Two different soil sampling techniques for assessing soil lead concentrations at the Overton Wildlife Management Area, Nevada

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Two Different Soil Sampling Techniques for Assessing Soil Lead Concentrations at the Overton Wildlife Management Area, Nevada

A thesis submitted in partial fulfillment of the requirement for the degree of Bachelor of Arts in Environmental Studies University of Nevada, Las Vegas by Kristen E Falc Spring, 2000

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Abstract

During the summer of 1999, soil samples were taken from the Overton Wildlife Management Area (OWMA), located in the Moapa Valley of Clark County, Nevada. Although lead shot has been banned for the hunting of waterfowl since 1986, it is still legal for upland game hunting. The field sampled serves primarily as a dove hunting area and is cultivated. A large sample size was taken to indicate the short-term effects of the deposition of lead shot in the area and a small sample size, the long-term. Lead shot was recovered from 64% of the small samples and the estimated concentration was 499,521 pellets/ha. Forty-eight percent lead shot was recovered from the large samples and the estimated concentration was 64,593 pellets/ha. The amount of lead shot found in the small samples was 29 and 15 in the large. Comparison was made to fields of similar circumstances around the country and the OWMA supersedes all. Although the OWMA is cultivating the field to reduce the availability of lead shot at the surface, the data from this study indicates that lead shot is potentially available to wildlife. I recommend that lead shot be banned at the Overton Wildlife Management Area.
Acknowledgements

My deepest appreciation goes out to Dr. Shawn Gerstenberger. Thank you for your persistence and your guidance. In addition to Dr. Gerstenberger, I would like to thank Jessica Larkin and Jackie Petrello for their help with the dirty work in the middle of summer. Without you, I would still be in the field collecting samples! A special thank you goes to the staff at the Overton Wildlife Management Area and to all of the hunters.
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INTRODUCTION

Poisoning that results from ingestion of spent lead shot is well established as a mortality factor in waterfowl populations (Bellrose, 1959). The Overton Wildlife Management area (OWMA) is the only legal area in Southern Nevada for the lead shot hunting of upland game. This may result in the accumulation of lead shot that could cause significant lead poisoning of waterfowl (ducks, geese), doves, pigeons, other upland game birds (pheasants, quail), and some small mammals (rabbit). Judging by the number of spent shot shell casings on this land, large amounts of lead shot may be concentrated in these areas and may be available for ingestion. Although the OWMA cultivates the land after every season, the lead concentration in the soil may be the same in top soil samples and on deeper soil samples because of the length of time the lead has been shot on this land.

The local, regional and global biogeochemical cycles of lead have been affected by man to a greater degree than those of any other toxic element (Hutchinson and Meema, 1987). There are now few areas on earth that are free of anthropogenic lead. The lead concentration at the North Pole is 10 to 100 times higher than the values in prehistoric times (Boutron and Patterson, 1983). Lead levels in urban areas exceed pre-technological times several thousand-fold, as a result, lead presents a more serious environmental and health hazard than does any other element (Hutchinson and Meema, 1987).

Lead is an integral part of the economy; U.S. industry consumes about 1.3 million tons of lead annually (Cheremisinoff and Cheremisinoff, 1993). The low melting point, durability, corrosion resistance, and the ease with which it can be worked account for its early use as a construction material. A variety of uses release ultimately about 600,000 tons of lead into the environment each year in the United States, and additional discharges
occur in smelting, mining, manufacturing, and recycling processes (Cheremisinoff and Cheremisinoff, 1993).

One of the markets for lead is shot. For each cartridge fired by waterfowl hunters, approximately 300 shot enter the environment, often falling into prime waterfowl feeding habitat (Pain, 1991). In the area of the OWMA, lead shot is still approved for the use of hunting upland game. Some of the reasons that hunters still choose to use lead pellets are lead has been used for many years, lead shot is well liked by hunters, it is just as good or better than the alternatives, it is cheaper than the alternatives, and has a well-established distribution and sales network. It is likely that a market for lead shot will continue to exist as long as lead shot is available for sale.

To aid in the mechanical breakdown of food, waterfowl ingest grit and retain it in their muscular gizzard. Frequently, birds ingest the spent shot, mistaking it for grit. Once ingested, the lead pellets often become lodged in the gizzard, where ionic lead is released as a result of the grinding action of the gizzard combined with the acidic environment of the digestive tract (Scheuhammer, 1952). The ingestion of a large number (>10) of shot causes acute lead poisoning and birds will usually die within a few days. Victims of acute poisoning can appear to be in good condition, without pronounced weight loss (Scheuhammer, 1952). Birds that die following ingestion of a smaller number of shot pellets have chronic lead poisoning. This occurs most commonly and has distinctive signs of lead poisoning. These include green, watery feces, drooping wings, anemia, weight loss, and distension of the proventriculus (Scheuhammer, 1952). These signs appear more gradually and affected birds die approximately two to three weeks after ingesting the shot, often in a very emaciated condition (Scheuhammer, 1952). Lead exerts sub lethal toxic
effects on many tissues, primarily the central and peripheral nervous systems, the kidneys, and the circulatory/hematopoietic systems (Scheuhammer, 1952). The lesions caused in these tissues result in biochemical, physiological, and behavioral impairments. These impairments contribute to an increased risk of predation, starvation, and disease in affected birds. Sublethal exposure results in an impaired ability to cope with other potential sources of mortality. The estimate yearly loss of North American waterfowl from lead poisoning from shot ingestion at 2-3% of the continental “population” or about 1.5-4.0 million individuals (Bellrose, 1959).

The likelihood that a bird will ingest shot depends on shot density and availability (related to grit availability in feeding areas and depth distribution). Generally, it is considered that a high proportion of shot ingested by waterfowl is usually recently deposited. However, in soils which allow only a slow rate of sedimentation, shot accumulated from year to year near the surface, increase in the amount available to feeding waterfowl (Mudge, 1984). Physical factors such as high water flow rates, frequent disturbance of contaminated soils, and soils of sediments dominated by the presence of coarse sand or gravel all serve to enhance the rate of lead pellet breakdown (Scheuhammer, 1952). In soils with a high pH and high organic content, lead transformation products are only slightly soluble and may adhere to pellet surfaces or remain bound in the upper soil layers (Jorgensen and Willems, 1987). For an uncultivated grassland with a soil pH of about 5.5, it was calculated that half of a lead pellet’s metallic lead content would be transformed into lead compounds within 54-63 years and that total pellet transformation would occur in 100-300 years (Jorgensen and Willems (1987). Under circumstances of intensive mechanical treatment, such as cultivation of the soils,
these time periods may be shortened to 15-20 and 30-90 years respectively 
(Scheuhammer, 1952). Soil pH is one of the most important factors affecting the mobility 
and bioavailability of lead (Swain, 1986). Increased risk of lead mobility occurs in 
environments with rocks, acidic soils, or surface waters.

On March 20, 1976, the Secretary of the Interior announced a decision to require 
the use of steel rather than lead shot for waterfowl hunting in certain areas in the United 
States. The US is also enforcing further bans on the use of lead shot for squirrel, 
pheasants, etc. in wetlands of National Wildlife Refuges. To reduce the hazard of 
waterfowl ingesting shot pellets, the soil is cultivated in hopes to work the lead shot 
deeper into the soil, beyond the reach of waterfowl. The purpose of the study reported 
here is to investigate the possibility that cultivating is not an appropriate preventative 
measure and to provide data on amounts and distribution patterns of lead shot in the 
OWMA.

MATERIALS AND METHODS

Soil samples were taken from the southern half of field 17 of the OWMA 
between 11:00 am and 4:00 pm on Sunday, August 22, 1999 (see map, figure1). These 
samples were taken to investigate the presence of lead shot in the area. This date was 
chosen because it was it was pre-season and post-cultivation. This field was cultivated 
after the last hunting season, which ended on September 30, 1998. The next hunting 
season would start on September 1, 1999. Transects were set every 100 feet apart and
samples collected every 150 feet along the transect (figure 2). The area was then gridded by using flags at each intersection, which were numbered. Two sample sizes were taken at each site, one being 6 inches by 6 inches by 6 inches (the small sample), and the other was 12 inches by 12 inches by .5 inches (the large sample). These sample sizes were chosen because other fields in the OWMA have been previously studied with the small size and the influence of sample size is unknown. Keeping the same sample sizes allow the different fields to be compared accurately. The samples collected alternated at each sampling point, thus, 25 samples of each size were taken, totaling 50 samples (figure 3). This procedure was followed to avoid areas of particularly low or high shot densities resulting from relative proximity to hunting blinds.

A six-inch wide shovel was used to collect the samples. The shovel was pushed into the ground until it was six inches deep and then made into a square for the small sample size. The large sample was taken by making a square out of the shovel that was 12 inches (two of the 6-inch shovels) by 12 inches and then scraping .5 inches off the top of the soil. The soil removed from each site was placed in a plastic bag that was identified by the number and size of the sample.

The shot were separated from the soil samples by using Hubbard soil sieves of mesh sizes 5, 120, and 230. Mesh size 5 was used to remove large material and sizes 120 and 230 have sieve openings of 125 um and 63 um respectively. The soil was removed from the plastic bag and placed into a 5-gallon bucket and water was added. The soil was
then mixed and filtered thru the sieves. The lead shot was subsequently retrieved from the soil. Plant material was examined manually.

Once the shot was retrieved, they were individually measured and identified as to metal type. The shot were measured using a caliper. The shot retrieved were made of either lead, steel, bismuth, or tungsten. The procedure used for the separation of the shot was (see appendix A):

1. place a magnet on the shot (this will separate out steel and tungsten).
2. place each bullet into a glass vial.
3. identify the sample area on the vial.
4. fill each vial with 1 ml of HCL (37 % solution)
5. seal the vial tight and mix it for a few seconds.

The type of shot was determined by its reaction. The bismuth bubbled for a minute and then stopped. The lead shot continued to bubble vigorously, and after sometime began to flake off and dissolve (about 10-20 minutes). The steel bullets bubbled vigorously and then instantly turned the solution a bright yellow. The bubbling continued for hours. The tungsten bullets had a faint yellow tint and the bubbling stopped. Most of the shot found were lead, however, a few were not.

RESULTS

The total number of shot found in the southern half of field 12 in the OWMA was

6
48, 44 of which were lead. Exact locations can be seen in figures 4 and 5. The soil in the field was dry and alkaline. Lead pellets do not break down unless the environment is acidic. The diameter of individual shot were measured and ranged in size from 0.2 cm to 0.35 cm. Of these shot, one was Tungsten (A1L) and measured at .23 cm, one was Steel, (B2L) and measured at .34 cm, two were Bismuth (D3S and E2S) and measured at .35 cm and .26 cm respectively, and 44 were Lead (figure 6). Table 1 illustrates the average diameter of spent lead shot recovered from the southern half of field 12. The larger the diameter of the shot, the more likely the shot is being used for waterfowl. The smaller shot are usually used for upland game such as dove. This table concludes the use of smaller shot, most likely used for dove hunting.

The total number of shot found in the small samples was 31. Two were bismuth and 29 were lead. A total of 17 shot were found in the large samples. Fifteen shot were lead, one was Tungsten and one was steel. Figure 7 illustrates the number of lead shot found in the small and large samples and their location.

Pellet densities were estimated by using the mean number of pellets found and the surface area of each sample. Pellet concentration was estimated by comparing the mean number of pellets found and the surface area of each sample.

The surface area for the large sample was 1 square foot and the small sample was .25 square feet (0.5 ft. X 0.5 ft.). The total surface area sampled was 450,000 square feet. A conversion of the sampled surface area to hectares was done by using 43,560 square
feet per acre and .4046856 hectares per acre giving a surface area of approximately 4.18 hectares.

The shot density for the small samples was calculated as 29 pellets/ 25 samples = 1.16 pellets/ sample. This result times 4 equals 4.64 pellets/ square foot, and multiplying by 450,000 estimates 2,088,000 pellets. Pellets per hectare is then calculated as 2,088,000 pellets/ 4.18 ha = 499,521 pellets/ ha.

The shot density for the large samples was calculated as 15 pellets/ 25 samples = .60 pellets/ sample. This multiplied by 450,000 square feet equals 270,000 pellets. This figure divided by 4.18 hectares results in 64,593 pellets/ ha.

Out of a total of 48 shot found, 31 of 48 (65%) were found in the small samples and 17 of 48 (35%) in the large. Forty-four of the 48 shot found are made of lead. Twenty-nine of 44 (66%) shot found were from the small samples and 14 of 44 (32%) were from the large. Of the soil samples collected, 26 of 50 (52%) contained one or more lead shot. Of the large soil samples collected 10 of 25 (40%) and of the small samples collected 16 of 25 (64%) contained one of more lead shot. The mean number of lead shot per large sample was 1.5 and per small sample 1.8. Then comparing the number of shot found in the large samples to the small, the small had 24% more that contained one or more shot.

The findings of this study compared to others reported in literature that have cultivated fields suggest that shot concentrations at OWMA are higher than most areas.
Bertoy (1998) did a study in the OWMA on fields 14, 15, and 16 and found a low end shot concentration of 73,231 pellets/ha and a high end of 741,557 pellets/ha. Both results from the studies at the OWMA report that there is a high shot concentration when comparing it to similar studies done in Indiana where the low end was 2,152 pellets/ha and the high end was 83,928 pellets/ha. (Castrale, 1989). A study in Ramsey's Field, TN estimates the low end at 26,910 pellets/ha and the high at 107,639 pellets/ha (Lewis and Legler, 1968). A study in Illinois estimates the low end at 69,928 pellets/ha and the high at 180,875 pellets/ha (Bertoy, 1998).

CONCLUSION

Two sample sizes were taken to compare the concentration of lead shot in the field. The large sample size (12" x 12" x .5") is indicative of the short-term effects of deposition and the small sample size (6" x 6" x 6"), the long-term. The large sample size can be used to estimate the number of pellets available for ingestion at any time. It could also indicate how important or not important short-term preventative measures for lead poisoning are in a specific area. Bellrose (1959) reported an area in Minnesota closed to hunting for 5 years which still had about as many shot present as areas not closed to hunting. It may also indicate how well cultivation is working in a field. A comparison can be made by taking the small sample size before and after cultivation. The small sample
size may be used to assess annual inputs of shot. The purpose of cultivation is to improve the surface of the land, which in turn, moves the shot deep into the soil profile. Obtaining samples 6” down once a year estimates the number of shot that is being inputted annually. After cultivating a field for a number of years, this size may indicate how many shot appear to be successfully unavailable to upland game. This sample size can also be used to guess the amount of shot that could resurface to the top of the field the next time that the land is cultivated.

Many studies have been done on the effectiveness of cultivating land to reduce shot availability. For example, Lewis and Legler (1968) indicate that discing or plowing a field soon after hunting season can only reduce the quantity of lead pellets available in the top two inches of soil surface as much as 78 %. Brakhage (1966) pointed out that cultivation can substantially reduce shot availability. Fredrickson et al., 1977 acknowledges that the cultivation of land, particularly in areas of high shot density such as near hunting blinds, has been shown to reduce shot availability by redistribution away from the surface. Although few or no long-term studies have been done on cultivation, it would appear that after cultivating a field over a number of years, the concentration of shot throughout the soil would eventually be equal, therefore would not be a viable option for the mitigation of lead.

After cultivating this field for approximately 40 years, it was found that the concentration of lead at the surface is less than the deeper layers. There are approximately
64,593 pellets/ha on the surface of the field and 499,521 pellets/ha on the studied lower layers of the field. This data indicates that cultivation has worked for short-term exposure reduction, however, over time, the amount of lead at the surface may not be reduced. This would happen if the concentration of shot through the field becomes equal due to the amount of shot being distributed during the month long season. If this were to happen, cultivation would no longer be an option for mitigation. Bertoy (1998) estimated conservatively that 3000 pounds of lead per one month long season at the OWMA is shot and available for ingestion.

For reasons listed above, cultivation appears to be a quick-fix solution as opposed to a long-term solution. Two possible long-term solutions are education, incentives, and the banning of lead.

One possible solution is to educate the hunters of the effects of shooting lead. For example, the OWMA could require the hunters to attend short classes on the effects that lead has on upland game. They could also sell substitutes for lead to encourage the use of nontoxic shot and provide reimbursement for the lead shot the hunters already have. This alternative might work for some of the hunters, however, the nontoxic substitutes are more costly. This potentially reduces the ability of lower socioeconomic hunters to participate. If the hunters are not required to change their habits, they may not.

Another alternative would be incentives. Since the OWMA already has lotteries to gain access to hunt, one incentive could be to put the hunters that use nontoxic shot into
the first pool of hunters to be drawn. Another could be the elimination of some fields available to hunt on while using lead shot. During dove season, potentially 50 hunters are permitted to hunt at OWMA (Bertoy, 1998). With the limitation of fields, the amount of hunters allowed would decrease and the amount of nontoxic shot would increase. This alternative is not practical and would require a change in the law.

Another alternative would be the mandatory use of nontoxic shot. The state would have to change the law and prohibit the use of lead shot for upland game hunting. Some states such as South Dakota have already banned the use of lead shot for upland game hunting. Although the nontoxic substitutes are a higher cost, cultivation seems to be a short-term solution to the problem. The banning of lead shot would be a long-term solution.

The toxicity of lead has been known for many years. There have been articles and books written many years ago about the effects that it has on children, waterfowl, and upland game. Lead is a known toxic element and it is only logical to reduce the potential exposure to this element. The use of lead shot for waterfowl hunting is not permitted in the OWMA, but is permitted for upland game hunting in the same area. Is this logical? The data from this study indicates that lead shot is potentially available to wildlife despite the remediation efforts that are being enforced. I recommend that lead shot be banned at the Overton Wildlife Management Area.
FIGURE 2

Sampling Design for the Southern Half of Field 16 of the OWMA, Transects Were Set Every 100 Feet Apart and Samples Were Collected Every 150 Feet Along the Transect.
FIGURE 3
Sampling design for the Southern Half of Field 16 in the OWMA, Samples Collected Alternated at Each Sampling Point, thus 25 Samples of Each Size Were Taken, Totaling 50 Samples.

S = SMALL SAMPLE = 6" X 6" X 6"
LARGE = LARGE SAMPLE = 12" X 12" X .5"
FIGURE 4

Type and Amount of Shot Found in the Small Sample Size of the Southern Half of Field 16 in the OWMA.

SMALL SAMPLE = 6" X 6" X 6"

A B C D E

1 0 0 2 2 2

2 0 0 1 1 1+1 BISMUTH

3 1 3 1 1 BISMUTH+ 2 2

4 0 0 2 3 3

6 0 2 0 1 0

750' 150' 600' 100'
FIGURE 5
Type and Amount of Shot Found in the Large Sample Size of the Southern Half of Field 16 in the OWMA.

LARGE SAMPLE = 12" X 12" X .5"

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<tbody>
<tr>
<td>1</td>
<td>1 TUNGSTEN</td>
<td>2</td>
<td>1</td>
<td>0</td>
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<tr>
<td>2</td>
<td>0</td>
<td>1 STEEL</td>
<td>1</td>
<td>2</td>
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150', 750', 100', 600'
FIGURE 6
Size of Lead Shot Found in the Southern Half of Field 16 in the OWMA.
TABLE 1

Average Diameter of Spent Lead Shot Recovered from
the Southern Half of Field 17.

<table>
<thead>
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<th>Shot Size</th>
<th>Diameter (mm)</th>
<th># of Shot Found</th>
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<td>2</td>
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<td>4</td>
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<td>5</td>
<td>2.91-3.16</td>
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<td>6</td>
<td>2.58-2.90</td>
<td>6</td>
</tr>
<tr>
<td>7.5</td>
<td>2.33-2.57</td>
<td>15</td>
</tr>
<tr>
<td>8</td>
<td>2.21-2.32</td>
<td>17</td>
</tr>
<tr>
<td>8.5</td>
<td>2.09-2.20</td>
<td>3</td>
</tr>
<tr>
<td>9</td>
<td>1.66-2.08</td>
<td>2</td>
</tr>
<tr>
<td>12</td>
<td>&lt;1.66</td>
<td>0</td>
</tr>
</tbody>
</table>

* Categories for shot diameters were modified from the Winchester reloading guide and NRA firearms fact book.
FIGURE 7

Lead Shot Found in the Large and Small Sample Sizes in the Southern Half of Field 16 in the OWMA.

SMALL SAMPLE = 6" X 6" X 6"

LARGE SAMPLE = 12" X 12" X .5"

<table>
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</table>

150'

100'
APPENDIX A

Separation of Metal Shotgun Bullets

For the Separation of Metal Shotgun Bullets: Mixtures of Lead, Copper-coated Lead, Steel, Copper-coated Steel, Bismuth, and Tungsten.

Materials:

HCl (37% solution)
Small glass vials with airtight seals (about 2 ml volume)
Pipette and pipette tips
DI water
Acetone
Tweezers

Procedure:

- Clean bullets by rinsing them off with DI water and then Acetone to remove any organic matter and let dry.
- Application of a strong magnet will separate out Steel(S), copper-coated Steel(Cu-S), and Tungsten(T). (keep these separated from the rest)
- The remaining three types will include the Lead(L), copper-coated Lead(Cu-L), and Bismuth(B).
- Place each bullet in a glass vial.

(One of each bullet new in labeled vials before addition of HCL)
Coated Lead bullets will take a long time to start to bubble and corrode depending on how much of the copper coat is left on the bullet.

- The other plain Lead bullets can be identified as the ones continuing to bubble vigorously, and after sometime will begin to flake off and dissolve (about 10-20 minutes).

To separate the Tungsten from the Steel, place each bullet in a glass vial and add 1 ml of HCl, mix for a few seconds then observe.

- The Steel bullets will bubble vigorously and instantly turn the solution a bright yellow. Bubbling will continue for hours.
- The copper-coated Steel will also do the same as the plain steel but might take longer depending on how much of the copper coat remains. (Similar to the Lead.)
- The Tungsten bullets, if left to sit still, will have a small dark blue film coming off the bullet. If mixed, the solution will have a faint yellow tint, and bubbling will stop.
- Within 10 minutes all bullets can be identified and the glass vials labeled to the corresponding metal bullet it contains.
- If weights of the individual bullets are needed, the HCl should be disposed of once the bullet is identified and filled with DI water to avoid any further decaying.

(Plain Lead bullets appear cloudy from flakes and bubbles.)

(Notice the blue film coming off the tungsten bullet.)
- If bullets are left remaining in solution for a few days, identification can also be easily observed by the unique appearance of each. By now any copper coating on Steel or Lead bullets has been dissolved away.
- Both the Lead and copper-coated Lead will corrode into lead mulch at the bottom of the vial and can be shaken up to see the flakes it has corroded into.
- The Bismuth bullet will not do much of anything: a slight corrosive outer surface and a very small amount of flakes may be observed in the nearly clear solution.
- The Steel and copper-coated steel will turn the solution a very bright, obvious yellow color, whereas the Tungsten will turn the solution a dark yellow-green color. Both will show a slight corrosiveness on the surface of the bullets.

(bullets within minutes of HCl addition.)  (After let sitting for 5 days in HCl.)

- In most cases bullets cannot be identified by appearance. Many of the bullets will have a change of color, a build up of rust, or flattened and deformed shapes.
- The copper of the coated Lead and Steel bullets will also be very hard, if even possible to see, if they were left in the soil or gizzard too long.

(Example of appearance of bullets found in the gizzard of a bird.)