STUDIES OF LEAD TOXICITY IN BALD EAGLES AT THE LAC QUI PARLE WILDLIFE REFUGE

A THESIS
SUBMITTED TO THE FACULTY OF THE GRADUATE SCHOOL
OF THE UNIVERSITY OF MINNESOTA

By
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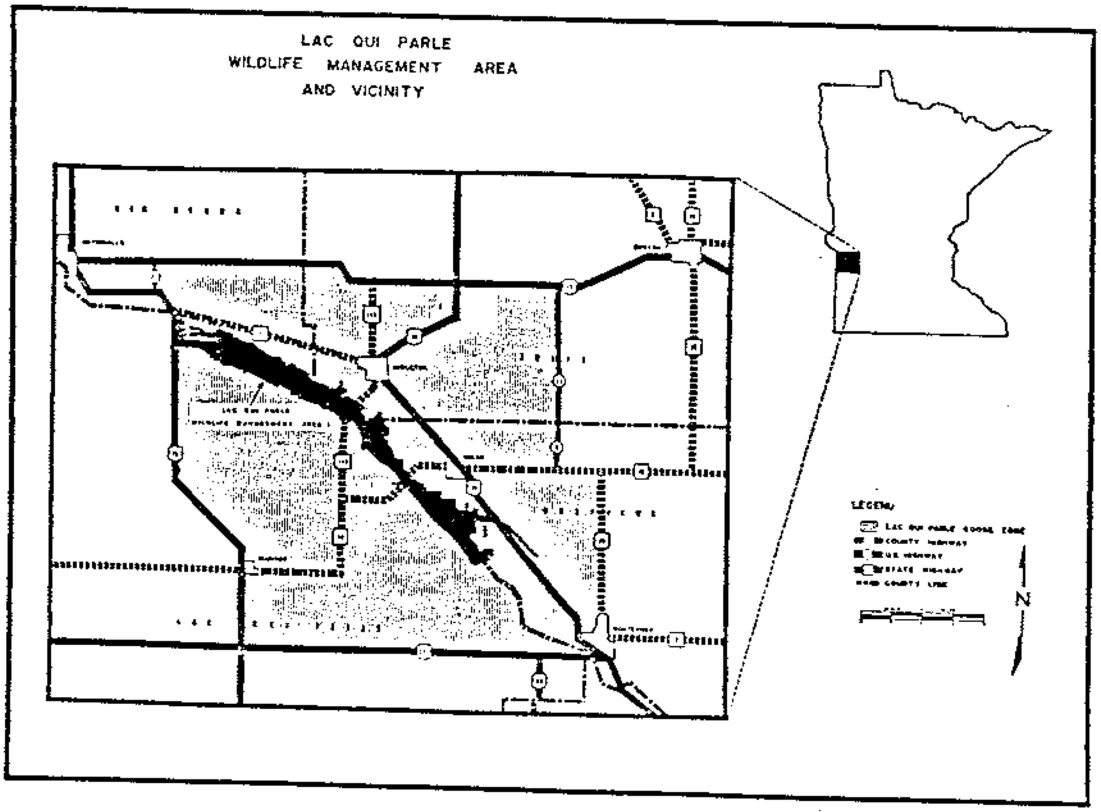
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF
MASTER OF SCIENCE

September 1984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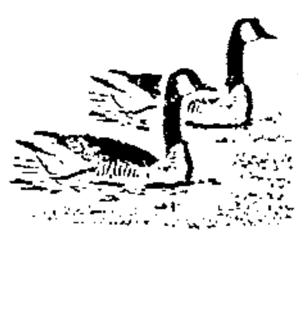

ABSTRACT

Lead poisoning is a significant mortality factor in waterfowl populations and other aquatic related species. Recent evidence suggests that raptors, particularly bald eagles, also are affected from eating prey that contain embedded lead shot and/or tissue-bound lead. These 1981-1983 Lac qui Parle Wildlife Refuge (LQPWR) studies in western Minnesota monitored specific impacts of available lead shot on migrant bald eagles and Canada geese by various methods and evaluated effectiveness of current limited steel shot regulations as a management technique for these two species. Sampling for shot in the LQP traditional hunting areas, and observing occurrence, feeding behaviors, and determinating physiological presence of lead in bald eagles and Canada geese were undertaken to describe lead shot impacts on these resources.

Pre-hunting surface shot densities ranged from 13-1,939 pellets/ha for 1981-1983. Yearly significant decreases ($p<0.05$) in lead-steel shot ratios occurred from 1980-1983, although in 1983 lead shot constituted over 80% of sampled pre-hunting season surface shot. Yearly decreasing pre-hunting season surface lead-steel shot ratios follow very closely to a negative log-linear relationship ($r=0.996$). Private lands adjacent to the LQPWR had surface densities of lead and steel shot 2-150 times the amount found in state lands. Shot densites in LQP study plot soils ranged from 106,000-328,708 pellets/ha from 1981-1983. Seasonal shot deposition at state blinds ranged from 1,429 to 12,857 pellets/ha from 1981-1983. Lead shot used illegally accounted for 7%, 9%, and 7% of shot deposited for the three study years. Harvest of crops without cultivation reduced pre-hunting season lead shot densities at LQP by 59% and 32% in 1981 and 1982, respectively.

Yearly pre-hunting season surface lead-steel shot ratios are greater than ratios found in soil because geophysical processes of wind and water erosion in agricultural fields selectively expose a higher proportion of lead than steel shot. A 10 to 15 year period may be necessary before lead shot densities in and on LQP upland soils are reduced to acceptable levels.

Freshly dead waterfowl were preferred bald eagle food. Canada geese were scavenged over 60% of the time. Physical lead poisoning symptoms of collected Canada geese did not correlate with their liver tissue lead contents. Lead poisoning in Canada geese was substantially reduced at LQP from 1978-1982.

The proportion of shot positive castings from bald eagles varied between 9% and 20% from 1978-1983. Since 1980 the proportion of lead shot positive castings has varied between 68% and 78%. Two bald eagles with suspected lead poisoning symptoms were recovered at LQP in 1981-1983. Both died with death attributed to lead poisoning. Conservatively, 4-5% of the estimated 100-150 bald eagles that stop over at the LQPWR annually may eventually die of lead related causes. Corrective management requires improved steel shot regulations for all waterfowl hunting nationally and internationally. Other management recommendations based on study results were listed.

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ACKNOWLEDGEMENTS

This study was conducted with the support and cooperation of numerous organizations and people. Funding and logistic assistance were provided by the University of Minnesota Department of Fisheries and Wildlife, the Minnesota Agricultural Experimental Station, and the Department of Veterinary Biology, College of Veterinary Medicine. A special computer service grant was received from the University of Minnesota Computer Center. Research grants were received from the U.S. Fish and Wildlife Service via the Nongame Wildlife Program - Section of Wildlife, Minnesota Department of Natural Resources (DNR), as well as funds from nongame wildlife tax check-off donations. Additional logistic support was received from the Minnesota DNR - Section of Wildlife Lac qui Parle Wildlife Management Area and the Ecological Services Section Carlos Avery Chemical Laboratory.

Special thanks go to my faculty adviser and project leader, Dr. L. Daniel Frenzel, Professor of Wildlife, Department of Fisheries and Wildlife, who gave continued guidance, support, encouragement, and constructive criticism throughout this study. Also, I wish to thank the other members of my graduate committee, Dr. Gary Duke, Department of Veterinary Biology, and Dr. John R. Tester, Department of Ecology and Behavioral Biology, for their suggestions and help during this study.

Dr. Patrick Redig, Department of Veterinary Biology, and Mr. Carrol Henderson, Minnesota DNR, served as background advisers to this study and their help is appreciated. Ms. Lee Pfannmuller, Minnesota

DNR Zoologist, was most helpful in special administrative aspects related to this study.

Dennis Heisey, Minnesota DNR biometrician, provided assistance with the statistical aspects of this study. Bob Glaser and Ron Lawrenz, Minnesota DNR - Ecological Services Section, performed laboratory tissue lead analyses. I am grateful to Arlin "Andy" Anderson and Dave Soehren, Wildlife Manager and Assistant Wildlife Manager of the Minnesota DNR Lac qui Parle Wildlife Management Area for their assistance, support, and willingness to provide needed information. I also thank Steve Hennes, Minnesota DNR, for sharing his expertise and knowledge gained from the first phase of these Lac qui Parle bald eagle studies.

Excellent field assistance was provided by Brian Cypher, Chris Loggers, Gretchen Mehmel-Bengtson, Larry Leininger, and Larry Petersen.

A special thanks go to my wife, Gretchen, for her help, patience, and encouragement during the course of this study.

Finally, to my family, and especially my mother, who did not live to see this project completed but knew it would be, I express my sincere thanks and appreciation for their continued support and understanding.

INTRODUCTION

Increased prevalence of lead toxicity in certain wildlife species, particularly in areas where there is concentrated hunting pressure, has recently become of greater concern to natural resource managers. Lead poisoning from ingested lead shot has long been considered a significant mortality factor in waterfowl populations. Impacts of lead toxicity on other species, however, may be as serious as it is for the waterfowl resource. The bald eagle (*Haliaeetus leucocephalus*) is a wildlife species of particular concern due to its specialized feeding habits which usually include scavenging upon crippled, moribund or dead prey. Thus, bald eagles are susceptable to lead poisoning due to a greater probability of ingesting embedded lead shot and tissue-bound lead from certain game animals.

Waterfowl are considered to be the most likely source of lead to bald eagles in many areas. Winter concentrations of migratory waterfowl usually associated with federal and state wildlife refuges are known to attract and hold significant numbers of wintering or migrating bald eagles. In these areas waterfowl are commonly the most important food resource available to bald eagles.

Lead toxicity in waterfowl has been documented by several investigators. It has been estimated that 2 to 3 % of North American waterfowl die every year of lead poisoning (Bellrose 1959). Death from lead poisoning generally occurs within several days to several weeks after lead shot ingestion, depending on the number of pellets ingested, diet of the bird, environmental conditions, and physical condition of the bird (Trainer and Hunt 1965). Most reported incidents of mortality have involved ducks ingesting lead shot from aquatic habitats (Bellrose 1959, Hunt 1960, Bellrose 1964, Anderson 1975, Stout and Cornwall 1976, Moore 1978). However, large lead poisoning die-offs of Canada geese (Branta canadensis) have been reported in Delaware (Bagley et al. 1967), Wisconsin (Trainer and Hunt 1965), Colorado (Szymczak and Adrian 1978), and Illinois (Esslinger 1979). The lead shot source was primarily associated with upland agricultural fields in heavily hunted waterfowl areas rather than in aquatic ecosystems.

Rivers, reservoirs, and impoundments often provide winter habitat for migrating waterfowl and bald eagles (Grewe 1966, Lish 1975, Servheen 1975, Steenhof 1976, Griffin 1978). Types and quantities of food available to bald eagles are highly variable in these areas. Fish are usually the preferred food item of bald eagles (Wright 1953, Southern 1963 and 1964, Servheen 1975); however, studies conducted by Lish (1975), Griffin (1978), and Hennes (in prep.) found waterfowl. specifically Canada geese, important winter food resources to bald eagles. On the Mississippi River at Savannah, Illinois, bald eagles consistently fed on dead waterfowl, but no predation on live birds was observed (Southern 1964).

A bald eagle's tendancy to select crippled, sick, or dead Canada geese as prey, (Griffin 1978) results in a high probability of exposure to embedded lead shot and/or tissue-bound lead (Pattee and Hennes 1983). Bellrose (1959) estimated that 20 to 25% of migratory waterfowl have body shot in skeletal muscle. Of Canada geese examined by Elder (1955) 47% carried embedded lead shot. Grieb (1962) reported that, on an annual basis, 34-38% of the immature and 45-65% of the adult Canada geese captured immediately after the waterfowl season in Colorado had at least one lead pellet imbedded in their body. At the Lac qui Parle Wildlife Refuge (LQPWR) in western Minnesota, 52% of dead or moribund Canada geese collected from 1978-1980 contained shot (Hennes, in prep.). Griffin et al. (1982) stated that 43% of adult Canada geese from Swan Lake National Wildlife Refuge in Missouri contained shot.

Actual bald eagle mortality due to lead poisoning is relatively unknown. Mulhern et al. (1970) examined 69 dead bald eagles between 1966-1968 with lead poisoning found in only one eagle. Jacobson et al. (1977) reported that a bald eagle with 75 lead pellets in its gizzard died from lead poisoning. Kaiser et al. (1980) examined 168 dead bald eagles between 1975 and 1977. Lead poisoning was diagnosed in 9 individuals (5.4 %) and ranked fourth behind electrocution (10.1 %), impact injuries (13.1 %), and shooting (17.9 %) as a mortality factor. These data indicate that lead poisoning in bald eagles has become a more serious problem in the past 15 years, or possibly diagnosis in the past was difficult to ascertain.

This potential for bald eagle consumption of shot-affected waterfowl has recently resulted in laboratory dosing experiments with lead and steel shot being administered orally to various captive raptors (Pattee et al. 1981, Hoffman et al. 1981, Durham 1983). Four of 5 captive bald eagles dosed with as few as 10 and as many as 156 lead shot died within 125 days after dosing; 3 of the 4 eagles died in less than 20 days (Pattee et al. 1981). Tissue lead levels of these dead eagles were significantly higher than those of control tissues.

Emaciation, hydropericardium, and renal and cardiovascular lesions were present in the dead birds.

Another possible pathway of lead to bald eagles is via tissue-bound lead from lead poisoned wildlife. Earlier investigators (Benson et al. 1974) concluded that lead poisoning in certain raptor species resulted from ingestion of tissue-bound lead. American kestrels (Falco sparverius) fed 10 and 50 ppm lead in their diets had blood lead levels of 0.67-0.76 and 1.30-2.40 ppm, respectively (Franson et al. 1983). There was no significant difference between lead levels from controls and 10 ppm birds. Liver lead residues from birds in the 50 ppm group were greater than residues in the two other treatment groups. Stendell (1980) found little change in liver lead levels of American kestrels fed for 60 days on homogenized mallards that died of lead poisoning. Redig et al. (1980) concluded that there are insufficient amounts of tissue-bound lead in most lead poisoned prey to cause acute lead poisoning in raptors and that contact with affected prey would be only intermittent. Pattee and Hennes (1983) concluded that tissue-bound lead could contribute to the problem, but is unlikely to cause acute lead poisoning in raptors.

Several techniques have been employed to determine the extent of lead toxicity in wild bald eagles. One index to bald eagle lead shot exposure is collection of their pellets or castings. Casting formation in the gizzards of raptor species involves incorporation of undigested materials (hair, bones and feathers) into a compact pellet cemented together with a thick mucus (Reed 1925, Chitty 1938, Rhoades and Duke 1975). The casting is usually orally expelled every 24 hours

(Errington 1930, Durham 1983). Most bald eagle castings are found under traditional roost or perch sites. Bald eagle castings are usually composed of indigestible waterfowl remains (Griffin et al. 1982, Dunstan 1974, Steenhof 1976, Jonen 1973, Grewe 1966, Lish 1975). Frequently, lead and/or steel shot from ingested tissues are incorporated into a casting when sufficient indigestible material is present. Dunstan (1974) found lead shot in 50-60% of bald eagle castings collected near the Mississippi River. Platt (1976) in Utah found lead shot in 71 % of castings from bald eagles with road and hunter-killed black-tailed jackrabbits (Lepus californicus) the most common prey species. Griffin et al. (1980) found lead shot in 9 % of examined bald eagle castings from Swan Lake National Wildlife Refuge where Canada geese are the primary prey. Hennes (in prep.) reported that nearly 11% of examined castings in 1978-1980 from the LQPWR in western Minnesota contained lead shot.

A more direct method of determining the extent of lead toxicity in bald eagles is to analyze blood samples from captured birds (Hennes, in prep., Hoffman et al. 1981). This method works well when comparing against background levels and known levels of toxicity.

Diagnosis of lead poisoning in waterfowl is commonly based on one or more of the following findings or physical symptoms: lead shot in the gastro-intestinal (GI) tract, crop impaction, emaciation, wing or leg paralysis, bile stained GI tract and vent, lowered delta-aminolevulinic acid dehydratase in plasma, and high lead content (ppm) in certain tissues (Jacobson 1977).

The importances of chemical or tissue analyses can not be overestimated in any ecotoxicological study. The basis for sound conclusions rests ultimately with accurate laboratory findings. Earlier field and laboratory studies have focused specific attention on tissue analyses as a means of determining lead exposure in animals suspected of dying from lead poisoning. Longcore et al. (1974) reported significant differences between control mallards and mallards dosed with lead shot when comparing liver, kidney, and lung tissues. Adler (1944), Coburn et al. (1951), and Cook and Trainer (1966) reported that the liver is the most useful tissue in diagnosing acute lead poisoning. Background levels of lead in 11 species of ducks ranged from 0.5 to 1.5 ppm (wet weight) from liver analyses (Bagley and Locke 1967). Longcore et al. (1974) concluded that liver lead levels in ducks that range between 6 and 20 ppm (wet weight) should be considered as acute lead exposure. Cook and Trainer (1966) considered liver lead levels of 5 to 32 ppm (wet weight) diagnostic of lead poisoning in Canada geese. Karstad (1971) reported a similar range of 8 to 42 ppm (wet weight) in experimentally dosed Canada geese as indicative of acute lead poisoning. Other tissues such as muscle and bone have been used to diagnose lead poisoning (Szymczak and Adrian 1978, Longcore et al. 1974, Stendell et al. 1979), but were found to be poor indicators of acute lead toxicity. However, analyses of lead in wing bones was found to adequately describe chronic exposure of waterfowl to lead (Stendell et al. 1979).

Recent laboratory investigations have provided information on various tissue lead levels in captive bald eagles subjected to doses of lead shot. Pattee et al. (1981) reported that bald eagle liver lead levels above 10 ppm (wet weight) and kidney lead levels above 5 ppm (wet weight) can be used as indicators of acute lead poisoning. Hoffman et al. (1981) found that within 24 hours after lead shot exposure, mean bald eagle blood lead concentrations had increased from less than 0.1 (background levels) to 0.8 ppm. By the end of 1 week levels had increased to 3 ppm; after 2 weeks lead concentrations were over 5 ppm with birds exhibiting signs of lead poisoning. This range of blood values can be used to diagnose recent lead exposure.

DEVELOPMENT OF THE LAC QUI PARLE LEAD TOXICITY STUDY

Many waterfowl refuges throughout the United States have significant densities of lead shot in marshes, lakes and/or uplands due to concentrated waterfowl hunting (Bellrose 1959). In western Minnesota, the Lac qui Parle Wildlife Management Area (LQPWMA) and LQPWR have received close attention as a likely source for lead toxicity in waterfowl, bald eagles and associated wildlife species (Henderson, personal communication). After 20 years of concentrated Canada goose hunting in uplands adjacent to the refuge, the soil was suspect of containing a high enough density of lead shot to warrant concern (Frenzel and Hennes, personal communication).

Consequently, two consecutive studies were undertaken at the LQPWR to determine the impact of lead shot on bald eagles as well as Canada geese. Objectives of the first study (1978-1980) were to determine if lead toxicity occurred at levels of concern for these two ecologically related species (Hennes, in prep.). This, the second study, was designed to measure shot densities around hunting blinds in upland soils and to evaluate expected changes in lead shot occurrence after restricting the use of lead shot to hunt waterfowl in the designated Lac qui Parle Steel Shot Zone (LQPSSZ). Other treatments were designed to measure primary and secondary impacts of lead shot on bald eagles and Canada geese.

Defining biological criteria for levels of concern for bald eagle and Canada goose lead poisoning requires a knowledge of their life histories and population dynamics. The relatively high turn-over rates and reproductive potential of Canada geese may reduce the magnitude of lead related mortality on their populations. Bald eagles, however, could suffer more due to a lower reproductive potential and with comparatively fewer reproducing members in a population (Pattee and Hennes 1983). As a result, standards or criteria for defining impacts of lead toxicity in these two species must be different. Thus, priorities of concern must be outlined for management considerations.

STUDY OBJECTIVES

This study attempted to monitor impacts of available lead shot on bald eagles and Canada geese by various techniques, and to evaluate the effectiveness of steel shot regulations as a management technique at Lac qui Parle (LQP) for these two species.

1. Objectives regarding bald eagles were to:
   a) Monitor LQP bald eagle numbers throughout October - December study periods.
   b) Determine lead and steel shot incidence in egested eagle castings (1981-1983), and relate findings to 1978-1980 non-steel shot years.

c) Observe and describe feeding patterns and site preferences for correlation with casting data.

d) Describe any diagnostic bald eagle behaviors that would indicate lead exposure.

2. Objectives regarding Canada geese were to:

a) Monitor Canada goose numbers throughout the 1981 to 1983 October-December study periods.

b) Determine lead and steel shot incidence in the gastrointestinal tracts of Canada geese.

c) Observe and describe Canada goose feeding patterns and feeding site preferences.

d) Collect dead, crippled, and moribund Canada geese for physical diagnosis and tissue lead analyses.

3. Objectives regarding evaluating steel shot regulations as a management tool were to:

a) Determine pre- and post-hunting soil surface densities of lead and steel shot around public and private hunting blinds for comparisons of study years.

b) Determine soil depth densities of lead and steel shot around public and private hunting blinds for comparisons of study years.

c) Measure and compare deposition of shot each year by means of shot collectors or traps distributed in front of traditional state goose hunting blinds.

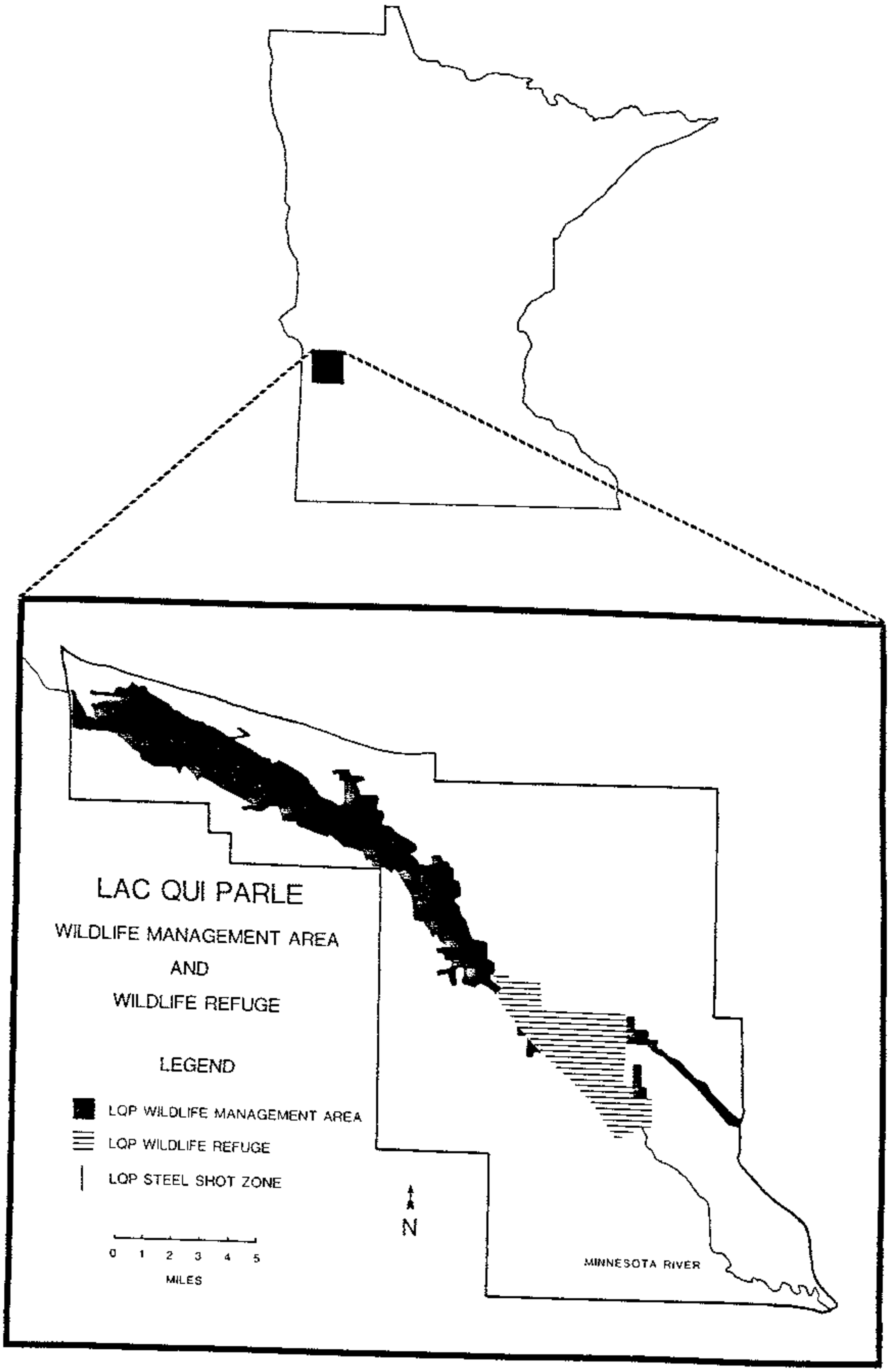
d) Use bald eagle casting and Canada goose gizzard data to evaluate steel shot regulation effectiveness.

e) Recommend management strategies to possibly alleviate any recognized lead related problems affecting bald eagles and Canada geese.

STUDY AREA

These studies were conducted on the LQPWMA located along a dammed portion of the Minnesota River in western Minnesota about 16 km (10 mi) northwest of Montevideo, Minnesota in Bigstone, Swift, Chippewa, and Lac qui Parle counties (Fig. 1). Included were all of the 3,238 ha (8,000 acre) LQPWR and some of the adjoining private lands southeast of Minnesota Highway 40 (Fig. 2). Most of the study area lies in the broad valley of the ancient River Warren which originated from glacial Lake Agassiz. River bottomland soils are generally sandy and gravelly; terraced upland soils are usually a fine silty loam suitable for agriculture.

The total study unit comprises approximately 11,736 ha (29,000 acres) of lakes, marshes, prairies, croplands, and deciduous forests. The remaining native grasslands or midgrass prairies are dominated by big bluestem (Andropogon gerardi), little bluestem (Andropogon scoparius), switchgrass (Panicum virgatum), Indian grass (Sorghastrum nutans), and gramma grasses (Bouteloua spp.). Introduced grasses such as smooth brome (Bromus inermis) and quack grass (Agropyron repens) dominate old fields and roadside ditches. Since settlement, these rich prairies have been converted to croplands. Major cash crops consist of corn (41%), soybeans (23%), small grain (20%), and hay and pasture (16%). More than 809 ha (2,000 acres) of cooperative farming leases and 121 ha (300 acres) of state food plots are maintained in the



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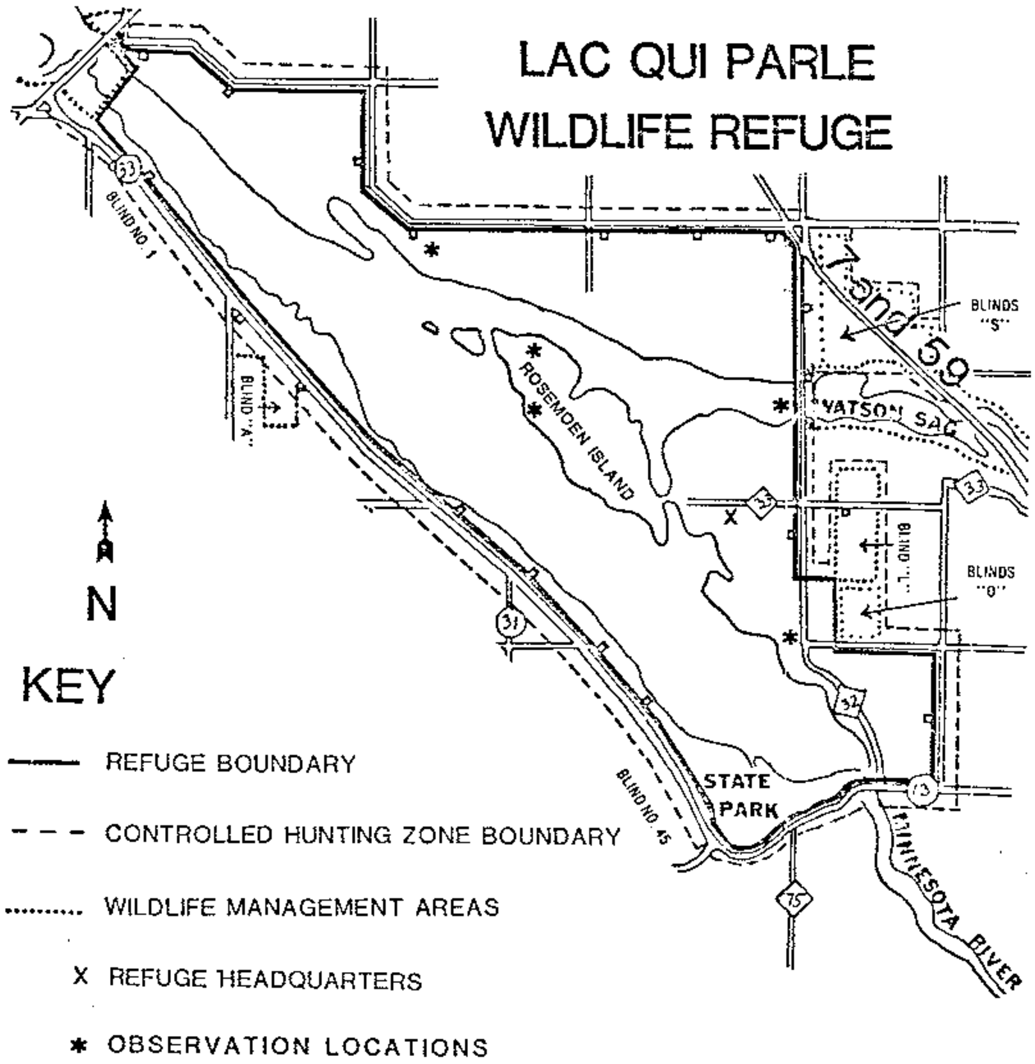


LQPWMA. Wetlands in the LQP region are by far the greatest attractant to migrating waterfowl. Two large impoundments, Lac qui Parle Lake and Marsh Lake, plus numerous smaller permanent and semi-permanent wetlands comprise over 60% of the total management area. Dense stands of cattail (Typha spp.), sedges (Carex spp.), and phragmites (Phragmites communis) surround most of these wetlands. Near the river and larger lakes, willows (Salix spp.) and mature cottonwoods (Populus deltoides) are the more common shrub and tree species. Bottomland hardwoods found near the river are American elm (Ulmus americanus), silver maple (Acer saccharinum), and green ash (Fraxinus pennsylvanica). Bur oak (Quercus macrocarpa), basswood (Tilia americana), and box elder (Acer negundo) are usually found on the drier river valley slopes.

More than 250 bird and 52 mammal species occur on the LQPWMA with many nongame species of wildlife common to the area. Waterfowl, however, are managed most intensively. The primary goal for the LQPWMA and LQPWR has been to establish a resident breeding flock of giant Canada geese and to encourage migrant Canada geese and ducks of the Eastern Prairie Population (EPP) and ducks to use the wildlife refuge and management areas.

A captive Canada goose flock was initiated on the management area in 1957. In 1982 the expanded free flying population was 500-1000 birds. In addition, peak numbers of migrating EPP Canada geese stopping at LQP have steadily increased from 2,500 in 1961 to 80,000 in 1982 (Arlin Anderson, personal communication). The mallard (Anas platyrhynchos) is an equally important migrant and resident of the management area with peak fall populations ranging from 10,000 to

65,000 (Minnesota Department Natural Resources 1977). Likewise, hunter utilization at LQP has increased dramatically since 1957.

In recent years the bald eagle has become a conspicuous component of the LQP wildlife community, occupying an important ecological niche. Numbers of bald eagles utilizing the refuge have increased in proportion to yearly increases of waterfowl. Lac qui Parle Lake which constitutes about 80 percent of the wildlife refuge provides suitable eagle habitat with abundant prey, tall perching trees, access to large bodies of water, and absence of human disturbances.

Other raptors occur in the LQP area. The golden eagle (*Aquila chrysaetos*) has been sighted occasionally, but is not common. The red-tailed hawk (*Buteo jamaicensis*), broad-winged hawk (*Buteo platypterus*), Swainson's hawk (*Buteo swainsoni*), marsh hawk (*Circus cyaneus*), and American kestrel are all common to the area.

These LQP descriptions are from a MN-DNR publication (1977). Detailed area physiography, common plant, and animal species are described by Anderson et al. (1976), Benson (1975), and Schneider (1966).

THE STEEL SHOT REGULATION

The U.S. Fish and Wildlife Service in 1976 recommended use of non-toxic steel shot by waterfowl hunters in lead poisoning problem areas (U.S. Fish and Wildlife Service, 1976). This was established on in the Atlantic, Mississippi and both the Central and Pacific Flyways in 1976, 1977 and 1978, respectively. A total of 33 states have expanded steel shot zones to areas outside of federal wildlife refuges and waterfowl production areas. Steel shot was chosen because it is nontoxic to waterfowl and its specific gravity is high enough for acceptable ballistics.

Presence and availability of residual lead shot in marshes, lakes, and uplands was expected to decline with the use of steel shot. Earlier studies by Bellrose (1959), Willis and Glasgow (1964) and Shranck and Dollahan (1975) reported elevated soil densities of lead shot in traditional waterfowl hunting areas as indicative of lead shot availability to waterfowl. Trost (1980) concluded that shot is ingested as a mistaken grit item, not as food. Therefore, dilution of lead shot in the wild would likely reduce the probability of shot ingestion in areas where grit is relatively scarce. Calle et al. (1982) concluded that with conversion to steel shot in Pennsylavania, ducks with ingested steel shot increased and those numbers of ducks with ingested lead shot decreased thereby decreasing waterfowl lead toxicity impacts.

That lead shot availability is variously reduced after implementation of steel shot regulations has been reported (White and Stendell 1977, Mikula et al. 1978, Humburg 1979, Welch 1979, Moore and King 1980). However, Longcore et al. (1978) did not find any reduction in lead shot density one year after only steel shot had been required to hunt waterfowl. After steel shot was required for waterfowl hunting on Turk's Pond in Colorado, shot densities in fields were reduced but use of lead shot continued (Szymczak 1978).

THE CONTROLLED HUNT

The LQP controlled goose hunt and blind reservation system were initiated in 1975 for blinds operated by the Minnesota Department of Natural Resources in specific areas that encircle the refuge and certain parts of the wildlife management area (Fig. 2). Hunting of geese and ducks is restricted to only those hunters legally occupying state blinds. All 113 state blinds are situated around the refuge with most adjacent to the refuge boundary in roadside ditches. No more than 3 hunters are allowed per blind. These hunters are limited to 6 shells per person per day in blinds. When a party at a blind has completed their hunt, they are replaced providing hunters are available. This system was chosen after many years of problems with masses of hunters congregating in state land and roadside ditches adjacent to the LQPWR.

Persons hunting waterfowl in the LQPSSZ also have been required to shoot steel shot since the fall of 1980. However, hunters on private lands are not limited to numbers of shells they may use. In the LQPSSZ the bag limit is 1 goose per hunter per day. Of the estimated 46,330 goose hunter-use days in the control zone in 1975, approximately 27% of this effort came from the 113 state blinds. Private lands within 0.8 km (1/2 mi) of the refuge provided 29% of the goose hunter-use days. The remaining 44% effort occurred beyond the 0.8 km (1/2 mi) distance from the refuge. Hunter densities averaged about 66 hunters per 2.6 square km (1.0 sq. mi) within 0.8 km (1/2 mi) of the refuge (Minnesota Department of Natural Resources 1977).

METHODS

STUDY APPROACH

An ecosystem approach was considered more meaningful in meeting study objectives than a single species approach because of complex environmental interactions affecting lead shot occurrence and availability. Work by Hennes's (in prep.) in 1978-1980 at LQP focused specific attention on collecting physiological data from bald eagles and Canada geese to determine the magnitude of their exposure to lead. With these baseline values known it was decided that documentation of point sources of lead would be important in describing the hypothesized problem of continuing availability of lead shot at LQP to wildlife.

For this study an experimental design was established to adequately sample residual lead and steel shot in traditional upland goose hunting areas. Also, physiological monitoring for lead presence in bald eagles and Canada geese was continued to document any significant changes in lead exposure that could be attributed to the steel shot regulation. Since modes of ingestion of lead differ for the two species, various techniques were employed to measure intake rates. Comparisons of 1981-1983 field season results with previous data provided necessary information to evaluate effects of lead availability immediately after 1980 local termination of lead shot use in waterfowl hunting on the LQPWR study areas.

Lac Qui Parle Bald Eagle and Canada Goose Observations

Bald eagle and Canada goose occurrences were observed at LQP during the fall of 1981 and 1982 in order to interpret incidences of lead shot ingestion for these species. Weekly population estimates of Canada geese and crippling rates were obtained from Arlin Anderson, LQP Wildlife Manager. Weekly counts of LQP bald eagles were made from 15 September to 15 December of 1981, 1982, and 1983. These counts involved intense searches in LQPWR areas known to attract bald eagles.

Counts at evening roosting sites provided the best data of eagles present on the area.

On alternating days, morning and evening goose observations were executed randomly at 5 locations around the refuge (Fig. 2). The other days were spent following presumed Canada goose feeding flights during morning and evening hours. Starting observation times varied between 0800-1000 and 1400-1700 and lasted 1-2 hours. Observations were made every day during the week preceding opening of the waterfowl season, 5 days each week from 15 October through 30 November, and each day during 1-15 December to document certain feeding behaviors of eagles and geese. This was undertaken to help understand lead pathways from hunters to geese to eagles. Observations were not designed to delineate time budgets, but rather to record specific behavior associated with feeding patterns and site preferences of both species.

Shot Densities near Lac Qui Parle Hunting Blinds

Surface Shot

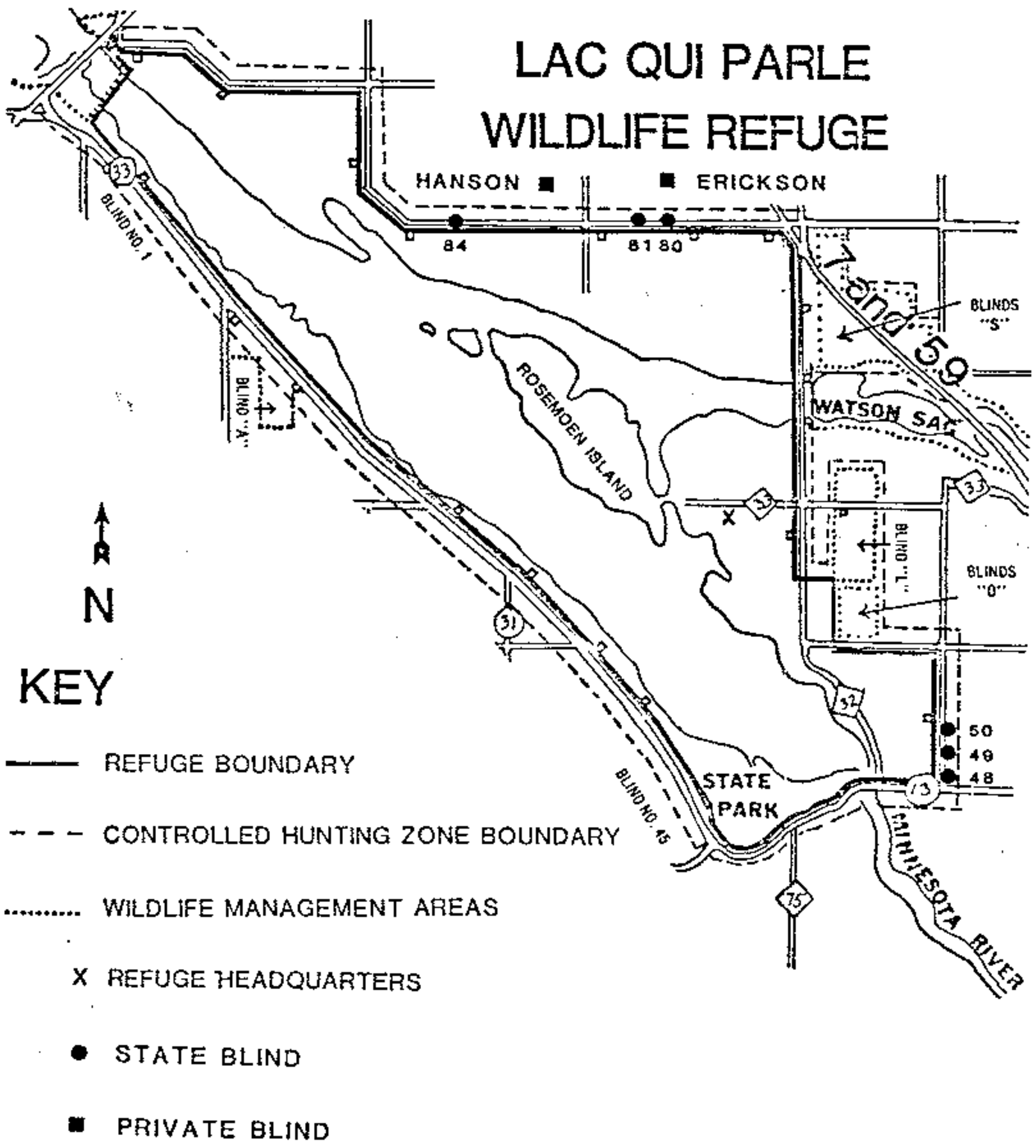
Soil surface sampling was the primary method of determining shot densities in areas of traditional goose hunting for 3 reasons: 1) surface shot represent the actual biological density of shot a Canada goose potentially would encounter while feeding near shot affected areas; 2) more soil surface area can be covered per unit effort thereby increasing the efficiency and accuracy of measurements; and 3) specific areas within a sampled area can be categorized and mapped as to the degree of density or availability of shot.

Agricultural fields in front of 6 state controlled blinds and 2 private blinds leased for goose hunting were selected for surface shot sampling (Fig. 3). State blinds 48, 49, 50, 80, 81, and 84 were considered moderate to high hunter-use blinds (MN-DNR LQP Files). All 6 state blinds are surrounded by agricultural lands and have been used seasonally for at least 5 to 10 years. Rectangular sample plots around two different sets of private blinds (Hanson and Erickson plots) considered high hunter-use areas (Anderson, personal communication) were established for sampling. All 8 areas were sampled for surface shot before the 1981, 1982, and 1983 waterfowl hunting seasons. Due to weather constraints, post-hunting season sampling was limited to state blinds 80, 84 and the Hanson and Erickson plots.

All 6 state blind areas sampled were located along roadside ditches on the side bordering the wildlife refuge. Shot sampling was within a 6.3 ha half-circle with the diameter parallel to the road and the radius extending 200 m from the blind, which was mid-point on the half-circle diameter. This sampling area was selected after preliminary data indicated that about 90% of surface shot was less than 200 m from the blind.

Year to year locations of private hunting blinds were not consistent. Furthermore, private hunting areas near the refuge have a history of close spacing between blinds. Thus, a 200 m X 200 m sampling area was assigned at the two separate private hunting areas. Both were about 300 m from the wildlife refuge and in close linear proximity to 3 of the 6 sampled state blinds (Fig. 3).

Agricultural crop rows such as corn and soybeans provided convenient transect lines approximately 1 m wide for sampling. At most state blinds, sampling rows ran perpendicular to the refuge boundary.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33
31
32
13
75
BLIND "L"
BLINDS "O"
50
49
48
STATE PARK
BLIND NO. 45
MINNESOTA RIVER
N
KEY
REFUGE BOUNDARY
CONTROLLED HUNTING ZONE BOUNDARY
WILDLIFE MANAGEMENT AREAS
X REFUGE HEADQUARTERS
STATE BLIND
PRIVATE BLIND

Crop rows also were used as transects for surface sampling in the 2 private goose hunting areas.

All state sampling areas except blind 84 in 1981 contained approximately 400 rows of corn or soybeans. In 1981, wheat was planted in front (refuge side) of blind 84 and harvested before the pre-hunting surveys. Twenty of 400 rows were selected at random to be sampled in 5 of the 6 public areas. Fourty rows were sampled at blind 80 to compare intensive sampling. Each transect length varied depending on the distance from the end of the field nearest the road to the point on the curvature of the half-circle plot. Shot was collected along 5.0 m intervals of row transects using a 2.5 m rod to measure distances. Fourteen rows were randomly chosen out of 200 for transect sampling in each of the 2 private areas. Each 200 meter transect was searched and provided coverage equivalent to state sampled areas. Otherwise, procedures for data collection remained the same.

The soil surface was searched carefully along transects from a standing or kneeling position. Soil surface visibility was extremely variable due to vegetation and debris. These varying conditions are considered to reflect the relative availability of shot that is also perceivable to a Canada goose. Shot sizes used for goose hunting were generally easy to see on the soil surface since the LQP upland soil is relatively gravel free. Shot pellets found along transects were collected and information on the location, size, and type of shot were recorded. Transects were altered for pre-and post-hunting season surveys to ensure that the same transect was not searched twice in one year.

A 1981 field season test was conducted to ascertain an observer's perception of surface shot under field conditions. Ten shot pellets representing sizes of lead and steel in proportion to that found in pre-sampling surveys were distributed by a MN-DNR technician along a 50 m crop row in a non-goose hunting part of the wildlife refuge. Data relating to shot found along transects were recorded. Trials (36) were run in different crop types to test differences in shot perception.

Soil Depth Shot Density

During the first field season (1981), need for additional shot density information was realized to document expected changes in soil lead-steel shot ratios and to supplement surface shot data.

Upland and aquatic substrates have been sampled for shot to depths ranging from 2.5 cm to 30.0 cm (Esslinger 1979, Bellrose 1959). Shot availability to geese in agricultural fields and agricultural practices that incorporate shot pellets into the soil are primary points addressed by this study. Maximum average depth of tillage in agricultural fields defined how deep to remove soil samples. Mollboard plow furrow depths were used to calculate the mean tillage depth for soil sampling.

A cylindrical, $0.0033 m^3$ sample of soil (diameter, 15.0 cm; depth, 17.5 cm) was removed at random locations in private and state surface sampling areas to determine shot densities and lead-steel shot ratios. In 1981, 35 soil samples were removed from the Hanson plot and 30 from state blind 80 during the first week of the waterfowl season. The top 2.5 cm of soil was scraped away at the sampling site to remove any shot deposited in 1981. Sampling was expanded in 1982 and 1983 with 50 soil samples each removed before the opening of the waterfowl season from the Hanson and Erickson plots and state blinds 50 and 80. Soil samples were placed in individual, labeled plastic bags and later washed under high water pressure through a #10 U.S. Standard Soil Sieve to recover shot.

Shot Trap Sampling

Amounts of shot deposited in the 1981, 1982, and 1983 waterfowl seasons were measured in front of state blinds 50, 80, and 84 via 0.21 m^2 shot collectors (shot traps) designed to collect and hold spent shot. Collectors were constructed from 0.52 m X 0.41 m plastic greenhouse flats lined with burlap or woven plastic to absorb shot impact, and covered with 1.25 cm X 1.25 cm wire mesh to prevent shot removal. The wire mesh was not observed to hinder shot from entering traps in preliminary trials. Prior to the 1981, 1982, and 1983 waterfowl seasons, 100 shot traps were placed at each of blinds 50, 80, and 84 (total = 300) in a radial pattern varying from 20 to 120 meters in front of the blinds. Traps were visited once a week to insure that each was in position. After the goose season closed, traps were collected; numbers and size of spent lead and steel shot were recorded.

Canada Goose Collection - Physical Diagnosis and Tissue Analyses

Crippled, moribund, and dead Canada geese were collected inside the refuge from 15 October to 15 December in 1981 and 1982. A numbered leg tag was fastened to each goose on which date, location, and condition of the bird when found were recorded. Geese were then frozen for later radiography and tissue dissection. Gross examinations were performed on collected geese and occurrence of emaciated breast muscle tissue, impaction of the proventriculus, and a green vent were recorded. Liver, muscle, and bone tissue samples were removed from each goose. Bone samples were frozen for future analyses. Liver and muscle samples were submitted to the Carlos Avery Chemistry Laboratory (Ecological Services Section - MN DNR) to be analyzed for lead content. Liver and muscle samples (1.0 g.) were digested in a nitric acid solution as outlined by Adrian (1971). A Perkin-Elmer Model 603 atomic absorption spectrophotometer was used to measure the lead content of each sample.

Radiography of goose carcasses and gizzards was performed via image intensification with video monitoring (six inch cesium iodide crystal: Phillips, Super M100, Phillips Medical Systems, Shelton, CT) at the University of Minnesota, College of Veterinary Medicine. Embedded or ingested shot pellets were readily visible by radiography and their anatomical locations could be precisely determined and recorded.

Bald Eagle Casting Collection

Weekly efforts were made each season to search the LQPWR for bald eagle castings. Most castings were collected under traditional roosting perches. Later in the season after Lac qui Parle Lake had frozen, castings were collected under feeding perches situated over water. Feathers, hair, bones, and other casting contents were examined to identify prey or scavenged species. Castings also were radiographed to identify presence of shot. Type and size of shot in castings were determined by individual examination and recorded.

Bald Eagle Capture

Trapping of wild bald eagles was not attempted in this study. However, each season the study area was carefully searched for sick, injured, or dead bald eagles. On 14 December 1981 one eagle was found alive and in poor physical condition. It was taken to the University of Minnesota Raptor Research and Rehabilitation Center for diagnosis and treatment. A second bald eagle was found alive on 14 April 1983 but died a day later. It was sent to the U.S. Fish and Wildlife Health Lab in Madison, Wisconsin for autopsy.

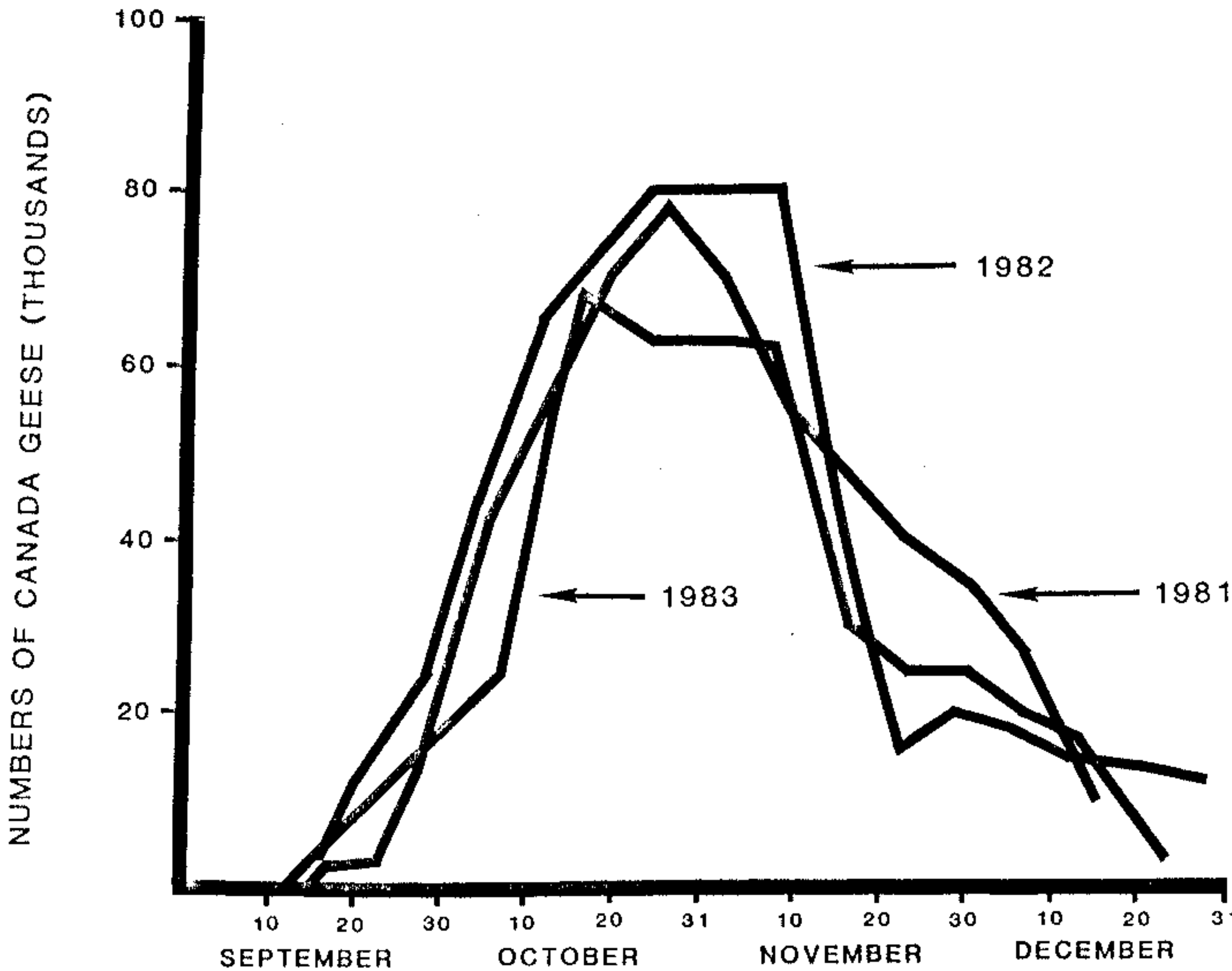
RESULTS AND DISCUSSION

LAC QUI PARLE CANADA GOOSE AND BALD EAGLE OBSERVATIONS

Canada Goose Observations

In the fall, migrating EPP Canada geese traditionally begin arriving at the LQPWR around 13 September. In 1981 the first group arrival was seen on 12 September (Arlin Anderson, personal communication). Numbers of geese continued to build up to a peak of 79,000 on 26 October 1981 (Fig.4). By 14 December 1981 their numbers had slowly decreased to 13,500.

The first fall flock of migrating Canada geese arrived at LQP on 12 September 1982 and peaked on 25 October 1982 at 80,000 birds. The population remained at that level until 8 November, then declined gradually to 12,000 on 29 December 1982 (Fig. 4).


NUMBERS OF CANADA GEESE (THOUSANDS)
100
80
60
40
20
1982
1983
1981
10
20
30
10
20
31
10
20
30
10
20
31
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER

Feeding and Site Preference Behavior

LQP Canada goose feeding and site preference behavior were recorded in pre-hunting, hunting, and post-hunting season periods.

Pre-Hunting Season

During the 15 September to 1 October pre-hunting season period, 5,000 to 30,000 Canada geese may occur daily on the refuge. The majority of these spend their time inside the refuge utilizing Lac qui Parle Lake and lands adjacent to the water. Rosemoen Island, a waterfowl sanctuary within the refuge (Fig. 2), is managed intensively for migrating waterfowl with over half of its 121 ha (300 acres) planted in corn and winter wheat. Pre-hunting season observations indicated concentrated refuge and sanctuary use by Canada geese from late afternoon through early morning hours. Canada geese were observed feeding and resting in food plots on the sanctuary. Large goose concentrations also were seen on the lake in close proximity to the shoreline or larger refuge islands. During the day flocks of geese would make flights out of the bottomlands to the upland agricultural fields to feed on waste corn, soybeans, and grain. Geese appeared to prefer recently harvested fields and were observed continually returning to certain fields to feed.

LQP area cropland inside the refuge was usually the first to be harvested due to concerns for outside depredation losses. Therefore, from about 15-23 September in 1981 and 1982 the majority of geese tended to remain inside the refuge to feed. The proportion of Canada geese inside and outside the refuge did not change significantly between years for the days between 17 and 25 September (Table 1, x^2 =

0.46 $p > 0.10$). However, more geese started feeding outside of the refuge the last week of September 1981 and 1982 when more private cropland was being harvested (Table 1, $\chi^2 = 12.03$, x = 24.37 $p<0.05$). Human disturbance was minimal during this period with the exception of farm machinery operating in areas used by the geese.

Table 1. Flocks of Canada geese observed leaving Lac qui Parle Lake and landing in the LQPWR or private lands between 17-23 and 24-30 September 1981 and 1982.

OBSERVED DESTINATION	1981 17-23 Sept.	(%)	24-30 Sept.	(%)	1982 17-23 Sept.	(%)	24-30 Sept.	(%)
LQPWR	236	(78.7)	167	(65.5)	186	(76.2)	136	(55.1)
PRIVATE	64	(21.3)	88	(34.5)	58	(23.8)	111	(44.9)

The importance of these observations in relation to possible goose lead poisoning rests in the differential availability of lead shot in areas occupied by Canada geese. Field study data discussed later indicate that surface lead shot is readily available to geese feeding in certain LQP areas but that steel shot gradually replaces lead shot. Lead shot is relatively unavailable to geese well inside the LQPWR. However, this is not the case within 200 meters of the refuge boundary due to closeness of state goose hunting blinds. Geese feeding within 200 m of the refuge boundary have an increased probability of ingesting lead shot and even more so if goose hunting blinds are nearby.

Likewise, geese leaving the refuge and feeding in adjacent private agricultural fields have a substantial liklihood of ingesting lead shot. Observations indicate that the week preceding opening of waterfowl hunting (24 September - 1 October) is potentially hazardous for Canada goose lead poisoning due to increased feeding in private lands within 1.6 km of the refuge . Observation data in 1981 indicate that the 2 private sampling areas received 25,000 and 11,500 goose use days, respectively, in the week preceding the opening of the waterfowl season. Before the season in 1982, the Hanson plot received approximately 18,000 goose use days and the Erickson plot received about 22,000. Differences between years most likely reflect times at which part or all of the sampling area crops were harvested. Early harvesting resulted in increased use of an area by Canada geese.

Similar data were collected for sampling areas in front of state blinds 80 and 81 in the week preceding opening of the waterfowl season. In 1981 blinds 80 and 81 received 3,500 and 3,000 goose use days, and 5,000 and 4,000 in 1982, respectively. It is of management importance that private sampling areas have the highest densities of lead and steel shot, and also attract more Canada geese during the week preceding the waterfowl hunting season than state controlled areas. Lead shot was found to be available to Canada geese in these high density areas 2 years after the steel shot regulation had been in effect. Part of this problem was found to be lead shot used illegally, but a greater proportion was found to be residual soil lead shot that becomes available at the soil surface as described later.

These pre-hunting season goose feeding behaviors relate to possible management strategies needed to discourage Canada geese from feeding in problem areas to reduce lead related mortality. Such techniques as maintaining the steel shot regulation, selectively harvesting crops in certain areas within the refuge to promote Canada goose use, allowing crops to stand in private areas, hazing fields to discourage Canada geese from occupying certain areas, and tilling soils to reduce soil surface lead shot density would decrease goose ingestion of lead. To accomplish these strategies wildlife managers must be willing to work and cooperate with landowners.

Hunting Season Period

Lac qui Parle goose season length and harvest statistics have varied over the years (Table 2). The Canada goose harvest must be limited to 4,000 to 8,000 in the Lac qui Parle Goose Management Zone to conform with state waterfowl policy (Minnesota Conservation Department, 1968). If the harvest quota is reached before the regular waterfowl season ends, the Lac qui Parle Goose Management Zone is closed to goose hunting only.

Canada goose behavior was observed to change substantially with the start of waterfowl hunting. Elevated human (hunter) disturbance forced geese to either stay in the refuge or make longer outside flights for food. Private lands near the refuge averaged between 55 and 95 hunters per 2.6 km^2 (1.0 mi^2) through the entire goose hunting season.

During the 1981-1982 hunting seasons limited observations were made of Canada goose flocks leaving the refuge and of geese feeding in vicinities of state blinds inside the refuge. Data collected on goose flight destination during morning and evening hours of the hunting season are summarized in Table 3.

Table 2. Lac qui Parle Canada goose season lengths and harvest statistics from 1978-1983.

YEAR	SEASON LENGTH (Days)	SEASON QUOTA	STATE BLIND HARVEST (a)	TOTAL HARVEST (b)	% SUCCESS	% CRIPPLING LOSS (TOTAL) (c)
1976	45	8,000	2,208	8,118	24	11.0
1977	33	5,000	1,806	5,799	23	-
1978	45	7,000	1,909	6,238	22	17.6
1979	50	7,000	2,002	4,988	20	22.5
1980*	50	5,500	2,470	5,700	23	17.6
1981	37	5,500	2,345	5,560	24	17.0
1982	50	5,500	2,448	5,479	19	9.6
1983	50	4,500	1,310	2,392	13	9.7

(a) - Canada geese registered at check station
(b) - Harvest within LQP Steel Shot Zone (state + private)
(c) - Calculated from post-season crippled and dead goose search
* - First year of steel shot regulation
(Source- LQP files)

Data from 1981 and 1982 indicate a higher proportion of Canada geese leaving the refuge to feed outside of the steel shot zone in morning hours than evening hours (Table 3, x^2 = 8.48 and 11.46 $p<0.05$). Observed harvest rates indicated fewer, but a substantial number, of LQP Canada geese were killed outside the steel shot zone. One Canada goose was harvested within the steel shot zone out of every 14.5 and 11.7 flocks leaving the LQPWR during 0800 - 1000 goose hunting hours in 1981 and 1982, respectively. In 1981 and 1982, respectively, one Canada goose was harvested outside the steel shot zone out of every

Table 3. Destination of LQPWR Canada geese during the Canada goose hunting seasons, 1981-1982.

Destination	1981 AM Feeding (A)	%	1981 PM Feeding (B)	%	1982 AM Feeding (C)	%	1982 PM Feeding (D)	%
Inside LQP Steel Shot Zone	13	18.3	22	42.3	18	22.2	25	51.0
Outside LQP Steel Shot Zone	58	81.7	30	57.7	63	77.8	24	49.0

A vs. B; X^2 = 8.48, significant difference between 1981 AM and PM destinations

C vs. D; X^2 =11.46, significant difference between 1982 AM and PM destinations

A vs. C; X^2 = 0.37, no sig. difference between years for AM destinations

B vs. D; X^2 = 0.77, no sig. difference between years for PM destinations

29.6 and 26.9 flocks leaving the LQPWR during morning hunting hours. In 1981 and 1982 average morning flock size was 38.1 and 32.8 geese/flock, respectively. Flock size ranged between 2-146 geese/flock in 1981 and 2-95 geese/flock in 1982. Evening harvest rates were not calculated because the Minnesota waterfowl season closes daily at 1600 the first half of the season and closes at sunset the last half.

The importance of these observations related to bald eagle lead toxicity is in tracing the lead pathway from Canada geese to bald eagles. Hunted waterfowl are subject to lethal shot and crippling mortalities in addition to non-fatal shot injuries. EPP Canada geese at Swan Lake National Wildlife Refuge experienced a 20% crippling rate (Vaught and Kirsch 1966). A large proportion of ducks and geese carry shot pellets in their bodies with no apparent harmful effects (Elder 1955, Griffin et al. 1982), while others die from disease, starvation, predation, lead toxicity and other shot related causes. Being opportunistic, bald eagles tend to identify and select these latter birds as prey. This non-random feeding strategy predisposes bald eagles to ingestion of lead shot and tissue-bound lead from affected waterfowl.

The lead shot restriction inside the LQP Steel Shot Zone was expected to diminish the proportion of lead shot in bodies of Canada geese and ducks. However, among hunters, lead shot is generally preferred over steel shot due to beliefs that lead shot has ballistics superior to steel shot. As a rule it has been found that most waterfowl hunters will shoot lead shot if no restriction exists against it. The majority of goose hunting at LQP is done within the steel shot zone. Observations, however, revealed that in 1981 and 1982 a substantial number of geese were harvested outside the steel shot zone. Observations indicated that Canada geese outside the steel shot zone, but within Chippewa, Lac qui Parle, Swift, and Big Stone counties are harvested at 1/4 to 1/3 the rate of those inside the steel shot zone due to closeness of the refuge. It can be assumed that hunters outside the steel shot zone are shooting lead shot at Canada geese. However, numbers of hunters doing so are small compared to those inside (MN DNR Files), and amounts of deposited lead can be considered negligable. Even with lesser total kill, it appears that a smaller percentage of hunters harvest a substantial proportion of Canada geese outside the steel shot zone. This may have serious implications for LQP bald eagles with Canada geese returning to the refuge with lead shot in their bodies from outside the steel shot zone. The U.S. Fish and Wildlife Service estimates that 15% of geese shot go unretrieved. The LQP Canada goose crippling rate averaged 13% between 1976 and 1982 (MN-DNR Files). The proportion of crippled and wounded Canada geese outside the LQP Steel Shot Zone was not determined in this study. However, from data collected at LQP from goose carcasses and bald eagle castings, it appears that lead shot is still prevalent in bodies of Canada geese and other waterfowl despite the steel shot regulation. Apparently, outside sources of lead shot are contributing to the problem as well as illegal lead shot use at LQP. Also, it is very likely that in addition to legal and illegal use of lead shot at LQP, Canada geese are subject to intensive legal shooting by hunters using lead shot throughout the flyway. Lead shot retention by waterfowl from non-fatal shot injuries is an important toxicological consideration in this predator - prey relationship.

Post-Hunting Season

The closure of the LQP goose hunting season results in an immediate reduction in human (hunter) disturbance. Canada geese were observed landing in agricultural fields leased for private hunting the day after the end of the goose hunting season in 1981 and 1982. This is also the period of time when Canada goose numbers decline due to their southward migration (Fig. 4).

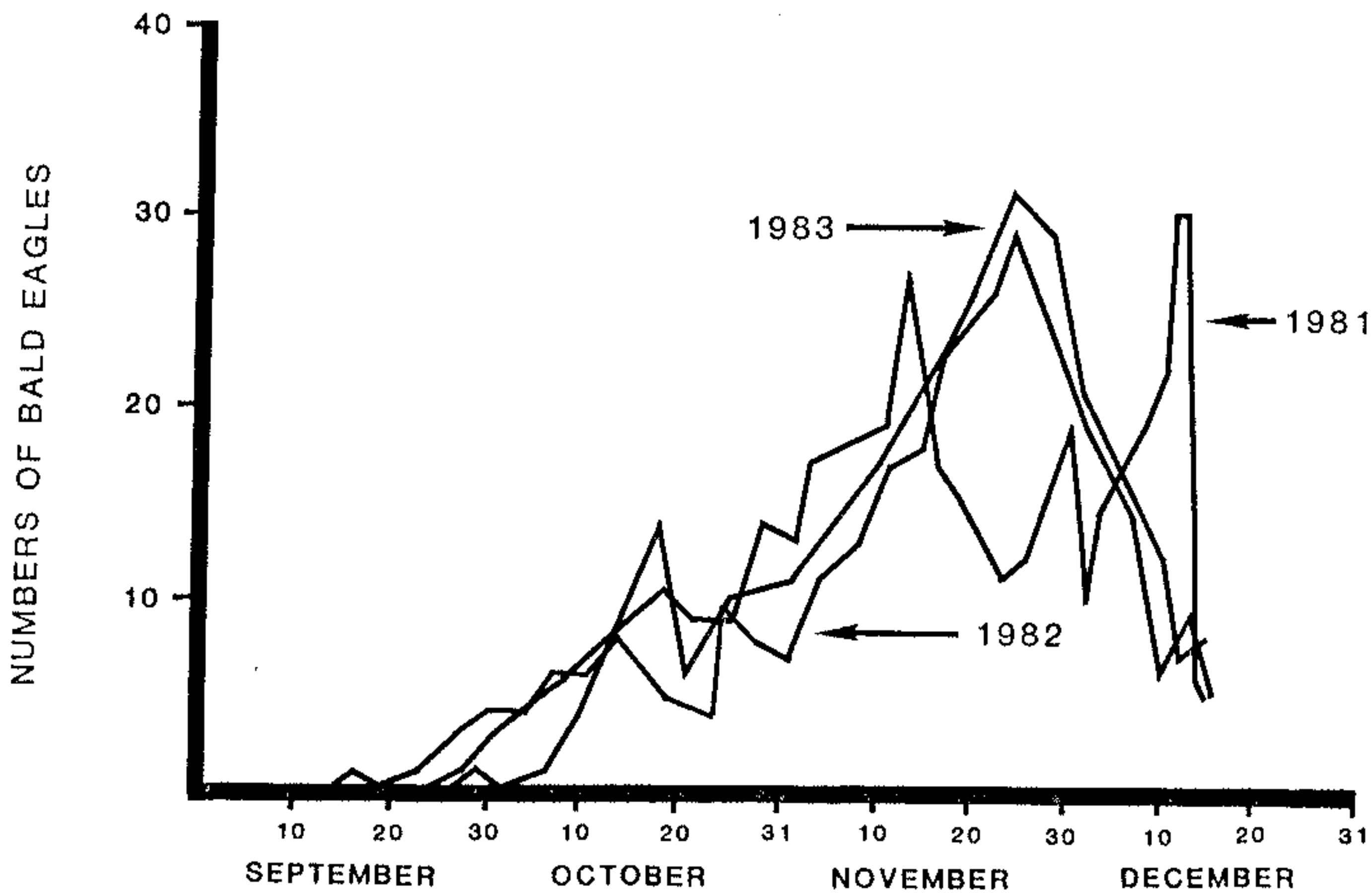
Post-hunting season observations indicated renewed goose use of private agricultural fields adjacent to the refuge. Inclement weather conditions typical of late November and early December in Minnesota appeared to deter geese from making long feeding flights. Observation data indicate that geese made more morning feeding flights within the steel shot zone than outside after the close of the goose hunting season until 15 December. In 1981 and 1982 after the Canada goose season had ended, 81% and 62%, respectively, of Canada goose morning feeding flights ended in the LQPSSZ. Hunting pressure was apparently a primary cause of long Canada Goose feeding flights from the LQPWR to outside the steel shot zone during the LQP goose hunting season.

In the past the post-hunting season period was considered the most likely time for Canada geese to ingest lead shot due to the high surface density of deposited lead shot in leased agricultural fields. In addition, weather stresses and food shortages typical of late November increase foraging behavior in Canada geese. These factors are known to contribute to increased prevalence of lead toxicity in waterfowl (Bellrose 1959). However, since 1980 waterfowl hunters have been required to shoot steel shot in the LQP Steel Shot Zone. These studies show reduced lead shot impact in terms of seasonal deposition. Regardless, serious amounts of residual lead shot remain available to Canada geese, including new lead shot deposited annually in violation of the steel shot regulation.

Bald Eagle Observations

During study years, first migrating bald eagles were observed at the LQPWR on 25 September 1981, 16 September 1982, and 29 September 1983. Weekly counts of LQP bald eagles from 15 September to 15 December 1981 - 1983 are shown in Fig. 5. Peak counts of bald eagles on the LQPWR usually occurred towards the end of November with immature birds comprising over 70% of the population for all 3 field seasons. Estimating the weekly fall LQP population of bald eagles was difficult due to their extreme mobility. However, counts of bald eagles on traditional communal evening roost perches provided a reasonable approximation of eagle numbers on the LQP area.

Bald eagles were observed most often near Rosemoen Island, the wildlife santuary within the LQPWR. Bald eagles preferred areas occupied by large numbers of Canada geese, near open water, away from human disturbances, and in areas with tall perching trees. Freshly dead waterfowl were preferred food items. Only 1 apparent healthy mallard was seen preyed upon by eagles in 138 hours of observing eagles in 1981-1983. Non-crippled and crippled Canada geese were able to defend themselves and escape capture in all observed cases of attacks by bald eagles. The high proportion of apparently young-of-the-year



NUMBERS OF BALD EAGLES
40
30
20
10
1983
1982
1981
10
20
30
10
20
31
10
20
30
10
20
31
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER

bald eagles could explain this low hunting success together with the abundant food source of dead waterfowl within the LQPWR. Fish may also provide a food source to bald eagles during the waterfowl season before ice-up, although this was never observed.

Bald eagles were observed feeding on waterfowl carcasses in close proximity to water. Of 348 observed feeding sessions, 92.8% occurred on the lake ice or within 6.0 meters of the lake or river shoreline. Eagles were wary of recently dead waterfowl, but would continually return to ones previously scavenged. Many different eagles were observed feeding on a single scavenged carcass, but rarely fed together on one carcass. Because of greater availability, Canada geese were scavenged most frequently (Table 4). Obvious abundance of hunter-crippled Canada geese provided a constant food source to LQP bald eagles.

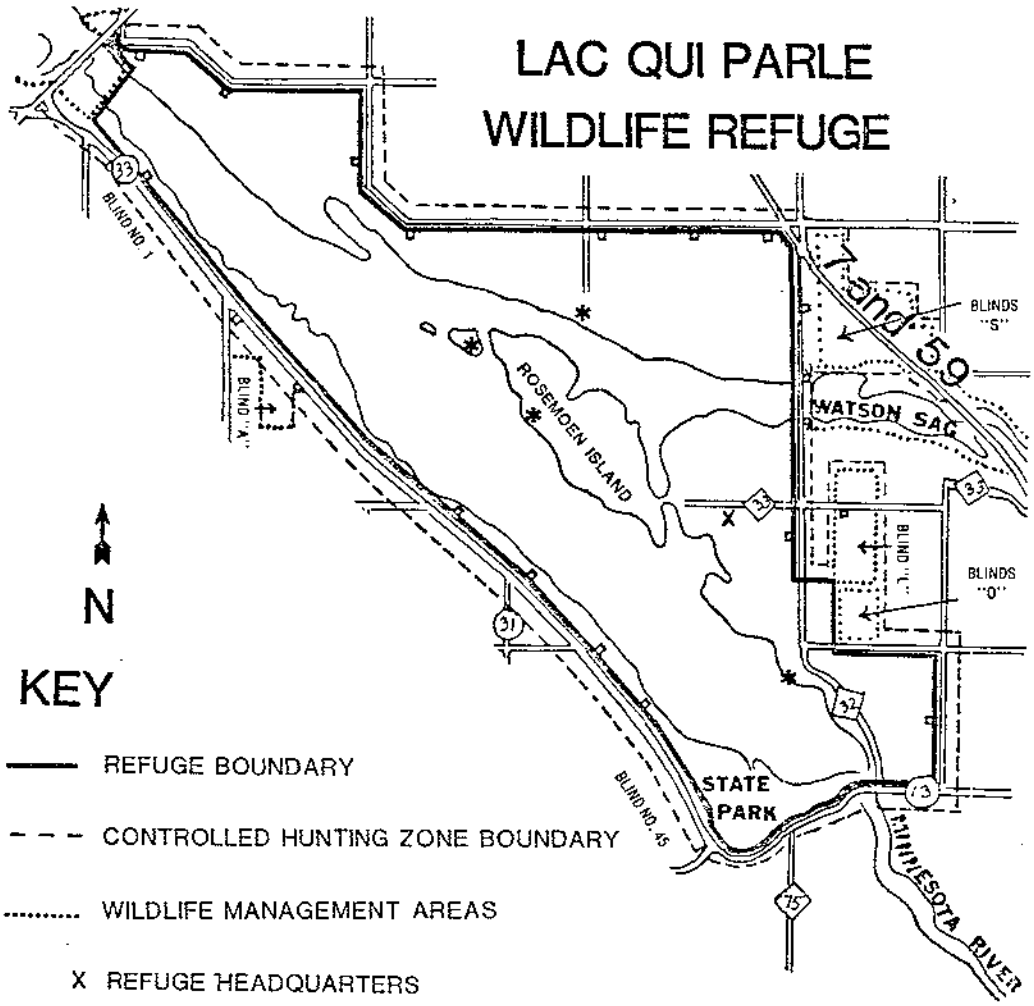
Table 4. Bald eagle prey type based on feeding observations

	1981		1982		1983		TOTAL	
PREY TYPE	N	%	N	%	N	%	N	%
Canada Goose	94	67.1	130	79.8	30	66.7	254	73.0
Mallard	41	29.3	25	15.3	12	26.7	78	22.4
Coot	3	2.1	3	1.8	2	4.4	8	2.3
Muskrat	1	0.7	0	0.0	1	2.2	2	0.6
WT Deer	1	0.7	5	3.1	0	0.0	6	1.7
TOTAL	140	99.9	163	100.0	45	100.0	348	100.0

Eagles were commonly observed in 4 areas (Fig. 6) where large numbers of Canada geese and mallards were typically attracted. Waterfowl were able to keep large areas of the lake ice-free for 1 to 4 weeks after ice-up in mid-November. During this time, eagles were commonly seen standing on the ice near open pools of water in close proximity to waterfowl. Segregated groups of crippled Canada geese were observed using these open pools of water with apparently healthy birds. Eagle activity became noticeably concentrated in these areas of open water. Canada goose carcasses also became more evident on ice bordering these open pools as time progressed.

Removing crippled and dead LQPWR waterfowl should be considered if lead shot continues to be contained within their bodies. Entire LQPWR searches would not be necessary since most eagle feeding is confined to margins of shorelines of Lac qui Parle lake and the Minnesota River. Waterfowl carcasses around winter lake pools should also be removed since eagles rely heavily on these for food in the latter part of the fall.

Cold weather down to -10 C in late November and early December did not appear to cause eagles to migrate from the LQPWR. Increased weather and food stresses on crippled waterfowl resulted in a continuous supply of weakened or dead waterfowl to the eagles. Ambient low temperatures after 15 December of below -10 C, a shrinking food supply, and severe ice and snow storms caused a major synchronized exodus of remaining Canada geese and bald eagles from the LQPWR in all 3 field seasons. Remnant portions of the eagle and Canada goose



KEY

REFUGE BOUNDARY

CONTROLLED HUNTING ZONE BOUNDARY

WILDLIFE MANAGEMENT AREAS

X REFUGE HEADQUARTERS

* AREAS COMMONLY OCCUPIED BY BALD EAGLES

populations remained on the LQPWR throughout winter periods in 1981 and 1982 because of relatively mild climatic conditions.

SURFACE SHOT SAMPLING

Pre-hunting Season

Surface shot sampling on LQP state and private land was a major study objective on the assumption that Canada geese were ingesting soil surface shot in upland agricultural fields used for hunting. Observer's perception of surface shot under field conditions was tested and is summarized in Table 5. Sampling efficiency (68%) was considered adequate for year to year trend values. Actual existing surface shot densities probably exceed that recorded.

Table 5. Field test data of observer perception of surface lead and steel shot under various crop types.

ROW TRANSECT	LEAD SHOT RECOVERY	%	STEEL SHOT RECOVERY	%	TOTAL RECOVERY	%
Standing Corn	26/30	86.7	23/30	76.7	49/60	81.7
Harvested Corn	17/30	56.7	13/30	43.3	30/60	50.0
Standing Soybeans	22/30	73.3	23/30	76.7	45/60	75.0
Harvested Soybean	26/30	86.7	24/30	70.0	50/60	83.3
Wheat Stubble	19/30	63.3	15/30	50.0	34/60	56.7
Plowed and Disked	20/30	66.7	18/30	60.0	38/60	63.3
TOTAL	130/180	72.2	116/180	64.4	246/360	68.3

Pre-hunting season surface shot sampling results for individual plots are summarized in Table 6. The relatively low availability of surface shot in front of blinds 48, 49, and 50 is considered due to a denser vegetative cover in the form of agricultural weeds and also to a history of recent shooting pressure. Blind 84 has a longer history of shooting pressure, but pre-hunting season conservation tillage practices in 1981 and 1982 significantly reduced the surface shot density due to soil disturbance. Lead shot tends to move more deeply into the soil profile as a result of cultivation (Fredrickson et al. 1977, Brakhage 1966). However, some shot is also redistributed to the soil surface by intensive tillage. Blinds 80 and 81 have higher surface shot densities due to yearly intensive shooting pressures and farming practices that promote exposed soil between crop rows. Private areas sampled had higher shot densities due to reasons stated above and also because of no limitation on the number of shells that can be fired per person per day during the waterfowl hunting season. Szymczak and Adrian (1978) estimated a crude surface shot density of 7,512 pellets/ha on private land in Colorado which is appreciably higher than the densities found at LQP.

Lead-Steel Shot Ratio Changes - 1980-1983

One study objective was evaluation of LQP steel shot regulation effectiveness in reducing residual lead shot in state and private upland fields. Most resource managers involved with this regulation expected significant reductions in residual lead shot within a few years after regulation onset.

Table 6. Pre-waterfowl hunting season surface shot sampling summary, 1981-1983.

PLOT	1981 Pellets/ha (SE)	1981 Pb:Fe	1982 Pellets/ha (SE)	1982 Pb:Fe	1983 Pellets/ha (SE)	1983 Pb:Fe
Blind 48	86 (24.8)	26.0:1.0	13 (4.8)	3.0:1.0	- -	-
Blind 49	80 (20.0)	5.3:1.0	115 (30.8)	35.0:1.0	- -	-
Blind 50	89 (23.0)	13.0:1.0	182 (32.6)	56.0:1.0	- -	-
Blind 80	221 (45.3)	138.0:1.0	287 (56.2)	24.7:1.0	619 (105.8)	11.5:1.0
Blind 81	191 (52.0)	60.0:1.0	242 (53.8)	37.0:1.0	1076 (148.1)	7.5:1.0
Blind 84	25 (9.7)	3.0:1.0	108 (20.0)	10.3:1.0	- -	-
Hanson	1461 (205.6)	28.2:1.0	793 (82.8)	6.9:1.0	729 (71.9)	5.2:1.0
Erickson	454 (61.7)	30.8:1.0	800 (97.9)	5.4:1.0	1939 (321.0)	3.0:1.0

Very little is known about processes causing shot availability and even less is known about replacement rates of lead shot with steel shot. Szymczak (1979) indicated that densities of lead shot were reduced slightly after one year of steel shot enforcement in Colorado. Karstad (1971) concluded that even with a change to only steel shot for waterfowl hunting, lead shot will remain in the environment indefinitely due to its relative inertness.

Yearly additions of steel shot and natural depletions of lead shot have changed surface lead-steel shot ratios significantly since 1980 when the steel shot regulation took effect (Table 7). Cumulative annual totals of shot collected from all sampled plots from 1981-1983 were used to calculate comparative lead-steel shot ratios. Steve Hennes (personal communication) provided 1980 pre-hunting season surface shot data to support a continuous data set.

Table 7. Shot density ranges and composite lead-steel shot ratios for 1980-1983 pre-waterfowl hunting season surface shot sampling.

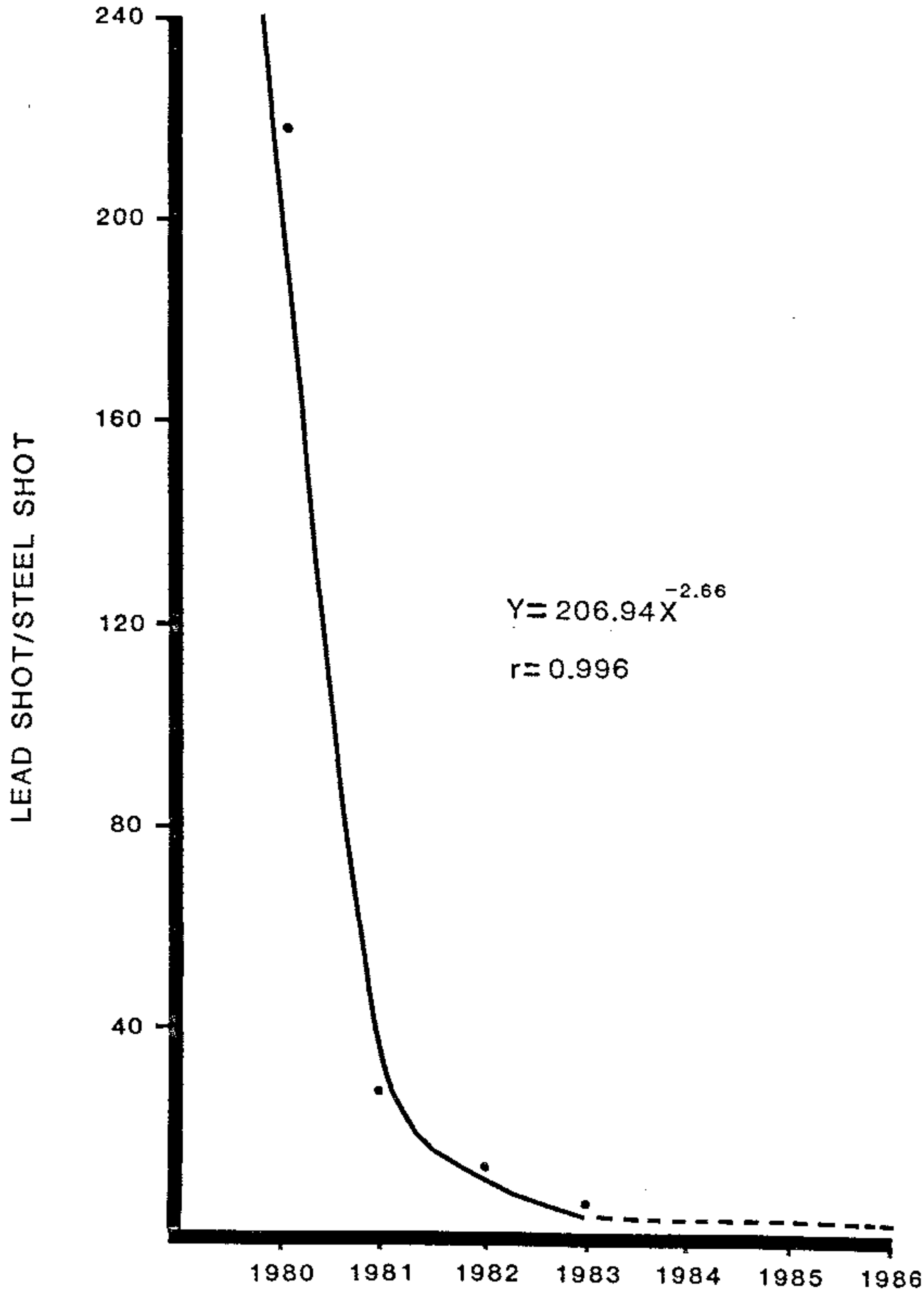
YEAR	RANGE pellets/ha	TOTAL PELLETS COLLECTED lead	steel	LEAD:STEEL
1980*	not comparable	873	4	218.3:1.0
1981	80 - 1,461	794	28	28.4:1.0
1982	13 - 793	739	61	12.1:1.0
1983	619 - 1,939	1,269	245	5.2:1.0

* - (Hennes, personal communication)

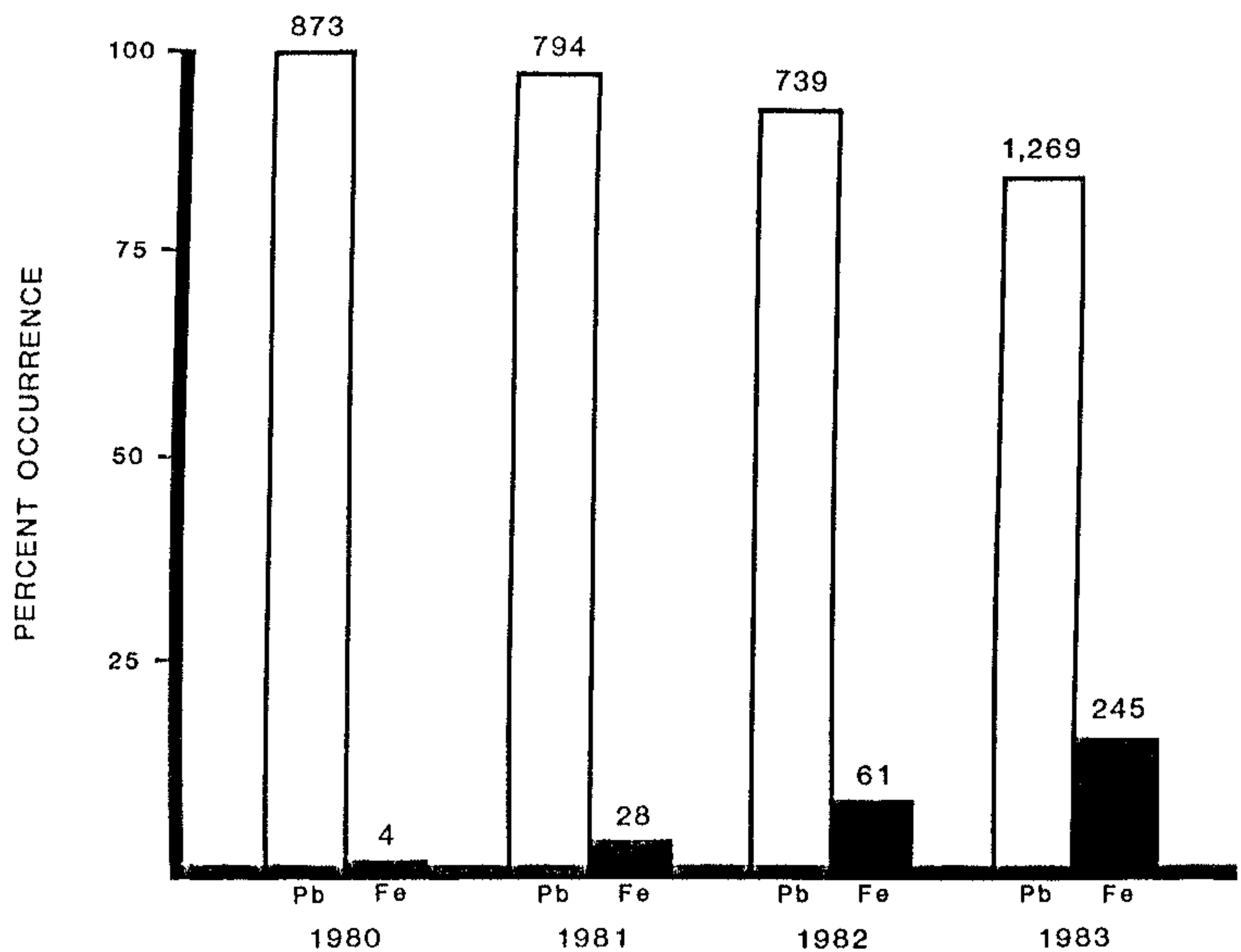
A higher proportion of steel shot was found in 1981 surface shot sampling than that found in 1980 (x^2 = 19.9, p<.005). A significant difference also occurred from 1981 to 1982 (x^2 = 13.7, p<.005). Likewise, 1983 steel shot was collected at a higher rate than in 1982 (x^2 = 31.8, p<.005). This indicates that replacement of soil lead shot with steel shot resulted from steel shot regulations, lessening lead shot availability. Figure 7 represents the yearly change in lead-steel shot ratios. The plot of values follows very closely to an exponential decay curve (Cockran and Snedecor 1967). The r value of 0.996 indicates a very close fit to a negative log-linear relationship. Predicted ratio values can be extrapolated for future years.

The proportional relationship between pre-hunting season soil surface lead and steel shot is represented for 1980-1983 in Figure 8 with greater proportional availability of residual lead shot being apparent. Even though lead-steel shot ratios have significantly decreased in 3 years, there is still more than an 80% chance that pre-hunting season surface shot encountered by Canada geese at LQP will be lead.

For management considerations this relationship is extremely important. Changes in shot composition in upland soils occur at a slow rate. Compared with most studied aquatic marshes (Backman and Low 1973), residual lead shot in LQP agricultural fields has remained available for many years. Extrapolation of the exponential decay curve indicates that by 1988 the surface lead-steel shot ratio still will be near 1.0 if the current trend holds. A 10 to 15 year period may be necessary before lead shot densities in disturbed upland soil are



LEAD SHOT/STEEL SHOT
240
200
160
120
80
40
Y= 206.94X^-2.66
r= 0.996
1980
1981
1982
1983
1984
1985
1986


PERCENT OCCURRENCE
100
75
50
25
873
794
739
1,269
4
28
61
245
Pb
Fe
1980
1981
1982
1983

reduced to acceptable levels. Any management plan that proposes a steel shot regulation to reduce an upland lead shot problem must consider that residual lead shot will continue to be available at densities warranting concern for a given period of time.

Lead shot replacement with steel shot at LQP is occurring at a slow rate. Up to twenty years of intensive goose hunting has resulted in extremely high lead shot densities just within and to 1.6 km (1.0 mi) outside the refuge boundary. Lead shot settling rates in undisturbed land would be expected to diminish densities of deposited shot. Agricultural practices, however, continually expose topsoil and the geophysical forces of wind and water work together to erode soil and uncover heavier elements such as lead shot. The LQP upland landscape is dominated by intensive row crop agricultural practices which necessitate exposed soil.

Intensive field sampling for surface shot resulted in unexpected discoveries of lead shot availability. Soil erosion was found to cause exposure of lead shot in almost all cases. In many instances lead shot found along sampling transect routes would be elevated above the ground level on a pinnacle of soil due to soil erosion around the pellet. In addition to this, larger sizes of shot were usually more evident along transects than smaller shot. Apparently, the greater mass and surface area of larger shot increases the likelihood for exposure as compared to smaller shot. Also, larger shot sizes tend to remain more stationary on the soil surface. Shot size identification was considered an important part of the sampling.

Data on the type and size of shot collected in 1981-1983 are summarized in Table 8 for pre-hunting season surface sampling. BB steel shot accounted for over 60% of all steel shot collected. Three size classes of lead shot (2, BB, and 4 buck) constituted over 75% of all lead shot found. These data reflect hunter preference for size classes when lead shot was legally used for hunting waterfowl at LQP. Lead 2 shot was slightly favored among goose hunters from 1981-1983. However, since it appears that lead and steel shot of different sizes are being

Table 8. Shot size by type collected from pre-waterfowl hunting season surface shot sampling, 1981-1983.

SIZE CLASS	1981	%	1982	%	1983	%	TOTAL	%
Pb								
8 shot	0	0.0	0	0.0	2	0.2	2	0.1
6 shot	10	1.3	8	1.1	26	2.1	44	1.6
4 shot	55	6.9	87	11.8	93	7.3	235	8.4
2 shot	233	29.4	230	31.1	374	29.5	837	29.9
BB	232	29.2	150	20.3	282	22.2	664	23.7
4 buck	213	26.8	200	27.1	374	29.5	787	28.1
3 buck	13	1.6	4	0.5	72	5.7	89	3.2
2 buck	5	0.6	30	4.1	9	0.7	44	1.6
0 buck	11	1.4	22	3.0	12	1.0	45	1.6
00buck	22	2.8	8	1.1	25	2.0	55	2.0
TOTAL	794	100.0	739	100.1	1,269	100.2	2,802	100.2
Fe								
4 shot	0	0.0	0	0.0	3	1.2	3	0.9
2 shot	4	14.3	6	9.8	23	9.4	33	9.9
1 shot	6	21.4	26	42.6	37	15.1	69	20.7
BB	18	64.3	28	45.9	162	66.1	208	62.3
4 buck	0	0.0	1	1.6	14	5.7	15	4.5
3 buck	0	0.0	0	0.0	6	2.5	2	1.8
TOTAL	28	100.0	61	99.9	245	100.0	330	100.1

exposed disproportionately at the soil surface, better conclusions of hunter preference for shot size can be made using soil shot composition data. The latter are more representative of actual hunter shot preference discussed later.

Lead shot analysis information can be useful for management to reduce impacts of lead poisoning on waterfowl. Szymczak and Adrians (1978) found that 59% of lead poisoned Canada geese ingested a 4 buck or larger sized pellet. At LQP 4 buck lead shot was found in 71% of lead shot positive Canada goose gizzards. Results of surface sampling data do not support the proportional hypothesis theory that Canada geese are believed to ingest shot sizes in proportion to that found in the field. Canada geese appear to select for larger sized shot. Therefore, eliminating the use of lead shot greater than BB for upland goose hunting could be considered as a management practice if a steel shot regulation is unacceptable. Also, sky-blasting and crippling by hunters prone to shoot at unreasonably distant birds with heavy loads would likely be reduced.

Shot Distribution

The distribution of shot on the soil surface was mapped from recorded data of location, size, and type of shot found on study plots at blinds. The various shot sizes of lead and steel were hypothesized to be deposited nonrandomly due to their different physical properties. No obvious shot density patterns or relationships could be discerned. However, shot densities generally decreased as the distance away from the border of the refuge (blind) increased (Table 9). Most state blinds are located at the refuge boundary and hunters are instructed

Table 9. Distribution of surface shot measured from the LQP refuge boundary.

METERS FROM REFUGE BOUNDARY	SHOT OCCURRENCE AND PERCENTAGE AT GIVEN DISTANCES BY YEAR							
	1981		1982		1983		TOTAL	
	N	(%)	N	(%)	N	(%)	N	(%)
0 - 25	38	(13.2)	55	(14.3)	107	(14.6)	200	(14.2)
26 - 50	62	(21.5)	82	(21.2)	169	(23.1)	313	(22.3)
51 - 75	63	(21.8)	87	(22.5)	195	(26.6)	345	(24.5)
76 - 100	65	(22.6)	86	(22.2)	108	(14.7)	259	(18.4)
101 - 125	34	(12.0)	64	(16.5)	92	(12.6)	190	(13.5)
126 - 150	22	(7.5)	13	(3.4)	45	(6.2)	80	(5.7)
151 - 175	3	(1.2)	0	(0.0)	17	(2.3)	20	(1.4)
176 - 200	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)

not to shoot until geese are vertically outside the refuge. For this reason, and because all shooting is not directly overhead or directed away from the refuge, most shot inside the LQPWR is deposited within 150 m of the refuge border. Canada geese were observed feeding well within this distance during pre-hunting, hunting, and post-hunting season periods.

Post-hunting Season

The results of post-hunting season surface sampling for each individual plot are summarized in Table 10. Only 4 of the 8 pre-hunting season plots were sampled due to weather and logistic constraints. When compared, post-hunting season shot densities are similar to pre-hunting season shot densities from 1981-1983. However, lead-steel ratios are obviously different. Lead shot exceeded pre-hunting steel shot densities; steel shot exceeded post-hunting season surface shot densities (Tables 10 and 11). The high proportion of pre-hunting season surface lead shot is primarily due to the yearly dilution of surface deposited steel shot with the soil lead shot reservoir via soil turnover by agricultural cultivation. Wind and rain act together to uncover lead and steel shot throughout the growing

Table 10. Post-waterfowl hunting season surface shot sampling results by plot, 1981-1982.

PLOT	1981 Pellets/ha	1981 Lead:Steel	1982 Pellets/ha	1982 Lead:Steel
Blind 80	236	1.0:1.4	525	1.0:1.3
Blind 84	45	1.3:1.0	280	1.0:1.8
Hanson	771	1.3:1:0	718	1.0:1.6
Erickson	750	1.0:1.6	887	1.0:2.0

Table 11. Shot density ranges and lead-steel ratios from 1981-1982 post-waterfowl hunting season surface shot sampling.

YEAR	RANGE Pellets/ha	TOTAL PELLETS COLLECTED Lead	TOTAL PELLETS COLLECTED Steel	LEAD:STEEL
1981	45-771	241	273	1.0:1.1
1982	280-887	247	407	1.0:1.6

season. By early fall surface lead-steel shot densities are nearly proportional to soil lead-steel shot densities.

Intensive 1981-1983 shooting by LQP goose hunters increased densities of steel shot deposited on soil surfaces by the end of each Canada goose hunting season. Pre-hunting season surface shot densities are also reduced during the waterfowl hunting season by agricultural equipment harvesting crops and disturbing the soil. Harvesting crops without cultivation reduced pre-hunting season surface lead shot densities at LQP by 59% and 32% in 1981 and 1982, respectively. This is beneficial to Canada geese during the post-hunting season period because lead shot densities are decreased and steel shot densities are increased, thereby reducing the potential for lead shot ingestion. The proportional relationship between post-hunting season surface lead and steel shot is represented for 1981-1983 in Fig. 9.

Type and size data of shot collected along transects are summarized in Table 12 for 1981-1982 post-hunting season surface sampling. Proportions of shot sizes collected are similar to those from pre-hunting season surface sampling.

SAMPLING OF SHOT IN SOIL

Results of soil shot sampling are summarized in Table 13 with soil shot densities and lead-steel ratios for each plot sampled. Densities, including lead and steel shot, ranged between 106,000 - 328,708 pellets/ha for 1981-1983. Sampling effort primarily was designed to describe soil lead-steel shot ratios but also provided soil shot density determinations. These density values are not precise measures but are considered useful as index figures of shot present.

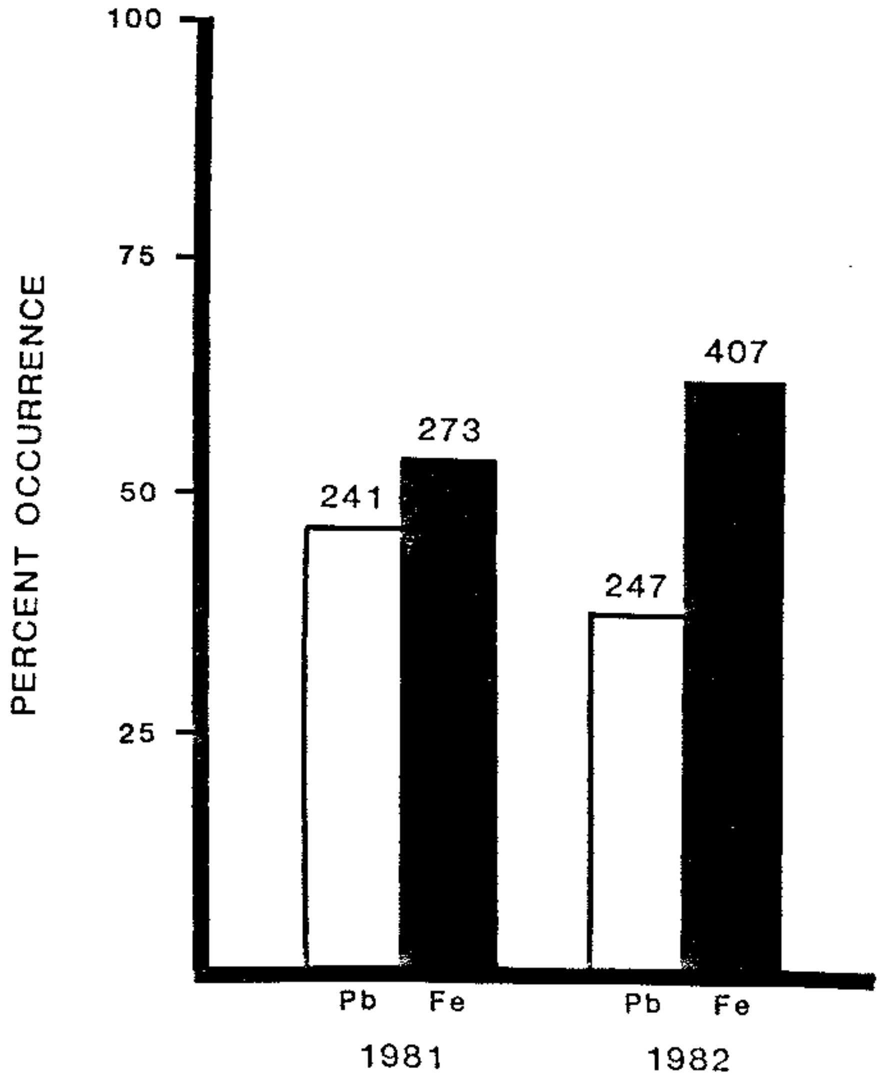

PERCENT OCCURRENCE
100
75
50
25
241
273
247
407
Pb
Fe
Pb
Fe
1981
1982

Table 12. Summary of shot size and type data from post-waterfowl hunting season surface shot sampling, 1981-1982.

SIZE CLASS	1981	%	1982	%	TOTAL	%
Pb						
8 shot	1	0.4	0	0.0	1	0.2
6 shot	3	1.3	1	0.4	4	0.8
4 shot	19	7.9	18	7.4	37	7.6
2 shot	67	27.9	64	26.1	131	27.0
BB	63	26.3	67	27.4	130	26.8
4 buck	73	30.4	83	33.9	156	32.2
3 buck	4	1.7	2	0.8	6	1.2
2 buck	1	0.4	1	0.4	2	0.4
0 buck	6	2.5	8	3.3	14	2.9
00buck	3	1.3	1	0.4	4	0.8
TOTAL	240	100.1	245	100.1	485	99.9
Fe						
4 shot	11	4.0	8	2.0	18	2.7
2 shot	3	1.1	11	2.7	14	2.1
1 shot	115	42.1	135	33.2	250	36.8
BB	131	48.0	240	59.0	371	54.6
4 buck	13	4.8	13	3.2	26	3.8
TOTAL	273	100.0	407	100.1	679	100.1

Differences in shot densities in plots varied from year to year. Sampling efforts in 1981 were not considered sufficient enough to adequately describe the soil shot reservoir. Expanded sampling in 1982 and 1983 provided data more suited to statistical treatment. The 2 private plots sampled had consistently higher densities of lead and steel shot than state plots. Yearly proportional increases of steel shot and decreases of lead shot occurred in most study plots.

Other reported soil shot densities compare with those found at LQP. Wills and Glasgo (1964) recorded 250,216 lead pellets/ha in front of Catahoula's oldest blind in Louisiana. Brakhage (1966) reported

Table 13. Results of soil shot sampling for state and private plots, 1981-1982.

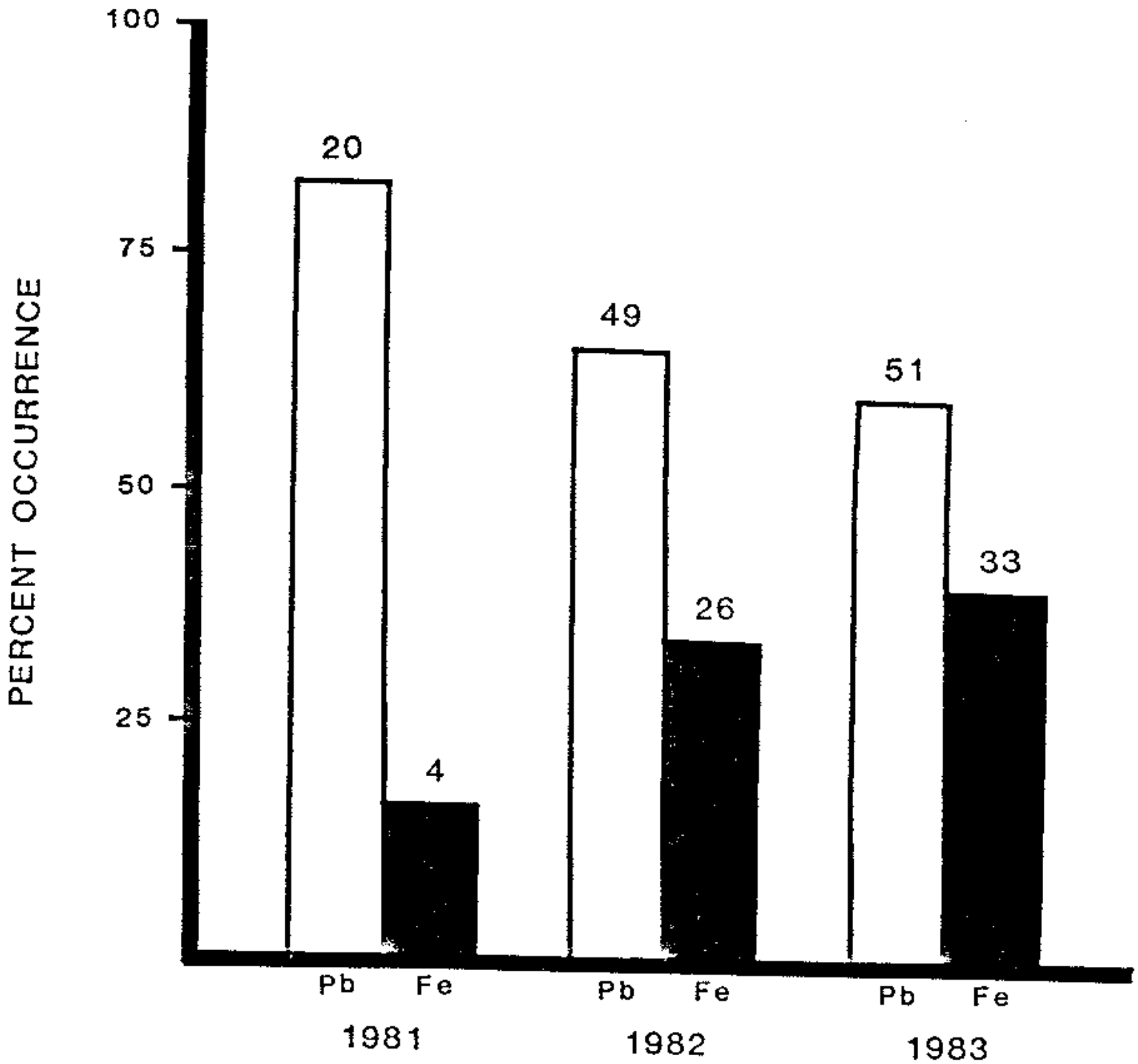
PLOT	1981 Pellets/ha (SE)	1981 Fe:Pb	1982 Pellets/ha (SE)	1982 Fe:Pb	1983 Pellets/ha (SE)	1983 Fe:Pb
Blind 50	- -	-	106,050 (32,609)	1.0:1.0	137,878 (35,934)	1.0:1.6
Blind 80	159,091 (49,380)	1.0:3.5	159,075 (34,716)	1.0:2.8	169,697 (34,948)	1.0:2.2
Hanson	227,500 (64,358)	1.0:6.5	233,275 (38,292)	1.0:4.5	254,545 (41,189)	1.0:1.7
Erickson	- -	-	296,975 (39,838)	1.0:1.2	328,788 (44,749)	1.0:1.2

303,412 lead pellets/ha in front of 10 year old traditional blinds in Missouri. Bishop (1972) found 125,930 and 279,742 lead pellets/ha in 5.1 and 10.2 cm deep samples at Forney's Lake, Iowa. Esslinger (1982) recorded 109,789 pellets/ha from 2.5 cm deep soil samples taken from upland soils in the Union County Conservation Area in Illinois. Jessen and Lound (1959) stated that lead shot is available in quantity to feeding waterfowl in heavily hunted areas when there is more than 100,000 pellets/ha.

Individual study plot data on soil shot composition were combined to arrive at an overall yearly lead-steel shot ratio (Table 14). The proportional composition of lead and steel shot from these data is illustrated in Figure 10. No significant difference ($p>.05$) could be detected for soil lead-steel shot ratios between individual years for 1981-1983 (1981 vs. 1982, x^2 = 2.85; 1982 vs. 1983, x^2 = 0.18). However, differences between soil lead-steel shot ratios for 1981 vs. 1983 are significant at the 0.05 level. Steel shot replaces lead shot in the soil reservoir, but actual replacement rates of steel shot with

Table 14. Density ranges and lead-steel ratios of sub-surface soil shot for all LQP study plots, 1981-1983 pre-hunting season soil shot sampling.

YEAR	RANGE Pellet/ha	LEAD:STEEL
1981	159,091 - 227,500	5.0:1.0
1982	106,050 - 296,975	1.9:1.0
1983	137,878 - 328,788	1.5:1.0



100
75
50
25
PERCENT OCCURRENCE
20
4
49
26
51
33
Pb
Fe
Pb
Fe
Pb
Fe
1981
1982
1983

lead occur at a slower rate than is evident from results of surface sampling.

Differences in yearly lead-steel shot ratios between surface and soil sampling is difficult to explain. Lead-steel shot ratios taken from surface shot data are consistently higher than those from soil shot data. It would be expected that both ratios would be similar from year to year. Two possible explanations exist for this: (1) a major bias occurred in one or both sampling techniques, and/or (2) geophysical processes are selectively exposing more lead shot than steel shot at the soil surface.

A major bias in sampling in one or both sampling methods is unlikely. Soil shot sampling methodologies do not allow for much sampling or observer error because all shot pellets occurring in a random sample of soil will be located. Also, surface shot sampling methods were tested as described earlier and found to be valid in terms of nearly proportional recovery of shot. A small degree of error in surface sampling can be expected because of visual cues selecting for the more commonly occurring lead shot.

Regardless, it appears that geophysical processes of wind and water erosion selectively expose a higher proportion of lead shot than steel shot. Erosive forces do not expose lead and steel shot at the same proportional rate. Lead is much denser than steel and remains more stationary while steel shot is carried off more easily by wind and water. Steel shot also retains its sphericity after being shot and tends to roll easier than lead shot which is deformed after shooting. Once a pellet loses its kinetic energy by rolling to a lower elevation it is subject to burial by sedimentation. Lead shot used in goose hunting is manufactured in much larger size classes than steel shot. Lead shot larger than BB (BB is the largest steel shot pellet currently manufactured) has a much greater thickness, surface area, and mass which increases the likelihood for exposure. The different physical properties of lead and steel shot together with certain geophysical processes are the major contributors in the yearly lead-steel shot ratio disparity between surface and soil sampling.

This concept of differences in lead-steel shot ratios between surface and soil sampling is important. Actual lead-steel shot ratios derived from soil sampling do not carry much meaning because geese do not typically dig in the soil for food. However, lead-steel shot ratios taken from surface sampling provide the best data on shot availability to foraging Canada geese. Wildlife managers must consider higher than expected surface lead-steel shot ratios in upland goose hunting fields, but be mindful of shot reservoirs in affected soils.

Shot type and size data collected from soil samples are summarized in Table 15. Three size classes of lead shot (2, BB, and 4 buck) constituted over 75% of all lead shot found. These reflect hunter size class preference when lead shot was used legally to hunt Canada geese at LQP. Also, 1981-1983 data indicate that lead 2 shot was the favorite shot size among goose hunters. However, a shotgun shell loaded with smaller sized shot can hold more pellets than a shell loaded with larger pellets. Therefore, total numbers of shot in size categories do not indicate hunter preference alone. A weighted scale must be used to relate numbers of shot in different size categories to

Table 15. LQP hunter shot size preferences determined by normal and weighted proportions of soil shot data 1981-1983.

SHOT SIZE CLASS	N	GROUP %	WEIGHTED FREQUENCY OF OCCURRENCE N/Pellets/ounce X 100	HUNTER SHELL PREFERENCE ADJUSTED GROUP %
Pb				
6 shot	5	4.4	2.2	1.0
4 shot	15	13.0	11.1	5.2
2 shot	45	39.1	51.7	24.3
BB	30	26.1	60.0	28.2
4 buck	17	14.8	60.7	28.6
3 buck	1	0.9	5.3	2.5
2 buck	1	0.9	7.1	3.4
00buck	1	0.9	14.3	6.7
TOTAL	115	100.1	212.4	99.9
Fe				
4 shot	5	7.8	2.6	3.8
2 shot	13	20.3	10.4	15.4
1 shot	22	34.4	21.4	31.6
BB	24	37.5	33.3	49.2
TOTAL	64	100.0	67.7	100.0

total shells expended for each shot size. This is represented in Table 12 with adjusted proportions as outlined. These percentages represent actual hunter lead shot (shell) preference. The same reasoning applies to hunter preference for steel shot. In 1976, hunter surveys indicated that 35% of the hunters in LQP state blinds used lead buckshot (Anderson et al. 1976) which supports current LQP findings.

ANNUAL SHOT DEPOSITION

To measure hunter deposition of shot in one goose season, 300 shot collectors were distributed in front of blinds during the 1981, 1982, and 1983 seasons. State blinds 50, 80, and 84 each had 100 shot traps every season.

Results from goose hunting seasons for each blind are presented in Table 16 . The 1981-1983 goose hunting seasons lasted 33, 50, and 50 days, respectively. Both the 1981 and 1982 LQP seasons were typical in respect to Canada goose migration and harvest. Harvest of 5,500 Canada geese both years followed past trends. Data from 1981 and 1982 are similar in respect to densities of deposited shot.

The 1983 LQP goose hunting season was atypical due to extremely low Canada goose production, and numbers were down from previous years (Fig. 5). Geese arrived later in September with adults making up a large proportion of the population. This combination of factors provided fewer opportunities for goose hunters to harvest Canada geese in 1983 (Table 3). This also apparently reduced the numbers of crippled geese in the refuge. Shot trap data from 1983 reflect reduced shooting pressure in 2 of 3 state blinds (Table 16).

Deposition rates of between 5,000 and 13,000 pellets/ha/year occurred in all 3 monitored state controlled blinds except for 1983. Uncontrolled private blinds had higher deposition rates undoubtedly due to closeness of blinds and lack of limitation on the number of shells permitted per person per day.

Illegal use of lead shot in state controlled blinds is shown in Table 17. Lead shot in 1981-1983, by year, was 7.0%, 9.0%, and 7.0% of the total shot collected in shot traps. Statistical analysis revealed no significant difference in the proportion of steel or lead

Table 16. Results of shot trap sampling in the LQPWR, 1981-1983.

LOCATION	1981 Pellets/ha	1981 Pb:Fe	1982 Pellets/ha	1982 Pb:Fe	1983 Pellets/ha	1983 Pb:Fe
Blind 50	7,143	1.0:14.0	8,571	1.0:17.0	9,048	1.0:19.0
Blind 80	12,857	1.0:8.7	9,524	1.0:9.0	1,429	1.0:2.0
Blind 84	5,238	Fe 100%	7,619	1.0:7.0	2,857	Fe 100%

Table 17. Shot density ranges and lead-steel ratios for 1981-1983 LQP hunting season shot trap sampling.

LOCATION	RANGE Pellets/ha	LEAD:STEEL
1981	5,238 - 12,857	1.0:13.0
1982	7,619 - 9,524	1.0:9.8
1983	1,429 - 9,048	1.0:13.0

shot found between any 2 years (x^2 range = 0.00-1.45 $p>0.05$). However, illegal additions of new lead shot may offset natural losses of old lead shot. LQP wildlife manager, Arlin Anderson (personal communication) and law enforcement officials (Pat Joyce and Steve O'Connell, personal communication) consider that lead shot violations occur at a higher rate in private areas. Stricter penalties and more thorough enforcement may lessen this impact.

The sampling technique of using shot collectors or traps provided a reliable source of data that measured annual shot deposition rates, shot distribution, and shot composition. Sampling effort could, however, be improved by increasing the surface area to be sampled and thereby increase the accuracy of measurements. Regardless, this would be very expensive, time consuming, and possibly not practical because of hunter and farmer objections.

A better field method to measure for shot deposition would be collection of plastic shot cups or wads which are used in shotgun shells to protect the barrel from contact with the shot and improve ballistics. Lead shotgun shell wads are identifiably different in having a protective cushion under the shot cup while steel shot wads do not. Most of these wads fall within 40 meters of the blind. At the close of the season calculation of number of wads, by type, per blind multiplied by the average number of pellets per wad type, would adequately estimate seasonal lead-steel shot deposition by or for all blinds.

CANADA GOOSE SAMPLING - COLLECTIONS AND PHYSICAL DIAGNOSIS

Physiological data collected from LQP crippled and dead Canada geese during 1978-1983 seasons are summarized in Tables 18 and 19. Proportions of geese with body shot have remained around 50% for 6 years (Table 18). Hennes (in prep.) found that the impact of lead poisoning was reduced from 1978-1980. Proportionally fewer lead pellets were found in Canada goose gizzards (1978 vs. 1979, x^2 = 25.45, $p<.005$; 1979 vs. 1980, x^2 = 11.78, $p<.005$). Differences between years with respect to proportion of gizzards containing shot for 1980-1982 did not change significantly (1980 vs. 1981, x^2 = 1.06; 1981 vs. 1982, x^2 = 0.64). Fewer shot positive gizzards occurred (mean = 4.0%) in the 3 years following the steel shot regulation. However, the proportion of lead shot in shot positive gizzards from collected Canada geese has remained high despite the steel shot regulation.

Shot positive gizzard data from harvested geese are summarized in Table 20. Decreases in lead shot in shot positive gizzards are offset by increases in steel shot. These data varied from previous crippled goose data with respect to lead-steel shot composition in shot positive goose gizzards. However, 1981-1983 harvested geese with gizzard shot

Table 18. X-ray determinations of body shot in LQP Canada goose carcasses, 1978-1982.

YEAR	TOTAL RADIO-GRAPHED	N CONTAINING EMBEDDED SHOT	(%)	PB %	AVERAGE SHOT/GOOSE	(RANGE)
1978	301	163	(54.2)	99.5	2.5	(1-12)
1979	164	80	(48.8)	100.0	3.1	(1-19)
1980	93	45	(48.4)	48.3	2.7	(1-14)
1981	155	70	(45.2)	-	3.3	(1-13)
1982	93	44	(47.3)	-	3.7	(1- 9)

1978-1980 data from Hennes (in prep.)

Table 19. Incidence of gizzard shot in LQP Canada goose carcasses determined by X-ray and physical examination, 1978-1982.

YEAR	TOTAL RADIOGRAPHED	N CONTAINING GIZZARD SHOT	(%)	PB %	AVERAGE SHOT/GIZZARD
1978	301	147	(48.8)	99.5	-
1979	164	23	(14.0)	100.0	-
1980	93	1	(1.1)	0.0	-
1981	155	5	(3.2)	60.0	1.0
1982	93	5	(5.4)	80.0	1.0

1978-1980 data from Hennes (in prep.)

Table 20. Gizzard shot recovered from harvested LQP Canada geese, 1981-1983.

YEAR	TOTAL GIZZARDS	POSITIVE GIZZARDS	(%)	% LEAD	% STEEL
1981	265	9	(3.4)	88.8	11.2
1982	234	15	(6.4)	66.7	33.3
1983	302	10	(3.3)	30.0	70.0

also would be expected to have a higher probability of steel shot in their gizzards; crippled and dead Canada geese would likely have a higher probability of lead shot in their gizzards. In both cases lead shot occurrence in goose gizzards is a biased indicator. The assumption is that Canada geese with lead shot in their gizzards have a higher mortality rate and a higher probability of being in a sample of sick crippled, and dead waterfowl than geese with gizzards containing steel shot. Bellrose (1959) found that waterfowl dosed with lead shot experienced a higher mortality rate than nondosed birds. The question to be answered is: whether a hunter harvested goose sample or a crippled goose sample is more appropriate in conservatively describing lead poisoning impacts in Canada geese? Both sampling techniques have merit. Sampling LQP hunter killed Canada geese, however, probably underestimates yearly impacts of lead poisoning due to the fact that geese suffering from lead poisoning are less likely to fly out of the refuge and be susceptable to hunter kill. On the contrary, sampling sick, crippled, and dead Canada geese overestimates yearly impacts of lead poisoning on the population, but provides a reasonable conservative index to measure lead shot impact.

Regardless of the sampling techniques, both data sets indicate a trend towards reduction of lead poisoning in Canada geese at LQP since 1978. The steel shot regulation appears to contribute to this, although farming practices and goose area utilization changes may be partially responsible.

Physical lead poisoning symptoms of 243 collected crippled or dead Canada geese did not correlate with chemical indications of liver tissues. Impaction of the proventriculus, emaciation of breast muscle, and/or a green stained vent, reported as symptoms of lead poisoning in waterfowl (Jordan and Bellrose 1959) were noted in 30.3% of Canada geese examined in 1981. Only 1 of 5 Canada geese diagnosed in 1981 as having toxic liver levels of lead had these symptoms. In 1982, 29.0% of crippled Canada geese examined had impaction, emaciation, and/or a green stained vent as a symptom, but only 3 of 6 geese with toxic liver lead levels had physical symptoms described for lead poisoning. In these study collections physical diagnosis significantly overestimates the actual number of lead poisoned geese and also did not adequately indicate all lead poisoned Canada geese. Tissue lead levels are the ultimate indicators of lead shot exposure.

Tissue Analyses

Liver, breast muscle, and bone (humerus) samples were removed from LQP crippled or dead Canada geese for lead determinations. Liver analyses were considered more important in describing lead exposure in Canada geese. Hennes (in prep.) collected 523 goose liver samples in

1978-1980 seasons at LQP. Liver lead values (N = 241) greater than 6.0 ppm for 1978-1982 are summarized in Table 21. A two sample t test was used to test if a difference existed between 1981-1982 years for mean liver lead values. The test was significant at p=0.246 (t=1.162). The null hypothesis of equivalent means can not be rejected at alpha = 0.05. Closer inspection of the liver data revealed that the elevated liver values acted as outliers causing standard deviations to become 3-4 times larger than the means. Deletion of these values reduced the variance to more acceptable levels. The two sample t test was significant at p=0.359 (t=0.92). Mean liver lead values again were not significantly lower in 1982 than in 1981. The steel shot regulation had no effect on lowering mean liver lead levels in sampled LQP Canada geese from 1981 to 1982.

Table 21. Liver lead concentrations from LQP crippled Canada geese, 1978-1982.

YEAR	N	PB> 6.0 PPM	%	PB PPM MEAN	(SE)	RANGE PB PPM
1978	302	190	62.9	14.0	(0.8)	<0.10-66.0
1979	161	38	23.6	5.5	(0.9)	<0.10-57.2
1980	90	2	2.2	0.5	(0.2)	<0.10-13.0
1981	150	5	3.3	0.77	0.31	0.01-31.0
1982	93	6	6.5	1.48	0.56	0.01-37.4

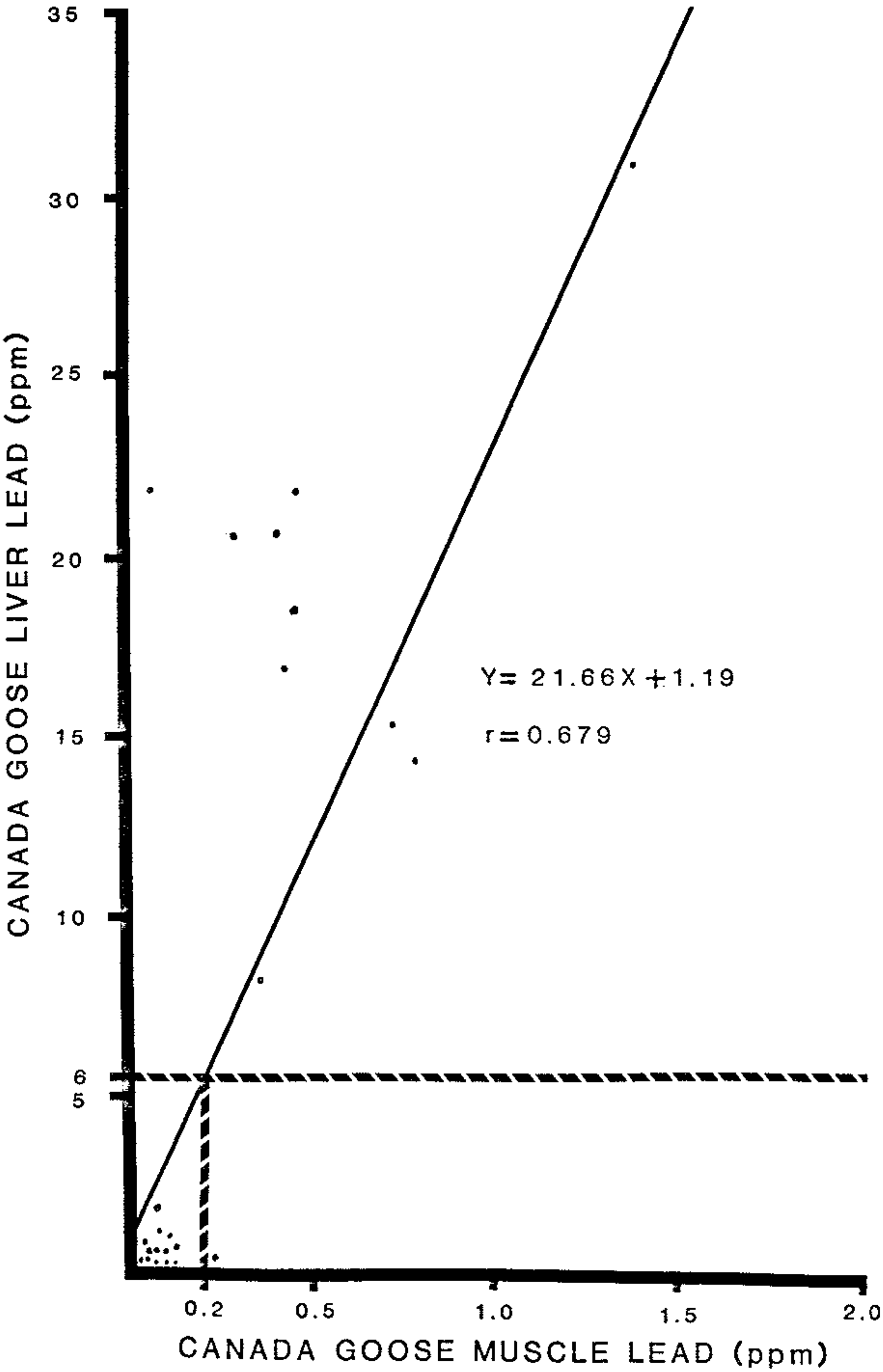
1978-1980 data from Hennes (in prep.)

Muscle samples (41) were removed for lead determinations from the breasts of crippled Canada geese collected in 1981 and 1982 seasons. Muscle samples from geese with known liver lead levels above 1.0 ppm were submitted as well as those randomly chosen from liver lead levels less than 1.0 ppm to test for any correlation between liver and muscle lead levels. Figure 11 represents a reasonably close correlation (r=0.679) between 1981 and 1982 muscle and liver lead levels. Muscle lead levels above 0.200 ppm (wet weight) adequately indicated toxic liver lead exposure (>6.0 ppm, wet weight) in 10 of 12 cases. If liver lead analyses can be considered 100% effective in diagnosing lead poisoning, then, at least for these studies, muscle lead analysis is 83.3% effective.

Bone samples were archived for future analyses. Bone lead analyses were limited by financial and logistic constraints. Bone lead content is considered more diagnostic of chronic lead exposure since lead mimics calcium and is ultimately stored in bone tissue.

BALD EAGLE CASTING ANALYSES

A total of 1,439 bald eagle castings have been collected since 1978 at the LQPWR. Canada goose remains occurred in 70.7% of 1981-1983 castings; mallard, coot, lesser scaup, muskrat, and white-tailed deer were also present (Table 22). The proportion of shot positive castings has varied between 9 and 20 percent from 1978-1983 (Table 23). Hennes (in prep.) found lead shot occurring in more than 90% of shot positive castings in 1978 and 1979 at LQP. In 1980, the first year of the steel shot regulation, the proportion of lead shot in shot positive castings dropped to 44%. Steel shot made up the remainder. Since 1980 lead



35
30
25
20
15
10
6
5
CANADA GOOSE LIVER LEAD (ppm)
Y= 21.66X +1.19
r=0.679
0.2
0.5
1.0
1.5
2.0
CANADA GOOSE MUSCLE LEAD (ppm)

Table 22. Frequency of occurrence of prey species remains in LQP bald eagle castings, 1981-1983.

PREY SPECIES	1981		1982		1983		TOTAL	
	N=110	%	N=200	%	N=66	%	N=376	%
Canada Goose	84	76.4	141	70.5	41	62.1	266	70.7
Mallard	31	28.2	49	24.5	26	39.4	106	28.2
Coot	1	0.9	3	1.5	2	3.0	6	1.6
Lesser Scaup	-	-	1	0.5	-	-	1	0.3
Unidentified duck	1	0.9	3	1.5	2	3.0	6	1.6
Unidentified avian	1	0.9	4	2.0	6	9.1	11	2.9
Muskrat	2	1.8	1	0.5	1	1.5	4	1.1
White-tailed deer	1	0.9	5	2.5	-	-	6	1.6
Total Mammalian	3	2.7	6	3.0	1	1.5	10	2.7

shot presence in positive castings varied between 68% and 78% (Table 23). No significant difference ($p>0.05$) could be detected for proportions of lead and steel shot in shot positive bald eagle castings for 1981-1983 (1981 vs. 1982, $x^2 = 1.25$; 1982 vs. 1983, $x^2 = 0.21$). Also, no differences could be detected for 1981 vs. 1983 data ($x^2 = 0.03$). Eagle casting analysis is considered the single best indicator of bald eagle exposure to lead shot.

The steel shot regulation appears to have reduced lead shot impacts on LQP bald eagles by 20-40%. However, with this restriction, lead shot continues to be available to eagles in Canada geese and other waterfowl. In 1981-1983 there were at least 5 possible pathways of lead to LQP bald eagles: 1) illegally used lead shot is embedded in Canada

Table 23. Frequency of occurrence of lead and steel shot in bald eagle castings from the LQPWR, 1978-1983.

YEAR	N	SHOT POSITIVE	%	SHOT POSITIVE CASTINGS % LEAD +	SHOT POSITIVE CASTINGS % STEEL +
1978	417	48	11.5	96.3	3.9
1979	432	42	9.7	94.4	5.6
1980*	214	24	11.2	44.1	55.9
1981	110	21	19.1	76.2	23.8
1982	200	37	18.5	67.6	32.4
1983	66	6	9.1	77.8	22.2

* First year of steel shot regulation at LQP. 1978-1980 data from Hennes (in prep.)

geese along the flyway and later is consumed by bald eagles at LQP, 2) lead shot illegally used to hunt waterfowl in the LQP Steel Shot Zone, 3) legal use of lead shot outside the steel shot zone on a substantial portion of the LQP goose population, 4) via numerous geese that have retained "old" lead body shot from before the steel shot regulation, and 5) eagle consumption of ducks with embedded lead shot.

Field observations and sampling indicate bald eagles ingest lead pellets from waterfowl via all 5 stated pathways. The EPP of Canada geese from Hudson Bay throughout fall migration south through Canada are exposed to lead shot from hunters. Major Canada goose stop-over areas in Minnesota such as State Wildlife Management Areas, Federal Waterfowl Production Areas, and National Wildlife Refuges have enforced steel shot regulations. However, points in between have no such regulations and non-fatal embedded lead shot potentially can be carried by Canada geese to areas like the LQPWR or Swan Lake National Wildlife Refuge in Missouri where bald eagles congregate and feed on crippled or dead waterfowl. In addition, this study has shown that lead shot is used illegally within the LQP Steel Shot Zone with more violations likely occurring in densely hunted private lands adjacent to the LQPWR. This additional lead shot availability causes increased detriment to LQP eagles. Further, sufficient Canada goose hunting with lead shot occurs outside the LQP Steel Shot Zone.

Canada geese and other waterfowl have a remarkable capability of surviving shot injuries if no vital organs are damaged. It is common for geese and ducks surviving shot injuries to retain shot pellets in their bodies (Griffin et al. 1982). Since geese and ducks may live up to 10 - 15 years, there are birds still carrying body lead shot from before the steel shot regulation, although this is a small fraction of the total population.

Ducks and migratory waterfowl other than Canada geese contain embedded or tissue-bound lead. Data in 1981-1983 indicate that 30% of collected eagle castings contained duck remains. This together with a greater proportion of smaller lead pellets (< 2 shot) found in eagle castings tends to incriminate ducks as a partial source of lead shot to bald eagles (Table 24).

Table 24. Shot size and type data from LQP bald eagle castings, 1981-1983.

SHOT SIZE	N	GROUP %	TOTAL %
Pb			
8 shot	3	5.9	4.2
6 shot	5	9.7	7.0
4 shot	15	29.4	21.1
2 shot	21	41.2	29.6
BB	6	11.8	8.5
4 buck	1	2.0	1.4
Total	51	100.0	71.8
Fe			
4 shot	0	0.0	0.0
2 shot	1	5.0	1.4
1 shot	5	25.0	7.1
BB	13	65.0	18.3
4 buck	1	5.0	1.4
Total	20	100.0	28.2

It seems logical that the physiological process of raptor casting formation and egestion is a natural protection mechanism against mechanical and chemical injury. This is applicable to poisoning from lead shot ingestion. It does appear that regurgitation of castings protects raptors from lead poisoning to a certain extent (Redig et al. 1980). However, continual ingestion and egestion of lead shot by bald eagles, as documented at LQP, results in a possible continuum of systemic exposure since castings are usually egested once a day (Errington 1930, Durham 1983). Stendell (1980) found that a kestrel's digestive system eroded an average of 1 mg of lead per shot in a 24 hour period. Results of casting analyses at LQP (1978-1983) indicate that eagles may ingest at least one lead or steel shot pellet every 5 to 10 meals. Also, lead shot may not always be incorporated into eagle castings or shot may be retained when material used for casting formation is not ingested. These circumstances can add to eagle lead poisoning.

Obviously the current steel shot regulations for waterfowl hunting did not eliminate lead shot availability to LQP bald eagles in 1981-1983. However, restrictions appear to reduce lead poisoning impacts on waterfowl at LQP. A national and international ban on lead shot use in waterfowl hunting is really necessary to effectively reduce lead shot availability and eventually prevent origin of new lead to migratory species like waterfowl and bald eagles. Anthropogenic pollutants like lead shot that endanger humans and wildlife necessitate intensive management strategies to alleviate or mitigate their impacts. In the case of lead shot used for waterfowling, elimination is the realistic strategy.

BALD EAGLE COLLECTION

Previous work by Hennes (in prep.) implicated lead exposure in bald eagles with blood lead levels averaging 1.11 ppm from 25 captured LQP eagles between 1978-1980. In 1980 and 1981 control blood samples were taken from 24 nestling bald eagles in the Chippewa National Forest in north central Minnesota (Frenzel and Hennes, personal communication). These blood values, believed to represent current natural or background levels prior to pre-flight exposure to lead shot, averaged 0.24 ppm. Blood lead levels in LQP and Chippewa birds were significantly different ($p<.005$). These increased lead levels in LQP bald eagles are indicative of elevated lead exposure. LQP observations and resulting quantitative data further indicated that hunted waterfowl was this lead source.

Bald eagle trapping was not undertaken in this study, but considerable time and effort were expended searching the LQPWR for sick, injured, or dead bald eagles. On 14 December 1981, an immature (male) bald eagle was observed behaving abnormally on Rosemoen Island. The eagle was first seen perched only 6 meters from the ground in a broken American elm in a dense stand of box elder, green ash, and cottonwood away from areas frequented by bald eagles. I could approach quite close to the eagle before it would elicit threatening responses such as beak snaps, vocalizations, and piloerection. The eagle was obviously in poor health and would not fly until I was nearly standing under the perch tree. Obvious physical signs of ailment included: 1) head shake, 2) loss of equilibrium, 3) green mucus material emanating from the mouth, 4) slight green stained tail feathers, 5) body droop, and 6) obvious depression. When the eagle was flushed it managed to fly about 100 meters to another tree. This occurred several times until it could not gain altitude and landed on the ground where I captured it and took it to the Raptor Research and Rehabilitation Center (RRRC), Department of Veterinary Biology, University of Minnesota for diagnosis and treatment. Lead determinations revealed 2.4 ppm occurring in its blood upon admittance to the RRRC. Treatments for lead poisoning were initiated immediately which included providing fluids, electrolytes, chelating agents, and rest. On 18 December blood lead values had dropped below 1.0 ppm with physical signs showing improvement. By January 1982 the eagle apparently was fully recovered. Lead poisoning treatments continued in efforts to mobilize body stores of lead. In February the eagle was taken to an outdoor flight pen near Hastings, Minnesota in anticipation of releasing it back to the wild. However, on 18 February 1982 the eagle was found dead in the flight pen after a severe drop in ambient temperature. Cause of death was attributed to debilitation of body defenses and reduced fat reserves from the lead poisoning incident. It is likely that similar events also occur to wild bald eagles where lead poisoning does not cause actual death but lowers defense mechanisms enough so that a stressful situation, which otherwise would have been avoided or tolerated, becomes life threatening or fatal.

A second mature (male) bald eagle near death was collected by Minnesota Conservation Officer Steve O'Connell on 14 April 1983 in the

LQPWR. The eagle died that evening and was shipped to the U.S. Fish and Wildlife Service Health Lab, Madison, Wisconsin. Clinical diagnosis concluded it died from lead poisoning. Its blood lead value was 1.36 ppm; the liver lead value was 12.46 ppm.

These 2 eagles are the only known lead poisoning cases found at LQP in 6 years of project field studies. They were found in the latter half of these 6 years, and after the steel shot regulation was implemented. This supports the need for steel shot regulation improvements, including that lead shot use in waterfowl hunting be restricted nationally and internationally.

No one knows the real magnitude of lead related mortality in bald eagles. The likelihood of finding a sick or dead bald eagle in close locality to "healthy" aggregations of bald eagles can be considered remote. Typically, sick or injured animals seek out areas in which to hide that makes them even more difficult to find. This appeared to be the case at LQP.

Bald eagles also are very mobile, especially during the fall period of migration. Those ingesting enough lead shot and tissue-bound lead from waterfowl at LQP to cause lead poisoning symptoms very likely do not show physical and clinical signs until they have migrated farther south. A conservative estimate is that 4-5% of bald eagles that stop-over at the LQPWR eventually die of lead related causes. With an estimated 100-150 bald eagles that migrate through LQP (Hennes, in prep.), this indicates 4-8 LQP bald eagles dying of lead poisoning related causes per year. The 20-40% reductions in the proportion of lead shot in LQP bald eagle castings since 1980 has improved LQP bald eagle survival, but a serious problem remains with respect to lead related mortality. Yearly collections of bald eagle castings should be continued to monitor any significant changes that occur. Further management at the federal level is needed to reduce lead poisoning impacts on bald eagles.

MANAGEMENT RECOMMENDATIONS

The health and well-being of wildlife populations are primary considerations in wildlife management. Human induced impacts that adversely affect wildlife populations must be monitored and acted upon to reduce or mitigate observed problems. This becomes an increasingly difficult task when migratory species are involved.

Undoubtedly the LQP lead toxicity problem is not at all unique. Other areas throughout the state and country probably experience losses of wildlife species to lead poisoning related causes. However, to effectively monitor and evaluate lead availabilitly to certain wildlife species it is important to focus specific attention on an area like LQP which has a diversity of wildlife potentially exposed to lead. The bald eagle and Canada goose can be considered important indicator species for this at LQP and possibly elsewhere. Knowledge gained from these predator-prey relationship studies has provided information that can be used in management decisions to minimize losses of bald eagles and Canada geese due to lead poisoning.

The following management strategies and considerations are recommended for further reducing lead toxicity impacts on eagles and geese at Lac qui Parle and areas with similar problems:

1) Maintain the current steel shot regulation.

2) To restrict all waterfowl hunting to steel shot nationally as well as internationally in North America. Co-involvement of private and professional wildlife organizations and state wildlife agencies with the U.S. Fish and Wildlife Service is necessary to formulate a comprehensive plan for this lead shot restriction in the United States as well as Canada and Mexico.

3) Until lead shot densities at LQP are reduced to more acceptable levels it is advised that the following land practices be followed if possible:

   a. Selectively harvest crops in areas within the refuge to encourage Canada goose feeding there.

   b. Encourage farmers not to harvest crops in private goose hunting fields before the waterfowl season.

   c. Use hazing practices to discourage Canada geese from occupying known problem fields.

   d. Most importantly, proper timing of agricultural practices that disturb the soil surface such as tillage and harvesting of crops should be encouraged. Conservation tillage practices are recommended.

4) A period of 10 to 15 years may be necessary before lead shot densities in upland soils are reduced to acceptable levels. Therefore, management needs to be expedited.

5) If lead continues to be used for North American waterfowling, enlarge the current LQP Steel Shot Zone to

minimize legal lead shot use on fall LQP Canada geese.

6) Increase enforcement efforts and legal authority in private lands adjacent to the refuge boundary to reduce illegal lead shot use.

7) Determine illegal lead shot use by collection of spent shotgun shell wads around state and private blinds.

8) Remove crippled and dead waterfowl from the LQPWR if lead shot continues to be contained in their bodies.

9) Avoid using physical diagnosis to quantify numbers of lead poisoned Canada geese. Laboratory lead determinations from liver or muscle samples are preferred if necessary for problem monitoring.

10) If broad lead shot restrictions are not implemented, continue the current steel shot regulation at LQP. This appears to reduce the incidence of lead poisoning in waterfowl and eagles. However, bald eagles continue to be seriously exposed to lead shot as indicated by continued incorporation of lead shot in geese and discovery of lead poisoned bald eagles.

11) Primary consideration for bald eagle survival should be a high priority in management decisions.

SUMMARY AND CONCLUSIONS

Lead poisoning is known to be a significant mortality factor in waterfowl populations. Spent lead shot in aquatic or upland habitats often occurs at high enough densities to be continuously available to feeding waterfowl. Waterfowl ingest lead shot, possibly as a mistaken grit or food item, and convert the ingested lead into a soluable and absorbable form through gizzard and other physiological activities. Waterfowl and other aquatic related species are most often affected; however, recent evidence suggests that raptors, particularly bald eagles, are subject to lead poisoning from eating prey that contain embedded lead shot and/or tissue-bound lead.

These 1981-1983 studies at the Lac qui Parle Wildlife Management Area in western Minnesota were focused on monitoring specific impacts of available lead shot on migrant bald eagles and Canada geese by various techniques, and evaluating the effectiveness of steel shot regulations as a management technique for these two species. Principal findings were:

1) Peak fall numbers of Canada geese at LQP approached 80,000 birds in late October and early November; most of the EPP Canada goose population stops over at LQP during fall migration.

2) Peak fall numbers of bald eagles at LQP approach 30 birds in late November and early December; an estimated 100-150 bald eagles migrate through LQP during the fall.

3) Canada geese spent proportionally more pre-hunting season time feeding in private agricultural lands adjacent to the LQPWR during 24-30 September 1981 and 1982 than they did from 17-23 September 1981 and 1982.

4) The goose hunting season caused Canada goose behavior changes. A higher proportion of Canada geese were observed

leaving the refuge to feed outside the steel shot zone in morning hours than evening hours in 1981 and 1982, apparently due to hunting pressure.

5) Inside the LQP Steel Shot Zone during 0800-1000 hours 1.0 Canada goose was harvested out of every 14.5 and 11.7 flocks that left the LQPWR in 1981 and 1982, respectively. Outside the LQP Steel Shot Zone during 0800-1000 hours 1.0 Canada goose was harvested out of every 29.6 and 26.9 flocks that left the LQPWR in 1981 and 1982, respectively. Thus more geese utilizing the LQPSSZ were killed inside than outside the zone.

6) Estimated crippling rate of Canada geese at LQP from 1978-1982 was 13%.

7) After the Canada goose hunting season had ended in 1981 and 1982, 81% and 62%, respectively, of Canada goose morning flights ended in the LQPSSZ. Hunting pressure apparently caused longer feeding flights.

8) Immature bald eagles made up over 70% of all counted from 1981-1983.

9) Freshly dead waterfowl were preferred bald eagle prey. Canada geese were scavenged over 60% of the time from 1981-1983. Of 348 observed bald eagle feeding sessions, 92.8% occurred on the lake ice or within 6.0 meters of the lake or river shoreline.

10) Ambient low temperatures after 15 December of below -10 degrees C, a shrinking food supply, and severe ice and snow

storms caused a major synchronized exodus of Canada geese and bald eagles from the LQPWR in all 3 field seasons.

11) Surface shot sampling on LQP state and private lands was a major study objective. Observer perception of surface lead and steel shot averaged 68%.

12) Pre-hunting surface shot densities ranged from 13-1,939 pellets/ha for 1981-1983. Yearly significant decreases ($p<0.05$) in lead-steel shot ratios occurred from 1980-1983.

13) Surface availability of lead and steel shot is reduced by soil disturbance (cultivation and harvest).

14) Private lands adjacent to the LQPWR had surface densities of lead and steel shot 2-150 times the amount found in state lands.

15) Yearly decreasing lead-steel shot ratios follow very closely to a negative log-linear relationship ($r=0.996$). Predicted ratio values can be extrapolated for future years. Data extrapolation shows that the soil surface lead-steel shot ratio will be 1:1 in 1988 if present change trends continue.

16) In 1983, three years after the steel shot regulation had been in effect, lead shot still constituted over 80% of sampled pre-hunting season surface shot.

17) A 10 to 15 year period may be necessary before lead shot densities in LQP upland soils are reduced to acceptable levels.

18) Three size classes of lead shot (2 shot, BB, and 4 buck) constituted over 75% of all lead shot found. BB steel shot

accounted for over 60% of all steel shot collected.

19) Lead shot is exposed at the soil surface at a greater proportional rate than steel shot.

20) The proportion of pre-hunting surface shot occurring at 50 meter intervals inside the refuge boundary was a) 0-50 meters = 36.5%, b) 51-100 meters = 42.9%, c) 101-150 meters = 19.2%, and d) 151-200 meters = 1.4%.

21) Post-hunting season surface shot densities are similar to pre-hunting season surface shot densities. However, steel shot made up 53% and 62% of collected post-hunting season surface shot in 1981 and 1982, respectively.

22) Harvest of crops without cultivation reduced pre-hunting season surface lead shot densities at LQP by 59% and 32% in 1981 and 1982, respectively.

23) Soil shot densities (17.5 cm depth) at LQP study plots near controlled blinds ranged from 106,000-328,708 pellets/ha from 1981-1983. Yearly proportional increases of steel shot and decreases of lead shot occurred in most study plots.

24) Yearly pre-hunting season surface lead-steel shot ratios are greater than soil lead-steel shot ratios because geophysical processes of wind and water erosion in agricultural fields selectively expose a higher proportion of lead shot than steel shot.

25) Lead-steel shot ratios and densities taken from surface sampling provide the best data on shot availability to foraging Canada geese.

26) Seasonal deposition of shot at state blinds ranged from 1,429 to 12,857 pellets/ha from 1981-1983. Lead shot accounted for 7%. 9%. and 7% of shot deposited in the 3 sampled years which approached deposition of one piece of new lead for every 13 pieces of new steel annually. These additions of illegal lead shot may offset losses of "old" lead shot.

27) The proportion of collected Canada geese with body shot averaged around 50% from 1978-1982.

28) Differences between years with respect to proportion of Canada goose gizzards containing shot for 1981-1982 did not change significantly. Average incidence of shot positive gizzards was 4.0% from 1980-1982.

29) Number 4 buck lead shot was found in 71% of lead shot positive Canada goose gizzards.

30) The proportion of lead shot in shot positive gizzards from harvested Canada geese decreased from 1981-1983.

31) Physical diagnosis of collected Canada geese did not correlate with lead content of liver tissues.

32) Mean Canada goose liver lead values were not significantly lower in 1982 than in 1981.

33) Muscle lead levels above 0.200 ppm (wet weight) adequately indicated toxic liver lead exposure in 10 of 12 cases (83.3%).

34) Lead poisoning impacts in Canada geese were substantially reduced at LQP from 1978-1982, but remain a management problem.

35) Canada goose remains occurred in 70.7% of bald eagle castings. Duck remains occurred in 29.8% of bald eagle castings.

36) The proportion of shot positive bald eagle castings varied between 9% and 20% from 1978-1983.

37) Since 1980 the proportion of lead shot in shot positive bald eagle castings has varied between 68% and 78%.

38) Bald eagle casting examination is considered the single best indicator of exposure to lead shot.

39) Lead shot continues to be available to bald eagles via Canada geese and other waterfowl. Current steel shot regulations appear to reduce lead shot impacts on bald eagles by 20-40%.

40) Two bald eagles (immatures) with suspected lead poisoning symptoms were recovered at LQP in 1981-1983. Both died with death diagnosed as due to lead poisoning related causes.

41) Conservatively, 4-5% of the estimated 100-150 bald eagles that stop over at the LQPWR annually may eventually die of lead related causes.

42) Lead poisoning in LQP bald eagles associated with fall concentrations of hunted waterfowl has been field documented for 3 years (1981-1983) after implementation of regulations requiring use of only steel shot by hunters in the LQPSSZ. Primary eagle lead source was body shot from hunted Canada geese. Corrective management requires improved steel shot regulations for all waterfowl hunting nationally and internationally. This would not negatively affect sport

hunting as a recreation resource.

43) Ingestion of spent lead shot around traditionally used state controlled and private hunting blinds remains a potential source of mortality to EPP Canada geese. Corrective management actions through improved steel shot regulations, conservation tillage and other agricultural practices, specific manipulations of feeding geese or their food resources, and blind distribution changes are recommended.

44) Field documentation of lead poisoning in LQP bald eagles and in LQP Canada geese warrants continued monitoring of these important resources together with appropriate rectifying management practices. Continued proper research to document problem changes is also warranted.

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