

## SURVEY OF LEAD TOXICOSIS IN FREE-RANGING RAPTORS FROM CENTRAL ARGENTINA

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ABSTRACT.—Lead toxicosis is a problem recognized worldwide in raptors that has seriously impacted the recovery efforts of several endangered species. Vultures, eagles and kites are commonly affected because, as scavengers, they ingest lead ammunition residues when feeding on the remains of gun-killed animals. In South America, lead toxicosis in birds has been scarcely investigated. Raptors have been occasionally reported with the presumptive diagnosis of lead poisoning in hunting areas of central Argentina, although no systematic surveys have been conducted. Given the current understanding and knowledge we have on lead toxicosis in raptors in other parts of the world, the intense year-round wildlife hunting activities occurring in central Argentina, and the clinical diagnosis of lead poisoning in some birds presented to rehabilitation centers, we hypothesize that scavenging birds of prey in central Argentina could be systematically exposed to this heavy metal. Recently, we detected lead in the blood and bones of Argentine Solitary Crowned Eagles (*Harpyhaliaetus coronatus*), a severely endangered species from central and northern Argentina. Together with recent findings of lead in Andean Condors (*Vultur gryphus*) and in waterfowl, these studies are a first step to determine the extent of this problem in Argentine birds. Systematic studies of lead toxicity in wild birds in Argentina are needed in order to educate hunters toward a switch to non-lead substitutes. Received 4 August 2008, accepted 22 October 2008.

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LEAD TOXICOSIS caused by the ingestion of contaminated tissues of animals shot with lead ammunition is a phenomena recognized worldwide and an emerging health problem for wildlife and humans (De Francisco et al. 2003, Fischer et al. 2006, Stroud and Hunt 2009, Friend et al. 2009, Matz and Flint 2009, Beintema 2001, Mateo 2009). Among numerous reports and reviews on the toxicological effects, clinical manifestations, diagnosis, and treatment of spent lead ammunition in humans and wildlife are Samour and Naldo (2002), Grandjean and White (2002), Murata et al. (2003), Parish et al. (2006), Wynne and Stringfield (2007), and Kosnett (2009). The risk of lead exposure from spent ammunition in humans is higher for those populations that rely on game meat as a main source of animal protein (Johansen et al. 2004, Mateo et al. 2007, Cornatzer et al. 2009, Verbrugge et al. 2009, Hunt et al. 2009).

Raptors, both scavengers and predators, are exposed to lead when feeding on the remains of shot animals or when hunting prey injured with lead shot or bullets (Church et al. 2006, Cade 2007). Particularly susceptible to lead toxicosis are scavenger species (Platt et al. 1999, García-Fernandez et al. 1997, Hunt et al. 2006) like the California Condor (*Gymnogyps californianus*), a severely endangered species (Snyder and Snyder 2000). Spent lead ammunition appears to be not only the main cause of its decline in the wild during the 20<sup>th</sup> Century, but continues to undermine current recovery efforts aimed to establish self-sustaining populations in California, Utah and Arizona (Sorenson et al. 2000, Parish et al. 2006, 2009, Woods et al. 2006, Cade 2007). Furthermore, lead toxicosis has been reported as an important contributing factor in the population decline of other endangered species, including Steller's Sea Eagles (*Haliaeetus pelagicus*), White-tailed Eagles (*Haliaeetus albicilla*), Red Kites (*Milvus milvus*), Spanish Imperial Eagles (*Aquila adalberti*), and Egyptian Vultures (*Neophron percnopterus*) (Kurosawa 2005, Pain et al. 2005, 2007, Saito 2009, Krone et al. 2009, Gangoso et al. 2009, Mateo 2009).

Given the accumulating body of evidence about spent lead ammunition and its relationship with

toxicosis in raptors worldwide, it is likely that the same occurs in Argentine birds of prey in the presence of comparable ecological and epidemiological conditions. Moreover, given their top position in the food chain, raptors may become valuable sentinels to detect the presence of lead toxicosis caused by spent ammunition in other species of wildlife. However, the investigation of lead exposure in Argentine birds has thus far received little attention. Therefore, the main goal of this communication is to review and summarize the limited available information about spent lead ammunition in Argentine raptors and other wildlife and to discuss future research needs.

## MATERIALS AND METHODS

We conducted a detailed search of the literature about lead toxicosis and spent lead ammunition in raptors and other wildlife in Argentina. We searched BioOne, Raptor Information System, Pubmed, Global Raptor Information Network, SORA and Scielo databases, as well as various technical and local reports. Given the relative lack of official information about the extent of hunting activities in most Argentine provinces, we also consulted Argentine colleagues and hunters. Additional information about hunting activities in Argentina was obtained from web pages publicizing hunting activities and from provincial wildlife agency web pages. We also present limited unpublished data recently gained by the authors on lead levels in selected species of raptors.

## RESULTS AND DISCUSSION

*Lead Toxicosis in Argentina.*—When compared with the information available for North America and Europe, knowledge about the effects of spent lead ammunition in raptors and other species in Argentina is limited. Recognized sources for humans include foundries, mines, car painting shops, batteries, cemeteries, plumbing, toys, waste from electronic and other industries, gas, soldering, prints, and pottery (Lacasaña et al. 1996, Hansen et al. 1999). Lead is a significant health problem in humans in Argentina, especially in children (Hansen et al. 1999, Martinez et al. 2003). Recent studies

estimated that 10–40% of children less than 15 years old living in Buenos Aires and Córdoba have blood lead levels over 10 µg/dL (García and Mercer 2003). As elsewhere, spent ammunition has not been reported as a source of lead for humans in Argentina or in other Latin-American countries (Lacasaña et al. 1996). Whether the lack of such reports reflects a lack of exposure to this source or an uninvestigated problem is unknown.

Prior to 2006, studies on lead and other heavy metals in Argentine wildlife focused mainly on aquatic invertebrates (Amin et al. 1996, 1998, Ferrer et al. 2000, Perez et al. 2005 and references therein) and mammals (Marcovecchio et al. 1990, 1994). Two scientific communications reported low levels of this element in a small number of marine birds (Gil et al. 1997, 2006). In 2007, two different groups of researchers found lead and other heavy metals in blood samples of Olrog's Gull (*Larus atlanticus*) (L. La Sala pers. comm.) and in feathers of Common Terns (*Sterna hirundo*) (L. Mauco et al. unpubl. data). However, the source of lead for these birds may have originated in invertebrate prey consumed by these birds and not from ammunition (L. LaSala pers. comm., L. Mauco et al. unpubl. data).

Evidence for spent lead ammunition exposure and toxicity in Argentine birds is recent and comes from ongoing studies conducted in waterfowl and raptors in central Argentina. In 2007, lead shotgun pellets were found in two species of ducks in Santa Fe province (H. Ferreyra pers. comm.). In the same year, a blood lead concentration of 0.27 µg/dL was detected in a severely anemic and dehydrated nestling Crowned Eagle (*Harpyhaliaetus coronatus*) (A. Quaglia et al. unpubl. data.). An opportunistic investigation of lead in a Turkey Vulture (*Cathartes aura*) found dead in the same area revealed a bone lead concentration of 3.5 µg/g (A. Quaglia et al. unpubl. data). To the author's knowledge, this is the first time that lead exposure has been confirmed in waterfowl and raptors in this country.

Additional evidence of exposure to lead came from Andean Condors (*Vultur gryphus*), a species very sensitive to this metal (Pattee et al. 2006). High blood lead levels were recently confirmed by laboratory investigation in Andean Condors admitted for rehabilitation at Fundación and Zoo Temaikén

in Buenos Aires province (G. Gachen pers. comm.). Further evidence of lead toxicosis in this species came from another ongoing study in northern Patagonia; lead ammunition fragments observed in the ventriculus of a radiographed bird and corresponding high lead concentrations in wing feathers were detected there in Andean Condors (S. Lambertucci et al. unpubl. data).

Taken together, these limited data confirm that Argentine birds of prey are being exposed to lead in several and distant geographic areas of Argentina, although the quantitative extent of this exposure is unknown. These findings are of concern, considering that Crowned Eagles and Andean Condors are endangered species in the Neotropical region (BirdLife 2008).

*Sources of Spent Lead Ammunition for Argentine Raptors.*—Given its large area and diversity of habitats, Argentina is a country rich in large and small game species. Both native and exotic mammals and birds are hunted for sport and also for subsistence throughout the country. Commonly hunted species include tinamous (Tinamiformes), geese and ducks (Anseriformes), doves and pigeons (Columbiformes), quail (Galliformes), foxes and wildcats (Carnivora), hares and rabbits (Lagomorpha), wild boars, guanacos, cervids, and antelope (Artyodactyla), among others. Alien species, such as introduced cervids (e.g. *Axis axis*, *Cervus elaphus*, *Dama dama*) and bovids (*Antilope cervicapra*) are bred and kept in semi-captivity as well as in wild conditions for hunting on numerous private ranches in Patagonia and central provinces of Argentina (Novillo and Ojeda 2008, and references therein).

Another important source of spent lead ammunition for raptors and other wildlife in Argentina appears to be hunted waterfowl. Despite the banning of lead ammunition for waterfowl hunting in North America and Europe, it is still legally used in Argentina. With the convenience of travel, thousands of hunters visit wetlands and rice fields in Buenos Aires, Santa Fé, Corrientes, and Entre Rios provinces for waterfowl hunting, thus contributing to the seeding of spent lead ammunition in these water bodies and providing lead shot prey for raptors.

In Argentina, sport and recreational hunting is regulated through national and provincial laws. Hunting seasons, species, and daily and seasonal bag limits, are determined by provincial wildlife agencies. However, enforcement of these regulations is poorly accomplished due to the paucity of trained personnel and limited economic resources. As a result, large areas of the country lack effective police control. Thus, sport and subsistence hunting of large and small game remains in practice poorly regulated and difficult to control in most provinces. Moreover, subsistence hunting of waterfowl and other small game occurs year round in most Argentine provinces and has dramatically increased in recent decades as the result of economic crisis, unemployment, and rise in poverty levels (Anonymous 1997).

Of special concern is the sport hunting of pigeons and doves in central Argentina (Gordillo 2008). This activity has increased considerably in recent years in provinces like Córdoba, where several species of pigeons and Eared Doves (*Zenaida auriculata*) are considered overpopulated (Mourton et al. 1974). Hunting of these doves is allowed year round, without any limits regarding the numbers of birds killed daily. Given the increasing interest of hunters around the world in these game species, a large number of ranches have transformed completely or partially into private hunting grounds in recent years. In the last 15 years, it has been estimated that more than 10,000 hunters, coming mainly from North America and Europe, visit Córdoba every year attracted by the low rates and unlimited number of birds they can shoot each day (Gordillo 2008, M.L. Pignata pers. comm.). Recent estimations suggest that each hunter shoots more than 1000 cartridges a day (Gordillo 2008, M.L. Pignata pers. comm.). The total amount of lead ammunition spent in northwestern Córdoba, where dove hunting activities predominate, has been calculated to be approximately 1,600 tons of lead per year (Gordillo 2008). Thousands of doves and pigeons are killed, most of these birds remaining unrecovered in the fields (Gordillo 2008) where scavenging raptors are attracted to the easy food (M.L. Pignata pers. comm., S. Seipke pers. comm.). The carcasses are also given as "payment" to local children that assist the hunters and are used as food.

*Species of Argentine Raptors at Risk of Lead Toxicosis.*—Given the extension and diversity of habitats in Argentina, ranging from mountain forests and high Andean plateaus to prairie lands and patagonian steppes, approximately 1000 species of birds have been recorded in the country (Narosky and Yzurieta 2003). Among them, 65 (6.5%) species are diurnal birds of prey. Nine (56%) species of Argentine raptors are considered obligate scavengers (Andean Condor, King Vulture *Sarcorhamphus papa*, Turkey Vulture, Lesser Yellow-Headed Vulture *Cathartes burrovianus*, Greater Yellow-Headed Vulture *Cathartes melambrotus*, Black Vulture *Coragyps atratus*, Mountain Caracara *Phalcoboenus megalopterus*, White-throated Caracara *Phalcoboenus albogularis*, and Striated Caracara *Phalcoboenus australis*), while seven (44%) species are considered facultative scavengers (Crowned Eagle, Solitary Eagle *Harpyhaliaetus solitarius*, Great Black-Hawk *Buteogallus urubitinga*, Black-Chested Buzzard-Eagle *Geranoaetus melanoleucus*, Southern Caracara *Caracara plancus*, Chimango Caracara *Milvago chimango*, Yellow-headed Caracara *Milvago chimachima*). Thus, a significant percentage (25%) of Argentine diurnal birds of prey are potentially exposed to spent lead ammunition, including three species of particular concern (Andean Condor, Crowned Eagle and Striated Caracara) given their conservation status in Argentina and South America. In addition, Peregrine Falcons (*Falco peregrinus*), Aplomado Falcons (*F. femoralis*), and other bird-eating falcons and accipiters may ingest lead shot from waterfowl, columbiforms, and others carrying lead shot in their tissues.

*Current Studies on Lead Toxicosis in Argentine Raptors.*—Studies on the population impact of environmental pollutants have rarely been conducted in Argentina (Sagge 2007). Considering the increasing body of evidence on the effects of spent lead ammunition in raptors worldwide and the extensive and widely distributed hunting activities occurring in Argentina, it is expected that in some areas scavenging birds of prey may be systematically exposed to this heavy metal. Whereas the overall impact that lead may be having on Argentine raptor populations is unknown, significant effects upon species with severely reduced and localized populations like those of Crowned Eagles and Andean Condors ap-

pear highly probable. Scientific documentation of exposure to spent lead ammunition and its effects on these and other species in Argentina is therefore required if there is to be education of hunters and lead's eventual replacement with non-lead substitutes.

Currently, five different research groups are systematically trapping wild birds of prey or collecting samples for biomedical studies in Argentina. Two groups are located in La Pampa province and the others are in Mendoza, Buenos Aires and Northern Patagonia provinces, all areas of high hunting pressure. Species being studied are Crowned Eagles, Chimango Caracaras, Andean Condors, and others. Given that blood from these wild birds is regularly collected for nutritional and physiological studies, simultaneous investigations of blood lead levels are feasible. Raptors admitted to rehabilitation centers are another potentially useful source to investigate lead exposure and toxicity. Therefore, a survey aimed to investigate the prevalence of lead exposure and toxicosis in Argentine raptors will begin in 2009. Blood from free-ranging birds, as well those admitted to several rehabilitation centers in Mendoza and Buenos Aires provinces, will be collected and analyzed using an automatic electrochemical system (LeadCare® Blood Lead Testing System, ESA Inc, Chelmsford, MA, USA). Results of this study are expected to demonstrate and quantify lead exposure in both facultative and obligate scavengers, and to contribute to the design of further studies identifying lead sources in wild raptors.

*Further Recommendations and Conclusions.*—Spent lead ammunition affects not only wildlife, but it may affect humans and even domestic animals as well. Understanding its social, medical, and biological consequences requires a multidisciplinary team (Pokras and Kneeland 2009). A conservation medicine approach based on a collaborative working relationship between those interested in human and animal health has therefore been recommended (Saggese 2007, Pokras and Kneeland 2009). Needed evidence about exposure and the effects of spent lead ammunition in Argentine wildlife and humans include: (1) the investigation of stomach contents in hunted waterfowl and upland game bird carcasses (Degernes et al. 2006), (2) radiological investigation of raptor pellets and carcasses (Martin

et al. 2008), (3) investigation of lead concentrations in feathers, liver, bone, bone marrow and kidneys of scavenger birds of prey, waterfowl, and ground-feeding birds (Martin et al. 2008, Mateo 2009), (4) imaging examination (x-ray, computed tomography) of hunted animal remains abandoned in the field (Hunt et al. 2009), (5) investigation of blood lead levels in hunters and their families that consume game meat (Verbrugge et al. 2009), and (6) the use of lead isotope patterns to identify the source of this element (Matz and Flint 2009).

The effects of spent lead ammunition on Argentine raptor populations are currently unknown. Biomedical studies, including the investigation of other heavy metals and environmental pollutants, should be added to the study of factors that may cause demographic changes in Argentine birds of prey. Given the current understanding we have about lead toxicosis in other parts of the world, together with the intense year-round wildlife hunting activities detected in central Argentina, we hypothesize that scavenging birds of prey may be systematically exposed to lead, particularly in central Argentina and Patagonia where most hunting activities seem to concentrate. Results of future, rapid, short-term assessments of this problem, combined with the now widely available scientific background information about the perniciousness of lead, may support a move toward nontoxic substitutes for lead bullets and shotgun pellets.

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