

Lead Shot Concentrations in and Adjacent to Fields Managed for Mourning Doves and Effects of Tillage on Shot Concentrations in Tangipahoa Parish, Louisiana

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Abstract: Concentrating hunters on dove fields could place mourning doves (*Zenaida macroura*) and other ground foraging birds at risk of lead poisoning. We collected soil samples during three time periods (pre-soil disturbance [i.e., disking], post-soil disturbance [disking, roller harrow, planting], and post-hunting / field preparation [i.e., mowing, raking, burning]) to determine if soil disturbance reduced the amount of lead shot potentially available to ground foraging birds in managed dove fields. We also collected soil samples in the woods adjacent to these fields. Disking and site preparation did not have an impact on the number or the mass of lead pellets found on the soil surface and to a depth of 1 cm within the dove fields. More lead pellets were collected in the soil samples in the woods adjacent to dove fields than were collected in the dove fields. Lead concentration in the woods with respect to both number and mass did not differ by sampling period for the soil surface or to a depth of 1 cm. There was more shot found to a depth of 1 cm in the woods in year 2 than year 1 of the study. Deposition of lead pellets in wooded areas adjacent to fields managed for dove hunting could pose as big a risk to birds and other wildlife feeding in these areas as to birds feeding within dove fields.

Key words: mourning dove, *Zenaida macroura*, lead deposition, disk, field

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Lead has long been recognized as a poison to vertebrates with negative effects on general health, reproduction, behavior, and potentially leading to death (Fisher et al. 2006). Between 1987 and 1991 the use of lead shot for waterfowl was phased out in the United States after research (Bellrose 1951, 1953; Friend 2009) concluded that the use of lead shot during hunting caused significant toxicity to these birds (USFWS 1988) and other wildlife. Since this nationwide ban, there has been a growth in acute and chronic lead toxicosis concerns for upland game birds as well as non-game avian species due to the continued use of lead shot for recreational and hunting activities (Kendall et al. 1996, Pain et al. 2009).

Concentration of hunters on fields managed for doves typically results in a considerable amount of spent lead shot being released into the environment each year (Castrale 1989, Best et al. 1992, Schulz et al. 2002). Lead shot ingestion rates by mourning doves (*Zenaida macroura*) typically range from 0.2% to 6.5% (Schulz et al. 2002, Kendall et al. 1996) with liver, bone and kidney analysis revealing considerably higher lead exposure rates, up to 26.8% (Kendall and Scanlon 1979, Best et al. 1992, Franson et al. 2009).

Lead shot deposition in and around managed dove fields is likely to impact a variety of wildlife species in addition to mourning doves. For example, Lewis et al. (2001) revealed that 33% of birds and mammals collected near a shooting range had elevated lead levels and Labare et al. (2004) demonstrated elevated con-

centrations of lead in earthworms collected at a small-arms firing range. Gallinaceous birds, including northern bobwhite (*Colinus virginianus*) and eastern wild turkey (*Meleagris gallopavo silvestris*), raptors, and passerines have all been shown to have elevated lead levels due to lead shot and/or contain lead shot in their gizzards (Kendall et al. 1996, Lewis et al. 2001, Pain et al. 2009).

The Louisiana Department of Wildlife and Fisheries, like many other state management agencies, provides managed shooting fields focused primarily on attracting and concentrating doves for hunting opportunities. With large amounts of lead shot being deposited in and around dove fields, concerns have arisen about the impact of lead shot on mourning doves as well as other wildlife species. Although studies have examined lead shot concentration in fields managed for doves, we are aware of no published studies examining lead shot on the soil surface. Further, most, but not all, previous studies on lead shot in dove fields have occurred on fields managed for doves for a relatively short period of time (i.e., <10 years). Our objectives were to identify and quantify spent shot on both the soil surface and in the upper layers of the soil column of four dove fields that had been managed for ≥ 17 years and the woods immediately adjacent to these fields at Sandy Hollow Wildlife Management Area (SHWMA) in Hammond, Louisiana. We also wanted to examine the effects of disking, mowing, raking, and burning on shot concentrations in these fields over time.

Study Area

SHWMA is located approximately 30 km northeast of Hammond, Louisiana, in Tangipahoa Parish. The area is divided into two tracts: one north of LA Highway 10 and west of LA Highway 1061, and the other south of LA Highway 10 and west of LA Highway 1061. Comprised of rolling hills with a few stream bottom hardwood zones, the area is mostly longleaf pines (*Pinus palustris*) with only a small portion having mature trees due to the extensive cutting that took place in the mid-1980s. The WMA is primarily managed for northern bobwhite.

Our study was conducted on four fields managed for mourning dove hunting. Soils at our study sites consisted of Tangi-Ruston-Smithdale: moderately well drained and well drained soils that have a loamy surface layer and a loamy and clayey subsoil (Natural Resource Conservation Service 2016). Fields were 2, 4, 5, and 7 ha in size, three of which had been established 26 years and one 17 years prior to the initiation of this study. Fields were far enough apart (range 1,500–5,600 m) and separated by woods so that shot fired would not reach from one field to the next. Each field was managed annually for mourning dove harvest. The fields are prepared by being sprayed in April with an herbicide (glyphosate), and then disked once to an approximate depth of 15 cm, roller harrowed, planted, fertilized, and roller harrowed again. Early brown top millet (*Urochloa ramosa*) (BTM) is planted in half of each field the first week of May at a rate of 4.5 kg ha⁻¹ and accompanied by 46 kg ha⁻¹ of 13-13-13 fertilizer. The other half is planted with BTM the first week of June with the same preparation. Following seed maturation, the fields are mowed, raked, and burned two weeks prior to opening of dove season. All management practices are completed by mid-August and have been conducted in this manner for at least a decade.

Methods

To quantify the amount of lead shot present in the soil, samples were collected in both 2013 and 2014 using some methods similar to those used by Lewis and Legler (1968), Castrale (1989), and Best et al. (1992). A 30.5 × 30.5 cm plot was used as a guide to determine the edges of the sample plot. The 30.5 × 30.5 cm plot was placed on the bare soil and a trench approximately 5-cm deep was dug around it (Schulz et al. 2002). Soil samples were then taken by either scraping the top layer of soil with a garden trowel, being careful not to dig down into the soil, or collecting all soil to a depth of 1 cm using a 17-cm wide flat head shovel. Each sample was individually bagged. Throughout each field, six random samples were taken of the top scraping and six random samples were taken at the 1-cm depth for a total of 12 samples from each field. The woods directly abutting each field were also sampled by the same process, with the

exception of leaf litter being carefully removed from the plot prior to sampling ensuring no shot that may have been on the leaf litter was removed from the plot. A total of 12 samples were taken from each of the adjacent wooded areas. Samples taken from the woods were gathered within 5–20 m of the field edge.

Samples were collected three times per year. First round (Period 1) samples were gathered during March before management practices had taken place. Second round (Period 2) samples were collected during June at the completion of most management practices, specifically soil manipulation and planting but prior to hunting. Third round (Period 3) samples were collected in October which included post-mowing, raking, burning, and hunting. A total of 96 samples were collected during each sampling period.

Each soil sample was processed by rinsing the sample with high pressure water through a number 18 sieve with 1-mm mesh, U.S. Standard Sieve Series, to remove small soil particles and separate any shot and soil particles greater than 1 mm. Samples containing an abundance of leaf litter and other organic matter were first soaked in water to remove any floating organic debris. A magnet was passed through any material left in the sieve to identify steel shot. The remaining material was hand sorted to identify any lead shot present. All shot found in the samples was cataloged by the appropriate field and location from the soil column in which it was collected, then further separated into groups of toxic (lead) and nontoxic shot. All shot found was counted and weighed to the nearest 0.0001 g using an Ohaus digital scale.

Statistical analyses for this study were conducted using SAS version 9.3 (2003). Analyses were used to test for differences in the amount of spent lead shot found based on sampling depth, location, and the time of year (Period) in which the sample was taken. This was done for fields and woods separately, combining fields and woods, and also comparing lead shot found between fields and woods. A nested Analysis of Variance (ANOVA) was used to test for differences in the amount of spent lead shot found by Year (the two years of collection), Period (the three sampling rounds per year: Period 1, pre-soil manipulation; Period 2, post-soil manipulation; Period 3, post-hunt), Field (the four managed fields within the study area), Site (the field and woods sampling locations), and Depth (top and 1 cm sampling depths). Since the spent shot found were of varying size, both the mass and number of shot found (count) were used in analyses. When significant differences were found ($P \leq 0.05$), Post-hoc Tukey tests were used to show differences.

Results

A total of 576 soil samples were collected during this study. From these samples there were 348 spent lead shot found and 4 spent nontoxic (steel) shot found. Due to the low number of nontoxic

shot found, these were eliminated from analyses. The mean number of pellets per sample was 0.60 (SE 0.04). Based on the mean number of pellets collected at the soil surface, the overall estimate was 10,472 pellets ha⁻¹ and 0.71 kg ha⁻¹ for the dove fields and 34,382 pellets ha⁻¹ and 2.45 kg ha⁻¹ for the woods. The overall estimate for pellets collected to a depth of 1 cm was 62,789 pellets ha⁻¹ and 4.25 kg ha⁻¹ for the field and 152,471 pellets ha⁻¹ and 11.02 kg ha⁻¹ for the woods.

The overall model was significant for the field for both mass ($F = 3.51$, $df = 9,278$, $P = 0.0004$) and count ($F = 3.72$, $df = 9,278$, $P = 0.0002$). For both mass (Figure 1) and count (Figure 2) there was more lead to a depth of 1 cm than at the soil surface. Neither mass ($F = 0.28$, $df = 2,30$, $P = 0.76$) nor count ($F = 0.17$, $df = 2,30$, $P = 0.84$) (Figure 3) differed among sample periods for the field. No other variables differed for the field. Likewise, the overall model was significant for the woods for both mass ($F = 8.59$, $df = 9,278$, $P < 0.0001$) and count ($F = 8.80$, $df = 9,278$, $P < 0.0001$). For both

mass (Figure 1) and count (Figure 2) there was more lead to a depth of 1cm than at the soil surface. There was also a depth by year interaction for both mass ($F = 3.78$, $df = 1,20$, $P = 0.05$) and count ($F = 4.64$, $df = 1,20$, $P = 0.03$) in the woods, with a tendency for more mass and count to a depth of 1 cm in year 2 but not so in the top layer, and a year interaction for count ($F = 3.80$, $df = 1,20$, $P = 0.05$) with more pellets found in year 2. Neither mass ($F = 0.28$, $df = 2,30$, $P = 0.75$) nor count ($F = 0.19$, $df = 2,30$, $P = 0.83$) (Figure 4) differed among sample periods for the woods. No other variables differed for the woods.

The model was significant for both mass ($F = 19.67$, $df = 7,568$, $P < 0.0001$) and count ($F = 19.53$, $df = 7,568$, $P < 0.0001$) when combining fields and woods. There was greater mass and count to a depth of 1 cm than at the soil surface. There was also a greater mass and count of lead in the woods than in the fields. No other variables differed when combining fields and woods.

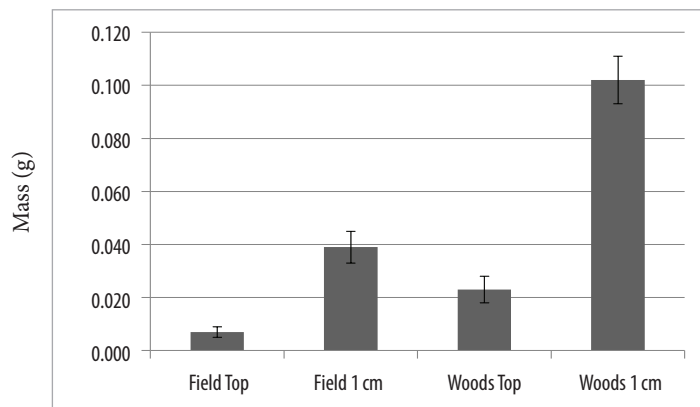


Figure 1. Mean mass (g) of spent lead pellets collected per 30.5 x 30.5-cm plot on the soil surface (Top) and to a depth of 1 cm in dove fields and the adjacent woods at SHWMA.

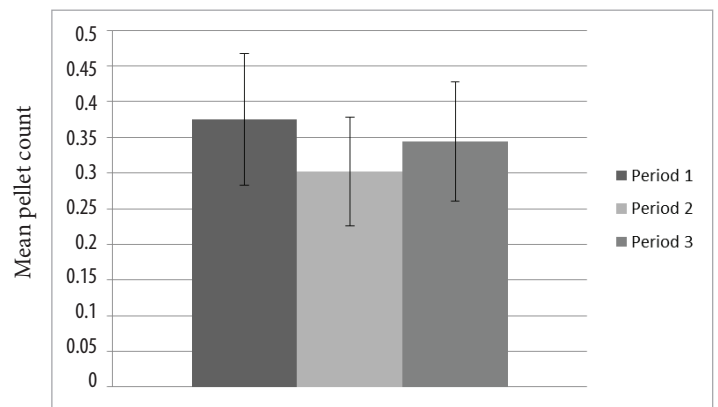


Figure 2. Mean number of spent lead pellets collected per 30.5 x 30.5-cm plot by sample period (Period 1 = pre-soil manipulation, Period 2 = post-soil manipulation, Period 3 = post-hunt) in dove fields at SHWMA.

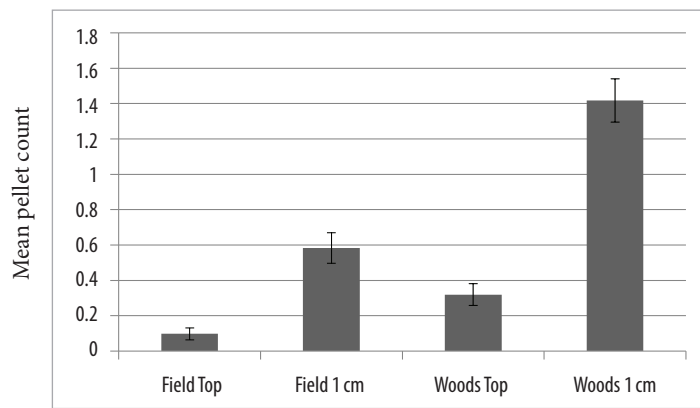


Figure 3. Mean number of spent lead pellets collected per 30.5 x 30.5-cm by sample period (Period 1 = pre-soil manipulation, Period 2 = post-soil manipulation, Period 3 = post-hunt) in woods adjacent to dove fields at SHWMA.

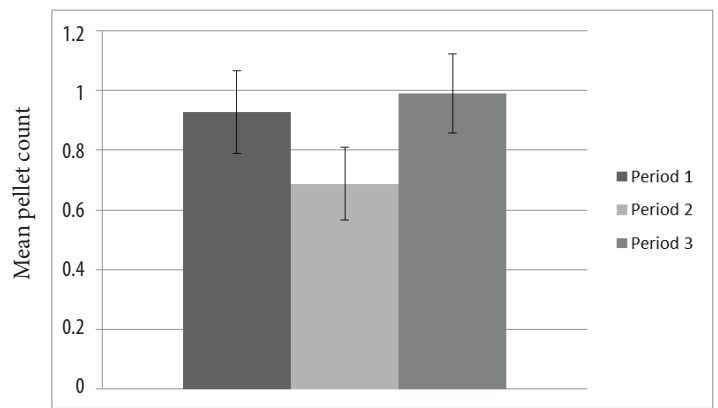


Figure 4. Mean number of spent lead pellets collected per 30.5 x 30.5-cm by sample period (Period 1 = pre-soil manipulation, Period 2 = post-soil manipulation, Period 3 = post-hunt) in woods adjacent to dove fields at SHWMA.

Discussion

Our lead shot estimates of 62,789 pellets ha⁻¹ to a depth of 1 cm are within range of what other studies have shown (Lewis and Legler 1968, Castrale 1989, Douglass et al. 2016). There was no significant difference in the amount of lead, mass or count, found among the three sampling periods, suggesting that disking and site preparation does not reduce lead shot concentrations in the dove fields at our study sites. Douglass et al. (2016) likewise did not find a reduction in lead shot with disking. However, the study by Douglass et al. (2016) did not include site preparation as did our study did. Results of our study, however, contradict those of Lewis and Legler (1968), Castrale (1989), and Schulz et al. (2002), who reported shot concentrations significantly increase after hunting activities have taken place and a decrease is seen in spent shot when fields are disked (Lewis and Legler 1968, Castrale 1989). The dove fields sampled at SHWMA had been managed for 17–26 years for public dove hunting at the initiation of this study and those by Douglass et al. (2016) had been intensively managed for dove hunting for 10 years prior to the initiation of their study. The studies by Castrale (1989) and Lewis and Legler (1968), however, were on fields that had been managed for hunting for 3–8 years prior to the initiation of their studies. We suggest that lead deposition within dove fields over an extended period of time at our study sites has resulted in enough lead accumulation in the soil column so that disking has no effect on lead concentration to a depth of 1 cm.

Unlike other studies which sampled for spent lead shot to a depth of approximately 1 cm (Lewis and Legler 1968, Anderson 1986, Castrale 1989, Best et al. 1992, Douglass et al. 2016), we also sampled the soil surface for spent shot. Mourning doves are sight feeders and do not scratch through ground litter to obtain seeds. Therefore, lead below the soil surface is not readily available to foraging mourning doves. Our study revealed 10,472 spent lead pellets per ha on the soil surface within dove fields, making these spent pellets readily available to ground foraging birds. Indeed, brown thrashers (*Toxostoma rufum*) and northern cardinals (*Cardinalis cardinalis*) collected adjacent to a shooting range (Lewis et al. 2001) and mourning doves collected from managed dove fields (Kendall and Scanlon 1979, Schultz et al. 2002, Franson et al. 2009) have been shown to have elevated lead levels. Considering that disking and dove field preparation does not result in spent lead shot being displaced from the soil surface, birds foraging on these fields are likely to be susceptible to lead poisoning throughout the year.

We found more lead shot, by mass and count, in the woods than in the field. Our dove fields were relatively small (2–7 ha) and linear, and field size and shape can affect the amount of shot that is ultimately deposited on a field (Castrale 1989) with highest concentrations of shot 100–200 m from the point the shot was fired

(Fredrickson et al. 1977). Due to the shape of the fields, most hunters hunted within 200 m of wooded areas; the average field dimensions were 144 × 231 m. Anderson (1986) reported increased shot concentrations in fencerows adjacent to the fields. These increased amounts may be due to distance and direction of shots taken by hunters. While other studies have also shown high lead shot concentrations in dove fields (e.g. Castrale 1989, Schultz et al. 2002) the lead shot concentrations in the woods adjacent to the dove fields at our study sites is concerning. Lewis et al. (2001) revealed elevated lead tissue levels in small mammals and non-game birds collected in the immediate vicinity of an outdoor shooting range. Presumably these mammals and birds were ingesting spent lead bullets and/or lead bullet fragments. Considering that many species of non-game birds occur in high abundance at forest edges (Yahner 1991, Thompson et al. 1992, Sallabanks et al. 2000) and that they likely ingest spent lead shot (Lewis et al. 2001), it is possible that lead deposition in woods adjacent to dove fields is negatively impacting a variety of wildlife.

Overall, there was more shot found in the woods in year 2 than in year 1 and there was also more shot found to a depth of 1 cm, but not the top layer, in the woods in year 2 than in year 1. The increase in shot to a depth of 1 cm in year 2 suggests that soil properties may have resulted in shot migrating downward into the soil column (Jorgensen and Willems 1987, Murray et al. 1997). Indeed, the particle size of the loamy soils at our study sites are likely to allow shot to migrate below the soil surface (Duggan and Dhawan 2007). More lead shot, by mass and count, also was found to a depth of 1 cm than at the soil surface for both the woods and fields. The volume sampled to a depth of 1 cm was greater than that sampled at the soil surface. This greater volume sampled may account for more shot being detected in the samples to a depth of 1 cm than the soil surface samples. Additionally, soil characteristics may be influencing the migration of shot into the soil column at our study sites (Jorgensen and Willems 1987, Murray et al. 1997, Duggan and Dhawan 2007). Shot appeared to be migrating downward into the soil column within the woods, there was more shot to a depth of 1 cm in year 2 than in year 1; however, this was not the case within the dove fields. Perhaps soil manipulation within the dove fields redistributed shot that may otherwise have migrated further downward into the soil column.

Management Implications

Our research has demonstrated that disking does not result in reduced lead shot concentration on the soil surface in dove fields that have been intensively managed for dove hunting ≥17 years and that lead shot concentrations can be higher in the woods adjacent to dove fields than within dove fields. Considering that lead

is known to be toxic to all vertebrate species (Mielke 1999), that many species of wildlife have been demonstrated to ingest spent lead pellets, and non-toxic alternatives to lead shot are readily available and as effective as lead for dove hunting (Pierce et al. 2015), state wildlife agencies concentrating doves and dove hunters on managed dove fields may want to consider requiring non-toxic alternatives to lead shot.

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