Lead Shot Densities in a Site of Grit Ingestion for Greylag Geese Anser anser in Doñana (Spain)

Rafael Mateo1,*, Andreu Bonet2, Joan Carles Dols3 & Raimon Guitart4
1Laboratory of Toxicology, Faculty of Veterinary, Autonomous University of Barcelona, 08193 Bellaterra, Spain. 2Department of Ecology, University of Alacant, PO. Box 99, 03080 Alacant, Spain. 3Conselleria de Medi Ambient, Generalitat Valenciana, Churrucu 29, 03071 Alacant, Spain. *e-mail: Rafael.Mateo@uab.es

SUMMARY

Cerro de los Ánsares is a mobile dune in the Doñana National Park where wintering greylag geese (Anser anser) fly every morning to ingest grit. Hunting was allowed until 1983, generating accumulation of lead shot in the dune. We studied shot density in Cerro de los Ánsares by two methods, one on the surface by visual examination of squares of 1 m² to ingest grit. Hunting was allowed until 1983, generating accumulation of lead shot in the dune. We studied shot density in Cerro de los Ánsares  mediante dos métodos, uno sobre la superficie estuvo alrededor de 5 perdigones/m² (n=100), y otro tomando columnas de arena de 20 cm de profundidad (n=100). Dichas columnas fueron cribadas en dos porciones correspondientes a profundidades de 0-10 cm y 10-20 cm. La densidad de perdigones sobre la superficie estuvo alrededor de 3 shot/m², pero rose a 16.2 shot/m² en el 20 cm column. Shot density was higher near the base of the dune than near the crest. This could be explained by the movement of the dune, which leaves behind shot pellets, or by a higher grit search and consequently shot ingestion by greylag geese near the crest of the dune because it is safer than the base. Grit found in the gizzard of greylag geese hunted in the Guadalquivir Marshes around Doñana National Park had more particles >1.5 mm than the sand of Cerro de los Ánsares. This can be explained by an active selection by the gese of the largest particles, where shot are included, or by a higher retention of these particles in the gizzard. Lead shot (26 kg/ha) should be extracted from Cerro de los Ánsares, by manual or mechanical methods, to reduce lead poisoning in Greylag geese in Doñana.

Keywords: Lead, shot, grit, greylag goose, Doñana.

RESUMEN

El Cerro de los Ánsares es una duna móvil del Parque Nacional de Doñana donde los ánsares comunes (Anser anser) inviernantes acuden cada mañana para ingerir gastrolitos. La caza fue permitida allí hasta 1983, generando una acumulación de perdigones de plomo en la duna. Hemos estudiado la densidad de perdigones en el Cerro de los Ánsares mediante dos métodos, uno sobre la superficie por examen visual de cuadros de 1 m² (n=100), y otro tomando columnas de arena de 20 cm de profundidad (n=100). Dichas columnas fueron cribadas en dos porciones correspondientes a profundidades de 0-10 cm y 10-20 cm. La densidad de perdigones sobre la superficie estuvo alrededor de 5 perdigones/m², pero alcanzó los 16,2 perdigones/m² en el total de los 20 cm de profundidad. La densidad de perdigones fue mayor cerca de la base de la duna que en las zonas cercanas a la cresta. Esto puede ser debido al movimiento de la duna, que deja los perdigones atrás, o a una mayor búsqueda de gastrolitos y consecuentemente de ingestión de perdigones por parte de los ánsares comunes cerca la cresta de la duna por ser un lugar más seguro que la base. Los gastrolitos encontrados en la molleja de ánsares comunes cazados en las Marismas del Guadalquivir, en el entorno del Parque Nacional de Doñana, correspondieron a partículas >1,5 mm en mayor proporción que en la arena presente en el Cerro de los Ánsares. Esto puede ser debido a una selección activa por parte de los ánsares comunes de estas partículas más grandes, donde se incluyen los perdigones, o a una mayor retención de estas partículas en la molleja. Una solución adecuada para la intoxicación por plomo en el ánsar común en Doñana sería la extracción de los perdigones de plomo (26 kg/ha) del Cerro de los Ánsares mediante métodos manuales o mecánicos.

Palabras clave: Plomo, perdigón, gastrolitos, ánser común, Doñana.

INTRODUCTION

The first report of lead poisoning in the Guadalquivir Marshes (Spain), also known as Doñana, was an epizootic outbreak of greater flamingos (Phoenicopterus ruber) that appeared in Lucio de Marílópez in 1991 (Ramó et al., 1992). Later, ingestion of lead shot was detected in 10% of 20 greylag geese (Anser anser) shot by hunters (Mateo et al., 1998). Moreover, 28% of 46 greylag geese found dead had ingested lead shot, and most of them (20%) died by lead poisoning according to necropsy findings. Lead poisoning was the second leading cause of death in this sample, after hunting injuries (Mateo et al., 1998). The prevalence of lead shot ingestion in greylag species from North America is usually below 10% (Sanderson and Bellrose, 1986; DeStefano et al., 1991), and the prevalence in greylag geese in the United Kingdom is 7.1% (Mudge, 1983). We also found a lead poisoned Northern pintail (Anas acuta) in the Guadalquivir marshes (Mateo et al., 1998), which is one of the species most affected by lead poisoning in the Palearctic flyway (Pain, 1991; Mateo et al., 1997).

Lead shot densities in sediment of two zones of the Guadalquivir Marshes, Lucio de Caraviruelas lagoon and Hato Blanco rice fields were 14 shot/m² and <1 shot/m² in the upper 15 cm respectively (Mateo et al., 1998). These densities were lower than those described in other Spanish wetlands such as the Natural Parks of the Ebro Delta, L’Albufera de València or El Fondo, where there are as many as 163-300 shot/m² (Bonet et al., 1995; Mateo et al., 1997, 1998). In another wetland, Tablas de Daimiel National Park, where hunting has been banned since 1965, approximately 100 shot/m² remain in the upper 20 cm of sediment (Mateo et al., 1998).

Although lead shot densities as low as 0.7 shot/m² were enough to produce massive mortalities in Canada Geese in Colorado (Szyczk and Adrian, 1978), high rates of lead shot ingestion in greylag geese in the
Guadalquivir Marshes could be better explained by the accumulation of shot in a dune called Cerro de los Ánsares (“Geese’s Hill”) rather than in flooded areas. Large flocks of greylag geese wintering in the Guadalquivir Marshes fly to this dune to ingest grit every morning (Sánchez et al., 1977). Hunters exploited this behaviour to shoot the geese, an activity that has resulted in an accumulation of lead shot pellets at this site. The purpose of this study was to improve the knowledge available (Calderón et al., 1996) about density and distribution of lead shot pellets in this gritting site for geese. This information can be essential when it comes to applying measures to alleviate lead poisoning in greylag geese in the Guadalquivir Marshes.

**Material and Methods**

Cerro de los Ánsares is a mobile dune located in the southern part of the Doñana National Park and is one of the furthest inland eolian dunes of a system which covers an area 30 km long and 3-5 km wide and migrates from the Atlantic Ocean towards the marsh (Llamas, 1990). These dunes have an average speed of 5-6 m/year and their shape is flattened on the side toward the sea but more abrupt on the side toward the land (García-Novio et al., 1976). We studied lead shot densities on the sea side or tail of the dune with two methods on February 1997, one on the surface and another up to 20 cm of depth. Densities on the surface of the dune were studied by counting shot in 100 squares of 1 m² which were located on a grid of 20x20 m and covered an area of 3.24 ha. Core samples of 20 cm of depth were collected with a PVC tube of 11.9 cm of diameter in the NE corner outside each square. The number of shot on the surface of each core was noted. These samples were divided in two parts of 0-10 cm and 10-20 cm of depth and were filtered with water across a sieve of 1 mm of mesh size. Shot were weighed. All the sand particles retained in the sieve were pooled, dried, and sorted with sieves of 4, 3, 2, 1.5, 1 and 0.5 mm of mesh size.

**Table 1. Shot densities (shot/m²) estimated in the mobile dune Cerro de los Ánsares using two methods.**

<table>
<thead>
<tr>
<th>Depth</th>
<th>Method</th>
<th>Shot found</th>
<th>Mean ± s.e.</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface</td>
<td>Square</td>
<td>474</td>
<td>4.7 ± 0.9</td>
<td>0-46</td>
</tr>
<tr>
<td>Surface</td>
<td>Core</td>
<td>6</td>
<td>5.4 ± 2.5</td>
<td>0-180</td>
</tr>
<tr>
<td>0-10 cm</td>
<td>Core</td>
<td>8</td>
<td>7.2 ± 2.8</td>
<td>0-180</td>
</tr>
<tr>
<td>10-20 cm</td>
<td>Core</td>
<td>4</td>
<td>3.6 ± 1.8</td>
<td>0-90</td>
</tr>
<tr>
<td>Surface-20cm</td>
<td>Core</td>
<td>18</td>
<td>16.2 ± 3.9</td>
<td>0-180</td>
</tr>
</tbody>
</table>

*Arithmetic mean ± standard error

*Excluding the surface

Figure 1: Map of shot densities (shot/m²) in Cerro de los Ánsares made with the ordinary kriging method.

We used ordinary kriging to map lead shot densities on the surface. This best linear unbiased estimator method uses spatial linear interpolation by means of autocovariance matrix applied to the grid of data to minimize the variance of the errors (Isaak and Srivastava, 1989). Graphics have been softened with an algorithm that assumes linear variograms generated by the data obtained in two axes of coordinates (Bonet et al., 1995).

We studied the distribution of shot densities on the surface of the dune, with transects (n=10) and height of the dune (n=10) as class factors of a general linear model. In order to stabilize variances, shot number was transformed to the square root of its sum with 3/8 (Zar, 1996). Shot distribution in depth was also studied using the data obtained in core sampling by including this factor (0-10 cm and 10-20 cm) in the model. The Mann-Whitney test was used to compare the weights of lead shot collected by the square and core methods.

**Results**

Mean shot density on the surface obtained with both square and core methods was about 5 shot/m². However, most of the shot were buried (Table 1). According to the square method, higher densities appeared in the eastern half of the studied area, but differences among perpendicular transects to the crest of the dune were not statistically significant (Figure 1). However, there were significant differences related to the height (F<sub>9,81</sub> = 3.49, p=0.001), with the highest densities found on the base or tail of the dune (Figure 1). We also found this trend with the core sampling (Figure 2), but differences among heights were not significant (p=0.053). With this
method, shot densities were higher in 0-10 cm of depth than in 10-20 cm ($F_{1,171} = 5.32, p = 0.022$). Moreover, there was a significant interaction between depth and height of the dune ($F_{9,171} = 2.28, p = 0.020$). In fact, shot present in the top 10 cm of sand were more abundant in the lower half of the dune (92.3%) than in the upper half (40%) (Figure 2).

Lead shot found with the square method, on the surface, weighed less ($n = 398$, median = 0.138 g, range = 0.052-1.280 g) than those found with the core ($n = 12$, median = 0.185, range = 0.114-0.343 g, Mann-Whitney, $Z = 2.28, p = 0.023$).

Granulometric analysis showed that particles larger than 1.5 mm were 4.2% of the weight of sand larger than 1 mm in the dune, while in the gizzards of greylag geese they were about 62.0% of the weight of grit larger than 1 mm (Figure 3).

**DISCUSSION**

Shot distribution in the dune is similar to that reported by Calderón *et al.* (1996), but densities described by us were higher (Table 2). These authors also found that more than 50% of shot were buried in the sand. The higher shot density on the surface of the tail of the dune may have been caused by the movement of this eolic system of dunes. Considering that hunting in Cerro de los Ánarees has been banned since 1983 and the average speed of this dune system is about 5-6 m/year (García-Novato *et al.*, 1976), it seems normal to find the highest densities more than 200 m behind the present crest. There can be another factor, such as a higher grit and shot ingestion by greylag goose near the crest of the dune, because it is safer than closer to the base. It could also explain the lower presence of shot on the surface of the higher half (Figure 2). Wintering census of greylag goose in Doñana range from 40,000 to 80,000 (Sánchez *et al.*, 1977; Troya and Bernués, 1990). If we assume that 10% of them have one shot in the gizzard (Mateo *et al.*, 1998), and considering the persistence of shot in the gizzard as 21 days (Bellrose, 1959), and the length of the wintering season of 4 months (Sánchez *et al.*, 1977), therefore we can estimate the ingestion of 23,000-46,000 shot every year by the wintering greylag goose, which may be a significant percentage of the shot on the surface at some parts of the dune. A better knowledge of the number of geese and their frequency of visits to Cerro de los Ánarees would be necessary.

The total density in the upper 20 cm of Cerro de los Ánarees was lower than those found in other Spanish wetlands (Guiralt *et al.*, 1994; Bonet *et al.*, 1995; Mateo *et al.*, 1997, 1998), but was quite similar to the density observed in a lagoon of the Guadalquivir Marshes (Mateo *et al.*, 1998). However, in Cerro de los Ánarees shot are easily available to greylag geese because their abundance on the surface. There could be an additional risk if the geese visually select grit particles. In fact, large grit was more abundant in the gizzard of geese than would be expected from its availability in the sand of the dune. This could be a consequence of a visual selection of these largest particles, similar in size to shot, but it could be also a result of a higher retention of these particles in the gizzard.

One method recommended to reduce shot ingestion is supplementation with suitable grit (Mudge, 1992), but experimental studies would be necessary to assess its usefulness. In other cases of lead shot ingestion by upland game birds, a case similar to the geese in this site of grit ingestion, the tillage of soil can reduce the availability of shot for birds (Kendall *et al.*, 1996). However, this measure may not be appropriate in a mobile dune.
The weight (mean ± s.e.) of shot found was 0.161 ± 0.086 g, thus we can estimate a mean of 26.1 ± 13.9 kg of Pb/ha in the upper 20 cm of sand of the study zone. The length of Cerro de los Ánsares is about 7 km, but the length hunted was only 3 km. If we assume a dispersion of shot 250 m around the hunting blinds (Mudge, 1984), the total hunting area of Cerro de los Ánsares was about 150 ha. We can estimate therefore an accumulation of 1.8-6 t of Pb in the upper 20 cm of sand. Lead on the surface of shot is transformed into a crust of sulfates and carbonates, leading to the total disintegration of shot in 30-300 years (Jørgensen and Willems, 1987; Lin et al., 1995). The shot collected in Cerro de los Ánsares showed a certain degree of erosion because #4 shot employed to hunt greylag geese usually weighs 0.21-0.24 g (Anonymous, 1991), and collected shot weighed about 0.16 g. Those shot found on the surface showed clear signs of erosion, possibly produced by sand moved by wind. Bioavailability of eroded lead depends on acidic pH of soil, which increases the absorption of lead by plants, and the presence of clay particles or organic material, which adsorb lead and reduce its uptake by plants (W.H.O., 1989; Pain, 1993). Although sandy soil of dunes is not rich in organic matter and clay, the groundwater in these dunes is rich in calcium bicarbonates (Llamas, 1990) and it could limit the lead uptake by plants. However, greylag geese that have ingested lead shot or have been injured by hunters with lead ammunition are a risk to food chains in Doñana (Mateo et al., 1997), because this species is one of the main prey of the endangered Spanish imperial eagle (Aquila adalberti Brehm, 1861) in winter (González, 1991).

Calderón et al. (1996) reported that three people collected 800 shot during 30 minutes in the part of the dune with highest density. A person could collect by hand 533 shot/h, thus 94 h/ha would be necessary to clean only those shot accumulated on the surface (50,000 shot/ha). However, most of the shot are buried, and specialized machinery designed to collect shot in shooting ranges should be employed to clean Cerro de los Ánsares. This machinery is expensive, but it should not deter the public administrations and hunting or shooting associations to employ this machinery here or at similar sites where accumulated lead shot represents a threat to wildlife or agriculture in Spain or elsewhere.

ACKNOWLEDGEMENTS

We wish to thank the personnel of the National Park of Doñana, in special to Dr. Manuel Mátiz and Antonio J. González, their help in the collection of samples, to Cristina Beans the revision of the English language and to Dr. Pedro Puig his help in the statistical analysis. We must also give thanks to Isidro Barroso from the Doñana Natural Park and to the Doñana Biological Station for their logistic support. We thank Dr. Nelson Beyer his comments to the manuscript.

REFERENCES

Mudge, G.P. 1984. Densities and settlement rates of spent shotgun pellets in British wetland soils. Environmental Pollution