projects that mitigate the human-eagle conflict from different approaches and adjust to local realities and opportunities (see Rivas-Fuenzalida 2019), 4) develop permanent environmental education programs, 5) promote better regulation and supervision of land use by government entities, and 6) promote the creation of new protected areas prioritizing the conservation of large tracts of primary montane forests.

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