



# Lead pollution from hunting ammunition in Argentina and current state of lead shot replacement efforts

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**Abstract** Waterfowl hunting in Argentina is a profitable industry that attracts hunters from all over the world. Most hunting occurs as high-end hunting tourism, through which registered outfitters service predominantly foreign clients on private lands. Lead pollution from hunting ammunition is increasingly recognized as a significant local problem, impacting wildlife, aquatic and terrestrial habitats, and extending to vulnerable human rural communities. Regulatory frameworks that restrict lead shot use are a budding success story but remain challenged by their constrained geographic range and limited compliance rooted in unavailable nontoxic ammunition. Changes in hunting practices in Argentina are long overdue.

**Keywords** Lead toxicity · Public health · Waterfowl · Wildlife health

## INTRODUCTION

Lead pollution from hunting ammunition is a global environmental health problem for which there is a simple and scientifically validated solution, but also an overwhelming resistance to change (Mateo et al. 2014; Arnemo et al. 2016; Hampton et al. 2018). Factors associated with the controversy surrounding lead shot replacement have been addressed elsewhere and remain a standing, unresolved issue of significant health and conservation impact (Friend et al. 2009; Cromie et al. 2015; Kanstrup 2015).

Despite worldwide evidence of wildlife and human lead poisoning over nearly a century, rarely have nations acted until local data were garnered and local toxicity demonstrated (Avery and Watson 2009; Mateo 2009). Hunting pollution was a foreseen yet poorly addressed issue in

Argentina until a decade ago when concerns over its magnitude triggered long-delayed research. In this paper, we provide a brief overview of hunting and associated lead pollution in Argentina, describe recent progress in restrictions to toxic ammunition use, highlight remaining obstacles, and recommend actions to overcome these challenges.

## HUNTING IN ARGENTINA

Sport hunting is significant in Argentina, yet there is a lack of publicly available data to fully assess its extent. An unpublished study conducted by Caselli et al. in 2011 collated information for 16 provinces from government websites ( $n = 11$ ) and/or from official responses to email surveys ( $n = 5$ ). The remaining seven provinces of the 23 in the country did not respond to the survey and had no accessible information on their websites. At that time, only seven (30%) provinces displayed hunting regulations on their websites, and 3 (13%) had maps showing areas where hunting was and was not allowed. Seven (30%) provinces kept records of annual hunting licenses sold. In terms of government control of hunting, overlap in regulatory mandates between offices charged with natural resource management and hunting control existed in seven provinces (30.4%). In nine provinces (39.1%), government responsibilities were based in different offices. In 2011, small game hunting was allowed for a total 53 native and exotic species and distributed in 16 provinces, with seasons ranging from 1 to 3 months in 6 (37.5%), 4–9 in 8 (50%) and 10–12 in 2 (12.5%). Large game hunting was permitted for 19 native and exotic species, in 12 provinces: during 1–3 months in 1 province (8.3%), 4–9 in 6 (50%), 10–12 in 3 (25%), and 2 (16.6%) provinces had variable seasons per species. Ten provinces allowed waterfowl hunting with

daily bag limits for different species ranging from 5 ducks in 2 provinces, to 10 in 3, 12 in 2, and 15 in the remaining 3 provinces.

## WATERFOWL HUNTING IN ARGENTINA

Waterfowl hunting in Argentina is a profitable industry that attracts hunters from all over the world (Zaccagnini 2002). It has grown considerably since the 1990s (Zaccagnini and Venturino 1992; Zaccagnini 2002). Most hunting occurs as high-end hunting tourism, through which registered outfitters service predominantly foreign clients on private lands.<sup>1</sup> While ten provinces allow waterfowl hunting, the largest volume of huntsmen converge at the wetlands of Santa Fe, Corrientes and Entre Ríos provinces. These sites harbor a wide diversity of waterfowl including species protected by the Convention of Migratory Species (CMS) such as flamingos, ducks, swans and plovers, and overlap with several Important Bird Areas (IBA) and Ramsar sites (Benzaquén et al. 2017). Although hunting quotas are deemed conservative, there is a paucity of information on waterfowl population status and trends, enforcement is weak and information on registered hunters is often unavailable.

## LEAD TOXICITY FROM SPENT AMMUNITION IN WATERFOWL

The massive use of lead ammunition in Argentinean wetlands is relatively recent, compared to Europe and North America. Based on government data, at least 56 tons of ammunition lead were added to wetlands in Santa Fe province alone between 2007 and 2009 by hunting. Non-quantified amounts, but presumably similar levels, are also deposited in other waterfowl hunting hotspots on an annual basis. Since 2007, we have undertaken collaborative studies between local universities (Universidad Nacional del Centro de la Provincia de Buenos Aires - UNICEN, Universidad Nacional del Litoral, and Universidad Nacional del Sur) and various nongovernmental organizations in the provinces of Santa Fe, Corrientes and Buenos Aires. Between 2007 and 2013 we examined 455 hunter-killed ducks for signs of lead exposure. Our study included only authorized species collected during the hunting season by registered hunters. Specifically, we studied the whistling duck (*Dendrocygna bicolor*), white-faced tree duck (*D. viduata*), black-bellied whistling-duck (*D. autumnalis*), rosy-billed pochard (*Netta peposaca*) and Brazilian duck (*Amazonetta brasiliensis*). We found prevalences of lead

pellet ingestion that varied between 7.6 and 50%, and lead accumulated in the bones of 100% of these birds due to long-term exposure (Ferreya et al. 2009, 2014; Natalini et al. 2014). We also documented toxic levels of lead in liver (60% prevalence) and blood of ducks (28% of 96 live ducks), which were associated with poor body condition and blood abnormalities (Ferreya et al. 2014, 2015).

## LEAD POLLUTION FROM SPENT AMMUNITION IN WETLAND ENVIRONMENTS

During the same period, we also documented accumulation of lead in natural wetlands and rice fields where waterfowl hunting is practiced. We found spent shot densities in the top 15 cm of wetland sediment as high as 141 pellets/m<sup>2</sup>, a value that resembles the most contaminated areas in Europe (Pain 1990; Mateo et al. 1997; Romano et al. 2016). Likewise, densities in rice fields reached 38 pellets/m<sup>2</sup> (Romano et al. 2016). Lead dissolved in sediment amounted to 79 ppm in the former, and 14 ppm in the latter (Romano et al. 2016). Regrettably, there is no regulation on acceptable contaminant levels for areas under conservation in Argentina. In the case of agricultural soils (only applicable to rice fields in this case), the tolerance level for lead is 375 mg/kg (equivalent to 375 ppm) (Regulatory Decree 831/93, Law on hazardous waste 24051). However, this category does not include productive systems with periodic flooding such as rice crops in which surface freshwater can transport the toxic elements. Although we did not measure lead in rice-field water, in natural wetlands, we found lead levels between 0.008 and 0.005 ppm. These exceeded acceptable levels for the protection of aquatic life in superficial freshwater in Argentina (0.001 ppm; Hazardous Waste Law 24051), and were near the limits for livestock and irrigation—0.002 and 0.004 ppm, respectively. Finally, we found maximum lead concentrations of 10.1 ppm in several plant species that are regularly consumed by fauna and domestic livestock in wetlands where hunting occurs. Moreover, in a small sample of preharvest rice crops, we found lead mainly in the roots (up to 22 ppm), 5.6 ppm in the stems, and levels decreasing toward the grain where the average values were < 0.6 ppm (maximum acceptable value in edible plants 2 ppm, Argentine Food Codex, Article 1546, 17.9.85) (Romano et al. 2016).

## THE TIP OF THE ICEBERG

Our work provides evidence of wetland pollution associated with high acute and chronic exposure to lead from spent ammunition in waterfowl in Argentina. Moreover, the levels found match reports from other parts of the world

<sup>1</sup> <http://catcyc.org.ar/index.php>.

with severe contamination problems and worrisome impacts on their avifauna (Mateo 2009). We, however, acknowledge that our studies represent only a small fraction of a significantly greater problem, with consequences and impacts at the ecosystem level that far exceed waterfowl and wetlands and shotgun ammunition. In other areas of the country, for example, exposure to lead from bullets has been documented in the near-threatened Andean condor (*Vultur gryphus*) (Birdlife International 2017). Lambertucci et al. (2011) found lead levels as high as 21.1 ppm in condor feathers from northern Patagonia. A recent study by Wiemeyer et al. (2017) found blood lead levels ranging from 0.2 to 1400 ppm in a set of 76 free-ranging condors from across Argentina submitted for rehabilitation. Additionally, through X-ray examination they identified 15 of 62 (24.2%) condors with ammunition fragments in their bodies (Wiemeyer et al. 2017). Whereas secondary lead poisoning has been documented in numerous predator and scavenger bird species, particularly raptors, there are few studies involving other taxonomic groups (Tranel and Kimmel 2009). In an exploratory study in Argentina, Rago et al. (2012) noted lead in blood (0.005–0.066 ppm) in 12/16 Yellow anaconda (*Eunectes notaeus*) from Corrientes province, a core waterfowl hunting area, versus no lead in 30 anacondas from a hunting-free zone (Formosa province). Moreover, they observed significantly superior health parameters (i.e., body mass, blood cells, parasitism and plasma chemistries) in anacondas from Formosa. They hypothesized that lead levels and poor health in the Corrientes anacondas were associated to dietary intake of contaminated waterfowl. Yellow anacondas are considered vulnerable (Giraud et al. 2012), and while the effects of lead exposure in this species are unknown, other reptiles have shown reproductive failure, anorexia, weight loss, poor growth, lethargy, and death when fed ammunition-contaminated prey (Camus et al. 1998; Lance et al. 2006).

## UNASSESSED POLLUTION FROM DOVE HUNTING

When dove hunting is considered, lead entering the environment rises to astounding (but undocumented) levels in Argentina. Dove shooting is currently authorized in 11 provinces, two of which allow year-round hunting with no bag limits for the species considered agriculture pests, namely the eared dove (*Zenaida auriculata*) and rock dove (*Columbia livia*). There is some variation for Picazuro pigeon (*Patagioenas picazuro*) and spot-winged pigeon (*Patagioenas maculosa*) for which quotas range between 50 and 500 per hunter per day over 6-month periods. Lodges commonly promise 1–2000 cartridges per hunter per day. With approximately 10 000 hunters visiting the

“dove shooting capital” Córdoba province annually,<sup>2</sup> a conservative estimate is that 210 to 480 tons of lead are added to the environment per year (based on use of 21 or 24 g cartridges). Except for Santa Fe which restricts daily quotas to 50 eared doves when lead ammunition is used (since 2016<sup>3</sup>), no such regulations on lead-ammunition use exist elsewhere for this practice. Despite the magnitude of this industry, very few studies have documented lead pollution from dove hunting to date. Notwithstanding, there is increasing evidence that it is substantial (Rubio et al. 2014) and that it implies a significant risk for animal and human health (Wannaz et al. 2012; Salazar et al. 2012).

## IMPACTS ON PUBLIC HEALTH

Many lodges in Argentina regularly donate hunted game (ducks, doves) to the rural poor in the vicinity of their hunting grounds. Some lodges even advertise this as a community service.<sup>4</sup> In 2010, Mónica Parvellotti, a teacher from San Javier Santa Fe province, publicized her concerns about the frequency with which her students gathered dead ducks left on the shooting fields and took them home for supper.<sup>5</sup> Acting on these cues, a preliminary study led by Drs. Caselli (UNICEN) and Loyácono (Hospital de Clínicas, Universidad de Buenos Aires) in 2015 described lead exposure in children 1–12 years in our core study area in Santa Fe. Sixty-two percent of children who regularly ate hunted game (38/61) tested positive, with average blood lead levels > 0.09 ppm (maximum 0.28 ppm) (Caselli et al. unpubl.). Moreover, lead was also found in all baby teeth donated by 6–11-year-old school children (n = 38) between 2015 and 2017. Levels ranged from  $0.06 \pm 0.01$  to  $1.87 \pm 0.37 \mu\text{g/g}$ <sup>6</sup> (Caselli et al. unpubl.). Of 88 surveyed families in the blood lead study, equal proportions reported feeding on self-hunted versus hunter-donated ducks. Sixty-six percent of households indicated they removed pellets and the shot trace in game meat before cooking. Pellet recovery per dish at the time of eating was 3 pellets on average, maximum 10 (Caselli et al. unpubl.).

<sup>2</sup> <https://www.lanacion.com.ar/1881738-palomeros-para-los-extranjeros-la-meca-de-la-caza-de-aves-esta-en-la-argentina>.

<sup>3</sup> Resolution 123/16 [https://www.santafe.gov.ar/index.php/web/content/view/full/222271/\(subtema\)/210019](https://www.santafe.gov.ar/index.php/web/content/view/full/222271/(subtema)/210019).

<sup>4</sup> <https://www.daviddenes.com/bird-hunting-by-lodge/pica-zuro-lodge/>.

<sup>5</sup> <http://www.sanjavierenreflejos.com.ar/?p=137>.

<sup>6</sup> Inductively Coupled Plasma Mass Spectroscopy (ICP-MS), Comisión Nacional de Energía Atómica.

## TOWARD LEAD-AMMUNITION REPLACEMENT

A wave of positive outcomes followed awareness of the severity of ammunition lead pollution in several Argentina provinces stemming from our research. For example, the government of Santa Fe province contributed funding for environmental studies, and the Santa Fe hunter's association<sup>7</sup> facilitated waterfowl samples and covered some diagnostic expenses. Also, during this time, several participatory workshops convened all major stakeholders to discuss the problem of lead toxicity and develop a roadmap for transition to nontoxic ammunition. Finally, in November 2011, our team hosted the first national workshop on lead-ammunition toxicity and a nontoxic ammunition shooting clinic, co-convened by the Federal Wildlife Agency of Argentina and the Environment Secretariat of Santa Fe Province, and sponsored by the Argentina Firearms Registry RENAR, the Argentina Hunters Association, and several local universities. More than 80 people attended the 2-day event, including representatives from provincial governments (wildlife and environment agencies), hunters, hunting associations, hunting outfitters, and ammunition manufacturers. Instrumental to this effort were the two invited instructors from Denmark: Niels Kanstrup, a wildlife manager and head of the Danish Hunting Association; and Lars T. Andersen, a shooting instructor and ballistics specialist. As has been the case elsewhere in the world, having hunters speaking to hunters proved key to engage attendants and counter myths on non-lead-ammunition performance (Friend et al. 2009). Consensus on the need to transition to nontoxic ammunition was reached, yet a critical obstacle was identified: local availability, at a reasonable price and volume, of non-lead ammunition.

## REGULATORY AND TRANSITION ACTIONS IN ARGENTINA

In 2011, the provinces of Santa Fe and Córdoba established regulations to limit lead-ammunition use. A pioneer in this matter, Santa Fe enacted gradual restrictions on lead shot use in wetlands, completing the total ban by 2016.<sup>8</sup> Moreover, current legislation in that province encourages progressive substitution of lead ammunition in all forms, for all species and habitats.<sup>9</sup> Unlike Santa Fe which incorporated lead bans into their hunting legislation,

Córdoba prohibited the use of lead shot in wetlands through Hazardous Waste regulations.<sup>10</sup> Although this restriction remains in force, it does not appear annually in the small game hunting regulations which set quotas and species. Buenos Aires province initiated an exploratory substitution process in 2013<sup>11</sup>, but no progress has been made since.

In 2014, the federal government adhered to a global voluntary resolution to eliminate lead ammunition by 2020 (Convention of Migratory Species - UNEP 2014). In 2016, the Federal Council for the Environment (Consejo Federal de Medio Ambiente COFEMA) commended the path taken by Santa Fe province and declared lead-ammunition replacement a national environmental priority.<sup>12</sup> In the last 2 years, government agencies have been negotiating with local ammunition makers and retailers to facilitate non-lead-ammunition availability through importation and/or local manufacture. Progress has been slow, but some alternatives will likely reach the local market during 2019 (Roberti, pers. comm.<sup>13</sup>).

## UNRESOLVED CHALLENGES

Lack of availability of nontoxic alternatives in the country remains the biggest limitation to lead-ammunition replacement in Argentina. Not only does this void leave a huge environmental and health problem unresolved, but it hijacks hard-earned advances to date and directly conflicts with compliance of the existing regulations (see Santa Fe and Córdoba, previous section). It also creates unnecessary antagonism with the hunting sector, which feels threatened by the lack of options should they comply with current restrictions to lead use. Moreover, it likewise hampers regulatory efforts in a scenario of already weakened enforcement due to insufficient state resources. The delay in securing local alternatives to lead is a clear loss of opportunity at a time when there is broad and hard-earned consensus on the imminent need for change.

As has been noted in Europe (Kanstrup and Thomas 2019), availability of non-lead ammunition in Argentina is

<sup>7</sup> Cámara de empresas de turismo cinegético y pesca deportiva de la provincia de Santa Fe.

<sup>8</sup> Resolution 123/16 [https://www.santafe.gov.ar/index.php/web/content/view/full/222271/\(subtema\)/210019](https://www.santafe.gov.ar/index.php/web/content/view/full/222271/(subtema)/210019).

<sup>9</sup> Resolution 10/19 <http://www.santafe.gob.ar/index.php/web/content/download/251068/1318769/file/HABILITACION%20CAZA%20DEPORTIVA%202019-%2014821-6.pdf>.

<sup>10</sup> Resolution No. 1115/2011. [https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=2ahUKEwjJ8sb04ZrgAhVIGLkGHelxDNwQFjAAegQIAxAC&url=http%3A%2F%2Fww.cba.gov.ar%2Fwp-content%2F4p96humuzp%2F2014%2F07%2FRes.-1115-Turismo-cinegetico.pdf&usg=AOvVaw3hhYQPj1lbp\\_KXc\\_-3H\\_Zq](https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=2ahUKEwjJ8sb04ZrgAhVIGLkGHelxDNwQFjAAegQIAxAC&url=http%3A%2F%2Fww.cba.gov.ar%2Fwp-content%2F4p96humuzp%2F2014%2F07%2FRes.-1115-Turismo-cinegetico.pdf&usg=AOvVaw3hhYQPj1lbp_KXc_-3H_Zq).

<sup>11</sup> Resolution No. 63/13 <http://www.gob.gba.gov.ar/legislacion/legislacion/opds-13-63.html>.

<sup>12</sup> Resolution 7/2016 <http://cofema.ambiente.gob.ar/?aplicacion=normativa&IdNorma=1602&IdSeccion=32>.

<sup>13</sup> Servicios y Aventuras (<https://serviciosyaventuras.com.ar/>), Tucumán, Argentina. March 20th, 2019.

also constrained by poor demand and ill-enforced regulation. An added factor in this country is financial instability which inhibits investment through lack of market predictability. Nonetheless, a commercial activity catering overwhelmingly to affluent foreign hunters that benefit from local currency weakness should be capable of leveraging cost-related obstacles and ensure some degree of demand stability that would make local manufacture a viable option. To some extent, the hunting constituent's sluggishness and nonchalance contribute to the delay in effectively replacing lead shot in Argentina.

### COMPLEMENTARY BOTTOM-UP APPROACH

In our study sites, communities are acutely aware of daily shootings from hunting, but much less so about the negative impacts that current unsustainable practices are having on their natural surroundings and their own health. Hence, over time we have supplemented our advocacy efforts toward policy makers and hunters, with efforts to build a knowledgeable community-based constituency. The expectation is that these empowered and conservation-minded communities will then push the lead-ammunition agenda forward from a genuine and locally embedded concern about their immediate environs.

Our community interventions take place under the Community-based Territory Conservation Program (CTCP),<sup>14</sup> conceptualized and materialized by Dr. A. Caselli and a multidisciplinary core team from the Schools of Veterinary Medicine and Exact Sciences, UNICEN. The program's focus is on wetlands at risk from anthropogenic actions, including but not limited to unsustainable hunting. Wetlands are used as open classrooms to develop ecological literacy, thus positively reinforcing community ownership and enabling explicit participatory and community-driven interventions to halt pollution and biodiversity loss (Caselli et al. 2018).

### CONCLUSIONS AND RECOMMENDATIONS

Waterfowl hunting in Argentina is a profitable industry that attracts hunters from all over the world. Most hunting occurs as high-end hunting tourism, through which registered outfitters service predominantly foreign clients on private lands. Lead pollution from hunting ammunition is increasingly recognized as a significant local problem, impacting wildlife, aquatic and terrestrial habitats, and extending to vulnerable human rural communities. Regulatory frameworks that restrict lead shot use are a budding

success story but remain challenged by their constrained geographic range and limited compliance rooted in unavailable nontoxic ammunition. It is therefore of the highest priority to:

1. Grant state policy status to halting lead toxicity from spent ammunition. Recent inclusion of this issue in a national law for biodiversity protection to be soon submitted to Congress is hopeful progress.
2. Enable and expedite importation of nontoxic ammunition or bulk steel pellets to facilitate cartridge manufacture in Argentina. Alternatives to lead ammunition are urgently needed in the local market to validate existing regulatory efforts.
3. Encourage and entice local manufacture of nontoxic ammunition. Once available at reasonable cost, regulations could be expanded beyond current habitat and provincial boundaries.
4. Act on the recommendation of the Federal Council for the Environment (COFEMA) to prioritize replacement of lead ammunition nationwide. Convene provincial governments to define courses of action and the terms for transition in each jurisdiction.
5. Through provincial administrations, launch awareness campaigns targeting sport hunting associations and hunters. Make local efforts to ban lead shot and existing regulations well known to foreign hunters visiting Argentina. Locally, provide evidence that counters unfounded myths on non-lead shot performance.
6. Integrate the public health sector in efforts to ban lead ammunition. Increase awareness on ill-effects to human health through dietary intake and the need to avoid exposure through all pathways, particularly in children.
7. Expand, deepen, and communicate research on lead pollution at all scales through a One Health approach, extending to human health, environment, wildlife, and agriculture sectors.
8. Reinforce interdisciplinary and participatory forums where local characteristics of lead-ammunition pollution and substitution are explored and adequately addressed to facilitate behavior change.
9. Empower local communities to act on behalf of their environmental concerns and address threats like lead pollution and biodiversity loss in their immediate surroundings, driving policy change from the bottom-up.
10. Inform the general public. Stress availability of solutions and remediation via lead-ammunition bans and timely transition to sustainable and nontoxic options.

<sup>14</sup> <https://www.custodiosdelterritorio.com.ar/>.

In the specific context of Argentina, where hunting is minimally for subsistence and largely for sport, lead pollution stands out as a uniquely accessible and remediable environmental problem. This is one issue for which there is a known solution with proven chances of success if constituents understand the risks at stake and are willing to contribute individually to the collective wellbeing by switching to nontoxic options. Moreover, the recommended shift is neither opposed to progress and economic gain, nor does it disagree with the needs and livelihoods of the main constituents, since hunting itself is not contested, but rather urged to adapt to current societal, bioethical, and sustainability standards (Kanstrup et al. 2018). Changes in hunting practices in Argentina are long overdue.

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