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Deforestation May Trigger Black-and-Chestnut Eagle (*Spizaetus isidori*) Predation on Domestic Fowl

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Abstract

In anthropogenically transformed habitats, some birds of prey feed on domestic animals, triggering conflict between people and predators. To manage this conflict, it is important to understand the ecological circumstances associated with the predation of domestic animals. We studied variation in the diet of the endangered Black-and-chestnut Eagle (*Spizaetus isidori*) in four different Andean landscapes in Colombia. We analyzed 261 prey items brought to five *S. isidori* nests during the period when the nestlings were being raised. Domestic fowl are relatively frequent prey in the diet of *S. isidori* in three of the four localities studied (frequency: 9.3%–36%), representing 12.2% to 37.1% of the total biomass of prey consumed. In terms of biomass, in Ciudad Bolívar, Jardín, and Campohermoso, the sites with the greatest forest cover, mammals were the most important prey in the diet of *S. isidori*, while in Gachalá, the most deforested site, domestic fowl were the most important prey. We recommend that forest cover be maintained and increased to provide habitat for wild prey in the breeding territories of *S. isidori* using the landscape management tools best suited to the specific socioecological contexts of this eagle's territories. We also suggest that the management of domestic fowl under controlled conditions or the use of some deterrent be examined as strategies to mitigate or prevent conflict between people and *S. isidori*. Socioecological research and educational programs should be carried out to increase the public's understanding of this eagle and its benefits to the ecosystem.

Keywords

conservation, diet, endangered species, human–predator conflict, rural landscape, top predator

Introduction

Birds of prey play a determining role in the structuring of ecological communities (Jaksic & Marone, 2006). They control prey populations in natural environments and may help to control potential pests in crops and in urban environments, while their ecological requirements make them reliable indicators of ecosystem integrity (Donázar et al., 2016). Owing to their high degree of mobility, low population density, and specific habitat requirements, they can be considered umbrella species, such that protecting them safeguards other species and ecological processes, resulting in a broader, better articulated conservation of biodiversity (Bennett, Maloney, & Possingham, 2015; Palomino & Carrascal, 2007). When initiatives to protect particular species, such as umbrella species, are carried out efficiently in

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prioritization protocols to support actions that also benefit other species, the benefits for biodiversity are more significant (Bennett et al., 2015).

In anthropogenically transformed habitats, some birds of prey modify their diet and feed on domestic animals (i.e., Concepcion, Sulapas, & Ibañez, 2006; McPherson, Brown, & Downs, 2015; Sarasola, Santillan, & Galmes, 2010). As a consequence, this can affect human well-being, creating conflict between people and predators, and potentially leading to the persecution of species, which represents a significant threat to them (Margalida, Campión, & Donázar, 2014; Thirgood, Woodroffe, & Rabinowitz, 2005), as has been shown for the Crowned Eagle (*Harpyhaliaetus coronatus*) in Argentina (Sarasola & Maceda, 2006; Sarasola et al., 2010), and for the Ornate Hawk Eagle (*Spizaetus ornatus*) in Brazil (Trinca, Ferrari, & Lees, 2008; Zilio, 2017).

Human–predator conflicts, specifically with birds of prey, are defined as the negative interaction between ecological and social elements (Pooley et al., 2017). This type of conflict should be examined from different perspectives, in order to set clear, relevant ecological and social research objectives. The effective management of conflicts between humans and raptors should be based on an in-depth analysis of the ecological circumstances related to the predation of domestic animals (McPherson et al., 2015; Sarasola et al., 2010), and on the perception and behavior of the local inhabitants toward these birds (Cailly-Arnulphi, Lambertucci, & Borghi, 2017). This information is important in planning strategies that are ecologically and socially informed, in order to mitigate or prevent conflict between people and raptors.

The Black-and-chestnut Eagle (*Spizaetus isidori*) inhabits dense mountain forests throughout the Andes, from northwestern Venezuela to northern Argentina, and mountain ranges close to the Andes such as the Sierra Nevada de Santa Marta range in Colombia (Ferguson-Lees & Christie, 2001). The conservation status and population dynamics of this species are poorly known, and its worldwide population is estimated to have fewer than 1,000 adults (BirdLife International, 2018a). In Colombia, it is estimated that the population of *S. isidori* has 160 to 360 pairs and that the species has lost 60.6% of its natural habitat (Renjifo et al., 2014). As such, it is classified as endangered both nationally and globally (BirdLife International, 2018a; Renjifo et al., 2014). There is little information about its feeding habits. Both in Colombia and Argentina, based on the systematic monitoring of its nests, this species was found to mainly consume birds, with chickens (*Gallus gallus*) a relatively frequent prey in their diet (Aráoz, Grande, López, Cereghetti, & Vargas, 2017; Zuluaga & Echeverry-Galvis, 2016). At least in Colombia, predation of *S. isidori* on domestic fowl causes conflict with the local inhabitants who persecute this species (Lehmann, 1959; Echeverry-Galvis, Zuluaga, & Soler-Tovar, 2014; Zuluaga & Echeverry-Galvis, 2016).

The aim of this study was to quantitatively compare the diet of *S. isidori*, by analyzing the relative frequency and biomass of the different types of prey brought to the nest in four different Andean landscapes in Colombia, and to assess whether habitat loss could explain changes in the predatory habits of this species. It is essential to evaluate the food habits of *S. isidori* in order to apply this information when developing management strategies and conservation objectives for this species.

Methods

Study Area

The study was carried out in five different *S. isidori* nests and their surrounding landscapes in locations in Andean Colombia, two in the Western Andes and three in the Eastern Andes. The first locality is in the municipality of Ciudad Bolívar, Antioquia Department, on the eastern slope of the Western Andes. The focus nest was found in an emergent *Chionanthus* sp. (Oleaceae) tree, in a relict of forest in the Reserva Natural Farallones de Citará (05°48′N, 76°04′W) at 2,327 m a.s.l. The second locality is in the municipality of Jardín, Antioquia, on the eastern slope of the Western Andes. The corresponding focal nest was found in an emergent *Schefflera* sp. (Araliaceae) tree in a forest relict in the Distrito de Manejo Integrado Cuchilla Jardín-Támesis (05°31′N, 75°51′W) at 2,320 m a.s.l. The distance between the nests in Ciudad Bolívar and Jardín is 38.6 km. The third locality is in the municipality of Campohermoso, Boyacá Department, on the western slope of the Eastern Andes. The focal nest at this locality was in an emergent *Vochysia* sp. (Vochysiaceae) tree, in a forest relict located in the Quebrada Blanca basin (05°03′N, 73°09′W), at 2,013 m a.s.l. The fourth locality is in the municipality of Gachalá, Cundinamarca Department, on the eastern slope of the Eastern Andes. The first nest was found in an emergent *Vochysia* sp. (Vochysiaceae) tree at 2,038 m a.s.l., and the second nest was found in an emergent *Ficus* sp. (Moraceae) tree at 2,080 m a.s.l., about 300 m from the first nest. Both nests were found in the Farallones de Gachalá y Medina Biological Corridor (04°23′N, 73°16′W). This site is part of the buffer zone of the Parque Nacional Natural Chingaza and the Reserva Forestal Protectora Regional Tolima (Zuluaga & Echeverry-Galvis, 2016). The distance between the nests in Campohermoso and Gachalá is 56.5 km (Figure 1).

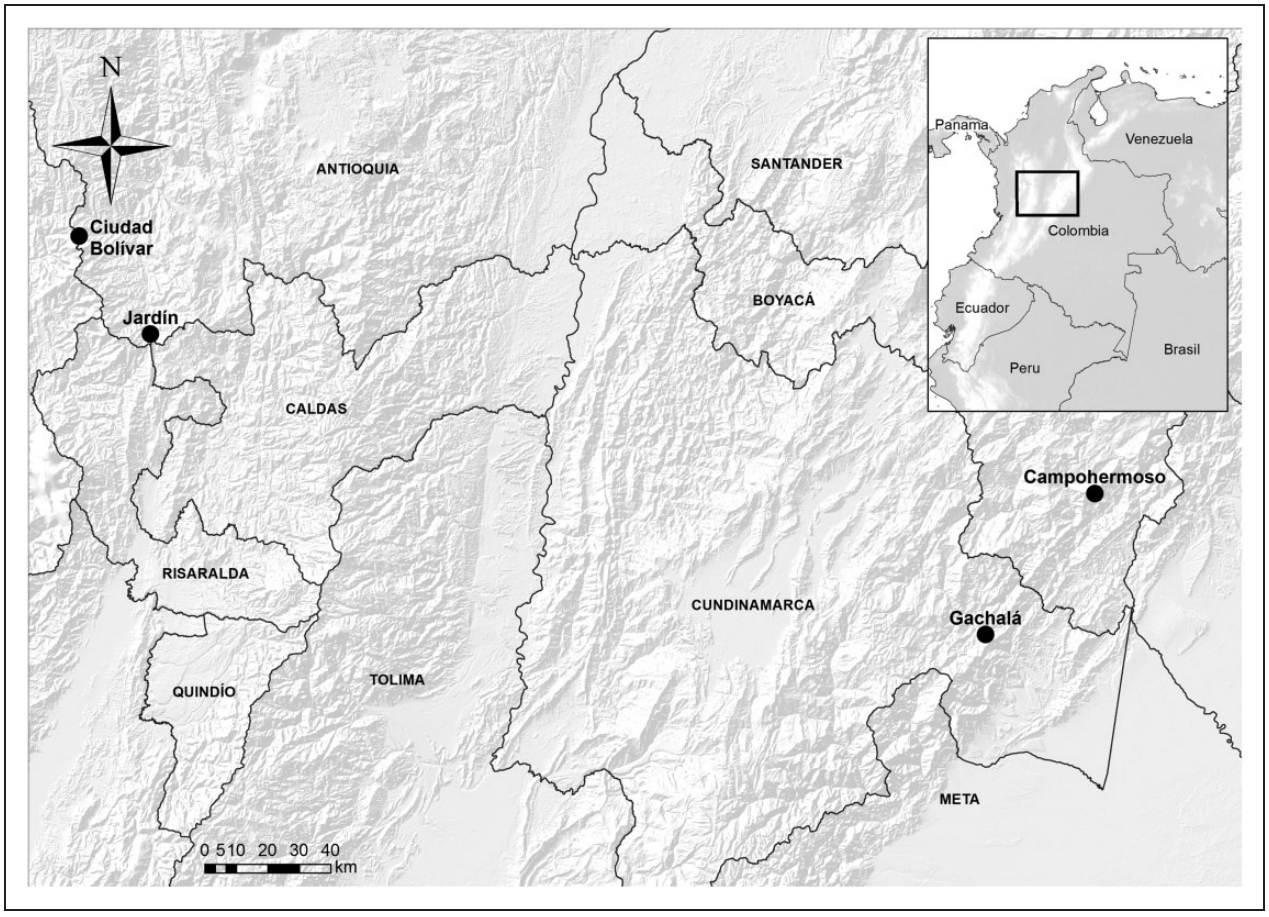

Figure 1. Locations of the five nests of the endangered Black-and-chestnut eagle (*Spizaetus isidori*) studied in Colombia.

Methodology

To evaluate the diet of *S. isidori*, we carried out systematic observations during its reproductive period between April and July 2018 in Ciudad Bolívar, May and August 2016 in Jardín, April and May 2010 in Campohermoso, and between April and May 2013 in Gachalá. Observations were made using binoculars (10×42 and 10×50), telescopes ($20–60 \times 60$ and $20–60 \times 65$) and photographic cameras, from high observation points at a horizontal distance of approximately 50 m from each nest. Observations were made between 0600 and 1800 h at each of the nests. When we began to observe the nests, in Ciudad Bolívar there was one 3-week-old eaglet; in Jardín, there was one 6-week-old eaglet; in Campohermoso, we recorded an approximately 12-week-old eaglet; and in Gachalá, we recorded an approximately 19-week-old eaglet. For Gachalá, we also used the results of Zuluaga and Echeverry-Galvis (2016) who, for the same locality, used a mix of techniques from collecting the remains of prey from the nest (2013–2015) to direct observation (2014) and video recording (2015).

We identified each prey item taken by the parents to the nest to the finest possible taxonomic level using bird, mammal, and snake guides (Hilty & Brown, 2001; Linares, 1998; Rodríguez, Renjifo, Ibañez, & Norato, 2010), or by consulting with experts on each taxonomic group using photographs of the prey that had been taken to the nest. Diet composition was expressed as the frequency of each type of prey relative to all types of prey. We also calculated the percent biomass contributed by each prey species to the diet of *S. isidori*. We obtained mean prey weight from the biological collections of the Instituto de Investigación de Recursos Biológicos Alexander von Humboldt, the Museo de Historia Natural de la Universidad de Caldas, the Centro de Atención y Rehabilitación de Fauna managed by CORPOCALDAS, and complemented this information with data published in the literature (Dunning, 2008; Linares, 1998; Tirira, 2007).

To describe landscape configuration, at each locality, the nest was taken as the center of origin and within an area of 50 km^2 surrounding the nest, the different types of vegetation cover and land use were identified using geographic information system tools and using the CORINE Land Cover definitions adapted for Colombia (Instituto de Hidrología, Meteorología y

Estudios Ambientales, 2010). An area of 50 km^2 around each nest was used because this is the estimated habitat requirement for a pair of *S. isidori* (Ferguson-Lees & Christie, 2001; Renjifo et al., 2014).

Landscape and Field Data Analysis

To evaluate the diet diversity of *S. isidori* and the trophic niche breadth (*B*), we used Levins' (1968) Index: $B = 1/\Sigma pi^2$, where *pi* is the proportion of each prey category in the diet of the eagle. To compare our results with the results obtained in other studies and between localities with a different number of prey categories, we calculated Levins' (1968) standardized trophic niche breadth index: $Bsta = (B-1)/(n-1)$, where *n* is the number of categories of prey (Colwell & Futuyma, 1971). The values of this index range from 0 (minimum niche breadth, which implies maximum selectivity) to 1 (maximum niche breadth, minimum selectivity; Krebs, 1999).

To evaluate whether there were significant differences in the frequency of prey consumed between localities, we did Chi-Squared tests of independence. The biomass contribution of prey species was calculated using Marti's (1987) index: $Bi = 100\,[(Spi\,Ni)/\Sigma\,(Spi\,Ni)]$, where *Spi* is the biomass of species *i*, *Ni* is the number of individuals of species *i* consumed, and *Bi* is the percent of the total biomass contributed by species *i*. To examine the relationship between percent forest cover and the percent biomass contributed by the mammals, wild birds and domestic fowl consumed by *S. isidori* at each locality, we performed simple linear regressions in R, version 2.1 (R Core Team, 2013).

Results

Diet Composition

In Ciudad Bolívar, we recorded 56 prey items during 658 h of observation. In Jardín, we recorded 75 prey items during 760 h of observation. In Campohermoso, we recorded 25 prey items during 340 h of observation. In Gachalá, we recorded 21 prey items during 240 h of observation, while Zuluaga and Echeverry-Galvis (2016) recorded 84 prey items that we included in our analyses. In terms of number of prey, in Ciudad Bolívar, *S. isidori* ate mostly birds, mainly Band-tailed Pigeons (*Patagioenas fasciata*), Sickle-winged Guans (*Chamaepetes goudotii*), Colombian Chachalacas (*Ortalis columbiana*), Great Thrushes (*Turdus fuscater*), one Yellow-eared Conure (*Ognorhynchus icterotis*), and a Cattle Egret (*Bubulcus ibis*). Mammals were eaten in smaller numbers, including squirrels (*Sciurus granatensis*), Kinkajous (*Potos flavus*), opossums (*Didelphis* sp.), and Colombian Night Monkeys (*Aotus lemurinus*). In Jardín, the diet of *S. isidori* was composed mainly of mammals, including *S. granatensis*, *P. flavus*, porcupines (*Coendou rufescens*), *Didelphis* sp., and an unidentified Procyonidae. A smaller proportion of birds was eaten, such as *C. goudotii* and chickens *G. gallus*, and even fewer *Chironius monticola* snakes. In Campohermoso, this eagle ate mostly birds, mainly *G. gallus* and the Band-tailed Guan (*Penelope argyrotis*). Mammals made up a much smaller part of its diet and included *S. granatensis*, South American Coatis (*Nassua nasua*), and a Tufted Capuchin (*Sapajus apella*). In Gachalá, *S. isidori* ate mostly birds, mainly Andean Guan (*Penelope montagnii*), *G. gallus*, one Laughing Falcon (*Herpetotheres cachinnans*), and a Domestic Turkey (*Meleagris gallopavo*). Mammals were eaten to a lesser degree, mainly *S. granatensis,* Western Mountain Coati (*Nasuella olivacea*), one Brown Woolly Monkey (*Lagothrix lagothricha*), and a Nine-banded Armadillo (*Dasypus novemcinctus*) (Table 1).

Prey Biomass

In Ciudad Bolívar, Jardín, and Campohermoso, mammals contributed the most biomass of all the prey consumed by *S. isidori*. While in Gachalá, birds contributed the greatest biomass to the diet of this eagle. In terms of biomass, in Ciudad Bolívar, the diet of *S. isidori* was mainly comprised of *P. flavus*, followed by guans *C. goudotii*, *P. fasciata*, *S. granatensis*, *O. columbiana*, and to a lesser degree, *A. lemurinus*, *Didelphis* sp., *O. icterotis, T. fuscater*, and *B. ibis*. In Jardín, *P. flavus* made the greatest contribution to the diet of *S. isidori*, followed by guans *C. goudotii*, chickens *G. gallus*, and to a lesser degree *Didelphis* sp., *C. rufescens*, an unidentified Procyonidae, and *C. monticola*. In Campohermoso, *N. nasua* and *G. gallus* made the most significant contribution to the diet of this eagle, followed by *P. montagnii*, *S. apella*, and to a lesser degree *S. granatensis*. In Gachalá, *G. gallus* made the greatest contribution to the diet of *S. isidori*, followed by *P. montagnii, Lagothrix lagotricha, M. gallopavo, S. granatensis, N. olivacea, D. novemcinctus*, and *H. cachinnans* (Table 1).

Trophic niche breadth values (*B*) and Levins' standardized index (*Bsta*) were 7.38 and 0.63, respectively, in Ciudad Bolívar, 6.28 and 0.66 in Jardín, 3.6 and 0.65 in Campohermoso, and 3.69 and 0.38 in Gachalá. The frequency of consumption of domestic fowl was significantly greater in Campohermoso than in Jardín (domestic fowl: $\chi^2 = 15.73$, $p < .01$), and also greater in Campohermoso than in Gachalá (domestic fowl: $\chi^2 = 6$, $p = .01$), but the consumption of mammals and wild birds did not vary significantly between Campohermoso and Jardín (mammals: $\chi^2 = 2.01$, $p = .15$, wild birds: $\chi^2 = 0.75$, $p = .38$), or between Campohermoso and Gachalá (mammals: $\chi^2 = 1.79$, $p = .18$, wild birds:

Table 1. Diet of the Endangered Black-and-Chestnut Eagle (*Spizaetus isidori*) in Four Localities in Andean Colombia.

			Ciudad Bolívar (in 2018)		Jardín (in 2016)		Gachalá[a] (in 2013–2015)		Campohermoso (in 2010)		
Prey		Weight (g)	*F* (%)	*B* (%)	*F* (%)	*B* (%)	*F* (%)	*B* (%)	*F* (%)	*B* (%)	IUCN[b]
Mammals			30.3	60.3	49.1	69. 6	25.5	36	36	63.2	
Opossum	*Didelphis* sp.	716.7	3.5	5.2	4	4.2					
Red-tailed Squirrel	*Sciurus granatensis*	295	14.2	8.6	21.3	9.2	17.1	8.8	16	3.8	LC
Stump-tailed Porcupine	*Coendou rufescens*	890			5.3	6.9					LC
Kinkajou	*Potos flavus*	2,750	7	40.1	10.6	43					LC
South American Coati	*Nasua nasua*	5,100							12	49.6	LC
Western Mountain Coati	*Nasuella olivacea*	1,286					3.8	8.5			NT
Colombian Night Monkey	*Aotus lemurinus*	866.6	3.5	6.3							VU
Common Woolly Monkey	*Lagothrix lagotricha*	6,800					0.9	11.3			VU
Tufted Capuchin	*Sapajus paella*	3,000							4	9.7	LC
Nine-banded Armadillo	*Dasypus novemcinctus*	4,500					0.9	7.4			LC
	Procyonidae unidentified[c]	3,193			1.3	6.2					
	Unidentified mammals		2		6.6		2.8		4		
Birds			57.1	39.7	30.6	27.7	50.3	63.8	52	36.7	
Sickle-winged Guans	*Chamaepetes goudotii*	693	12.5	17.7	12	12.2					LC
Andean Guan	*Penelope montagnii*	622					23.8	25.8			LC
Band-tailed Guan	*Penelope argyrotis*	807.5							16	10.4	LC
Colombian Chachalaca	*Ortalis columbiana*	550	7	8	4	3.2					LC
Band-tailed Pigeons	*Patagioenas fasciata*	342.5	14.2	10							LC
Yellow-eared Conure	*Ognorhynchus icterotis*	285	2	1							EN
Great Thrush	*Turdus fuscater*	143	5.3	1.5							LC
Cattle Egret	*Bubulcus ibis*	366	2	1.3							LC
Laughing Falcon	*Herpetotheres cachinnans*	583					0.9	0.9			LC
Domestic Turkey	*Meleagris gallopavo*	6,050					0.9	10.1			LC
Chicken	*Gallus gallus*	897.5			9.3	12.2	17.1	27	36	26.2	LC
	Unidentified birds		14.2		5.3		7.6				
Reptiles					8	2.5					
Mountain Sipo	*Chironius monticola*	220			8	2.5			12		LC
	Unidentified prey		12.5		12		23.8				
	Total prey		56		75		105		25		

Note. IUCN = International Union for Conservation of Nature. Mean weight (g), numerical percentage (*F*%), and percent biomass (*B*%) of all the prey. The IUCN risk category of the prey species is given in the last column.

[a]This column includes the 21 prey items recorded during this study in 2013 and 84 prey items recorded by Zuluaga and Echeverry-Galvis (2016) during 2013 to 2015.

[b]LC = least concern, NT = near threatened, VU = vulnerable, EN = endangered (International Union for Conservation of Nature, 2018).

[c]This category includes two species of coatimundi, *Nasua nasua* and *Nasuella olivacea*, and their mean weight was assigned to both species.

$\chi^2 = 1.85$, $p = .17$). The frequency of consumption of wild birds was significantly greater in Ciudad Bolívar than in Campohermoso ($\chi^2 = 23.10$, $p < .01$), greater in Ciudad Bolívar than in Jardín ($\chi^2 = 23.98$, $p < .01$), and greater in Ciudad Bolívar than in Gachalá ($\chi^2 = 4.94$, $p = .02$), while the consumption of mammals was significantly greater in Jardín than in Ciudad Bolívar ($\chi^2 = 4.45$, $p = .03$) and greater in Jardín than in Gachalá ($\chi^2 = 7.46$, $p < .01$) but did not vary significantly between Ciudad Bolívar and Campohermoso ($\chi^2 = 0.49$, $p = .48$) or between Ciudad Bolívar and Gachalá ($\chi^2 = 0.41$, $p = .52$). The frequency of consumption of wild birds and domestic fowl did not vary significantly between Jardín and Gachalá (wild birds: $\chi^2 = 1.85$, $p = .17$, domestic fowl: $\chi^2 = 0.11$, $p = .73$). The linear regression analyses revealed a negative relationship between percent forest cover and the percent biomass contributed by domestic fowl ($r = 0.99$, $P < 0.01$, intercept = 82.56). Although no significant relationship was found between percent forest cover and the percent biomass contributed by mammals ($r = 0.44$, $P = 0.33$, intercept = 18.71) and wild birds ($r = 0.22$, $P = 0.52$, intercept = -1.04), there was a trend.

Landscape Configuration

The landscape around the nest in Ciudad Bolívar is comprised mainly of Andean forest (3,886 ha; 78%), followed by heterogeneous agricultural areas (926 ha; 18%), cattle pastures (140 ha; 3%), and herbaceous or shrubby vegetation (49 ha; 1%). The landscape around the nest in Jardín is mainly Andean forest (3,283 ha; 66%), followed as well, by heterogeneous agricultural areas (982 ha; 20%), cattle pastures (606 ha; 12%), and herbaceous or shrubby vegetation (130 ha; 2%). The landscape around the nest in Campohermoso is comprised of Andean forest (2,663 ha; 53%), a mix of agricultural areas (999 ha; 20%), cattle pastures (989 ha; 20%), and herbaceous or shrubby vegetation (350 ha; 7%). The landscape around the nest in Gachalá is Andean forest (2,134 ha; 43%), heterogeneous agricultural areas (1,555 ha; 31%), cattle pastures (839 ha; 17%), and herbaceous or shrubby vegetation (419 ha; 8%), and water bodies (54 ha; 1%). It is worth mentioning that in each of the four of the study localities, we recorded at least 2,000 ha of forest within the defined perimeter.

Discussion

It is noteworthy that in terms of biomass, mammals were the most important prey in the diet of *S. isidori* in three of the four localities studied; the exception being Gachalá, the most deforested locality and the one where domestic fowl, mainly chicken but also one turkey, were the most important prey in this eagle's diet. In terms of prey number, in the municipality of Ciudad Bolívar, *S. isidori* mainly ate birds, while *P. flavus* contributed 40.1% to total prey biomass. This eagle's consumption of *O. icterotis* and *A. lemurinus* stands out as these species are classified as endangered and vulnerable in Colombia and worldwide, respectively (BirdLife International, 2018b; Morales-Jiménez & de la Torre, 2008; Renjifo et al., 2014; Rodríguez-Mahecha, Alberico, Trujillo, & Jorgenson, 2006), and are also affected by the same forces of habitat destruction and fragmentation that affect the eagle. This was the locality with the most forest cover and the only one where the eagle was not observed eating domestic fowl. In Jardín, *S. isidori* mainly fed on arboreal mammals, with *P. flavus* contributing 43% of total prey biomass, and Jardín was the only locality where the eagle was observed to eat snakes, a type of prey previously unknown for *S. isidori*. In Campohermoso, *G. gallus* was the most frequent prey and the second highest in biomass contribution (26.2% of total prey biomass). Of the mammals, *N. nasua* and *S. apella* eaten to a lesser extent and contributing 59.4% to total biomass prey. In terms of the number of prey, in Gachalá, *S. isidori* fed mainly on *P. montagnii*, but domestic fowl contributed 37.1% of the biomass of all the prey eaten (Table 1). This contrasts with the report of Aráoz et al. (2017) in Argentina where *S. isidori* was observed to feed exclusively on birds such as guans *Penelope* sp. (67%), Falconiformes (19%), and chickens (9%). In Brazil, the Harpy Eagle (*Harpia harpyja*) was reported to eat mainly arboreal mammals such as sloths, *Choloepus didactylus* and *Bicyrtes variegatus*, and *P. flavus* only accounted for 0.8% of all prey eaten (Aguiar-Silva, Sanaiotti, & Luz, 2014), while *S. ornatus* has been reported to eat mainly birds (90%), with squirrels the only mammals it consumes (Zilio, 2017).

The value of Levins' standardized trophic niche breadth was greater in Jardín and Ciudad Bolívar than in Gachalá (*Bsta* = 0.66, 0.63 and 0.38, respectively). We think that the value of Levins' standardized trophic niche breadth obtained in Campohermoso (*Bsta* = 065) was due to the limited number of prey registered in that site ($n = 25$). Our results suggest not only wide variation in the trophic niche of *S. isidori* but also less prey selectivity in Ciudad Bolívar and Jardín. Thus, at least during the time when prey items were recorded in Gachalá where trophic niche breadth values suggest that this eagle was more selective about the prey it consumed, *S. isidori* ate *G. gallus* as its main prey, and this species contributed more biomass, perhaps requiring a lower energetic expenditure to find, capture, and handle. According to the optimal diet theory (Sih & Christensen, 2001), during their reproductive season, organisms prefer to feed on prey that provide more energy per unit time, considering the costs associated

with locating, capturing, handling, and transporting prey to the nest (Rebollo et al., 2017).

Diet diversity and the contribution of the different types of prey varied among Ciudad Bolívar, Jardín, Campohermoso, and Gachalá. The trophic niche breadth of *S. isidori* in Ciudad Bolívar and Jardín—the localities with the largest proportion of forest on their landscapes and where the eagle hunted a wider variety of prey—compared with values calculated for Gachalá (Table 1), suggest plasticity on the part of this eagle that allows it to feed on different types of prey as a function of what is available in environments modified by humans. This could be related to changes in the composition of the landscape induced by anthropic processes that can lead to variations in the availability of prey eaten by raptors (i.e., Garcia-Heras, Mougeot, Simmons, & Arroyo, 2017; Murgatroyd, Avery, Underhill, & Amar, 2016; Rebollo et al., 2017). In Spain and Azerbaijan, in the face of changes in food availability induced by humans, a species with a mainly carrion-feeding habit such as the Griffon Vulture (*Gyps fulvus*) ate mainly domestic animals (Karimov & Guliyev, 2017; Margalida et al., 2014). Therefore, hunting alternative prey such as chickens and other domestic fowl could suggest a greater availability of this type of prey compared with the availability of wild prey in the breeding territories of *S. isidori* in rural landscapes.

For our study localities, there is no information on the availability of the prey species *S. isidori* eats, and there was relationship between percent forest cover and the percent biomass contributed by domestic fowl during reproductive events, a critical time for the species and its conservation. At Ciudad Bolívar, Jardín, and Campohermoso, where the landscape is dominated by forests that offer habitat for species such as *P. flavus* and *N. nasua*, the eagle did indeed feed on these species; while in Gachalá, where there is less forest cover, birds were the most important prey in the diet of *S. isidori*. Given these results, we suggest that as the percent forest cover decreases in the breeding territories of *S. isidori*, so does the importance of mammal prey in its diet, while the importance of domestic fowl and guans increases. In Pakistan, the Common Leopard (*Panthera pardus*) feeds mainly on domestic animals in face of habitat loss or reduced abundance of wild prey (Khan, Lovari, Ali, & Ferretti, 2018). Therefore, habitat loss would not only reduce the habitat available for the species but would also trigger conflict between humans and *S. isidori*, leading to the persecution of the species. The results from Colombia have implications for predicting the effects of habitat loss on populations of *S. isidori*, which is one of the main threats to this species throughout its distribution (BirdLife International, 2018a; Renjifo et al., 2014). Thus, the intensification of agricultural and livestock activities, and the consequent loss of forest cover in the Andean region of Colombia (Etter, McAlpine, Wilson, Phinn, & Possingham, 2006; Etter & van Wyngaarden, 2000), could be causing the lower dietary diversity of *S. isidori* and its more selective diet with the consumption of prey such as *G. gallus*. As such, one mechanism for decreasing predation on domestic fowl, and for reducing conflict with local inhabitants and their persecution of the eagle, would be to maintain an abundance of wild prey. Therefore, we recommend maintaining and, where possible, increasing forest and habitat coverage for *S. isidori* in its breeding territories, using the landscape management tools, such as those proposed by Renjifo et al. (2009), that are best suited to the species' specific socioecological contexts. It is important to keep in mind that while the regression analysis was done with a small, but indicative sample size, monitoring changes in diet over time using a larger sample size might produce other results, and so some degree of caution is suggested in interpreting the results of our analysis.

Similarly, given that the predation of domestic fowl could be the result of the greater accessibility of this type of prey in the territories we studied (i.e., Margalida et al., 2014; Peña-Mondragón, Castillo, Hoogesteijn, & Martínez-Meyer, 2016), it is important to know what management practices are being used by people with domestic fowl in these localities. With this information, it would be possible to evaluate alternatives that could reduce the vulnerability of these birds to aerial predators such as *S. isidori*, which hunts its prey from perches on trees near houses. We note that the nests detected in Ciudad Bolívar, Jardín, Campohermoso, and Gachalá (Figure 1), as well as others located in Santa Marta (Magdalena Department), Fómeque (Cundinamarca Department), Gigante, San Agustin and Pitalito (Huila Department), and in San Francisco (Putumayo Department), are all located where the agricultural frontier meets the native forest (pers. obs.). Except for the nests in Gachalá and Ciudad Bolívar, these nests are also located in areas that have not been assigned any conservation status and are managed by private owners. Therefore, when identifying areas that are important to the maintenance of *S. isidori* populations, it is essential to consider new potential areas of protection that offer direct benefits to the species, such as nesting sites and breeding territories in rural landscapes, as suggested by Restrepo-Cardona et al. (2018) for the Andean Condor (*Vultur gryphus*), another threatened species that nests in the rural landscapes of Andean Colombia.

Implications for Conservation

The notable proportion of domestic fowl in the diet of *S. isidori* in three of the four localities studied in Colombia

(frequency range: 9.3%–36%; contribution to total prey biomass: 12.2%–37.1%; Table 1), indicates that this is a common feeding behavior for this species. This rate of predation on domestic animals is the highest reported based on the information available on Neotropical raptors. In Argentina, for *H. coronatus* goats (*Capra hircus*) represented only 0.2% of its diet (Sarasola et al., 2010), while in Brazil, for *S. ornatus'* chickens made up 3.3% of its diet (Zilio, 2017). In this context, the consumption of domestic animals by *S. isidori* in Colombia is not unusual, and also indicates that with relative frequency, this species forages in habitats dominated by humans, thus creating conflict with communities of local inhabitants and leading to the persecution of the eagle. Hence, to adequately plan for the conservation of *S. isidori* in rural landscapes, it is crucial to carry out socioecological research and to offer educational programs to increase the public's understanding of this eagle and its benefits to the ecosystem.

Our results suggest that habitat loss could be a prime reason behind predation on domestic fowl by *S. isidori* and thus, it is important to not only maintain but also increase forest cover for the wild prey of this eagle using the landscape management tools best suited to the specific socioecological contexts of this eagle's territories. Furthermore, though we have no field data on this, it is very likely that deforestation occurs together with an increase in hunting pressure by people on the most important prey items of this eagle, thus exacerbating the effect of deforestation. Medium-sized mammals as kinkajous, coatis, monkeys, and armadillos, and birds such as guans are all actively hunted by Andean rural people for food or for their pelts and, therefore, it is important to control the hunting pressure on these animals in the eagle's breeding territories in Colombia. It is necessary to analyze whether habitat loss is a causal factor in the reduction of wild prey or whether it just increases the accessibility of domestic fowl to eagles. If prey availability is still high in forest remnants, and if domestic fowl are protected effectively, *S. isidori* could still find available wild prey and keep breeding. However, if native prey are scarce, and if the accessibility of domestic fowl is limited, then the breeding pairs studied could be hampered in their breeding and self-maintenance. If this is the case, then management alternatives such as supplementary feeding of the species, managing the *S. isidori* prey populations or economic compensation for domestic fowl losses to local settlers (see Dickman, Macdonald, & Macdonald, 2011; Kubasiewicz, Bunnefeld, Tulloch, Quine, & Park, 2016) must be examined as potential strategies for mitigating or preventing conflict between people and eagles and to contribute to the effective conservation of *S. isidori*.

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