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Abundance of Lead Shot in the Rainwater Basins of Nebraska

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TABLE OF CONTENTS

Figures

Tables

ABSTRACT

The Rainwater Basin (RWB) area encompasses over 4,200 square miles within 17 counties of southcentral Nebraska. Within the RWB area, the U.S. Fish and Wildlife Service (Service) administers 62 Waterfowl Production Areas (WPA) ranging from approximately 20 to 2,000 acres. Prior to the phase out of lead shot, an estimated 2.7 million kilograms of lead shot were deposited annually in lakes and marshes of the United States (USFWS 1976). Ingestion of this shot by birds can be lethal. Bellrose (1959) estimated that lead poisoning may result in a 2-3 percent annual loss to the North American waterfowl population. During the summers of 1997 and 1998, sediment samples were collected from five WPAs in the Rainwater Basins, Nebraska to determine the extent of lead shot deposition. Two of the basins sampled exceeded the concentration of concern for lead shot presence, 20,000 lead shot per acre (Anderson 1982). The samples collected at Mallard Haven WPA revealed a lead shot concentration of 19,466 and a 95 percent confidence interval of 12,150 - 26,782. Harvard WPA contained the highest concentrations of lead shot of all basin sampled. Processed samples revealed concentrations of 50,736 lead shot per acre with a 95% confidence interval of 42,464 - 59,008 lead shot per acre. Both of these basins were recommended for remediation.

INTRODUCTION

The Rainwater Basin (RWB) area encompasses over 4,200 square miles within 17 counties of southcentral Nebraska (Figure 1). Surface water drainage is poorly developed resulting in numerous closed watersheds that drain into low depression areas. Original soil survey maps from the early 1900's indicate that approximately 4,000 major wetlands totaling nearly 100,000 acres were present within this area at the time of settlement (Nebraska Game and Parks Commission 1984). Within the RWB area, the U.S. Fish and Wildlife Service (Service) administers 61 Waterfowl Production Areas (WPA) ranging from approximately 20 to 2,000 acres. These wetlands lie within the central flyway and provide important habitat to millions of birds. Ninety percent of the mid-continent population of 250,000 white-fronted geese (Benning 1987), over one million lesser snow geese (Gersib et al. 1989), 50 percent of the mid-continental breeding population of 5.4 million mallards (1991 survey data), and 30 percent of the continental breeding population of 1.8 million northern pintail (1991 survey data) are estimated to use the RWB area during spring migration (U.S. Fish and Wildlife Service 1986; Bortner et al. 1991). The RWB wetlands also provide important fall migration and breeding habitat for waterfowl, and spring and fall migration habitat for endangered species (e.g., whooping crane and bald eagles) and hundreds of thousands of shorebirds, wading birds, and other bird species (LaGrange 1996). Birds using these basins may be at risk of lead poisoning by ingesting lead shot.

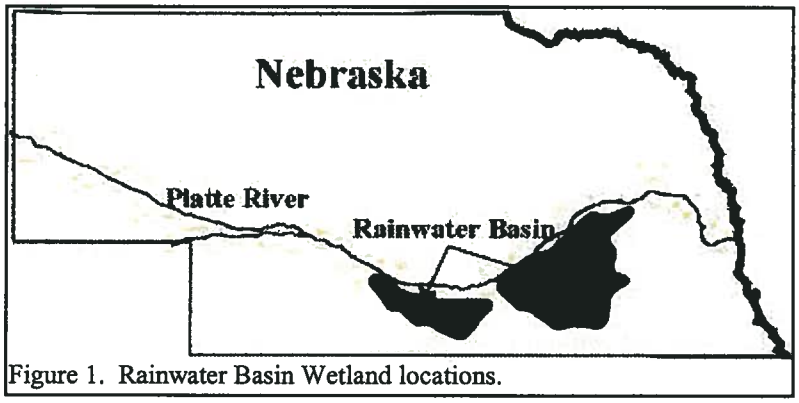

Figure 1. Rainwater Basin Wetland locations.

Ingestion of spent lead pellets resulting in lead poisoning of waterfowl is a long-recognized phenomenon and remains a problem in many areas (Phillips and Lincoln 1930; Bellrose 1959; Sanderson and Bellrose 1986; Pain 1992). The Service (1976), prior to the non-toxic shot requirement, estimated that 2.7 million kilograms of lead shot was deposited in lakes and marshes of the United States each year. Ingestion of this shot by birds can be lethal. Bellrose (1959) estimated that lead poisoning may result in a 2-3 percent annual loss to the North American waterfowl population.

Since 1978, non-toxic shot has been required for waterfowl hunting on Service RWB wetlands. However, because steel shot was initially available only in 12 gauge shells, lead shot was allowed for other gauge shells. In 1980, steel shot was required for all waterfowl hunting on Service RWB wetlands and in 1982 it was required for all shotgun hunting of all species on public wetlands. In 1986, steel shot was required statewide for all waterfowl hunting. Even with the implementation of these regulations, lead shot may remain available for many years (Bellrose 1959; Fredrickson et al. 1977; Peters and Afton 1993).

Previous studies indicate that waterfowl collected in the RWB ingest lead shot. The Nebraska Game and Parks Commission (NGPC) (1979) collected gizzards from 539 birds in three RWB counties during the 1978 hunting season. An average of 3.2 percent of the birds contained lead shot, with mallards comprising most of the mortality. These three counties were surveyed again during the 1979 hunting season. Of 699 birds examined, 3.4 percent contained lead shot (NGPC 1980). Waterfowl die-offs have also occurred in the RWB. During a dieoff of widgeon, redheads, lesser scaup, and mallards at Pintail Marsh in 1979, the NGPC submitted 34 birds to the National Wildlife Health Center (NWHC) for necropsy. Of the birds submitted, 41 percent were diagnosed with lead poisoning and an average of 18.7 lead pellets per bird was found (NGPC, unpubl. data). The average lead concentration in the livers from these birds was 154.9 ppm dry weight (dw) and ranged from 33 to 229 ppm. Longcore et al. (1982) and Sanderson and Bellrose (1986) considered liver concentrations exceeding 20 ppm (dry weight) indicative of recent, acute lead exposure and as being diagnostic of active lead intoxication. The NGPC collected 24 geese during a die-off at Schilling Marsh in 1982. Lead concentrations in livers averaged 74 ppm dw and ranged from below detection to 189 ppm (NGPC, unpubl. data). The NGPC diagnosed 19 birds with lead poisoning during a 1986 dieoff in three RWB counties (NGPC 1986). Necropsy reports (NWHC 1992 and 1996 unpubl. data) on birds collected from the RWB indicate lead poisoning of waterfowl continues to be a problem.

In addition to documented lead-associated waterfowl dieoffs within the RWB, waterfowl often display delayed mortality from lead-induced starvation (Dieter 1979). Further, losses are often unnoticed due to predation and scavenging. In central Missouri at Swan Lake NWR, 82 percent of "planted" carcasses were depredated within four days of placement (Sanderson and Bellrose 1986). Susceptibility to lead toxicosis is markedly influenced by species, the number and size of shot ingested, and by the types of foods eaten (White and Stendell 1977). Mallards on a diet of corn have died within 10 to 14 days after ingesting a single lead shot, whereas similar birds on a balanced commercial duck ration appear outwardly normal after ingesting as many as 32 pellets of the same size (Wobeser 1981).

This study was completed to determine if WPAs managed by the Service could pose a potential hazard to waterfowl because of high concentrations of lead shot in surficial sediments. Specific objectives of this study were to: (1) determine the extent of lead shot deposition within Service WPAs; and (2) document potential threats to migratory birds by comparing our results of lead shot abundance with published literature.

STUDY AREA

During the summers of 1997 and 1998, sediment samples were collected from five WPAs in the Rainwater Basins, Nebraska, to determine the extent of lead shot deposition. WPA selection was based on the following criteria: (1) interviews with Service and NGPC personnel to determine hunting pressure; (2) length of Service ownership; and (3) properties sampled previously by Oates (1989) to allow for comparison. Selected WPAs included Funk, Gleason, Harvard,

Lindau, and Mallard Haven. Wetlands within the WPA were selected for sampling and the total area of each selected wetland was determined using aerial photographs and a planimeter.

MATERIALS AND METHODS

Sample collection

A systematic sampling design was employed to collect samples (Schaeffer et al. 1979). Transects were established at each WPA; but, in order to obtain at least 100 sediment samples per site, the distance between the transects varied.) Most of the WPAs were of similar size and transects on these basins were established 50 m apart. Transects at Harvard, the largest basin sampled, were 100 m apart.

All transects were established within the high water mark of the wetland. A compass, measuring tape, and all-terrain vehicles (ATV) were used to lay out each transect. Transects were aligned in a north-south, or east-west direction depending on the shape and orientation of the wetland. The beginning and end of each transect was marked with PVC pipe with flagging tied to the top. The ATVs were then used to knock down vegetation between the two pipes creating the transect.

Sampling was conducted when each wetland was dry or nearly dry. At each sampling location, standing vegetation was removed using a weed trimmer. Then a welded 12x12x2-inch angle-iron frame was pounded into the ground using a sledge hammer (Figure 2). A 2-inch thick sample of sediment was removed from the inside of the frame using a flat-bladed shovel. The contents were placed in a heavy gauge plastic bag and labeled with a transect number and a sample number. A 100 meter measuring tape was then used to find the next sediment sample location along the transect. Most of the WPAs had sample locations 50 m apart along the transects; Harvard was the only variation with sample locations 60 m apart. This procedure was repeated until samples were collected from all transects.

Figure 2. The welded angle iron frame used for sampling.

Sample processing

Analyses followed methods described in previous studies (Anderson 1982; Oates 1989). Sediment sample reduction was achieved by first placing the sample in a five gallon bucket, filling it with water, and then left to soak. Soaking was incorporated because clay was the primary component of most of the sediment samples, and soaking was necessary to soften the clump for sample reduction. Floating vegetation present in the buckets (e.g., roots, sticks, leaves, etc.) was removed and hand-sorted for shot. The sample was then poured into a custom-made wash bucket with 1 mm stainless steel mesh (Wildco). The smallest shot size made (#9) is 2 mm, so the 1 mm mesh was selected to retain even highly weathered shot. The sample was forced through the wash bucket with a spray nozzle attached to a garden hose. The remaining sample, comprised of small rocks, shotgun pellets, and other miscellaneous material, was then arranged on a tray to air dry before being placed in a zip-lock bag.

Samples were evaluated for shot using a MiniScan Inspection System X-ray designed for examining postal packages (E.G. and G. Astrophysics, Berks, UK). Zip-lock bags containing reduced samples were placed in the system one at a time and examined for shot. If shot was apparent in the x-ray, the number of pellets was written on the bag. One confounding factor revealed in similar research was the presence of large numbers of soil concretions in RWB sediment. Previous research revealed that soil concretions appeared on fluoroscopes as fairly round and very similar to oxidized shot. Soil concretions are primarily comprised of iron, with varying amounts of magnesium, aluminum, silicon, sodium, and manganese (Oates 1989). Not accounting for soil concretions would likely lead to overestimates of actual shot densities, and only one listed citation addressed their presence (Oates 1989). Concretions did appear in the samples but were not as bright as lead or steel shot.

After all bags were x-rayed, samples were then scanned with a Falcon MD-10 metal detector (Falcon Prospecting Equipment, Mesa, AZ). This small hand held metal detector utilizes a 2.5 cm search coil enabling shot location within the sample bag. Lead and steel shot were easily detected with the metal detector, whereas soil concretions were not detected. Because soil concretions did not set off the metal detector, shot concentrations could not be overestimated.

Shot was removed from reduced sediment samples and placed in small (5 cm x 8 cm) zip-lock bags labeled with the transect and sample numbers. Several types of shot were likely. These were lead, steel, and bismuth (non-toxic shot approved for use at the time of this study was limited to steel and bismuth). Steel could be differentiated from lead and bismuth by using a magnet which would pick up steel shot but not lead and bismuth. Lead and bismuth could be differentiated by crimping with pliers. Lead shot merely compressed when crimped, whereas bismuth shot fractured. Remaining soil concretions not found when bags were x-rayed would not be picked up by the magnet and disintegrated when crimped.

The accuracy of shot detection using this methodology was further verified by having the samples from Harvard WPA (once all shot had been removed) examined at the Radiology Department of the Saint Francis Medical Center in Grand Island, Nebraska.

RESULTS AND DISCUSSION

A total of 775 sediment samples were collected during the study. From these samples, 410 lead shot, 161 steel shot, and 0 bismuth shot were found (Table 1). Lead shot was found in all five of the WPAs sampled. The number of lead pellets ranged from 10 to 304 per wetland and the average shot detected per sample was 0.52 pellets. Anderson (1982) suggested pellet densities exceeding 20,000 lead shot per acre be considered a threshold for lead poisoning problems in waterfowl because at this concentration of lead shot, mallards and other waterfowl will ingest spent pellets at relatively high rates.

Table 1. Number of Lead and Steel Shotgun pellets found in Sampled Rainwater Basin WPAs.

WPA	Aprox. Acres Sampled	Number of Transects	Sediment Samples Collected	Steel Shot Found	Steel Shot/ Acre	Lead Shot Found	Lead Shot/ Acre	Oates (1989) Lead Shot/Acre
Funk	97	15	105	17	7,052	10	4,149	
Gleason	90	17	137	8	2,525	17	5,366	
Lindau	101	19	161	6	1,623	29	7,846	22,508
Mallard Haven	172	14	112	33	12,834	50	19,446	17,082
Harvard	307	28	261	97	16,313	304	51,128	25,964

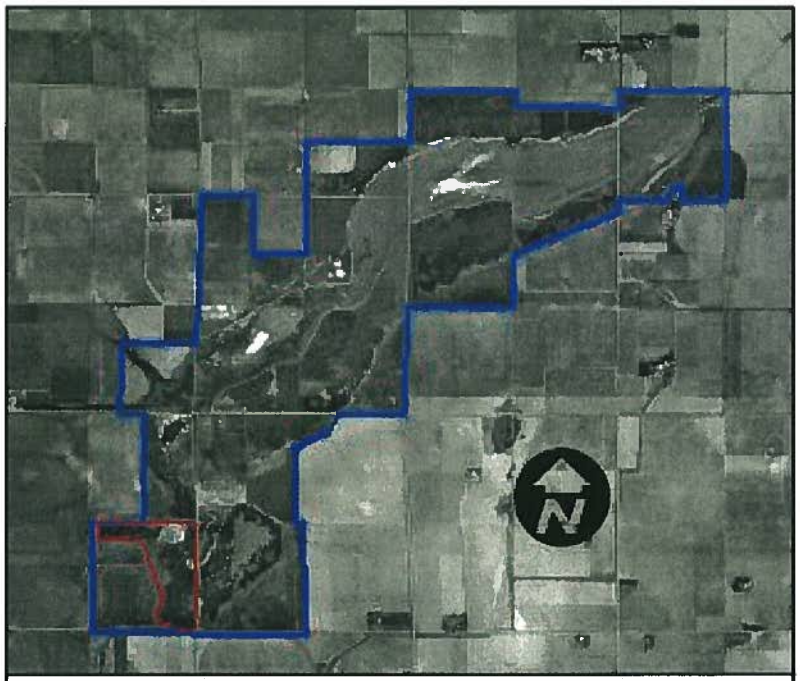

Figure 3. The basin sampled on Funk WPA depicted in red, boundary lines are depicted in blue.

The Pintail unit at Funk WPA (Figure 3.) was sampled in 1998. Fifteen transects set 50 meters apart were established to collect 105 samples. Results showed this basin had the fewest lead shot pellets (10) detected of the basins sampled. We found some form of shot in twenty percent of the sediment samples collected from this basin, 9 percent of the samples contained at least one lead shot, and 14 percent contained at least one steel shot. The number of lead shot pellets likely present in the basin we sampled at Funk WPA is 402,453 (lead shot/acre x acres sampled). The 95 percent confidence interval for the amount of lead shot per acre is 4,149 ±2,771. Lead shot pellets present at the southwestern basin of Funk WPA are below 20,000 shot/acre, and not likely a concern for waterfowl. Other basins in this large WPA receive more hunting pressure but are wet year-round and not conducive to sampling. The

Pintail Unit was private land prior to Service acquisition in 1986. It is noteworthy that this property was purchased after the lead shot ban, and is the only basin sampled where steel shot detection exceeded lead shot.

Figure 4. The basin sampled on Gleason WPA depicted in red, boundary lines are depicted in blue.

Gleason WPA (Figure 4) was sampled in 1997. Seventeen transects were established to collect 137 samples (see appendix for raw data). Results showed this basin also had low numbers of lead shot pellets with only 17 found. We found shot in 17 percent of the sediment samples collected. Twelve percent of the sediment samples contained at least one lead shot, and 6 percent contained at least one steel shot. The number of lead shot pellets present in the basin sampled at Gleason WPA is estimated to be 482,940. The 95 percent confidence interval for the amount of lead shot per acre is 5,366 ± 2,623. Based on the 95 percent confidence interval of lead shot per acre, the basin sampled at Gleason WPA, does not appear to be at levels of concern for waterfowl. The purchase of Gleason WPA was completed in 1967-68, and was private land prior to acquisition. Hunting prior to Service ownership was with permission only, and in the 1960s, Gleason only had one fall when the basin contained enough water to draw ducks (McMurtrey, unpubl. data). The RWB-WMD does not keep records on hunting pressure; however, concentrations of lead and steel shot indicate that hunting pressure at Gleason may be less than the other WPAs sampled in this study.

Lindau WPA (Figure 5) was sampled in 1997. We established 19 transects and collected 161 samples. Processed samples revealed Lindau WPA also had lead shot concentrations below levels of concern (raw data is contained in the appendix). A total of 29 lead pellets were found in the sediment samples. We found shot in 19 percent of the sediment samples. Sixteen percent of the sediment samples contained at least one lead shot and 4 percent contained at least one steel shot. The number of lead shot pellets present on the basin sampled on Lindau WPA is estimated

Figure 5. The basin sampled on Lindau WPA depicted in red, boundary lines are depicted in blue.

to be 792,467. The 95 percent confidence interval for the amount of lead shot per acre is 7,846 ± 3,155. Based on the 95 percent confidence interval of lead shot per acre, the basin sampled at Lindau WPA does not appear to be at levels of concern for waterfowl. Lindau WPA was also sampled for lead shot in 1986-87 as part of a NGPC study (Oates 1989) which found higher concentrations of lead (22,508 lead shot/acre). The discrepancies between the two studies is likely due to two factors. First, nine years passed between the two studies, and during that time, lead shot present in surficial sediments likely migrated below the two inches collected for the current study. Oates (1989) estimated that soil deposition in the RWB to be less than 1.25 cm per year. Even at that low rate, several inches of sediment would have likely accumulated in the basin at Lindau WPA. Secondly, we collected almost 2.5 times the number of samples collected for the earlier study (n=161 versus n=66) so the current numbers may be more predictive of true conditions in the basin.

Mallard Haven WPA was sampled in 1997. We established 14 transects and collected 112 sediment samples. Processed samples revealed that this basin had concentrations of lead at levels of concern for waterfowl.

Figure 6. The basin sampled on Mallard Haven WPA depicted in red, boundary lines are depicted in blue. The red arrow points to the portion of this basin owned by a private hunting club.

Fifty lead pellets were found in the 112 sediment samples collected. We found shot in 42 percent of the sediment samples collected. Twenty-eight percent of the sediment samples contained at least one lead shot, and 25 percent contained at least one steel shot. The number of lead shot pellets present in the basin is estimated to be 3,344,786. The 95 percent confidence interval for the amount of lead shot per acre is 19,446 ± 7,316. Results of the NGPC sampling completed in the 1986-87 were similar. Based on 34 samples, lead shot/acre was calculated to be 17,082 (Oates 1989). Because of the calculated lead shot/acre and the 95 percent confidence interval, Mallard Haven was recommended for remediation. Mallard Haven WPA has a long history of hunting pressure. The west side of the basin still has a private hunting club in the middle of the wetland and has been in existence since the 1950's. Hunting guides used the area heavily in the late 1950's and early 1960's. For example, the NGPC recorded 335 person days of hunting pressure in 1963 (McMurtrey, unpubl. data). Mallard Haven was also identified as one of Nebraska's premier waterfowl areas. Although the east side of Mallard Haven was private until the Service purchased the land in 1963, it likely had hunting pressure prior to purchase and has been hunted under Service ownership.

Harvard WPA was sampled in 1997. We established 28 transects and collected 261 samples. Harvard WPA contained the highest lead concentrations of all basins sampled. From the 261 sediment samples collected, 313 lead pellets were extracted indicating that lead concentrations are of concern for waterfowl. We found shot in 64 percent of the sediment samples. Fifty-three percent of the sediment samples contained at least one lead shot and 30 percent contained at least one steel shot. The number of lead shot pellets present in the basin is estimated to be 15,555,319. The 95 percent confidence interval for the amount of lead shot per acre is 50,736 ± 8,272. Results of the sampling conducted by Oates (1989) in 1986-87 were lower (n=109), but still characterized the lead shot

Figure 7. The basin sampled on Harvard WPA depicted in red, boundary lines are depicted in blue.

concentrations to be at levels of concern (25,964). Based on the calculated lead shot/acre and the 95 percent confidence interval, Harvard WPA was recommended for remediation. Harvard has been in Service ownership since 1970, and prior to purchase, was owned by the NGPC. This basin is usually wet in the fall and has been heavily hunted over the years (J. Kauffeld, USFWS, pers. comm.).

Samples collected at Harvard WPA were used to test our shot detection methods. After all sediment samples were processed (i.e., shot detected and removed), the remaining samples were evaluated by the Saint Francis Medical Center, Radiology Department (Grand Island, Nebraska). The Radiology Department found 10 samples which still contained shot (9 lead, 3 steel). Using more powerful equipment showed that our methods resulted in a 3 percent underestimate of shot.

We were unable to determine lead concentrations at Hansen WPA because this basin was never dry enough to sample. On two occasions, Hansen WPA was reported by Oates (1989) to have high lead shot concentrations. The extent of lead present within the top 2 inches of sediment was estimated at 36,500 Pb shot/acre in 1986, whereas repeat sampling in 1996 from the same locations yielded 52,700 Pb shot/acre (D. Oates, NGPC, pers. comm.). In the future, this basin should again be sampled to determine the extent of lead shot.

CONCLUSIONS

This investigation revealed that two of the five WPAs sampled should be considered a hazard to waterfowl because of elevated lead shot concentrations. Harvard WPA had the highest concentrations followed by Mallard Haven WPA. Both of these basins were recommended for cleanup and have since been disked to move the lead shot further down into the soil column. The cleanup and success of disking will be the subject of another report.

Further management of these basins to address lead shot deposition may need to rely on increasing public awareness on the effects of lead shot ingestion to waterfowl. This may increase compliance with the non-toxic shot requirement. In 1986, Hurt (NGPC, unpubl. data) examined 26 hunting blinds for spent shotgun shell casings and recovered 752 empty shells. Steel shot was apparently used in 80 percent of the blinds. Despite the mandatory steel shot requirement however, 75% of these blinds also contained empty lead shell cases. Oates (1989) speculated that lead deposition continues within the RWB, although a majority of the shot has been present for several years.

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Appendix

. Table 1. Number and type of shot found from transects at the Pintail Unit of Funk Lagoon WPA, Nebraska, 1997-98.

Funk	T1		T 2		T 3		T 4		T 5		T 6		T 7		T 8		T 9		T 10		T 11		T 12	
sample #	Steel	Lead	Steel	Lead	Steel	Lead	Steel	Lead	Steel	Lead	Steel	Lead	Steel	Lead	Steel	Lead	Steel	Lead	Steel	Lead	Steel	Lead	Steel	Lead
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	1
2	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
3	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
4	1	0	0	0	0	0	1	0	0	0	2	0	0	0	2	0	0	0	1	0	0	1	0	0
5	0	0	0	0	0	0	0	2	0	0	0	0	1	1	0	0	0	0	0	1	0	0	0	0
6			0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0
7			0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0		
8									0	0	0	0	0	0	0	0	1	0			0	0		
9											0	0	0	0	0	0								
10											0	0	0	0	0	0								
# of shot	1	1	0	0	1	0	1	3	0	0	2	0	1	1	4	1	2	0	3	1	0	1	1	1
#of samples	5		7		7		7		8		10		10		10		8		7		8		6	

Funk	T 13		T 14		T 15				
sample #	Steel	Lead	Steel	Lead	Steel	Lead			
1	0	0	0	0	0	0			
2	0	0	1	0	0	0			
3	0	0	0	0	0	0			
4			0	1					
5			0	0					
6			0	0					
7									
8									
9									
10								steel	lead
# of shot	0	0	1	1	0	0	Total Shot	17	10
# of samples	3		6		3		Total Samples		105

Table 2. Number and type of shot found from transects at Gleason WPA, Nebraska, 1997-98.

Gleason	T1		T 2		T 3		T 4		T 5		T 6		T 7		T 8		T 9		T 10		T 11		T 12	
sample number	Steel	Lead	Steel	Lead	Steel	Lead	Steel	Lead	Steel	Lead	Steel	Lead	Steel	Lead	Steel	Lead	Steel	Lead	Steel	Lead	Steel	Lead	Steel	Lead
1	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	2	0	0	0	0	0	1
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	1	0	0	0	0	0	0	1	1	0	1	0	0	0	0	0	0	1	0	0	0
4	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
9	0	0	0	0	0	0	0	0	0	0	0	0												
10	0	0	0	0	0	1	0	0	0	0														
11	0	0	0	0	1	0	0	1	0	1														
12	0	0							0	0														
13																								
# of shot	0	0	1	1	1	1	1	2	0	2	1	1	0	3	0	0	0	2	1	0	1	0	0	1
#of samples	12		11		11		11		12		9		8		8		8		8		8		7	

Gleason	T 13		T 14		T 15		T 16		T 17			
sample number	Steel	Lead	Steel	Lead	Steel	Lead	Steel	Lead	Steel	Lead		
1	0	0	0	0	0	0	0	0	0	0		
2	0	0	0	0	0	1	0	0	0	0		
3	0	0	0	0	1	0	0	0				
4	1	0	0	0	0	1	0	0				
5	0	0	0	0	0	1						
6	0	0	0	1	0	0						
7												
8												
9												
10												
11												
12											Total shot	
13											Steel	Lead
# of shot	1	0	0	1	1	3	0	0	0	0	8	17
											Total samples	
#of samples	6		6		6		4		2			137

Table 3. Number and type of shot found from transects at Lindau WPA, Nebraska, 1997-98.

Lindau	T1		T 2		T 3		T 4		T 5		T 6		T 7		T 8		T 9		T 10		T 11		T 12	
sample #	Steel	Lead	Steel	Lead	Steel	Lead	Steel	Lead	Steel	Lead	Steel	Lead	Steel	Lead	Steel	Lead	Steel	Lead	Steel	Lead	Steel	Lead	Steel	Lead
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0
2	0	0	0	0	0	1	0	0	0	0	0	2	0	0	0	0	0	1	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	1	0	0	0	0	0	0	3	0	0	0	0	0	1	0	0	0	0	0	1
6			0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	1	0	1	0	0
7			0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
8					0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
9					0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0
10									0	0	0	0	0	0					0	0			0	0
11																								
28																								
29																								
# of shot	0	0	0	0	1	1	0	1	0	0	1	5	1	1	0	3	1	2	0	2	1	2	0	1
# of samples	5		7		9		9		10		10		10		9		9		10		9		10	

Lindau	T 13		T 14		T 15		T 16		T 17		T 18		T 19				
sample #	Steel	Lead	Steel	Lead	Steel	Lead	Steel	Lead	Steel	Lead	Steel	Lead	Steel	Lead			
1	0	0	1	0	0	0	0	0	0	2	0	0	0	0			
2	0	1	0	0	0	1	0	0	0	0	0	1	0	0			
3	0	1	0	1	0	0	0	0	0	0	0	0	0	0			
4	0	0	0	1	0	0	0	0	0	0	0	0	0	0			
5	0	0	0	1	0	0	0	0	0	0	0	0	0	0			
6	0	0	0	0	0	0	0	0	0	0	0	0					
7	0	0	0	0	0	0	0	0	0	0							
8	0	1	0	1	0	0	0	0									
9	0	0	0	0	0	0											
10			0	0													
11																	
																Steel	Lead
# of shot	0	3	1	4	0	1	0	0	0	2	0	1	0	0	Total Shot	6	29
# of samples	9		10		9		8		7		6		5		Total Samples		161

Table 4. Number and type of shot found from transects at Mallard Haven WPA, Nebraska, 1997-98.

Mallard Haven	T 1		T 2		T 3		T 4		T 5		T 6		T 7		T 8		T 9		T 10		T 11	
sample number	Steel	Lead	Steel	Lead	Steel	Lead	Steel	Lead	Steel	Lead	Steel	Lead	Steel	Lead	Steel	Lead	Steel	Lead	Steel	Lead	Steel	Lead
1	0	0	1	2	0	0	0	0	1	5	0	0	2	3	2	2	0	0	0	0	0	0
2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	2
3	0	2	0	1	0	0	0	1	0	0	0	0	0	0	0	0	1	1	0	0	0	0
4	0	0	0	0	2	1	0	1	0	0	0	0	0	0	1	1	0	2	0	0	0	0
5			0	3	0	0	0	0	1	1	0	0	0	0	0	0	0	0	1	1	1	0
6			0	0	0	1	1	0	0	0	1	0	0	0	0	1	0	0	2	1	1	0
7					0	0	1	0	1	0	0	0	1	0	0	0	0	1	1	0	0	0
8					0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0
9					0	0	0	0	0	0	1	0	0	0	0	1	0	0	1	0	0	0
10					0	0					1	0					0	0	0	0	0	1
11					0	1																
12					0	0																
# of shot	0	2	2	6	2	3	3	2	3	6	3	0	3	3	3	5	1	4	6	6	2	3
# of samples	4		6		12		9		9		10		9		9		10		10		10	

Mallard Haven	T 12		T 13		T 14				
sample number	Steel	Lead	Steel	Lead	Steel	Lead			
1	0	1	0	1	0	0			
2	0	3	0	0	0	0			
3	1	0	0	1	0	1			
4	0	3							
5	1	0							
6	1	0							
7	2	0							
8	0	0							
9									
10									
11									
12								steel	lead
# of shot	5	7	0	2	0	1	Total Shot	33	50
# of samples	8		3		3		Total Samples		112

Table 5. Number and type of shot found from transects at Harvard WPA, Nebraska, 1997-98. Transects 1 and 2 were set up 200 m apart and samples collected every 30 m. The transects were then changed to every 100 m and sampled every 60 m. Transect 3 was then located halfway between T1 and T2.

Harvard Marsh	T1		T 2		T 3		T 4		T 5		T 6		T 7		T 8		T 9		T 10		T 11	
Sample number	Steel	Lead	Steel	Lead	Steel	Lead	Steel	Lead	Steel	Lead	Steel	Lead	Steel	Lead	Steel	Lead	Steel	Lead	Steel	Lead	Steel	Lead
1	1	0	0	0	1	5	2	2	2	2	1	5	0	0	0	4	0	2	0	4	0	1
2	0	5	0	2	0	5	0	0	0	1	0	4	0	1	0	2	1	2	0	2	0	0
3	1	1	1	0	0	0	0	0	0	1	0	2	2	0	3	1	0	0	2	0	0	0
4	0	0	2	1	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	1	4	0	0	0	0	0	0	0	0	0	0	1	3	0	0	0	0
6	0	0	0	1	1	0	0	0	0	0	0	0	1	0	0	0	1	1	0	0	0	0
7	0	3	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1	3	1	0	0
8	0	2	0	4	0	1	0	0	0	0	0	0	0	1	0	0	1	0	0	1	0	0
9	0	4	1	5	0	1	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	1
10	0	2	2	1	2	0	0	0	0	4	2	2	2	0	0	0	0	1	0	2	0	3
11	2	1	0	3	0	2	0	3	0	1	0	7	1	1	1	0	0	0	1	3		
12	0	1	1	1	0	3	0	4	0	2	1	3	0	3								
13	0	1	0	1					0	0	0	2										
14	0	3	1	0																		
15	1	4	0	0																		
16	0	1	0	1																		
17	1	1	3	1																		
18	0	4	1	1																		
19	0	3	1	1																		
20	0	0	0	3																		
21	0	2	1	1																		
22			3	0																		
23			0	1																		
24			0	1																		
25			0	0																		
26			1	1																		
# of shot	6	38	18	30	5	24	2	9	2	11	4	25	6	7	4	7	5	12	6	13	0	5
# of samples	21		26		12		12		13		13		12		11		11		11		10	

Table 5. cont.

Harvard Marsh	T 12		T 13		T 14		T 15		T 16		T 17		T 18		T 19		T 20		T 21		T 22		T 23	
Sample number	Steel	Lead	Steel	Lead	Steel	Lead	Steel	Lead	Steel	Lead	Steel	Lead	Steel	Lead	Steel	Lead	Steel	Lead	Steel	Lead	Steel	Lead	Steel	Lead

1	1	0	0	1	1	1	0	1	0	1	0	7	0	0	2	4	0	0	0	4	0	2	transect		
2	0	0	1	0	0	5	0	0	0	0	0	1	0	4	0	1	1	0	0	1	1	3	skipped		
3	0	0	1	0	0	0	1	0	0	1	1	1	0	0	0	0	0	0	0	6	1	1	because		
4	1	0	1	0	0	0	0	0	1	4	1	1	0	0	0	0	0	1	0	4	0	0	of error in		
5	1	0	0	0	1	0	1	0	0	4	1	0	1	0	1	0	0	0	0	0	0	4	numbering		
6	0	0	1	0	0	0	0	1	0	3	0	1	0	0	0	1	0	1	1	1	0	0			
7	0	0	0	3	1	1	1	3	0	0	0	2	0	0	1	0									
8	0	0	0	4	0	3	0	3	1	1															
9	1	2	1	1																					
10	0	0	0	1																					
11																									
12																									
13																									
14																									
15																									
16																									
17																									
18																									
19																									
20																									
21																									
22																									
23																									
24																									
25																									
26																									
# of shot	4	2	5	10	3	10	3	8	2	14	3	13	1	4	4	6	1	2	1	16	2	10	0	0	
# of samples	10		10		8		8		8		7		7		7		6		6		6				

Table 5. cont.

Harvard Marsh	T 24		T 25		T 26		T 27		T 28		T 29		T UNK*					
Sample number	Steel	Lead	Steel	Lead	Steel	Lead	Steel	Lead	Steel	Lead	Steel	Lead	Steel	Lead				
1	1	4	1	0	2	1	0	1	0	0			0	0				
2	1	1	1	0	0	0	1	2	0	0	0	0	0	1				
3	0	0	0	0	0	0	0	1					1	1				
4	0	0	0	2	0	1							0	6				
5	0	1	2	1									0	1				
6	0	4																
7																		
8																		
9																		
10																		
11																		
12																		
13																		
14																		
15																		
16																		
17																		
18																		
19																		
20																		
21																		
22																		
23																		
24																		
25																		
26																	steel	lead
# of shot	2	10	4	3	2	2	1	4	0	0	0	0	1	9	Total Shot	steel	97	304
															Hospital x-ray **	steel	3	10
# of samples		6		5		4		3		2		1		5				
															Total Samples			261

* Sample tags were damaged and unreadable.

**All samples from this WPA were x-rayed by the Radiology Department, Saint Francis Medical Center, Grand Island, NE. The numbers represent additional shot found using a more powerful x-ray.