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Impacts of Free-Ranging Dogs on a Community of Vertebrate Scavengers in a High Andean Ecosystem

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Abstract

Background and Research Aims: Native vertebrate scavenger communities may be affected by free-ranging dogs (*Canis lupus familiaris*), but little information is available on this subject. We aimed to evaluate the influence of free-ranging dogs on a community of native vertebrate scavengers and to propose management and conservation actions.

Methods: Between November 2014 and June 2016, we systematically monitored 37 ungulate carcasses in the buffer zone of Antisana National Park, Andes of Ecuador at an elevation range between 3000 and 4150 m asl. We monitored carcasses with camera traps operating 24 hours per day.

Results: We obtained 1010 independent events and recorded seven vertebrate scavenger species. Free-ranging dogs were present at carcasses for 40.39% of the total activity time, but the most frequently recorded species were the Andean fox (*Lycalopex culpaeus*) and the Carunculated Caracara (*Phalcoboenus carunculatus*). The scavenging birds were diurnal, the Andean fox was mostly nocturnal, and the free-ranging dogs were active in all periods of the day. Native scavenger species changed their peak of activity to times when the free-ranging dogs were less active, probably to avoid agonistic encounters. The presence of free-ranging dogs negatively influenced the number of independent events of the native species.

Conclusion: The presence of free-ranging dogs showed a negative relationship with the residence time and the number of independent events of native scavenging species. Furthermore, their presence modified the hour of the peak in the activity patterns of the scavenger community.

Implications for Conservation: The presence of free-ranging dogs may have important implications for the conservation of the Vulnerable Andean Condor (*Vultur gryphus*) in Ecuador. To achieve the conservation goals of native vertebrate scavengers, particularly of Andean Condors, it is necessary to develop environmental education programs, provide technical training in responsible dog ownership, and conduct campaigns to sterilize and control dogs.

Keywords
Alien species, *Canis lupus familiaris*, camera traps, Andean condor, conservation

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Introduction

Carrion is present in all terrestrial biomes and is important in the population dynamics of different species (Blázquez et al., 2009; Newsome et al., 2021). As a food resource, dead animals are scarcer than live prey. Thus, their presence in ecosystems influences the richness, abundance, and home ranges of scavenger species. However, alien species also use carrion as a resource, and they generate changes in the dynamic of scavenger communities (Butler & du Toit, 2002; DeVault et al., 2016; Hill et al., 2018).

Changes in the availability and use of carrion have a direct impact on the provision of ecosystem services. Alteration in scavenger´s community dynamics influences nutrient recycling and the process of biomass decomposition (Sebastián-González et al., 2016; Wilson & Wolkovich, 2011). Furthermore, scavengers are important for public health because they eliminate potential sources of pathogen transmission preventing the spread of diseases to humans (DeVault et al., 2016; Gu & Krawczynski, 2012; Hill et al., 2018).

Scavenger species are particularly sensitive to anthropogenic disturbance due to their specialized diet (Arrondo et al., 2019; Naves-Alegre et al., 2021; Sebastián-González et al., 2019). They face a wide variety of threats including poisoning with pesticides, shooting, and lead contamination (Plaza & Lambertucci, 2021; Restrepo-Cardona et al., 2022; Sebastián-González et al., 2019). Free-ranging dogs (*Canis lupus familiaris*) represent another important threat to scavenger communities, although little information exists regarding their impact on native scavenging species (Aliaga-Rossel et al., 2012; Butler & du Toit, 2002; Santangeli et al., 2022).

Free-ranging dogs prey and attack native wildlife species, including scavengers (Aliaga-Rossel et al., 2012; Restrepo-Cardona et al., 2022). In Ecuador, free-ranging dogs prey on livestock, which induces negative interactions with people who poison carcasses as retaliation, causing the unintentional poisoning of Andean Condors (*Vultur gryphus*) (Restrepo-Cardona et al., 2022). They also negatively influence the occupancy and activity patterns of large carnivores (e.g., puma *Puma concolor* and Andean bear *Tremarctos ornatus*) (Zapata-Ríos & Branch, 2018). However, the effects of the presence of free-ranging dogs on the timing of food consumption and activity patterns of native vertebrate scavenger communities are unknown.

Free-ranging dogs roam without human supervision into wild areas, and it is hard to determine their ownership status (Contreras-Abarca et al., 2022; Guedes et al., 2021). Nevertheless, most of these animals are pets under neglected ownership or abandonment. Their population is unknown in the Andean region of Ecuador; but a density of up to 1.1 individuals/km^2 has been found in some western areas (Zapata-Ríos & Branch, 2016; Zapata-Ríos et al., 2023). Based on the systematic monitoring of 37 carcasses, we evaluated the impacts of free-ranging dogs on the timing of food consumption and activity patterns of the native vertebrate scavenger community in a high Andean ecosystem in Ecuador. We aimed to evaluate the influence of free-ranging dogs on a community of native scavenging species and propose management and conservation actions.

Methods

Study Area

The study was conducted within the Chakana Reserve and the Antisana Water Conservation Area, located in the provinces of Pichincha and Napo in the northeastern Andes of Ecuador. Both reserves belong to the buffer zone of the Antisana National Park (Figure 1). They are limited to private ranches where cattle raising is the main activity. The nearest town is Pintag located approximately 35 km away (MAE, 2015). However, there are small human settlements along the main access road to the reserves.

The Chakana Reserve covers 5010 ha in an elevation range of 3000 to 4800 m asl. The reserve was a cattle ranch until 2011, when Jocotoco Foundation purchased it. The cattle population was reduced and nowadays, tourism is its main activity (Jocotoco, 2021). The Antisana Water Conservation Area belongs to the Water Protection Fund (FONAG) and the Quito Metropolitan Public Water and Sanitation Company (EPMAPS), it has an area of 8487 ha in an elevation range of 3720 to 4760 m asl. This area was a ranch with over 22,000 animals for 100 years. Since 2011, farm animals were eradicated, and the area was devoted to ecosystem restoration and conservation activities (EPMAPS & FONAG, 2018).

The area where both reserves are located has a mean annual temperature that varies between 3 and 17 °C (Chuncho & Chuncho, 2019; MAE, 2013) and is characterized by the presence of evergreen shrubland and paramo grasslands, an ecosystem dominated by grasses (*Calamagrostis* spp.), cushion plants (*Azorella* sp., Asteraceae) and shrubs (*Chuquiraga jussieui*, *Gynoxys* sp., *Puya* sp.) (Chuncho & Chuncho, 2019; MAE, 2013).

Data Collection

Between November 2014 and September 2016, we systematically monitored 37 carcasses using camera traps. We randomly placed carcasses at seven stations distributed between 3500 and 4150 m asl (Figure 1). Those sites were selected after locating natural carcasses where we observed condors landing and feeding relatively close to roosting or nesting sites. We placed carcasses in the same locations due to the accessibility and security of camera traps. The carcasses were placed monthly at two camera stations. This rotation meant that some camera stations had no carrion between months. Since the camera stations were separated by less than 5 km and located at about the same elevation, the environmental conditions were assumed to be the same as those described for the study area.

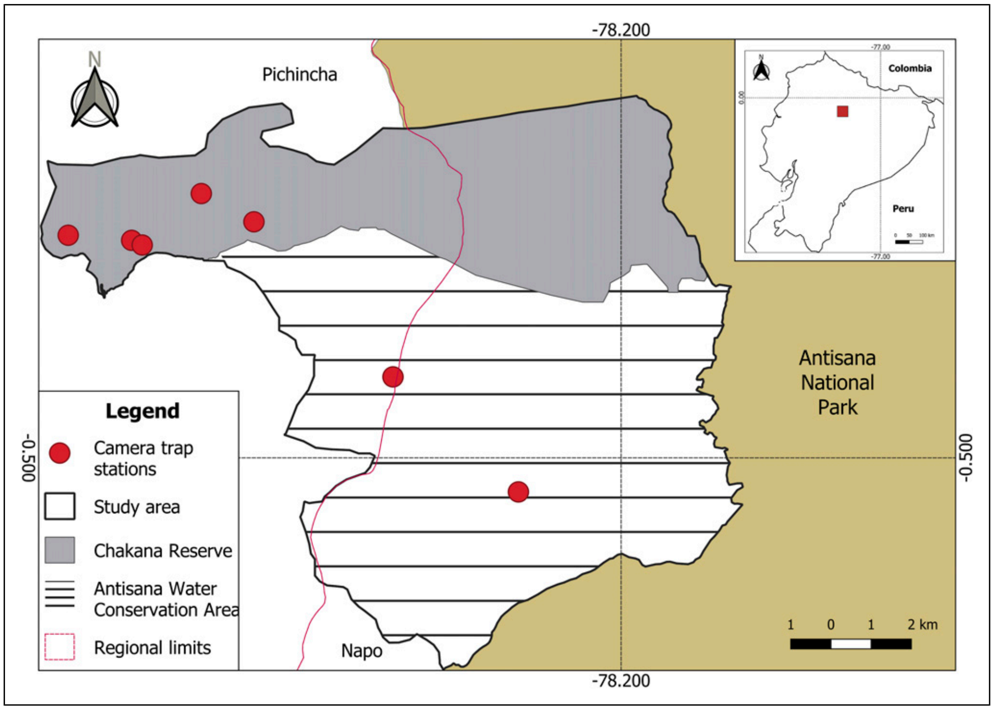

Figure 1. Location of camera-trapping stations for 37 carcasses monitored in the Chakana Reserve and Antisana Water Conservation Area, Ecuador, between 2014 and 2016.

Thirty-five carcasses were experimental, and two further carcasses were found killed by predators. The researchers provided experimental carcasses after local cowboys (Chagras) killed them. The carcasses comprised cattle (*Bos taurus*) (89.1% of the total number of carcasses), horses (*Equus caballus*), and alpacas (*Vicugna pacos*) (each 5.4% of the total number). The average weight of the monitored carcasses was 385 kg, 464 kg, and 60 kg respectively (García Neder et al., 2009; Tirira, 2017).

We monitored carcasses by photo-trapping with a camera trap. We used Bushnell 8MP Trophy Cam HD Hybrid and Reconyx HC600 Hyperfire camera traps. These cameras operated 24 hours per day and were programmed to capture a burst of three photographs with a one-minute interval between detections. Each camera was mounted on a wooden pole at a distance between 5 and 10 m from the carcass. Photographic data were retrieved every 15 days and entered into a database. We registered species that fed on carrion, pecked/bit, chewed, or torn carcasses. We considered independent events as consecutive photographic records of the same species separated by at least 60 minutes. For each independent event, we recorded the time, the time spent at the carcass, the species photographed, the abundance, and the number of days since carcass placement.

Data Analysis

We calculated the sampling effort (trap-nights) using R version 4.0.0 (R Core Team, 2021) through the R package "*camtrapR*" (Niedballa et al., 2016). We obtained the value from the total number of camera traps distributed in the field, multiplied by the total number of days in which they were active for 24 hours. We calculated a species accumulation curve and three estimators (Chao, Jackknife 1, and Bootstrap) to determine the representativeness of the scavenger community. The species accumulation curve and the estimators were calculated by the R package "*biodiversityR*" (Kindt & Coe, 2005).

Relative frequency of detection was calculated as the percentage ratio of independent events of a given species relative to the total number of all scavenging species detections. Minimum abundance corresponded to the highest number of individuals of the same species recorded in an independent event. It was estimated as from individuals recorded together in a single photo or individuals recognizable by sexual and age. The 37 carcasses were monitored until complete consumption (bones, fur, and skin remaining) (Orihuela-Torres et al., 2021). The persistence time was the number of days which scavengers fed on the carcasses; from the date of placement until the last scavenger species was recorded. The average persistence time was calculated from the persistence time of all the carcasses and each carcass species. We estimated the residence time of each independent event as the difference between the time of the first and the last recorded photograph. The residence time of a scavenging species was estimated as the sum of the time between their independent events.

Activity patterns were described for species with at least 30 independent events between all stations (Fonseca-Prada et al., 2023; Zapata-Ríos & Branch, 2016). Species were classified into four categories, (a) diurnal, species detected in the period 06:00 to 18:00 h; (b) nocturnal, species detected between 20:00 and 04:00 h; (c) crepuscular, species recorded from 04:00 to 06:00 h or from 18:00 to 20:00 h; and (d) cathemeral, species with 24-hour activity (Monroy-Vilchis et al., 2011; Mosquera-Guerra et al., 2018). Due to equatorial latitude, sunrise and sunset are regular and transformation was unnecessary to account for differences across seasons. The graphical representation was produced using the R package "*Circular*" (Lund et al., 2017).

We divided carcasses into two categories to describe changes in the activity patterns of native scavenging species. We divided the data into carcasses with high activity of free-ranging dogs (dogs` records represented more than 25% of the total independent events) and carcasses with low/null activity of free-ranging dogs (dogs´ records represented less than 25% of the total independent events). We chose 25% as an approximation of dogs´ relative frequency of detection. We represented the activity patterns using the R package "*Overlap*" (Meredith & Ridout, 2021).

We fitted Generalized Linear Mixed Models (GLMM) by the R package "*lme4*" (Bates et al., 2015) to test the influence of free-ranging dogs´ presence in native scavenging species. We included the species-independent events as the response variable and the free-ranging dogs´ presence as the predictor variable. We also added the number of days since carcass placement as covariable and a random intercept of the carcass ID. We used the negative binomial distribution to adjust data overdispersion (Lindén & Mäntyniemi, 2011).

Results

Independent events

We obtained a total of 1010 independent events and a total sampling effort of 1065 trap-nights. We recorded seven vertebrate species feeding on carcasses: three mammal and four bird species. The species accumulation curve reached the asymptote (Figure 2). We got a 100% of representativeness according to all the species richness estimators calculated (Chao1=7±0; Jackknife1=7±0; Bootstrap= 7.17±0.4 (stimation±standard deviation)).

The species with the highest number of independent events were the Andean fox (*Lycalopex culpaeus*, n= 279), the Carunculated Caracara (*Phalcoboenus carunculatus*, n=257), the free-ranging dogs (n=233), and the Andean Condor (n=191). These species accounted for 95% of the total number of independent records. For the Black-chested Buzzard-Eagle (*Geranoaetus melanoleucus*, n=33), the Black Vulture (*Coragyps atratus*, n=10), and the Andean bear (*Tremarctos ornatus*, n=7), we obtained a combined value of 50 records, which represented 4.95 % of the total number of records (Table 1).

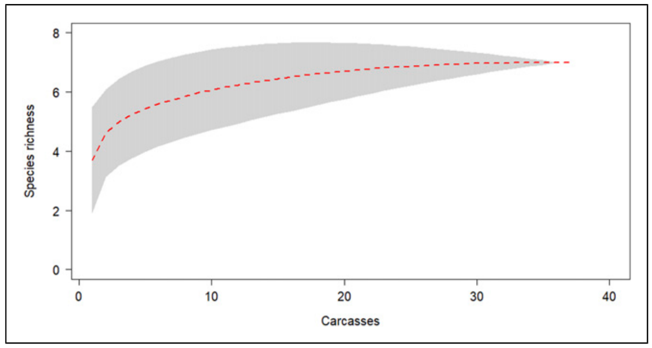

Figure 2. Species accumulation curve of vertebrate scavenger species studied between 2014 and 2016 in the buffer zone of Antisana National Park. The grey area represents the confidence interval at 95%.

Minimum Abundance

The Andean Condor and the Carunculated Caracara were recorded in groups over 10 individuals. They were followed by free-ranging dogs, with groups up to five individuals, Andean foxes (four individuals), and Black Vultures (three individuals). The average minimum abundance of Carunculated Caracara was 2.28. Andean Condor, free-ranging dogs, and Black Vulture' average minimum abundance was between 1.82 and 1.90 individuals (Table 1). Andean foxes average minimum abundance was 1.10. All the records of Andean bear and Black-chested Buzzard-Eagle were of only one individual (Table 1).

Time of Food Consumption

The average carcass persistence time was 29±14 (mean±standard deviation) days. Cattle carcasses were fully consumed in an average of 31±14 days. For horse and alpaca carcasses, the average persistence time was 14±14 and 18±5 days, respectively.

We recorded 2407 hours of activity in front of the camera traps. Free-ranging dogs were present at carcasses for 40.39% (972 hours) of the total activity time, followed by the Andean fox (784 hours), the Carunculated Caracara (436 hours), and the Andean Condor (174 hours). These three native species along occupied 57.93% of the total time spent scavenging the carrion. The Black-chested Buzzard-Eagle, Black Vulture, and Andean bear together remained at the carrion for 1.68% of the time (Figure 3).

Activity Patterns

The scavenging birds were diurnal, the Andean Condor and the Carunculated Caracara fed on carrion between 06:00 and 18:00 h. More scavenging bird records were in the early morning hours with another peak in activity between 14:00 and 15:00 h. Mammals had a cathemeral pattern with activity

Table 1. Vertebrate scavenger species recorded at 37 carcasses in the buffer zone of Antisana National Park, between 2014 and 2016.

Order	Common name	Species	Independent events	Relative frequency of detection	Minimum abundance: Mean ± standard deviation	Minimum abundance: Range	IUCN category*
Mammals							
Carnivora	Andean Fox	*Lycalopex culpaeus*	279	27.60%	1.10 ± 0.38	1-4	LC
Carnivora	Free-ranging dogs	*Canis lupus familiaris*	233	23.10%	1.84 ± 0.89	1-5	-
Carnivora	Andean Bear	*Tremarctos ornatus*	7	0.70%	1.00 ± 0	1	VU
Birds							
Cathartiformes	Black Vulture	*Coragyps atratus*	10	1%	1.90 ± 0.57	1-3	LC
Cathartiformes	Andean Condor	*Vultur gryphus*	191	18.90%	1.82 ± 1.71	1-12	VU
Accipitriformes	Black-chested Buzzard-Eagle	*Geranoaetus melanoleucus*	33	3.30%	1.00 ± 0	1	LC
Falconiformes	Carunculated Caracara	*Phalcoboenus carunculatus*	257	25.40%	2.28 ± 1.70	1-14	LC

*Threat categories according to the International Union for Conservation of Nature (IUCN, 2022): Vulnerable (VU), Least Concern (LC).

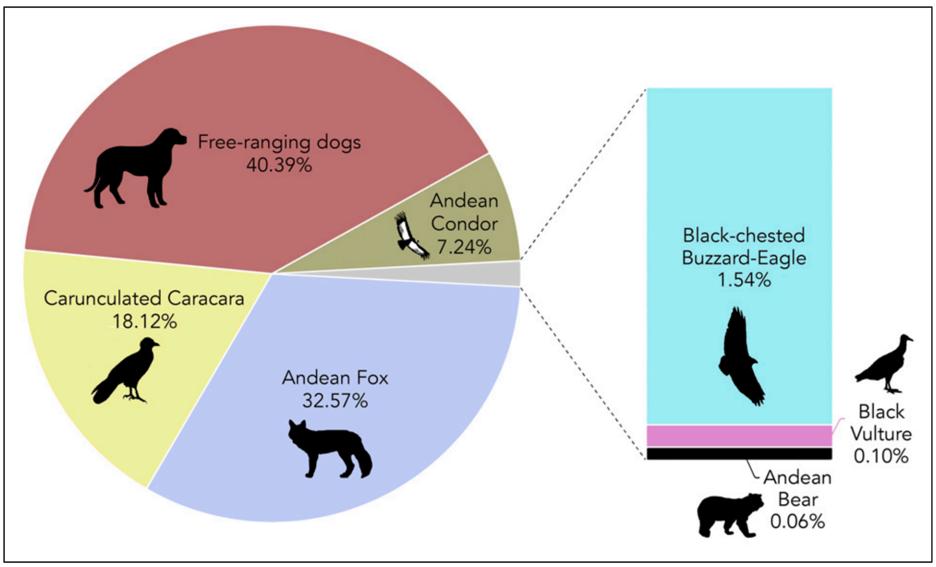

Figure 3. Percentage of total persistence time of seven vertebrate scavenger species at 37 carrion carcasses monitored between 2014 and 2016 in the buffer zone of Antisana National Park.

recorded across the 24-hour cycle. The Andean fox concentrated its activity at night, between 19:00 and 06:00 h. In contrast, free-ranging dogs mainly accessed the carrion in the morning hours, with a peak observed between 06:00 and 07:00 h (Figure 4).

Twenty-two carcasses were considered as low-activity and fifteen as high-activity. We found an increase in the records of the Andean fox in high-activity carcasses, between 18:00 and 24:00 h (Figure 5). The peak activity of the Andean Condor changed from 06:00 to 11:00 h in low-activity carcasses to 10:00 to 11:00 h in high-activity carcasses (Figure 5).

Impacts of Free-Ranging Dogs

Free-ranging dogs visited 28 carcasses and were absent from nine of them. The GLMMs showed that free-ranging dogs´ presence negatively influenced the number of independent events of the Andean Condor, the Andean fox, the Carunculated Caracara, and the Black-Chested Buzzard Eagle (p-value<0.05; Table 2). The number of days since carcass placement was significant for all the scavenging species except the Carunculated Caracara (p-value=0.69; Table 2).

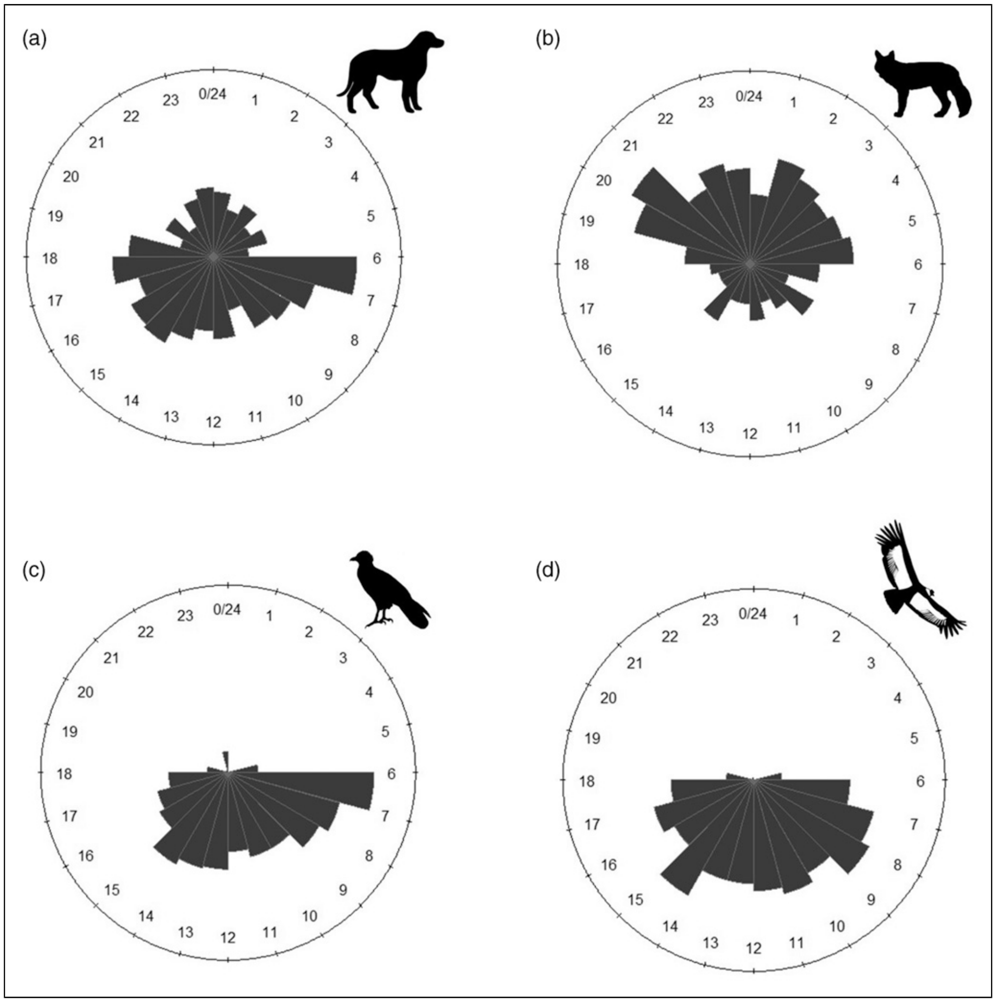

Figure 4. Activity patterns of the most abundant vertebrate scavenger species recorded at 37 carcasses monitored between 2014 and 2016 in the buffer zone of Antisana National Park. A. Free-ranging dogs *Canis lupus familiaris*, B. Andean Fox *Lycalopex culpaeus*, C. Carunculated Caracara *Phalcoboenus carunculatus*, D. Andean Condor *Vultur gryphus*.

Discussion

We found that free-ranging dogs occupied the carrion for more time than the native species, despite not being the most frequently recorded species or presenting the highest number of independent events in the camera traps. Scavenging birds were diurnal, and the Andean fox was most active at night, while free-ranging dogs were active in all periods of the day. Native scavenger species changed their peak of activity to times when the free-ranging dogs were less active, probably to avoid agonistic encounters. The presence of free-ranging dogs negatively influenced the number of independent events of the native species.

Andean fox, Carunculated Caracara, and free-ranging dogs were the most frequent species recorded at carcasses. We found that facultative scavengers were more frequent than Andean Condors, as described with other vultures (Moleón et al., 2015; Olea et al., 2022; Orihuela-Torres et al., 2021). However, native facultative scavenging species spent less time at the carrion than the free-ranging dogs. In African rural landscapes, free-ranging dogs have been reported to consume 90-95% of the carcass mass when present (Butler & du Toit, 2002). Our findings add evidence to the statement that the presence of free-ranging dogs represents an important threat to native vertebrate scavenger species, both within protected areas and those devoid of any conservation status (Butler & du Toit, 2002; Zapata-Ríos & Branch, 2018).

The Andean fox maintained a cathemeral pattern, but they were more active in high-activity carcasses at night when free-ranging dogs reduced their activity. The Andean Condor probably changed the peak of its activity to avoid the time when free-ranging dogs were more active. The use of the food resource at different times probably allows native species to avoid agonistic encounters with free-ranging dogs (Aliaga-Rossel et al., 2012; Olea et al., 2022; Zapata-Ríos & Branch, 2018). The decrease in the number of independent events of scavenging species in carcasses with free-ranging dogs could be explained by the tendency of free-ranging dogs to monopolize carrion (Butler & du Toit, 2002).

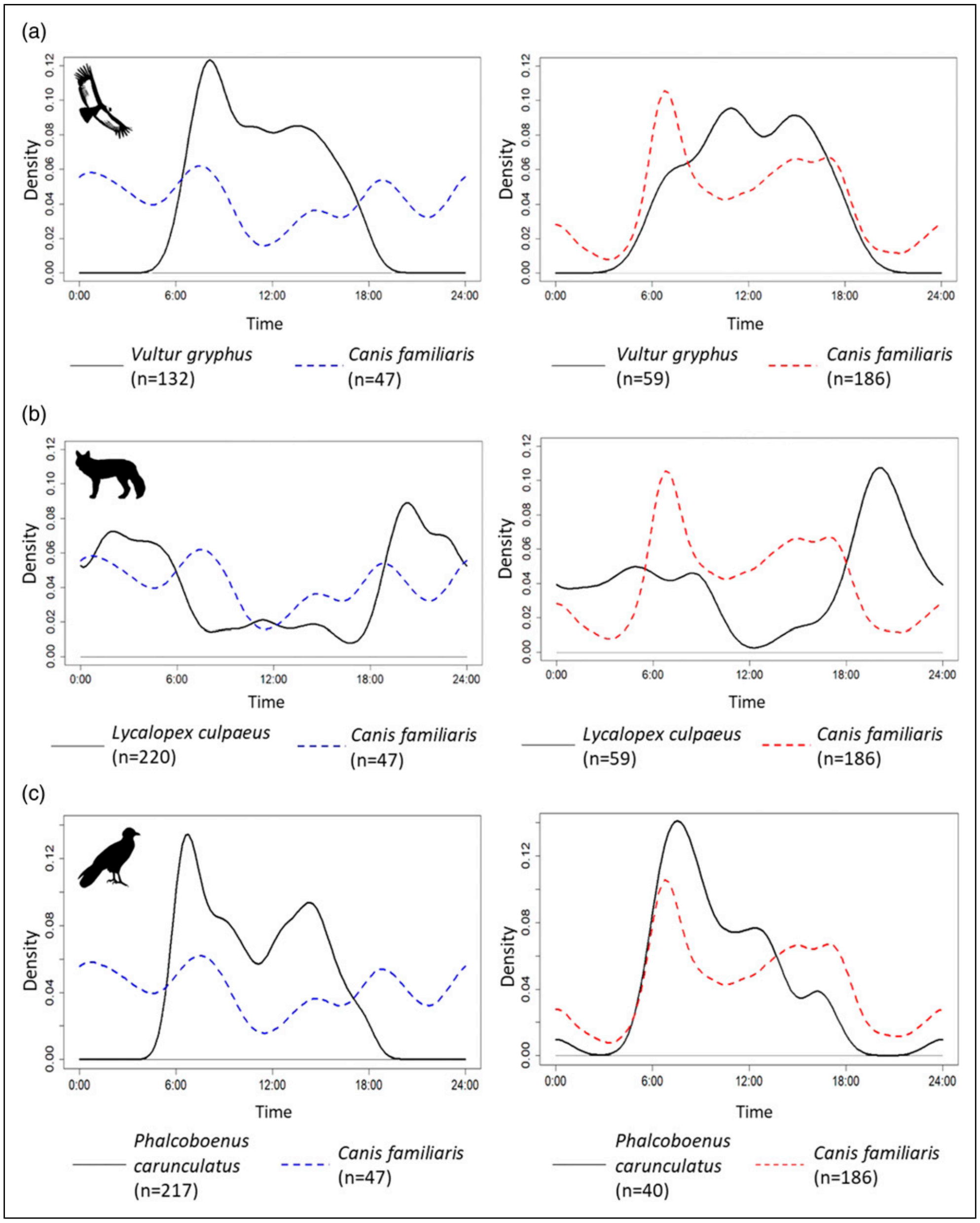

Figure 5. Activity patterns of free-ranging dogs and four species of native vertebrate scavengers recorded at 37 carcasses studied between 2014 and 2016 in the buffer zone of Antisana National Park. The Y-axis is the Kernel density of species-independent events. A. Andean Condor *Vultur gryphus*, B. Andean Fox *Lycalopex culpaeus*, C. Carunculated Caracara *Phalcoboenus carunculatus*. Black-continued line represents the activity pattern of native scavenger species. The blue-dashed line represents the activity pattern of free-ranging dogs in carcasses with low activity. The red-dashed line shows the activity pattern of free-ranging dogs in carcasses with high activity.

Camera traps did not record the presence of humans, except for park rangers and researchers. Free-ranging dogs tolerate human presence (Butler & du Toit, 2002; Contreras-Abarca et al., 2022). Furthermore, the decrease in nighttime records of free-ranging dogs may suggest that some of them were returning to human settlements. Thus, human presence was not a driver of free-ranging dogs' absence in the study area.

The Andean Condor is listed as a Vulnerable species worldwide (BirdLife International, 2023), and the Ecuadorian population is listed as Endangered (Freile et al., 2019). Our study recorded a high number of Andean Condors, indicating the importance of the study area for their conservation. The Antisana National Park and its buffer zone host between 21 and 27% of the total estimated population of Andean Condors in Ecuador, ranging from 94

Table 2. Results of the GLMMs testing the influence of free-ranging dogs´ presence in the number of independent events of the Andean Condor, the Andean fox, the Carunculated Caracara, and the Black-chested Buzzard Eagle.

	Model	Estimate	Std. Error	z value	Pr(>|z|)
Andean Condor	(Intercept)	-0.732	0.183	-4.010	**<0.001**
	Dogs presence	-1.074	0.233	-4.603	**<0.001**
	Carcass age	-0.027	0.007	-3.774	**<0.001**
Andean fox	(Intercept)	-0.699	0.205	-3.408	**<0.001**
	Dogs presence	-0.680	0.197	-3.447	**<0.001**
	Carcass age	-0.020	0.006	-3.043	**0.0023**
Carunculated Caracara	(Intercept)	-0.943	0.205	-4.608	**<0.001**
	Dogs presence	-0.561	0.204	-2.754	**0.0058**
	Carcass age	-0.002	0.006	-0.398	0.6904
Black-chested Buzzard Eagle	(Intercept)	-4.253	1.219	-3.488	**<0.001**
	Dogs presence	-1.086	0.435	-2.498	**0.0125**
	Carcass age	-0.053	0.022	-2.431	**0.0150**

Significant p-values are in bold.

to 150 individuals (Naveda-Rodríguez et al., 2016; Vargas et al., 2018). The impacts of free-ranging dogs on the Andean Condor in Antisana National Park and its buffer zone, the most important population stronghold for the species in Ecuador, could therefore have important implications for the persistence of the condor population in the country.

Our results suggest that free-ranging dogs competed or at least interfered with the Andean Condor feeding. In Ecuador, the effects of free-ranging dogs on Andean Condor have been reported. At least 16% of the condors killed in recent years consumed poisoned carrion, which had been deliberately placed as retaliation to cattle attacks by free-ranging dogs. Also, free-ranging dogs have attacked and injured Andean Condors (Restrepo-Cardona et al., 2022). Competition for food can particularly affect obligate scavenging species such as the Andean Condor due to their dependence on carrion.

The impact of free-ranging dogs on native wildlife has been evidenced worldwide (Doherty et al., 2017). Moreover, the impacts of free-ranging dogs on native vertebrate scavenger communities could harm ecosystem services and directly affect human health. Scavengers keep water sources clean by consuming biomass in decomposition (Markandya et al., 2008; DeVault et al., 2016; Sebastián-González et al., 2020). Obligate scavengers, such as the Andean Condor, are more efficient at consuming carrion and can feed on carcasses in an advanced state of decomposition (Ogada et al., 2012; Hill et al., 2018). Thus, a decline in vulture populations would deaccelerate this process. It could free up carcasses as food, increasing free-ranging dog populations triggering negative interactions with humans and spreading diseases (Santageli et al., 2022; Sebastián-González et al., 2020). Provisioning services are essential in high Andean ecosystems which provide water for humans (Chuncho & Chuncho, 2019; Hofstede et al., 2023). The Antisana National Park and its buffer zone are good examples since they supply potable water to more than 650,000 people in Quito (EPMAPS and FONAG, 2018).

Implications for Conservation

The impacts of free-ranging dogs on scavenger communities have implications for ecosystem services and public health. As the source of these animals is relatively near human settlements, it is necessary to take measures to control the population and ensure responsible ownership. A legal framework to support these actions is indispensable (Contreras-Abarca et al., 2022; Santangeli et al., 2022; Zapata-Ríos and Branch, 2018). Thus, the integration of local governments, NGOs, and private institutions is required to develop conservation and management programs.

For the conservation of native vertebrate scavengers in the high Andean ecosystems of Ecuador, particularly the Andean Condor, it is necessary to develop environmental education programs, provide technical training in responsible dog ownership, and conduct dog sterilization and control campaigns.

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