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LEAD SHOT: ITS SETTLEMENT, OXIDATION, AND GENERAL AVAILABILITY TO WATERFOWL IN UTAH MARSHES.

by

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The following report is a condensed version of eleven years of study conducted at Bear River Migratory Bird Refuge by members of the Utah State University Cooperative Wildlife Research Lab, lead by Dr. J. B. Low. Portions of this report are verbatim and portions are paraphrased.

In an attempt to further knowledge in the area of lead poisoning of waterfowl from spent shot pellets, students from the Utah Cooperative Wildlife Research Unit (under the direction of J. B. Low) conducted a 12 year study at Bear River Migratory Bird Refuge. Entitled "LEAD SHOT: ITS SETTLEMENT, OXIDATION, AND GENERAL AVAILABILITY TO WATERFOWL," the study plan stated two objectives:

1. To determine the rate and depth of settlement of lead shot in a clay marsh soil.
2. To determine the rate and degree of oxidation and decomposition of lead shot in a saline marsh soil.

Later studies conducted in conjunction with the settlement investigation dealt with pellet availability to waterfowl. The objectives were:

3. To determine the availability of lead shot pellets to waterfowl in a "typical" waterfowl feeding area.
4. To ascertain the general distribution of lead pellets in a "typical" western marsh.

OBJECTIVES 1 AND 2

STUDY AREA

The area selected for study is a part of Unit 2-A located on the Bear River Migratory Bird Refuge at Brigham City, Utah.

The study plots were established in a marshland feeding area which has shallow water (6"-18") during the entire year. The area is free from waterfowl hunting to eliminate the chance of additional pellets entering the plot, as well as being protected from hunters who might walk through the plots. The entire study plot is covered with a wire mesh to protect it from disturbances by water-birds and carp.

Two sites were established for the study. One site, established in 1961, included settlement and oxidation rates for pellet sizes 2,5,6, and 7½ (Fig. 1). A second site was established in 1966 and monitored settlement and oxidation rates for #4 lead pellets (Fig. 2).

PLOT CONSTRUCTION

The 1961 experimental area was 23' X 11' and was composed of 24 plots (2' X 2') each with 4-1 ft.^{2} subplots. The 1966 area was 5' X 8' consisting of 6 plots, each with 4 1 ft.^{2} subplots.

The plots were arranged in rows with walkways around each row. Row corners were marked with metal fence posts. A chain ladder was suspended from corner posts to define each plot. The plots were marked with metal tags to enable identification and relocation.

PELLET DISTRIBUTION

After the chain boundary markers were installed, the different sized lead pellets were deposited over randomly selected sub plots. The lead pellets (50 pellets per sub plot) were scattered by hand over the water and sank through 8" of water before settling on the mud bottom. The 1961 plots were "seeded" with 4 shot sizes (2,5,6,7½), one size per sub plot. The 1966 sub plots were seeded with #4 lead pellets.

SAMPLE METHOD

Each year soil samples were taken with a sheet metal sampling box which measured 1 ft.^{2} by 2' deep. The plots were located by the chain ladder and metal identification tags. The actual sampling proceedure was as follows:

1. The sampling box was pushed into the mud until the hard-pan bottom was reached (6"-8").

2. Water was removed from the box by means of a bilge pump.

3. One inch layers of soil were removed from the box by means of a small garden trowel.

4. Each 1" layer was placed in a plastic bag and labled accordingly. Samples were taken to an 8" depth.

5. After the sampling was completed, each soil layer was washed and sieved through a #10 mesh screen to recover the pellets. Samples were processed at the Cooperative Wildlife Research Unit Lab.

6. Recovered pellets were counted and recorded as to shot size, depth of occurrance, and degree of oxidation. A binocular scope (200X) was used to examine recovered lead pellets and a comparison was made to new pellets to determine the extent of decomposition (oxidation).

RESULTS AND DISCUSSION

A total of 30 sub plots were sampled. Six of these were used for each shot size: of which one was sampled each year; thereby, totaling six sampling years for each shot size.

RECOVERY RATES

During the process of sampling, 2,907 of the originally planted 6,000 pellets were recovered; thereby giving an overall recovery rate of 48.5% (Table 1). The number of pellets, and percent recovery rate for a given shot size at a given depth during a given sampling year are given in Table 2.

The general trend in recovery rates was a lowered recovery rate during each consecutive sampling year except for sampling years six and seven.

This recovery trend, except for sampling years six and seven, follows a texture and density pattern trend of the soil, with a resulting trend in susceptibility to lateral shifts of the mud by wind and wave action. For example, the results of this study show that the highest loss of planted shot per years in the soil occurred during the first year of shot settlement, when the majority of the shot was in the least packed, top three inches of soil. Also, samples taken from soils adjacent to the sampling area showed that the planted shot had moved horizontally out of the sampling area. These shot were identified as those belonging to the study by their uniform roundness, which indicates that they were not fired through a shot-gun barrel, because shooting usually causes flattening or barrel deformity to the shot.

SINKING RATES OF ALL SHOT SIZES

The results as to where the shot from a given shot size was found in a given sampling year are shown in Table 2. Statistical tests run on all shot sizes showed that the difference in sinking rates of various shot sizes was non-significant. This was also found during a similar study conducted at Catahoula Lake, Louisiana (Wycoff, et. al. 1971).

Since there is no significant difference between various shot sizes sinking rates; the total of all shot sizes can be used in discussing sinking rates, thereby giving a larger sample size and perhaps a more accurate picture of lead shot's sinking rate.

At the end of the first year of settlement, the majority (46.5%) of the planted lead shot was found at the one and two inch level. At the end of the second year of sampling the majority (33%) of the lead shot was found at the three to four inch level. At the end of the third year of settlement the majority (39.9%) of the lead shot was found at the three to four inch level. At the end of the fourth year of settlement the majority (48%) of the planted lead shot was at the four to five inch level. At the end of the fifth year of settlement the majority (48%) of the planted lead shot was found at the five to six inch level. At the end of the sixth year of settlement the majority (39%) of the seeded lead shot was found at the four to five inch level. And at the end of the seventh year of settlement the majority (43.2%) of the lead shot was found at the five to six inch level (Table 2).

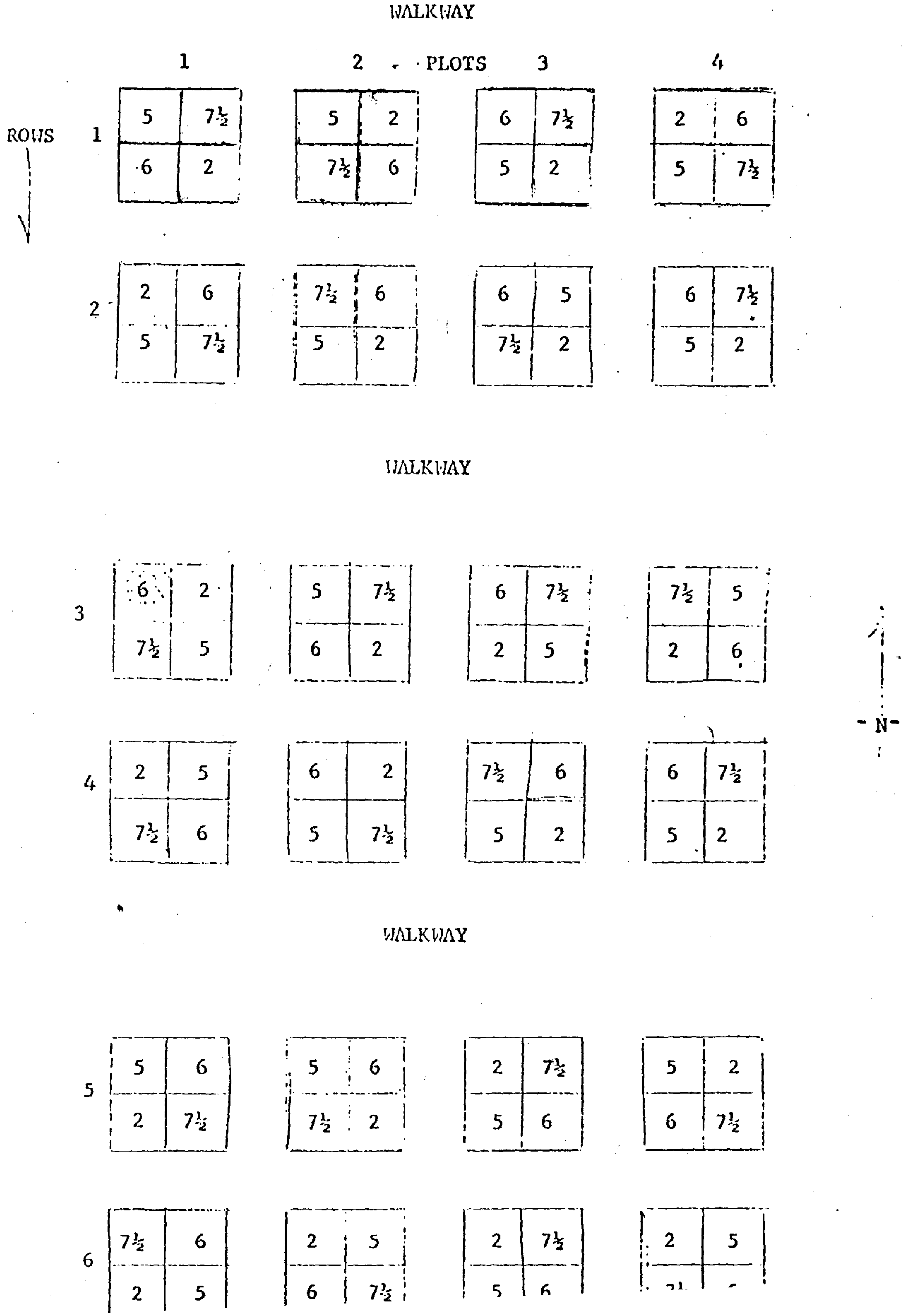
The whole process of lead shots sinking rate seems to depend on the density trends of the soil it (the shot) is located in. In the study area the data indicates that lead shot moves rapidly through the loosely packed first three to four inch level. At this point, it starts to slow down and then stops and stays at a depth between five to seven inches. This stopping of the shots downward movement is caused by a layer of soil which is packed or compressed. This layer is called the clay or hardpan layer. Since lead shot is not going to sink lower than seven inches into the soils of the study area, it seemed desirable to know if it was going to decompose or oxidize.

<u>OXIDATION OF THE LEAD SHOT</u>

In all the lead shot samples taken there were no signs of oxidation on any of the individual pellets. The only flaws to the lead shot were factory molding imperfections and in some cases, slight deposits of calcium carbonate.

This lack of oxidation was expected due to the chemistry of lead oxidation. Lead oxidizes just enough to form a black or grey coat over the metal, which is dense enough to retard further oxidation, especially in a saline marsh such as the study area.

Figure 1. Experimental Design of Study Area.



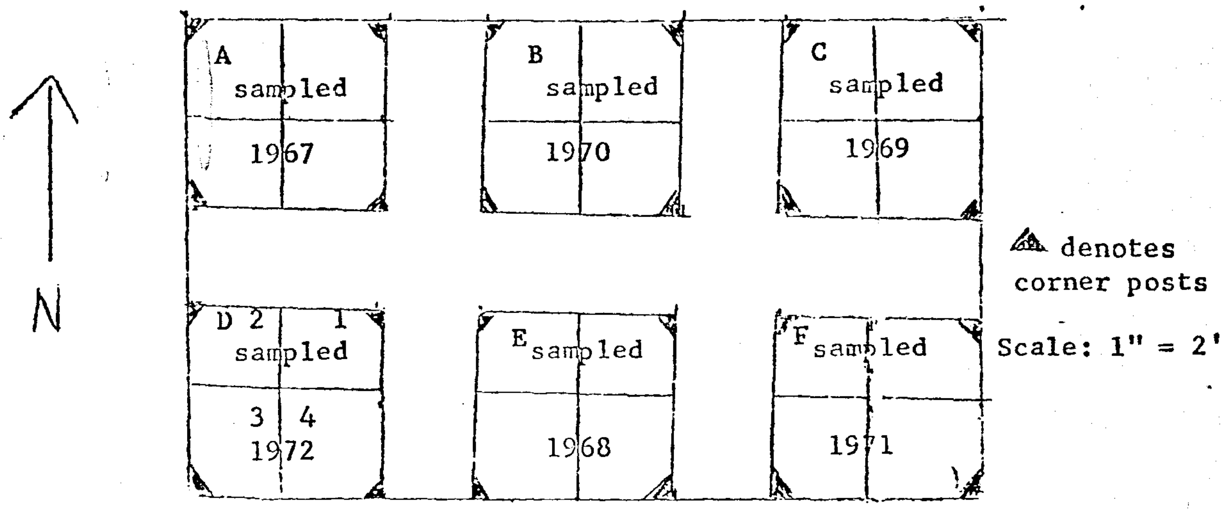


Figure 2. Study area sampling plots for the No. 4 shot phase of the lead shot study at Bear River Migratory Bird Refuge, Brigham City, Utah.

TABLE 1. Number of shot pellets recovered per sample year by shot size.

YEAR	SHOT SIZE 2	4	5	6	7 1/2
1	122	163	128	118	146
2	111	98	102	121	128
3	--	103	--	--	--
4	81	68	93	97	109
5	68	53	54	63	56
6	90	121	97	98	97
7	90	--	91	58	79
TOTAL PELLETS	566	606	565	555	615
PERCENT RECOVERY	47.2%	50.5%	47.1%	46.2%	51.2%
OVERALL TOTAL	2,907 pellets recovered/6,000 pellets deposited 48.5%				

TABLE 2. Sinking rates and recovery percentages of lead shot pellets. From the Cooperative Wildlife Research Unit 12 yr. study. Bear River MBR.

The Numbers and Percentages of Recovered Shot

Shot Size

YEAR SAMPLED	Depth in Inches	#2		#4		#5		#6		#7 1/2		Total of all shot Sampled	
		*#	*%	#	%	#	%	#	%	#	%	#	%
	0-1	10	8.2	118	72.4	20	15.6	9	7.6	1	.7	158	23.3
	1-2	77	63.1	29	17.8	78	60.9	68	57.6	63	43.2	315	46.5
1	2-3	24	19.7	7	4.3	22	17.2	17	14.4	44	30.1	114	16.8
	3-4	11	9	9	5.5	8	6.3	23	19.5	24	16.4	75	11.1
	4-5	0	0	0	0	0	0	1	.9	14	9.6	15	2.2
	5-6	--	--	0	0	--	--	--	--	--	--	--	--
	6-7	--	--	0	0	--	--	--	--	--	--	--	--
	7-8	--	--	'61 0	0	--	--	--	--	--	--	--	--
	0-1	0	0	0	0	1	1	1	.8	0	0	2	.4
	1-2	14	12.6	0	0	10	9.8	28	23.1	7	5.5	59	10.5
	2-3	24	21.6	0	0	37	36.3	26	21.5	29	22.6	116	20.7
	3-4	29	26.1	0	0	31	30.4	43	35.5	54	42.2	157	28
2	4-5	44	39.6	9	9.2	23	22.5	23	19	38	29.7	137	24.5
	5-6	--	--	16	16.3	--	--	--	--	--	--	16	2.9
	6-7	--	--	28	28.6	--	--	--	--	--	--	28	5
	7-8	--	--	45	45.9	--	--	--	--	--	--	45	8
	0-1	--	--	0	0	--	--	--	--	--	--	0	0
	1-2	--	--	1	1	--	--	--	--	--	--	1	1
	2-3	--	--	13	12.6	--	--	--	--	--	--	13	12.6
	3-4	--	--	41	39.9	--	--	--	--	--	--	41	39.9
	4-5	--	--	26	25.2	--	--	--	--	--	--	26	25.2
3	5-6	--	--	13	12.6	--	--	--	--	--	--	13	12.6
	6-7	--	--	7	6.8	--	--	--	--	--	--	7	6.8
	7-8	--	--	2	1.9	--	--	--	--	--	--	2	1.9
	0-1	0	0	0	0	1	1.1	1	1	3	2.7	5	1.1
	1-2	2	2.5	0	0	1	1.1	3	3.1	3	2.7	9	2
	2-3	4	4.9	1	1.5	11	11.8	12	12.4	21	19.3	49	10.9
	3-4	22	27.2	5	7.3	29	31.2	27	27.8	39	35.8	122	27.2
	4-5	53	65.4	14	20.5	51	54.8	54	55.7	43	39.4	215	48
4	5-6	--	--	24	35.5	--	--	--	--	--	--	24	5.4
	6-7	--	--	14	20.5	--	--	--	--	--	--	14	3.1
	7-8	--	--	10	14.7	--	--	--	--	--	--	10	2.2
	0-1	0	0	0	0	0	0	0	0	0	0	0	0
	1-2	0	0	0	0	0	0	1	1.6	0	0	1	0
	2-3	1	1.5	0	0	3	5.5	1	1.6	4	7.1	9	3.1
	3-4	3	4.4	1	1.9	7	13	5	7.9	10	17.9	26	8.9
	4-5	19	27.8	9	17	17	31.5	28	44.4	18	32.1	91	31.1
5	5-6	45	66.2	17	32	27	50	28	44.4	24	42.9	141	48.1
	6-7	--	--	16	30.2	--	--	--	--	--	--	16	5.4
	7-8	--	--	10	18.9	--	--	--	--	--	--	10	3.4
	0-1	0	0	0	0	0	0	0	0	0	0	0	0
	1-2	0	0	0	0	0	0	2	2	2	2	4	.8
	2-3	1	1.1	7	5.8	24	24.7	1	1	5	5.2	38	7.5
	3-4	12	13.3	21	17.5	10	10.3	20	20.4	24	24.7	87	17.3
6	4-5	33	36.7	43	35.5	45	46.4	48	49	28	28.9	197	39.2
	5-6	44	48.9	39	32.2	18	18.6	27	27.6	38	39.2	166	33
	6-7	--	--	9	7.4	--	--	--	--	--	--	9	1.8
	7-8	--	--	'72 2	1.6	--	--	--	--	--	--	2	.4
	0-1	0	0	--	--	0	0	0	0	0	0	0	0
	1-2	0	0	--	--	0	0	0	0	2	2.5	2	.6
	2-3	1	1.1	--	--	4	4.4	17	29.5	3	3.8	25	7.8
	3-4	11	11.7	--	--	17	18.7	23	39.5	7	8.9	58	18
	4-5	27	28.7	--	--	32	35.2	9	15.5	30	38	98	30.4
7	5-6	55	58.5	--	--	38	41.7	9	15.5	37	46.8	139	43.2
	6-7	--	--	--	--	--	--	--	--	--	--	--	--
	7-8	--	--	--	--	--	--	--	--	--	--	--	--

The actual number of shot recovered of a given size during a given sample year, and at a given depth.

% The percentage of recovered shot from one sampling year, found at a given depth and from a given shot size.

OBJECTIVE 3

INTRODUCTION

The verticle distribution of lead shot pellets over a seven year period was discussed in the previous study. To gain understanding as to what depths (combinations of water and marsh soil) dabbling ducks would feed in marsh situation, the Cooperative Wildlife Research Unit conducted feeding trials using mallards (Anas platyrhynchos).

PROCEEDURE

Ducks were arbitrarily divided into six pairs (one male and one female) and each pair given a number. The six pairs were used in a repeating order until testing was completed.

Twenty-four hours before a test was run, the pair to be used was caught and placed in a separate pen which was supplied with water and grit but no food. At the end of the 24 hour starvation period, the birds were placed into a metal stock watering tank (food tank) for an additional 24 hours. Wire enclosures were made to cover the tops of the tanks so that the ducks could not escape during the test.

The food tanks were set-up as follows: 400 kernels of cracked corn were counted and checked to be sure they could not pass through a 1/8" mesh screen. The corn was scattered evenly over the tank bottom and the appropriate depth of marsh mud was then spread evenly over the corn. The marsh mud was collected from the marsh at Bear River Migratory Bird Refuge. The desired water depth was then added.

After the birds were removed from the tanks, the water was drained and the soil was sifted through the 1/8" mesh screen. A record was kept of the remaining kernels.

RESULTS

Tests were begun using mud only (no overlying water). At 2 inches of mud the ducks were able to eat 90% of the corn. The mud conditions were probably somewhat different than would be found in the wild on a mudflat however, in that the ducks were simply wading in the mud and standing on the bottom of the tank. This was also the case in the 4" and 6" mud trials.

In 4" of mud, the ducks were able to eat 16.75% of the corn.

At the 6" level, the birds ate 21.25% but were so covered with mud after 24 hours that they could hardly move. For all practical purposes, ducks would not feed under these conditions in the wild if the mud were any more solid. It is doubtful that the birds could penetrate 6" of mud.

In the tests of water depth only, the birds ate essentially 100% of the corn at every water depth from 2" to 14". At 16" consumption was cut in half. This is interesting in the light of the fact that the average length of our drakes from the front of the leg to the nail of the bill was 14.5". This indicates that 14" is the maximum depth at which mallards can feed by tipping up. Beyond the 14" level, these dabblers are not effective feeders. Under wild conditions, this 14" to 15" depth is very significant.

The water and mud combination teats presented some difficulties. Two inches of water and two inches of mud became a soupy suspension as soon as the ducks were placed in the tank. Similar results were obtained with 4" of water and 2" of mud. To circumvent this problem, trials were begun at the other end of the scale, with deep water over mud and moved toward shallower water until again, the mud went into suspension. We hoped for good results at least until we arrived at the critical 14"-16" level; below this, the feeding success is interesting but not highly significant.

The next test was with 20" over 2" of mud. We were interested to see whether the ducks would be successful here as they had been with 20"-22" of water only. We theorized that eventhough the birds could dive to the bottom, they would not be able to dig through the mud and pick up the corn. We were proved right. After 24 hours of attempt, the birds had not ingested a single kernel. This information lead us to believe that feeding success should remain at zero until the tipping depth was reached (14"-16"). Feeding success remained at zero at the 18" and 16" levels. The birds were able to ingest 9.5% of the corn at the 14" level. The test of 12" of water over 2" of mud again produced problems as half the mud went into suspension.

The next test was 14" of water over 4" of mud. We assumed that the birds would be unsuccessful with 16" of water (beyond the "critical" level). At 14" the ducks were unable to eat any corn. At 12", 19.25% of the corn was eaten. With 10" of water over 4" of mud, 62.25% of the corn was eaten. At the 8" level 70% was eaten. At the 8" level some mud went into suspension so the 6" mud trials were begun.

With 10" of water over 6" of mud no corn was ingested. No corn was eaten with an overlying water layer of 8". When 6" of water was placed over 6" of mud, 25% of the mud went into suspension. The birds did manage to ingest 64% of the food. At the end of this test the ducks were completely covered with mud so it seemed pointless to continue the tests with shallower water.

Tests were not conducted with 8" of mud for obvious reasons.

CONCLUSIONS

The most important finding of this study was that the maximum total mud and water combination that the ducks could successfully feed in was sixteen inches. This held true for both the 2" and 4" mud depths under water. This is the maximum depth that mallards can feed by tipping up. This is especially significant when the average length (of the mallards) from front of leg to bill tip is 14.5". The birds apparently can strain and feed to sixteen inches.

Since tubers important as duck food usually lie in the top 2" of mud, 14" of water could be maintained over a marsh and the ducks could feed. Assuming most shot lay deeper than 2", lead ingestion (for birds of similar length to mallards) should be greatly reduced.

Mallards definately proved their ability to feed by diving but there are probably few natural situations where they could use this ability.

If a marsh was frequented heavily by smaller ducks (eg. Green-winged Teal), it seems logical that the measurement from the bill tip to the front of the leg plus 1" to 2" could be taken and used as an approximate maximum tipping depth, and also as the depth to which the water could be kept over the marsh soil to reduce the ingestion of shot pellets by waterfowl.

OBJECTIVE 4

INTRODUCTION

To ascertain the general distribution of lead pellets in the soil of a "typical" western marsh, members from the Cooperative Wildlife Research Unit conducted a study at Bear River Migratory Bird Refuge to determine: the density of spent lead pellets in the marsh soil, and the horizontal and verticle distribution of spent pellets.

STUDY AREA

Since waterfowling on the Bear River marshes has traditionally been shooting over decoys from points of land jutting from the bays, it was assumed that the heaviest concentrations of spent shot would be offshore from these popular points. These desired points have likely had blinds on them for at least 70 years. Thus, the points selected for the study was what is known to most hunters as "Slaughter Point" in Unit 2.

PROCEEDURE

A stake was driven in the center of the blind located on Slaughter Point. From this point, a transect was established to a point 200 yds. out into the water. Along this line stakes were driven at 20 yd. intervals to define sampling stations. At each station, core samples were taken. The core sampler was aluminum tubing, 4" in diameter. The sampler was driven into the soil as far as possible (down to the underlying "hard-pan"). Samples averaged 10" deep. Three cores were collected at each station, one directly on the transect and one 2' either side of the line.

As the cores were taken, they were carefully removed from the sampler and cut into 1" segments. Each segment was placed in a labled plastic bag. Sample segments taken to the lab were washed through a fine screen to separate the pellets from the mud.

RESULTS

A total of 30 cores were taken; of these, 9 contained a lead pellet. None of the cores contained more than one pellet, but in two cases two cores from the same station contained pellets (80 and 160 yards). Three stations (20, 120, and 180 yds.) produced no pellets.

Since the cores averaged 10" deep and were 4" in diameter, a total of 26.2 $ft.^3$ were screened in which 9 pellets were found. This calculates to approximately 1 pellet/2.9 $ft.^3$ of soil.

There was no area offshore which appeared to have more lead pellets than any other (Fig. 1). The shot seems to be evenly spread over the 200 yards. This conflicts with Wetmore's (1919) findings, in which no pellets were recovered closer than 130 yards from the blind.

Vertically, pellets were found everywhere from the surface inch to a depth of 9"-10" (Fig. 2).

Since the water depth in the area sampled ranged from 1"-6", 2/3 of the pellets found (six pellets) would have been available to large surface feeding ducks (assuming that 14" total water and soil to be the maximum tipping-up depth for feeding).

CONCLUSIONS

1. In the 26.2 $ft.^3$ of soil samples, 9 pellets were found giving a density of ~~2.9~~ 1 pellets per 2.9 cubic foot of soil.
2. Shot seemed to be evenly distributed horizontally over the 200 yards adjacent to the point.
3. Shot was found from the soil's surface to a depth of 10". There was no apparent depth of pellet concentration.

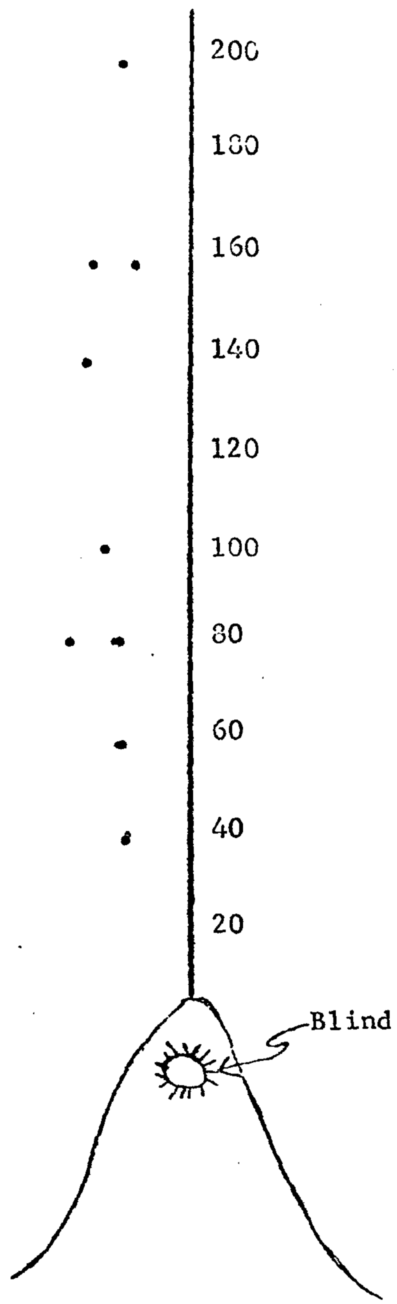


Figure 1. Horizontal distribution of lead pellets in the marsh at Bear River Bird Refuge, Utah, 1970

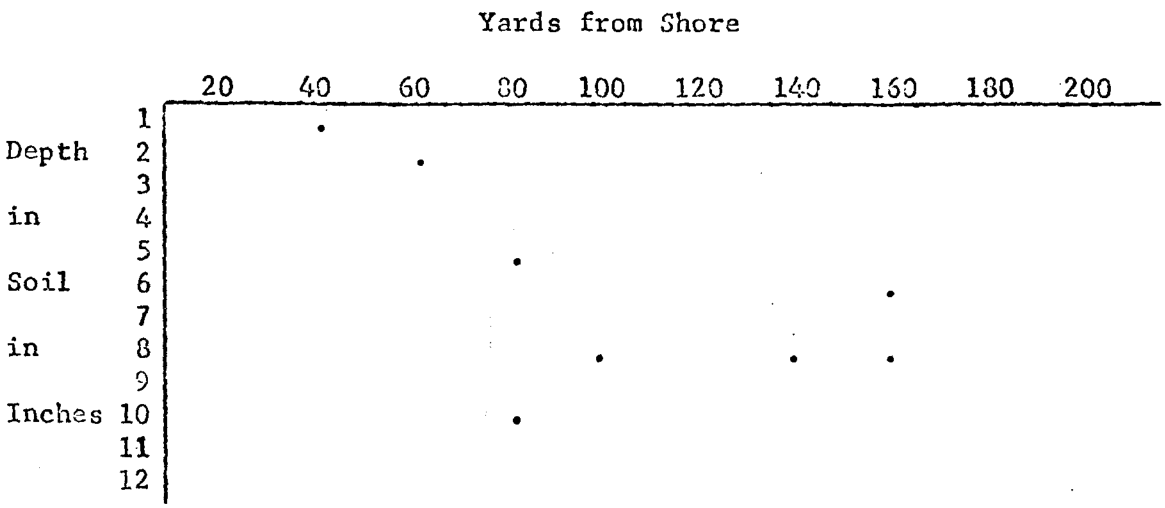


Figure 2. Vertical distribution of lead pellest in the marsh soil at Bear River Migratory Bird Refuge, Utah 1970.

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