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First Report of a Replacement Clutch in the Endangered Chaco Eagle (*Buteogallus coronatus*), a Large Neotropical Raptor with Low Fecundity

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Replacement clutches, defined as a second clutch laid following the failure of an initial breeding attempt, can play a crucial role in the reproductive success of single-brooded avian species (Bettega et al. 2011). Among raptors, the occurrence of replacement clutches is more frequently reported in smaller-bodied species and in those inhabiting tropical regions, compared to larger species and those in temperate zones (Newton 1979). Although renesting behavior has been examined in various bird taxa, often through experimental studies, documentation of replacement clutches in raptors remains sparse and largely anecdotal. Most reports pertain to species capable of double-clutching following the fledging of young (e.g., Curtis et al. 2005, Krol 2018). Moreover, few reports of replacement clutches involve raptor species of conservation concern, with only two documented cases in the southern hemisphere: the Reunion Marsh-Harrier (*Circus maillardi*) and the African Pygmy-Falcon (*Polihierax semitorquatus*; Table 1).

Here we report the first documentation of a replacement clutch in the endangered Chaco Eagle (*Buteogallus coronatus*), marking the first known instance of such behavior in a raptor species that lays a single egg per breeding attempt. The Chaco Eagle is among the most imperiled raptor species in the Neotropics (Sarasola et al. 2018) and is listed as endangered by the International Union for Conservation of Nature (IUCN), with a global world population estimated at 800–2000 adult individuals (BirdLife International 2024). The species occupies open landscapes across Brazil, Paraguay, Bolivia, and Argentina, and is considered extinct in Uruguay where it has not been recorded since the 1930s (Sarasola et al. 2022).

During the breeding season (October–February, austral spring and summer; Galmes et al. 2018), the Chaco Eagle lays one egg per reproductive attempt. This extremely low fecundity, combined with a high incidence of human-induced mortality, has contributed significantly to the species' decline and current risk of extinction (Sarasola et al. 2022). The single egg is laid in October, with the female conducting most incubation duties. The egg hatches in December and the young fledges in late January to February (Galmes et al. 2018). After leaving the nest, juveniles enter a prolonged post-fledging dependence period lasting approximately 8 mo (Gallego-García et al. 2025). Adults are territorial during the breeding season, although shifts in breeding territories have been observed (Canal et al. 2025).

As part of a long-term population monitoring of this endangered species in central Argentina, we tracked the movements of an adult female in La Pampa province (approximately 36.67°S, 65.67°W) using a GPS transmitter. On 13 October 2022, GPS data indicated that the female had become nearly stationary, suggesting nesting behavior. We visited

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Table 1. Raptor species with documented replacement clutches and their IUCN conservation status (LC = least concern; NT = near threatened; EN = endangered; CR = critically endangered).

Family	Scientific Name	Common Name	Status	Reference
Accipitridae	*Accipiter nisus*	Eurasian Sparrowhawk	LC	Otterbeck et al. (2019)
	Aquila fasciata	Bonelli's Eagle	LC	Moleón et al. (2009)
	Buteo ridgwayi	Ridgway's Hawk	CR	Woolaver et al. (2015)
	Circus aeruginosus	Western Marsh-Harrier	LC	Soper (1958)
	Circus cyaneus	Hen Harrier	LC	Balfour (1957)
	Circus hudsonius	Northern Harrier	LC	Simmons (1984)
	Circus maillardi	Reunion Marsh-Harrier	EN	Fay et al. (2023)
	Gypaetus barbatus	Bearded Vulture	NT	Margalida and Bertran (2002)
	Gyps fulvus	Griffon Vulture	LC	Martínez et al. (1998)
	Haliaeetus albicilla	White-tailed Eagle	LC	Fentzloff (1975)
	Haliaeetus leucocephalus	Bald Eagle	LC	Wood and Collopy (1993)
	Neophron percnopterus	Egyptian Vulture	EN	Martínez and Blanco (2002)
Falconidae	*Falco cherrug*	Saker Falcon	EN	Beran et al. (2012)
	Falco peregrinus	Peregrine Falcon	LC	Cade and Temple (1977)
	Falco rusticolus	Gyrfalcon	LC	Cade and Temple (1977)
	Falco sparverius	American Kestrel	LC	Lesko and Smallwood (2012)
	Polihierax semitorquatus	African Pygmy-Falcon	LC	Olubodun et al. (2023)
Strigidae	*Bubo bubo*	Eurasian Eagle-Owl	LC	Karyakin (2009)

the area on 8 November 2022 and used a drone to confirm that she was incubating in a nest on the top of a *caldén* (*Neltuma caldenia*) tree (Fig. 1A; Gallego and Sarasola 2021). However, by 28 November, the female's locations indicated that she had abandoned this nest site, and during the next nest check on 17 December 2022, we found the nest empty. On 26 December 2022, GPS data once again showed the female localized at a specific site, this time at a site near the original nest. A field visit on 04 January 2023 confirmed a new nest with the female incubating again (Fig. 1B). The second nest was located in a burned *caldén* tree, 139 m northeast of the original tree, but within the same patch of forest. A nestling was banded here on 16 April 2023 and fledged in May 2023, as verified by images from a camera trap installed during the tagging event.

Many bird species renest after failure of an initial breeding attempt, with replacement clutches potentially contributing to an individual's lifetime reproductive success (Bettega et al. 2011). Among raptors, however, renesting is more common among smaller species than among larger ones. Due to the extended duration of the nestling period and the high energetic cost of egg production, replacement clutches are generally considered unlikely in large raptors (Newton 1979, Martínez et al. 1998, but see Wood and Collopy 1993). Nonetheless, in species with relatively long breeding seasons, such as the Chaco Eagle, there may be sufficient time for a female to initiate a second clutch before environmental conditions deteriorate. This is particularly feasible if the reproductive investment is offset by the fitness gains from successfully producing a young eaglet (Antczak et al. 2009, Bettega et al. 2011).

Although we did not directly observe eggs during either nest check, multiple lines of evidence suggested that the female was incubating at both sites. Her behavior during the drone surveys was consistent with incubation, as adult Chaco Eagles tend to leave the nest more readily when it is empty (Gallego and Sarasola 2021). In addition, both nesting attempts occurred within the known breeding season for this species in this region (Galmes et al. 2018), and GPS data showed that the female remained localized at the nest sites in the days leading up to the nest check (8 November 2022 for the initial nest and 4 January 2023 for the replacement nest), suggesting she was incubating.

Although precise laying dates could not be confirmed, we estimated the original egg was laid between 13 October 2022 (based on movement data) and 8 November 2022 (based on the drone check), and the replacement egg between 26 December 2022 (movement data) and 4 January 2023 (drone check). This suggests an interval of 48–83 d between the original and replacement clutches, and 28–37 d between failure (approximately 28 November) and initiation of the second clutch. These estimated intervals are slightly longer

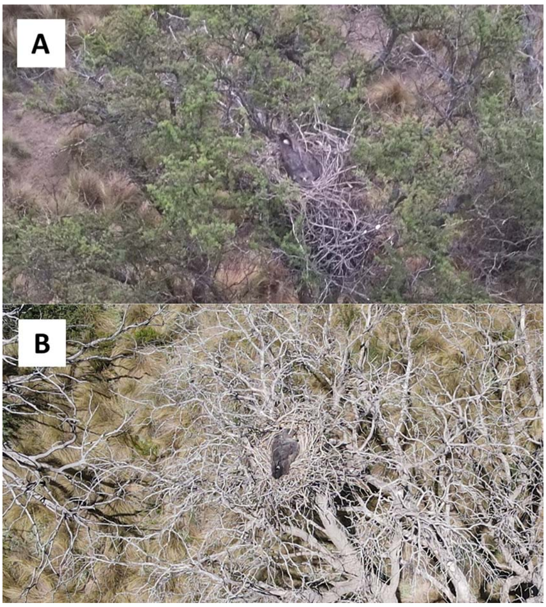

Figure 1. Aerial images captured by drone showing the same adult female Chaco Eagle (*Buteogallus coronatus*) incubating at two different nests: (A) the original nest on 8 November 2022; and, (B) the replacement nest on 4 January 2023, located approximately 140 m from the initial nest site.

than those reported for other large raptor species. In the Bonelli's Eagle (*Aquila fasciata*), the interval between clutches has been estimated at 46–58 d, and 19–30 d between failure and renesting (Pompidor and Cugnasse 1990, Cabeza and de la Cruz 2001, Moleón et al. 2009). Similarly, for the White-tailed Eagle (*Haliaeetus albicilla*) renesting typically occurs 19–29 d after failure (Fentzloff 1975), whereas the Griffon Vulture (*Gyps fulvus*) can renest after an interval of 25 d (on average; Martínez et al. 1998).

The relatively longer intervals exhibited by the Chaco Eagle may be facilitated by their prolonged incubation and post-fledgling dependency periods, which could allow sufficient flexibility in their breeding schedule to accommodate delayed replacement clutches. This extended breeding window may enable females to initiate a second attempt well beyond the usual phenology, which typically concludes with the young fledging from the nest in February (Sarasola et al. 2022). In fact, some previously recorded cases of delayed successful breeding in the Chaco Eagle might have resulted from undocumented replacement clutches (J. H. Sarasola unpubl. data), suggesting that time constraints may not be a limiting factor in this species' reproductive cycle.

The replacement clutch was laid in a different nest than the original one. For many bird species, it is common to avoid reusing a nest after a failed breeding attempt (Simmons 1984, Martínez and Blanco 2002, Wysocki 2004). Nest predation is the leading cause of breeding failure in birds and exerts strong evolutionary pressures on nest-site selection and reuse behavior (Martin 1995). Although predation of the original Chaco Eagle nest is a possible explanation for its failure, we were unable to determine the cause definitively. Other potential causes, such as severe weather events (e.g., rain storms) could also be responsible (Gallego and Sarasola 2022).

Large raptors, such as the Chaco Eagle, which hold territories over multiple years and often face a limited availability of suitable nesting sites, frequently construct and maintain several nests within the same territory (Malan 2009, Sarasola et al. 2022). This behavior may serve as an adaptive strategy, enabling a rapid response to nest failure and facilitating the initiation of a replacement clutch (Martínez and Blanco 2002).

This represents the first documented case of replacement clutch in a raptor species that lays only a single egg per reproductive attempt. In some avian species, replacement clutch sizes tend to be smaller than the original one (e.g., Willow Ptarmigan [*Lagopus lagopus*]; Ludwig et al. 2018), which aligns with observed declines in breeding performance over the nesting season (Verhulst and Nilsson 2008), and reduced survival and recruitment of late-hatched young (Wiens et al. 2006, Brommer et al. 2014). However, for the Chaco Eagle, the reproductive effort invested in the replacement clutch is likely comparable to that of the initial attempt, given the species' single-egg strategy. This novel observation also highlights an unexpected degree of flexibility in the breeding cycle of this endangered raptor, consistent with previous reports of reproductive adaptability in the species. Examples include the successful use of artificial nests (Sarasola 2018), cross-fostering of nestlings (Capdevielle et al. 2021), and tolerance of nest reconstruction by humans during the breeding season (Gallego and Sarasola 2022).

From a conservation and management perspective, the confirmed replacement clutch in this study represents a significant discovery for an endangered species with a clutch size of one. In scenarios in which the population size declines to critically low levels and extinction becomes imminent, understanding the species' potential for replacement laying may inform last-resort conservation strategies. Because manipulation of clutch or brood size is not feasible for the Chaco Eagle (Negro et al. 2007), early removal of an egg for captive-breeding purposes could trigger the laying of a replacement egg that would be hatched in the wild. This technique has been successfully applied in other large raptors, such as the Bald Eagle (*Haliaeetus leucocephalus*; Wood and Collopy 1993).

Our findings underscore the importance of expanding reproductive monitoring efforts in raptor populations globally, particularly for threatened and understudied species. Building a stronger foundation of knowledge on the flexibility and constraints of raptor breeding behavior under different ecological scenarios is essential for the design of effective, evidence-based conservation strategies (Tapia and Zuberogoitia 2018).

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