

# Lead poisoning in wild birds from southern Spain: A comparative study of wetland areas and species affected, and trends over time

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## Abstract

We studied lead (Pb) shot contamination in sediments from the Guadalquivir marshes and six other closed-basin lagoons in Southern Spain that are of major importance for threatened species of waterbirds. Shot densities were relatively low in Doñana, ranging from 0 to 25 shot/m<sup>2</sup> in the top 10 cm of sediments. The density at Medina lagoon (Ramsar site) was 148 shot/m<sup>2</sup>, making it the most contaminated wetland known in Europe. Densities in the other five lagoons ranged from 9 to 59 shot/m<sup>2</sup>. We studied the prevalence of ingested Pb shot in waterbirds from Doñana and found a lower prevalence in ducks than previously recorded in other Spanish wetlands. Lead shot were also found embedded in tissues of some waterbirds, proving that protected species such as the greater flamingo (*Phoenicopterus ruber*) and the glossy ibis (*Plegadis falcinellus*) are subjected to illegal hunting. The prevalence of embedded shot for geese was especially high (44% for trapped birds). Lead shot were detected in 2.8% of the pellets of the Spanish imperial eagle (*Aquila adalberti*) which usually preys on geese. We found that the prevalence of ingested Pb shot in geese and in Spanish imperial eagles has significantly decreased in recent years, possibly due to restrictions on hunting activity, efforts to remove shot from a sand dune used by geese to obtain grit, and to the high rainfall in Doñana during the last years that permitted waterfowl to stay more within the protected areas.

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## 1. Introduction

Wetlands in Andalusia (Southern Spain) are hugely important for migratory and sedentary waterbirds (Martí and del Moral, 2002, 2003) and are also important breeding areas for other birds such as raptors. The largest of these wetlands are the Guadalquivir Marshes (also known as Doñana, with a total area of 230,000 ha), but there are also several small lagoons of great interest for threatened waterfowl like the white headed duck (*Oxyura leucocephala*) and the crested coot (*Fulica cristata*) (Martí and del Moral, 2003). Doñana is one of the most important sites for wintering waterfowl in the Western Palearctic (Scott and Rose, 1996), with maximum counts of 82,000 greylag geese (*Anser anser*) in 1985 and 500,000 ducks in 1992 (Estación Biológica de Doñana, unpublished data).

This abundance of waterfowl has been exploited by hunters, leading to the spread of lead (Pb) shot pellets in these wetlands and consequent risk of Pb poisoning in birds (Mateo et al., 1998, 2000a, 2001a). In the Doñana National Park, several hunting techniques were used in the past, before the protection of the area and the ban of hunting in 1983. Geese were shot at several points where they concentrated in a predictable manner, especially at the Cerro de los Ánsares (goose hill), which is the largest sand dune in the Park. Hunting there from permanent blinds led to the accumulation of 16.2 shot/m<sup>2</sup> in the upper 20 cm of sand in 1997 (Mateo et al., 2000a). Ducks were hunted by following flocks on horseback with a large gun capable of shooting a particularly high number of pellets. The horse served as a support for the gun while shooting and also as a mobile hide. This type of hunting produced a more diffuse contamination of Pb shot in the marshes. As in other Spanish Mediterranean wetlands, ducks were also hunted from blinds around the deepest and most permanent areas

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(called “Lucios”) of the Doñana marshes. However, previous studies of shot densities suggest that this type of hunting had a relatively low intensity in Doñana (Mateo et al., 1998).

Use of Pb shot for waterfowl hunting has been illegal in Andalusia since 2002, although it is unclear to what extent hunters have respected this ban. The Pb shot pellets accumulated in wetlands are ingested by waterfowl such as the greylag goose, causing prevalences around 10% and Pb poisoning to be a major cause of mortality in geese studied in Doñana before 2001 (Mateo et al., 1998). Other waterbirds have also previously been shown to be affected by Pb poisoning in Doñana: Pb poisoning killed 22 greater flamingos (*Phoenicopterus ruber*) in 1991 (Ramo et al., 1992), and Pb shot ingestion was recorded in 7.4% of purple gallinules (*Porphyrio porphyrio*) (Rodríguez and Hiraldo, 1975). The use of Pb shot for waterfowl hunting in Doñana also has an impact on raptors. Spanish imperial eagles (*Aquila adalberti*) and red kites (*Milvus milvus*) regularly ingest Pb shot embedded in the flesh of their prey (Mateo et al., 2001a), and high Pb bone levels ( $> 50 \mu\text{g/g}$  d.w.) have been detected in Spanish imperial eagles (Pain et al., 2005).

Here, we present a study of Pb shot densities in some of the most important wetlands in Andalusia, both in and outside the Doñana area. We assess the prevalence of Pb shot in a range of waterbird and raptor species from Doñana, most of which have not previously been studied. Finally, we establish the trends of Pb shot ingestion in recent years for geese and raptors in Doñana, and consider how they are related to annual variation in the flooding pattern in the marshes and to the recent hunting restrictions.

## 2. Methods

### 2.1. Pb shot densities in sediments

Pb shot density was studied in various Andalusian wetlands between 2001 and 2003 (Fig. 1). Within the strictly protected Doñana National Park (54,252 ha) where hunting has been illegal since 1983, samples were taken at the Laguna de Santa Olalla (a permanent brackish lagoon) and Lucio de Marilópez (seasonal, brackish lagoon). Two areas where hunting still occurs were sampled in the neighboring Doñana National Park (53,835 ha): Lucio del Italiano in Veta la Palma (seasonal lagoon transformed into managed hunting ponds) and Salinas de Santa Teresa y San Carlos in Sanlúcar (four salt ponds dedicated to salt production, three of which have been abandoned). Four oxbows within the Brazo del Este Natural Area (1336 ha) were also sampled. Hunting was banned in the Brazo del Este (one of three original branches of the Guadalquivir River) in 1989, but illegal hunting continues there.

Outside the Doñana area, Pb shot were sampled in five complexes of closed-basin, semipermanent lagoons where waterfowl hunting was commonplace before their protection as Natural Reserves in 1987–1989. In Cádiz province we studied Salada de Zorrilla lagoon (19 ha) in the Espera complex, Salada (27 ha) and Chica (8 ha) lagoons in the Puerto de Santa María complex, Jeli lagoon (24 ha) from the Chiclana complex, and Medina lagoon (108 ha). We also studied Taraje lagoon (7.5 ha) in Sevilla province. Doñana National Park, Medina lagoon, and Salada de Puerto de Santa María lagoon are also protected as wetlands of international importance under the Ramsar Convention (Bernués, 1998). The other

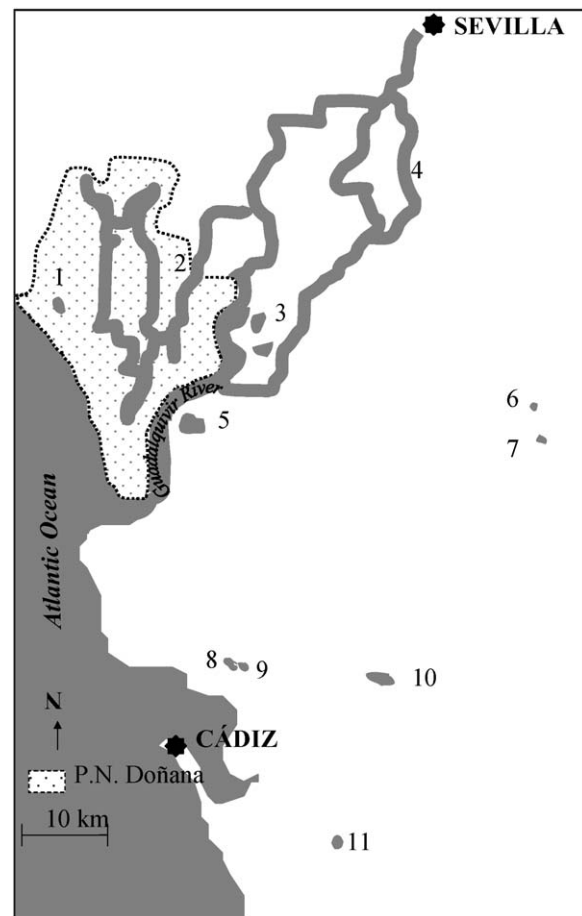


Fig. 1. Map of the study area with sampling sites for Pb shot densities in sediments. 1, Santa Olalla; 2, Lucio de Marilópez; 3, Veta la Palma; 4, Brazo del Este; 5, Salinas de Sanlúcar; 6, Taraje de Sevilla; 7, Zorrilla de Espera; 8, Salada del Puerto; 9, Chica del Puerto; 10, Medina; 11, Jeli de Chiclana. P.N. Doñana = Doñana National Park.

wetlands studied are likely to be designated as Ramsar sites in the near future.

Sediment samples were collected from points spaced along transects with a PVC corer of 10 cm diameter for soft sediments or with a metal corer of 6 cm of diameter for harder ones. In the latter case, three subsamples were collected at each point to approach the same surface area sampled with the PVC corer, and densities were calculated as Pb shot pellets/m<sup>2</sup>. Samples were taken by wading along transects from the bank toward the deepest central area. When information on the position of blinds used by hunters was available (Santa Olalla and Salinas de Sanlúcar), transects included the areas most likely to be contaminated by shot. The number of transects and samples collected on each varied between wetlands according to their surface area and depth profile (Table 1).

The depth of sediments sampled was 10 cm, and densities were studied for the 0–5 and 5–10 cm fractions separately. At Medina lagoon, which showed the highest Pb shot densities, an additional more detailed sampling was done to 30 cm depth to establish the viability of potential cleaning operations. When possible, sediment samples were sieved through a 1-mm mesh and Pb shot pellets were counted. The surface of shot pellets was scratched to confirm that they were Pb and not steel shot. After sieving, grit particles were retrieved, dried, and weighed in fractions of 1–2, 2–3, 3–4, and  $> 4$  mm diameter in 10% of the samples. Samples composed of clay that was difficult to sieve were studied by X-ray to establish the presence of Pb shot.

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