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EVIDENCE OF HIGH CONSUMPTION OF WASTE BY THE ANDEAN CONDOR (*VULTUR GRYPHUS*) IN AN ANTHROPIZED ENVIRONMENT OF CHILE

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Abstract · Anthropogenic food subsidies and waste disposals have become a new food resource for wildlife, including the Andean Condor (*Vultur gryphus*), a situation that implies benefits and health risks. To increase understanding of Andean Condor feeding habits in the most anthropized area in Chile, we analyzed 280 pellets collected during 2016 from one roost in the Metropolitan Region, central Chile. We identified the main diagnostic elements microscopically and expressed them as percentage of occurrence (percentage of each item in relation to all pellets). We found 12 prey categories (including mammals, birds, and plant material) and 9 waste categories. Condors fed mainly on mammals (99%); livestock was their main feeding source (52%), followed by native (22%) and exotic wild species (19%). Birds were detected less frequently (8%). We found a high occurrence of waste (31%), of which plastic remains were the main item (27%). According to our results, landfills serve as a complementary food source for condors, probably a low-quality but easily accessible, and which exposes them to a variety of health and mortality risks. Despite the fact that Andean Condors can reach distant places in foraging flights to find food resources, a high proportion of the population is attracted to rubbish dumps and landfills. Despite the spatio-temporal limitations of our results, this is the first record that describes and quantifies a high presence of waste as a component of the Andean Condor diet. We recommend a more comprehensive study to assess their feeding habits and habitat preferences in a broader spatio-temporal context, and to determine the possible impact of the use of waste disposals on Andean Condor populations.

Resumen · Evidencia de alto consumo de basura por el Cóndor Andino (*Vultur gryphus*) en un ambiente antropizado de Chile

Los subsidios antropogénicos y sitios de disposición de basura se han convertido en una nueva fuente de alimentación para la fauna, incluido el Cóndor Andino (*Vultur gryphus*), lo que implica beneficios y riesgos. Con el fin de estudiar los hábitos alimenticios del cóndor andino en un área altamente antropizada, analizamos 280 egagrópilas colectadas durante 2016 en un dormidero de la Región Metropolitana, en Chile central. Identificamos microscópicamente los principales elementos diagnósticos y los expresamos como porcentaje de ocurrencia (porcentaje de cada ítem respecto del total de pellet). Encontramos 12 ítems dietarios (incluyendo mamíferos, aves y materia vegetal) y 9 ítems de basura. Los cóndores se alimentaron principalmente de mamíferos (99%); el ganado fue la principal fuente de alimento (52%), seguido por especies silvestres nativas (22%) y exóticas (19%), mientras que las aves estuvieron escasamente representadas (8%). Encontramos una alta ocurrencia de basura (31%), de la cual los restos de plástico fueron el principal ítem (27%). De acuerdo a nuestros resultados, los basurales sirven como una fuente complementaria de alimentación para los cóndores, probablemente de baja calidad, pero de fácil acceso, y que los expone a una variedad de riesgos de mortalidad y para su salud. Aunque el Cóndor Andino puede alcanzar lugares distantes en sus vuelos de forrajeo, una alta proporción de su población es atraída a vertederos y rellenos sanitaros. A pesar de las limitaciones espacio-temporales de nuestros resultados, esto es el primer registro que describe y cuantifica la alta presencia de basura como componente de la [illegible] ias de hábitat en un contexto espacial y temporal amplio y poder determinar el posible impacto del uso de basurales en poblaciones de Cóndor Andino.

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Key words: Andean Condor · Feeding strategies · Food subsidies · Scavengers

INTRODUCTION

Vultures, including condors, are obligate scavengers that provide an array of ecological, economic, and cultural services (Ogada et al. 2012). Currently, 52% of vulture species worldwide are threatened with extinction and 65% of vulture populations are decreasing (BirdLife International 2017) as a consequence of poisoning and human persecution (Ogada et al. 2012). However, human activities can also alter the availability and quality of food resources for scavengers, promoting less obvious effects on populations and communities (Cortés-Avizanda et al. 2016). Indeed, the lack of food due to overhunting or changes in livestock

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husbandry has contributed to large-scale declines in Old World vultures (Liberatori & Penteriani 2001, Thiollay 2007, Hla et al. 2011).

Recently, predictable anthropogenic food sources such as supplementary feeding stations, carcass dumps and protected areas for the feeding of scavengers, have become effective and important tools for conservation and reintroduction of avian scavengers in Europe (Donázar et al. 2009, Cortés-Avizanda et al. 2016). Unintentional predictable anthropogenic food sources in the form of waste disposals, rubbish dumps and landfills (Olea & Baglione 2017, Tauler-Ametller et al. 2017), have also become a new feeding source for wildlife, and specifically for vultures (Pavez 2012, Plaza & Lambertucci 2017, Tauler-Ametller et al. 2017). However, this potentially valuable food source (Oro et al. 2013) can also produce direct and indirect detrimental effects on individual's health (Blanco et al. 2017a, 2017b; Pitarch et al. 2017, Plaza & Lambertucci 2017, Blanco 2018). This is particularly concerning as the gregarious feeding strategies of vultures make them more vulnerable than other carnivores to environmental disturbances and massive loss of individuals, as a large number of birds can be affected by a single food item. Indeed, dramatic population declines of vulture species in the Asian subcontinent occurred due to ingestion of diclofenac residues from carcasses (Houston 1996, Shultz et al. 2004, Lambertucci & Speziale 2009, Ogada et al. 2012).

The Andean Condor, *Vultur gryphus* (Linnaeus, 1758) (Falconiformes: Cathartidae), the largest obligate terrestrial scavenging bird, inhabits the Andean range from Venezuela to Cabo de Hornos (del Hoyo et al. 1994, Lambertucci 2007). Globally, it is considered a Near-threatened and decreasing species (BirdLife International 2017). Populations have been critically reduced in the northern part of their range, while southern populations are considered healthier, but still show signs of retraction (Lambertucci 2007, BirdLife International 2017). The population in Chile has declined due to persecution and a decline in food resources, except in the southernmost tip of the country where it may be stable (Jaksic & Jimenez 1986). In the Metropolitan Region (central Chile), the Andean Condor population is declining due to habitat loss, hunting, and reduction in food resources (Jaksic et al. 2001).

Like other vulture species worldwide, the Andean Condor has had to modify its feeding habits and adapt to a changing environment; some of these changes potentially involve an increase in population threats (Houston et al. 2007). More than a hundred years ago in Patagonia (southern distribution range), Andean Condors used to feed from marine-derived prey near the coast (Lambertucci et al. 2018) and almost exclusively from native prey (guanacos and Lesser Rheas) further inland (Lambertucci et al. 2009b). At present, Andean Condors feed mainly on domestic and wild exotic species in rural environments (Lambertucci et al. 2009b, 2011). They are very sensitive to urbanization (Speziale et al. 2008, Lambertucci et al. 2009a) and tend to occur far from human occupied areas (Speziale et al. 2008), but waste products associated with human populations have become a new food source (Pavez 2012). This type of feeding behavior increases their exposure to threats, such as toxic baits (del Hoyo et al. 1994), lead pellets (Lambertucci et al. 2011), pesticides (Rideout et al. 2012), and collisions with anthropic structures (Martínez-Abraín et al. 2012, Sanz-Aguilar et al. 2015, Péron et al. 2017). Poisoning and collisions with power lines were the two most frequent causes of condor admittance into a rehabilitation center in Chile (Pavez & Estades 2016), suggesting that this feeding behavior can be an important risk factor for the Andean Condor population.

In this article, we aimed to study Andean Condor feeding behavior in an area under extensive anthropization and to determine the relevance of waste consumption. To achieve this purpose, we analyzed 280 pellets from the main roost near Santiago in central Chile, determined quantitatively the diet composition, and identified potential health and mortality risks for Andean Condors due to waste consumption.

METHODS

Study area. The study area is in the Metropolitan Region of central Chile (Figure 1), which concentrates about 6.5 million people in an area of 15,800 km^2 and harbors an important population of the Andean Condor (Pavez 2012). The area belongs to the Mediterranean biome, with a semiarid climate. Winters are cool and slightly rainy, and summers are warm and dry. The original vegetation was cleared for agriculture and livestock activity, but, as the human population has grown, prime agricultural and livestock lands have been absorbed by encroaching industrial and urban development (Hajek et al. 1990, Gross & Hajek 1998).

The study site is located at the northwest of the Metropolitan Region and consists of a biogeographic unit characterized by an intermediate depression between the coastal and Andean mountain ranges, with transversal mountain ranges that allow condors to travel easily in their seasonal movements. This site has been used for over 20 years as an industrial site (mainly mining waste deposits and landfills), and is surrounded by primarily rural areas with agricultural and small-scale livestock activity. Native herbivores have historically declined and disappeared from the area (Torres 1985, Franklin et al. 1997).

The pellet collection site consisted of one communal roost, which is, to our knowledge, the largest Andean Condor roosting place established in central Chile (1200 m a.s.l., Figure 1). It is a small and isolated hill of approximately 1 km^2 and 500 m elevation, with rocky cliff edges. It is about 50 km north of Santiago, the main city and capital of Chile, and 4 km from the nearest rubbish dump. The site is mainly a winter roost (from May to October) where up to 100 individuals gather every night to rest (EFP pers. obs.).

Collection and analysis of pellets. We collected 280 non-fragmented Andean Condor pellets during two visits to the roost, in early August and late September 2016 (Austral winter). To avoid disturbing the individuals at the roost, we visited the site between 12:00 and 16:00 h, which is the moment when condors are mostly in foraging flights. Considering a high persistence of pellets in protected environments such as roost places (Marti et al. 2007), we selected old and new pellets based on external features (i.e., level of disaggregation and compaction of the content, presence of substrate incrustations, fungi, lichens, insects, among others) to cover a wider period of time (one year proximately, because winter rains tend to disaggregate them).

We dried all pellets at room temperature in the laboratory for one week. Then we mechanically disaggregated them

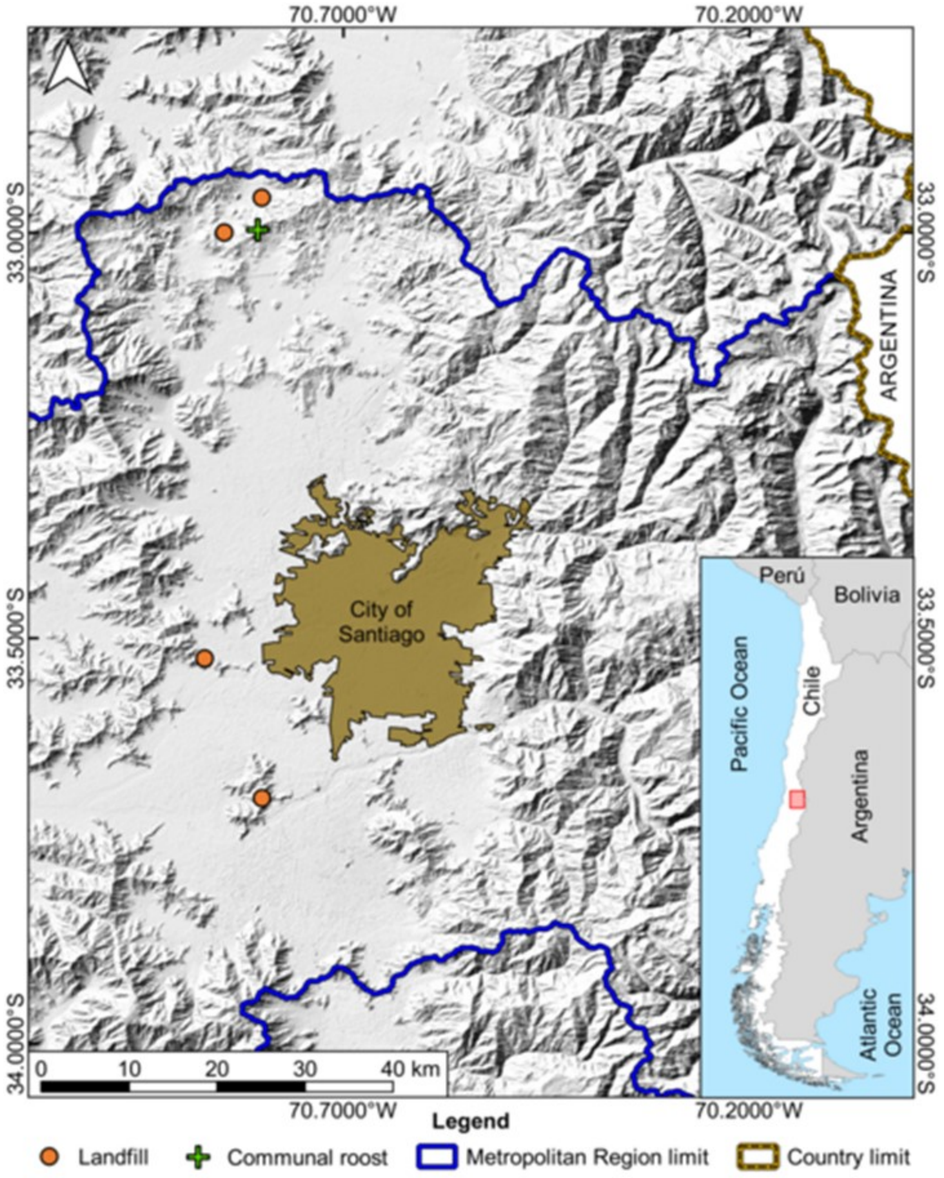

Figure 1. Study area. Location of the Andean Condor (*Vultur gryphus*) communal roost (green cross) and landfills in the surrounding areas (orange dots) in the Metropolitan Region (blue perimeter line) of central Chile.

using tweezers to separate the main diagnostic elements considered in this study: mammal hair, bird feathers, plant materials, and waste. We identified prey items microscopically (Nikon Model Eclipse E200) following techniques and keys described by Chehébar & Martin (1989). We followed laboratory techniques described by Wolfe & Long (1997) to distinguish the two introduced species of lagomorphs: European rabbit (*Oryctolagus cuniculus*) and European hare (*Lepus europaeus*). We observed feather barbs and nodes microscopically, following the techniques described by Day (1966) and Peterson (2010). We grouped prey items/elements in four categories: (i) mammals at species level, (ii) birds at order level, (iii) plant material, and (iv) waste and debris.

We eliminated feathers identified as order Falconiformes from the analysis, because they were probably condor feathers ingested during grooming and not as prey item. Given that it is not possible to determine if condors consumed completely the prey, we did not consider the prey biomass nor digestibility of prey items.

Results are presented as (i) frequency of items (n): number of times each item occurs in relation to total number of items in all pellets; (ii) percentage of total items (PI %): percentage of occurrence of each item in relation to the total number of items in all pellets; and (iii) percentage of occurrence over total pellets (PO %): percentage of each item in relation to the total number of pellets. All subsequent results will be expressed as a percentage of occurrence (iii).

To obtain the number of pellets required to accurately estimate the diet of condors, we constructed a sample-based rarefaction curve calculating $Chao_2$ and S_{Mean} richness estimator (Chao 1987), derived from 100 bootstrap randomizations and performed by Estimates 9.1.0 software (Colwell 2013), obtaining a sampling efficiency of 72.23%.

RESULTS

We identified 514 items in 280 pellets, and the number of items per pellet varied between 1 and 8 (mean = 1.7, SD = 1.1). We found 12 prey and 9 anthropogenic items in the pellets, which we classified within four trophic categories: mammals, birds, plant material, and a variety of wastes of human origin (Table 1). Overall, 81% of all pellet analyzed contained one or two items (61% and 19% respectively), and

Table 1. Frequency of items (n), percentage of total items (PI%), and percentage of occurrence of total pellet (PO%) of trophic and anthropogenic items found in Andean Condor (*Vultur gryphus*) pellets in one roost of the Metropolitan Region of Chile.

Items	**(n)**	**(PI%)**	**(PO%)**
Mammals			
Lama guanicoe	62	12	22
Capra aegagrus hircus	55	11	20
Equus ferus caballus	50	10	18
Ovis orientalis aries	27	5	10
Oryctolagus cuniculus	24	5	9
Lepus europaeus	17	3	6
Bos taurus	12	2	4
Unidentified mammals	35	7	13
Unidentified lagomorphs	11	2	4
Subtotal pellets with mammals	276	54	99
Birds			
Pelecaniformes	9	2	3
Charadriiformes	6	1	2
Unidentified birds	6	1	2
Subtotal pellets with birds	21	4	8
Plant material			
Subtotal of unidentified plant material	40	8	14
Waste/garbage			
Plastic	75	15	27
Paper	29	6	10
Twine/textile	17	3	6
Shredded tickets	13	3	5
Polystyrene	11	2	4
Aluminum foil	5	1	2
Glass	5	1	2
Leather	3	1	1
Human hair	2	0.4	0.7
Subtotal pellets with waste/garbage	87	17	31
Total items analyzed			514
Total pellets analyzed			280

those that contained more items, were due to the presence of waste.

Among trophic categories, mammals represented a percentage of occurrence (PO) of 99%, birds 8%, plant material 14%, and anthropogenic waste 31%. Among mammals, domestic livestock represented a PO of 52%, followed by a native herbivore (guanacos; 22%), and introduced lagomorphs (hare, rabbit and unidentified lagomorph; 19%). Birds were the less represented category, finding only two orders (Pelecaniformes and Charadriiformes), with a PO of 3% and 2%, respectively. Finally, within the anthropogenic category, plastic remains were the most common waste element found in the pellets, with a PO of 27%, followed by paper (10%) and twine/textile (6%) (Table 1).

DISCUSSION

Our results reinforce the high dependence of condors on large domestic herbivores, which were the main food source in other dietary studies of the Andean Condor in Argentina (Lambertucci et al. 2009b, Perrig et al. 2016, Ballejo et al. 2017). Particularly, two diet studies in Argentina's northern Patagonia (Lambertucci et al. 2009b, Ballejo et al. 2017) also revealed that domestic ungulates followed by introduced hare/rabbit were the main food source for Andean Condors. In contrast, a study in northwestern Argentina (San Guillermo National Park; Perrig et al. 2016) described wild camelids as the main prey of Andean Condors, followed by the European hare and livestock. The relative importance of native, wild introduced, or domestic herbivores varied among different studies, probably because of changes in local food avail-ability (i.e., animal mortality) and seasonal prey movements (DeVault et al. 2003, Ruxton & Houston 2004).

Condors are known to be highly mobile with large home range (14,000 and 67,000 km^2 recorded for two condors in central Chile, Pavez 2014), capable of travelling up to 800 km in a north-south range and up to 350 km/day (Lambertucci et al. 2014, Pavez 2014). Nevertheless, our findings of waste in pellets reflect a strong local component in the diet as described before by Lambertucci et al. (2009b) and Ballejo et al. (2017). However, the presence of mountain range species, such as guanaco, in pellets indicated that condors foraged far from the roost, too.

The plant remains found in pellets can be attributed to gastric or intestinal content of the herbivores consumed, as described by Donázar (1993), del Hoyo et al. (1994), and Buckley (1999) in Old and New World vultures. Blanco et al. (2013, 2014) reported a high prevalence (~ 90%) of plant remains in Andean Condor pellets and suggested the use of dietary plant supplements as providers of pigment for color-signaling strategies in sexual and competitive contexts, and for micronutrients that are scarce or missing in carrion.

Consumption of waste as a novel feeding behavior was documented and explained by Houston et al. (2007) and Ballejos et al. (2017) for other Old and New World vulture species, but not for the Andean Condor. Consumption of waste by condors in landfills in central Chile has been known for more than 20 years (Pavez & Tala 1995; Pavez 2001, 2012), but it had never been characterized or quantified up to now. Indeed, during the past 12 years, the landfill 4 km north of the communal roost has been frequented by a high number of condors (about 100–150 per day), especially in winter, and primarily by females and juveniles (EFP pers. obs.), who are subordinate to the males and adults, respectively (Wallace & Temple 1987, Donázar et al. 1999). This fact leads us to assume that waste consumption has become frequent since then. This situation may constitute a novel ecosystem (Hobbs et al. 2006), where waste disposals and landfills are probably a low-quality but easily accessible food source, especially for individuals of low hierarchical status (Donázar et al. 1999).

Waste ingestion has been described as an important cause of death in vultures (Houston et al. 2007) and all age classes in the California Condor (Rideout et al. 2012). Artificial elements, such as glass fragments, plastic, metal, and strings found in pellets are of particular concern, because they may constitute a significant cause of nestling mortality (Houston et al. 2007, Rideout et al. 2012). Further, the Andean Condor presence in highly anthropized areas, where landfills and surrounding livestock activities serve as attractors, may also increase fatal risks such as poisoning, hunting by local people, and collisions with power lines and other infrastructures (Martínez-Abraín et al. 2012, Sanz-Aguilar et al. 2015, Pavez & Estades 2016, Péron et al. 2017). Thus, lowlands in central Chile could be considered as a demographic sink for Andean Condors (Pavez & Estades 2016).

Food subsidies derived from waste disposals (rubbish dumps and landfills) have some positive attributes (Plaza & Lambertucci 2017). They are distributed worldwide, and provide abundant and predictable food that can support wildlife and, in this case, condors with valuable organic waste to meet their caloric requirements (Oro et al. 2013, Plaza & Lambertucci 2017). Other food resources of natural origin could be scarce in specific areas or periods of time, so dumps and landfills could help individuals or even populations to meet nutritional and caloric requirements from an anthropogenic food subsidy. As described by Plaza & Lambertucci (2017), predictable anthropogenic food sources could be considered beneficial for Black Vultures (*Coragyps atratus*) due to their increased body mass, but may also affect their nutritional and health status.

However, waste places also may have direct negative attributes, such as providing inorganic remains, or may generate indirect sublethal long-term effects. Landfills are characterized by high levels of toxic metals (De la Casa-Resino et al. 2014, Martínez-López et al. 2015) and organic pollutants (Weber et al. 2011), which are known to produce endocrine disruption, immune and metabolic dysfunctions, and a variety of toxicities, with consequences on reproduction, early development, and behavior (Odermatt et al. 2006, Jacob & Cherian 2013). Therefore, the effects of a regular consumption of waste could represent a potential threat, considering the high number of condors that uses the landfill in winter (~ 150 per day, EFP pers. obs.), which is reflected in the high number of individuals in the roost (~ 100 individuals gather to rest some winter nights, EFP pers. obs.). Considering the density of condors estimated by Pavez (2012) in central Chile (0.0455 condors/km^2), during winter ca. 14% of the Metropolitan Region and 2% of the central Chilean condor population would be present in the roost some nights. Correspondingly, the proportion feeding in the landfill per day would be approximately 21% of the Metropolitan Region and 3% of the central Chilean condor population. Furthermore, considering the high daily rotation rate of condors both in the roost and landfill (determined by some individual characteristics, patagial tags and satellite transmitters; EFP pers. obs.), and the large home range recorded in central Chile (Pavez 2014), the influence of the use of the landfill on the condor population in central Chile seems important.

Despite the methodological limitations of this study in terms of spatial and temporal patterns, we believe that the high presence of waste found as a component of the diet in our study area is relevant, and we see this contribution as the first report of this situation, which should give impetus to new studies at a broader spatio-temporal scale to deepen the real relevance of these findings. Finally, the management of supplementary feeding stations for scavengers is currently an important conservation tool to control different threat factors (Gilbert et al. 2007, Donázar et al. 2009, Virani et al. 2011, Ogada et al. 2012). To reduce the risks associated with the consumption of urban waste, the company KDM, owner of the landfill, has implemented a carefully managed feeding station as an intervention that benefits the conservation of the Andean Condor. This action is expected to be a long-term contribution to help this at-risk population.

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