AVAILABILITY AND INGESTION OF LEAD SHOT BY MOURNING DOVES (*ZENAIDA MACROURA*) IN SOUTHEASTERN NEW MEXICO

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ABSTRACT—During 1987, soil samples were collected before (August) and after (October) the first dove hunting season near a stocktank in Eddy Co., New Mexico. Lead shot were recovered from 54% of 120 soil samples (30.5 by 30.5 by 1.3 cm deep) collected in August (181 shot) and from 68% of 120 soil samples collected in October (929 shot). These data provided estimates of 167,593 and 860,185 lead shot/ha in the upper 1.3 cm of soil for August and October, respectively. Examination of gizzards collected from 420 mourning doves (*Zenaida macroura*) during 1985, 1986, and 1987 revealed that only one had ingested lead shot. Analyses of livers of 250 doves revealed that nine (3.6%) contained concentrations of lead >7 ppm wet weight (range of 8 to 257). Though large amounts of lead were available for ingestion, doves had a low incidence of lead consumption.

Poisoning that results from ingestion of spent lead shot is well established as a mortality factor in waterfowl populations (Bellrose, 1959). In contrast, relatively little is known about effects or incidence of lead poisoning in mourning doves (*Zenaida macroura*; Locke and Bagley, 1967; Lewis and Legler, 1968; Kendall and Scanlon, 1979; Buerger et al., 1983, 1986; Marn et al., 1988). The increasing popularity of dove hunting, particularly in southeastern New Mexico, may result in accumulations of lead shot that could cause significant lead-poisoning of doves and other upland gamebirds. Judging by the thousands of spent shotshell casings at stocktanks on public lands in southeastern New Mexico, large numbers of lead shot may be concentrated in these areas. Because of large aggregations of doves around these water sources, hunters return year after year and add to the numbers of lead shot available for ingestion. Lead shot may be more accessible to doves than other upland gamebirds because they primarily are hunted over stocktanks and fields where they aggregate.

According to data from the New Mexico Department of Game and Fish, approximately 340,000 mourning doves were harvested in five southern counties of New Mexico during 1985: Dona Ana, 97,081; Eddy, 92,088; Lea, 81,858; Chavez, 47,000; Luna, 21,763. Hunters take five to eight shotshells to harvest one dove (Lewis and Legler, 1968), so approximately 1,700,000 to 2,720,000 shotshells were fired in these five counties during 1985. If each shotshell averaged one ounce of lead shot, then 53 to 85 tons of lead shot were deposited therein during 1985. These figures do not include accumulations of lead shot over the past 10 to 20 years or more, lead shot used to harvest quail and waterfowl, or the rest of southern New Mexico.

Because of the number of lead shot that have been deposited in areas occupied by mourning doves, numerous questions have arisen regarding the effect of lead shot on this species in southern New Mexico. The purposes of this study were to determine how many lead shot are available for ingestion and how many lead shot actually are ingested by mourning doves.

MATERIALS AND METHODS—The number of lead shot available was determined by a procedure similar to that described by Lewis and Legler (1968). Hill Tank (Eddy Co., T22S, R30E, Sec. 24) was selected as the sampling site because of its extensive use by hunters. In August 1987, before the onset of gamebird seasons, 120 soil samples were obtained at Hill Tank. An additional 120 soil samples were collected at Hill Tank in mid-October between the split dove seasons.

Soil samples were collected along six 100-m transects. Before visiting the site, an arbitrary point was selected about 30 m from the water on the north and south side of the stocktank. On the north side, three transects were placed toward the west, north, and east, and on the south side, transects were placed toward the east, south, and west. At 5-m intervals along each transect a soil sample 30.5 by 30.5 cm and 1.3 cm deep was collected using a 30.5- by 30.5- by 1.3-cm steel square to precisely measure each sample area.

Soil samples were individually numbered and stored in paper bags until processed. Contents were soaked in water and sieved through a tea-strainer with the aid of running water. Because lead and steel shot were much heavier than most of the contents of each soil sample, they were readily separated from organic matter by flotation. Initial separation of shot from gravel was accomplished by rolling the gravel and shot around in the tea-strainer in a manner similar to "panning gold." Subsequently, all of the washed gravel was examined using a dissecting microscope to assure that no shot had been overlooked. A magnet was used to determine whether shot were steel or lead; lead shot that were difficult to distinguish from other contents of soil samples were scratched with a pocket knife or examined using a dissecting microscope.

During 1985, 1986, and 1987, 420 specimens of mourning doves (*Zenaida macroura*) were collected within a 11.2-km radius of the Los Medaños Waste Isolation Pilot Plant (T22S, R31E, Sec. 20, SE¼). The study area was approximately 40 km E of Carlsbad, primarily in Eddy Co., but it also extended into western Lea Co., New Mexico. Within this 400-km² study area, specimens of doves primarily were collected at five stocktanks. Vegetation of the study area was dominated by shinnery oak (*Quercus havardii*) and honey mesquite (*Prosopis glandulosa*), and soils were sandy (Best and Smartt, 1985, 1986). The sex of each specimen was determined by examination of gonads, and age was determined using the criteria of Pearson and Moore (1940).

In 1985 and 1986, doves were collected using lead shot, and, in 1987, only steel shot was used in collecting activities. Upon collection, a tag was attached to each dove indicating time of day and precise location on the study area; sex, age, and weight were determined later. Gizzards and livers were removed and stored in plastic bags on dry or wet ice until they could be taken to the laboratory for analyses.

Gizzards collected in 1985 (85 doves), 1986 (126), and 1987 (209) were dissected, the contents were sieved through a tea-strainer, the number of lead shot in each was determined, and the lining was examined for the dark-green stain that is associated with ingestion of lead shot (Locke and Bagley, 1967; McConnell, 1968). Shot found in gizzards with holes in them were assumed to have entered the gizzards during collecting activities. A magnet was used to ascertain whether shot were steel or lead; verification of lead shot that were difficult to distinguish from other gizzard contents (e.g., seeds and rounded gravel) was accomplished as previously described.

Livers collected in 1985 (51 doves), 1986 (127), and 1987 (72) were subjected to chemical analysis similar to that described by Locke and Bagley (1967). Lead content of livers was determined by a dry-ashing technique. Livers were weighted in crucibles, dried at 100°C for 48 h, and ashed in a muffle furnace. The temperature of the furnace was raised to about 200°C and maintained until the samples ceased smoking. The temperature then was raised to 450°C and maintained for 2 h. Upon cooling, the ash was dissolved in 6M HCl with heating. The dissolved ash was filtered through acid-rinsed filters, and the filtrate was brought to a volume of 50 ml. This solution was analyzed by atomic absorption spectroscopy using an air-acetylene flame with deuterium-lamp background correction. Lead-content was determined in parts per million wet weight. Statistical analyses were performed using BioStat I (Smith and Pimentel, 1981).

RESULTS—*Soil Samples*—For soil samples collected in August, 65 of 120 (54%) contained one or more lead shot, for a total of 181 lead shot or 167,593 lead shot/ha in the upper 1.3 cm of soil. For soil samples obtained in October, 82 of 120 (68%) samples contained one or more lead shot for a total of 929 lead shot, or 860,185 lead shot/ha in the upper 1.3 cm of soil. The mean number of shot per sample was 1.5 ($SE = 0.19$, range of 0 to 10) in August and 7.7 ($SE = 5.72$, range of 0 to 688) in October. When the soil sample with 688 shot was excluded from the October sample, the mean number of lead shot recovered per sample was 1.9 ($SE = 0.22$, range of 0 to 13) with a total of 241 shot recovered. This converts to 231,731 lead shot/ha. In addition to the lead shot recovered in soil samples collected in October, four of 120 (3%) contained a total of five no. 6 steel shot.

After discovering the sample with 688 shot, we returned to Hill Tank on 18 December 1987 to examine the site where the sample had been collected. There was no evidence that the lead shot had come from a discarded shotshell. This also was supported by the occurrence of several sizes of lead shot in that sample (from no. 7½ or 8 to no. 4). However, we noticed several hundred lead shot on the surface of the ground. These were concentrated in tiny washes along the inside of the stocktank embankment. Apparently, lead shot were being transported into the tiny washes during rainstorms, then into the stocktank.

Comparison of the number of lead shot recovered from soil samples obtained in August (prehunt) and October (posthunt) revealed differences in variances between samples ($F = 927.39$, $d.f. = 119$, $P < 0.001$), but there was no difference in variances of the two samples ($F = 1.32$, $d.f. = 118$, $P = 0.06$) when the sample with 688 shot was excluded from the analyses.

Gizzard Samples—For 420 doves, 15 (3.5%) gizzards contained lead or steel shot. Except for one dove, all shot recovered were in gizzards with holes. A subadult male collected 16 October 1987 contained one no. 7½ or 8 lead shot in the gizzard; the lining of the gizzard was not discolored. We found discoloration of the lining of the gizzard in four doves, all collected in 1987. One collected 20 August had a bright-green lining, two collected 20 August had some blackish discoloration, and one collected 15 October had a dark-green lining.

Liver Samples—Nine (3.6%) of the 250 livers of doves contained concentrations of lead >7 ppm wet weight (0.4 to 7.0 ppm was considered to be normal by Bagley and Locke, 1967). These doves were collected 16 August 1985 (adult female), 21 August 1986 (adult female, subadult female), 22 August 1986 (adult male, adult of undetermined sex, adult male, adult male), 17 October 1986 (adult male), and 16 October 1987 (subadult male). Concentrations of lead in their livers were 25, 15, 100, 9, 12, 127, 257, 8, and 9 ppm, respectively. Twenty (8.0%) of the 250 livers contained lead concentrations of ≥3 ppm. The dove that contained one lead shot had a high value for lead-content in the liver (9 ppm). Lead content of livers in each sampling period is represented in Table 1.

TABLE 1—Lead content of livers (in parts per million wet weight) for mourning doves collected in southeastern New Mexico, 1985 to 1987.

Sample groups	n	$\bar{X}$	SD	Range
Among months (1985 to 1987)[1]				
August	178	3.303	22.734	0–257
October	66	0.515	1.629	0–9
December	6	0.000	0.000	
Within 1985[2]				
August	43	0.814	3.838	0–25
October	8	0.125	0.354	0–1
Within 1986[3]				
August	102	5.422	29.813	0–257
October	25	0.440	1.685	0–8
Within 1987[4]				
August	33	0.000	0.000	
October	33	0.667	1.780	0–9
December	6	0.000	0.000	
Between lead and steel shot years[5]				
1985 and 1986 (lead)	178	3.371	22.733	0–257
1987 (steel)	72	0.306	1.241	0–9

[1] F-ratio = 0.556 ($P > 0.05$).
[2] F-ratio = 0.253 ($P > 0.05$).
[3] F-ratio = 0.693 ($P > 0.05$).
[4] F-ratio = 2.705 ($P > 0.05$).
[5] F-ratio = 1.304 ($P > 0.05$).

DISCUSSION—*Soil Samples*—Bellrose (1959) reported accumulations of lead shot on 24 waterfowl hunting areas ranged from zero to 295,120/ha. In southeastern New Mexico, we found 167,593 to 860,185 lead shot/ha, which is at the upper end of the scale, even when compared to waterfowl hunting areas where huge amounts of lead shot have accumulated. Lewis and Legler (1968) collected prehunt and posthunt soil samples from a field in Tennessee with a history of 8 years of dove shooting and found 27,225 lead shot/ha before the hunt, and the posthunt sample yielded 108,900 lead shot/ha in the top 1 cm of soil. We also found a larger number of lead shot in the sample taken after the hunting season; no statistical differences existed between prehunt and posthunt soil samples due to the wide range in numbers.

In addition to lead shot recovered in soil samples collected in southeastern New Mexico during October, four of 120 soil samples contained a total of five no. 6 steel shot. Because steel shotshells are much more expensive than lead shotshells, because they are not required by law for hunting upland gamebirds, and because we used no. 6 steel shotshells to collect gamebirds, we believe the steel shot were deposited when we collected samples of doves at Hill Tank during August. In August, we collected 100 doves at Hill Tank. During that collecting trip, we averaged three shotshells per specimen collected. Thus, we shot about 300 steel shotshells while collecting at Hill Tank. Using the same ratio of shotshells to shot recovered, recovery of five steel shot indicates that it may have taken 66,600 shotshells to deposit the 1,110 lead shot recovered from the 240 soil samples. Excluding the sample with 688 lead shot, that would be 25,320 shotshells to deposit the 422 lead shot that were recovered. Lewis and Legler (1968) estimated that 16,415 shotshells were required to harvest 3,283 doves; they found that it took five to eight shotshells to harvest one dove. If their data provide a more accurate estimate of the number of shotshells required by an average hunter to collect one dove, then 42,200 to 177,600 shotshells were required to deposit the 422 to 1,110 lead shot recovered from our soil samples. This suggests that the number of shotshells expended, particularly in the vicinity of stocktanks on public lands, is enormous.

Though large numbers of lead shot are available for ingestion near stocktanks, doves primarily go there to drink and may forage comparatively little there. Our observations indicate that doves forage near the edge of water, along earthen embankments, and in adjacent pastureland. Because doves are highly mobile, they also may cover large areas in their search for food. Doves do not scratch the surface while feeding, but trampling of the area around stocktanks by livestock regularly disturbs soil to a depth of about 1.3 cm. This disturbance could bury exposed lead shot or bring it to the surface.

Gizzard Samples—Presence or absence of lead shot in gizzards of dead birds was once considered to be a reliable indicator of lead poisoning. At best, this is a very conservative estimate (Anderson and Havera, 1985). Death actually is caused by lead that has been dissolved, transformed into lead salts, and absorbed into the body (Friend, 1985). Lead shot in the gizzard is most representative of lead ingested in a period of a week or several weeks (McConnell, 1968).

McConnell (1968) found only 32% of mourning doves died after being fed lead shot. Buerger et al. (1986) found mourning doves dosed with lead shot had greater mortality than controls and those that received two or four shot had greater mortality than those dosed with one shot. None of the doves fed one lead shot by Marn et al. (1988) died, but lead-treated doves had higher concentrations of lead in their tissues than controls.

Environmental conditions may be especially important when considering lead contamination in doves because ingestion of lead shot is most probable during or after hunting seasons, which often occur during periods of environmental stress (Buerger et al., 1986). Marn et al. (1988) found that captive doves on a pelleted diet retained lead shot longer and eroded more lead than did doves on a mixed-seed diet. Doves in southeastern New Mexico have a diet most similar to the mixed-seed diet of their experimental population (Best and Smartt, 1986).

In southeastern New Mexico, we found only one dove (0.24%) that definitely had ingested a lead shot. Previous estimates of the proportion of mourning doves ingesting lead shot, as determined from gizzard analyses, have ranged from 1.0 to 6.5% (Locke and Bagley, 1967; Lewis and Legler, 1968) in Tennessee and Maryland, respectively. Because of similar or greater numbers of lead shot being available in southeastern New Mexico compared to Tennessee and Maryland, we would expect to find a similar ratio of lead shot in gizzards of doves in New Mexico. Perhaps the lower incidence of lead shot in gizzards of doves in southeastern New Mexico is a result of chance alone, higher mortality among doves that ingest lead shot, because there are fewer doves that ingest lead shot, or for some other reason. Our exclusion of 14 doves containing both shot and holes in their gizzards provides a very conservative estimate of ingestion. However, if 15 of the 420 doves had consumed shot, the incidence of lead shot in gizzards from southeastern New Mexico would be 3.6%—within the range of previous studies.

Liver Samples—Locke and Bagley (1967) described an immature mourning dove that was suffering from apparent lead-poisoning. The bird was extremely emaciated, the pectoral muscles were atrophied, and there was no subcutaneous fat. The gizzard contained two lead shot and its lining was stained blackish-green. Concentrations of lead in its liver and tibia were 72 and 187 ppm wet weight, respectively. Though we found doves with high concentrations of lead, we did not observe doves with similar symptoms.

Bagley and Locke (1967), studying concentrations of lead in normal liver tissues of birds, reported a range of 0.4 to 7.0 ppm for mourning doves. Buerger et al. (1986) found kidney and liver lead concentrations for control doves compared favorably with other studies on wild (Kendall and Scanlon, 1982*a*) and captive (Kendall et al., 1983) mourning doves and rock doves (*Columba livia*) from rural (Johnson et al., 1982) and urban areas (Kendall and Scanlon, 1982*b*). Their values for lead levels in livers of mourning doves support previous findings for mallards (*Anas* *platyrhyncos*; Longcore et al., 1974) that levels of 6 to 20 ppm wet weight should be considered indicative of acute lead exposure. Values within and exceeding this range were found for doves in southeastern New Mexico.

In southeastern New Mexico, 3.6% of doves in our sample contained concentrations of lead >7 ppm wet weight. Based upon values reported by previous investigators, all of these birds may have ingested lead shot at some time in their life. In addition, Locke and Bagley (1967) presented data for three doves that contained lead shot and contained a lead concentration of 3 ppm or less. This indicates that other doves may have ingested lead shot at one time. Doves with lead concentrations of 3 ppm or greater make up 8.0% (20 of 250) of our sample.

Ingestion of lead shot may have effects other than increased mortality among post-fledgling doves. Buerger et al. (1986) found that ingestion of one lead shot by female doves caused a reduction in hatchability of their eggs but did not influence productivity or fertility. In ringed turtledoves (*Streptopelia risoria*), testes weights were lower in lead-treated males, and spermatozoan numbers tended to be lower (Kendall and Scanlon, 1981).

Management Implications—Huge numbers of lead shot are available for ingestion by doves in southeastern New Mexico and decomposing lead shot may serve as a source of lead in drinking water. Because sick and dying birds may be captured and consumed by predators, may seek shelter in dense cover (Carrington and Mirarchi, 1989) and in rodent burrows, or otherwise are not easily observed, it is difficult to assess the numbers of birds that are killed each year by lead poisoning. It is equally difficult to assess what the long-term effect will be. The numbers of lead shot that will continue to become available by erosion and exposure of buried shot or new deposition by hunters may affect populations of various species of birds for years.

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