5-1952

The Incidence of Lead Shot in Waterfowl of the Pacific Flyway, With Special Reference to the Great Salt Lake Basin

Wayne H. Heuer
Utah State University

THE INCIDENCE OF LEAD SHOT IN WATERFOWL OF THE PACIFIC FLYWAY, WITH SPECIAL REFERENCE TO THE GREAT SALT LAKE BASIN

by

Wayne H. Heuer

A thesis submitted in partial fulfillment
of the requirements for the degree

of

MASTER OF SCIENCE

in

Wildlife Management

UTAH STATE AGRICULTURAL COLLEGE
Logan, Utah

1952

Approved:

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGEMENTS

I wish to express my sincere appreciation to Allen G. Smith and G. Hortin Jensen, Biologists, U. S. Fish and Wildlife Service, for use of the laboratory, its facilities and equipment, and to Mr. Vanez T. Wilson, Superintendent of the Bear River Migratory Bird Refuge, for use of equipment.

I also wish to acknowledge the information received from Harold Frazier, former graduate student at Utah State Agricultural College, and Frank C. Bellrose, Illinois Natural History Survey, on ingested lead and body shot.

To Dr. Jessop B. Low, Utah Cooperative Wildlife Research Unit, for assistance, in choosing a problem and throughout the study; to Drs. M. L. Miner and Wayne Binns, of the Department of Veterinary Science, Utah State Agricultural College, for use of the X-ray unit; and to Mr. Robert Fuller and Robert Dahlgren, graduate students, for assistance and encouragement, I am deeply grateful.

To my wife, for helpful criticism, assistance and encouragement, this work is dedicated.

INTRODUCTION

This study was conducted to determine basic data on the incidence of lead shot in ducks using the Great Salt Lake Basin. The study has been divided into two parts; (1) incidence of ducks carrying lead shot in their tissues and (2) incidence of ducks carrying ingested lead shot.

Lead Shot in the Tissues

Hunting pressure has been defined as the amount of hunting borne by a waterfowl species or by the waterfowl population as a whole in any given season. For many years the hunting pressure on waterfowl has been based on the number of hunters and their success during the waterfowl season. Total hunters and their success have been used to determine total kill. In addition, crippling loss must be added before a complete picture of the waterfowl loss for any one season may be obtained.

Hunting pressure is difficult to determine because it is a factor which is dependent on many forces, such as the number and skill of the hunters, abundance of game during the season, habits of the species, and effects of the weather on chronology of waterfowl migrations. Frequently, hunting pressure, borne by waterfowl populations, is measured by kill data alone or by numbers of duck stamps sold. Kill data are not always reliable because of the difficulty in gathering accurate harvest figures. Checking stations help to a great extent but, at best, they sample only a small segment of the waterfowl hunting population. Post-season surveys of waterfowl hunters, either by personal

contact or by mail, rely on the memory of the hunter and thus a large undetermined error in estimating the kill for the season may be encountered. Hunting pressure as determined by duck stamp sales raises the question as to actual pressure exerted by those purchasers on any one species or on the population as a whole. Weather, migration patterns, frequency of hunting, abundance of buffer species, selectivity between species, and open seasons on other game species during the waterfowl season may all influence the actual pressure sustained by waterfowl when measured solely by this method.

Another means of measuring hunting pressure was suggested by the following reasoning (Elder, 1950). The amount of lead shot fired at waterfowl in any particular year, or at any one species in that year, should be proportionate to (1) the number of ducks killed or (2) the number killed of that species, also to (3) the number of ducks that are crippled and die, and (4) the number that survive their wounds and carry shot in their flesh as a permanent mark of their escape. An accurate measure of any one of these four factors should give an index to all the others.

The most practical of these factors to measure seemed to be the percent of ducks carrying lead shot in their tissues after the hunting seasons. A lead shot in the body of a bird remains intact, and being more radio-opaque to X-rays than are bones, is easily seen. By use of an X-ray fluoroscope in a dark room, a duck may be quickly and easily examined for shot in the tissues.

The lead shot observed in the tissues of waterfowl indicates the bird had received a wound that was either in an area of the body that was less vulnerable to a fatal wound such as the legs or wings, or that

they were at the extreme range of the hunter's gunshot pattern and the pellets entered the body with insufficient force to kill, leaving the bird with a permanent indication that it had been through at least one hunting season. Only birds that were more than one year old and therefore had been exposed to at least one waterfowl hunting season were examined for tissue lead. The study was conducted during the summers of 1950-51 when sufficient birds could be obtained for examination.

Ingested Lead Shot

Apparently lead poisoning from ingested shot is a serious cause of mortality in some areas (Bellrose, 1951). There is very little information available for making even a rough estimate of the nation-wide losses resulting from lead poisoning in wild waterfowl.

The shot pellets are taken into the stomach during the normal feeding activities of the birds. After ingestion, when the shot finally comes to rest in the gizzard of the bird, it is subjected to erosion by the grinding action of the gizzard and its contents. In addition to this it is acted upon by the digestive juices. When the lead compounds enter the intestine some of them are absorbed by the blood stream and apparently damage the liver and kidneys. The normal activity of the muscles of the digestive tract may be reduced to an extent as to seriously impair or stop digestion and the assimilation of food (Bellrose, 1951).

In addition to the data on ingested lead shot accumulated during the summer the writer participated in a nation-wide study conducted by Frank C. Bellrose of the Illinois Natural History Survey. Mr. Bellrose is accumulating data on ingested lead shot from various parts of the United States in an effort to ascertain waterfowl losses from lead

poisoning (Figure 1). Gizzards were collected from several sources in the Great Salt Lake Basin area during the waterfowl hunting season and fluoroscoped by the writer. These included both adult and juvenile duck gizzards, whereas the summer figures include only adult birds.

By determining the percentage of waterfowl carrying ingested lead shot and the numbers of lead pellets carried by each bird, it is possible to determine the probable loss on a population of waterfowl on a given area. However, correlated with the determination of incidence of ingested lead, the mortality resulting from various doses of lead pellets ingested must be experimentally evaluated.

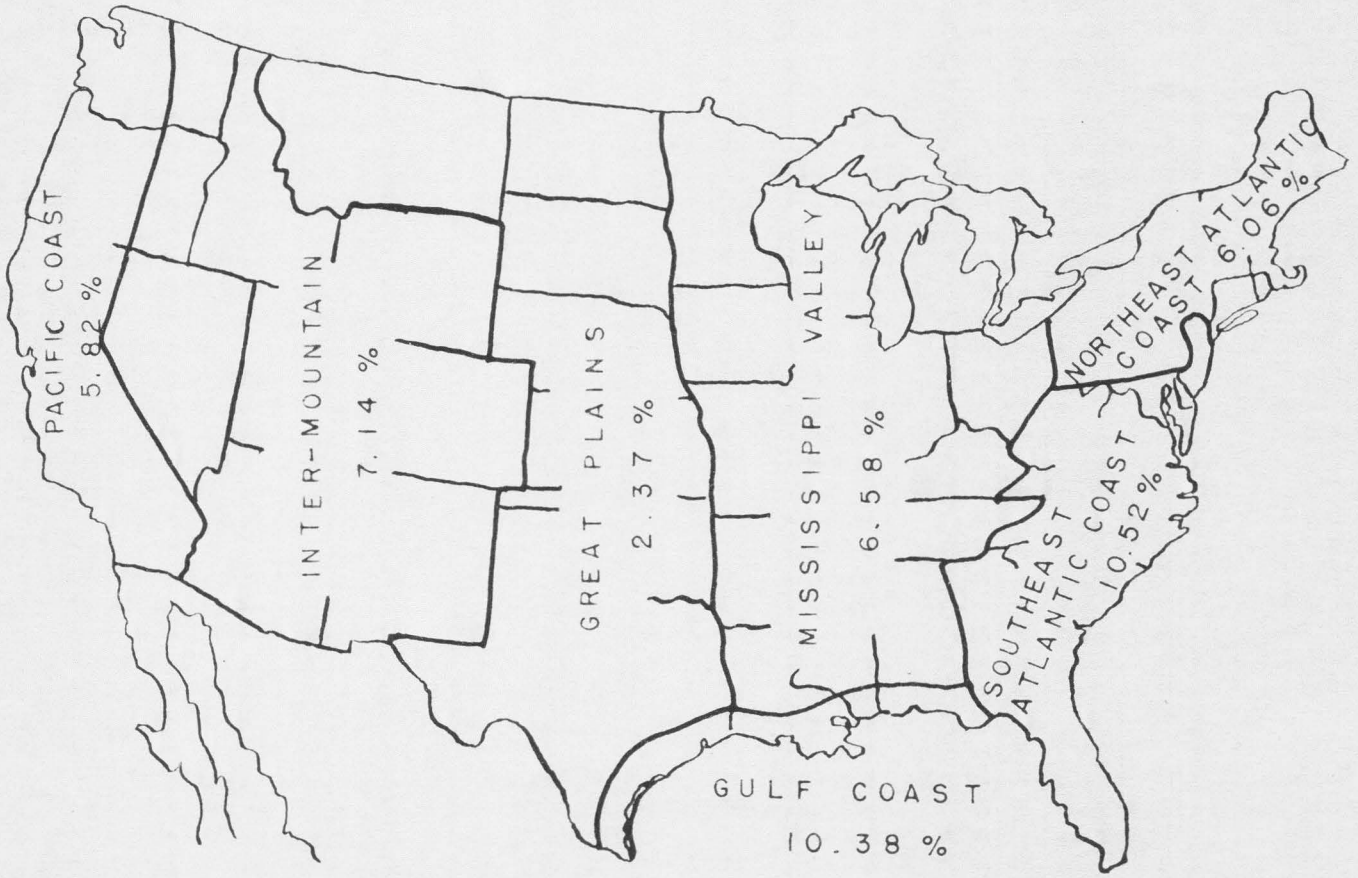

Figure 1. Percentage of waterfowl populations carrying ingested commercial shot pellets in autumn and early winter. Data for six regions of the United States are based upon an examination of 22,071 gizzards collected in recent years (Bellrose, 1951).

LEAD SHOT IN THE TISSUES

Review of Literature

The use of fluoroscopy as a method to determine hunting pressure is relatively new in the field of waterfowl management.

In the winter of 1940-41, Whitlock and Miller (1947), attempted to use the X-ray in determining the incidence of lead shot in the gizzards of waterfowl wintering in Michigan. The high cost of X-ray plates lead them to experiment with the X-ray fluoroscope as a substitute. They found the fluoroscope sufficiently accurate to establish a generalization as to the numbers of flying wild ducks that were carrying lead shot in their gizzards.

A side line developed which offered even more interesting possibilities. They found that approximately 30 percent of the waterfowl examined showed evidence of having gun-shot wounds as evidenced by the presence of shot pellets scattered throughout their bodies. When the experiment was repeated the next winter, about 23 percent of the ducks were found to be carrying body shot. From their findings they suggested:

> "... that our limited and admittedly incomplete study on gunshot wounds in ducks by means of the fluoroscope offers the possibility of still another method of estimating gun pressure on waterfowl if carried out in a systematic manner on a sufficiently large number of ducks."

Findings from Illinois (Bellrose, 1947) indicated that approximately 39 percent of a sample of 181 ducks carried body shot. The data in this study were not differentiated as to species or sex so cannot be directly compared with those of Elder (1950). However, analysis of

Illinois band returns showed mallard hens less vulnerable to hunting than the drakes. Bellrose and Chase (1950) determined that nearly half the birds in an adult population of mallards are more than one year of age and consequently have been subjected to one or more hunting seasons. Therefore, any increase or decrease in shooting pressure, such as measured by the percent of birds carrying body shot, would be masked by a carry-over of these older birds. This indicated that only the extreme variations from year to year would be significant or that only the broader changes occurring over a period of years could be measured.

Elder (1950) explained in detail his method of using the X-ray fluoroscope and his findings.

Neff and Sperry (1950) found in Colorado a differential between pintails and mallards. Their work was started on February 1, approximately 75 days after the close of the 1949 hunting season, and the writers felt that most of the birds which were seriously wounded by the hunters' shots had died or fully recovered by the time the study began. The writers concluded:

> "More definite data on delayed mortality of such wounded ducks could be determined if a duplicate of the present study in another year was preceded by a similar study started immediately on the close of the local shooting season."

Method of Procedure

Location of study area. The Bear River Migratory Bird Refuge, located approximately 15 miles west of Brigham City in Box Elder County, Utah, was the area in which the study was conducted (Figure 2). It was chosen because (1) waterfowl sick or dead from botulism outbreaks were readily available for examination and (2) the research laboratory, situated at the refuge headquarters, was an ideal

location in which to house the fluoroscope unit. It was felt that this area, centrally located as it is, would be representative of the Great Salt Lake Basin.

Procedure. During the course of botulism outbreaks, ducks were gathered by means of an air-thrust boat (Figure 4). This is a flat-bottomed, aluminum-hulled boat with a 65 horsepower aircraft engine mounted on the rear deck. It is fast, easily transported, and very manueverable in the shallow water areas of the marsh.

After the birds were picked up, they were taken to the laboratory in a pick-up truck. The live birds were held in a covered, screened cage, and the dead birds were placed in covered tubs until they could be examined. Prior to examination, all birds were aged and sexed by cloacal and tail feather methods (Kortright, 1943), and separated accordingly. They were then fluoroscoped dorso-ventrally and laterally, to make certain all shot were located and to determine the location of the shot within the body of the bird. The length of time the bird was beneath the fluoroscope varied from 3 to 5 seconds.

Equipment. The fluoroscope unit used in the study was an Army surplus, Picker portable model, loaned to the Utah Cooperative Wildlife Research Unit by the Department of Veterinary Science, Utah State Agricultural College.

Some adjustments were necessary to adapt the unit to waterfowl fluoroscopy. The adjustments consisted of removal of the black-out hood, timer, and wound locator arm, and the addition of an aluminum, lead-lined box, open on one side to permit entry and removal of the bird (Figure 5). This lead-lined box, while serving as a support for the fluorscent screen and the shelf to hold the bird, was an

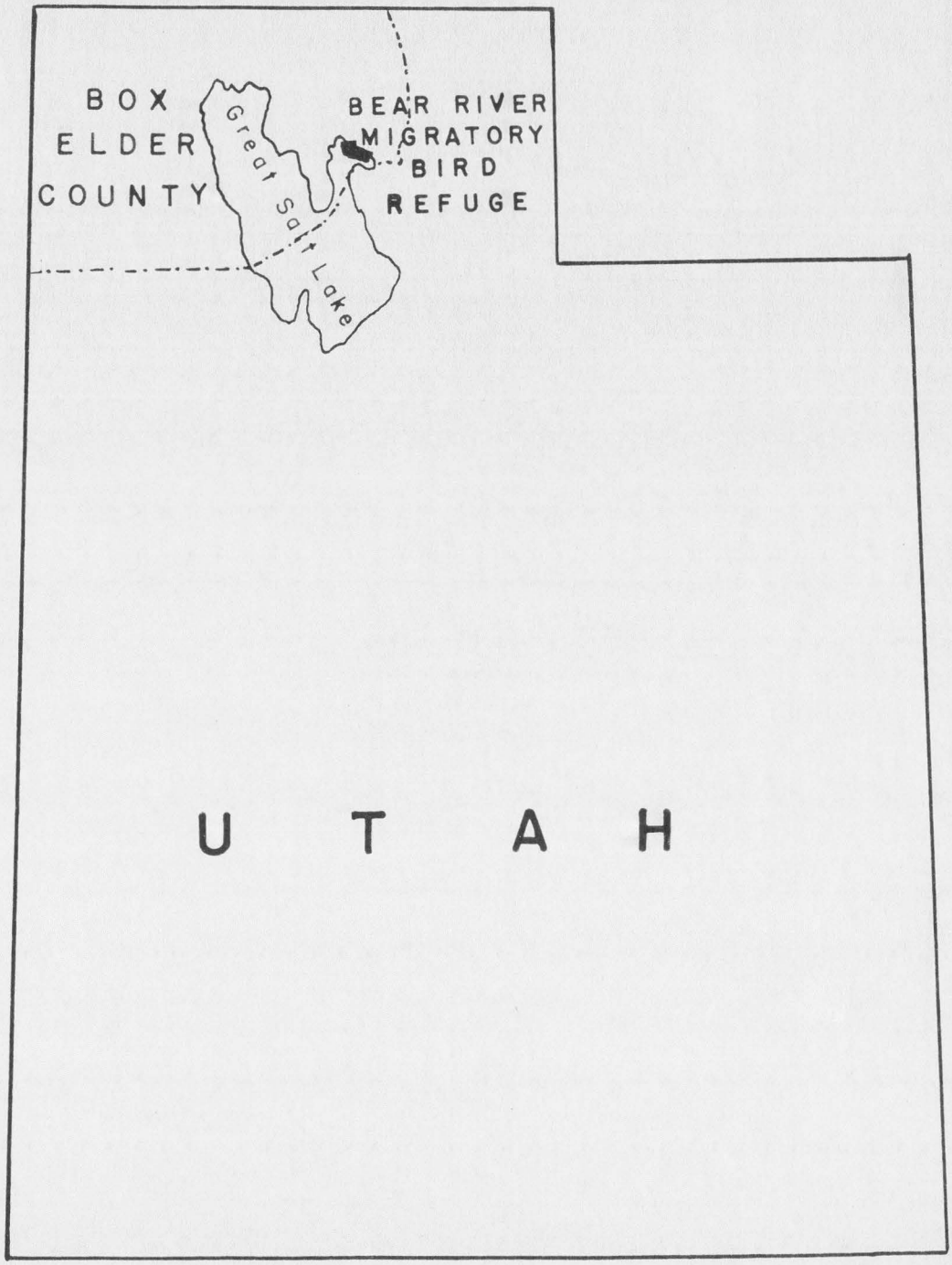

Figure 2. Map of Utah showing location of study area in Box Elder County. The Bear River Migratory Bird Refuge was taken as representative of the Great Salt Lake Basin Area.

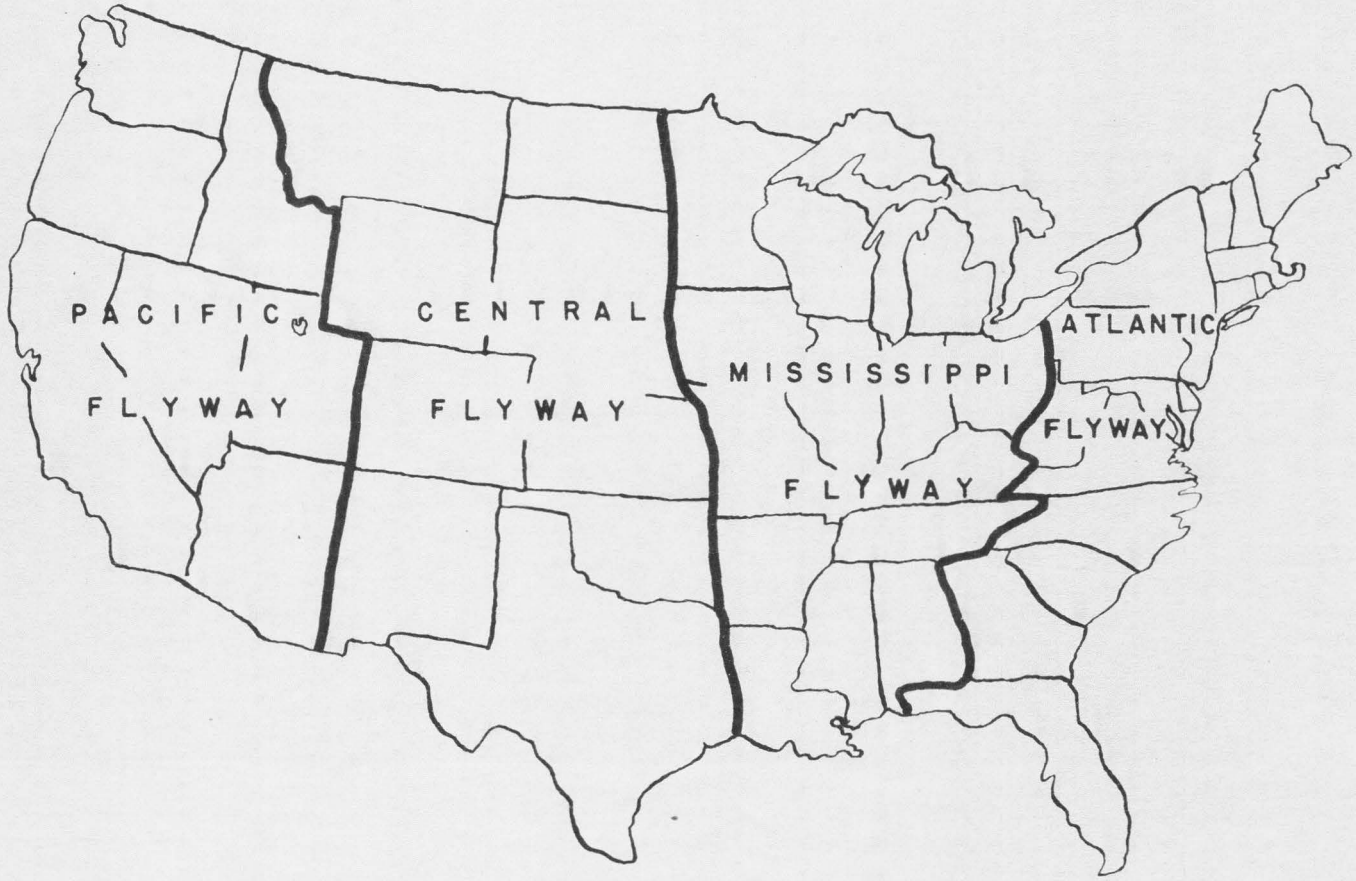

Figure 3. Map of the United States showing the division of the states into the various flyways. These are administrative divisions but generally conform to the various flyways used by waterfowl.

Figure 4. Air-thrust boat used in picking up waterfowl for examination. It can manuever in shallow water and is easily transported. (Fish and Wildlife Service photo)

additional safety measure to protect the operator from the harmful effects of the X-rays. Additional protection was given the operator by means of a lead-lined apron and a pair of elbow-length, lead-lined gloves.

The fluorescent screen was the standard 14 X 18 inch screen and did not need alteration except for the removal of the mount which held the black-out hood. As best results are obtained when the screen is not less than 22 inches from the control head, the lead-lined box was built to this height and the screen rested directly upon it. Approximately 10 inches below the screen, a fibre-board shelf was built to support the bird while being fluoroscoped. Fibre-board was used to permit free passage of the X-rays. A small strip of fibre-board, 1 inch by 10 inches, with the various sizes of shot cemented to it was placed on the shelf to aid in determining the size of shot in the tissue of the bird.

When operated in the laboratory the unit was plugged into a wall socket. However, it can be used in the field with a 60 cycle, 110 volt current supplied by a generator. The room in which the fluoroscope was used was blacked out as completely as possible by use of heavy paper window covering, blinds, and heavy cloth drapes. It was found that the darker the room could be made, the less amperage was needed to produce a clear image on the screen. Reduced amperage presented less danger to the operator from radiation and also lengthened the life of the X-ray tube. When operating the fluoroscope unit, red U. S. flying goggles were worn when outside of the darkened room, to reduce the time needed to re-adapt the operator's eyes to the darkness of the room.

The fluoroscope unit was completely checked by a representative of

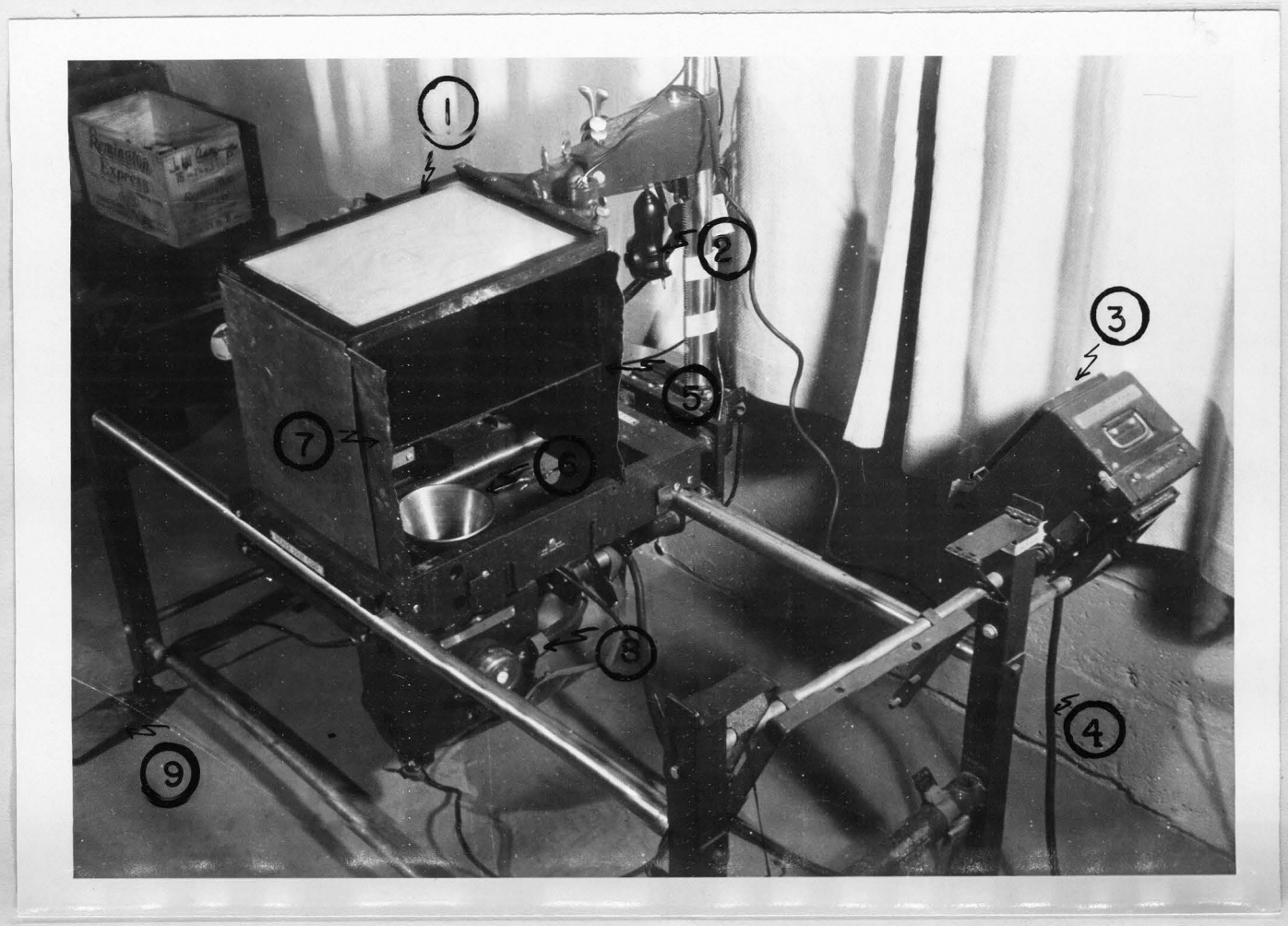

Figure 5. Fluoroscope used in the study.

1. Florescent screen
2. Automatic timer
3. Control box
4. Cable to source of power
5. Shelf to hold bird
6. Aluminum cone which directs rays upward
7. Lead lining in aluminum box
8. X-ray head
9. Foot control

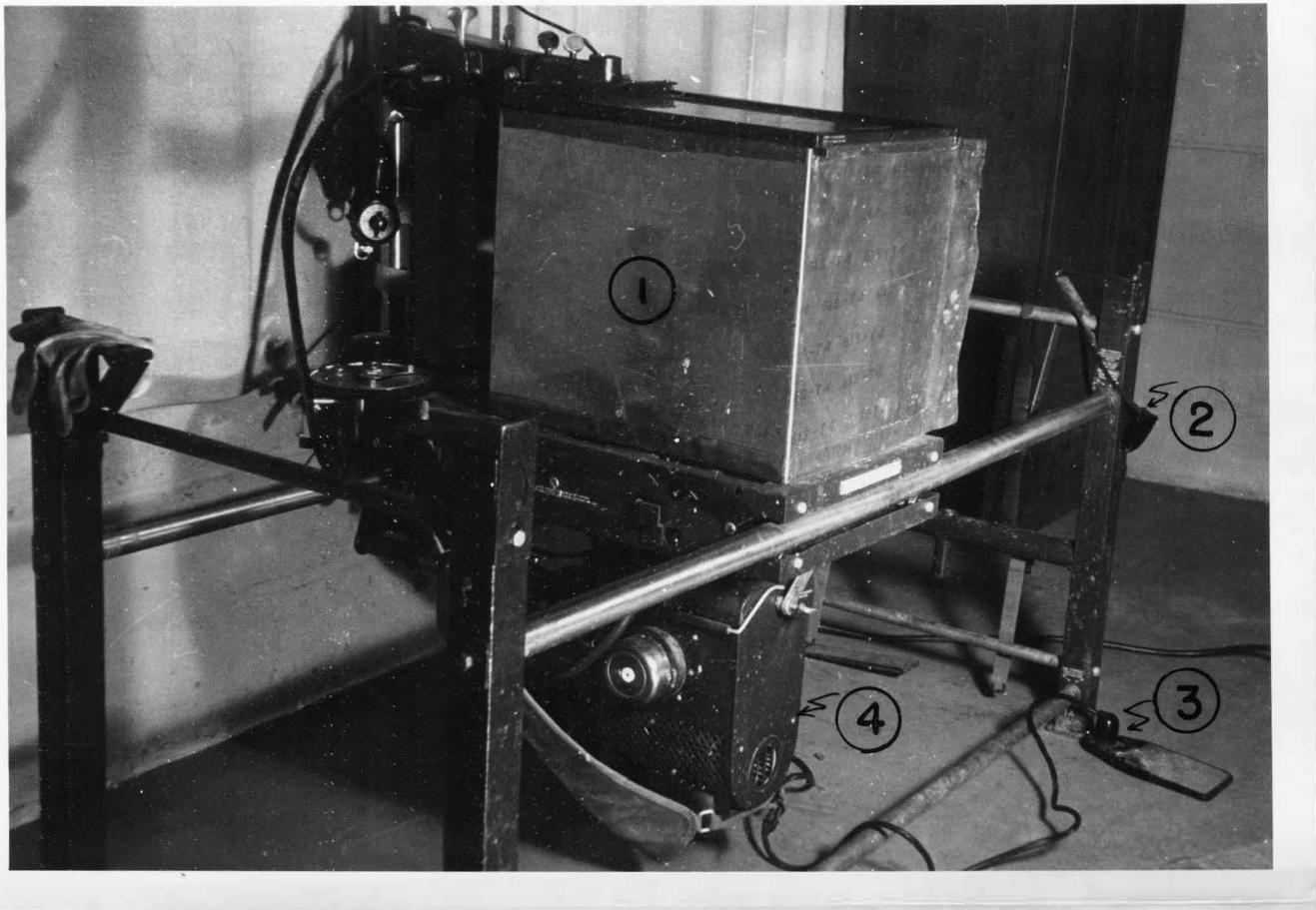

Figure 6. Rear view of fluoroscope with [illegible]

1. Lead-lined aluminum box
2. Infra-red goggles
3. Foot control
4. X-ray head

Examination. The bird to be examined was placed on its back on the shelf beneath the screen and the fluoroscope was turned on by means of a foot switch. After examination in this position, the unit was turned off and the bird placed on its side and examined in this position. Dead birds were easily placed in these positions and live birds, weakened by botulism, gave little trouble.

Source and species of waterfowl examined. The waterfowl examined in this study were obtained during botulism outbreaks at the Bear River Migratory Bird Refuge. The outbreaks occurred during the warm summer months, especially July, August and September. At this time the preponderance of the waterfowl present was pintails. This is reflected in the relative sample size of the various species examined (Table 1).

The waterfowl examined during the study on tissue lead included pintail, Anas acuta tzitzihoa, common mallard, Anas p. platyrhynchos, green-winged teal, Anas carolinensis, cinnamon teal, Anas cyanoptera, baldpate, Anas americana, gadwall, Anas streperus, and shoveller, Spatula clypeata.

The American Ornithological Union Check-list of North American Birds (1931), and the nineteenth through the twenty-second supplements to this check-list were used as the source of scientific names for the birds referred to in the study.

Analysis of Data

From the data obtained in this study during the summers of 1949, 1950, 1951, at the Bear River Migratory Bird Refuge, it was found that approximately 13.8 percent of the 3,528 waterfowl examined carried lead shot in their tissues (Table 2).

Incidence of lead shot by species. The species of waterfowl carrying

Table 1. Sample size of the various species of waterfowl examined in 1949, 1950, 1951, at the Bear River Migratory Bird Refuge.

Species	Number examined	
	For body shot	For ingested shot
Pintail	2,677	2,776
Mallard	180	1,086
Green-winged Teal	306	1,201
Baldpate	178	451
Shoveller	147	791
Gadwall	31	285
Cinnamon Teal	9	3
Redhead	0	215
Canvasback	0	793
Scaup	0	12
Total	3,528	7,635

Table 2. Incidence of lead shot in tissues of waterfowl in the Great Salt Lake Basin, 1949, 1950, 1951.

Species	Number examined	Number with shot	Percent with shot	Total shot	Average shot per bird
Pintail	2,677	419	15.7	670	1.6
Mallard	180	34	18.9	51	1.5
Green-winged Teal	306	11	3.6	12	1.1
Baldpate	176	15	8.4	20	1.3
Shoveller	147	8	5.4	12	1.5
Gadwall	31	1	3.2	1	1.0
Cinnamon Teal	9	1	11.1	1	1.0
Total	3,528	489	13.8	767	1.56

the highest percentage of lead shot in the tissues was the mallards with 18.9 percent. The pintails were next with 15.7 percent. Other species were green-winged teal 3.6 percent, baldpate 8.4 percent, shoveller 5.4 percent, gadwall 3.2 percent, cinnamon teal 11.1 percent and redhead 0.0 percent. The numbers of gadwall, cinnamon teal and redheads examined were insufficient to permit reasonably accurate indications of percentages, but were included in the tables for sake of comparison of numbers examined.

These data suggest that the higher percentage of shot in the pintails and mallards may be due to greater hunting pressure on these species. This greater pressure may be that (1) in many hunters' opinion these are the choice waterfowl and therefore more sought after; (2) many hunters shoot at them at ranges they would not otherwise attempt in hopes of a chance shot bringing them down; (3) the migration habits of the species affects the pressure borne by them. Pintails are early migrants are are among the first to appear in the hunters' bag, while mallards are among the last to leave the marshes in the fall (Kortright, 1943). That teal, especially blue-winged teal, escape heavy shooting pressure is probably attributable to their early fall departure from the United States (Elder, 1950).

A contributing factor to the variation of incidence of shot among the species may be the vulnerability of certain species, such as the teals, to shooting pressure. The mallards and pintails which are larger and more wary, stay farther away from the hunter than the smaller ducks which fly lower and are more easily killed.

Actually the number of ducks which have been wounded and have survived is slightly greater than the incidence of body shot indicates, since some ducks are wounded with shot which perforates the body and leaves no trace. Whitlock and Miller (1947), found on examination of

329 ducks bagged by hunters, about 10 percent showed no fluoroscopic lead and evidently were killed by shot which passed cleanly through the body.

Elder (1950) found in Saskatchewan that adult drake mallards had the highest incidence of body shot. This was a sample of 3,638 adult dabbling ducks. It was also found that pintails from the same region sustain only three-fourths the hunting pressure that mallards do, and teal only about one-fourth (Table 3). Other species in this study were subjected to shooting pressures heavier than the teal but lighter than the more popular mallards and pintails. Band analysis by Hawkins and Bellrose (1939), Baumgartner (1942), Bellrose (1944a; 1944b), and Bellrose and Chase (1950), have indicated the same differences.

Table 3. Incidence of body shot in adult dabbling ducks fluoroscoped in Manitoba and Saskatchewan. Data from Elder, 1950.

Species	Males		Females	
	Number examined	Percent with shot	Number examined	Percent with shot
Pintail	654	21	295	16
Mallard	1,055	28	336	21
Green-winged Teal	121	8	58	2
Blue-winged Teal	652	7	153	5
Baldpate	139	11		
Shoveller	113	10		
Gadwall	62	16		
Total	2,796		842	

Neff and Sperry (1950), found in Colorado that 13.81 percent of the pintails and 11.86 percent of the mallards were carrying body shot (Table 4). The Utah studies showed that the reverse was true. Mallards carried

18.9 percent and pintails 15.7 percent.

Incidence of lead shot by sexes. There was no great difference between sexes of the same species in percentage of lead shot carried in the tissues at the Bear River Refuge during the course of the study. The small variation that did occur could be due to the smaller and possibly insufficient sample size of females (Table 5). It was necessary, however, to treat the sexes separately as in some parts of the United States the females of the species are subjected to as much as one-fourth less hunting pressure (Table 3).

Bellrose and Chase (1950) found, on analysis of Illinois band recoveries, that mallard hens were less vulnerable to hunting than the drakes. This variation may be very different in diving ducks, especially the redhead, for the reasons Hochbaum (1946), has given, such as soft primaries in females which may render them more vulnerable to shot pellets and also affect their flying ability.

Incidence of lead shot by years. The yearly variation in percentages of birds carrying body shot is difficult to determine with accuracy. Bellrose and Chase (1950), have shown that nearly half the birds in an

Table 4. Incidence of body shot in mallards and pintails fluoroscoped in Colorado from February 1, to March 27, 1950. Data from Neff and Sperry, 1950.

Species	Number viewed	No. carrying body shot	Percent carrying body shot
Mallard drakes	817	112	13.70
Mallard hens	422	35	8.29
Total	1239	147	11.86
Pintail drakes	181	19	10.49
Pintail hens	123	23	18.79
Total	304	42	13.81

Table 5. Incidence of lead shot in tissues of waterfowl by sex for the years 1949, 1950, 1951, in the Great Salt Lake basin area.

Species	Male			Female		
	No. examined	No. with shot	Percent with shot	No. examined	No. with shot	Percent with shot
Pintail	2,196	340	15.5	481	79	16.4
Mallard	152	28	18.4	28	6	21.4
Green-winged Teal	203	7	3.4	103	4	3.8
Baldpate	138	12	8.7	40	3	7.5
Shoveller	101	7	7.1	46	1	2.1
Gadwall	26	0	0.0	5	1	20.0
Cinnamon Teal	0	0	0.0	9	1	11.1
Total	2,818	394	14.0	714	95	13.5

Table 6. Incidence of lead shot in tissues of waterfowl by years for the years 1949, 1950, 1951, in the Great Salt Lake basin area.

Species	1949			1950			1951		
	No. examined	No. with shot	Percent with shot	No. examined	No. with shot	Percent with shot	No. examined	No. with shot	Percent with shot
Pintail	478	79	16.5	1,150	179	15.6	1,049	161	14.4
Mallard	58	9	15.5	94	13	13.8	28	12	42.9
Green-winged Teal	93	1	1.0	54	4	7.4	159	6	3.8
Baldpate	80	7	8.8	36	4	11.1	62	4	6.5
Shoveller	70	2	2.8	53	6	11.3	24	0	0.0
Gadwall	15	1	6.6	10	0	0.0	6	0	0.0
Cinnamon Teal	1	1	100.0	0	0	0.0	8	0	0.0
Total	795	100	12.6	1,401	206	14.7	1,336	183	13.7

Table 7. Incidence of lead shot in tissues of waterfowl in the Great Salt Lake basin for years 1949, 1950, 1951, expressed in percentages for each sex.

Species	1949		1950		1951	
	Male	Female	Male	Female	Male	Female
Pintail	16.4	16.9	15.5	16.2	15.1	16.3
Mallard	16.3	11.1	15.2	6.7	33.3	100.0
Green-winged Teal	00.0	2.6	7.1	8.3	3.7	3.8
Baldpate	6.9	13.6	11.1	00.0	9.1	00.0
Shoveller	2.0	5.0	13.7	00.0	00.0	00.0
Gadwall	00.0	20.0	00.0	00.0	00.0	00.0
Cinnamon Teal	00.0	100.0	00.0	00.0	00.0	00.0

adult population of mallards are more than one year of age and consequently have been subjected to more than one hunting season. Therefore, any increase or decrease in shooting pressure, such as measured by percent of birds carrying body shot, would be masked by the carry-over of these older birds. For this reason, only the extreme yearly variations would be significant. The value of using incidence of body shot to determine hunting pressure would lie, not in measuring yearly variations, but in measuring broad changes over a period of years. It was found in the study in the Great Salt Lake Basin, that the yearly percentages of body shot varied little (Tables 6 and 7). Again, in the phase of the study, concerning yearly variation, the size of sample could affect the percentages to a great extent as shown by the mallards with 15.5 percent in 1949, 15.8 percent in 1950, and 42.9 percent in 1951. Where the sample was of fairly large size the yearly variation was small as in the pintails, with 16.5 percent, 15.6 percent and 14.4 percent for the years 1949-51 respectively.

Anatomical distribution of body shot. It was found, in the examination of waterfowl, that shot occurred in every part of the bird including feet, bill, eye, brain cavity and neck (Figure 7). In all species, except cinnamon teal, the largest percentage of shot carried was in the breast, with abdomen and tail next highest (Table 8, Figure 8).

The smaller ducks, such as the teals and shovellers, carried shot only in the body proper and the legs and wings, indicating perhaps, that they were unable to survive wounds in other parts of their anatomy as well as the larger ducks.

Only the pintails were found to have any shot in the head. From this it is apparent that a bird can survive a wound which is generally considered fatal. Four pintails and three mallards were found to have

Figure 7. X-ray photograph showing lead pellets in tissues of wild mallard.

Table 8. Antomical distribution of lead shot in tissues of waterfowl bypercent and numbers for the years 1949, 1950, 1951, in the Grat Salt Lake basin.

Species		Abdomen and tail	Breast	Wings	Legs	Neck	Head	Back	Total Shot
Pintail	Numbr	206	272	83	52	27	12	18	670
	Percnt	30.7	40.6	12.4	7.8	4.0	1.8	2.7	100.0
Mallard	Numbr	19	21	4	3	2	0	2	51
	Percnt	37.1	41.2	7.9	5.9	3.9	0.0	3.9	100.0
Green-winge Teal	Numbr	33	6	0	3	0	0	0	13
	Percnt	25.0	50.0	0.0	0.0	0.0	0.0	0.0	100.0
Baldpate	Numbr	6	8	3	2	0	0	1	20
	Percnt	30.0	40.0	15.0	10.0	0.0	0.0	5.0	100.0
Shoveller	Numbr	3	8	1	0	0	0	0	12
	Percnt	25.0	66.6	8.4	0.0	0.0	0.0	0.0	100.0
Gadwall	Numbr	0	1	0	0	0	0	0	1
	Percnt	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0
Cinnamon Tea	Numbr	0	0	1	0	0	0	0	1
	Percnt	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0
Total	Numbr	237	316	92	60	29	12	21	767
	Percnt	30.9	41.3	11.9	7.8	3.8	1.6	2.7	100.0

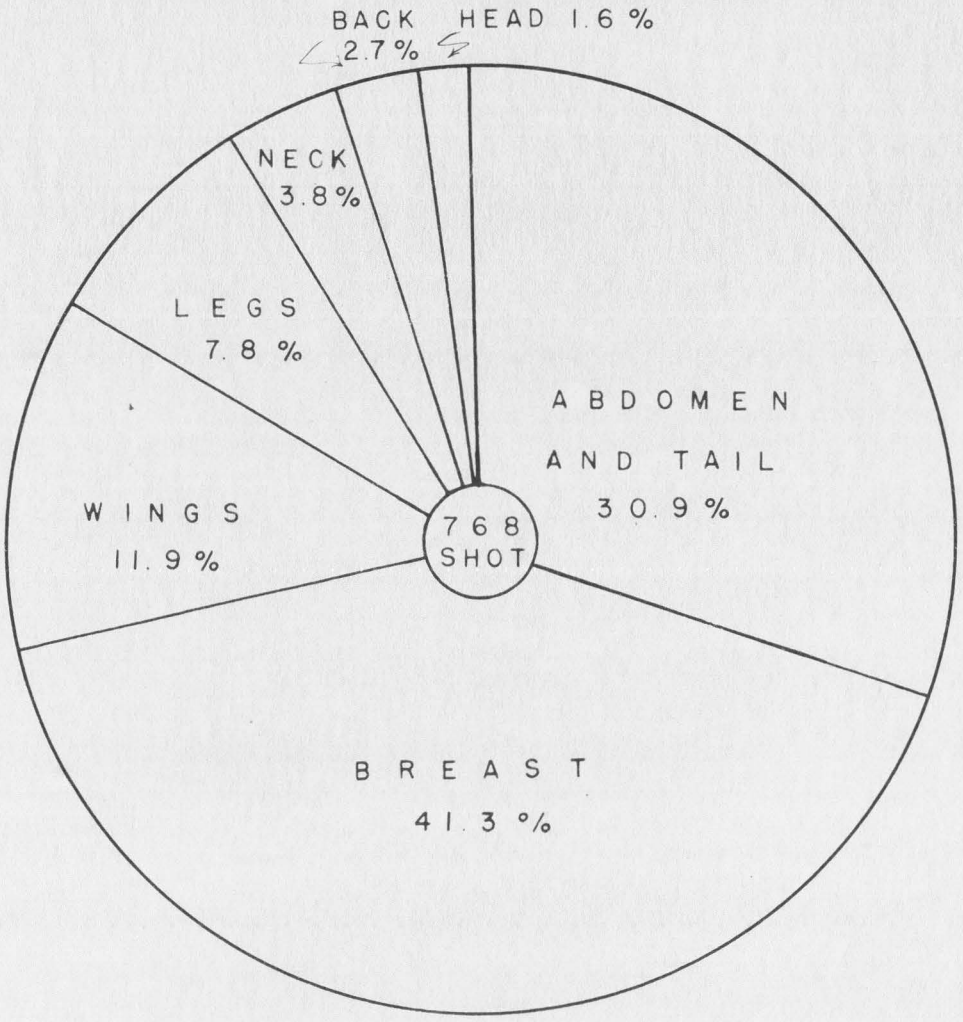

Figure 8. Anatomical distribution of lead shot in waterfowl for the years 1949-51, in the Great Salt Lake Basin.

healed wing fractures showing that even with a crippling wound such as a broken wing, some ducks may be able to survive and fly again.

Four pintails were found with healed leg fractures, one of which had healed in nearly a 90 degree angle outward from the body in an abnormal manner thereby rendering the member useless except perhaps in swimming.

The one pintail found with shot in the brain cavity appeared normal in every respect. It had botulism when picked up but soon recovered and left the cage with no apparent physical disability.

The ducks observed with shot in the neck were birds killed by botulism and there was no opportunity to determine any crippling effects the shot may have had.

Sizes of shot in the tissues. The size of shot most prevalent was number 6 shot and constituted about 81 percent of all shot found. Number 5 shot was next most common with numbers 4, 2 and 7½ occurring in that order. In several birds shot of larger size than number 2 were found but the occurrence in comparison with other sizes was negligible (Table 9).

No shot of larger size than number 5 were found in any of the species other than pintails and mallards. This may be due to the relative inability of the smaller species to survive a wound made by the larger sizes of shot. The large percentage of number 6 shot found seems to indicate a hunter preference, at least in the Great Salt Lake Basin, for this size shot.

There were 14 ducks which contained shot of two sizes, and 2 birds were found carrying three sizes of shot, which gives evidence of their having been wounded more than once.

An interesting side light to these data was the finding of two pieces of metal; one in an adult male pintail, another in an adult female pintail. The male was carrying a flat L-shaped piece of steel approximately

Table 9. Size of shot expressed in percentage of occurrence in tissues of waterfowl in the Great Salt Lake Basin, 1949, 1950, and 1951.

Species	Total shot	Size of shot					
		$7\frac{1}{2}$	6	5	4	2	BB
		Percent of occurrence					
Pintail	670	0.5	81.4	12.2	3.3	1.8	0.4
Mallard	51	1.9	70.6	17.6	5.9	1.9	0.0
Green-winged Teal	12	8.3	83.3	8.3	0.0	0.0	0.0
Baldpate	20	5.0	80.0	15.0	0.0	0.0	0.0
Shoveller	12	8.4	91.6	0.0	0.0	0.0	0.0
Gadwall	1	0.0	100.0	0.0	0.0	0.0	0.0
Cinnamon Teal	1	0.0	0.0	100.0	0.0	0.0	0.0
Total	767	0.9	80.8	12.5	3.3	1.7	0.4

three-fourths inch on the longest side. The female carried a U-shaped piece of steel resembling a half link of a small chain, about one-half inch across the open end. Both birds had these pieces of metal imbedded in the muscles of the breast. The male also carried shot in the back and thigh of the right leg. These pieces of metal may have been acquired by the birds in an accident or in a struggle to escape a trap of some type, such as a banding trap. They also may have received these pieces of metal in the form of projectiles which were used in some of the so-called "armadas" of a few years ago. These "armadas" were multi-barrelled shotgun-type weapons used in killing ducks for the market.

Hunting pressure as measured by duck stamp sales, waterfowl kill and incidence of body shot

Hunting pressure in the United States has been determined by two methods; number of hunters purchasing duck stamps and total waterfowl kill for the season. A third method has been added, namely, the determination of percentage of birds carrying body shot.

The data on waterfowl kill were obtained by samples of hunters' bags and post-season contact. The data on numbers of hunters were estimated as the difference of total duck stamp sales in the Pacific Flyway less 13.5 percent to compensate for purchasers of these stamps who did not hunt (Pacific Flyway Waterfowl Report, August, 1951).

Of the three methods of measuring hunting pressure, the easiest and most practical is by use of fluoroscopy in determining the percentage of body shot carried by waterfowl. Hunting pressure as measured by duck stamp sales alone does not give the pressure on any one species or an accurate picture of the pressure on the waterfowl population as a whole. In addition to the small fraction that does not hunt, open seasons on

upland game birds at the same time as the waterfowl season, hunting frequency by the purchaser, weather conditions, and migration habits of the waterfowl affect the actual pressure exerted by purchasers of duck stamps.

Kill figures used to express hunting pressure are unreliable as the problem of gathering accurate kill data has not been solved. The data are obtained by means of bag checks at strategically located areas, such as public and private gun clubs, public shooting areas and checking stations on main roads leading to waterfowl hunting areas. This at best covers a very small sample of the total population of hunters. Another method of obtaining waterfowl kill data is by post-season survey of hunters, either by mail or personal contact. It can be readily seen that this method would be based on the memory and honesty of the hunter contacted and thus an error of unknown proportions would be introduced into the data.

There appears to be a possible correlation between the three methods (Table 10). The hunting season 1948-49 does not correlate with the other methods as closely as does the seasons of 1949-50 and 1950-51, but this may be due to the size of the sample of waterfowl examined for incidence of lead shot.

Table 10. Comparison of hunting pressures for the hunting seasons 1948-49, 1949-50, 1950-51, in the Pacific Flyway, by use of incidence of body shot, duck stamp sales, and waterfowl kill.

Season	Percent with shot	Number of hunters*	Number of waterfowl killed
1948-49	12.6	359,378	4,707,970
1949-50	14.7	350,364	4,106,332
1950-51	3.7	329,645	4,265,540

* Based on 86.5 percent of duck stamp sales, to compensate for purchasers who did not hunt waterfowl.

INCIDENCE OF LEAD SHOT

Review of Literature

Lead poisoning in waterfowl and the resultant mortality has been known since about 1874 (Phillips and Lincoln, 1930). Grinnel (1901) described symptoms of lead poisoning in waterfowl, following ingestion of shot at Currituck Sound, North Carolina. Bowles (1908), found similar symptoms in waterfowl at Puget Sound, Washington. Losses from lead poisoning also were reported in Texas by McAtee (1908). It remained for Wetmore (1919), to conduct the first experimental work on lead poisoned waterfowl. His accurate descriptions of the symptoms of lead poisoning and pioneering research with captive and wild ducks have been a great contribution to the field of lead poisoning research. He revealed in his experiments that, while one number 6 shot may cause death in a bird, six number 6 shot pellets were nearly always fatal. This suggested that an indication of losses in waterfowl from lead poisoning may be acquired by determination of incidence of ingested lead shot in the various species of waterfowl.

Shillinger and Cottam (1937), found many factors influencing the effects of lead and a fatal dose was not determined at that time. Jordan and Bellrose (1950), in their research on ingested lead found that (1) 60 to 80 percent of the wild mallard drakes carrying one shot pellet in nature were likely to succumb if they depended on a diet of wild seeds, and (2) the lead contained in the commercial alloy shot pellet was shown to be the sole cause of lead poisoning in waterfowl.

Jordan and Bellrose (1951), in their experiments with wild trapped

mallards, found that ducks severely affected by lead poisoning suffer marked weight losses, and those that die are emaciated. The vital organs and muscles are abnormally small, and the gizzards show evidence of decreased activity. Their experiments have been the most inclusive to date. Following is a partial summary of their findings:

1. Outbreaks of lead poisoning in wild waterfowl usually occur late in fall or in winter after large numbers of ducks have moved to heavily shot-over areas to feed.

2. Day-to-day losses in wild waterfowl can be evaluated by determining the proportion of birds with ingested lead shot, the numbers of pellets in the gizzards, and the rates of mortality produced by given numbers of pellets among waterfowl in a wild state.

3. Food was found to have an important influence on the effect of the lead shot ingested by penned waterfowl:

    a. Penned ducks fed on food items of small size and the succulent parts of aquatic waterfowl food plants were affected less by lead poisoning than those fed on food items of large size and greater hardness.

    b. Symptoms of lead poisoning failed to appear in lead-dosed, penned mallards that maintained a normal rate of food intake. The amount of food consumed varied with sex and age, and the effect of ingested lead varied accordingly.

4. Increasing the shot dose (within the limit of four pellets) administered to penned mallards was found (1) to increase the proportion of ducks affected, (2) to increase the rate of mortality, but, (3) not to increase the severity of symptoms nor (4) to shorten the survival period of poisoned ducks.

5. Some severely affected penned mallards apparently recovered from lead poisoning following elimination of shot or renewal of appetite.

6. Lead-induced starvation appeared to be the immediate cause of death in lead-poisoned mallards.

7. Of the three metallic components (lead, arsenic, and antimony) of commercial shot, lead was found to be the only one to produce ill effects when fed to ducks.

8. At the present time only stopgap measures can be undertaken to

> reduce wild waterfowl losses from lead poisoning. The following remedial measures are suggested: (1) increase the amounts of certain natural waterfowl food plant resources, (2) disperse waterfowl from known focal areas of lead poisoning, (3) exercise greater care in shooting and thereby reduce the cripple loss as well as the amount of expended lead pellets deposited on the feeding grounds of waterfowl.

Neff and Sperry (1950) found the ingested shot in waterfowl in Colorado difficult to see under the fluoroscope due to the high mineral content of the grit the ducks had utilized. Two hundred drake mallards and 125 hen mallards were banded and released lead-free. The same number of mallards of each sex were fed six number 6 shot, banded and released. One month later, 19 or 5.85 percent of the lead-treated mallards had been found dead, while only 2 or 6 percent of the untreated birds were found dead.

In the course of this lead poisoning experiment, all ducks found dead in the study area were examined for cause of death. The pathological conditions of the dosed birds were an aid in interpreting post-mortem signs in non-dosed ducks. The writers stated:

> "The presence of lead pellets in a gizzard was an added positive sign, but the absence of such shot did not rule out lead poisoning as a cause of death for many of the dosed mallards passed or ground away the lead shot which had been placed in their gizzards at an earlier date."

Bellrose (1951) stated that it is unlikely that shot is taken to any large degree as a substitute for grit. The close relationship between frequency of occurrence of ingested shot and feeding habits of the species seems to indicate, however, that the shot is taken for food.

By means of band returns, Bellrose (1951) determined the average distance per day ducks with various doses of shot would travel. Ducks with no shot averaged about 7 miles a day, while those dosed with one and two number 6 shot pellets averaged 5 and 4 miles a day respectively. The decrease in rate of movement indicated the more shot a duck ingests,

the more its mobility is reduced. Thus, heavy losses from lead poisoning are likely to point up a local problem area.

He also found prior to the hunting season that only 3 to 4 percent of the birds examined contained ingested pellets, but the proportion of birds carrying ingested shot steadily increased into late fall and winter. This suggested that the critical period is during the hunting season and immediately following it. This is borne out by Shillinger and Cottam (1937) who reported that most of the losses from lead poisoning were found in late fall, winter, and early spring.

Method of Procedure

Location of study area and waterfowl examined. The fluoroscopy was conducted at the Bear River Migratory Bird Refuge. However, the gizzards were gathered from areas of the Great Salt Lake Basin other than the Bear River Migratory Bird Refuge. They were collected from the Bear River Gun Club and the Duckville Gun Club in Box Elder County, Ogden Bay Refuge, and Cache Valley.

The species of waterfowl examined included pintail, mallard, redhead Aytha americana, gadwall, baldpate, canvasback Athya valisineria, shoveller, green-winged teal, cinnamon teal, and scaup Athya sp.

Examination. When fluoroscoping gizzards collected during the hunting season, from 10 to 15, depending on the size, were placed on the shelf beneath the screen. When the unit was turned on, those with shot could readily be differentiated from those without shot. The gizzards were rotated, as it was found that shot may be overlooked when worn to a small disk or accompanied by large quantities of food or gravel. Those with shot in the lumen, or cavity, were removed and opened and the contents placed in small envelopes. If there was any question as to whether the shot was actually in the lumen, the gizzard was removed and treated

with those definitely having shot in this area. The envelopes were then fluoroscoped and the incidence, number and size of shot recorded. As the entire sample was from birds killed by hunters, it was to be expected that a certain amount of shot in the gizzard was shot into it rather than ingested. To reduce this error as much as possible, the shot were examined for signs of wear and erosion when the gizzards were opened.

Analysis of data

During the course of the investigation of incidence of body shot, any ingested lead pellets that were noted were also recorded. Data were also gathered by the flyway biologists and the writer at the Bear River Migratory Bird Refuge during the fall waterfowl seasons 1949, 1950 and 1951 (Tables 11 and 12).

These data were obtained from examination of duck gizzards which were collected from the north Great Salt Lake Basin area, during and immediately after the waterfowl seasons. Each gizzard was fluoroscoped and those which appeared to contain ingested lead shot were opened and the contents put into small envelopes and then refluoroscoped (Figures 9 and 10). Since this entire sample was killed by hunters, it was to be expected that a certain percentage of the shot in the lumen or food sac of the gizzard was shot into it by the hunter. These pellets which were shot into the food sac penetrated the hard wall of the gizzard and either left a trace of feathers in the food sac or damaged the wall. Data on the incidence of shot in these gizzards was not included in the study. In most cases also, the ingested shot in the gizzard showed some effects of the process of digestion. It is probable that errors have been made in the segregation of arrested and ingested shot, but it is believed that sufficient accuracy was maintained for practical usefullness.

Table 11. Ingested lead shot in waterfowl in the Great Salt Lake Basin, summer and fall seasons, 1949, 1950, 1951.

Species	1949		1950		1951	
	Summer 1/	Fall	Summer	Fall	Summer	Fall
	Percent		Percent		Percent	
Pintail	---	5.9	0.6	10.0	0.6	5.8
Mallard	---	10.9	3.2	15.1	14.3	8.9
Green-winged Teal	---	0.2	0.0	0.2	0.0	0.2
Baldpate	---	0.0	0.0	3.2	0.0	3.9
Shoveller	---	0.1	1.8	0.9	0.0	1.1
Gadwall	---	0.0	0.0	0.7	0.0	2.7
Cinnamon Teal	---	0.0	0.0	0.0	0.0	0.0
Redhead	---	27.2	0.0	21.1	0.0	23.2
Total	0.2 2/	6.3	0.8	6.7	0.7	5.6

1/ Waterfowl examined during the summer were adults only; fall season samples included gizzards from adult and juvenile ducks shot during the hunting season.

2/ Only total summer figure was available.

Table 12. Incidence of ingested lead shot in waterfowl of the Great Salt Lake Basin area, by species for the hunting seasons 1/ 1948-49, 1949-50, 1950-51.

Species	Number examined	Number with shot	Percent with shot
Pintail	2,776	219	7.9
Mallard	1,086	136	12.5
Redhead	215	49	22.8
Gadwall	285	5	1.8
Baldpate	451	16	3.5
Canvasback	793	94	11.9
Shoveller	791	8	1.0
Green-winged Teal	1,201	6	0.5
Cinnamon Teal	25	0	0.0
Scaup	12	1	8.3
Total	7,635	534	7.0

1/ Gizzards collected from waterfowl shot during the fall hunting seasons.

Figure 9. Dorso-ventral photograph of wild mallard with ingested lead. Five pellets are in the gizzard and two in the proventriculus.

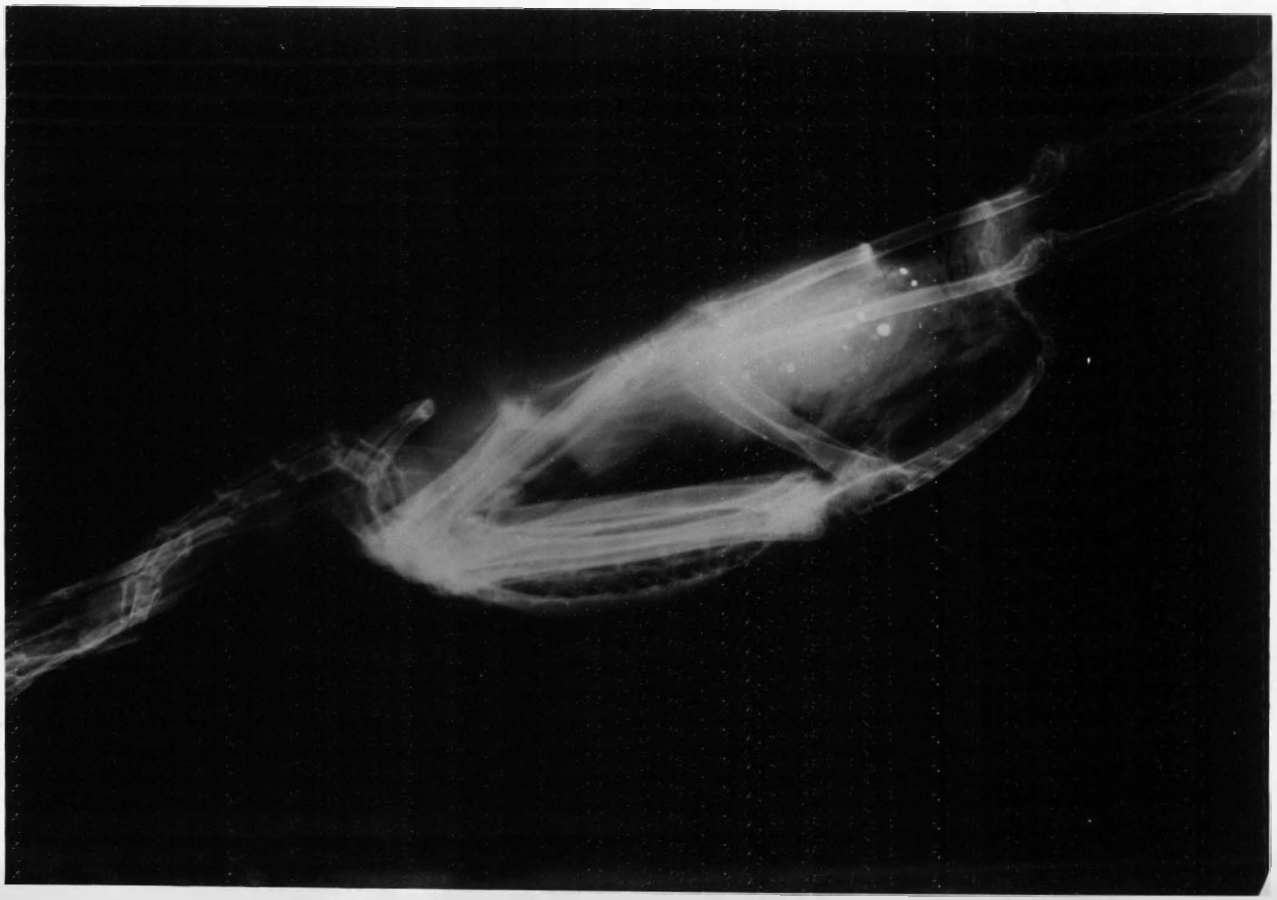

Figure 10. Lateral photograph of Figure 9. Smaller white areas appearing in gizzard may be finely ground shot. As can be seen, there is more than one size of shot.

The percentage of birds carrying ingested shot rose sharply during the hunting season. This indicates that the availability of lead shot to waterfowl increases during the hunting season and decreases during the winter and spring months, or that birds with ingested shot either pass the shot out of their digestive systems or do not survive the winter. That it is probably the latter case is shown by Wetmore (1919), and Jordan and Bellrose (1950), in their experiments on ingested lead shot. Wetmore determined that six number 6 shot in the gizzard were always fatal, while Jordan and Bellrose found that 60 to 80 percent of wild mallard drakes carrying one shot pellet were likely to succumb. However, the studies showed that mortality would be lessened if the birds had access to green leafy foods.

The fact that availability of shot decreased during the winter and spring months may be because of the shot sinking into the mud and thereby becoming inaccessible to the waterfowl. Also, waterfowl are forced to move from the shallow water areas into deeper water when these shallow areas freeze, and as the deeper water areas are comparatively less hunted, the chances of picking up shot are reduced.

Bellrose (1951), prior to the hunting season in Illinois, found only 4.37 percent of the waterfowl examined contained ingested pellets, but the proportion of birds carrying ingested shot steadily increased until, by early December, it had risen to 11.51 percent of those examined. The study conducted at the Bear River Refuge showed the percentage rising from 0.2 to 6.3 percent in 1949, 0.8 to 6.7 percent in 1950 and 0.7 to 5.6 percent in 1951.

Observation of feeding habits (Cottam, 1935; Kortright, 1943; Bellrose, 1951), suggests that food habits may be very important in influencing

the incidence of ingested shot for any species. Feeding pintails and mallards have been known to dig holes to 8 inches deep in the muck in shoal water. Green-winged teal and shovellers feed on mud flats and shallow water areas but they do not appear to dig into the mud to any great extent, thereby lessening their chances of picking up shot. Baldpates and gadwall are more inclined to feed on foliage of aquatic plants than in the bottom mud, and this is reflected in the low incidence of ingested shot in these species. The diving ducks, such as the redhead, canvasback and ring-neck, usually dig for seeds and tubers in the bottom mud in shoal water areas where there would be large amounts of expended shot available to them. Bellrose (1951) stated that it is unlikely that shot is taken to any large degree as a substitute for grit. The close relationship between frequency of occurrence of ingested shot and feeding habits seems to indicate that the shot is taken for food. Otherwise, such species as the baldpate, gadwall, shoveller and green-winged teal could be expected to show a higher incidence of shot (Figure 11).

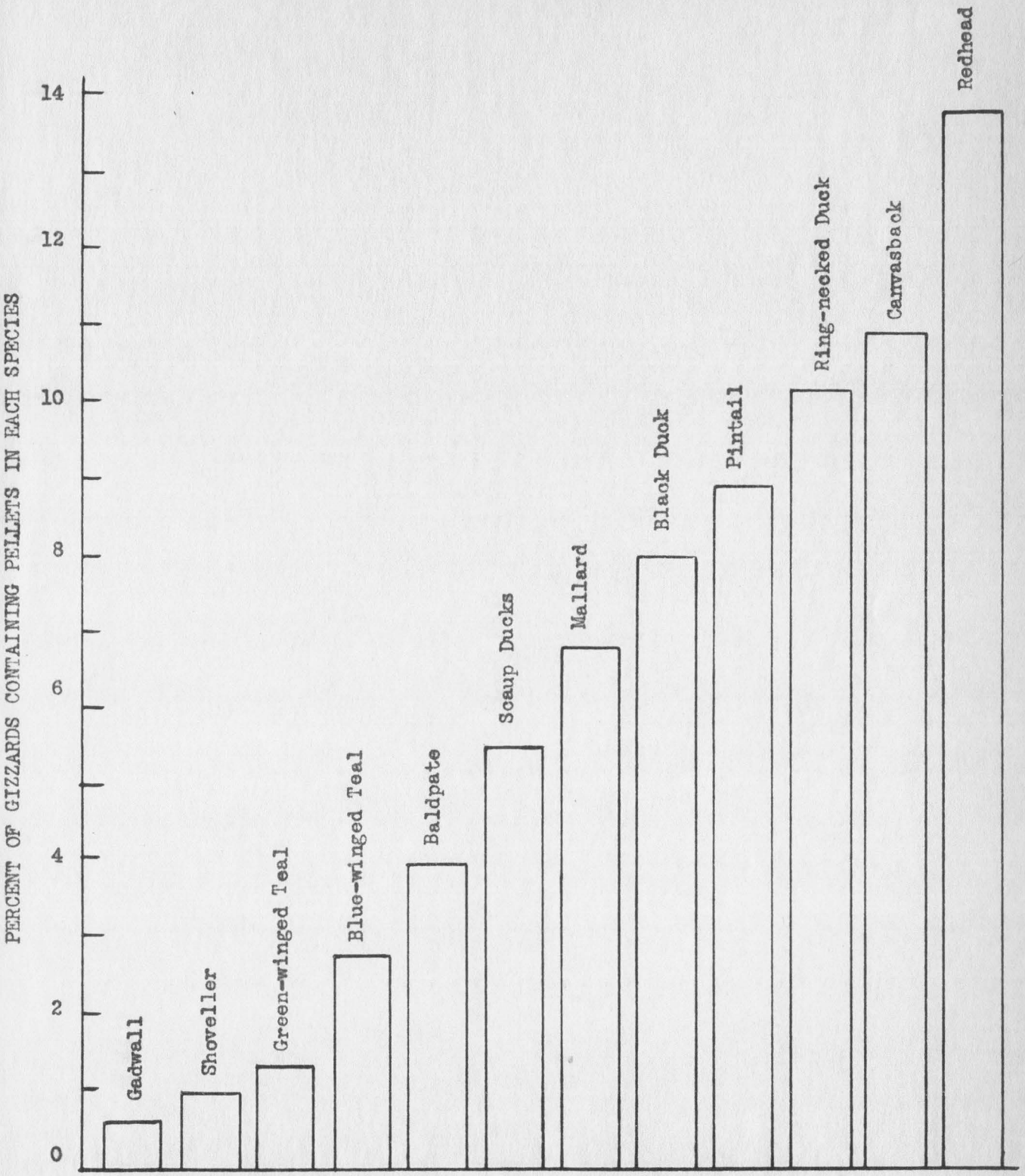

Figure 11. Occurrence of commercial shot pellets in the gizzards of 18,454 ducks of various species. The gizzards were collected in recent years from many parts of the United States in autumn and early winter. Data from Bellrose, 1951. Figures include 7,435 ducks examined in Utah in 1949, 1950 and 1951.

SUMMARY

1. The study was conducted at the Bear River Migratory Bird Refuge, Box Elder County, Utah.

2. An X-ray fluoroscope was employed to determine the incidence of body shot in waterfowl using the Great Salt Lake Basin.

3. The waterfowl examined were obtained during botulism outbreaks in the summers of 1949, 1950, and 1951.

4. A total of 3,528 ducks were examined. Of these 489 or 13.8 percent carried body shot.

5. Mallards had the highest percentage of body shot of the 8 species with 18.9 percent, followed by pintails with 15.7 percent. Baldpate, shovellers, and green-winged teal carried 8.4 percent, 5.4 percent and 3.6 percent respectively. It was felt that the sample size of the other species, gadwall, cinnamon teal, and redhead, was too small to be significant.

6. There was no significant difference in the incidence of body shot between sexes of the same species.

7. The size of shot in waterfowl varied from number 7½ to BB; number 6 shot which occurred most frequently constituted 80.8 percent of all shot found. Number 5 shot followed with 12.5 percent; number 4 shot 3.3 percent; number 2 shot 1.7 percent; BB 0.4 percent; and 7½ 0.9 percent.

8. The anatomical distribution of tissue shot showed 41.3 percent in the breast followed by abdomen and tail with 30.9 percent, wings 11.9 percent, legs 7.8 percent, neck 3.8 percent, head 1.6 percent and back 2.7 percent.

9. Several birds carried shot of more than one size which indicated that they had been wounded more than once.

10. Healed wing and leg fractures showed that birds with crippling injuries may survive.

11. Hunting pressure as measured by incidence of body shot, when compared with hunting pressure as measured by duck stamp sales and waterfowl kill, showed some relationship.

12. Ingested lead, or lead taken into the stomach during the normal feeding activities, is a serious cause of mortality in some areas.

13. Gizzards were collected throughout the Great Salt Lake Basin from birds shot during the waterfowl season.

14. It was found in 1949 that 0.2 percent of the waterfowl were carrying ingested lead prior to the hunting season and 6.3 percent carried ingested shot after the season. In 1950 0.8 percent were carrying shot prior to the waterfowl hunting season, and 6.7 percent were found with ingested shot after the season. Data in 1951, indicated 0.7 percent carried pellets in their gizzards before the hunting season, and 5.6 percent were found with ingested pellets after the hunting season.

15. A three-year total of 7,635 gizzards examined showed that 6.3 percent carried ingested shot.

16. Every year the gizzards from the redheads showed the highest percentage of ingested lead with about 23 percent carrying shot in the gizzard. The mallards averaged approximately 12 percent having shot, while the pintails averaged 8 percent. Green-winged teal carried 0.2 percent ingested lead per year for the three year period. Baldpate showed no shot in 1949, 3.2 percent in 1950 and 3.9 percent in 1951. Shovellers showed 0.1 percent, 0.9 percent, and 1.1 percent respectively for the three year period. Gadwall showed no shot in 1949, 17 percent in 1950, and 2.7 percent

in 1951. Cinnamon teal were the only species examined which contained no shot in the gizzard during the three year period.

17. Several gizzards contained shot of more than one size. Thirty-eight shot was the largest number obtained from one gizzard.

18. The greatest amount of shot were found after the hunting season which may indicate more availability of shot to waterfowl at this time.

LITERATURE CITED

American Ornithologists' Union
1931. Check-list of North American birds. Ed. 4, 526 pp., Lancaster, Pa.

1944. Nineteenth supplement to the American Ornithologists' Union check-list of North American birds. Auk 61: 441-464.

1945. Twentieth supplement to the American Ornithologists' Union check-list of North American birds. Auk 62: 436-449.

1946. Twenty-first supplement to the American Ornithologists' Union check-list of North American birds. Auk 63: 428-452.

1947. Twenty-second supplement to the American Ornithologists' Union check-list of North American birds. Auk 64: 445-453.

Aub, J. H., L. T. Fairhall and others
1926. Lead poisoning. Williams and Wilkins Co., 265 pp., Baltimore, Md.

Baumgartner, F. M.
1942. An analysis of waterfowl hunting at Lake Carl Blackwell, Payne County, Oklahoma, for 1940. Jour. Wildlife Mgmt. (1) 6:83-91.

Bellrose, Frank C.
1944a. Waterfowl hunting in Illinois: its status and problems. Ill. Nat. Hist. Surv. Biol. Notes 17, 33 pp.

1944b. Duck populations and kill. An evaluation of some waterfowl regulations in Illinois. Ill. Nat. Hist. Surv. Bull. (2) 23:327-372.

1947. Ducks and Lead. Ill. Conservationist (1) 12:10-11.

1951. Effects of ingested lead shot. Trans. Sixteenth N. Am. Wildlife Conf. :125-135.

Bellrose, Frank C., and E. B. Chase
1950. Population losses in the mallard, black duck, and blue-winged teal. Ill. Nat. Hist. Surv. Biol. Notes 22, 27 pp.

Bowles, J. H. 1908. Lead poisoning in ducks. Auk 25 (3):312-313.

Cantarow, Abraham, and Max Trumper 1944. Lead poisoning. Williams and Wilkins Co., Baltimore, Md. 264 pp.

Cottam, Clarence 1939. Food habits of North American diving ducks. U. S. Dept. Agr. Tech. Bull. No. 643.

Elder, William H. 1950. Measurement of hunting pressure in waterfowl by means of X-ray. Trans. Fifteenth N. Am. Wildlife Conf.: 490-504.

Green, R. G., and R. L. Dowdell 1936. The prevention of lead poisoning in waterfowl by the use of disintegrable lead shot. Trans. First N. Am. Wildlife Conf.:486-489.

Grinnell, George Bird 1901. American duck shooting. Willis McDonald and Co., New York. pp. 598-603.

Hawkins, Arthur S. and Frank C. Bellrose 1939. The duck flight and kill along the Illinois river during the fall of 1938. Amer. Wildlife, July-Aug.

Hochbaum, H. Albert 1946. Recovery potentials in North American waterfowl. Trans. Eleventh N. Am. Wildlife Conf.,:403-418.

Jordan, James S., and Frank C. Bellrose 1950. Shot alloys and lead poisoning in waterfowl. Trans. Fifteenth N. Am. Wildlife Conf.:155-170.

_____ 1951. Lead poisoning in wild waterfowl. Ill. Nat. Hist. Surv. Biol. Notes 26, 27 pp.

Kortright, F. H. 1943. The ducks, geese, and swans of North America. The American Wildlife Institute, Washington, D. C. 476 pp. illus.

McAtee, W. L. 1908. Lead poisoning in ducks. Auk 25 (4): 472.

Neff, Johnson A. and Charles C. Sperry 1950. Lead poisoning in waterfowl; a field experiment. Special report, Wildlife Research Laboratory, Denver, Colorado, 16 pp.

Nord, Warren H. 1941. Technique for removing lead from the gizzards of living waterfowl. Jour. Wildlife Mgmt. 5(2):175-179.

Phillips, John C. and Frederick C. Lincoln
1930. American waterfowl, their present situation and the outlook for their future. Houghton Mifflin Co., Boston and New York. 312 pp.

Shillinger, J. E. and Clarence C. Cottam
1937. The importance of lead shot in waterfowl. Trans. Second N. Am. Wildlife Conf.:398-403.

U. S. Fish and Wildlife Service
1951. Pacific Flyway waterfowl report. No. 15, Aug. pp. 2-5.

Wetmore, Alexander
1919. Lead poisoning in waterfowl. U. S. Dept. Agr. Bull. No. 793.

Whitlock, S. C. and H. J. Miller
1947. Gunshot wounds in ducks. Jour. Wildlife Mgmt. (3) 11:279-281.