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# Population status of Andean Condors in central and southern Bolivia

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ABSTRACT. Andean Condors (*Vultur gryphus*) are a Near Threatened species that was formerly distributed along the entire length of the Andes from western Venezuela to Tierra del Fuego. Populations have been severely reduced in north of Peru, but several thousand Andean Condors still exist in the southern portion their range in Argentina and Chile. Little is known, however, about the size of the Andean Condor population in the central part of their distribution in Peru and Bolivia. From June to September 2012, we used feeding stations to attract Andean Condors and estimate the size and structure of the population in the eastern Andes of central and southern Bolivia. We estimated a minimum population of 253 condors, an adult male-to-female ratio of 1:0.6, an immature male-to-female ratio of 1:0.9, and an adult-to-immature ratio of 1:1.1. At our five survey areas, estimated abundance ranged from 15 to 100 condors per area. Males outnumbered females in three areas and the opposite was true in two areas. Our estimated adult-to-immature ratio, overall and in each area, suggests that the populations could be breeding at a high rate. As previously observed in other Andean Condor populations, skewed sex ratios could be associated with differences between sexes and age classes in habitat selection. Although our results suggest that Bolivian populations of Andean Condors are still reasonably large, population monitoring is urgently needed, including use of feeding stations throughout the entire Bolivian range of the species and intensive searches for roosting and nesting sites.

RESUMEN. **El estado de la población de cóndores andinos en los Andes del centro y el sur de Bolivia**

El cóndor andino (*Vultur gryphus*) es una especie casi amenazada que se distribuye a lo largo de los Andes desde el oeste de Venezuela hasta Tierra del Fuego. Las poblaciones han sido severamente reducidas al norte de Perú, pero varios miles de cóndores andinos todavía existen en la porción sur de su área de distribución en Argentina y Chile. Sin embargo, se conoce poco sobreel tamaño de las poblaciones de cóndor andino en la parte central de su distribución en Perú y Bolivia. Se utilizaron estaciones de alimentación para estimar el tamaño y la estructura de la población de cóndor andino en los Andes orientales del centro y sur de Bolivia. Se estimó una población mínima de 253 cóndores andinos, la proporción de entre machos y hembras adultos fue 1: 0.6, la proporción entre machos y hembras inmaduros fue 1: 0.9, y la proporción entre adultos e inmaduros fue 1:1.1. En nuestras cinco áreas de estudio, la abundancia estimada varió de 15 a 100 cóndores por área. En tres áreas los machos fueron más numerosos que las hembras, en cambio se observó lo contrario era cierto en las otras dos áreas. La proporción estimada entre adultos y jóvenes, en general y en cada área, sugiere que las poblaciones podrían tener una alta tasa de reproducción. En otras poblaciones del cóndor andino se observó que las proporciones desiguales entre sexos podrían estar asociadas con diferencias en la selección de hábitat en función al sexo y edad de los cóndores. Aunque nuestros resultados sugieren que las poblaciones de cóndor andino en Bolivia siguen siendo razonablemente grandes, es necesario continuar con su monitoreo, extendiendo el uso de estaciones de alimentación al resto del país, y de la misma forma realizar búsquedas sistemáticas de dormideros y sitios de anidamiento.

*Key words:* feeding stations, minimum population size, population structure, *Vultur gryphus*

Andean Condors (*Vultur gryphus*) occur throughout the Andes from western Venezuela and northern Colombia to southern Chile and Argentina (Houston 1994). They are considered globally Near Threatened (BirdLife International 2015) and are listed in CITES Appendix I and CMS Appendix II. Andean Condors are threatened by habitat loss, human persecution due to alleged attacks on newborn livestock (e.g., sheep, llamas, and cattle), and cultural beliefs and rituals in which body parts or even entire condors are used (Williams et al. 2011, GRIN 2014). Andean Condors are categorized as critically endangered in Venezuela (<10 individuals; Sharpe et al. 2008), endangered in Colombia (<60 individuals; Rodríguez-Mahecha and

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Orozco 2002), and critically endangered in Ecuador (<100 individuals; Koester 2002), but are more abundant in Chile and Argentina where ~70% of the global population occurs (Díaz et al. 2000).

The conservation status of Andean Condors in the central Andes (Bolivia and Peru) has not been fully assessed. However, Peruvian populations are assumed to be decreasing (More 2010). Andean Condors are still widely distributed in Bolivia (Balderrama et al. 2009), but population trends are unknown. In the only study of this species in Bolivia to date, Rios-Uzeda and Wallace (2007) reported a population estimate of 78 individuals in the Apolobamba Mountains in northwest Bolivia.

Because landscapes inhabited by Andean Condors (hereafter condors) are largely inaccessible, monitoring their populations is difficult and traditional census techniques may be unsuitable in some locations (Alcaide et al. 2010). As an alternative, feeding stations have been used to estimate local minimum population sizes (Ríos-Uzeda and Wallace 2007, Astudillo 2011, Cailly-Arnulphi et al. 2013). Using the method described by Ríos-Uzeda and Wallace (2007), we estimated the minimum population size and the sex and age structure of condor populations in the eastern Andes of central and southern Bolivia, which will help determine appropriate conservation measures and design future population monitoring programs for the species.

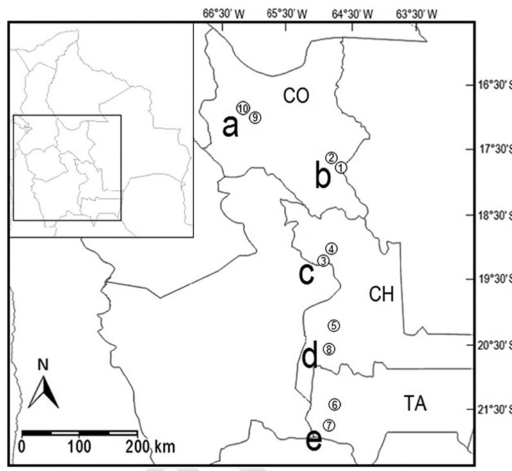


Fig. 1. Location of feeding stations (numbered circles) in five survey areas in the departments of Cochabamba (CO), Chuquisaca (CH), and Tarija (TA): Cordillera del Tunari (a), Omereque (b), Cordillera de Mandinga (c), Cordillera de Tarachaca (d), and Cordillera de Sama(e) in Bolivia. Feeding station survey dates in 2012: (1) 1–3 June, (2) 22–24 June, (3) 19–21 July, (4) 25–29 July, (5) 9–13 August, (6) 18–20 August, (7) 23–27 August, (8) 3–5 September, (9) 1–13 September, and (10) 20–22 September.

## METHODS

Our study was conducted from June to September 2012 (dry season) at five survey areas (mean distance apart = 145 ±16.8 [SD] km) along a 180-km northwest-to-southwest and a 415-km north-to-south section of the eastern Andes of central and southern Bolivia. The elevation of survey areas ranged from 1650 to 4400 m (Fig. 1). Survey areas were located in the inter-Andean dry forest and semi-humid northern Puna ecoregions (Ibisch and Mérida 2003) and the interface between both. At the landscape level, the survey areas encompassed wide and steep valleys, plains and rocky cliffs, including diverse vegetation types such as deciduous and evergreen forests, scrublands, and grasslands. The main human activities in the region are small-scale cultivation and livestock grazing (cattle and, to a lesser extent sheep, goats and llamas). This region of Bolivia has been historically disturbed by human activities and few natural spaces remain intact (Ibisch and Mérida 2003).

**Field design.** We followed methods used by Ríos-Uzeda and Wallace (2007) with some minor modifications. At each survey area, we established two feeding stations 25–30 km apart (Fig. 1) in rather undisturbed sites at least 1 km from villages or roads. Feeding stations were located in open places at the top of hills or next to cliffs. We used donkey carcasses as bait. Carcasses were observed at distances of 80–200 m from a blind for three consecutive days (beginning the day condors started feeding on a carcass) from 07:00 to 18:00. Weather conditions during observations were characterized by temperatures between 10 and 20 ºC and wind speeds of 25–48 km/h.

Condors were observed with 10 × 50 binoculars (Tasco, Overland Park, KS) and counted hourly. All individuals were assigned to one of the following age and sex classes:

juvenile females, juvenile males, subadult females, subadult males, adult females, and adult males (Ríos-Uzeda and Wallace 2007). We photographed and filmed each condor approaching the feeding station using a digital camera (Coolpix P60, Nikon, Tokyo, Japan) mounted on a Kowa TSN-DA4 adaptor attached to a Kowa TSN-771 spotting scope (Kowa, Torrance, CA). Photography and filming were focused more intensively on adult males than birds in the other classes because reliable individual recognition of adult males was possible based on variation in the size and shape of crests and skin folds (Ríos-Uzeda and Wallace 2007).

**Data analysis.** Andean Condors range over large areas in search of food (Lambertucci et al. 2014) so some individuals were likely to be observed at more than one of our survey areas. However, we were able to individually identify adult males and, in addition, we assumed that we were observing population structures characteristic of the survey area in question (Ríos-Uzeda and Wallace 2007). Therefore, we used the number of individually identified adult males (i.e., adult males actually observed) as a surrogate for the number of condors actually observed, and considered that the proportion of the former in the total number of observed adult males reflected the proportion of the latter in the total number of condors observed. For each survey area, we then estimated the minimum population size as the number of condors derived from this proportion (Ríos-Uzeda and Wallace 2007).

For determination of sex and age ratios in each survey area, we combined juveniles and subadults into a single class (immatures). We calculated the adult-immature ratio and the sex ratios for all condors and separately for adults and immatures. We tested whether sex/age ratios deviated from 1:1 using binomial tests (Lambertucci et al. 2012). Values are provided as means ± 1 SD.

## RESULTS

Condors visited all 10 feeding stations at the five survey areas. Maximum simultaneous counts per station ranged from four to 72 condors (mean = 33.4 ± 26.8), with a total of 335 individuals observed during the study (Table 1). Feral dogs prevented condors from landing and feeding on carcass at three stations (3, 8, and 10; Fig. 1) after condors had fed the previous day.

At the five survey areas, we counted between 30 (Cordillera de Tarachaca) and 128 (Omereque) condors across all age and sex classes (Table 1). The number of adult males counted varied from 6 (Cordillera de Tarachaca) to 45 (Omereque). Individual recognition allowed us to determine that the number of adult males varied from 3 (Cordillera de Tarachaca) to 35 (Omereque), and that the proportion of individually identified adult males in the total counted adult males varied from 50% (Cordillera de Tarachaca) to 88.6% (Cordillera de Sama). Based on this proportion, we derive minimum population sizes ranging from 15 (Cordillera de Tarachaca) to 100 (Omereque) condors, and a minimum population of 253 condors across all survey areas (Table 1).

We recorded 13 adult males at both feeding stations within the same survey area (25 km apart). Nine adult males visited both stations in Omereque, two were recorded at both stations in Cordillera de Sama, one at both stations in Cordillera del Tunari, and one both stations in Cordillera de Mandinga. Four adult males were observed at more than one survey area. One was observed at Omereque and Cordillera de Mandinga (143 km apart), another at Cordillera de Mandinga and Cordillera de Tarachaca (125 km apart), and two at Cordillera de Tarachaca and Cordillera de Sama (134 km apart).

The ratio of adults to immatures varied among survey areas (Fig. 2). Adults slightly outnumbered immatures in Omereque and in Cordillera de Sama, but this ratio did not differ significantly from a balanced (1:1) ratio in either area (Fig. 2). At the remaining survey areas, immatures outnumbered adults by a factor of up to 2.5 (Fig. 2). At Cordillera de Mandinga and Cordillera del Tunari, age ratios differed significantly from a balanced ratio, but not in Cordillera de Tarachaca (Fig. 2). Across all survey areas, the mean proportion of adults was 42.6% ± 12.3%, corresponding to an adult-immature ratio of 1:1.1.

Adult sex ratios ranged from moderately female-skewed (1:1.4 in Cordillera de Mandinga) to strongly male-skewed (1:0.2 in Cordillera de Sama) (Fig. 2). Male-skewed sex ratios in Omereque and Cordillera de Sama differed significantly from a balanced ratio, but not in Cordillera del Tunari, and neither did

Table 1. Estimated minimum population size of Andean Condor populations in five areas of the eastern Bolivian Andes derived from the proportion of individually identified adult males in the total counted adult males. We considered this proportion as the proportion corresponding to that of the condors we actually observed in the total observed condors.

| | Counted condors[a] | | | | | | | Individually identified adult males and | Minimum |
|---|---|---|---|---|---|---|---|---|---|
| Area | AM[b] | AF | SM | SF | JM | JF | Total | proportion[c] | population size |
| a | 8 | 5 | 6 | 4 | 9 | 7 | 39 | 787.5% | 34 |
| b | 45 | 27 | 11 | 9 | 18 | 18 | 128 | 3577.8% | 100 |
| c | 7 | 10 | 3 | 7 | 15 | 17 | 59 | 457.1% | 34 |
| d | 6 | 6 | 4 | 3 | 5 | 6 | 30 | 350% | 15 |
| e | 35 | 8 | 10 | 1 | 11 | 14 | 79 | 3188.6% | 70 |
| Total | 101 | 56 | 34 | 24 | 58 | 62 | 335 | 80 | 253 |

[a]Sum of the maximum number of condors per feeding station (two feeding stations per area) and proportion in the total.
[b]Age/Sex classes: AM, adult males; AF, adult females; SM, subadult males; SF, subadult females; JM, juvenile males; JF, juvenile females.
[c]Proportion in the total counted adult males.

the female-skewed sex ratio in Cordillera de Mandinga (Fig. 2). Across all survey areas, the mean proportion of adult males (26.4% ± 13.1%) was greater than that of adult females (16.2% ± 4.7%), corresponding to an adult male-to-female ratio of 1:0.6.

Immature sex ratios showed similar tendencies, ranging from slightly female-skewed (1:1.3) in Cordillera de Mandinga to moderately male-skewed (1:0.7) in Cordillera del Tunari and Cordillera de Sama, but, except for Cordillera de Sama, none differed significantly from a balanced ratio (Fig. 2). Across all survey areas, mean proportions of immature males and immature females were similar (29.6% ± 5.8% vs. 27.8% ± 8.6%), corresponding to an immature male-to-female ratio of 1:0.9.

The overall sex ratio was male-skewed at Cordillera del Tunari, Omereque and Cordillera de Sama, and differed significantly from a balanced ratio in the latter (Fig. 2). At Cordillera de Mandinga, the overall sex ratio was female-skewed whereas it was balanced at Cordillera de Tarachaca. Across all survey areas, this ratio was male-skewed and differed significantly from a balanced ratio (Fig. 2).

## DISCUSSION

We estimated a minimum population size of 253 condors across our five survey areas in the eastern Andes of central and southern Bolivia, corresponding to 4.1% of the estimated global population of 6200 individuals (Díaz et al. 2000). Our highest estimates were at Omereque and Cordillera de Sama (Table 1); lower estimates at Cordillera del Tunari, Mandinga, and Tarachaca may have been influenced by the presence of feral dogs that deterred condors from feeding, as has been reported elsewhere in Bolivia (Aliaga-Rossell et al. 2012).

A potential bias to our minimum population size estimate is that numbers of adult males may not be representative of other age and sex classes and, therefore, for the whole population. However, because the foraging areas of Andean Condors appears to be comparable among sex and age classes (De Martino et al. 2011, Lambertucci et al. 2014), we consider that, as observed by Ríos-Uzeda and Wallace (2007) in northwest Bolivia, the numbers of adult males likely reflect overall numbers and our estimates are close to the minimum population in the area.

Comparing our results to those of other studies where feeding stations were used to estimate populations, our population estimates for Andean Condors are substantially higher than those reported by Astudillo et al. (2011) for Cajas National Park in Ecuador (six condors). Similarly, our estimates for the two undisturbed areas without feral dogs are higher than those reported by Cailli-Arnulphi et al. (2013) in Ischigualasto National Park in west-central Argentina (62 condors).

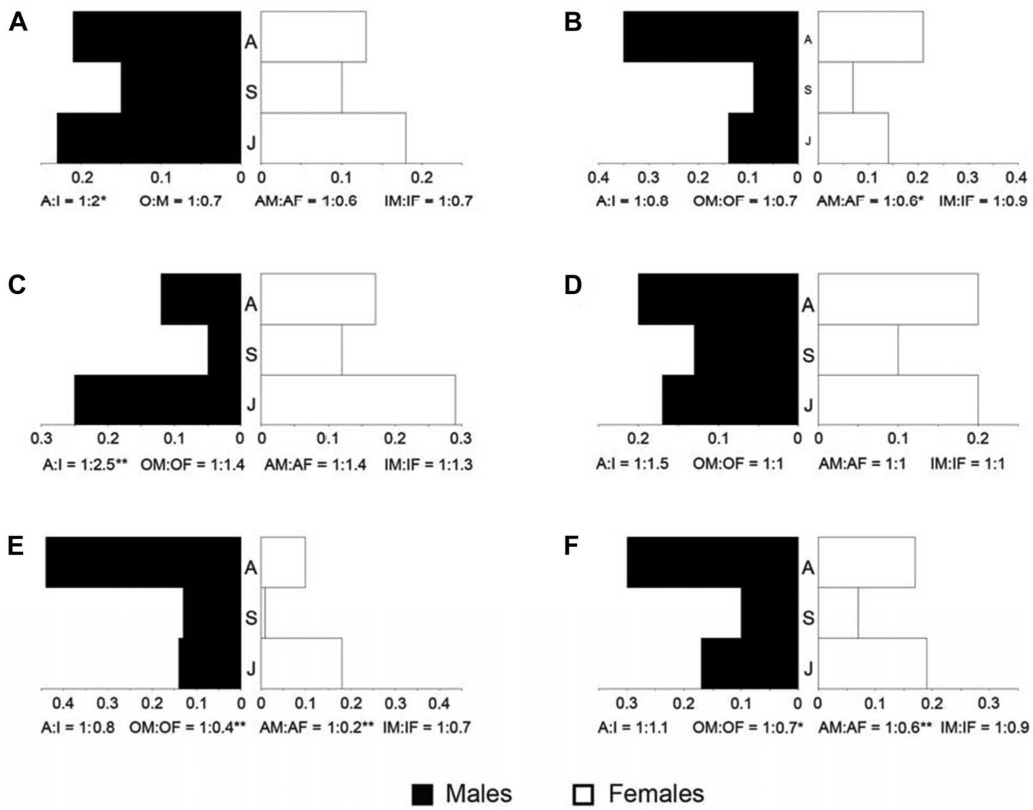


Fig. 2. Estimated Andean Condor population structure in (a) Cordillera del Tunari, (b) Omereque, (c) Cordillera de Mandinga, (d) Cordillera de Tarachaca, (e) Cordillera de Sama, and (f) across all areas expressed in percentage of each age/sex class in the population. Age/sex classes: A, adults; S, subadults; I, immatures (subadults and juveniles combined); M, males; F, females. Ratios: A:I = adults:immatures, OM:OF = overall males:overall females, AM:AF = adult males:adult females, and IM:IF = immature males:immature females. Significance levels (binomial test): $^{*}P \leq 0.05$, $^{**}P \leq 0.001$; unmarked ratios not significant ($P = 0.09$).

Counts at roost sites in northwest Patagonia, where the largest Andean Condor population occurs, revealed 246 individuals in an area of 6300 km$^2$, corresponding to a population density of 3.9 condors per 100 km$^2$ (Lambertucci 2010). Our estimate of 253 condors in an area of ~40,000 km$^2$ (the estimated area of the surveyed mountain ranges; Montes de Oca 2005) translates to a population density of 0.6 condors per 100 km$^2$. Counts at roost sites may provide more precise estimates if all roosting sites in a given area are found. Feeding stations, on the other hand, may not attract all individuals (e.g., if other carcasses are present in the same area). Further work is needed to determine if densities of Patagonian populations of condors are higher than those in Bolivia.

Adult-skewed age ratios have been commonly reported in Andean Condor populations (Koenen et al. 2000, Sarno et al. 2000, Lambertucci 2010), except for the Apolobamba Mountains, where the adult-immature ratio was 1:1.5 (Ríos-Uzeda and Wallace 2007). We found that immatures were more abundant than adults, markedly so in Cordilleras del Tunari, Mandinga, and Tarachaca (Fig. 2). Although not fully understood, adult-skewed ratios in the Andean Condor may be due to differences in habitat use, low reproductive rates, or higher natural mortality rates of juveniles and immatures (Donázar et al. 1999, Sarno et al. 2000, Lambertucci 2010). The ratio of adults to immatures may also be indicative of population trends (Koenen et al. 2000) and may reflect the reproductive rate of Andean Condors, with a surplus of immatures possibly indicating greater recruitment. Thus, our results suggest that populations in Cordilleras del Tunari, Mandinga, and Tarachaca may have higher reproductive rates (Wallace and Temple 1988), than populations at Omereque and Cordillera de Sama. However, only long-term monitoring and systematic nest surveys will provide conclusive data on local and regional population trends.

Overall, males outnumbered females in our study, but sex ratios differed among survey areas (Fig. 2). Estimates of Andean Condor population structure throughout most of their range (Lambertucci et al. 2012) showed that adult sex ratios were skewed in favor of males, whereas immature sex ratios were balanced or even female-skewed. Greater human-induced mortality rates for females, especially juveniles, may explain the male-skewed sex ratios of adult condors (Lambertucci et al. 2012). This may be due to differences in habitat use, with dominant males found in higher-quality habitats and females found in more disturbed, lower-quality habitats associated with higher risks (Donázar et al. 1999, Lambertucci et al. 2012).

In most of our survey areas, we observed sex ratios consistent with the male-skewed population structure reported by Lambertucci et al. (2012). In Cordilleras de Mandinga and Tarachaca, however, females were more abundant than males (Fig. 2). Differences between the sexes in foraging habitat selection are unlikely to explain these female-skewed sex ratios if only carcass-site characteristics are considered, because all our feeding stations were located at high-quality sites (Donázar et al. 1999). Rather, possible differences in spatial use between sexes at a larger spatial scales, with adult males prefently foraging in landscapes that in general have a better conservation status (i.e., carcass availability in high-quality sites is higher) and females being relegated to overall more disturbed landscapes, as recently suggested for Patagonian populations (Alarcón et al. 2013), may explain the locally observed female-skewed sex ratios.

In general, Andean Condor abundance and population structure estimates have been obtained using point counts—mostly at communal roosts—and feeding stations (Lambertucci et al. 2012). Although feeding stations outperformed point counts and transects for monitoring the species in Ecuador, where the population is small and scattered (Astudillo et al. 2011), counts at roosts were successfully used in Patagonia, where the population is larger and information about the location of roosts was available (Lambertucci 2010). Although both approaches have advantages and limitations, we believe both methods can be useful depending on the conditions of study areas (e.g., anthropogenic disturbance, conservation status, and topography). Because the location of Andean Condor roosts in Bolivia is not currently known, feeding stations are, at least in the short term, the most suitable method for studying this species in the Bolivian Andes. The accuracy of population estimates using feeding stations could be improved by assessing the number of carcasses required to survey a particular area and using mark-recapture techniques at feeding stations, based on the facial recognition of adult males (Ríos-Uzeda and Wallace 2007) complemented by plumage pattern recognition that might allow identification of birds in all age and sex classes (Snyder and Johnson 1985, Murn 2012).

Our results, along with those reported by Ríos-Uzeda and Wallace (2007), suggest that condor populations in Bolivia are still reasonably large and highlight the importance of the country for Andean Condor conservation. However, further research and population monitoring is urgently needed, including the use of feeding stations to cover the entire Bolivian range of the species along with intensive searches for roost and nesting sites. Such an approach would be more likely to provide the data needed for the development of effective conservation actions.

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