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CAUSES OF ADMISSION TO A REHABILITATION CENTER FOR ANDEAN CONDORS (*VULTUR GRYPHUS*) IN CHILE

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Abstract.—Causes of admission to rehabilitation centers can provide valuable information about factors that cause mortality in the wild. We studied causes of admission to a rehabilitation center for 108 Andean Condors (*Vultur gryphus*) in Chile. Seventy-nine, 28, and one condor came from central, south, and northern Chile, respectively. From central Chile, an area with high human population, the majority of condors received were adults. The most frequent causes of admission to the rehabilitation center were poisoning (52%) and collisions with power lines (13%). Seventy-two percent of the radiographed birds showed ammunition in their bodies. Almost all the condors (85%) were received during the wintering period, when condors use the lowlands, thus increasing the probability of interaction with humans. The condors admitted from southern Chile, an area with low human pressure, were mainly juveniles. The most frequently admitted birds in the south were young birds that were trapped just after fledging (68%), which made up only 4% of the cases in central Chile. There were no poisonings or collisions with power lines. Only 25% of the radiographed birds were positive for ammunition. No seasonal variation in admissions was observed, indicating that risk factors in the southern zone did not operate on a seasonal basis. The sample of birds admitted from central Chile had similar sex and age structure as the wild population, with some bias toward juveniles, in contrast with the sample from southern Chile, in which young birds dominated. In conclusion, we observed an important anthropogenic effect on causal and temporal patterns of admissions to a rehabilitation center for Andean Condors; for the segment of the population in central Chile, the mortality pressure is apparently higher than expected under natural conditions, which could promote a demographic sink in this region.

Key Words: *Andean Condor*; Vultur gryphus; *Chile*; *mortality*; *rehabilitation center.*

CAUSAS DE INGRESO DE *VULTUR GRYPHUS* A UN CENTRO DE REHABILITACIÓN EN CHILE

Resumen.—Las causas de ingreso a centros de rehabilitación pueden aportar valiosa información sobre los factores de mortalidad de la fauna silvestre. Se determinaron las causas de ingreso de 108 individuos de *Vultur gryphus* a un centro de rehabilitación en Chile. Setenta y nueve individuos provinieron del centro, 28 del sur y uno del norte de Chile. Para el centro de Chile, un área densamente poblada, la mayoría de los cóndores recibidos fueron adultos. Las causas más frecuentes de entrada fueron intoxicaciones (52%) y colisiones con líneas eléctricas (13%). El 72% de las aves radiografiadas presentaron municiones en su cuerpo. Casi todos los cóndores (85%) fueron recibidos durante el invierno, cuando los cóndores usan tierras bajas lo que aumenta la probabilidad de interacción con los humanos. Los cóndores ingresados provenientes del sur de Chile, un área con baja densidad de población humana, fueron mayormente ejemplares juveniles. La causa más frecuente de entrada fue la captura de aves jóvenes luego de abandonar el nido (68%). En el centro de Chile esta causa constituyó solo el 4% de los casos. No hubo intoxicaciones ni colisiones con líneas eléctricas. Sólo el 25% de las aves radiografiadas presentaron municiones en el cuerpo. No se observó una variación estacional en el ingreso al centro de rehabilitación, indicando que los factores de riesgo en la zona sur no estarían operando de forma estacional. La muestra de Chile central tuvo una estructura de sexos y edades parecida a la población silvestre, con algún sesgo hacia los juveniles, en contraste con la muestra del sur en la cual las aves jóvenes fueron dominantes. En conclusión, observamos un importante efecto

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antrópico sobre los patrones causales y temporales de los factores de ingreso de *V. gryphus* a un centro de rehabilitación. En Chile central la presión de mortalidad sería mayor a la esperada en condiciones naturales, lo cual podría dar lugar a una situación de sumidero demográfico en esta región.

[Traducción de los autores editada]

The distribution of the Andean Condor (*Vultur gryphus*), the largest raptor in the world, encompasses the entire range of the Andes Mountains, from Venezuela to Tierra del Fuego, in South America (del Hoyo et al. 1994). Once dependent on the wild camelids that roamed throughout most of the Andes, this carrion-eating species now relies mostly on domestic livestock (Pavez 2004, Lambertucci et al. 2009). In the northern part of its range (Venezuela, Colombia, and Ecuador), the condor is very rare. In Bolivia and Perú, the population is larger, but Chile and Argentina host the largest proportion of the world's population of the species (Fig. 1). According to BirdLife International (2009), the species is globally near-threatened and declining. The Andean Condor has exceptionally low natural mortality and reproductive output, with one of the highest survival rates among birds (Ricklefs 1973) and is therefore very vulnerable to human persecution (Houston 1994). Most known threats to Andean Condors are anthropogenic, and it has been suggested that mortality rates are directly correlated with the frequency of contact with humans (Temple and Wallace 1989). Under the best conditions, condors breed every two years, although this frequency is often lower, depending on the region and food supply (Wallace and Temple 1988, Lambertucci 2007). Furthermore, the first fertile egg-laying does not occur before 8 yr of age (Amadon 1964, del Hoyo et al. 1994). Therefore, given the low and irregular reproductive rate, any increases in the factors that may cause mortality may pose a serious problem for the persistence of Andean Condor populations (Wallace et al. 1983).

Populations of raptors are regulated by both external (environmental) and internal (demographic) factors, which can interact with each other and change across time and space (Newton 1998). Among demographic factors, mortality is likely the most difficult to assess correctly because most deaths are not easily detectable and most recorded cases are associated with human activities (Newton 1980). In addition, raptors dying near centers of human populations are more likely to be detected than those that die in remote areas (McIntyre 2012). This makes it particularly difficult to accurately assess mortality over large areas and long periods of time (Kalpakis et al. 2009).

The study of raptors received in rehabilitation centers can provide important information on the mortality and morbidity sources for their populations (Wendell et al. 2002), helping to identify the natural and anthropogenic risk factors to which they are exposed (Molina-López and Darwich 2011). Admitted animals may come from a wide area and admission data may have been collected over an extended period of time, representing a valuable source of information for the establishment and evaluation of priorities and ecological risks (International Wildlife Rehabilitation Council 2007). The quantitative assessment of these risk factors might allow managers to improve their approaches to the conservation of wildlife and their habitats (Leston et al. 2006, Sullivan et al. 2006), and may help garner support from governments and organizations who value objective information (Johnson et al. 2005, Mishra et al. 2006). Alternative sources of information on mortality, such as radiotelemetry, can be logistically infeasible in a rugged landscape and for species with large home ranges, such as the Andean Condor (De Martino et al. 2011, Lambertucci et al. 2014). Satellite-tracking, on the other hand, is a very effective, but expensive, technique.

Based on a group of Andean Condors admitted to a rehabilitation center, we characterized the main potential mortality sources for the species in two broad geographical regions of Chile, which differed significantly in terms of human influence. Our study is the first to quantitatively determine potential causes of death in the species.

METHODS

Between 1993 and 2014, we recorded all the wild Andean Condors admitted to a rehabilitation center for raptors run by the Chilean Ornithologists' Union and the Ministry of Agriculture, located 35 km SW of Santiago. It is the only rehabilitation center in Chile that specializes in raptors and most, if not all, injured condors treated in the country during the study period were received at this center. All analyzed birds were badly injured or in poor condition

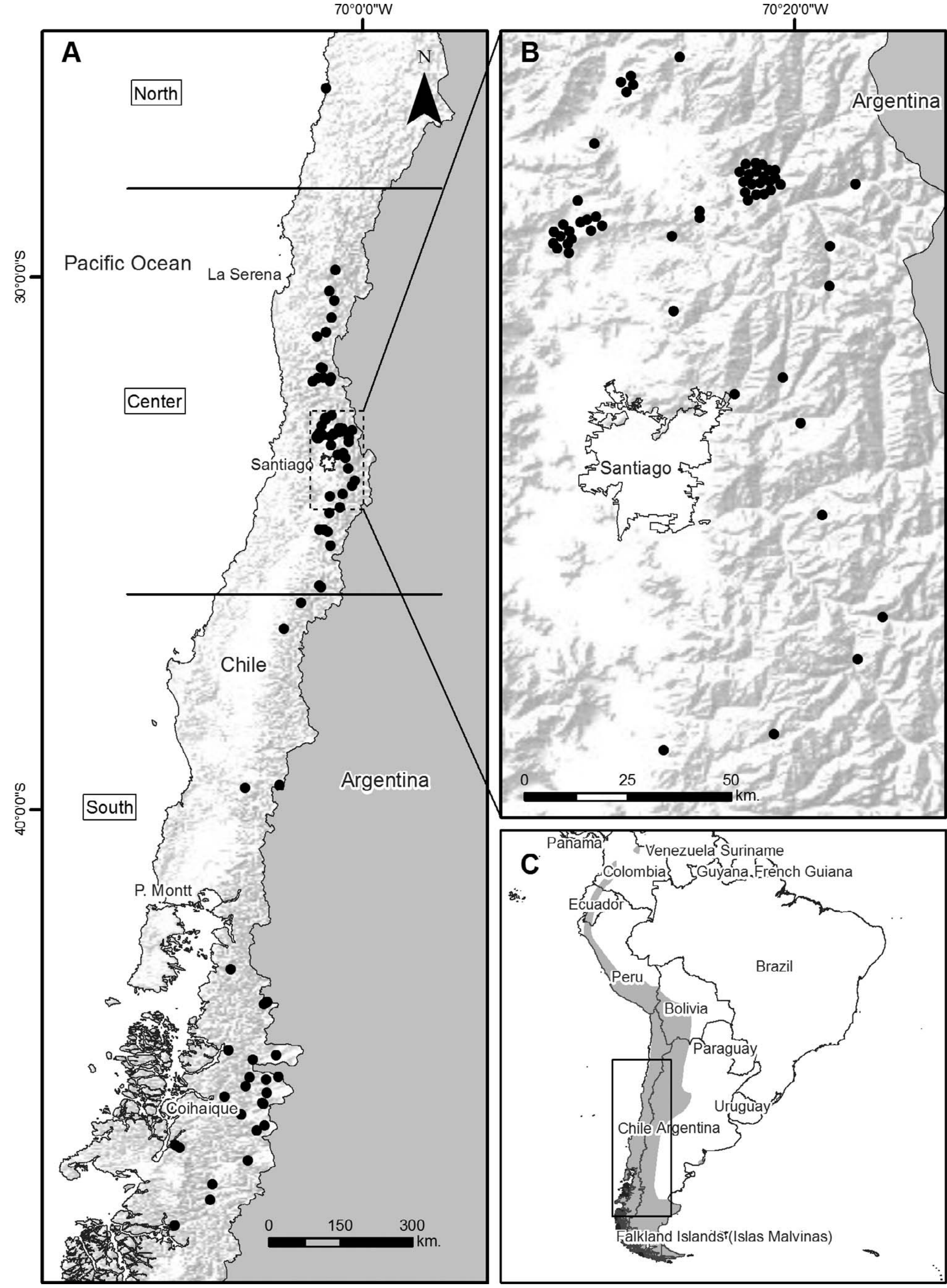

Figure 1. Origin of the condors admitted to the rehabilitation center. The black dots represent the sites of origin of condors. (A) Complete study area, showing the northern, central, and southern regions. (B) Area where a large number of condors were found, including those poisoned in a sanitary landfill (left) and poisoned with bait (center and right). (C) Andean Condor distributional range (gray; adapted from BirdLife International and NatureServe 2014) and the location of the study area (rectangle).

and would have likely died had not they been rescued and treated.

Birds from central (Coquimbo, Valparaiso, Metropolitana, O'Higgins, and Maule regions) and southern Chile (from Biobío region to the southern border) were analyzed separately, as these two regions represent significantly different situations relative to human population density. Central Chile (95 people/km^2, Instituto Nacional de Estadística 2010) contains most of the urban and industrial centers in the country, which are continuously expanding, competing for land with agricultural and cattle ranching. The southern portion is lightly populated (12 people/km^2, Instituto Nacional de Estadística 2010) and is dominated by natural ecosystems, agricultural land, and cattle ranches. Northern Chile (from the northern limit to the Atacama region) was not included in the analysis because only one condor was received from this region during the 22 yr of the study.

All admitted birds were classified to age and sex. Age classes were: juvenile (between 1–4 yr old), subadult (5–6 yr) and adult (7 or more yr old). In addition, the probable cause of admission was determined for all admitted birds. A specialized team of veterinarians from Chile's National Zoo examined each bird and assessed body condition, and possible injuries and their causes. Data on the place and circumstances under which each bird was rescued were also recorded. Twenty-nine birds were X-rayed, particularly those that were thought to have been shot.

Because the proportion of ages and sexes in the wild population could influence the type of individuals admitted for rehabilitation, we compared the ages and sexes of birds received with the proportions of age and sex in a sample of 226 condors observed in the wild in Chile. The latter observations were made from 757 high points with wide visibility (Reynolds et al. 1980), distributed throughout Chile, between 2002 and 2011. At each point, we recorded the number, sex, and age of each condor observed flying during a 10-min period.

We used chi-square and Fisher's exact tests to look for differences in the causes of admission to the rehabilitation center among age classes, sexes, and geographic regions. To conduct pair-wise proportion comparisons for age classes and sexes of birds admitted compared to those in the wild, we built confidence intervals through randomization (Manly 1997). All statistical analyses were performed with the R statistical software (R Development Core Team 2008).

RESULTS

A total of 108 wild Andean Condors were admitted during the study period. Among these birds, one came from northern Chile, 79 came from central Chile and 28 from southern (Fig. 1, Table 1). Twenty-five percent were adult males, 18% were adult females, 3% were subadult males, 2% were subadult females, 26% were juvenile males, and 26% were juvenile females. The main cause of admission was poisoning (38%). These birds were usually unable to fly and lacked coordination. Most of these had been found in four groups (20, 9, 4, and 3 birds) near poisoned carcasses. All poisoning cases were confirmed through laboratory analyses.

Other birds admitted were young birds captured by humans shortly after having left the nest (20%). Minor causes of admission included collisions with power lines (9%), possible starvation (8%), shooting (7%), unspecific trauma (6%), taken from a nest (4%), entanglement (1%), falling into tailings pond (1%), falling into lake (1%), hit by a motor vehicle (1%), and undetermined (3%). Fifty percent of the admitted condors were rehabilitated and released.

Central Chile. Of 79 condors coming from central Chile, most were adult males (33%, n = 26), followed by juvenile females (27%, n = 21), and adult females (22%, n = 17; Table 1). Birds of ages 1 yr, 2 yr, 3 yr, 4 yr, 5 yr, and 6 yr old made up 13%, 16%, 8%, 3%, 1%, 5%, respectively. For both sexes, the number of adult birds admitted was significantly fewer than expected by chance (P = 0.004, Table 2), whereas the juveniles were significantly more frequent ($P < 0.001$, Table 2).

The most frequent causes of admission were poisonings and collisions with power lines. There were also cases in which the only symptoms were extreme weakness and cachexia, suggesting starvation, and seven birds were admitted with evident gunshot wounds (Table 1). Of 25 birds (19 adults and six juveniles, including the above seven) for which X-rays were taken, 18 (72%, 16 adults and two juveniles) had non-ingested ammunition in their bodies, indicating they had been shot at some point during their life. The proportion of adults shot (16/43) by ranchers and/or hunters was significantly higher (Fisher's exact test, $P < 0.0001$) than that of young birds (2/36). Most condors (95%) were found between May and November (Fig. 2), coinciding with the

Table 1. Sex, age, and cause of admission to a rehabilitation center for Andean Condors received from central (Coquimbo to del Maule regions) and southern Chile (Biobío to Aysén regions) at the Chilean Rehabilitation Center for Birds of Prey, 1993–2014.

cause of admission to rehabilitation center	central chile								southern chile							
	adult		subadult		juvenile		total		adult		subadult		juvenile		total	
	male	female	male	female	male	female	*n*	%	male	female	male	female	male	female	*n*	%
Poisoning	15	6	2	2	2	14	41	51.9	0	0	0	0	0	0	0	0
Collision with power line	3	5	0	0	0	2	10	12.7	0	0	0	0	0	0	0	0
Possible starvation	4	2	0	0	0	1	7	8.9	1	1	0	0	0	0	2	7.1
Gunshot wounds	2	3	0	0	1	1	7	8.9	0	0	0	0	1	0	1	3.6
Unspecific trauma	2	0	0	0	2	0	4	5.1	0	0	0	0	1	2	3	10.7
Taken from nest	0	0	0	0	3	0	3	3.8	0	0	0	0	1	0	1	3.6
Captured after leaving nest	0	0	0	0	1	2	3	3.8	0	0	0	0	14	5	19	67.9
Entanglement	0	0	0	0	0	1	1	1.3	0	0	0	0	0	0	0	0
Falling into tailing pond	0	0	0	0	1	0	1	1.3	0	0	0	0	0	0	0	0
Falling into lake	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	3.6
Undetermined	0	1	1	0	0	0	2	2.5	0	1	0	0	0	0	1	3.6
Total	26	17	3	2	10	21	79		1	3	0	0	17	7	28	
%	32.9	21.5	3.8	2.5	12.7	26.6		100	3.6	10.7	0	0	60.7	25		100

wintering period for livestock, with a peak (51%) of cases in August.

Southern Chile. Of 28 condors coming from the southern region, the most common birds were juvenile males (61%, $n = 17$) and juvenile females (25%, $n = 7$; Table 1). Birds 1 yr old, 2 yr old, and adults made up 75% ($n = 21$), 11% ($n = 3$), and 14% ($n = 4$), respectively. As in the central Chile, adults were less frequent than expected ($P < 0.001$, Table 2) and the opposite was true for juveniles (P < 0.001–0.007, Table 2).

The most commonly admitted were young birds that had been captured by humans shortly after having left the nest (68%, $n = 19$). There were also condors with unspecific trauma and symptoms of starvation (Table 1). Of four radiographed birds, only one had ammunition in its body. Condors were admitted from southern Chile from March–December, with no discernible peaks in temporal distribution, likely because of the small sample size (Fig. 2).

Although in both regions the numbers of admitted adults were lower than expected by chance, and the number of juveniles higher, the proportion of adults/nonadults in central Chile (43/36) was significantly higher (chi-square, $P < 0.001$) than that in the south (4/24). The birds admitted from central Chile showed a significantly higher proportion of poisonings than those admitted from southern Chile (52% vs. 0%, chi-square, $P < 0.001$). Although the frequency of collisions with power lines was also higher in central Chile (13% vs. 0%), this difference was not statistically significant (Fisher's exact test, $P = 0.10$). The proportion of radiographed birds with ammunition in their bodies (72% in the central vs. 25% in the south), did not differ statistically (Fisher's exact test, $P = 0.11$), probably because of small sample sizes (25 birds radiographed from central vs. 4 from southern Chile).

Discussion

Reports on wild animals admitted to rehabilitation centers are an important source of information on the threats that wildlife face in modern landscapes (Sleeman and Clark 2003, Mazaris et al. 2008, Molina-López and Darwich 2011). These datasets may include cases distributed over large regions and long periods of time, allowing for comprehensive analyses that are useful for assessing and prioritizing ecological risks (International Wildlife Rehabilitation Council 2007). However, an intrinsic caveat of this type of information is its potential bias toward

Table 2. Number of Andean Condors admitted to the Chilean Rehabilitation Center for Birds of Prey and recorded in observations of flying birds in the wild (Reynolds et al. 1980), by sex and age.

		ADMITTED BIRDS					
		CENTRAL		SOUTH		POPULATION[a]	
SEX	AGE	*n*	*P*[b]	*n*	*P*	*n*	%
Males	Adults	26	0.004 (-)	1	<0.001 (-)	114	50.4
	Subadults	3	0.031 (+)	0	0.779	2	0.9
	Juveniles	10	<0.001 (+)	17	<0.001 (+)	6	2.7
Females	Adults	17	0.004 (-)	3	<0.001 (-)	81	35.8
	Subadults	2	0.148	0	0.613	4	1.8
	Juveniles	21	<0.001 (+)	7	0.007 (+)	19	8.4
Total		79		28		226	100

[a] Obtained from a sample of flying birds.
[b] Significance and sign of deviation from expected number (comparison within lines: admitted birds in each region vs. wild population). Based on confidence intervals built through randomization.

anthropogenic factors, because animals that are directly or indirectly hurt by humans are more likely to be found by people and brought to rehabilitation centers (Newton 1979, 2002, Spalding and Forrester 1993, Real et al. 2001, Molina-López and Darwich 2011). In our study, most Andean Condors came from areas with high population density of both condors and humans (i.e., around the capital, Santiago, Fig. 1). To account for such biases, studies that compare the prevalence of different threat sources in areas with differing amounts of human influence may be particularly useful (Brown and Sleeman 2002).

Our study is the first quantitative characterization of factors causing admission of Andean Condors to rehabilitation centers, and thus of likely causes of mortality for this species. It is based on data collected over a long period of time (22 yr) and over a large proportion of the country's territory, including two areas with contrasting human population densities. Despite potential biases in our data set, we believe

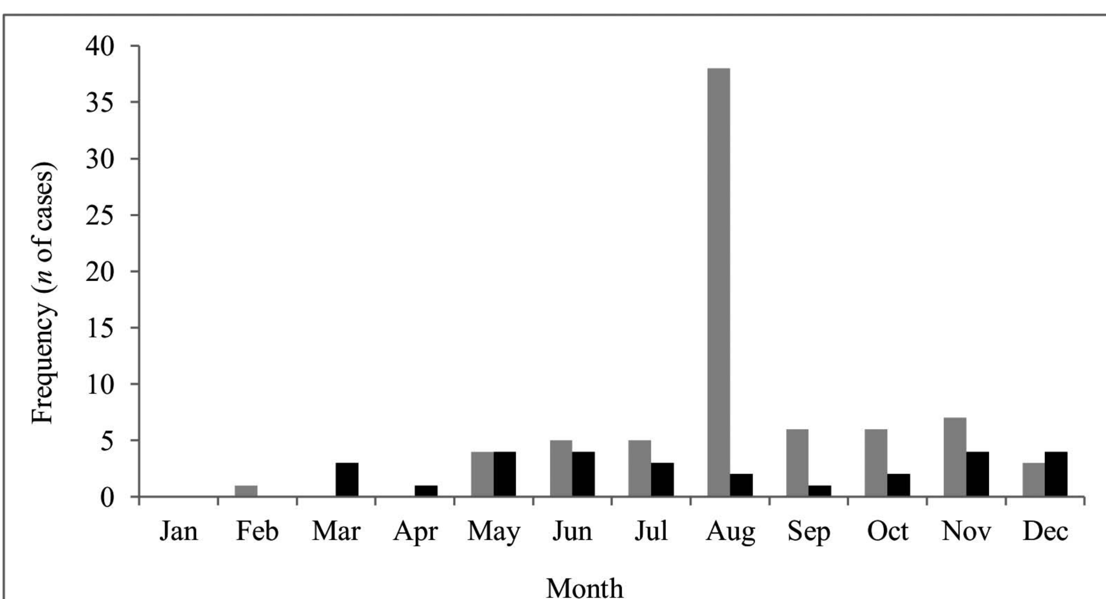

Figure 2. Monthly distribution of admission of condors from central Chile (Coquimbo to Maule regions, gray bars, $n = 79$ cases) and southern Chile (Biobío to Aysén regions, black bars, $n = 28$ cases) to a rehabilitation center, between 1993 and 2014.

that our results give some valuable insight into the threats that these long-lived birds face in Chile.

Almost all mortality sources affecting Andean Condors reported in the literature are more or less related to human activities. Among the most frequently cited are hunting and capture (Castellanos 1923, McGahan 1972), and poisoning with poisoned baits used for predator control (Beltrán 1992, Cuesta 2000, Ferguson-Lees and Christie 2001, Lambertucci 2007) or lead ammunition (Locke et al. 1969, Cuesta 2000, Lambertucci et al. 2011). Accidents are usually associated with collisions with power lines (Pavez 2001) or collisions with vehicles when condors use roads to feed on road-killed animals (Cuesta 2000, Speziale et al. 2008), as was the case with the single condor received from northern Chile. Finally, there are risks associated with the use of certain anti-inflammatory drugs in cattle that might be passed to condors and other carrion-eating birds (Oaks et al. 2004). Our results also point to a strong effect of anthropogenic factors on the mortality of Andean Condors in central Chile, with poisonings and collisions with power lines causing most cases of condors being admitted to rehabilitation centers (>65%).

Condor poisonings in central Chile occur in two contexts. First, birds can accidentally ingest poisoned carcasses (usually sheep or goats) placed in the field by ranchers mainly to control feral dogs, particularly during the calving season for cattle (Ministerio de Agricultura 2010). In our study, 28 condors were poisoned in this way (making up 35% of all cases from central Chile). The second way condors may be poisoned is by ingesting toxic products in landfills. We found nine condors in August 2005, three in October 2009, and one in July 2014, with signs of organophosphate poisoning after feeding in a landfill located north of Santiago de Chile (E. Pavez unpubl. data). The fact that all these poisonings seemed to be with similar products suggests that the condors may have eaten baits laced with organophosphate-based products purposely deployed to kill scavengers at the landfill, although this activity is illegal in Chile because all the birds of prey are protected by law.

Collision with power lines was a common cause of injuries for condors in central Chile (13% of cases), likely associated with the high concentration of people and density of power lines in this region, with more than 480 km of high-voltage power lines in mountainous areas frequented by condors (Pavez 2012). The rapid development of new mining and hydropower projects in the Andean region of central Chile suggests that the importance of this type of threat may increase in the near future in this region.

Most admittance of birds from central Chile occurred during the cold season (Fig. 2), when condors move to the lowlands (Pavez 2012) and, therefore, are more exposed to people and infrastructure (Pennycuick and Scholey 1984, Mundy et al. 1992). For southern Chile, there was no temporal concentration of cases (Fig. 2), and neither were there cases of poisoning or collisions with power lines (Table 1), the two most important factors for central Chile.

Although not all birds were radiographed, we found that at least 22.8% (18/79) of the birds from the central part of the country had been shot. This is likely due to the old and deep-rooted belief among many ranchers that condors are a threat for their livestock. This myth was assumed true even by some early naturalists in the 19th century who depicted condors attacking cattle calves (Gay 1854).

Under natural conditions, the mortality rate of Andean Condors is extremely low, and lower in adults than juveniles. A study from Peru reported estimated annual mortality rates of 40% and 25% for nestlings and 1-yr-old birds, respectively, and 5% for adults (Temple and Wallace 1989). A theoretically stable population of California Condors had 15% annual mortality among 2-yr-old birds and only 5–7% in adults (Verner 1978, Meretsky et al. 2000). During the most critical period for the California Condor (1982–1985), human-caused mortality rate reached 27% for adults and 22% for juveniles, suggesting age-independence of mortality factors of human origin (Meretsky et al. 2000). This point is relevant to our study, considering the differences in human influence between central and southern Chile. In the south, condors arriving at rehabilitation centers were juveniles, and the majority of these were <1 yr old. In most of these cases, people found the recently fledged birds, thinking that they were injured. Like other vultures, condor fledglings may fall to the ground and stay there several days without regaining a higher position. During this time, the parent birds feed them normally, but they are extremely vulnerable to predation and other threats.

Compared to the proportions of different age classes in the wild, juvenile condors in central and southern Chile were admitted more frequently than adults in the rehabilitation center (Table 2). However, in the central part of the country, the percentage of adults was significantly higher than that of the south, suggesting that in central Chile, condor admission causes probably represent more age-independent factors (e.g., hunting, poisoning, collisions with power lines, etc.), which tend to affect adults and juveniles equally.

Female condors are behaviorally subordinate to males (Donázar et al. 1999, Donázar and Feijóo 2002), suggesting that they may be forced to forage further into anthropic landscapes, thus reducing their survival. This seems to be confirmed by several researchers who have observed that Andean Condor populations of Chile (Sarno et al. 2000), Argentina (Donázar et al. 1999, Feijóo 1999, Alcaide et al. 2010, Lambertucci et al. 2012), and Bolivia (Ríos-Uzeda and Wallace 2007) have a greater proportion of males at older ages, implying a higher mortality rate among females (Lambertucci et al. 2012). Our results, however, did not support this hypothesis, as admittances of adult males did not differ from those of females when compared to the proportion of sexes in the wild (27/114 vs. 20/81, chi-square, $P = 0.89$, Table 2).

Although we do not have information regarding absolute mortality rates, the strong predominance of anthropogenic, age-independent threat factors in central Chile suggests that this population may have higher mortality rates than what would be expected under natural conditions. In long-lived species, high mortality among adults may have catastrophic effects, as these species are especially sensitive to adult losses (Saether and Bakke 2000, García-Ripollés and López-López 2011), due to an additional negative effect on reproduction. More research is needed to understand whether these factors imply additive or compensatory mortality (Longcore and Smith 2013), and the extent to which they might be creating a demographic sink (Pulliam 1988) for Andean Condors in central Chile, a population that represents >20% of the total population in the country (Pavez 2012). Our results showed that causes of admission to a rehabilitation center with anthropogenic origin seem to be common in central Chile, and include deliberate and accidental persecution, as well as collisions with human-made infrastructures. Although we do not yet have unbiased estimates of the real effect of these factors, we recommend that immediate action should be taken to reduce the negative perception of ranchers toward condors and to reduce the exposure of these birds to toxic baits. Although not quantified, evidence suggests that power lines are an important threat to condors and, therefore, corrective measures should be explored to reduce such a risk. Failure to do so may be catastrophic for the Andean Condor population in central Chile.

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LITERATURE CITED

ALCAIDE, M., L. CADAHÍA, S.A. LAMBERTUCCI, AND J.J. NEGRO. 2010. Noninvasive estimation of minimum population sizes and variability of the major histocompatibility complex in the Andean Condor. *Condor* 112:470–478.

AMADON, D. 1964. The evolution of low reproductive rates in birds. *Evolution* 18:105–110.

BELTRÁN, J. 1992. Proyecto Cóndor: antecedentes, resultados y conclusiones. Boletín Técnico 7, Fundación de Vida Silvestre Argentina, Buenos Aires, Argentina.

BIRDLIFE INTERNATIONAL. 2009. Species factsheet: *Vultur gryphus*. http://www.birdlife.org/datazone/speciesfactsheet.php?id=3822 (last accessed 11 September 2014).

BIRDLIFE INTERNATIONAL AND NATURESERVE. 2014. Bird species distribution maps of the world. 2012. *Vultur gryphus*. The IUCN Red List of threatened species. Version 2015.2. http://maps.iucnredlist.org/map.html?id=22697641 (last accessed 6 October 2015).

BROWN, J.D. AND J.M. SLEEMAN. 2002. Morbidity and mortality of reptiles admitted to the wildlife center of Virginia, 1991 to 2000. *Journal of Wildlife Diseases* 38:699–705.

CASTELLANOS, A. 1923. Cómo cazan los cóndores *Vultur gryphus* (Linnaeus). *Hornero* 3:89–90.

CUESTA, M.R. 2000. Memorias de la primera reunión internacional de especialista en cóndor andino (*Vultur gryphus*). WWF and Fundación Bioandina, Mérida, Venezuela.

DEL HOYO, J., A. ELLIOTT, AND J. SARGATAL [EDS.]. 1994. Handbook of the birds of the world. Vol. 2. New World Vultures to Guineafowl. Lynx Edicions, Barcelona, Spain.

DE MARTINO, E., V. ASTORE, M. MENA, AND L. JACOME. 2011. Estacionalidad en el home range y desplazamiento de un ejemplar de cóndor andino (*Vultur gryphus*) en Santa Cruz, Argentina. *Ornitología Neotropical* 22:161–172.

DONÁZAR, J.A. AND J. FEIJÓO. 2002. Social structure of Andean Condor roosts: influence of sex, age and season. *Condor* 104:832–837.

DONÁZAR, J., A. TRAVAINI, O. CEBALLOS, A. RODRÍGUEZ, M. DELIBES, AND F. HIRALDO. 1999. Effect of sex-associated competitive asymmetries on foraging group structure and despotic distribution in Andean Condors. *Behavioral Ecology and Sociobiology* 45:55–67.

FEIJÓO, J. 1999. Primer censo de cóndores para la Quebrada del Condorito. *Registro Nacional del Cóndor Andino, Zoológico de Buenos Aires* 7:18–25.

FERGUSON-LEES, J. AND D.A. CHRISTIE. 2001. Raptors of the world. Christopher Helm, London, U.K.

GARCÍA-RIPOLLÉS, C. AND P. LÓPEZ-LÓPEZ. 2011. Integrating effects of supplementary feeding, poisoning, pollutant ingestion and wind farms of two vulture species in Spain using a population viability analysis. *Journal of Ornithology* 152:879–888.

GAY, C. 1854. Atlas de la historia física y política de Chile. Imprenta de E. Thunot, Paris, France.

HOUSTON, D.C. 1994. Cathartidae (New World vultures). Pages 24–41 *in* J. del Hoyo, A. Elliott and J. Sargatal [EDS.], Handbook of the birds of the world. Lynx Edicions, Barcelona, Spain.

INSTITUTO NACIONAL DE ESTADÍSTICA. 2010. Compendio estadístico 2010. Chile. http://www.ine.cl/canales/menu/publicaciones/compendio_estadistico/pdf/2010/1.2estdemograficas.pdf (last accessed 1 September 2014).

INTERNATIONAL WILDLIFE REHABILITATION COUNCIL. 2007. Conserving and protecting wildlife and habitat through wildlife rehabilitation. http://www.iwrc-online.org (last accessed 1 February 2013).

JOHNSON, A., S. SINGH, M. DUANGDALA, AND M. HEDEMARK. 2005. The western black crested gibbon *Nomascus concolor* in Laos: new records and conservation status. *Oryx* 39:311–317.

KALPAKIS, S., A.D. MAZARIS, Y. MAMAKIS, AND Y. POULOPOULOS. 2009. A retrospective study of mortality and morbidity factors for Common Buzzards *Buteo buteo* and Long-legged Buzzards *Buteo rufinus* in Greece: 1996–2005. *Bird Conservation International* 19:15–21.

LAMBERTUCCI, S.A. 2007. Biología y conservación del cóndor andino (*Vultur gryphus*) en Argentina. *Hornero* 22: 149–158.

———, P.A.E. ALARCÓN, F. HIRALDO, J.A. SANCHEZ-ZAPATAD, G. BLANCO, AND J.A. DONÁZAR. 2014. Apex scavenger movements call for transboundary conservation policies. *Biological Conservation* 170:145–150.

———, M. CARRETE, J.A. DONÁZAR, AND F. HIRALDO. 2012. Large-scale age-dependent skewed sex ratio in a sexually dimorphic avian scavenger. *PLoS ONE* 7(9):e46347. http://www.plosone.org/article/info%3Adoi%2F10.1371%2Fjournal.pone.0046347 (last accessed 1 April 2014).

———, J.A. DONÁZAR, A. DELGADO HUERTAS, B. JIMÉNEZ, M. SÁEZ, J.A. SANCHEZ-ZAPATA, AND F. HIRALDO. 2011. Widening the problem of lead poisoning to a South American top scavenger: lead concentrations in feathers of wild Andean Condors. *Biological Conservation* 144:1464–1471.

———, A. TREJO, S. DI MARTINO, J.A. SÁNCHEZ-ZAPATA, J.A. DONÁZAR, AND F. HIRALDO. 2009. Spatial and temporal patterns in the diet of the Andean Condor: ecological replacement of native fauna by exotic species. *Animal Conservation* 12:338–345.

LESTON, F.V.J., D. AMANDA, AND D.A. RODEWALD. 2006. Are urban forests ecological traps for understory birds? An examination using Northern Cardinals. *Biological Conservation* 131:566–574.

LOCKE, L.N., G.E. BAGLEY, D.N. FRICKIE, AND L.T. YOUNG. 1969. Lead poisoning and aspergillosis in an Andean Condor. *Journal of the American Veterinary Medical Association* 155:1052–1056.

LONGCORE, T. AND P.A. SMITH. 2013. On avian mortality associated with human activities. *Avian Conservation and Ecology* 8(2):1. http://dx.doi.org/10.5751/ACE-00606-080201 (last accessed 27 September 2015).

MANLY, B.F.J. 1997. Randomization, boot-strap and Monte Carlo methods in biology, Second Ed. Chapman and Hall/CRC, London, U.K.

MAZARIS, D.A., Y. MAMAKIS, S. KALPAKIS, Y. POULOPOULOS, AND G.Y. MATSINOS. 2008. Evaluating potential threats for birds in Greece: an analysis of a 10 year data set on injured birds. *Oryx* 42:1–7.

MCGAHAN, J. 1972. Behavior and ecology of the Andean Condor. Ph.D. thesis, Univ. Wisconsin, Madison, WI U.S.A.

MCINTYRE, C.L. 2012. Quantifying sources of mortality and winter ranges of Golden Eagles from interior Alaska using banding and satellite tracking. *Journal of Raptor Research* 46:129–134.

MERETSKY, V., N. ZINDER, S. BEISSINGER, D. CLENDENEN, AND J. WILEY. 2000. Demography of the California Condor: implications for reestablishment. *Conservation Biology* 14:957–967.

MINISTERIO DE AGRICULTURA. 2010. Manejo de ganado caprino-ovino en situación de déficit hídrico. http://www.minagri.gob.cl/wp-content/uploads/2013/02/02.pdf (last accessed 1 September 2014).

MISHRA, C., M.D. MADHUSUDAN, AND A. DATTA. 2006. Mammals of the high altitudes of western Arunachal Pradesh, eastern Himalaya: an assessment of threats and conservation needs. *Oryx* 40:29–35.

MOLINA-LÓPEZ, R.A. AND L. DARWICH. 2011. Causes of admission of Little Owl (*Athene noctua*) at a wildlife rehabilitation centre in Catalonia (Spain) from 1995 to 2010. *Animal Biodiversity and Conservation* 34:401–405.

MUNDY, P.J., J.A. LEDGER, AND R. FRIEDMAN. 1992. The vultures of Africa. Academic Press, London, U.K.

NEWTON, I. 1979. Population ecology of raptors. T. and A.D. Poyser Ltd., Berkhamsted, U.K.

———. 1980. Mortality factors in wild populations-chairman's introduction. Page 141 *in* J.E. Cooper and A.G. Greenwood [EDS.], Recent advances in the study of raptor diseases. Chiron, Keighley, West Yorkshire, U.K.

———. 1998. Population limitation in birds. Academic Press, London, U.K.

———. 2002. Diseases in wild (free–living) raptors. Pages 217–234 *in* J.E. Cooper [ED.], Birds of prey: health and disease, Third Ed. Blackwell Science Ltd., Oxford, U.K.

OAKS, J.L., M. GILBERT, M. VIRANI, R.T. WATSON, C.U. METEYER, B.A. RIDEOUT, H.L. SHIVAPRASAD, S. AHMED,

M.J. CHAUDHRY, M. ARSHAD, S. MAHMOOD, A. ALI, AND A. KHAN. 2004. Diclofenac residues as the cause of vulture population decline in Pakistan. *Nature* 427:630–633.

PAVEZ, E.F. 2001. El cóndor andino (*Vultur gryphus*): conservación y nuevas fuentes de alimentación. Recuadro 13.3. Page 409 *in* R. Primack, R. Rozzi, P. Feinsinger, R. Dirso, and F. Massardo [EDS.], Conservación biológica. Fondo de Cultura Económica, Ciudad de México, México.

———. 2004. Descripción de las rapaces chilenas. Pages 29–103 *in* A. Muñoz-Pedreros, J. Rau, and J. Yánez [EDS.], Aves rapaces de Chile. Centro de Estudios Agrarios y Ambientales (CEA), Valdivia, Chile.

———. 2012. Ecología y estado de conservación del cóndor andino (*Vultur gryphus*) en Chile. Ph.D. dissertation, Universidad de Chile, Santiago, Chile.

PENNYCUICK, C.J. AND K.D. SCHOLEY. 1984. Flight behaviour of Andean Condors (*Vultur gryphus*) and Turkey Vultures (*Cathartes aura*) around the Paracas peninsula, Peru. *Ibis* 126:253–256.

PULLIAM, H.R. 1988. Sources, sinks, and population regulation. *American Naturalist* 132:652–661.

R DEVELOPMENT CORE TEAM. 2008. R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. http://www.R-project.org (last accessed 27 September 2015).

REAL, J., J.M. GRANDE, S. MAÑOSA, AND J.A. SÁNCHEZ-ZAPATA. 2001. Causes of death in different areas for Bonelli's Eagle *Hieraetus fasciatus* in Spain. *Bird Study* 48:221–228.

REYNOLDS, R.T., J.M. SCOTT, AND R.A. NUSSBAUM. 1980. A variable circular plot-method for estimating bird numbers. *Condor* 82:309–313.

RICKLEFS, R. 1973. Fecundity, mortality, and avian demography. Pages 366–447 *in* D.S. Farner [ED.], Breeding biology of birds. National Academy of Sciences, Washington, DC U.S.A.

RÍOS-UZEDA, B. AND R.B. WALLACE. 2007. Estimating the size of the Andean Condor population in the Apolobamba Mountains of Bolivia. *Journal of Field Ornithology* 78:170–175.

SARNO, R., W. FRANKLIN, AND W. PREXL. 2000. Activity and population characteristics of Andean Condor in southern Chile. *Revista Chilena de Historia Natural* 73:3–8.

SAETHER, B.E. AND O. BAKKE. 2000. Avian life history variation and contribution of demographic traits to the population growth rate. *Ecology* 81:642–653.

SLEEMAN, J.M. AND E.C. CLARK. 2003. Clinical wildlife medicine. *Journal of Avian Medicine and Surgery* 17:33–37.

SPALDING, M.G. AND J.D. FORRESTER. 1993. Disease monitoring of free-ranging and released wildlife. *Journal of Zoo and Wildlife Medicine* 24:271–280.

SPEZIALE, K.L., S.A. LAMBERTUCCI, AND O. OLSSON. 2008. Disturbance from roads negatively affects Andean Condor habitat use. *Biological Conservation* 141:1765–1772.

SULLIVAN, J.B., A.T. REID, AND L. BUGONI. 2006. Seabird mortality on factory trawlers in the Falkland Islands and beyond. *Biological Conservation* 131:495–504.

TEMPLE, S. AND M. WALLACE. 1989. Survivorship patterns in a population of Andean Condor *Vultur gryphus*. Pages 247–251 *in* B.-U. Meyburg and R.D. Chancellor [EDS.], Raptors in the modern world. World Working Group on Birds of Prey and Owls, Berlin, Germany and London, U.K.

VERNER, J. 1978. California Condors: status of the recovery effort. U.S.D.A. Forest Service Gen. Tech. Rep. PSW-28, Washington, DC U.S.A.

WALLACE, M.P. AND S.A. TEMPLE. 1988. Impacts of the 1982–1983 El Niño on population dynamics of Andean Condors in Peru. *Biotropica* 20:144–150.

WALLACE, M., S. TEMPLE, AND T. TORRES. 1983. Ecología del cóndor andino (*Vultur gryphus*) en el norte del Perú. Pages 69–76 *in* F.G. Stiles and P. Aguilar [EDS.], I Simposio de Ornitología Neotropical, IX Congreso Latino-
americano de Zoología (Arequipa, Perú). Lima, Perú.

WENDELL, D.M., J.M. SLEEMAN, AND G. KRATZ. 2002. Retrospective study of morbidity and mortality of raptors admitted to Colorado State University Veterinary Teaching Hospital during 1995 to 1998. *Journal of Wildlife Diseases* 38:101–106.

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