FINAL REPORT

RELATIVE EFFECTIVENESS OF NO. 4 STEEL AND NO. 6 LEAD SHOT FOR HUNTING DUCKS--THE LACASSINE STUDY

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Abstract: Relative effectiveness of No. 4 steel and No. 6 lead shot for hunting ducks was tested under field conditions on Lacassine National Wildlife Refuge during the 1980-81 and 1981-82 waterfowl seasons. Federal Hi-Power No. 6 lead was compared with Federal No. 4 steel in 2-3/4 inch 12-gauge loads. Significantly more ducks were hit per shot fired ($P < 0.01$) with No. 6 lead (mean = 0.196) than with No. 4 steel (mean = 0.159). Ducks hit per shot was nearly twice as high for both loads at closer ranges than for shots greater than 32 m (35 yd). The proportion of ducks crippled per hit was significantly higher ($P < 0.01$) for No. 4 steel (mean = 0.334) than for No. 6 lead (mean = 0.236), resulting in a 41.5% increase in cripples per hit with No. 4 steel. The proportion of ducks crippled per hit was significantly greater for both load types at longer ranges (> 32 m).

INTRODUCTION

Controversy continues to surround the use of non-toxic steel shot for hunting waterfowl, even though much research has been conducted on steel shot (Andrews and Longcore 1969, Kozicky and Madson 1973, Nicklaus 1976, Mikula et al. 1977, Anderson and Roetker 1978, Anderson and Sanderson 1979, Humburg et al. 1982). Results of most steel shot studies have shown little or no differences in effectiveness between steel and lead shot. However, some hunters have not accepted the results of these studies, maintaining that there is a real difference in effectiveness when they use steel shot while hunting ducks.

In July 1979, a group of Louisiana hunters petitioned the U.S. Fish and Wildlife Service to conduct further research on steel shot in Louisiana. Subsequently, a shooting study was conducted at Lacassine National Wildlife Refuge by the Louisiana Cooperative Wildlife Research Unit in cooperation with the U.S. Fish and Wildlife Service and the Louisiana Department of Wildlife and Fisheries. The purpose of the Lacassine shooting study was to determine the relative effectiveness, in an actual duck hunting situation, of the most popular lead load used by Louisiana duck hunters and the steel load that was ballistically most comparable of those readily available to hunters.

We are grateful to the 33 observers and more than 1000 hunters who participated in the study. Thanks are due B. Brown, K. Ouchley and the staff of Lacassine National Wildlife Refuge for their valuable help. We thank D. Hewitt, P. Shealy and students of the Louisiana Cooperative Wildlife Research Unit for conducting drawings for hunts. Appreciation is extended L. Soileau, Louisiana Department of Wildlife and Fisheries, for assistance given through all phases of this study. R. Aycock provided valuable help with technical and financial matters. T. Roster deserves thanks for training the observers and assisting in other ways. We also express our appreciation to D. Hayne and P. Geissler who assisted in study design and review of statistical methods. The project was supervised through the Louisiana Cooperative Wildlife Research Unit; Louisiana State University, U.S. Fish and Wildlife Service, Louisiana Department of Wildlife and Fisheries and Wildlife Management Institute, cooperating.

DESCRIPTION OF STUDY AREA

The study was conducted on Lacassine National Wildlife Refuge (LNWR) located in the coastal Chenier Plain marshes of southwest Louisiana approximately 24 km (15 mi) southwest of Lake Arthur (Fig. 1). The study area is a freshwater marsh dominated by dense stands of bull tongue (Sagitaria lancifolia) and maidencane (Panicum hemitomon) surrounding shallow open water ponds. Aquatics, including water lotus (Nelumbo lutea) and white water lily (Nymphaea odorata), were abundant in open ponds. Ponds with dense aquatic vegetation became more open as temperatures dropped and hunting seasons progressed. Marsh-vegetation was fairly homogeneous throughout the study area; however, pond-size and interspersion of vegetation varied considerably between blind sites.

Water depth in ponds usually varied from 10 cm to 30 cm (4-12 in), dependent upon wind speed and direction, but was generally similar for all blinds. Marsh water levels were lower during 1980 than 1981. Low water levels and strong north winds in 1980 sometimes left decoys stranded on the mud, causing poor hunting conditions. Lacassine marsh has a soft bottom which makes walking very difficult in most areas and impossible in several of the areas that were hunted. Thus, hunters were frequently forced to use a flatboat or a dog to retrieve the downed ducks.

Hunting blinds were constructed on pond edges throughout the study area. All blinds were consistently located on the southeast side of a pond with each blind facing towards the northwest. Each blind consisted of a 1.2 m by 2.4 m (4 x 8 ft) platform surrounded by mesh wire. A blind for hiding a small flatboat was attached to the rear. The entire structure was camouflaged with Roseau cane (Phragmites communis), a common plant in the study area. Traditionally, hunting blinds have been camouflaged with similar vegetation, although blinds used in this study were larger than a typical south Louisiana marsh blind.

The study area has received heavy hunting pressure for many years. Waterfowl hunters have been required to use steel shot on the Refuge since 1974.

Historically, a variety of duck species have been taken by hunters using the study area. Mallard (Anas platyrhychos), mottled duck (Anas fulvigula), pintail (Anas acuta), gadwall (Anas strepera), wigeon (Anas americana), blue-winged teal (Anas discors), green-winged teal (Anas crecca), wood duck (Aix sponsa), shoveler (Anas clypeata), ring-necked duck (Aythya collaris), and lesser scaup (Aythya affinis) make up the majority of the bag at LNWR (Appendix A).

METHODS

The study was conducted during the duck hunting seasons of 1980 and 1981 (November, December, and January). Morning-only hunting was allowed on Wednesday through Sunday for a total of 39 hunting days each year. The test procedure was for a trained observer to occupy a duck blind with hunters. Observers recorded data while participants hunted in their normal duck hunting manner. Observers used the same procedures both years.

Hunters applied by mail to participate for each hunting day and were selected by a drawing of applications. Hunters were preassigned by random numbers to blinds for each day of hunting. For each day of hunting in 1980, hunters were assigned to 19 of 23 blinds used in the study. In 1981, hunters were assigned to 12 test blinds. The number of blinds was reduced because only 12 of the 23 blinds used in 1980 provided sufficient data to be analyzed statistically.

About 20% of the blinds were filled by additional hunters on a first-come daily basis when either 1 or both of the assigned hunters did not show up to hunt. In 1980, such hunters were given their choice of empty blinds; in 1981, they were generally assigned to empty blinds. Another change that occurred between years was that hunters had to provide their own transportation to traverse the 10 to 19 km (6 to 12 mi) of water from the Refuge headquarters to the blinds in 1980; all boat transportation to blinds was provided hunters in 1981.

Observers came from many different states and had a wide range of background and experience. The educational level of observers in 1980 ranged from not completing high school to a Master's degree. The majority had a college background in wildlife. In 1981, all observers had a college background in wildlife with 3 having a Master's degree. For each day of hunting, observers were randomly preassigned to blinds.

Observers were given 2 weeks of intensive training prior to each hunting season. They were trained to estimate distances both visually and using a mechanical rangefinder (Rangematic Ranging 610) through a series of repetitive exercises and testing of individual ability. Field training included instruction on data gathering as well as distance measurements under actual hunting conditions.

Standard factory loads of 2-3/4-inch 12-gauge Federal Hi-Power No. 6 lead and Federal Steel Shot No. 4 were tested in this study. No. 6 lead was chosen because it was determined to be the most popular load for duck hunting, based on a mail survey of randomly selected Louisiana duck hunters conducted by the Louisiana Department of Wildlife and Fisheries (Appendix B). No. 4 steel was chosen as the steel load for comparison because, of the steel loads readily available for use by duck hunters, it was judged to be ballistically most comparable to the No. 6 lead load. Steel shot shells used were factory loads of 1-1/8 ounce No. 4 steel with 213 pellets with an average muzzle velocity of 1365 fps. Lead shot shells used were a factory load of 1-1/4 ounce No. 6 lead with 279 pellets and average muzzle velocity of 1330 fps. The velocities indicated are according to manufacturers' standards.

Design of the test included a double-blind secrecy on knowledge of load-types that were tested. Observers and hunters did not know what loads were being tested. Also, hunters and observers did not know whether lead or steel was used in their blind each day. To further confuse hunters attempting to determine load type, 4 secondary "confusion" loads were used in the test about 5% of the time.

All markings were removed from the shells, thus making all loads identical in external appearance. Test loads were then coded in special boxes with 26 letters of the alphabet. Eleven letters were assigned to load-type I (later identified as No. 6 lead), 11 were assigned to load-type II (later identified as No. 4 steel), and 1 was assigned to each of 4 "confusion" loads. Identification of the loads being tested was not revealed to the shell handler, project field supervisor, or statistician until the study was completed. For each day of hunting,1 shell was retained from each blind to provide verification of the shot-type used. Observers distributed 50 shot shells (2 boxes) to each hunter in the blind. Observers were required to account for all shells after each hunt.

One load was assigned to each blind each day using a restricted randomization scheme. First, blinds were separated into groups based on size of ponds in the marsh. Days were then grouped into 4-day blocks in 1980 and 8-day blocks in 1981. Confusion loads were assigned at random, with the restriction that 2 confusion loads were assigned to day-block and blind-group selected. Test loads were assigned randomly to the remaining blinds and days with the restriction that each blind used each load the same number of days and each blind-group used each load equally often on a given day.

Observers recorded only shots fired at ducks. Data were recorded by attempts, defined as 1 or more shots fired at a flight of ducks, usually without reloading. For each attempt, the observer recorded the distance at which the first shot was fired, number of shots fired, number of ducks bagged, number of ducks hit but not recovered, and number of shots fired at wounded ducks on the water. Distance recorded on an attempt was the observer's estimate of the distance to the closest duck when the first shot was fired. All measurements were recorded in yards but converted to meters for consistency of presentation. A downed duck was not recorded as bagged until it was recovered by the hunter. A cripple was defined as a duck that was visibly hit but not retrieved, including any dead duck not recovered (bagged) by the hunter.

Observers recorded whether or not a retrieving dog was used and choke information on the gun used by each hunter. Observers asked each hunter, "Do you think you know which type of shot shell you were using"? If a hunter answered, "yes", he was then asked whether he thought he was using lead or steel. Also recorded was whether or not the observer had any evidence that the hunter actually knew what shell-type was used. When hunters returned to the check station each day, number and species of ducks bagged were recorded and checked against the observer's data.

For analysis, the experimental unit was defined as the results of all attempts with the same load for a particular blind each season. This unit was then split into distance categories to establish sampling units. Also for analytical purposes, hits were defined as the sum of ducks bagged and ducks crippled. The proportion of ducks hit per shot and crippled per hit were calculated for each sampling unit. These proportions were transformed using the angular transformation (Arcsine $\sqrt{P}$) (Steel and Torrie 1980). Transformed variables were used in a weighted analysis of variance (ANOVA), weighting hits per shot with the number of shots and crippled per hit with the number of hits. Means were calculated by back-transforming the means of the transformed variables.

The Lacassine study was designed to have sufficient power to detect a 33% or greater difference in ducks cripplied per hit between No. 6 lead and No. 4 steel if 2500 or more ducks were hit. A difference of 14% or more in ducks bagged per shot could be detected if at least 10,000 shots were fired (D. Hayne, in a letter to L. Soileau, Louisiana Department of Wildlife and Fisheries dated October 24, 1980) (Appendix C). Because insufficient data were collected in 1980 to meet these criteria, the study was continued for a second year.

Screening the data to identify uncontrollable factors that might be confounded with the effects of the load was accomplished by cross-classification of the data not utilizing the experimental units. Chi-square tests were used to test whether these classification criteria were independent.

RESULTS

Data Selection

Observations were summed for each season for all hunters shooting from the same blind with the same load type. Only those parties shooting No. 6 lead shot or No. 4 steel shot were included in the analysis. Observations on an attempt were deleted when some information--usually distance to first shot or number of cripples--was not recorded. For each year, 12 blinds were available on each of 2 loads yielding 48 experimental units. Data were further divided into 2 distance categories, totaling 96 sampling units in the study (Table 1).

Distance data were grouped into 2 categories after studying the frequency of occurrence of birds bagged, birds crippled and shots fired at 4.6 m (5 yd) intervals (Appendix D). Attempts to separate the observations into 3 distance categories were discontinued when inspection showed several blind-load-distance groups would have zeros in some categories for ducks crippled or bagged. Distance categories used in the analysis were less than or equal to 32 m (35 yd) and greater than 32 m (35 yd) for first shot fired. The 32 m (35 yd) class separated the number of ducks crippled into 2 nearly equal groups, while the 27.4 m (30 yd) class separated the number of ducks bagged and the number of shots fired almost evenly. The 32 m (35 yd) class was chosen because the number of ducks crippled was the variable with least data and considered the variable of greatest importance.

A total of 834 blind-days was recorded when No. 6 lead and No. 4 steel were used. In 1980, 11 of 23 test blinds (109 blind days) did not produce sufficient data to be analyzed (at least 50 birds bagged plus crippled). Data for the 11 excluded blinds are listed in Appendix E.

Certain uncontrolled factors within the study, such as ability to identify load being used, different chokes of shotguns used, and use or non-use of a retrieving dog could be confounded with the effects of load. Each was addressed separately to identify confounding effects.

Either 1 or both hunters in 39% of the hunting parties attempted to guess which load-type they were using. Nearly 70% of the hunters who guessed thought they were using steel shot. The data did not indicate that hunters who guessed were actually shooting either load more frequently (X^2 test, P=0.54). More hunters guessed correctly than would have been expected by chance (X^2 test, $P < 0.01$). This could mean that hunters were either basing their guess on a variety of cues that gave them a higher chance of being correct or that some hunters could differentiate between loads being tested.

Because hunters that participated repeatedly had more opportunities to learn to distinguish between loads, records of these individuals were reviewed. Only one frequent participant consistently guessed correctly. Based on this, we think that few hunters who attempted to guess what they were shooting could actually differentiate between the loads being tested.

About 57% of the hunters used modified chokes, 40% used full chokes and 3% used open chokes (Appendix F). No significant difference was found in the number of times each choke-type was used by hunters shooting No. 6 lead and No. 4 steel (X^2 test, P=0.97).

The final uncontrolled factor considered was the use of retrieving dogs by some hunting parties. During 1980, 21.8% of the hunting parties used dogs; in 1981, 16.3% of the hunting parties used dogs (Table 4). A significantly higher proportion of the hunters using No. 4 steel used dogs in 1980 (X^2 test, P=0.01), but the proportion of hunters using dogs was nearly identical for the 2 loads in 1981 (X^2 test, P=0.84). Little difference was found in ducks hit per shot fired between hunters with or without dogs, but significantly fewer ducks were crippled per hit for hunters with dogs in both distance categories (binomial test, $P < 0.02$, ≤ 32 m; $P < 0.01$, > 32 m) (Table 5).

Evaluation of the effects of these factors for each load indicated that they were not sufficiently important to require deleting observations or incorporating additional factors in the analysis.

Comparison of Loads

The loads were compared using data from 8023 No. 6 lead shells and 8615 No. 4 steel shells shot at ducks during the 2-year study. A total of 802 ducks were crippled: 366 with lead shot and 436 with steel shot. Hunters bagged 2228 ducks: 1242 with lead shot and 986 with steel shot. Table 6 summarizes the raw data by year and distance.

Mallard and gadwall were the most common species bagged followed by green-winged teal and blue-winged teal (Table 7). The relative abundance of each species in the bag was significantly different between years (X^2 test, $P < 0.01$) with a higher proportion of green-winged teal and pintail in 1980 and blue-winged teal, wigeon and scaup in 1981. There was no evidence that the species composition of the bag differed between loads (X^2 test, P=0.42, 1980; P=0.18, 1981).

The hypothesis that the ducks hit per shot was the same for No. 6 lead and No. 4 steel was tested with the ANOVA shown in Table 8. Blind was considered a random effect, while load and distance were considered fixed effects. Both load and distance were significantly different ($P < 0.01$). None of the interaction terms for the varible were significant. No. 4 steel had an 18.9% lower hits per shot mean (0.159) than No. 6 lead (0.196) (Table 9). A plot of ducks hit per shot at 4.6 m (5 yd) intervals showed that No. 6 lead consistently hit a higher proportion of the shots (Sign test, $P < 0.01$) (Fig. 2).

The ANOVA for the variable ducks crippled per hit showed that load and distance again were both significant ($P < 0.01$) (Table 8). The blind by distance interaction was significant ($P=0.03$) for the variable ducks crippled per hit. The mean number of ducks crippled per hit was 0.236 for No. 6 lead and 0.334 for No. 4 steel: a 41.5% increase in crippling rate for the steel load over all distances (Table 9). For both loads combined, a 77% increase in ducks crippled per hit resulted for shots beyond 32 m (35 yd) over shots at less than 32 m. A plot of ducks crippled per hit against distance in 4.6 m (5 yd) intervals for the 2 loads shows that the use of No. 6 lead resulted in fewer ducks crippled per hit than No. 4 steel (Sign test, $P=0.035$) (Fig. 2).

The effectiveness of No. 6 lead and No. 4 steel in killing wounded ducks that fell into the water was compared (Table 2). The difference between loads was within the realm of what would be expected by chance (X^2 test, $P=0.12$). Insufficient evidence was found to indicate a difference in the proportion of wounded ducks shot at on the water that were recovered by hunters using No. 6 lead and No. 4 steel.

DISCUSSION

The Lacassine shooting test compared the lead load most often used by duck hunters in Louisiana, No. 6 lead, to the most comparable of readily available steel loads, No. 4 steel, in an actual duck hunting situation. Results of this study showed that participating duck hunters hit significantly fewer ducks per shot with No. 4 steel shot than with No. 6 lead shot. Also, the proportion of ducks crippled per duck hit was significantly greater with No. 4 steel than with No. 6 lead.

The species composition of the bag was not significantly different between the two loads. Thus, no evidence was found to indicate that a higher proportion of any species was bagged by No. 4 steel or No. 6 lead.

The lead and steel loads tested did not show relative performance differences at different ranges. Both loads hit more ducks per shot at closer ranges than at longer ranges. The lack of a significant interaction between loads and distances in the ANOVA for ducks hit per shot implies no difference between relative effectiveness for the 2 distances categories. The nearly parallel lines (Fig. 2) indicate that the differences noted are consistent across the range of distances of shots in the study.

Similarly, the load by distance interaction for ducks crippled per hit was not significant. Both loads crippled more ducks per hit at longer distances than at shorter distances. Differences between loads were again consistent across all intermediate ranges (23-46 m).

The significant interaction term for ducks crippled per hit between blind and distance means that the number of ducks crippled per hit was higher at longer ranges for some blinds. This significant interaction may have been influenced by the size of the pond at each blind. Pond size was difficult to determine and rank due to interspersion of vegetation and irregular shapes. However, the blind with the highest number of ducks crippled per hit was located on the smallest pond and the blind with the lowest number of ducks crippled per hit was located on the largest pond.

Hunting conditions encountered on Lacassine during this study were similar to conditions, in general, in the marshes of southwest Louisiana during the same years. Poor duck nesting success during 1980 and 1981 resulted in a lower-than-normal harvest in south Louisiana. Low water levels and mild weather also contributed to the small number of ducks bagged in the study.

We believe that the hunters participating in this study were reasonably representative of southwestern Louisiana duck hunters, although no data are available for documentation. Most Louisiana hunters have had little experience shooting steel shot. Yet, LNWR has required the use of steel shot for the past 8 years, so some test hunters had experience with steel. Lacassine, being an established public hunting area, has its own clientele of avid hunters who continued to use the area by participating in this study. In the other extreme, many novice hunters participated in the study, especially in 1981, when they did not need access to a boat capable of traversing 10 to 19 km (6 to 12 mi) of water to reach the blind.

The species composition of ducks bagged was reasonably representative of the area. The composition of the bag at Lacassine during the 2 years prior to the study (US Fish and Wildlife Service 1979, 1980) was similar to the bag during the test (Appendix A). Some of the difference is attributable to the slightly lower than normal number of mallards and higher number of shovelers bagged during the years of the test.

The effectiveness of a shotgun load can be conceptualized as the probability of hitting a duck (hit per shot) and the probability of recovering a duck that is hit (bagged per hit). The probability that a duck was hit with a particular shot was not precisely measured because the observers did not record if a duck was hit by more than 1 shot. However, ducks hit per shot is a reasonable index to the probability of hitting a duck.

The proportion of the ducks actually hit that were recovered (bagged per hit) was measured by its complement, ducks crippled per hit. This variable has not been used in previously published studies. Crippled per hit was chosen because it accurately measures the conditional probability of recovering a duck after it has been hit.

The variable, ducks crippled per shot (Anderson and Sanderson 1979, Humburg et al. 1982), is the product of ducks hit per shot and ducks crippled per hit. In the Lacassine study, ducks hit per shot was significantly less for No. 4 steel, while ducks crippled per hit was significantly greater. These conflicting tendencies may result in the variable ducks crippled per shot not being significant when used.

Neither variable, hit per shot or crippled per hit, attempts to measure the total number of ducks that are hit and never retrieved. These variables do, however, compare the relative effectiveness of the 2 loads tested.

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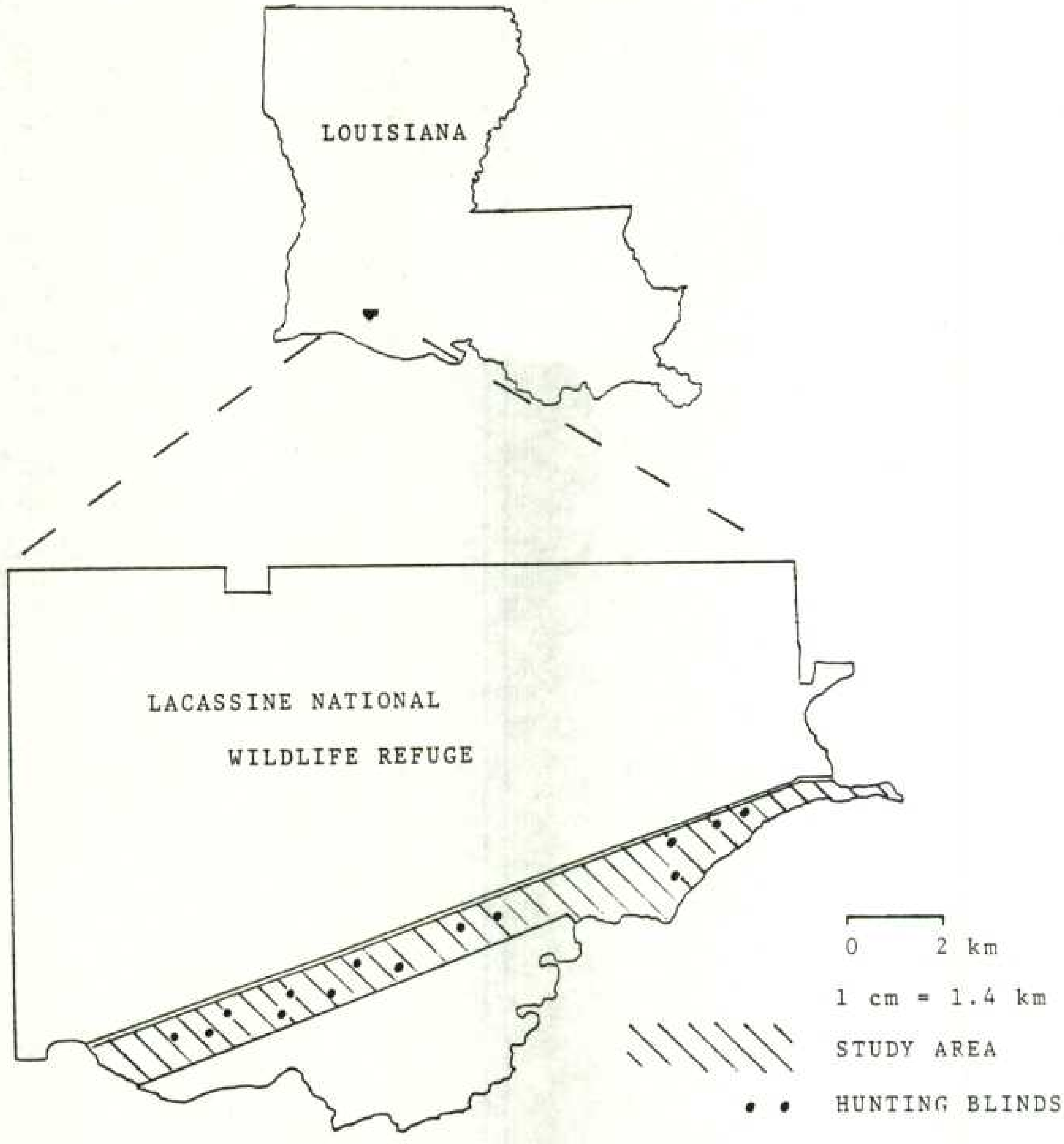

Figure 1. Location of study area, Lacassine National Wildlife Refuge, Louisiana.

Figure 2. Plot of proportion of ducks hit per shot and ducks crippled per hit at 4.6 meter (5 yd) distance intervals.

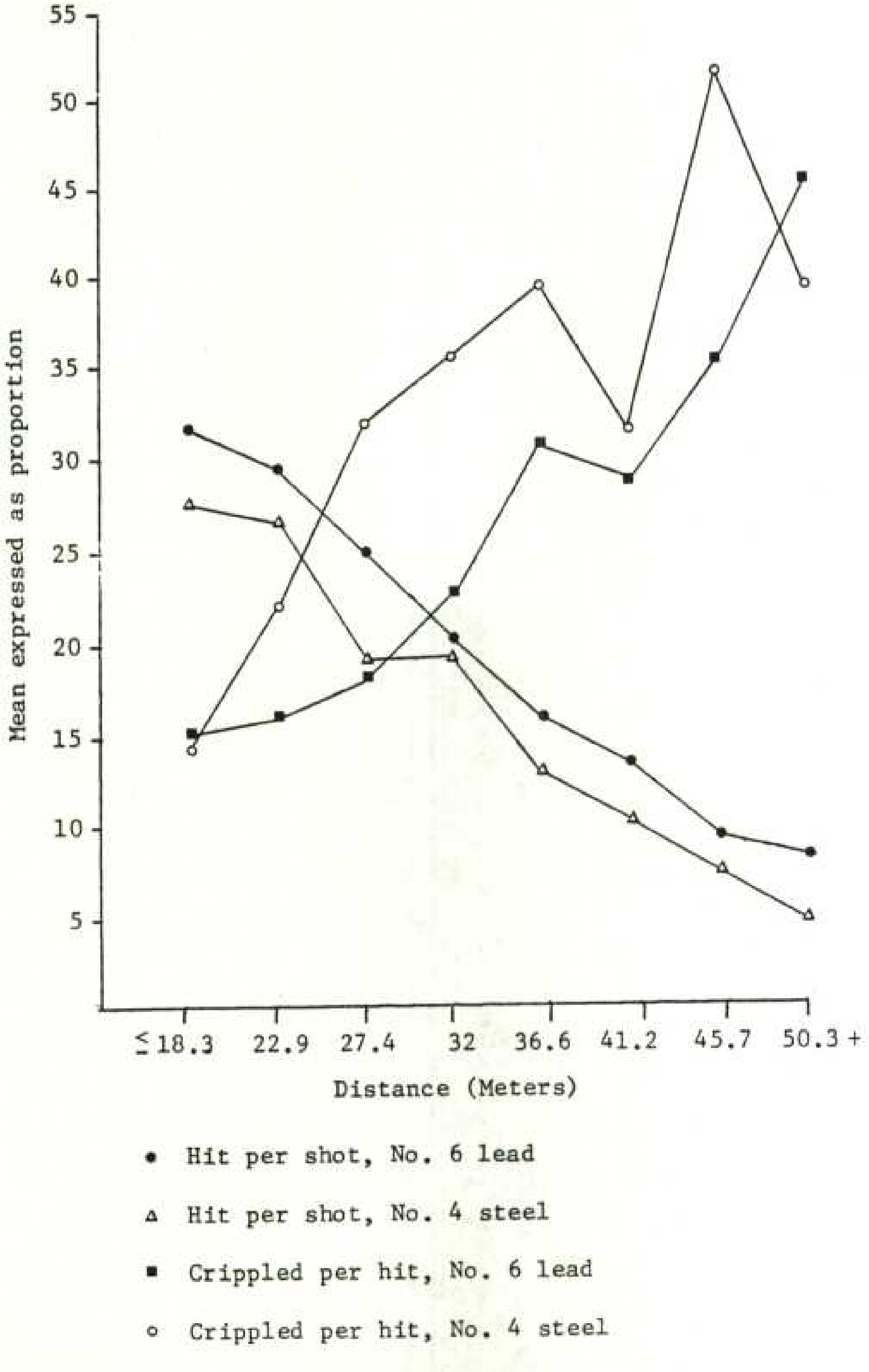

Table 1. Listing of 96 sampling units (12 blinds by 2 years by 2 loads by 2 distances) used in final analysis of the Lacassine study.

Blind No.	Days Used Lead 6	Days Used Steel 4	Distance (meters)	Number Bagged Lead 6	Number Bagged Steel 4	Number Crippled Lead 6	Number Crippled Steel 4	Shots Fired Lead 6	Shots Fired Steel 4
				1980					
2	12	8	≤ 32	29	11	4	4	121	82
			> 32	15	12	5	4	146	149
3	10	9	≤ 32	27	22	6	8	112	105
			> 32	8	8	12	6	95	110
6	8	12	≤ 32	19	36	5	13	90	176
			> 32	11	8	1	3	55	196
7	13	11	≤ 32	58	43	15	9	279	243
			> 32	29	9	12	2	181	141
14	7	11	≤ 32	8	16	2	5	51	100
			> 32	6	7	3	8	84	137
21	10	10	≤ 32	19	11	4	4	71	42
			> 32	10	3	2	3	78	69
22	14	13	≤ 32	18	22	0	1	59	120
			> 32	5	12	4	3	79	189
23	13	18	≤ 32	37	24	1	6	131	126
			> 32	16	15	6	15	162	260
25	11	14	≤ 32	23	45	4	4	97	210
			> 32	15	16	4	5	130	147
26	16	13	≤ 32	28	20	6	14	150	123
			> 32	23	6	9	4	181	154
27	15	13	≤ 32	19	19	2	7	103	85
			> 32	10	2	9	7	153	114
28	18	17	≤ 32	59	30	10	13	253	228
			> 32	27	17	5	8	230	232

Continued.

Table 1. Continued.

Blind No.	Days Used Lead 6	Days Used Steel 4	Distance (meters)	Number Bagged Lead 6	Number Bagged Steel 4	Number Crippled Lead 6	Number Crippled Steel 4	Shots Fired Lead 6	Shots Fired Steel 4
				1981					
2	17	20	≤ 32	34	36	10	10	161	235
			> 32	11	6	11	5	193	143
3	21	18	≤ 32	45	61	12	15	233	313
			> 32	20	13	9	10	201	198
6	19	18	≤ 32	86	60	27	30	408	375
			> 32	27	22	12	7	242	194
7	15	18	≤ 32	36	47	5	22	136	300
			> 32	18	17	13	7	264	181
16	16	18	≤ 32	41	28	9	18	187	231
			> 32	10	11	13	9	174	229
22	16	19	≤ 32	29	36	10	14	174	190
			> 32	13	7	5	5	177	197
23	17	21	≤ 32	31	38	8	13	175	213
			> 32	17	17	4	13	179	259
24	18	14	≤ 32	24	6	6	6	132	78
			> 32	17	2	5	4	164	79
25	18	17	≤ 32	47	23	13	13	204	171
			> 32	16	18	10	12	191	289
26	18	20	≤ 32	50	37	10	5	207	156
			> 32	5	9	6	5	185	162
27	18	19	≤ 32	37	26	6	16	174	225
			> 32	10	3	7	7	151	124
28	20	17	≤ 32	74	31	13	19	327	221
			> 32	25	18	11	15	293	314

Table 2. Comparison of ducks retrieved or lost when shots were fired at wounded birds on the water using No. 6 lead and No. 4 steel.

	Retrieved	Not Retrieved
No. 6 lead	291	42
No. 4 steel	251	52

Table 3. Frequency of responses of hunter parties when asked if they knew what load they were using.

Hunter parties response to which load was being used	Load Actually Used	
	No. 6 lead	No. 4 steel
Did not guess	224	216
One guessed lead	29	18
One guessed steel	33	51
Both guessed lead	25	10
Both guessed steel	38	61
One guessed lead, one guessed steel	10	11

Table 4. Number of blind-days when dogs were used or not used each year for each load.

	1980		1981	
	Lead 6	Steel 4	Lead 6	Steel 4
Dog used	23	41	34	36
No dog used	123	106	179	180

Table 5. Comparison of mean number of ducks hit per shot and crippled per hit by distance for hunter parties with and without dogs.

		Means*	
Was Dog Used?	Distance (meters)	Hit per Shot [1]	Crippled per Hit [2]
No	≤ 32	0.245	0.231
Yes	≤ 32	0.250	0.183
No	> 32	0.115	0.377
Yes	> 32	0.124	0.290

*Mean of all observations.

[1] Mean calculated as total number of hits divided by total number of shots.

[2] Mean calculated as total number crippled divided by total number of hits.

Table 6. Number of ducks bagged, crippled and shots fired for each load, year and distance category.

Distance (meters)	Number bagged		Number crippled		Number Shots Fired	
	Lead 6	Steel 4	Lead 6	Steel 4	Lead 6	Steel 4
			1980			
32	344	299	59	88	1517	1640
32	175	115	72	68	1574	1898
			1981			
32	534	429	129	181	2518	2708
32	189	143	106	99	2414	2369
			Both Years Combined			
32	878	728	188	269	4035	4348
32	364	258	178	167	3988	4267
			Total			
	1242	986	366	436	8023	8615

Table 7. Species composition of bag for each year and load.

Species	1980 Lead 6	1980 Steel 4	1981 Lead 6	1981 Steel 4
	Number of Ducks Bagged			
Mallard	133	102	182	136
Mottled Duck	13	14	30	21
Pintail	52	41	41	37
Gadwall	82	64	118	90
Wigeon	20	11	57	37
Green-winged Teal	67	79	68	45
Blue-winged Teal	41	25	77	70
Scaup	4	3	24	14
Ring-necked Duck	31	30	36	52
Other[a]	85	71	107	90

[a] Consisted mostly of Northern Shoveler and Wood Duck.

Table 8. The weighted analysis of variance for the arcsine of the square root of the hits per shot and crippled per hit in the Lacassine study.

		Hit per Shot[1]		Crippled per Hit[2]	
Source	df	MS	F	MS	F
Blind	23	0.3654	-	0.6309	-
Load	1	8.165	37.44***	5.883	14.79***
Blind X Load (error a)	23	0.2181	.74	0.3978	1.78
Distance	1	106.089	360.47***	17.056	36.21***
Distance X Blind (error b)	23	0.2943	.79	0.4710	2.11*
Distance X Load	1	0.2754	.74	0.6608	2.96
Distance X Blind X Load (error c)	23	0.3722	-	0.2232	-

* P < .05.

*** P< 0.001.

[1]Weighted by number of shots.

[2]Weighted by number of hits.

Table 9. Means for hit per shot and crippled per hit for each load and distance.

Distance (meters)	Means[a]	
	Hit Per Shot	Crippled Per Hit
	No. 6 lead	
≤32	0.2630	0.1564
>32	0.1372	0.3264
All distances	0.1963	0.2360
	No. 4 steel	
≤32	0.2326	0.2632
>32	0.0963	0.4095
All distances	0.1585	0.3340

[a]Back-transformed means.

Appendix A. Comparison of species composition of ducks bagged during the Lacassine study and 2 previous years.

Species	Percent of Total Bag			
	1978-79[a]	1979-80[b]	1980-81[c]	1981-82[c]
Mallard	26	35	24	24
Mottled Duck	5	3	3	4
Pintail	6	8	10	6
Gadwall	15	13	15	16
Wigeon	8	6	3	7
Green-winged Teal	16	16	15	8
Blue-winged Teal	9	8	7	11
Scaup	-	-	1	3
Ring-necked Duck	5	5	6	7
Wood Duck	2	1	3	4
Other[d]	7	5	13	10

[a] From US Fish and Wildlife Service 1979.

[b] From US Fish and Wildlife Service 1980.

[c] From Lacassine shooting study.

[d] Primarily Northern Shovelers.

LOUISIANA DEPARTMENT OF WILDLIFE AND FISHERIES

DISTRICT OFFICE
P.O. BOX 585
OPELOUSAS, LOUISIANA 70570

June 9, 1980

MEMORANDUM

TO: Bob Smith, Jacque Wiener, Jr., John Newsom, Ken Black, Ray Aycock, Milton Friend

FROM: Larry Soileau LS

SUBJECT: Shotgun Shell Survey

I have attached a copy of Louisiana's recently completed shotgun shell usage survey. A total of 4,230 copies of the enclosed questionnaire was sent to a random sample of Louisiana duck hunters selected from recent state and federal waterfowl harvest surveys.

An individual record card was punched and verified for each completed questionnaire. No effort was made to purge loads which were not commercially available from the report with an edit program. We chose instead to report all responses exactly as they were received.

If you have any questions concerning this report, please give me a call. All completed questionnaires and return envelopes have been stored and are available for examination.

LS:ms

LOUISIANA DEPARTMENT OF WILDLIFE AND FISHERIES

Game Division

SHOTGUN SHELL SURVEY

May, 1980

LA. DEPT. OF WILDLIFE AND FISHERIES
GAME DIVISION
SHOTGUN SHELL SURVEY
MAY 1980

GAUGE OF SHOTGUN SHELL USED FOR DUCK HUNTING

10 GAUGE	3	0.1%	3-INCH 20 GAUGE	47	2.2%
3-INCH 12 GAUGE	191	8.9%	2-3/4 INCH 20 GAUGE	125	5.9%
2-3/4 INCH 12 GAUGE	1512	70.8%	OTHER	7	0.3%
16 GAUGE	181	8.5%	UNKNOWN	70	3.3%

SHELLS MOST OFTEN USED FOR DUCK HUNTING

FEDERAL DUCK + PHEASANT	365	17.1%	WINCHESTER DUCK + PHEASANT	81	3.8%
FEDERAL HI-POWER	192	9.0%	WINCHESTER SUPER X	451	21.1%
FEDERAL PREMIUM	8	0.4%	WINCHESTER SUPER DOUBLE X	53	2.5%
REMINGTON DUCK + PHEASANT	151	7.1%	RELOADS	185	8.7%
REMINGTON EXPRESS	376	17.6%	OTHER	23	1.1%
REMINGTON NITRO MAG	23	1.1%	UNKNOWN	228	10.7%

SHOT USED IN THE SHELLS FOR DUCK HUNTING

7/8 OZ	39	1.8%	1-5/8 OZ	92	4.3%
1 OZ	122	5.7%	1-7/8 OZ	106	5.0%
1-1/8 OZ	349	16.3%	2 OZ	14	0.7%
1-3/16 OZ	16	0.7%	2-1/4 OZ	23	1.1%
1-1/4 OZ	923	43.2%	OTHER	12	0.6%
1-3/8 OZ	110	5.1%	UNKNOWN	198	9.3%
1-1/2 OZ	132	6.2%			

SHOT SIZE USED FOR DUCK HUNTING

2	7	0.3%	7-1/2	231	10.8%
4	293	13.7%	OTHER	5	0.2%
5	113	5.3%	UNKNOWN	126	5.9%
6	1361	63.7%			

TOTAL MAILING	4230
TOTAL RESPONSES	2136
RESPONSE RATE	50%

LA. DEPT. OF WILDLIFE AND FISHERIES
GAME DIVISION
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MAY 1980

GAUGE OF SHOTGUN SHELL USED FOR DUCK HUNTING

10 GAUGE	0	0. %	3-INCH 20 GAUGE	0	0. %
3-INCH 12 GAUGE	191	100.0%	2-3/4 INCH 20 GAUGE	0	0. %
2-3/4 INCH 12 GAUGE	0	0. %	OTHER	0	0. %
16 GAUGE	0	0. %	UNKNOWN	0	0. %

SHELLS MOST OFTEN USED FOR DUCK HUNTING

FEDERAL DUCK + PHEASANT	9	4.7%	WINCHESTER DUCK + PHEASANT	5	2.6%
FEDERAL HI-POWER	17	8.9%	WINCHESTER SUPER X	59	30.9%
FEDERAL PREMIUM	6	3.1%	WINCHESTER SUPER DOUBLE X	25	13.1%
REMINGTON DUCK + PHEASANT	5	2.6%	RELOADS	15	7.9%
REMINGTON EXPRESS	33	17.3%	OTHER	0	0. %
REMINGTON NITRO MAG	7	3.7%	UNKNOWN	10	5.2%

SHOT USED IN THE SHELLS FOR DUCK HUNTING

7/8 OZ	5	2.6%	1-5/8 OZ	47	24.6%
1 OZ	2	1.0%	1-7/8 OZ	45	23.6%
1-1/8 OZ	14	7.3%	2 OZ	5	2.6%
1-3/16 OZ	3	1.6%	2-1/4 OZ	2	1.0%
1-1/4 OZ	21	11.0%	OTHER	3	1.6%
1-3/8 OZ	17	8.9%	UNKNOWN	17	8.9%
1-1/2 OZ	10	5.2%			

SHOT SIZE USED FOR DUCK HUNTING

2	1	0.5%	7-1/2	10	5.2%
4	56	29.3%	OTHER	0	0. %
5	15	7.9%	UNKNOWN	8	4.2%
6	101	52.9%			

TOTAL MAILING 4230
TOTAL RESPONSES 191
RESPONSE RATE 4%

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GAUGE OF SHOTGUN SHELL USED FOR DUCK HUNTING

10 GAUGE	0	0. %	3-INCH 20 GAUGE	0	0. %
3-INCH 12 GAUGE	0	0. %	2-3/4 INCH 20 GAUGE	0	0. %
2-3/4 INCH 12 GAUGE	1512	100.0%	OTHER	0	0. %
16 GAUGE	0	0. %	UNKNOWN	0	0. %

SHELLS MOST OFTEN USED FOR DUCK HUNTING

FEDERAL DUCK + PHEASANT	271	17.9%	WINCHESTER DUCK + PHEASANT	70	4.6%
FEDERAL HI-POWER	139	9.2%	WINCHESTER SUPER X	320	21.2%
FEDERAL PREMIUM	2	0.1%	WINCHESTER SUPER DOUBLE X	21	1.4%
REMINGTON DUCK + PHEASANT	117	7.7%	RELOADS	143	9.5%
REMINGTON EXPRESS	268	17.7%	OTHER	13	0.9%
REMINGTON NITRO MAG	12	0.8%	UNKNOWN	136	9.0%

SHOT USED IN THE SHELLS FOR DUCK HUNTING

7/8 OZ	21	1.4%	1-5/8 OZ	38	2.5%
1 OZ	41	2.7%	1-7/8 OZ	51	3.4%
1-1/8 OZ	190	12.6%	2 OZ	7	0.5%
1-3/16 OZ	9	0.6%	2-1/4 OZ	11	0.7%
1-1/4 OZ	845	55.9%	OTHER	6	0.4%
1-3/8 OZ	80	5.3%	UNKNOWN	106	7.0%
1-1/2 OZ	107	7.1%			

SHOT SIZE USED FOR DUCK HUNTING

2	5	0.3%	7-1/2	156	10.3%
4	190	12.6%	OTHER	1	0.1%
5	79	5.2%	UNKNOWN	65	4.3%
6	1016	67.2%			

TOTAL MAILING 4230
TOTAL RESPONSES 1512
RESPONSE RATE 35%

LA. DEPT. OF WILDLIFF AND FISHERIES
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MAY 1980

GAUGE OF SHOTGUN SHELL USED FOR DUCK HUNTING

10 GAUGE	0	0. %	3-INCH 20 GAUGE	0	0. %
3-INCH 12 GAUGE	0	0. %	2-3/4 INCH 20 GAUGE	0	0. %
2-3/4 INCH 12 GAUGE	0	0. %	OTHER	0	0. %
16 GAUGE	181	100.0%	UNKNOWN	0	0. %

SHELLS MOST OFTEN USED FOR DUCK HUNTING

FEDFRAL DUCK + PHEASANT	41	22.7%	WINCHESTER DUCK + PHEASANT	3	1.7%
FEDERAL HI-POWER	18	9.9%	WINCHESTER SUPER X	36	19.9%
FEDERAL PREMIUM	0	0. %	WINCHESTER SUPER DOUBLE X	2	1.1%
REMINGTON DUCK + PHEASANT	13	7.2%	RELOADS	8	4.4%
REMINGTON EXPRESS	32	17.7%	OTHER	6	3.3%
REMINGTON NITRO MAG	0	0. %	UNKNOWN	22	12.2%

SHOT USED IN THE SHELLS FOR DUCK HUNTING

7/8 OZ	5	2.8%	1-5/8 OZ	2	1.1%
1 OZ	5	2.8%	1-7/8 OZ	3	1.7%
1-1/8 OZ	109	60.2%	2 OZ	1	0.6%
1-3/16 OZ	3	1.7%	2-1/4 OZ	6	3.3%
1-1/4 OZ	20	11.0%	OTHER	0	0. %
1-3/8 OZ	6	3.3%	UNKNOWN	15	8.3%
1-1/2 OZ	6	3.3%			

SHOT SIZE USED FOR DUCK HUNTING

2	0	0. %	7-1/2	30	16.6%
4	26	14.4%	OTHER	1	0.6%
5	10	5.5%	UNKNOWN	8	4.4%
6	106	58.6%			

TOTAL MAILING	4230
TOTAL RESPONSES	181
RESPONSE RATE	4%

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GAUGE OF SHOTGUN SHELL USED FOR DUCK HUNTING

10 GAUGE	0	0. %	3-INCH 20 GAUGE	47	100.0%
3-INCH 12 GAUGE	0	0. %	2-3/4 INCH 20 GAUGE	0	0. %
2-3/4 INCH 12 GAUGE	0	0. %	OTHER	0	0. %
16 GAUGE	0	0. %	UNKNOWN	0	0. %

SHELLS MOST OFTEN USED FOR DUCK HUNTING

FEDERAL DUCK + PHEASANT	9	19.1%	WINCHESTER DUCK + PHEASANT	0	0. %
FEDERAL HI-POWER	8	17.0%	WINCHESTER SUPER X	9	19.1%
FEDERAL PREMIUM	0	0. %	WINCHESTER SUPER DOUBLE X	1	2.1%
REMINGTON DUCK + PHEASANT	3	6.4%	RELOADS	3	6.4%
REMINGTON EXPRESS	9	19.1%	OTHER	0	0. %
REMINGTON NITRO MAG	3	6.4%	UNKNOWN	2	4.3%

SHOT USED IN THE SHELLS FOR DUCK HUNTING

7/8 OZ	0	0. %	1-5/8 OZ	1	2.1%
1 OZ	9	19.1%	1-7/8 OZ	2	4.3%
1-1/8 OZ	8	17.0%	2 OZ	0	0. %
1-3/16 OZ	1	2.1%	2-1/4 OZ	0	0. %
1-1/4 OZ	18	38.3%	OTHER	0	0. %
1-3/8 OZ	3	6.4%	UNKNOWN	4	8.5%
1-1/2 OZ	1	2.1%			

SHOT SIZE USED FOR DUCK HUNTING

2	0	0. %	7-1/2	8	17.0%
4	8	17.0%	OTHER	0	0. %
5	0	0. %	UNKNOWN	0	0. %
6	31	66.0%			

TOTAL MAILING	4230
TOTAL RESPONSES	47
RESPONSE RATE	1%

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GAUGE OF SHOTGUN SHELL USED FOR DUCK HUNTING

10 GAUGE	0	0. %	3-INCH 20 GAUGE	0	0. %
3-INCH 12 GAUGE	0	0. %	2-3/4 INCH 20 GAUGE	125	100.0%
2-3/4 INCH 12 GAUGE	0	0. %	OTHER	0	0. %
16 GAUGE	0	0. %	UNKNOWN	0	0. %

SHELLS MOST OFTEN USED FOR DUCK HUNTING

FEDERAL DUCK + PHEASANT	28	22.4%	WINCHESTER DUCK + PHEASANT	3	2.4%
FEDERAL HI-POWER	8	6.4%	WINCHESTER SUPER X	21	16.8%
FEDERAL PREMIUM	0	0. %	WINCHESTER SUPER DOUBLE X	3	2.4%
REMINGTON DUCK + PHEASANT	10	8.0%	RELOADS	11	8.8%
REMINGTON EXPRESS	24	19.2%	OTHER	3	2.4%
REMINGTON NITRO MAG	1	0.8%	UNKNOWN	13	10.4%

SHOT USED IN THE SHELLS FOR DUCK HUNTING

7/8 OZ	6	4.8%	1-5/8 OZ	1	0.8%
1 OZ	64	51.2%	1-7/8 OZ	4	3.2%
1-1/8 OZ	17	13.6%	2 OZ	0	0. %
1-3/16 OZ	0	0. %	2-1/4 OZ	2	1.6%
1-1/4 OZ	6	4.8%	OTHER	1	0.8%
1-3/8 OZ	2	1.6%	UNKNOWN	18	14.4%
1-1/2 OZ	4	3.2%			

SHOT SIZE USED FOR DUCK HUNTING

2	0	0. %	7-1/2	21	16.8%
4	10	8.0%	OTHER	2	1.6%
5	4	3.2%	UNKNOWN	6	4.8%
6	82	65.6%			

TOTAL MAILING	4230
TOTAL RESPONSES	125
RESPONSE RATE	2%

APPENDIX C

NORTH CAROLINA STATE UNIVERSITY AT RALEIGH

INSTITUTE OF STATISTICS

Raleigh Division
Box 5457 Zip 27607

24 October 1980

Mr. Larry D. Soileau
Department of Wildlife and Fisheries
P. O. Box 585
Opelousas, Louisiana 70570

Dear Larry:

This is a report on the statistical characteristics of the experimental test of steel vs. lead shot to be carried out in Louisiana this fall, with my conclusions on the power. First I will describe the results (Results) of my work on this problem; this section is self-contained. Then, second, I will go into the background and show how these results were obtained (Explanations).

Results. Table I shows the results of the analysis of power of this test, stated as proportions that can be distinguished from some arbitrarily chosen proportion, here approximately the results with lead shot (labeled Comparison Value). One-tailed tests are assumed, with the direction of the test differing among the parameters.

Table I. Power analysis for Louisiana test of steel vs. lead shot; value that can be discriminated from the stated comparison value, with Type I error 0.05 and Type II error 0.20, using one-tailed tests and the arcsin transformation.

	Parameter				
	Bagged per Shot with interaction	Bagged per Shot without interaction	Crippled per Shot	Crippled per Hit*	Crippled per Bagged
Comparison Value	< 0.200	< 0.200	> 0.0500	> 0.200	> 0.250
Level of Data					
High	0.163	0.179	0.0621	0.260	0.351
Medium	0.159	0.172	0.0665	0.281	0.391
Low	0.155	0.166	0.0706	0.301	0.431

*Ducks hit = ducks bagged plus ducks crippled.

With number bagged per shot we are only interested in whether use of steel shot resulted in fewer bagged than with lead shot. With number crippled per shot we are only interested in whether using steel shot results in more cripples per shot. With cripples per bird hit, we are again interested only in whether using steel shot cripples more than using lead shot. I believe that it is reasonable to use a one-tailed test for each of these questions. For each parameter, a separate value is calculated for each level of data. These levels of data are specified in Table II; that termed "medium" assumes a total of 10,000 shots fired and 2,000 ducks bagged.

In Table I, the two columns under bagged per shot represent separate calculations, one allowing for an interaction of load and blinds, with the other assuming no such interaction. Surprisingly enough, such an interaction appeared in the Missouri study and I see no way of predicting whether it will appear in the Louisiana study or not. There is more discussion of this interaction below. The two righthand columns in the table simply state the same values for crippling in a different way, first as cripples per bird hit and second as cripples per bird bagged; it is more convenient to carry out these statistical calculations with the first quantity but the second is probably more understandable by the hunter. The two are related by the expression $b = h/(1-h)$ where b is cripples per bagged and h is cripples per bird hit.

As an example of use of the table, if the medium level of data is achieved the difference that can be discriminated in birds crippled per bird bagged would be between lead shot at 0.250 and steel shot at 0.391, an increase of 56 percent. The test would do better with the high level of data available and less well with the low level.

If you wish to use comparison values that depart much from those given here (which are approximately the results from the Missouri study) then the values that can be discriminated should be recalculated because the actual differences vary depending upon the position in the proportional scale from 0 to 1; this fact is illustrated by the figures given here for crippled per shot as compared to bagged per shot (without interaction) where the tests are about the same power.

Explanations. These numbers in Table I have been derived through use of tables in J. Cohen (1969. Statistical Power Analysis for the Behavioral Sciences. Academic Press). The tables used (pp. 27-37) are for the t test and are appropriate here because we have only two shell types (one steel, one lead) even though the analysis of variance is used to derive the error variance and make the actual test. To select which table to use, one must state Type I error (I used 0.05), Type II error (I used 0.20) and whether the test is to be two-tailed or one-tailed (I chose the last).

Next, to use the chosen table, one must know the sample sizes involved and the error standard deviation. Given the sample sizes, the table give a value that Cohen calls the "Effect Size Index"; this is multiplied by the error standard deviation to estimate the difference detectable. Thus, beyond the statistical characteristics that are specified, one must know the sample sizes and the standard deviation.

The sample sizes follow from the experimental plan. There will be 20 blinds and at each blind each shell type will be used in a random pattern. Thus, considering that there will be 3 distance categories, there will be 60 measurements made for each shell type. While the numbers of shots fired and numbers of ducks bagged and crippled are also truly elements of sample size, in terms of this discussion, and use of the Cohen tables, these numbers do not contribute to sample size. Rather, as subsamples they determine the magnitude of the standard deviation; the greater these numbers, the less the standard deviation, and the more powerful the test.

When using the arcsin transformation in the form: arcsin of the square root of the proportion, and expressing it in radians, the average value of the error variance will be $1/4n$ where n is the harmonic mean of the numerical denominators of the various proportions. Such a relationship holds if each basic unit of the study is based on a single homogeneous proportion (not a mixture of proportions). In the usual experience we expect the actual error variance to be greater than this theoretical value because a mixture of proportions may be expected. With the Missouri study, however, this formula predicted the error variances quite well when the data were summarized in 12 different ways (3 parameters, each summarized according to 4 different bases). But for the Louisiana study the harmonic mean is unknown, although the arithmetic mean number of shots or of birds crippled plus bagged is known, subject to your assumptions of total numbers of shots, ducks bagged, and ducks crippled, as presented in Table II, and the fact that there will be 120 units of data in the analysis (20 blinds, 2 loads, and 3 distances). Therefore, I calculated the linear regression of the logarithm of the error variance on the logarithm of the arithmetic mean for the 12 different ways of working up the data from the Missouri test. This relationship can be expressed as follows:

$$y = 1.175867 - 1.428527x$$

where:

y = natural logarithm of error variance

x = natural logarithm of arithmetic mean number of the denominator

The error variance referred to here is the so-called "measurement error" or B x L x D in the analysis of variance plan (Table IV).

This relationship was used with the expected mean numbers of shots fired and of ducks bagged and crippled (Table II) to estimate the variances to be expected without

Table II. Anticipated characteristics of Louisiana test of steel vs. lead shot.

Level of data	Total numbers of Shots	Ducks bagged	Ducks crippled	Number per unit, of Shots	Ducks bagged plus crippled
High	15,000	3,000	750	125.0	31.2
Medium	10,000	2,000	500	83.3	20.8
Low	7,500	1,500	375	62.5	15.6

interaction (Table III). For cases where interaction was accounted, these values were increased by the variance component calculated for the interaction of blinds and loads in the Missouri study, multiplied by the coefficient 3. The standard deviation to be used in estimating the discriminating ability (Table I) is the square root of the corresponding value in Table III.

Table III. Error (B x L x D) variances predicted for the Louisiana test of steel vs. lead shot, based on the anticipated characteristics as shown in Table II, and use of arcsin transformation (radians).

Level of data	Error variance (B x L x D) expected for: Bagged per Shot	Crippled per Shot	Crippled per Duck Hit*
High	0.003275	0.003275	0.02378
Medium	0.005848	0.005848	0.04244
Low	0.008815	0.008815	0.06401

*Ducks hit = ducks bagged plus ducks crippled.

I assume that the basic experimental unit will be the results (shots fired, birds bagged and birds crippled over the whole season at each blind for each shell type at each distance; for each unit the following ratios will be calculated from these sums: bagged per shot, crippled per shot, and crippled per bird hit (hit = bagged plus crippled). Then the analysis of variance will proceed with these proportions, arcsin transformed. Probably a weighted analysis should be used because the proportions are based on varying sample sizes; this discussion assumes an unweighted analysis.

For the analysis, the model in Table IV is appropriate. It seems to me that this experiment conforms to a "split block" design rather than a "split plot" because distance is determined by the event; trials are not assigned at random to distances.

Table IV. Form of analysis of variance, and expected mean squares, for Louisiana test of steel vs. lead shot.

Source of Variation	Degrees of Freedom	Expected mean square
Blinds	19	$\sigma^2 + 3\sigma^2_{LB} + 2\sigma^2_{DB} + 6\sigma^2_{B}$
Loads	1	$\sigma^2 + 3\sigma^2_{LB} + 60\theta^2_{L}$
L x B	19	$\sigma^2 + 3\sigma^2_{LB}$
Distance	2	$\sigma^2 + 2\sigma^2_{DB} + 40\theta^2_{D}$
D x B	38	$\sigma^2 + 2\sigma^2_{DB}$
L x D	2	$\sigma^2 + 20\theta^2_{LD}$
L x D x B	38	σ^2

Here σ^2 designates a variance component for a random effect and θ^2 that for a fixed effect, with the effect indicated by the subscript used. Blinds are assumed to be selected at random from some large population; loads and distances are fixed.

This layout of the analysis of variance shows that the appropriate error to test Loads is the term Load x Blind; if this term is about the same size as the measurement error (Load x Distance x Blind), one may assume no interaction of load with blind and use a pooled error term. It still seems to me that an interaction of load and blind should not be expected, but with bagged per shot in the Missouri study, this interaction was significant ($0.025 < p < 0.05$) when using blinds as the blocking element (and highly significant ($p < 0.005$) when using blindsets, the blocking element actually planned in that study). The interaction was not statistically significant in the analysis of data from either crippled per shot or crippled per bird hit.

I spent considerable time examining this interaction but I do not yet really understand it, except that the data show that for certain blinds (or blindsets) the comparative results with the different loads differ from those for other blinds. For this reason, I calculated the power of the Louisiana test under the two conditions of whether there will or will not be an interaction of loads and blinds.

Sincerely yours,

Don

Don W. Hayne
Professor

cc: Mr. Joseph Colson
Dr. Vernon Wright

Appendix D. Number of ducks bagged and crippled and number of shots fired of each load in 4.6 meter (5 yards) intervals.

Distance (meters)	Number Bagged		Number Crippled		Number Shots	
	Lead 6	Steel 4	Lead 6	Steel 4	Lead 6	Steel 4
≤ 20.1	201	183	36	31	725	756
21.0-24.3	226	208	44	59	889	980
25.6-29.3	262	181	55	88	1240	1395
30.2-33.8	226	181	68	104	1408	1450
34.2-38.4	155	105	72	71	1404	1343
39.3-43.0	103	77	43	37	1056	1070
43.9-47.5	39	25	22	28	624	707
≥ 48.5	30	26	26	18	677	914

Appendix E. Data for blinds that were excluded from analysis due to insufficient number of hits (bagged plus crippled less than 50) in 1980.

		No. 6 lead			No. 4 steel		
Blind	Distance (meters)	Ducks Bagged	Ducks Crippled	Shots Fired	Ducks Bagged	Ducks Crippled	Shots Fired
11	≤ 32	14	2	49	5	2	40
11	> 32	6	2	52	1	3	23
12	≤ 32	0	0	0	11	0	25
12	> 32	0	0	0	1	0	6
13	≤ 32	6	0	30	8	0	25
13	> 32	3	2	34	3	2	41
15	≤ 32	3	0	5	1	0	7
15	> 32	0	0	2	0	0	6
16	≤ 32	5	3	47	7	1	24
16	> 32	3	0	25	0	1	48
17	≤ 32	2	2	20	1	0	7
17	> 32	2	1	25	1	0	9
18	≤ 32	3	0	16	1	0	4
18	> 32	3	1	33	1	0	15
19	≤ 32	11	4	56	9	0	33
19	> 32	5	5	60	1	4	55
20	≤ 32	0	0	0	1	1	10
20	> 32	0	0	15	1	0	6
24	≤ 32	6	2	28	5	1	19
24	> 32	7	6	109	1	4	44
29	≤ 32	1	0	1	22	1	64
29	> 32	0	0	27	10	5	87

Appendix F. Summary of choke types used by hunters in the Lacassine study, by load type.

Chokes Used[a]	Number of Times Used	
	Lead 6	Steel 4
Full	223	240
Modified	335	332
Open	18	22

[a]Guns having more than one choke were omitted from this table.