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Repeated conservation threats across the Americas: High levels of blood and bone lead in the Andean Condor widen the problem to a continental scale☆

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ABSTRACT

Wildlife lead exposure is an increasing conservation threat that is being widely investigated. However, for some areas of the world (e.g., South America) and certain species, research on this subject is still scarce or only local information is available. We analyzed the extent and intensity of lead exposure for a widely distributed threatened species, the Andean Condor (*Vultur gryphus*). We conducted the study at two different scales: 1) sampling of birds received for rehabilitation or necropsy in Argentina, and 2) bibliographic review and extensive survey considering exposure event for the species' distribution in South America. Wild condors from Argentina ($n = 76$) presented high lead levels consistent with both recent and previous exposure (up to 104 μg/dL blood level, mean 15.47 ± 21.21 μg/dL and up to 148.20 ppm bone level, mean 23.08 ± 31.39 ppm). In contrast, captive bred individuals -not exposed to lead contamination- had much lower lead levels (mean blood level 5.63 ± 3.08 μg/dL, and mean bone level 2.76 ± 3.06 ppm). Condors were exposed to lead throughout their entire range in continental Argentina, which represents almost sixty percent (>4000 km) of their geographical distribution. We also present evidence of lead exposure events in Chile, Ecuador, and Peru. Lead poisoning is a widespread major conservation threat for the Andean Condor, and probably other sympatric carnivores from South America. The high number and wide range of Andean Condors with lead values complement the results for the California Condor and other scavengers in North America suggesting lead poisoning is a continental threat. Urgent actions are needed to reduce this poison in the wild.

1. Introduction

Lead poisoning related to human activities has been recognized as a threat for both wildlife and human health worldwide (Watson et al., 2009; Lambertucci et al., 2010). It has been extensively documented as a conservation problem by studying selected species (Church et al., 2006; Pain et al., 2005, 2009; Fisher et al., 2006), or potentially contaminated territories (Martínez-López et al., 2004; Gómez-Ramírez et al., 2011; Madry et al., 2015). To estimate the actual impact of lead poisoning as a conservation threat, widely distributed species should be surveyed at different spatial scales. Those species could be useful as indicators of a local or a wide range threat that can affect other sympatric species with similar feeding behavior (Gómez-Ramírez et al., 2014).

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Currently the main source of lead available to animals is spent ammunition from hunting activities. (Hunt et al., 2006; Church et al., 2006; Jenni et al., 2015). Among birds, both waterfowl and scavengers are prone to accidental ingestion of lead due to their feeding habits, and therefore much information has been reported from these groups (Guillemain et al., 2007; Friend et al., 2009). Birds of prey have been used as biomonitors for heavy metal exposure since they are at the end of the food chain, and they have large home ranges where they can be exposed to contamination (Dauwe et al., 2003). Lead poisoning, particularly in relation to scavengers, has been poorly studied in South America although hunting has increased in some countries like Argentina during recent decades (Saggese et al., 2009; Lambertucci et al., 2011; Ferreyra et al., 2014). This situation increases the risk of accidental consumption of lead in the form of wounded animals, non-retrieved carcasses or gut piles left in the field (Hunt et al., 2006), creating a dangerous scenario for obligate scavengers.

Many obligate and facultative scavenger populations are experiencing abrupt declines across the globe (Ogada et al., 2012, 2015). Incidental ingestion of Diclofenac ranks high among main causes for vulture decline (Ogada et al., 2012), but lead poisoning events affecting different vulture species have been documented for North America, Europe and Asia (Fisher et al., 2006; Hernández and Margalida, 2009; Kenny et al., 2015; Nam and Lee, 2009; Pain et al., 2009). In fact, incidental ingestion of spent ammunition from hunted animals is considered the primary factor threatening California Condor (*Gymnogyps californianus)* survival and recovery in the wild (Church et al., 2006; Parish et al., 2009; Finkelstein et al., 2012).

In a given individual the effect of lead contamination can be evaluated not only by lethal effects (Pattee et al., 2006), but also by sub-lethal detrimental effects on physiological functions (Gangoso et al., 2009; Espín et al., 2015), immune system (Franson and Pain, 2011) and behavior (Burger and Gochfeld, 2000). Beyond death of individuals, sublethal long-term effects could play an important role in shaping populations of long lived scavenging species feeding in frequent hunting or contaminated areas. The Andean Condor (*Vultur gryphus*) is a good model species to evaluate the impact of lead exposure in South American carnivores because it is a long-lived top scavenger that feeds mainly on medium-to-large herbivores, many species of which are hunted (Lambertucci et al., 2009a, 2011). Moreover, it is widely distributed throughout the South American Andes, has a low reproductive rate, and depends on high adult survival to maintain a stable population (Lambertucci, 2007). Andean Condor poisoning with lead bullets has been reported and studied in captivity (Locke et al., 1969; Pattee et al., 2006). However, there is a lack of information regarding lead poisoning in wild condors. The only report of lead exposure in free ranging individuals comes from Patagonia, Argentina, through feathers collected in three of the thirteen Argentinean provinces that the species inhabits. Lead concentrations in feathers from condors in those areas were generally low but some individuals were clearly exposed to this metal, with an isotopic signature resembling a mixture of two types of ammunition sources used for local hunting (one used for big game and another for hare hunting, Lambertucci et al., 2011).

In this study, we documented lead poisoning events for the Andean Condor populations by integrating two different scales. First, we determined the geographic extent and intensity of lead exposure in Andean Condors in Argentina (over *ca*. 60% of the area of distribution of condors), analyzing both previous (bone) and recent (blood) exposure events for each location. We then evaluated lead exposure for the species at a global scale by reviewing scientific and technical reports, and collecting unpublished data coming from surveys conducted in different South American countries within the species' range.

2. Materials and methods

2.1. Study species

The Andean Condor (*Vultur gryphus*) is the largest new world vulture. Its sexual dimorphism allows sex determination, and age class can be determined according to feather pattern (del Hoyo et al., 1994). This species inhabits a total North-South distance of *ca*. 7200 km throughout the Andes Mountains (Ramos, 1999), from northern Venezuela and Colombia to southern Argentina and Chile (del Hoyo et al., 1994, Fig. 1a). Its habitat along the Andes between Argentina and Chile covers *ca*. 4400 km, around 60% of the total North-South length of its geographical distribution. The Andean Condor is classified as Near Threatened worldwide and it is being negatively affected by several human disturbances (Speziale et al., 2008; Lambertucci et al., 2009b, 2011; BirdLife International, 2016). Northern populations are critically endangered, and it is considered Vulnerable in Chile and Argentina (Glade, 1988; López-Lanús et al., 2008). Its low genetic diversity (Hendrickson et al., 2003), retraction in its distribution range and local extinction events for South America could lead to population isolation and fragmentation. Southern populations are probably the largest (Lambertucci, 2010), but they show signs of retractions (Lambertucci, 2007; BirdLife International, 2016).

2.2. Sample collection for lead exposure assessment in Argentina

When possible lead concentrations were measured both in blood and bone samples, when possible, using protocols certified by a local ethics committee (CICUAL No. 2013/44, School of Veterinary Medicine, University of Buenos Aires). We surveyed lead in blood to know recent exposures, because lead is cleared relatively rapidly from blood with an estimated elimination half-life of 13 days (Finkelstein et al., 2012). On the contrary, lead stored in bones is considered the best indicator for evaluating lead exposure over the total lifetime (Franson and Pain, 2011).

To analyze background lead concentration for Argentine condors, we sampled 10 captive reared chicks (5 males and 5 females) between 6 and 9 months of age (See Table S1 Supplementary Material). Those condors with no history of previous lead exposure events were housed at Buenos Aires Zoo and fed with a controlled diet (certified bovine meat and lab rodents).

Recent lead exposure was determined through blood samples (from 10 to 20 ml, never exceeding 1% body mass). After bleeding from the metatarsal or cubital vein, 0.5–1 ml aliquots of heparinized blood were refrigerated and sent to the laboratory for lead determination. Bone stored lead was analyzed from live birds through bone biopsies from the proximal tarsus-metatarsus. Bone biopsies were performed with minimally invasive techniques under general anesthesia following surgical aseptic protocols and using an 8G Jamshidi Biopsy Needle. Birds handling and sampling protocols were certified by ethics committee approval (CICUAL No. 2013/44).

We analyzed a total of 76 free ranging individuals from Argentina (42 males including 6 juveniles, 7 subadults, 28 adults and 1 non available data; 34 females including 10 juveniles, 3 subadults and 21 adults) that either arrived at the Buenos Aires Zoo facilities for rehabilitation ($n = 62$) or were submitted for necropsy ($n = 14$). Those individuals came from all 13 continental provinces of Argentina within the species' area of distribution, and were admitted between 2008 and 2014. We recorded lead concentrations for each bird in both blood and bone tissue, linking these results to the bird's trapping site (as a proxy for province of origin).