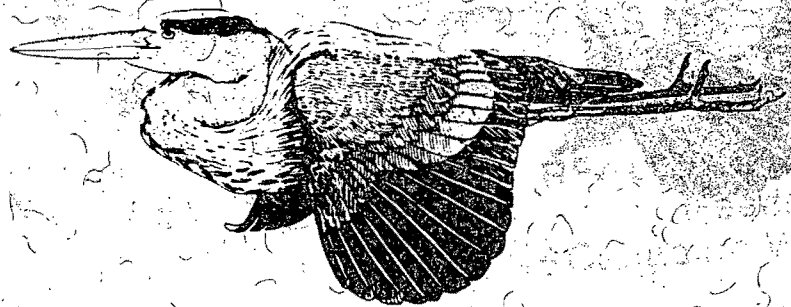


# LEAD SHOT CONTAMINATION OF WATERFOWL AND THEIR HABITATS IN CANADA

J.A. Kennedy  
S. Nadeau

Reçu le 11 JUIN 1993



**TECHNICAL REPORT SERIES No. 164**  
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Judith Kennedy and Simon Nadeau  
(editors)

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Technical Report Series No. 164  
Headquarters 1993  
Canadian Wildlife Service



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This document may be cited as:

Kennedy, J.A. and Nadeau, S. 1993. Lead shot contamination of waterfowl and their habitats in Canada. Canadian Wildlife Service Technical Report Series No. 164, 109 pp. Canadian Wildlife Service, Headquarters, Ottawa.

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## INTRODUCTION

J.S. Wendt

The purpose of this collection of technical papers is to document what is known about which locations are sources of lead for waterfowl across Canada. This is an important consideration, because much of the lead exposure in wildlife is thought to be due to hunters' use of lead shot in their shotguns. The choice of ammunition can be controlled fairly easily, and the studies described here will help indicate where that control is most needed.

Exposure to a toxic substance does not necessarily mean that the symptoms of poisoning will follow. Poisoning, if it occurs, does not necessarily lead to death. The papers in this collection are not intended to provide direct information about mortality due to lead poisoning, nor to relate this mortality to the overall population dynamics of waterfowl.

### Background

Lead has been mined and used by people since ancient times. Gale and Stos-Gale (1981) suggested that lead smelting began at least as early as the seventh millennium B.C. They suggested that lead, because of its low melting point, could have been smelted accidentally at a campfire. This could not have occurred with copper. They describe the development of a metallurgical technology for the extraction of silver from lead-rich ores in which lead was probably produced as a low-value by-product. Early uses of lead included spindle whorls for the spinning of yarn, fishing sinkers, wires, and rivets for the repair of pottery.

Today, lead has many uses. The largest commercial use is in batteries. Until recently, gasoline additives were the next most important (Greniger et al. 1976). The forms of lead used in gasoline are tetramethyl lead and tetraethyl lead, which are more toxic to humans than inorganic lead (Goyer 1988). The use of lead in gasoline in Canada has now been almost eliminated by regulations.

A relatively minor use of lead is in ammunition (5.7% of uses in 1972 - Greniger et al. 1976). Lead has several properties that make it attractive for making projectiles. These include low cost, malleability (which allows it to deform rather than shatter), softness (which reduces the potential of damage to gun barrels), high density (which leads to high impact on the target), and workability at relatively low temperatures. Historically, almost all small arms ammunition has used lead.

One kind of ammunition that has been traditionally made of lead is the shotgun shell used for hunting waterfowl. A typical shell contains several hundred pellets. In use, most of these pellets do not strike the bird, but fall into the environment, usually

a wetland environment. The pellets, being made of inorganic lead, are relatively inert in most environments, except for those of exceptionally high pH (Royal Society of Canada 1986). Thus, in most cases, the toxicological significance of the spent lead pellets is low. If a bird ingests the pellets, however, poisoning can occur.

Birds do not have teeth. When a bird ingests a hard particle such as a stone, it often retains the particle in its gizzard where it is used to grind food. The particle may remain in the gizzard for a month until it, too, is ground away. Thus a large proportion of the lead in the pellet can be available for absorption into the bird's body. To make matters worse, birds will seek out hard particles (grit) for their gizzards. Lead pellets from hunting may be one of the most abundant sources of grit available to waterfowl in certain environments.

Sometimes a combination of factors has led to major mortality (die-offs) of waterfowl due to lead poisoning (Bellrose 1959). Thousands of ducks and geese have been found dead during such events. Major die-offs have been associated with areas of high hunting intensity, where many lead pellets are deposited on wetland bottoms. Other factors that are important include the climate and time of year, the diet of the birds, the makeup of the wetland bottom, and the length of time the birds stay in the area.

Bellrose suggested that major die-offs do not account for most waterfowl mortality due to lead poisoning. There is the possibility that numbers of birds suffering symptoms of lead poisoning withdraw from flocks to die alone, or die and are removed by predators. These losses would not often be observed by people.

There is little direct information on mortality of waterfowl due to lead poisoning in Canada. Major die-offs of waterfowl have not been common. Still, there has been concern about lead poisoning here for many years. In the United States, the higher apparent level of poisoning, and in particular some secondary poisoning of Bald Eagles, led to a progressive ban on the use of lead shot for waterfowl hunting. By 1991 lead shot could not be used for this purpose anywhere in the U.S.

In Canada, the first bans on the use of lead shot for waterfowl hunting were instituted regionally in 1989 and 1990. Selected areas of Ontario, Manitoba, and British Columbia were included, where it had been shown that there was a high risk of lead poisoning in waterfowl. The Canadian reaction was tempered by two factors. There were some perceived shortcomings of steel shot, the proposed alternative to lead. It was argued that steel shot could lead to an increase in the number of birds that are crippled, but not killed outright, particularly with inexperienced hunters. As there was a perception that many areas of Canada do not have appreciable lead poisoning risk (Wendt and Kennedy 1992), the risk of increased crippling rates was an important consideration. Since that time there have been improvements in steel shot,

and better public information on its qualities. Concerns about the possibly poorer killing performance of steel have diminished, but not disappeared. None of the studies in this collection provide new information on this question.

To proceed with control of lead poisoning in waterfowl, it was decided that lead shot for waterfowl hunting would be banned in Canada wherever it was likely to cause significant poisoning of wildlife. Still, a framework was needed to help orient field studies and tie these to regulatory action. For this purpose, staff of the Canadian Wildlife Service developed a set of criteria for assessing the various measures of lead exposure in waterfowl, and relating these to regulations. This framework was approved by federal and provincial wildlife ministers as an interim policy in 1990. As most of the information available at that time related to gizzard samples, that interim policy established priorities for action in different areas of the country, based on the incidence of lead pellets in the gizzards of dabbling ducks. Wherever the ingestion rate exceeded 10 %, non-toxic shot zones were to be considered immediately. The next areas to be examined were to be those with over 5 % ingestion rate. The research summarized in these papers was based on this framework.

## **This Report**

In this collection of research papers, exposure of waterfowl to lead across Canada is assessed by a variety of techniques. The first paper deals with a nationwide survey that analyzed the concentration of lead in bones of young ducks of three species. Subsequent papers describe gizzard analyses, in which gizzards from dead birds are examined for pieces of lead pellets, and other techniques for detecting lead in tissue samples and in natural environments. The collection reveals a national picture of the areas where waterfowl are most exposed to the risk of poisoning from lead pellets in Canada, and attempts to assess the degree of this risk to Canadian wildlife in general.

The paper by Dickson and Scheuhammer presents maps showing lead exposure across Canada. Because of the graphic presentation, some readers may be tempted to focus only on these results. This would be a mistake. Each of the studies refers to samples (e.g. of waterfowl tissues like wings, gizzards and blood; of bottom sediments; or of incapacitated eagles), and samples are subject to error. It is important not to infer too much from a small amount of information, and to appreciate underlying assumptions made by the researchers. Dickson and Scheuhammer provide a useful discussion of the reliability of their assumptions. Their paper should be read as a large-scale overview of lead exposure in ducks, but it must be supplemented by the detailed information given in the other papers.

Also bear in mind that the studies in this report are not meant to quantify the mortality of waterfowl due to lead shot, much less to compare "birds saved" from

lead poisoning with "birds lost or saved" from a change in ammunition. A complete assessment of the overall impact on waterfowl populations of a Canadian decision to ban or allow lead shot in a certain zone, would be difficult for several reasons. First, the link between exposure to lead and mortality in wild birds is not well understood. There are examples of significant exposure apparently without significant mortality (e.g. Pintails, in Deuel 1985 - but note that in other conditions Pintails have proven susceptible to lead poisoning). Response appears to be vary widely with diet, climatic conditions, and species. Second, the impact of mortality from lead poisoning on the next season's breeding populations can probably not be measured, given the relative lack of success biologists have had in identifying a population effect from hunting mortality (e.g. Anderson 1976: in all estimates for hunted species, hunting mortality is much higher than that due to lead poisoning). Third, efforts to assess crippling loss differences among shot types have been ambiguous and controversial. The difficulties come from the measurement of crippling loss itself. Some of the best experiments on crippling loss have mostly demonstrated the high cost of obtaining samples, and the high variability in different hunting locations (e.g. Nieman et al. 1987). In view of these complications, the net effect on duck populations of lead shot vs. its alternatives in places with low lead exposure can only be speculated upon.

### **Future Directions**

The advisability of establishing additional regional bans or a national ban on the use of lead shot for waterfowl hunting is still in question. The purpose of this technical report is to provide information on where there is detectable risk of lead exposure in waterfowl. Public concern about the lead shot issue, the ability to enforce regulations, and the development of new alternative kinds of shot will all be important additional considerations.

The Canadian Wildlife Service will work to ensure that at least those areas that exhibit a significant risk of lead poisoning will be included in non-toxic shot zones. This will be accomplished through the normal process of consultations with provinces and other groups involved in the development of annual hunting regulations for migratory birds. This strategy will reduce lead poisoning of waterfowl to a negligible proportion of present values. The non-toxic shot zones may also be extended to areas where waterfowl are believed to be only minimally exposed to lead shot, according to the approach taken in each province.

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# CONCENTRATIONS OF LEAD IN WING BONES OF THREE SPECIES OF DUCKS IN CANADA

K.M. Dickson and A.M. Scheuhammer, Canadian Wildlife Service, Ottawa

## Abstract

Wing bones from immature Mallards, American Black Ducks, Mallard-Black duck hybrids (total sample 8692) and Ring-necked Ducks (821) were collected as part of the 1988 and 1989 National Harvest Survey (NHS). Dissolved wing bones were assessed for lead concentration by flame atomic absorption spectrophotometry. Frequency distributions of number of wings vs lead concentration were plotted and used to determine values for elevated lead levels ( $\geq 10$  mg/kg). Geographic distribution of elevated lead was mapped using SPANS, and overlaid on a map of hunting intensity determined from the NHS. Areas showing both high hunting intensity and elevated lead levels were identified as being prone to problems with lead contamination of waterfowl. Areas in each province except Saskatchewan were identified, and could be considered for non-toxic shot zoning.

## Introduction

Ingestion of lead shotgun pellets is an important source of lead for waterfowl. Lead poisoning can cause physiological disturbances of the digestive, circulatory and nervous systems that may eventually result in death. A detailed description of symptoms can be found in Sanderson and Bellrose (1986). Additional sources of lead to which waterfowl may be exposed include by-products of copper and nickel mining, waste tailings around lead mining areas, refineries, embedded lead shot and automobile fuel. However, ingestion of lead shot seems to be the major source of lead intoxication in waterfowl (Sanderson and Bellrose 1986).

The objectives of this paper are to examine the geographic distribution of elevated concentrations of lead in wing bones of juvenile ducks across Canada, and to identify areas where elevated concentrations of lead and intensive hunting co-occur.

## Methods

### Concentration of lead in wing bones

To evaluate the exposure to lead of wild ducks across Canada, wing bones were collected from immature Mallards, American Black Ducks, Mallard-American Black Duck hybrids and Ring-necked Ducks. These were submitted by hunters as part of

the 1988 and 1989 Wing and Tail Parts component of the National Harvest Survey (NHS) of the Canadian Wildlife Service. The age of the birds was determined by experienced biologists. Each hunter provided the sample location as a distance and direction from the nearest post office. These values were converted to a latitude and longitude describing the location of kill for each bird.

Only juvenile ducks were used so that the concentrations of lead could be attributed to exposure experienced in Canada during the first few months of life. Wing bones (radii) were excised, cleaned of associated muscle tissue, freeze-dried, weighed and digested in high-purity nitric acid under clean laboratory conditions. Any damaged bones were discarded. The concentration of lead in the bones was measured by flame atomic absorption spectrophotometry. These methods will be described in greater detail in subsequent reports.

Frequency distributions were calculated to examine the differences in concentrations of lead in wing bones among species and between the two years. The distributions were plotted as the number of wing bones against the concentration of lead in the wing bones. The similarity of this distribution between years for each species was tested using the goodness of fit described by Sokal and Rohlf (1981), as was the similarity of the distribution among species. The distributions were also used to determine the concentration that would be used in further analyses to indicate "elevated" levels of lead.

The geographic distribution of the incidence of elevated concentrations of lead in wing bones of ducks was mapped. For this analysis, the data were summarized by blocks measuring 10 minutes of latitude by 10 minutes of longitude (referred to as "10-minute blocks"). These areal estimates were treated as point data situated at the latitude and longitude of the centre of each 10-minute block.

#### Spatial distribution of hunting intensity

The number of days spent hunting ducks each season is estimated as part of the questionnaire component of the annual NHS. Hunters are asked to provide information on their hunting habits and success (e.g. how many days were spent hunting ducks, and the most often used location for hunting ducks). The number of duck hunter-days for each 10-minute block was calculated from this information. It is important to note that these estimates of hunting intensity represent only hunters that hold a Migratory Game Bird Hunting Permit; thus, kill by native people, who do not need permits, and illegal hunting are not included.

The average estimated hunter-days from 1972 to 1988 inclusive within each 10-minute block was used. This data set covered a significantly longer time period than the two years of wing collection. We wanted to minimize the number of blocks with unknown levels of hunting so as to distinguish blocks where there is no hunting

from those where hunting does occur but was not sampled. A block that did not show any hunting over the 17 years of the survey was considered to never have any hunting activity. Thus, blocks were required to have had at least 1 duck hunter-day between 1972 and 1988 to be considered in the following analyses. Again, the data were assigned the latitude and longitude of the centre of the 10-minute block.

A frequency distribution of the number of duck hunter-days was calculated to help identify the level of hunting that would be described as "intensive". The geographic distributions of resulting categories of hunting intensity were mapped.

### Mapping

The Spatial Analysis System (SPANS) was used to examine the spatial distributions of hunting intensity and of the frequency of elevated lead concentrations in wing bones. SPANS interpolates point data to create a smoothed or averaged surface that can be interpreted as a thematic map. POTMAP (Potential Mapping) starts with the assumption that the value of any point is related to the points around it and is less related to points farther away (Intera Tydac 1991).

The methodology is based on overlaying sampling circles. An averaged value is calculated for all point values falling within the circles and becomes the new value associated with the point at the centre of the sampling circles. The user specifies the value of parameters that describe how large the circles should be and the formula for weighting of neighbouring points. Alpha is the radius of an inner circle wherein all points are weighted equally, gamma is the radius of the sampling circle wherein all points are not weighted equally, and beta is the function that specifies how the points inside gamma will be weighted. The number of nearest neighbours to be used in the averaging process is also specified.

The data points were located at the centre of 10-minute blocks of latitude and longitude. As one moves north, the distance between lines of longitude decreases, so 10-minute blocks in the south are slightly larger than those farther north. In the area of the northernmost wing receipts, adjacent east-west points were separated by approximately 11.22 km, and adjacent north-south points were about 18 km apart. Alpha (the radius of the inner circle) was chosen to be 5.6 km (giving a diameter of 11.2 km, which was slightly less than the distance between points). This allowed the value of each centroid point to be retained while at the same time providing the required sense of "area" (rather than appearing as a point) for display purposes. Averaging, or smoothing, was not required, because each data point was a composite of all wings in a 10-minute block. Therefore, gamma (the radius of the sampling circle) was also chosen to be 5.6 km, and beta, the weighting factor, was equal to 1. Because gamma was also less than the distance between points, there was no smoothing of values according to the value of nearest neighbours.

Classification systems for the maps were based on the frequency distributions described earlier. Interpolated maps of hunting intensity and of the frequency of elevated concentrations of lead in wing bones were produced individually for dabbling ducks (Mallards and American Black Ducks combined) and Ring-necked Ducks. To compare the correspondence of hunting intensity with elevated concentrations of lead, these maps were combined using the Overlay procedure of SPANS. Overlay maps were created for Mallards in western Canada and for dabblers (Mallards plus American Black Ducks) and Ring-necked Ducks in eastern Canada. Ring-necked Ducks were treated separately from dabbling ducks because of the relatively high concentrations of lead in their wings.

## Results

### Concentration of lead in wing bones

In total, 5 322 Mallards, 3 300 American Black Ducks and 70 Mallard  $\times$  American Black Duck hybrids were represented in the sample. The distribution of the total number of dabbling duck wings sampled from each degree-block is shown in Figure 1. The sample showed good coverage of the settled portion of the country. A total of 821 Ring-necked Ducks was submitted throughout eastern Canada (from provinces east of, and including, Ontario).

The individual frequency distributions of the concentration of lead in wing bones of both Mallards and American Black Ducks were similar in each year (for Mallards,  $g=4104.82$   $df=4$ ; for American Black Ducks,  $g=13.12$   $df=4$ ) and to each other ( $g=18.81$   $df=4$ ). The data for both species in both years are hereafter combined as "dabbling ducks" (Figure 2). Based on the shape of the distribution curves, lead concentrations of  $\geq 10$  mg/kg (about 17% of the wing bones) were considered to be elevated.

The distribution of the concentrations of lead in wing bones of Ring-necked Ducks also appeared to be similar between years ( $g=19.62$   $df=4$ ). Figure 3 shows the data for Ring-necked Ducks with the two years combined.

The proportional distribution of the lead concentrations in wing bones from dabbling ducks and Ring-necked Ducks for each province is shown in Table 1. Categories were based on the distribution of lead in the wing bones of dabbling ducks. The first category represents the 8% of birds with very low bone lead concentrations. The second category contained 75% of the sample and represents the remainder of the birds that had lead concentrations below 10 mg/kg. Nationally, about 83% of the wing bones from Mallards and American Black Ducks contained lead concentrations of  $< 10$  mg/kg. Elevated concentrations of bone lead ( $\geq 10$  mg/kg) were found in 17% of the wing bones (Table 1).

There were some differences among provinces (Table 1). The Prairie provinces had a smaller proportion (6-11%) of wing bones with elevated bone lead compared to the average values for Canada ( $g=90.49$   $df=1$ ). In contrast, a higher than average proportion of wing bones from dabbling ducks in eastern Canada (with the exception of Newfoundland) exhibited elevated concentrations of lead ( $g=15.63$ ,  $df=1$ ) (Table 1).

The sample of wing bones from Ring-necked Ducks came primarily from eastern Canada. Only 52% of the sample had  $<10$  mg/kg of lead in the wing bones, and, of the remainder, 28% showed bone lead concentrations in excess of 20 mg/kg (Table 1).

### Hunter-days

Figure 4 shows the frequency distribution of the average number of duck hunter-days per year in each 10-minute block. About 3% of the blocks averaged more than 2000 hunter-days (where the plot was intentionally stopped). Break points were not obvious in this data set. However, the shape of the curve began to level off at about 500 duck hunter-days per year. This value was selected as the threshold above which hunting would be considered intensive. About 30% of the blocks where there is some hunting fell into the intensive category.

### Comparison of hunter-days with incidence of elevated lead

Maps showing the geographic distributions of incidence of elevated bone lead concentrations and of hunting intensity were combined to show the areas where high incidence of elevated bone lead and intensive hunting coincided. As noted above, intensive hunting was defined as an average of 500 or more duck hunter-days per year. Blocks with fewer than 500 duck hunter-days per year were assigned a low level of hunting intensity. High incidence of elevated lead was indicated at locations where at least 10% of the sample contained  $\geq 10$  mg/kg of lead. Otherwise, the block was assigned a low lead incidence. Figures 5, 6 and 7 show the results of the overlays of hunting intensity and incidence of elevated bone lead concentrations. More detail is provided in Appendix A, page 24, for specific regions where there were large samples.

The map illustrated in Figure 5 shows that, for immature dabbling ducks in eastern Canada, the areas of high hunting intensity and high incidence of elevated lead concentrations in wing bones included, by province:

Province	Areas of High Hunting and Elevated Lead Concentrations
Newfoundland	four small areas on the east coast (the three northernmost spots were each represented by <5 wings)
Prince Edward Island	large parts of the island
Nova Scotia	near Sydney, around Halifax, near Wolfville, in the southwest and the border marsh with New Brunswick
New Brunswick	the Saint-John River Valley, the border marsh with Nova Scotia and the area of Neguac
Québec	an area near Gaspé, the southeast end of Lac Saint-Jean, in the area of Baie-Comeau, along both shores of the St. Lawrence River from the Ile d'Orléans and the city of Québec to the Ontario border
Ontario	areas just west of Ottawa, around Cornwall, Kingston and the Rideau Lakes, Lake Simcoe and surroundings, Long Point and surroundings, the Lake St. Clair area, around Sudbury and North Bay and around Sault Ste. Marie

In western Canada, the areas of high hunting intensity and high incidence of elevated lead concentrations in juvenile Mallard wing bones (Figure 6) included, by province:

Province	Areas of High Hunting and Elevated Lead Concentrations
Manitoba	an area at the south end of Lake Winnipeg, the south parts of the Shoal Lakes, the south end of Lake Manitoba, an area around Hecla and Riverton and another around The Pas
Saskatchewan	no such areas
Alberta	four areas in the south near Calgary and Brooks (based on <5 wings each), an area just north of Buffalo Lake and three areas east of Edmonton near Beaverhill and Miquelon Lakes
British Columbia	near Duncan on Vancouver Island, in the area of the Fraser River Delta and its tributaries approximately as far as the town of Hope

Figure 7 shows the overlay of hunting intensity with frequency of elevated concentrations of lead for Ring-necked Ducks. The locations of areas showing both intensive hunting and high incidence of elevated lead concentrations were similar to those for dabbling ducks.

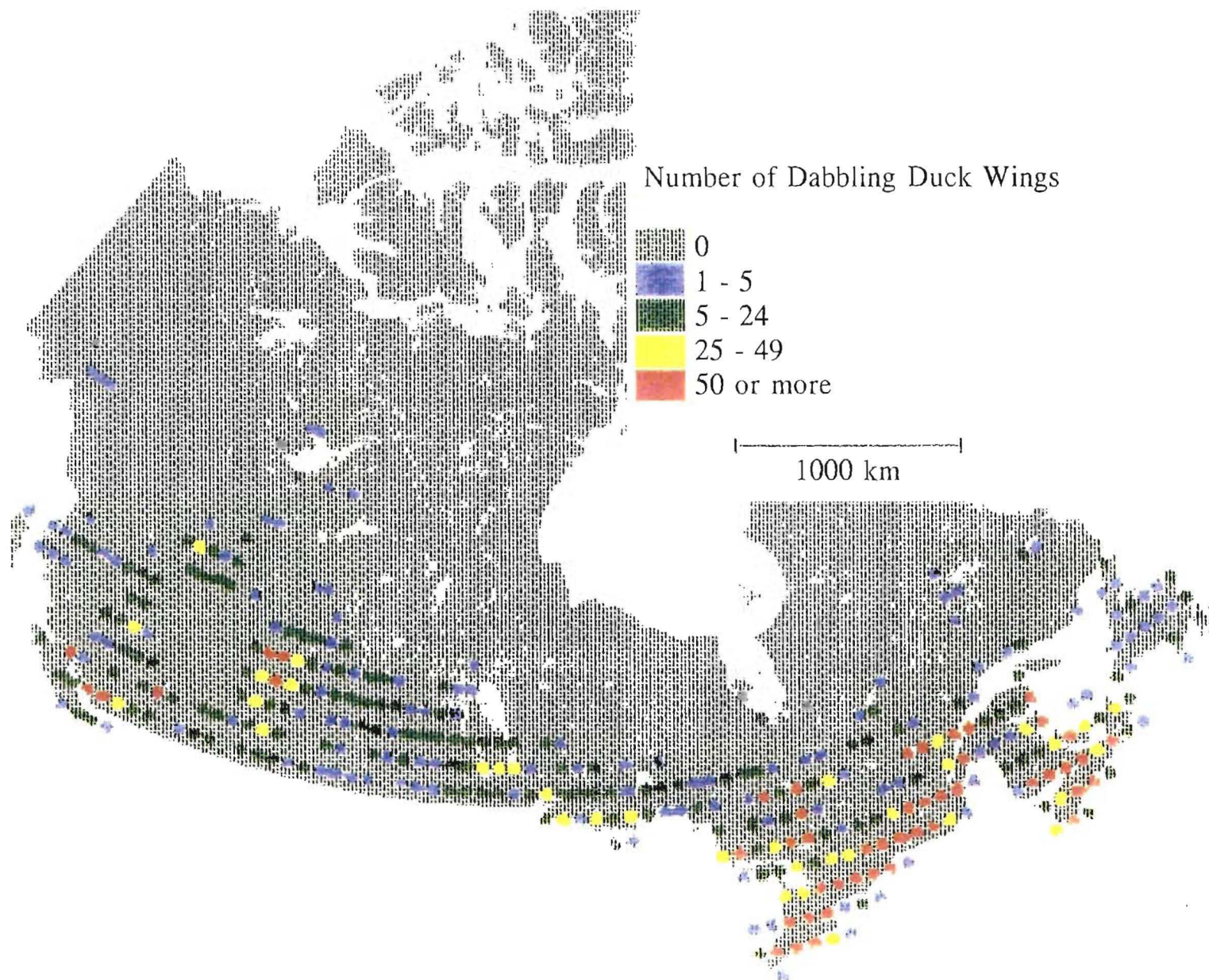


Figure 1. Number of Mallard, American Black Duck and Mallard  $\times$  American Black Duck hybrid wing bones analyzed, by degree-block.

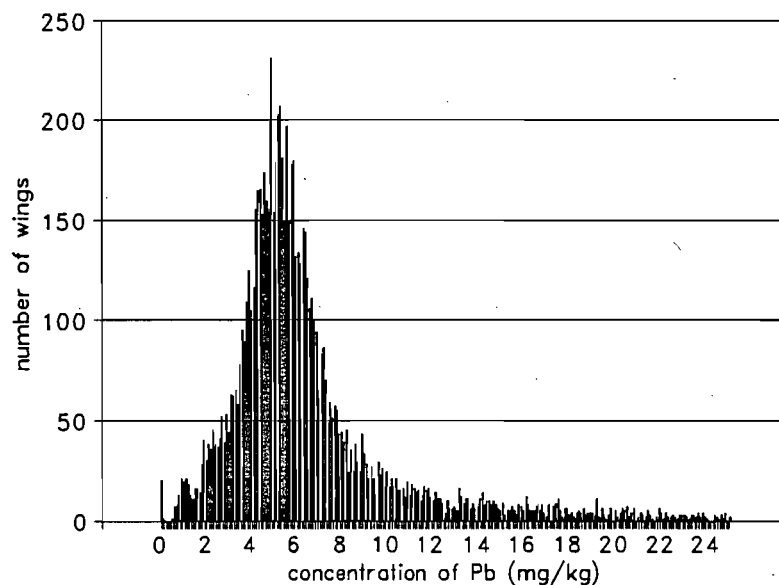


Figure 2. Frequency distribution for the concentration of lead in wing bones of Mallards and American Black Ducks (with  $\leq 25$  mg/kg of lead).

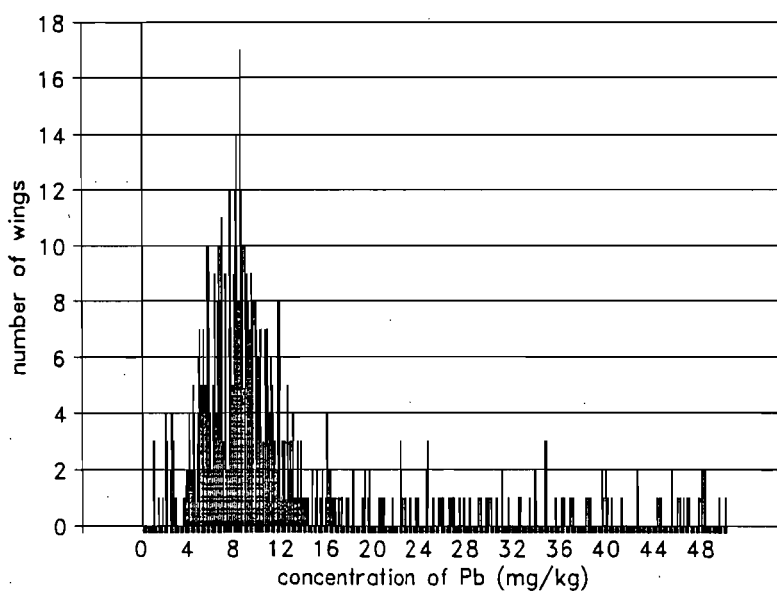


Figure 3. Frequency distribution for the concentration of lead in wing bones of Ring-necked Ducks (with  $\leq 50$  mg/kg of lead).

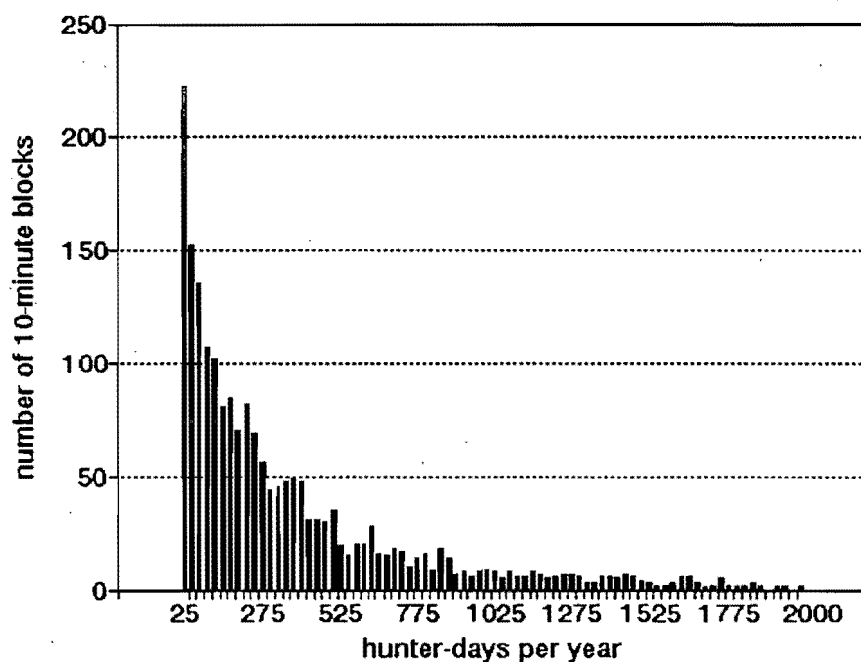


Figure 4. Frequency distribution for average annual hunter-days per 10-minute block of latitude and longitude (those with  $\leq 2000$  hunter-days).

# Legend

- unknown
- low lead, low hunting
- low lead, high hunting
- high lead, low hunting
- high lead, high hunting

500 km

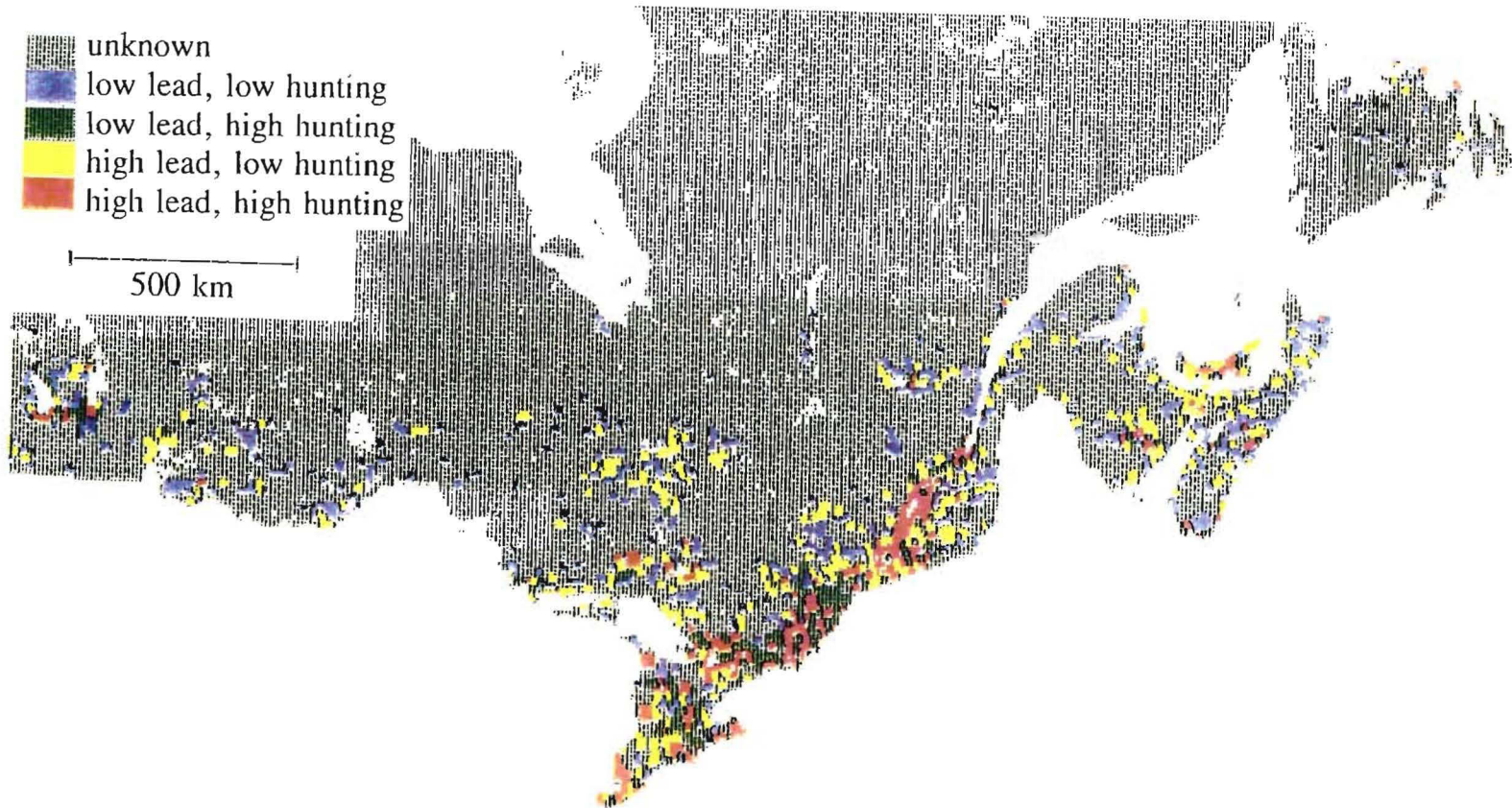


Figure 5. Geographic distribution, in eastern Canada, of the average number of hunter-days in a 10-minute block overlaid with the incidence of elevated lead levels in Mallard and American Black Duck wing bones.

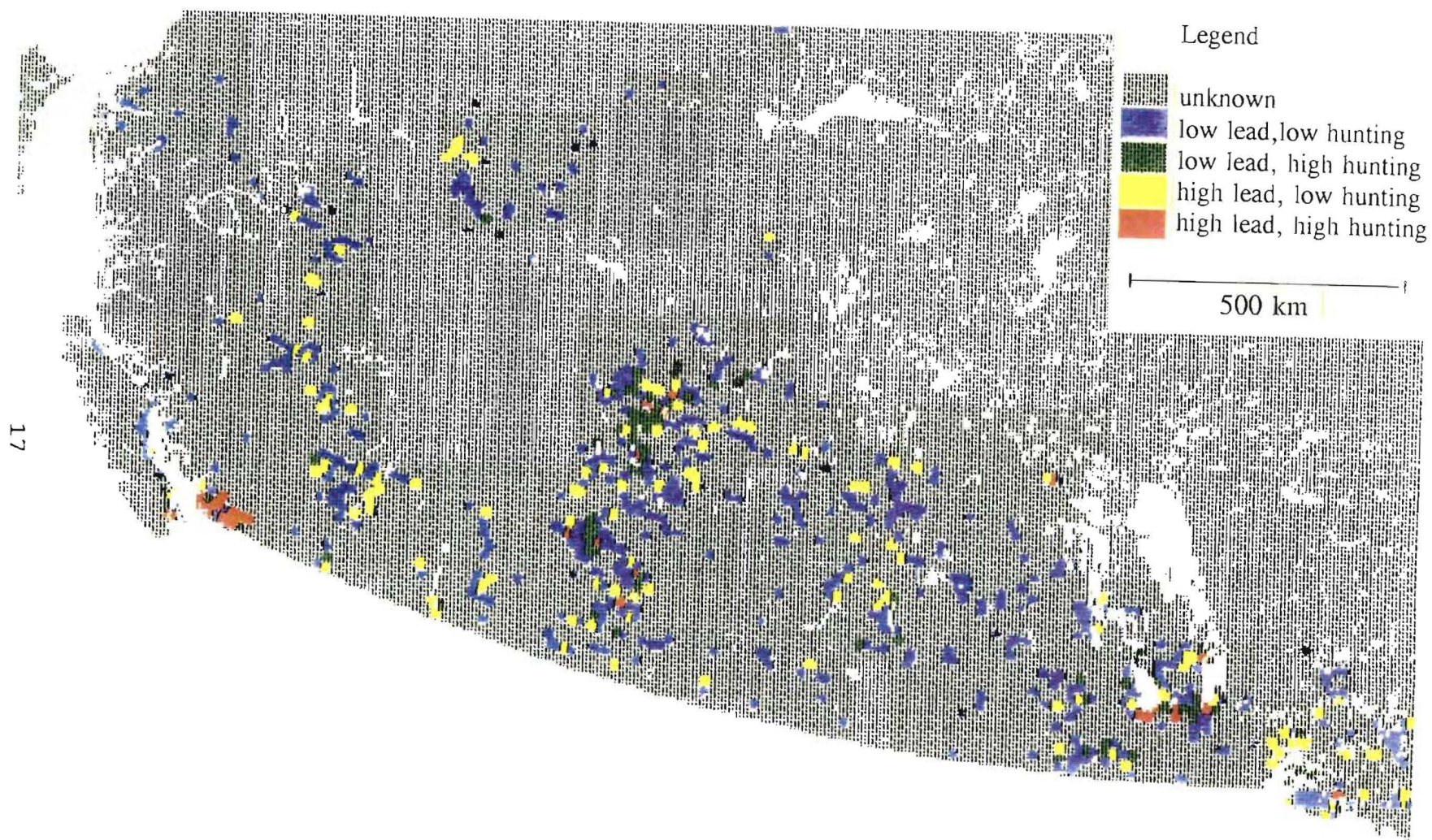


Figure 6. Geographic distribution, in western Canada, of the average number of hunter-days in a 10-minute block overlaid with the incidence of elevated lead levels in Mallard and American Black Duck wing bones.

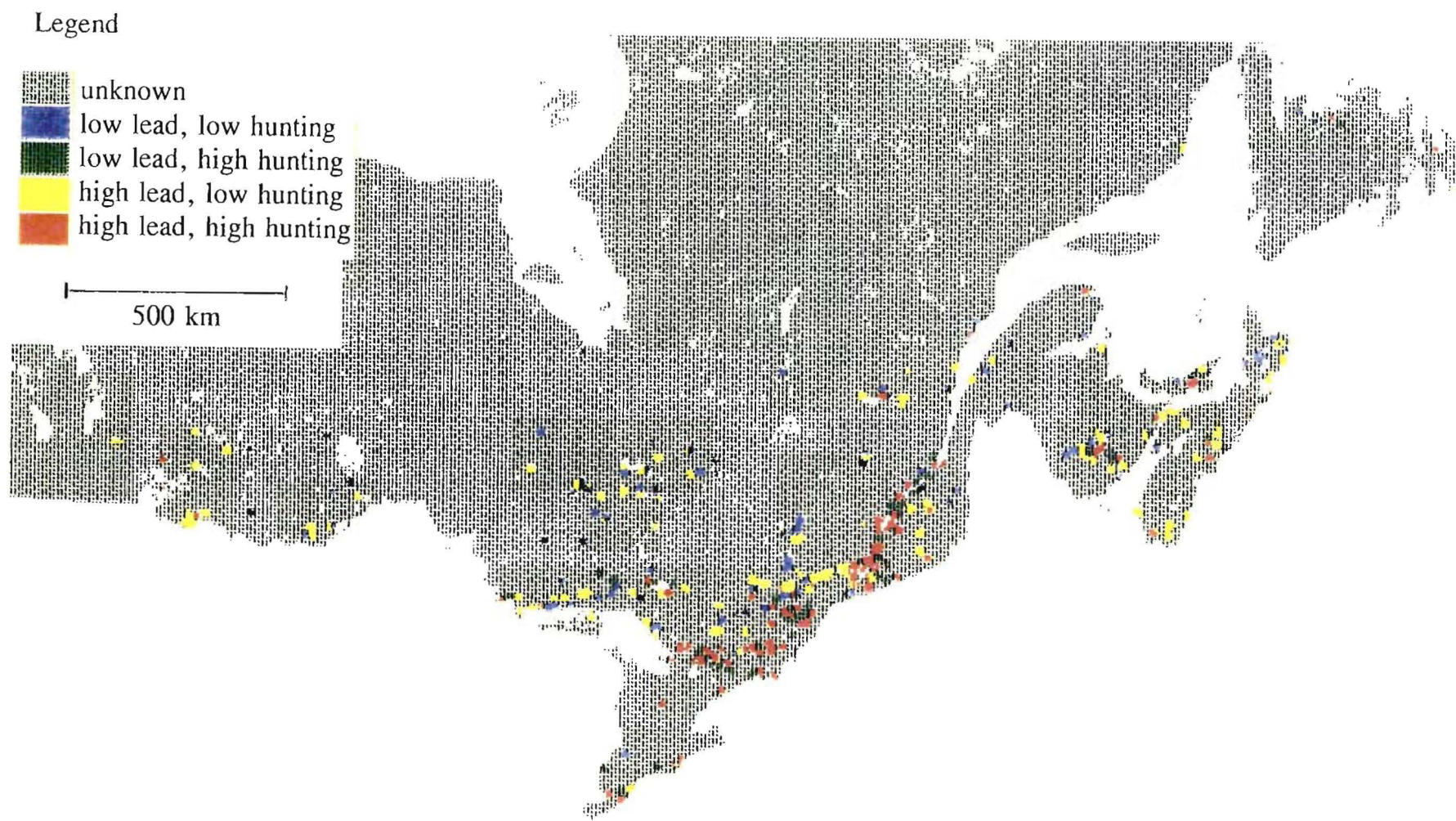


Figure 7. Geographic distribution, in eastern Canada, of the average number of hunter-days in a 10-minute block overlaid with the incidence of elevated lead levels in Ring-necked Duck wing bones.

Table 1. Proportional distribution of lead concentrations in wing bones (values are percentages).

Province	Dabbling Ducks					Ring-necked Duck				
	No. of wings	≤2.99 mg/kg	3.00-9.99 mg/kg	10.00-19.9 mg/kg	≥20 mg/kg	No. of wings	≤2.99 mg/kg	3.00-9.99 mg/kg	10.00-19.9 mg/kg	≥20 mg/kg
BC	1097	12	72	9	7	12	8	33	33	25
AB	690	7	86	4	2	1	0	100	0	0
SK	214	8	83	4	4	0	0	0	0	0
MB	326	7	83	7	4	8	12	50	13	0
ON	2429	5	75	12	8	354	4	55	14	27
QC	2408	7	75	11	8	259	8	42	27	23
NB	471	10	70	11	9	82	1	39	27	33
NS	787	12	73	10	4	60	7	37	25	31
PI	126	8	67	13	12	23	4	26	5	65
NF	120	12	78	8	2	20	5	70	10	15
NT	15	13	73	0	13	2	0	0	100	0
YK	9	22	78	0	0	0	0	0	0	0
Canada	8692	8	75	10	7	821	5	47	20	28

## Discussion

The utility and validity of defining areas of concern by overlaying patterns of intensive hunting with high incidence of elevated bone lead depend on the following assumptions:

Lead was ingested near the location at which the bird was killed.

Lead accumulates rapidly in bone following exposure. Stendell et. al. (1979) reported that lead concentrations in bones became elevated within 24 hours of lead shot ingestion. Also, lead in bone tissue is stable; once elevated concentrations have accumulated, they will remain elevated indefinitely. This may pose a problem, in that birds could accumulate elevated bone lead concentrations and then move to other locations before being shot by hunters. It is unlikely, however, that the overall incidence of elevated lead concentrations would be high in areas where substantial shot ingestion (or other sources of elevated lead exposure) does not occur, whereas mean lead concentrations should be elevated in areas where shot ingestion regularly occurs. This expectation is corroborated by the fact that areas already known to be "hot spots" of shot ingestion (e.g. Lake St. Clair, Ontario) are reliably identified in this wing bone survey.

An incidence of  $\geq 10\%$  of samples with  $\geq 10$  mg/kg of lead in bone is indicative of an area where elevated lead exposure is likely to occur.

The value of 10 mg/kg as a threshold defining "elevated" concentrations of lead is supported from both a statistical (the shape of the frequency distribution (Figure 2)) and an experimental perspective. Waterfowl that have not experienced significant lead exposure generally have  $< 10$  mg/kg lead in their bones, whereas those known to have ingested shot, as well as those purposely dosed with shot, almost invariably accumulate  $> 10$  mg/kg (Anderson 1975; Finley et al. 1976; Szymczak and Adrian 1978). This principle is true for other bird species as well. Eagles dosed with No. 4 lead shot contained an average of 10 mg/kg lead in tibias (Pattee et al. 1981), whereas a variety of seabird species sampled in areas remote from potential sources of lead exposure had bone lead concentrations averaging  $< 5$  mg/kg (Elliott et al. 1992).

The value of 10% incidence is based on the criteria for zoning listed by the Canadian Wildlife Service (CWS 1990), which indicate that an area should be zoned for non-toxic shot if the incidence of elevated blood lead or other equivalent measures of high lead exposure exceeds 10%. For the purposes of the present study, we considered a 10% incidence of high bone lead to be roughly equivalent to a 10% incidence of elevated blood lead.

There is a link between elevated concentrations of lead in bones and symptoms of lead poisoning.

This assumption is supported by numerous studies. For instance, adult Mallards dosed with two No. 4 shot demonstrated acute neurological signs of lead poisoning within 24 hours and accumulated concentrations of lead in their bones that exceeded their pre-dosing levels by about 10 mg/kg (Mautino and Bell 1987). The bone lead concentrations of geese that either were reared in captivity or were non-lead-poisoned wild birds ranged from 2 to 11 mg/kg, whereas the concentrations in birds deemed to have been lead poisoned ranged from 7 to 389 mg/kg (Szymczak and Adrian 1978). Wing bones of Lesser Scaup found dead or dying of lead poisoning contained 12-138 mg/kg of lead (Anderson 1975).

It should be noted that very high ( $> 100$  mg/kg) concentrations of bone lead frequently reported for waterfowl found dead of lead poisoning are not represented in the present survey of dabbling ducks because: 1) all of our samples were hunter-shot birds, thus none had died of lead poisoning; and 2) all of our samples are from juvenile birds, therefore we expect that their bone lead concentrations should be very low in the absence of shot ingestion. We would not have this expectation in the case of adult birds, which could conceivably accumulate high bone lead concentrations through gradual, long-term exposure. Although we do not have access, in the present survey, to birds that have died of lead poisoning, we assume that those areas having a high incidence of elevated bone lead ( $> 10$  mg/kg) are the same areas where the relative risk of lead poisoning is also high.

An average of 500 hunter-days or more each year in a 10-minute block is a useful indicator of intensive hunting.

A 10-minute block covers about 234 km<sup>2</sup> at 44°N latitude and decreases in size to about 200 km<sup>2</sup> at 55°N latitude. An average of 500 hunter-days per year represents about 2-2.5 hunter-days for each square kilometre. Because of the effect of decreasing size of 10-minute block with increasing latitude, the value ranges from about 2.1 in more southerly areas to 2.5 at about 53°N.

Hunting tends to be concentrated spatially, as good hunting spots within a block of land are clumped rather than uniformly distributed. Given this, the true density of hunters would be higher than that estimated above. Hunting is also concentrated temporally, with heavier hunting intensity taking place early in the season. This means that more pellets are deposited early and are available for ingestion as the season progresses.

The sample size was low ( $< 5$  wings) in some 10-minute blocks. In such areas, the blocks tended to have low hunting intensity, with either high or low

incidence of elevated lead concentrations. However, in other cases, blocks of "high days/high lead" were based on few wings. Examples are seen in southern Alberta and in coastal Newfoundland. Field studies are needed to look carefully at these locations.

Some areas exist where the incidence of elevated concentrations of lead in dabbling ducks was significant even though hunting intensities were relatively low ("low days/high lead"). Examples are areas of metal mining activity on the Canadian Shield in Ontario and Quebec, and parts of Saskatchewan and Alberta. In some cases, the high incidence of elevated lead concentrations might have resulted from shot deposited by hunters not requiring permits (and thus not sampled) or from harvest of immature birds that have moved away from the area where the lead shot was ingested. Also, very localized spots of intensive hunting may not have been detected by this analysis. In other cases, birds with high bone lead concentrations may have been adults that were misidentified as immature birds. S. Wendt (pers. comm.) estimated, based on rates of misclassification, that it would not be unreasonable for 2-3% of the wings in this study to have been from adult birds that have been exposed to lead in staging and wintering areas in the United States. Non-hunting, as well as hunting, sources of lead in regions of "low days/high lead" are the subject of another paper in preparation.

Concentrations of lead in wing bones of Ring-necked Ducks were much higher than the concentrations of lead in dabbling duck wing bones. It has been observed in gizzard samples that Ring-necked Ducks, and some other diving species, typically have a higher ingestion rate for lead pellets (Sanderson and Bellrose 1986), and it has been suggested that diving ducks feeding on items rich in protein are less susceptible to lead poisoning. Our analysis shows that lead is physiologically available to Ring-necked Ducks and that it accumulates in bone. In fact, one-half of the Ring-necked Duck sample had bone lead concentrations of  $\geq 10$  mg/kg. Areas of "high days/high lead" for Ring-necked Ducks appeared to coincide well with similar areas for dabbling ducks.

Establishment of non-toxic shot zones should result in a substantial decline in the frequency of elevated lead exposure in waterfowl. A second, future survey of lead in waterfowl wing bones would be a useful tool to monitor the effectiveness of non-toxic shot zones.

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## Appendix A

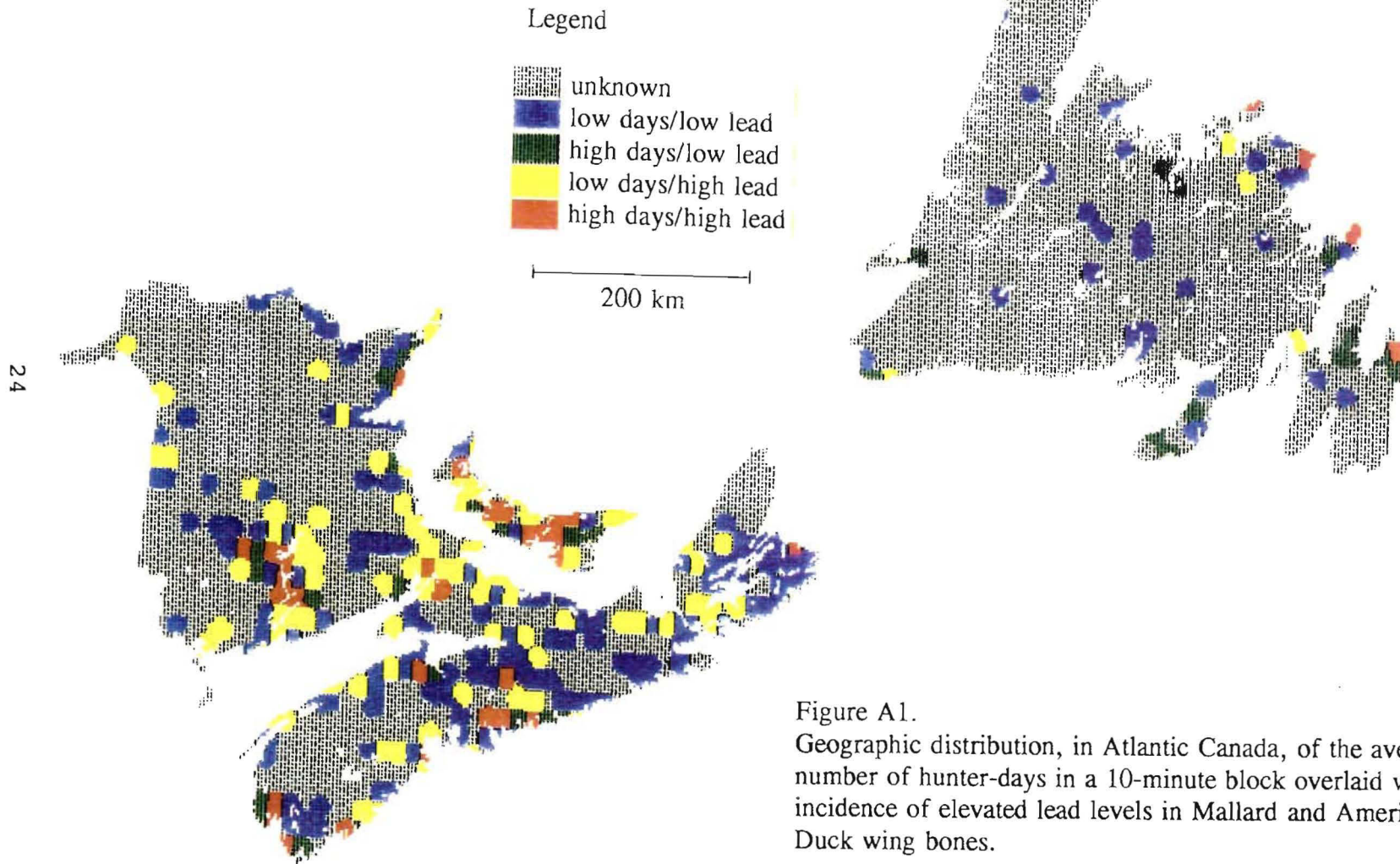


Figure A1.  
Geographic distribution, in Atlantic Canada, of the average number of hunter-days in a 10-minute block overlaid with the incidence of elevated lead levels in Mallard and American Black Duck wing bones.

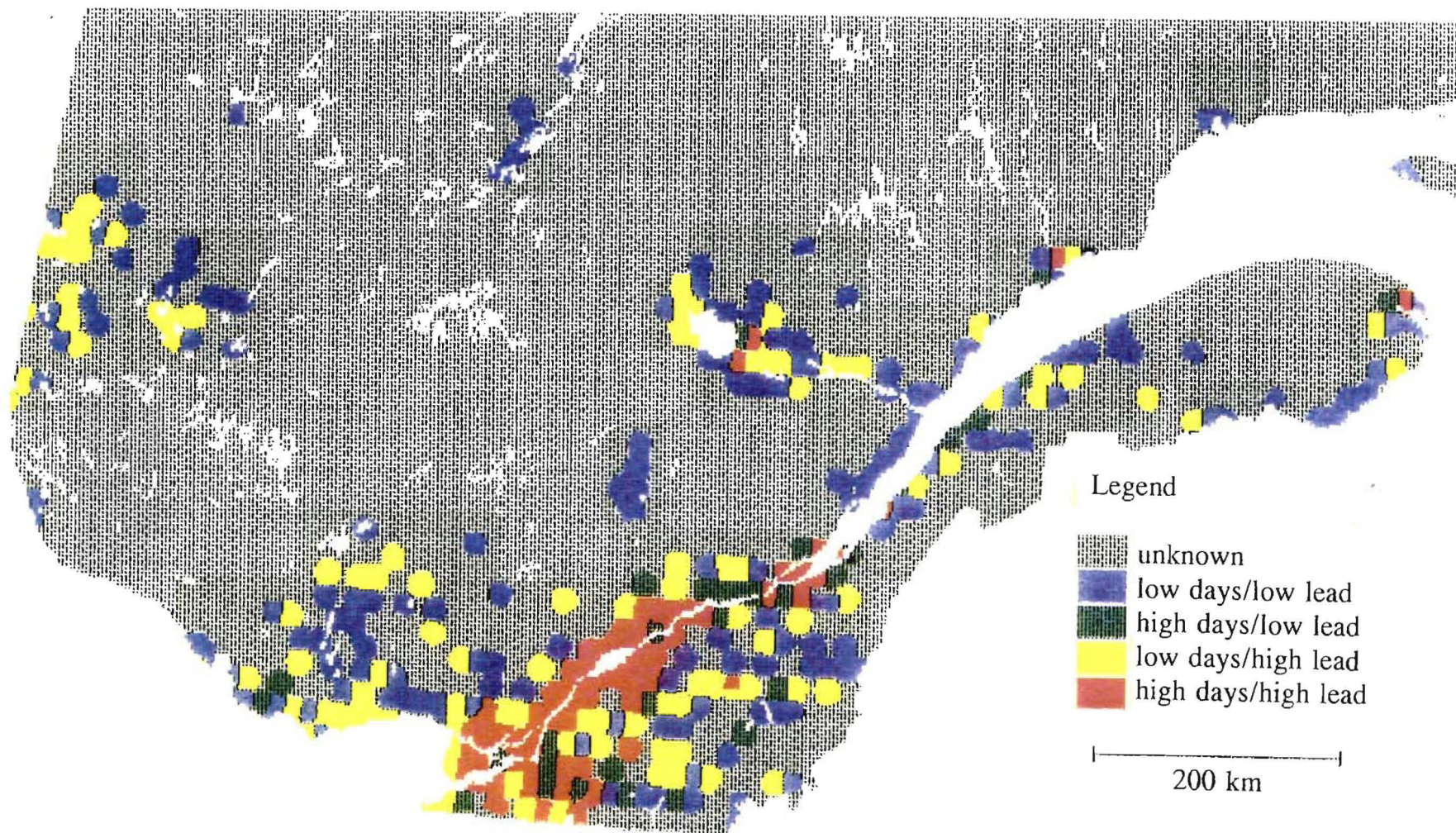


Figure A2. Geographic distribution, in southern Quebec, of the average number of hunter-days in a 10-minute block overlaid with the incidence of elevated lead levels in Mallard and American Black Duck wing bones.

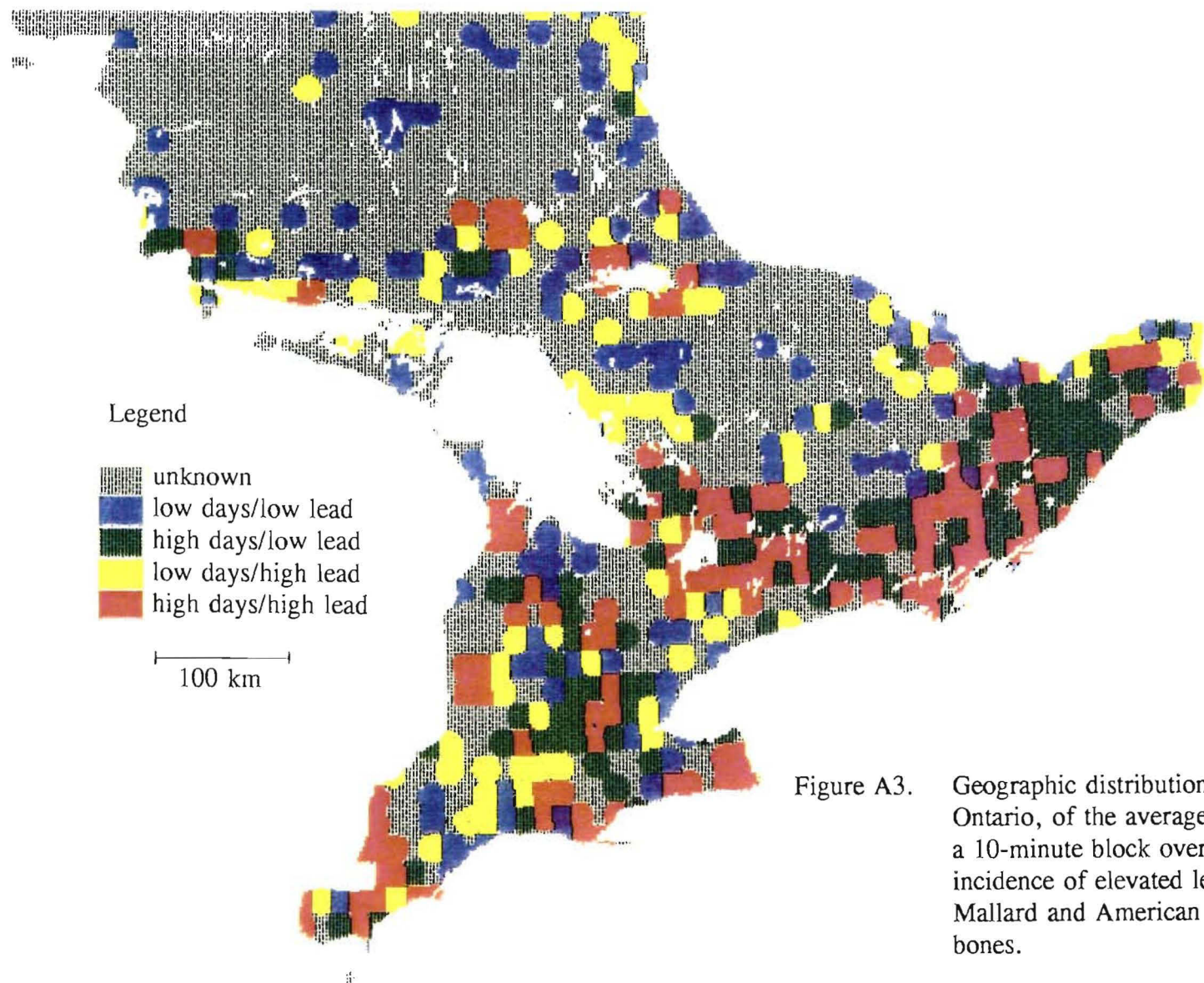


Figure A3. Geographic distribution, in southern Ontario, of the average number of days in a 10-minute block overlaid with the incidence of elevated lead levels in Mallard and American Black Duck wing bones.

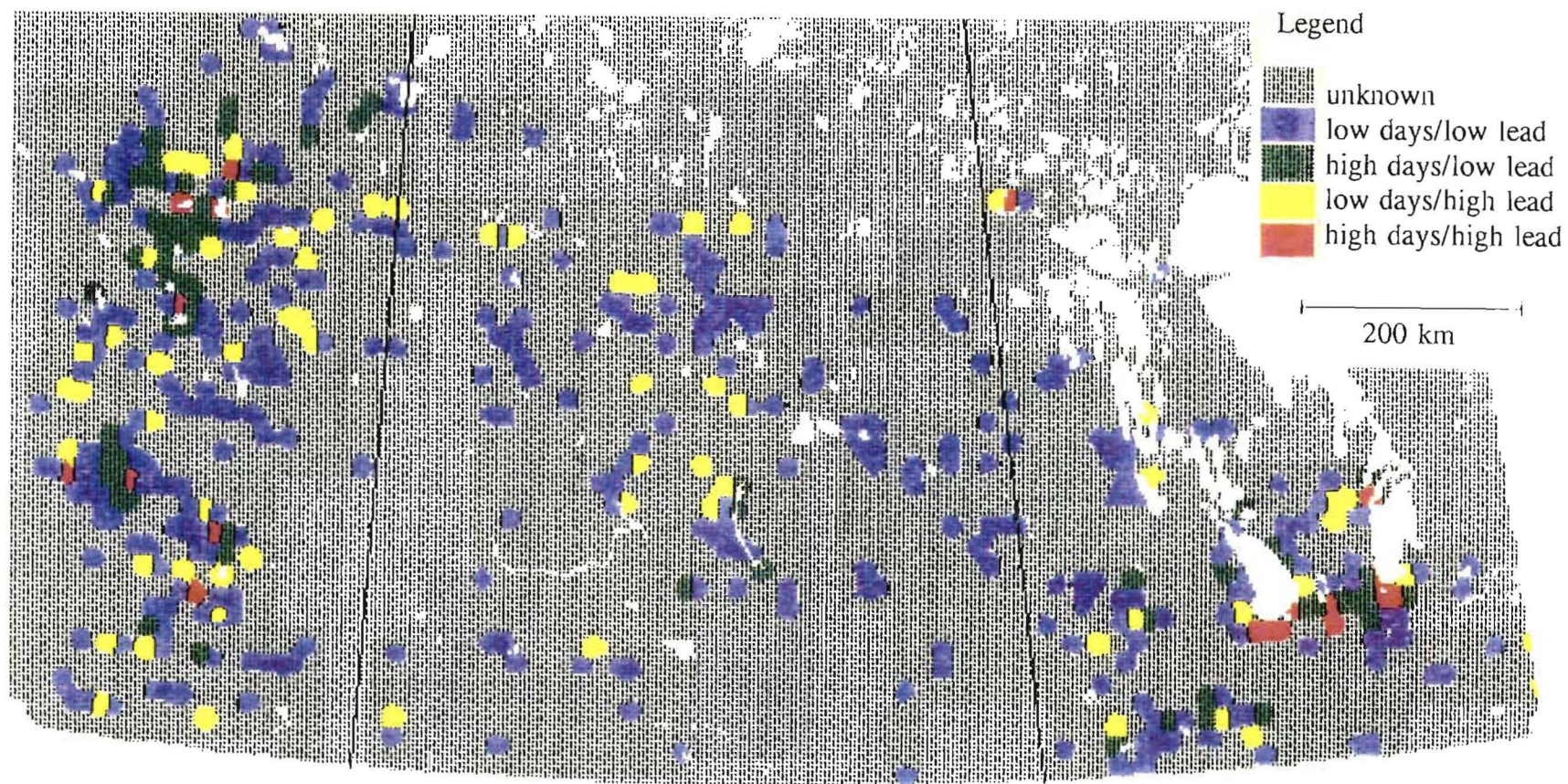


Figure A4. Geographic distribution, in the Prairie provinces, of the average number of days in a 10-minute block overlaid with the incidence of elevated lead levels in Mallard wing bones.

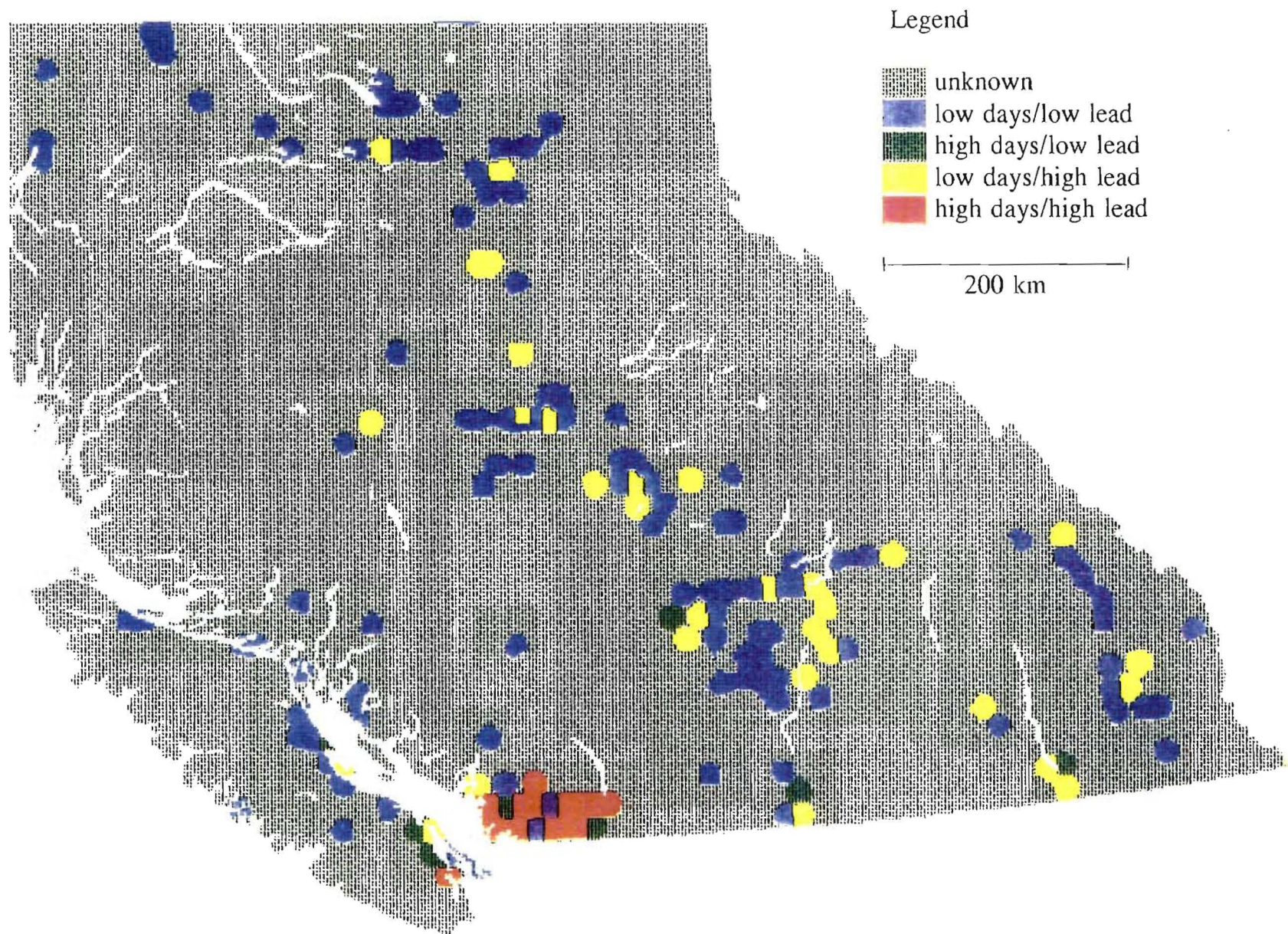


Figure A5. Geographic distribution, in southern British Columbia, of the average number of days in a 10-minute block overlaid with the incidence of elevated lead levels in Mallard wing bones.

# **INCIDENCE OF LEAD CONTAMINATION IN WATERFOWL AND OF LEAD POISONING OF BALD EAGLES FROM BRITISH COLUMBIA, 1988-91**

Adapted from: Elliott et al. 1992; and Whitehead 1989; additional information provided by P.E. Whitehead and J.E. Elliott from Canadian Wildlife Service, Pacific and Yukon Region

## **Abstract**

X-ray analysis of 487 waterfowl gizzards collected in 1988 and 1989 in southwestern British Columbia indicated 25.6% of Northern Pintail, 20.9% of Mallard, 12.8% of Canada Goose and 10.2% of Snow Goose had lead shot present. The overall mean for all waterfowl samples was 14%. An additional 108 gizzards from the Fraser River estuary were examined for lead shot in the winter of 1990-91. Of the three dabbling duck species examined, 3.7% had ingested lead pellets, and the same percentage contained steel pellets. This is evidence that the ban on the use of lead shot for waterfowl hunting in southwestern British Columbia during the 1990 hunting season had a positive effect. However, lead poisoning of 11 Trumpeter Swans may indicate that species feeding deep into sediments stay at risk for a longer period than water-column or over-bottom feeders.

The cause of death or sickness in 267 Bald Eagles was identified from 1989 to 1991. Lead exposure was determined by evaluating clinical signs, radiographs, pathology, aminolevulinic acid dehydratase (ALA-d) ratios in blood, and lead levels in kidney, liver and bone for a subsample of 65 Bald Eagles. The results indicate that 37% of eagles tested were lead contaminated, with 14% classified as lead poisoned and 23% as lead exposed. The greatest percentage of poisoned/tested birds was received during the months of January to March, when eagles feed heavily on wintering waterfowl. Although the majority of both lead-poisoned and subclinically exposed Bald Eagles came from the non-toxic shot zones, substantial numbers (i.e. 4/9 poisoned birds, 4/15 subclinically exposed birds) came from outside the zones.

## **Introduction**

Lead poisoning has long been known to affect waterfowl populations in the USA (Bellrose 1959; Longcore et al. 1974; Mudge 1983). Although lead concentrations are not biomagnified along the food chain (The Royal Society of Canada 1986), poisoning of Bald Eagles feeding on waterfowl carrying lead pellets was the primary incentive for the ban of lead shot in the USA. Before the present study, the situation in British Columbia was not well known. After cases of lead poisoning of B.C. Bald Eagles were documented in 1986 (Langelier et al. 1991), a study of lead contamination in Bald Eagles and waterfowl was initiated.

## Methods

Waterfowl gizzards were collected from hunters in the Lower Mainland (Westham Island, Boundary Bay, Abbotsford, Pitt River, Fraser River, Shuswap, Creston) and on Vancouver Island near Ladysmith, Nanaimo and Courtenay/Comox, from October 1988 through January 1989. Gizzards were packaged and frozen until examined for the presence of lead shot. Thawed gizzards were opened and the contents washed, dried and packaged individually in plastic bags. The bags were then x-rayed and the presence of lead shot or lead fragments was recorded. Gizzards collected during the winter of 1990-91 from the Fraser River estuary were x-rayed whole and examined for wound channels to separate shot-in shot from ingested shot. Following x-ray, the contents were emptied into aluminum pans and air dried. Steel pellets were retrieved with a magnet and lead pellets were found by visual examination. Total numbers of pellets retrieved from each gizzard were verified by comparison to the x-rays. Ingestion rates of lead pellets were compared between years for Mallard, Northern Pintail and American Wigeon by likelihood ratio chi-square. Fisher's exact test was used to compare historic ingestion rate values with data from 1990-91 for these three species combined.

In winter 1992, 25 carcasses of Trumpeter Swans, one Tundra Swan and one Common Goldeneye were found at Judson Lake, Abbotsford County. Twelve of these birds were necropsied and lead levels in kidneys and livers were measured; eight birds were examined for the presence of lead pellets in their gizzard; acetylcholinesterase level was evaluated for the remaining five birds.

Bald Eagle carcasses were obtained from the B.C. Ministry of Environment, Canadian Wildlife Service (CWS) field workers, wildlife rehabilitators and the public, after media advertisement and communication with different agencies. Autopsies were carried out at the Island Veterinary Hospital, Nanaimo, B.C. Blood samples were taken from sick birds for further analyses of aminolevulinic acid dehydratase (ALA-d) (see Scheuhammer 1989). Samples were stored in nitric acid rinsed cryovials and frozen in liquid nitrogen. Samples from kidneys and bones were stored in acetone/hexane cleaned jars and frozen. Tissue from a subsample of 65 birds was shipped on dry ice to the National Wildlife Research Centre (NWRC, Hull, Que.) for analysis. Sex was determined on post-mortem examination or by hallux claw and bill depth measurement (Bortolotti 1984). Juveniles were distinguished from adults based on moulting sequence (McCollough 1989).

Lead levels in bone were determined by flame atomic absorption spectrophotometer (AAS) and in kidney by graphite furnace AAS, and are expressed on a dry weight (dw) basis. ALA-d activity was determined by the ratio of activated:inactivated enzyme activity to eliminate sources of variation between species (Scheuhammer 1987, 1989).

## Results

### Lead shot in waterfowl gizzards

In 1988 and 1989, the overall incidence of lead shot in waterfowl gizzards from the Lower Mainland and Vancouver Island was 14% (Table 1). The highest proportions were in Northern Pintails (25.6%), Mallards (20.9%) and Canada Geese (12.8%). Sites that showed the highest levels of contamination were, in decreasing order of importance, the Fraser River, Boundary Bay, Pitt River and Westham Island. Historic values for the Fraser River estuary are summarized in Table 2, and are compared to values for winter 1990-91 in Table 3. Lead pellet ingestion rates for Mallards ( $df=7$   $\chi^2=46.0$   $p<0.001$ ), American Wigeons ( $df=6$   $\chi^2=34.0$   $p<0.001$ ) and Northern Pintail ( $df=6$   $\chi^2=17.6$   $p=0.007$ ) varied significantly between years. Ingestion rates in Mallards were low in 1990-91 ( $\bar{x}=5.4\%$ ) compared to previous years ( $\bar{x}=13.1\% \pm 5.2$ ). Mallards ranked second-lowest in ingestion rate, but did not contribute significantly to the chi-square (2.8%), because of the small sample size. For Northern Pintails, occurrence of ingested lead shot in the winter 1990-91 ( $\bar{x}=5.9\%$ ) showed the third highest value, but with a non-significant contribution to the  $\chi^2$  of 2.6%. The mean ingestion rate (%) for Northern Pintails in previous studies was  $\bar{x}=10.0 \pm 11.8$ . The result for American Wigeons ( $\bar{x}=0\%$ ) is similar to the results of previous studies ( $\bar{x}=2.2\% \pm 3.0$ ; 11.2% of the total  $\chi^2$  was due to 1990-91 data). The lead ingestion rate for Mallards, American Wigeons and Northern Pintails from the Fraser River estuary in 1990-91 was the lowest ever recorded (3.7%; equal to the steel pellet ingestion rate), compared to 20.3% in 1988, 4.4% in 1987, 6.9% in 1965-67, 16.3% in 1951, 6.1% in 1949 and 10.9% in 1948. However, the total pellet ingestion rate for these three species (lead+steel) in 1990-91 was no different than the rates in previous studies ( $df=1$   $N=1800$   $p=0.334$ ). Lead ingestion rates for six species from selected wildlife management units are presented in Table 1; Mallard data are isolated in Figure 1.

Of the 12 necropsied swan carcasses from Abbotsford management unit, 11 apparently died of esophageal impaction and proventricular dilatation caused by lead poisoning. All eight gizzards screened had lead pellets (about 10 per bird). Lead levels ranged from 5 to 28 ppm wet weight (ww) in kidneys and from 6 to 14 ppm ww in liver; values consistent with acute lead poisoning. Brain acetylcholinesterase levels appeared normal, ruling out cholinesterase-inhibiting pesticides as the cause of death. These poisoned swans were located in an area where non-toxic shot has been mandatory for waterfowl hunting since 1990. Judson Lake receives minimal hunting pressure, and sediment samples taken by the Washington State Wildlife Service did not contain any lead pellet. The occurrence of upland game bird hunting and trapshooting around this particular area is under investigation.

### Tissue lead levels and ALA-d activity ratios

Of the 65 eagles tested, 9 (13.8%) birds were classified as lead poisoned (Table 4), 15 (23.1%) as exposed (Table 5), and 41 (65.1%) as free from lead

exposure (Table 6).

Birds were classified as poisoned, if ALA-d ratios were greater than 5 (indicating a blood lead level above 80  $\mu\text{g/dl}$ ; similar to the 1 ppm critical value determined by Redig (1985)), and/or if lead levels in kidney were greater than 20 mg/kg dw (evaluated as an equivalent to the 5 ppm ww of Pattee et al. (1981) from a conversion factor of 4 between dw and ww in mammals). The mean ALA-d ratio for the acutely poisoned birds (Table 4) was  $16.7 \pm 9.4$  (N=5), while mean lead levels were  $34 \pm 18$  mg/kg dw in kidneys (N=5) and  $7.3 \pm 2.2$  mg/kg dw in bones (samples with detectable levels only: N=4).

Table 5 reports the results for the 15 eagles that showed subclinical lead exposure based on an ALA-d ratio greater than 2 and lower than 5, and/or lead levels in kidney greater than 2.0 and lower than 20.0 mg/kg dw, or detectable levels in bone. These threshold values reflect contamination beyond background levels, but under critical values for lead poisoning. Mean ALA-d ratios for this group were  $2.8 \pm 0.7$  (N=8), while mean tissue lead levels (including only those birds with results greater than the detection threshold) were  $2.8 \pm 0.9$  mg/kg in kidney (N=3) and  $1.9 \pm 1.4$  mg/kg in bone (N=6).

Table 6 shows the data for 41 eagles that were free from lead exposure. Lead levels were non-detectable in both kidney and bone for all birds analyzed (N=14 and 13, respectively), while mean ALA-d activity ratio for 27 birds was  $1.2 \pm 0.2$ . The mean ALA-d ratio was  $1.2 \pm 0.1$  for seven eagles kept in captivity for more than six months and therefore not exposed to lead during that time.

#### Geographical distribution of lead poisoning

Figure 2 shows the collection sites for the 65 eagles tested for tissue lead and/or ALA-d. Of the 9 birds classified as lead poisoned, 8 came from coastal areas and one from the interior of B.C. near Kamloops. Five of the poisoned birds were collected from areas currently zoned for use of non-toxic shot for waterfowl hunting. Of the 4 birds from outside non-toxic shot zones, one was the Kamloops bird, while the other 3 came from the northeast coast of Vancouver Island.

Thirteen of the 15 birds classified as lead exposed were picked up from coastal areas; the remaining 2 were from the interior. Most (11/15) were found in areas currently zoned for non-toxic shot.

#### Seasonal distribution of lead poisoning

The majority of eagles in the study were collected during the months of January to April (Figure 3). The greatest ratios of lead-poisoned and lead-exposed birds to the total number of eagles tested per month were found in December, March and May (Figure 4).

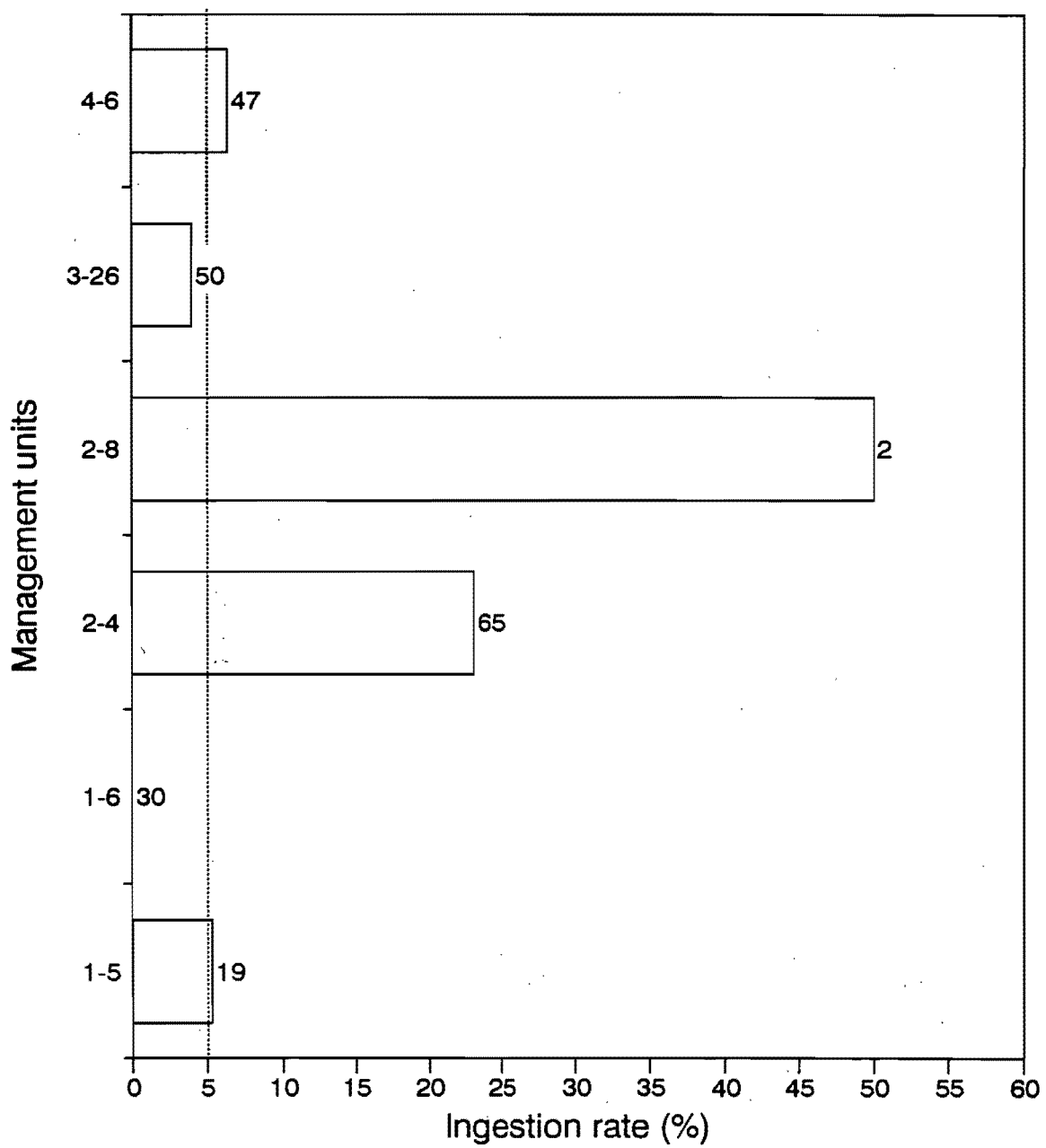


Figure 1. Lead pellet ingestion rates in Mallards in selected management units.



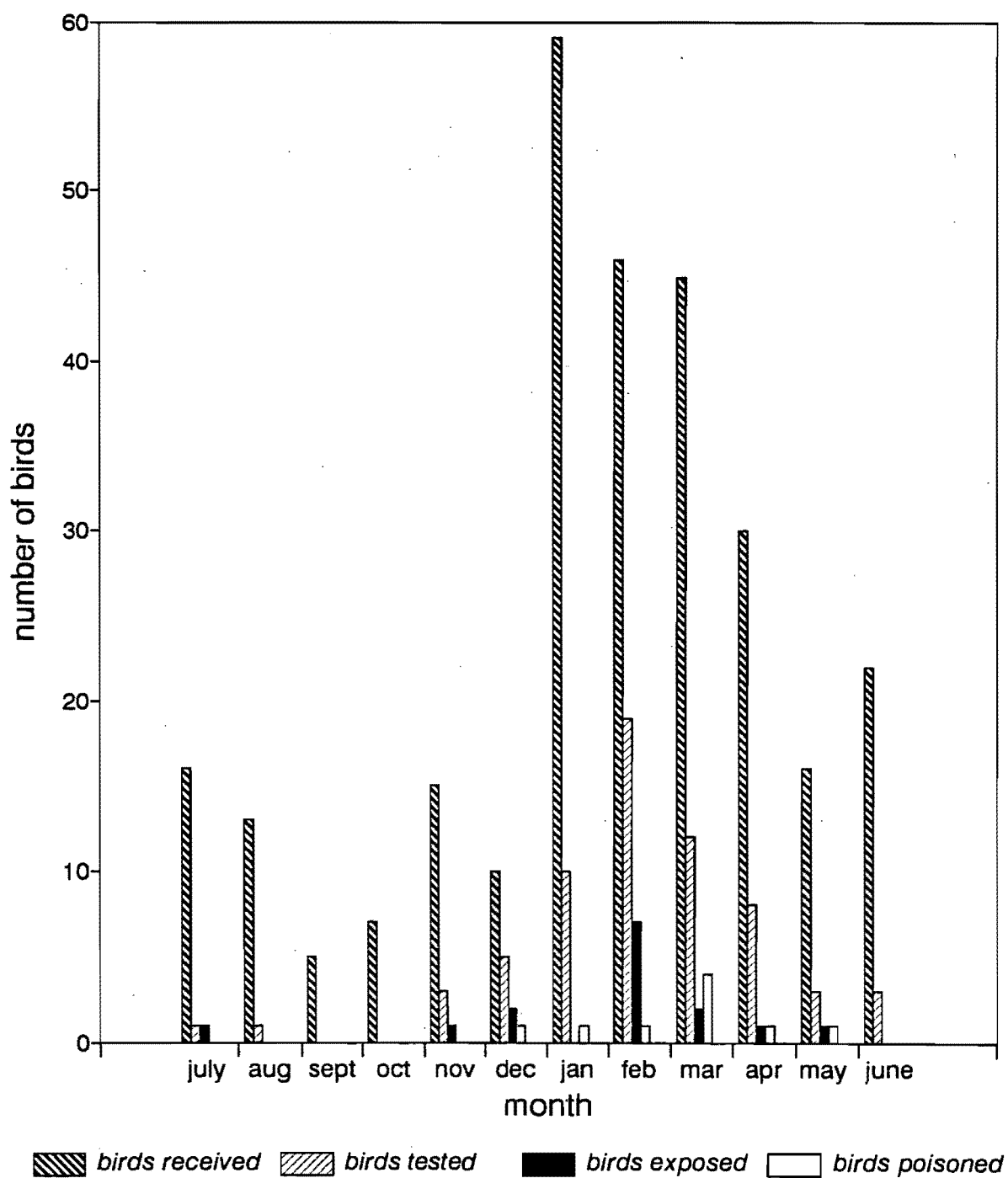


Figure 3. Seasonal distribution of lead poisoning in Bald Eagles collected from 1988 to 1990 in British Columbia.

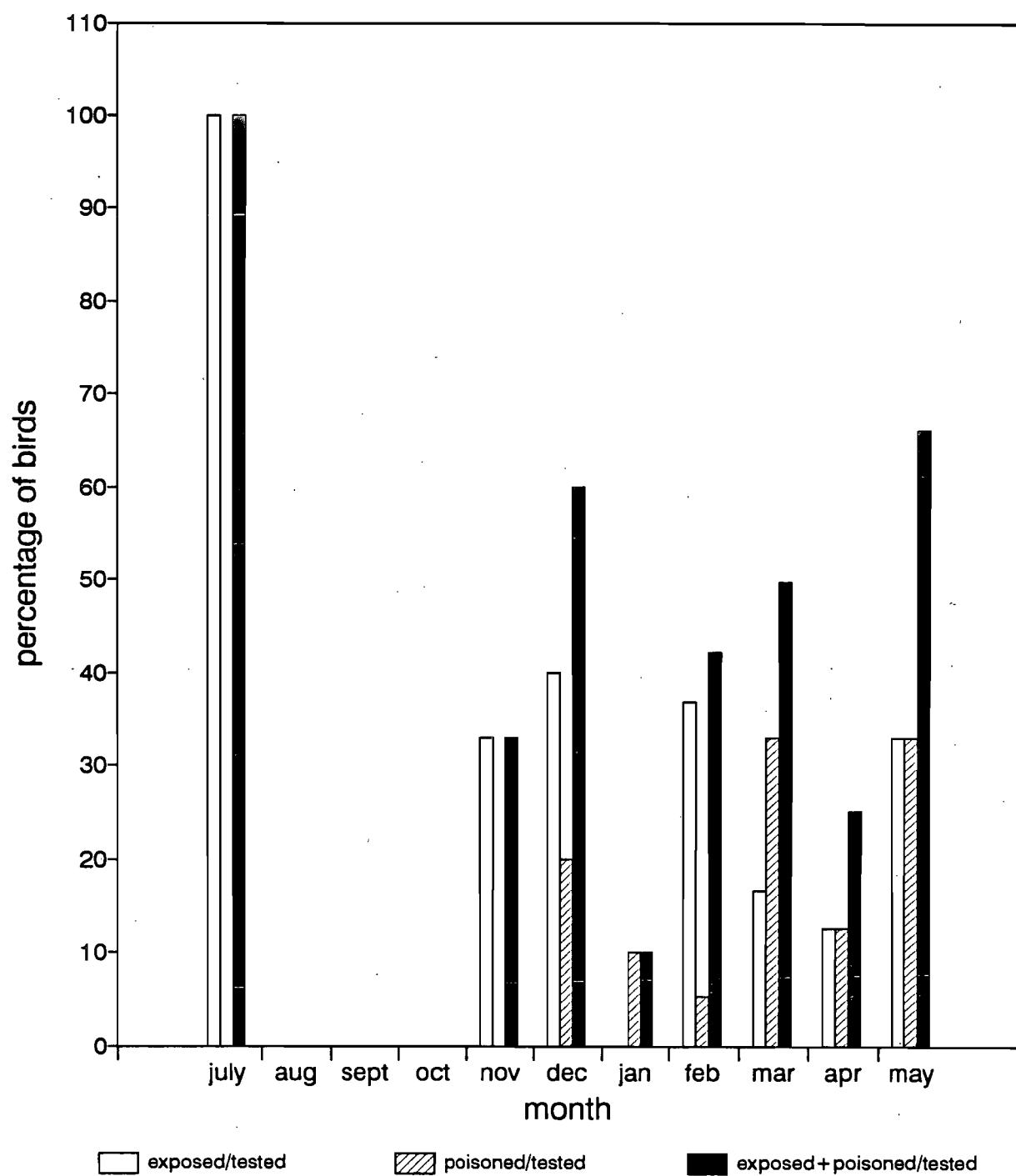


Figure 4. Lead-poisoned and lead-exposed eagles by month as a percentage of the total number tested for lead.

Table 1. Summary of presence of lead shot or lead fragments in gizzard contents of waterfowl collected in selected management units on the lower mainland and Vancouver Island in 1988 and 1989 (Whitehead 1989).

Location (management unit)	Mallard	N. Pintail	Am. Wigeon	B-w. Teal	Canada Goose	Snow Goose	Totals
Unknown	2/7 (28.6%)	0/9 (0%)	1/5 (20%)		0/4 (0%)	0/4 (0%)	3/29 (10.3%)
Nanaimo (1-5)	0/1 (0%)						0/1 (0%)
Ladysmith (1-5)	1/18 (5.5%)			0/3 (0%)			1/21 (4.8%)
Total	1/19 (5.3%)			0/3 (0%)			1/22 (4.5%)
Courtenay/ Comox (1-6)	0/30 (0%)						0/30 (0%)
Total	0/30 (0%)						0/30 (0%)
Westham Is. (2-4)	14/59 (23.7%)	4/39 (10.2%)	7/26 (26.9%)		1/16 (6.2%)	0/10 (0%)	26/150 (17.3%)
Boundary Bay (2-4)	1/6 (16.7%)		3/10 (30%)		1/8 (12.5%)		5/24 (20.8%)
Abbotsford (2-4)						0/2 (0%)	0/2 (0%)
Total	15/65 (23.1%)	4/39(10.2%)	10/36 (27.8%)		2/24 (8.3%)	0/12 (0%)	31/176 (17.6%)
Pitt River (2-8)	1/2 (50%)					2/14 (14.3%)	3/16 (18.7%)
Fraser River (2-8)						3/7 (42.8%)	3/7 (42.8%)
Total	1/2 (50%)					5/21 (23.8%)	6/23 (26.1%)
Shuswap (3-26)	2/50 (4%)				0/2 (0%)		2/52 (3.8%)
Total	2/50 (4%)				0/2 (0%)		2/52 (3.8%)
Creston (4-6)	3/47 (6.4%)	0/2 (0%)	3/128 (2.3%)	0/7 (0%)			6/184 (3.3%)
Total	3/47 (6.4%)	0/2 (0%)	3/128 (2.3%)	0/7 (0%)			6/184 (3.3%)
Overall total	46/220 (20.9%)	11/43 (25.6%)	5/156 (3.2%)	0/10 (0%)	5/39 (12.8%)	4/39 (10.2%)	68/487 (14%)

Table 2. Percent incidence of ingested lead shot in waterfowl in the lower Fraser River: 1936-88 (N) (Whitehead 1989).

Species	Author/Date							mean $\pm$ S.D.
	Munroe 1936	Tener 1948	Cottle 1949	Malysheff 1951	Burgess 1970	Pope 1988	Whitehead 1989	
Mallard	12.2 (11/90)	16.1 (10/59)	10.0 (6/61)	16.5 (13/79)	11.2 (22/196)	4.8 (450)	20.7 (247)	13.1 $\pm$ 5.2
Northern Pintail	-	5.0 (1/20)	0.0 (0/16)	22.9 (8/35)	5.0 (5/100)	0.0 (23)	26.8 (41)	10.0 $\pm$ 11.8
American Wigeon	-	0.0 (0/22)	0.0 (0/21)	0.0 (0/15)	1.6 (2/123)	4.4 (45)	7.1 (28)	2.2 $\pm$ 3.0
Canada Goose	-	-	-	-	-	13.5 (52)	13.5 (37)	13.5 $\pm$ 0.0
Snow Goose	-	-	-	-	-	6.7 (15)	8.3 (48)	7.5 $\pm$ 1.1

Table 3. Frequency of shot pellet ingestion for dabbling ducks taken by shotgun at the Fraser River estuary during the winter of 1990-91.

Species	No. of gizzards x-rayed	No. with ingested steel shot	No. with ingested lead shot	% steel shot/lead shot
Mallard	37	2	2	5.4 / 5.4
Am. Wigeon	37	1	0	2.7 / 0.0
N. Pintail	34	1	2	2.7 / 5.9
Total	108	4	4	3.7 / 3.7

Table 4. Statistics on the nine Bald Eagles that showed evidence of lead poisoning (Elliott et al. 1992).

Date	Age	Sex	Location	Lead in kidney (mg/kg)	Lead in bone (mg/kg)	ALA-d ratio	Initial diagnosis
Apr 89	Ad <sup>1</sup>	F	Denman Is.			25	Inanition
Dec 89	1	F	Bowser			24	Lead toxicosis
Jan 90	Ad	F	Eve R.			20	Lead toxicosis
Feb 90	Ad	M	Duncan	8.8	ND <sup>2</sup>	6.7	Gunshot
Mar 90	1	F	Port Hardy	48	6.9		Inanition
Mar 90	Ad	M	Coombs	49	10		Undetermined
Mar 90	2	M	Sointula	21	5.1		Lead toxicosis
Mar 90	Ad	M	Kamloops	42	7.0		Undetermined
May 90	Ad	F	Hornby Island			6.6	Interspecific aggression
Mean ± S.D.				34 ± 18	7.3 ± 2.2	16.7 ± 9.4	

<sup>1</sup> - Adult

<sup>2</sup> - Non-detectable

Table 5. Statistics on the 15 Bald Eagles that showed evidence of subclinical lead exposure (Elliott et al. 1992).

Date	Age	Sex	Location	Lead in kidney (mg/kg)	Lead in bone (mg/kg)	ALA-d ratio	Initial diagnosis
Jul 89	1	M	Houston			2.8	Nutritional deficiency
Nov 89	Ad <sup>1</sup>	F	Surrey	ND <sup>2</sup>	1.4		Intraspecific aggression
Dec 89	Ad	F	Squamish	ND	0.8		Undetermined trauma
Dec 89	1	M	Buckley Bay			3.9	Lead toxicosis/water soaked
Feb 90	Ad	M	Powell R.	2.6	ND	2.3	Undetermined trauma
Feb 90	Ad	M	Sointula	3.8	ND		Vehicle collision
Feb 90	Ad	F	Nanaimo	ND	1.2		Electrocution
Feb 90	Ad	M	Richmond			2.9	Pesticide toxicosis
Feb 90	4	M	Campbell R.			2.6	Oiled
Feb 90	1	F	Powell R.	ND	4.3	1.7	Undetermined trauma
Feb 90	4	M	Comox	2.0	ND		Power line collision
Mar 90	3	M	Ladysmith	ND	2.7		Undetermined trauma
Mar 90	3	M	Port Alice	ND	0.8		Myositis
Apr 90	Ad	F	Nanoose Bay			3.2	Undetermined trauma
May 90	Ad	F	Smithers			2.6	Intraspecific aggression
Mean $\pm$ S.D.				2.8 $\pm$ 0.9	1.9 $\pm$ 1.4	2.8 $\pm$ 0.7	

<sup>1</sup> - Adult<sup>2</sup> - Non-detectable

Table 6. Statistics on the 41 wild Bald Eagles free from lead exposure (Elliott et al. 1992).

Date	Age	Sex	Location	Lead in kidney (mg/kg)	Lead in bone (mg/kg)	ALA-d ratio
May 88	Ad <sup>1</sup>	F	Port Hardy	ND <sup>2</sup>	ND	
Jun 88	2	M	Summit Lake	ND	ND	
Jun 89	Ad	F	Port Hardy		ND	
Aug 89	1	M	Queen Charlotte Is.			1.1
Nov 89	1	F	Port Alberni			1.8
Nov 89	1	F	Unknown			1.2
Dec 89	Ad	M	Powell R.	ND	ND	
Dec 89	1	F	Sandspit			1.1
Jan 90	1	F	Comox	ND	ND	1.1
Jan 90	4	M	Squamish			1.0
Jan 90	2	M	Minstrel Is.	ND	ND	
Jan 90	Ad	M	Qualicum			1.1
Jan 90	Ad	F	Surrey			1.2
Jan 90	1	M	Kitimat			1.1
Jan 90	Ad	M	Point Roberts			1.3
Jan 90	Ad	M	Richmond			1.7
Jan 90	Ad	F	Powell R.			1.3
Feb 90	2	M	Sointula			1.5
Feb 90	1	F	Port Hardy			1.4
Feb 90	1	F	Kelsey Bay	ND	ND	
Feb 90	2	M	Surrey	ND	ND	
Feb 90	2	F	Mission			1.2
Feb 90	1	M	Surrey			1.3
Feb 90	Ad	M	Qualicum			1.1
Feb 90	Ad	F	Chain Is.			1.1
Feb 90	Ad	M	Sechelt			1.0
Feb 90	Ad	F	Quadra Is.	ND	ND	
Feb 90	1	M	Upper Squamish	ND	ND	
Mar 90	1	F	Englishman R.	ND	ND	
Mar 90	1	M	Nanaimo	ND		
Mar 90	1	F	Smithers	ND	ND	
Mar 90	1	M	Nanaimo	ND	ND	
Mar 90	3	F	Woss	ND		
Mar 90	Ad	F	Abbotsford			1.0
Apr 90	Ad	F	Campbell R.			1.4
Apr 90	1	F	Campbell R.			1.0
Apr 90	Ad	M	Port Hardy			1.0
Apr 90	Unknown	F	Bowen Is.			1.1
Apr 90	Unknown	M	Prince Rupert			1.0
Apr 90	Ad	M	Prince Rupert			1.1
Jun 90	Ad	M	Abbotsford			1.0
Mean $\pm$ S.D.						1.2 $\pm$ 0.2

<sup>1</sup> - Adult

<sup>2</sup> - Non-detectable

Table 7. Diagnosed cause of death or illness for entire study (267 birds included) and those tested for lead exposure (65 birds included - Elliott et al. 1992).

Diagnosis	All birds (%)	Tested for lead (%)
Flight collision	3.0	7.7
Power line collision	2.2	3.1
Vehicle collision	10.1	4.6
Undetermined trauma	15.7	21.5
Lead	8.6	13.9
Pesticide	3.7	6.2
Mercury	0.4	0
Undetermined	0.8	0
Electrocution	14.6	7.7
Fell from nest	6.4	0
Gunshot	6.0	1.5
Intraspecific aggression	4.9	4.6
Water soaked	5.2	3.1
Oiled	0.8	3.1
Inanition	3.0	7.7
Trapped	3.0	0
Infectious disease	4.1	4.6
Undetermined cause	4.9	1.5
Other causes	1.5	9.2

## Discussion

Visual examination to detect lead pellets in gizzards can miss up to 20-30% of the pellets, while almost 100% of the fragments are detected when gizzard contents are x-rayed. However, for pooled samples of Mallards, Northern Pintails and American Wigeons from the Fraser River delta collected in winter 1990-91, the incidence of lead shot in gizzards evaluated by x-ray is the lowest ever reported for this area. But if we consider all pellets present in gizzards (i.e. both steel and lead pellets), 1990-91 results for the three species combined are not different from results of previous studies. Data from 1990-91 represent a winter sample, which may explain why the incidence of lead pellets is not higher. Availability of lead pellets is known to decrease with time after deposition, due to siltation, and pellets are one to two inches deeper into the sediments after one year (Bellrose 1959). Waterfowl are an important winter food source for Bald Eagles on the Pacific coast (Stalmaster et al. 1985), particularly ducks that have been killed or crippled by hunters (Griffen et al. 1982). Recent studies show that lead shot crippling losses of ducks can be as high as 39% (Nieman et al. 1987), while large numbers (average 30%) of healthy ducks carry lead pellets (U.S. Fish & Wildlife Service 1986). Eagles may also be exposed to lead while consuming the intestinal tracts of waterfowl that were killed or debilitated from ingestion of lead shot.

In British Columbia, lead shot was banned in 1990 for waterfowl hunting in four wildlife management areas (1-5, 1-6, 2-4, 2-8) based on the data in Table 1, and on a high incidence of chronic lead poisoning of Trumpeter Swans on Vancouver Island (Langelier et al. 1989). Banning of lead shot should substantially reduce the number of sick and crippled ducks carrying both ingested and embedded lead shot in the zoned areas. Inspection of 108 duck gizzards collected from three species during the winter of 1990-91 (the first lead-free season) from the Fraser River delta showed that steel shot was present in amounts approximately equal to lead shot (Table 3). This should reduce the secondary lead exposure of scavenging eagles and other birds of prey in those areas. However, lead poisoning of waterfowl was observed in swans despite the fact that they were found in a non-toxic shot zone. This may be due to contaminated birds migrating into the area, or could demonstrate the importance of the "time factor" for eliminating the lead shot problem. Availability of lead pellets will reduce in time as the siltation process continues, but meanwhile species feeding deep into the sediments may remain at risk.

A higher percentage of eagles was classified as lead poisoned based on tissue analysis and/or ALA-d ratios (13.9%) compared to classification based on clinical signs (8.6%) (Table 7). Some of the birds that were diagnosed as having died from other causes, especially inanition, may be classified as lead poisoned, once tissue analysis for lead is completed for the entire collection of eagles.

The extent to which the incidence of acute lead poisoning reported in Table 7

is biased is not known, since the probability of finding a bird that is sick or dead as a result of lead exposure could be different from that of finding eagles that have died of other causes (e.g. automobile collision, shooting and trapping). Birds having lead-induced neurological impairment may be secretive and the probability of finding them lower than the probability of finding birds dead of other causes. The real percentage of birds that died of lead poisoning may then have been slightly underestimated. However, the percentage of carcasses classified as lead-poisoned Bald Eagles peaked at 25% in March, making lead a major potential cause of the population reduction at that time of the year.

Sublethal exposure to lead and the associated neurological effects can cause coordination problems and effects on other essential functions controlled by the central nervous system, such as vision and hearing, thus increasing the chances of dying from other causes.

Eagles may still be exposed to lead from feeding on migrant ducks carrying embedded or ingested shot acquired in other areas. Most of the ducks that migrate through or winter in southern B.C. come from the B.C. interior, Alberta, Alaska, Yukon and the Northwest Territories (McKelvey and Smith 1990). The Yukon and Northwest Territories are sparsely populated and waterfowl hunting pressure is low, and only steel shot is permitted in Alaska. Therefore, only in the B.C. interior and Alberta is there enough waterfowl hunting pressure with lead shot to produce a significant reservoir of ducks with embedded shot. Those ducks would become eagle prey mainly if they are then crippled (by steel shot) or fall sick during winter.

Our data show that 4/9 poisoned Bald Eagles came from outside the non-toxic shot zones. Those eagles were presumably exposed to lead shot from ducks that were debilitated as a result of waterfowl hunting in the local areas, particularly northeastern Vancouver Island. Additional sampling of waterfowl gizzards in this region would be useful.

In conclusion, lead poisoning is a significant mortality factor for British Columbia Bald Eagles. Monitoring eagles for lead exposure should be continued in order to assess the effectiveness of non-toxic shot zoning. The role of lead shot in eagle mortality should also be considered in other areas of Canada, such as New Brunswick, where waterfowl consumption by Bald Eagles has been reported (Wright 1953). Incidence of lead shot in waterfowl gizzards of four of the six species was over the 5% level for considering waterfowl at risk of lead poisoning (CWS 1990).

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## LEAD PELLET INGESTION IN PRAIRIE CANADA

Adapted from: Hochbaum et al. 1988; Hochbaum 1990; Hochbaum and Bain 1988; and Hochbaum and Leafloor 1988; additional information on 1991 data provided by G.S. Hochbaum.

### Abstract

Gizzards were collected from hunted areas in Manitoba, Saskatchewan and Alberta during the fall and from some Manitoba sites during summer. The percentage of each species with shot present in the gizzard (ingestion rate) was calculated. Four prairie sites had ingestion rates for dabbling ducks that indicate potential lead poisoning problems: Delta Marsh (8.4%), The Pas marshes (15.1%) and Dauphin Lake (5.0%) in Manitoba, and Ponass Lake (5.0% for Mallards, 3.5% for all dabblers) in Saskatchewan. No pellets were detected in waterfowl gizzards in Alberta. Only two of the Manitoba sites (Delta Marsh and The Pas marshes) showed differences in fall and summer ingestion rates with those in summer being higher. Comparison to summer ingestion rates at Delta Marsh in 1948-49 showed no significant difference, indicating a stable situation over time.

Pellet density, as estimated from dredged sediment samples, was highly variable from site to site. Samples from Saskatchewan contained only trace amounts of pellets, while Alberta sites were pellet-free. All Manitoba marshes had moderate to high pellet densities, except Oak Hammock Marsh, where hunting effort is restricted to adjacent fields. The Pas marshes had the highest pellet densities.

No problem is currently apparent in Saskatchewan and Alberta, although sample sizes are limited. In Manitoba, Oak Hammock Marsh is already designated a non-toxic shot zone, but The Pas, Dauphin Lake and Delta Marsh are still (1993) open for the use of lead for waterfowl hunting.

### Introduction

Lead poisoning is a known cause of mortality in waterfowl in Canada (Wendt and Kennedy 1992). Prairie Canada, as a major waterfowl breeding area, supports large numbers of birds which may be at risk of being poisoned by spent lead pellets. Although the provinces of Manitoba, Saskatchewan and Alberta are often considered as a unit, different habitats, hunting traditions and regulations influence the risk of lead poisoning. Data are presented for individual sites to provide details of the local situation.

Breeding and hunting areas overlap extensively in the Prairies; ducks present in hunted areas in the summer may be exposed to spent lead shot for several months,

Recommended citation:

Hochbaum, G.S. 1993. Lead pellet ingestion in prairie Canada.  
Pp. 47-64 in J.A. Kennedy and S. Nadeau (eds.), Lead Shot  
Contamination of Waterfowl and Their Habitats in Canada.  
Can. Wildl. Serv. Technical Report No. 164.

THIS  
Please insert ~~one of these~~ slips between pages 46 & 47 of each copy  
of the CWS Technical Report on Lead Shot (No. 164) which we  
recently sent you. Thank you.

with an increased risk of ingesting pellets. The presence of hunters during the fall disturbs birds and may force them out of preferred feeding areas into areas where spent shot may be less prevalent. The ingestion rates in both fall and summer were investigated in Manitoba, to determine if waterfowl on the breeding grounds showed evidence of greater exposure to lead than migrating birds in the fall. Because lead pellets are eliminated in about three weeks from waterfowl gizzards (Clemens et al. 1975), between season comparison of ingestion can be made without the concern that pellets ingested in the spring may be detected in the fall.

The results presented in this paper are categorized according to the 5% ingestion rate established in 1990 as the lowest level of concern by the Canadian Wildlife Service. If more than 5% of the dabbling duck population in a given area has ingested lead pellets, the area should be investigated to determine the likelihood of lead poisoning (CWS 1990).

## Methods

### Gizzard studies

#### *Manitoba*

In Manitoba, gizzards and wings of waterfowl were collected in summer prior to hunting and during the fall hunting season from 1979 to 1985. The gizzards were to be used to assess lead ingestion, the plumage on wings was used to identify the species, age and sex of the bird. Collection sites were selected on the basis of two criteria: occurrence of heavy hunting (more than 10,000 hunting days in 100 km<sup>2</sup>), and the availability of adequate samples for at least one species (Figure 1). Waterfowl for the summer sample were obtained from seven sites, mainly in southern Manitoba, as a result of accidental deaths such as drowning or predation from bait traps operated for banding. These birds were collected between late July and mid-September. For the fall sample, waterfowl gizzards and wings were donated by hunters during the annual migratory bird hunt from September 1 to November 30. All samples were kept frozen until laboratory analysis was carried out. When possible, samples were identified as to species, age and sex. Location and date of collection were also recorded. In the four areas with sampling in both summer and fall and for which lead pellets in waterfowl gizzards were detected (Delta, Oak Hammock, Dauphin Lake and The Pas), Fisher's exact tests were run on the null hypothesis that ingestion rates were the same in both seasons.

Ingestion rates for Delta Marsh were compared with ingestion rates determined by radiofluoroscoping live birds to detect the presence of lead shot in gizzards in 1948-49 at Delta Marsh. Two-way Fisher's exact tests were used for Mallards, Northern Pintails and Blue-winged Teals. No correction factor for the detection rates using fluoroscopy vs. manual examination for lead has been applied.

## *Saskatchewan*

Gizzards were collected in Saskatchewan from six sites (Figure 1) during the 1986 hunting season. Birds were donated by professional pluckers at the hunting sites examined and were assumed to have been shot in the local area. In certain areas, pluckers collected only the gizzard, with no indication of species, age and sex. These birds are included under the category Unknown Ducks in the tabular summaries.

## *Alberta*

Hunters in Alberta were solicited by direct contact in the field to provide gizzards at sixteen sites during the 1987 hunting season. Sites were selected based on traditional use for over-water shooting (Figure 1). Hunting intensity was increased for males of selected species to improve the representation of a few homogeneous groups. These species were Mallard, Northern Pintail, Canvasback and Lesser Scaup. Samples were obtained from areas around Beaverhill, Cooking and Bittern lakes near Edmonton, with some additional samples taken in the Calgary area. Species were identified, aged, and sexed by visual examination of the fully feathered bird. In fall 1991, 33 duck gizzards were collected from hunters at Inchent Marsh, near Lethbridge.

For all Prairie samples, gizzards were cut open over a white enamel dissecting pan and the contents washed into the pan with water. Plant material and other debris were decanted, retaining denser matter in the bottom of the pan. Less than 1 cm of water was kept in the pan while the contents were examined for pellets. Gizzards from fall samples that contained pellets were examined for perforations to ensure the shot had been ingested rather than shot in. Only pellets that showed visible signs of exposure to the action of the gizzard were considered as ingested. Recently ingested pellets may have been omitted by this screening process, resulting in a slight underestimate of the frequency of shot ingestion. Unidentifiable fragments were squeezed with pliers to determine their composition; malleable fragments were identified as lead, while those that shattered were called grit. For each species, the percentage of gizzards found to contain lead (the ingestion rate) was calculated.

## Sediment sampling

Sediment samples were also collected from hunted marshes in the Prairie provinces. These samples are useful for determining the abundance and availability of lead shot to waterfowl. Substrate samples were collected at 19 sites known to be used by both hunters and waterfowl. Different sites were sampled in 1981, 1988 and 1989. At each site, substrate type, water depth, depth of dredging, number and size of pellets found and distance from shore were recorded for samples. A 15 cm x 15 cm Flanigan Burton modified Eckman dredge was used in sampling. Ten samples

were taken at 25-m intervals from 25 m to 175 m from shore, for a total of 70 samples at each site. Dredged material was sieved through progressively finer screens. The smallest mesh size prevented the passage of a size 8 lead pellet. Remaining debris was sorted and the number of pellets in each sediment sample was recorded.

## Results

### Gizzard studies

#### *Manitoba*

The contents of 2 242 gizzards from Manitoba were examined. Shot ingestion rates for different sites during the summer and the fall hunting season are shown in Tables 1 and 2 respectively. Ingestion rates were the same in fall and summer at Oak Hammock and Dauphin Lake ( $N=56$   $p=1$  and  $N=80$   $p=0.272$ , respectively), but not at Delta Marsh and The Pas ( $N=1372$   $p=0.0221$  and  $N=150$   $p=0.0241$  respectively) where ingestion was significantly higher in the summer than in the fall (Figure 2). These results allow us to pool fall and summer samples for estimation of ingestion rate for Oak Hammock and Dauphin Lake only. Because there was no ingestion at Oak Lake in either season, the test could not be run. Notwithstanding the difference between summer and fall ingestion rates, data for Mallards were pooled and an histogram was generated (Figure 3) to give a general idea of lead contamination in various regions of Manitoba.

Three areas of Manitoba may be identified for further investigation for lead poisoning: Delta Marsh, with a maximum ingestion rate of 8.4% for dabblers ( $N=381$  - summer), The Pas northern marshes, with a maximum of 15.1% (Pasqua River and Pasqui lake -  $N=73$  - summer) and Dauphin Lake, with a mean ingestion rate of 5.0% ( $N=80$  - fall+summer) (Tables 1 and 2). Ingestion rates of lead pellets by ducks have not increased over time at Delta Marsh (Table 3).

No lead was found in duck samples for Big Grass Marsh or Oak Lake, and very few pellets were found in ducks at Oak Hammock.

Only two sites provided goose samples large enough for analysis (Table 2). All goose gizzards were obtained during the fall. Canada Geese at Oak Hammock and Delta marshes had ingestion rates of 6.9% ( $N=102$ ) and 10.0% ( $N=30$ ), respectively. Snow Goose ingestion rates were lower than 5% at both sites.

#### *Saskatchewan*

Ingestion rates for waterfowl at six sites in Saskatchewan are shown in Table 4. Sample sizes are very small for all species other than Mallard. Only one site in

the province is identified as potentially problematic for lead poisoning. Ponass Lake had an ingestion rate of 5.0% in Mallards (N=80), or 3.5% for all species of dabblers combined. Little Manitou also approached the threshold level when all dabblers were considered together, with an ingestion rate of 4.1%. A large proportion ( $199/1047=19.0\%$ ) of the waterfowl gizzards examined were from "unknown" species. Assuming that these unknown birds are dabblers, new ingestion rates can be calculated for Last Mountain Lake and the Quill Lakes, the sites where unknown birds had ingested lead. Even with the addition of these gizzards, the ingestion rate at Last Mountain Lake is 2.7%, and that at Quill Lakes is 2.9%. Based on one year of gizzard sampling, no critical problem was identified. Ponass Lake needs further sampling to confirm the almost critical ingestion rate we observed.

Canada Geese, which were shown to readily acquire lead in Manitoba fields with heavy hunting, showed little lead pellet ingestion in Saskatchewan. The highest ingestion rate was 2.9% at Kindersley. Only one Snow Goose with ingested lead pellets was found (at Quill Lakes), but the sample size was small (N=32).

### *Alberta*

In 1987, no pellets were detected in 727 samples of eleven duck species (Table 5). This corroborates the earlier findings of Weaver (1978), who found only three gizzards with lead pellets in a sample of 719 ducks.

In 1991, one Mallard and one Northern Pintail gizzard containing one lead pellet each were found in a sample of 33 gizzards, including 25 from Mallards and 2 from Northern Pintails collected at Inchant Marsh. The average ingestion rate is then 6.1% for the whole sample (G. Hochbaum, pers. commun.).

### Sediment sampling

Pellet densities in the Prairie provinces are variable. Only trace numbers of pellets were found in Saskatchewan, and no pellets were recovered from Alberta wetlands (Table 6).

In Manitoba, pellet densities were moderate to high for all marshes except Oak Hammock. Oak Hammock Marsh is a managed hunting area where shooting is prohibited except over fields bordering the wetlands. Densities were highly variable from site to site. Chatique Lake and Reader Lake, near The Pas, had high pellet densities. Chatique Lake had the highest density of spent lead pellets of all sites sampled. This area receives moderate use by both ducks and hunters. As with all sediment samples, the standard deviations are high because of the low frequency of lead pellets due to the small volume sampled. Pellet densities should not be extrapolated from one marsh to another, given the large variability among sites (Bellrose 1959).

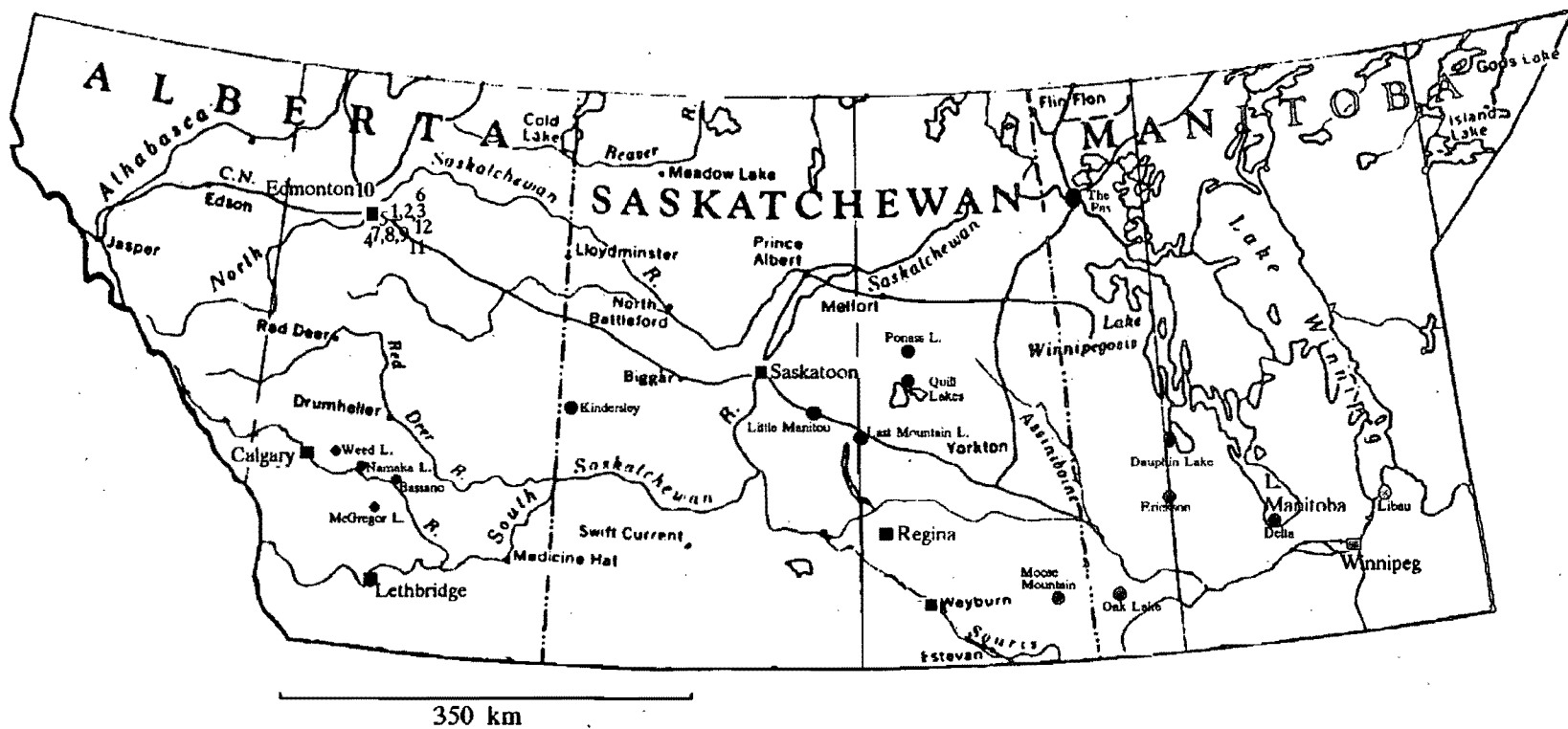


Figure 1. Location of sampling sites (filled circles and numbers) in Prairie Canada.

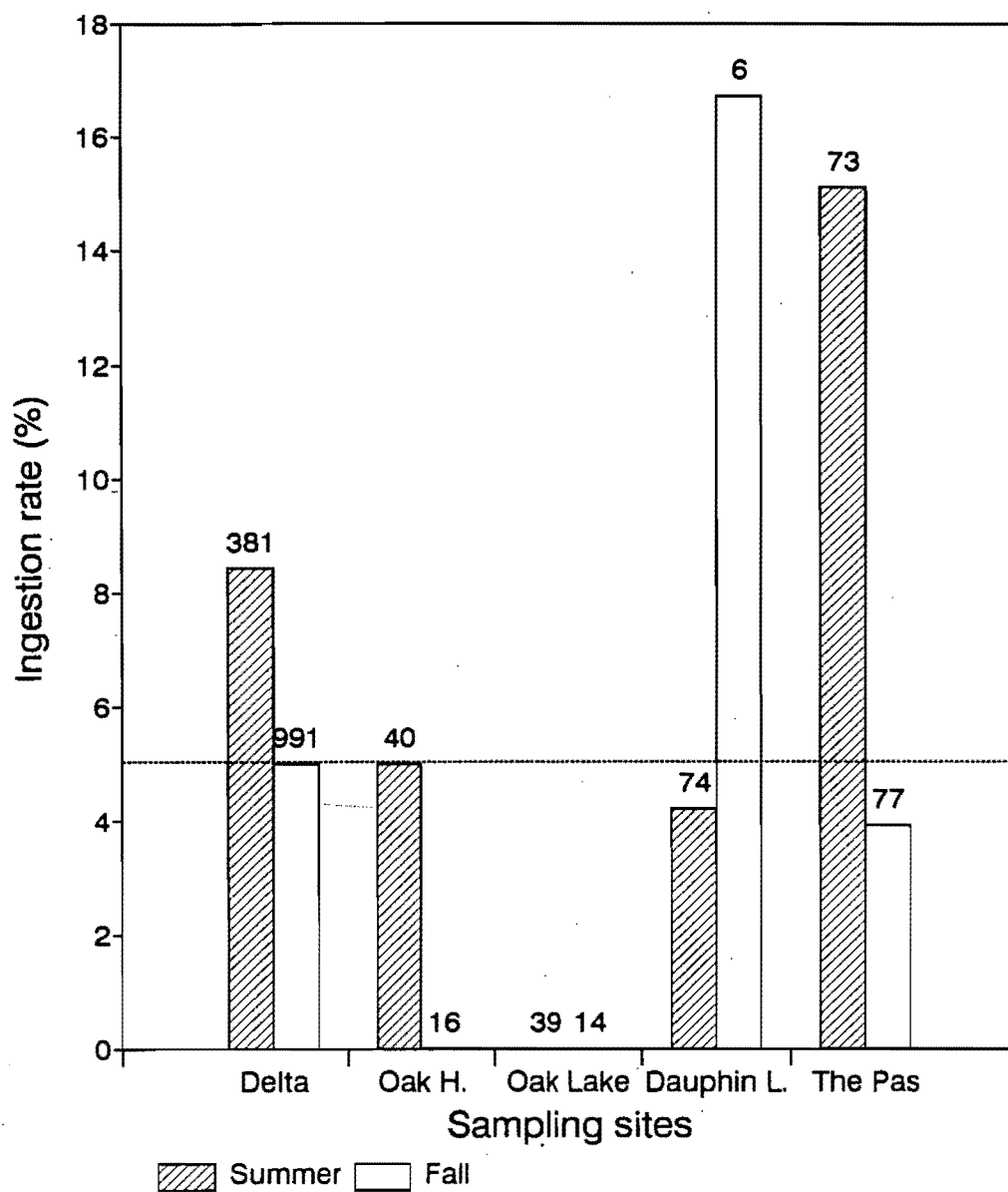


Figure 2. Seasonal frequency of lead pellets in dabbling duck gizzards from Manitoba.

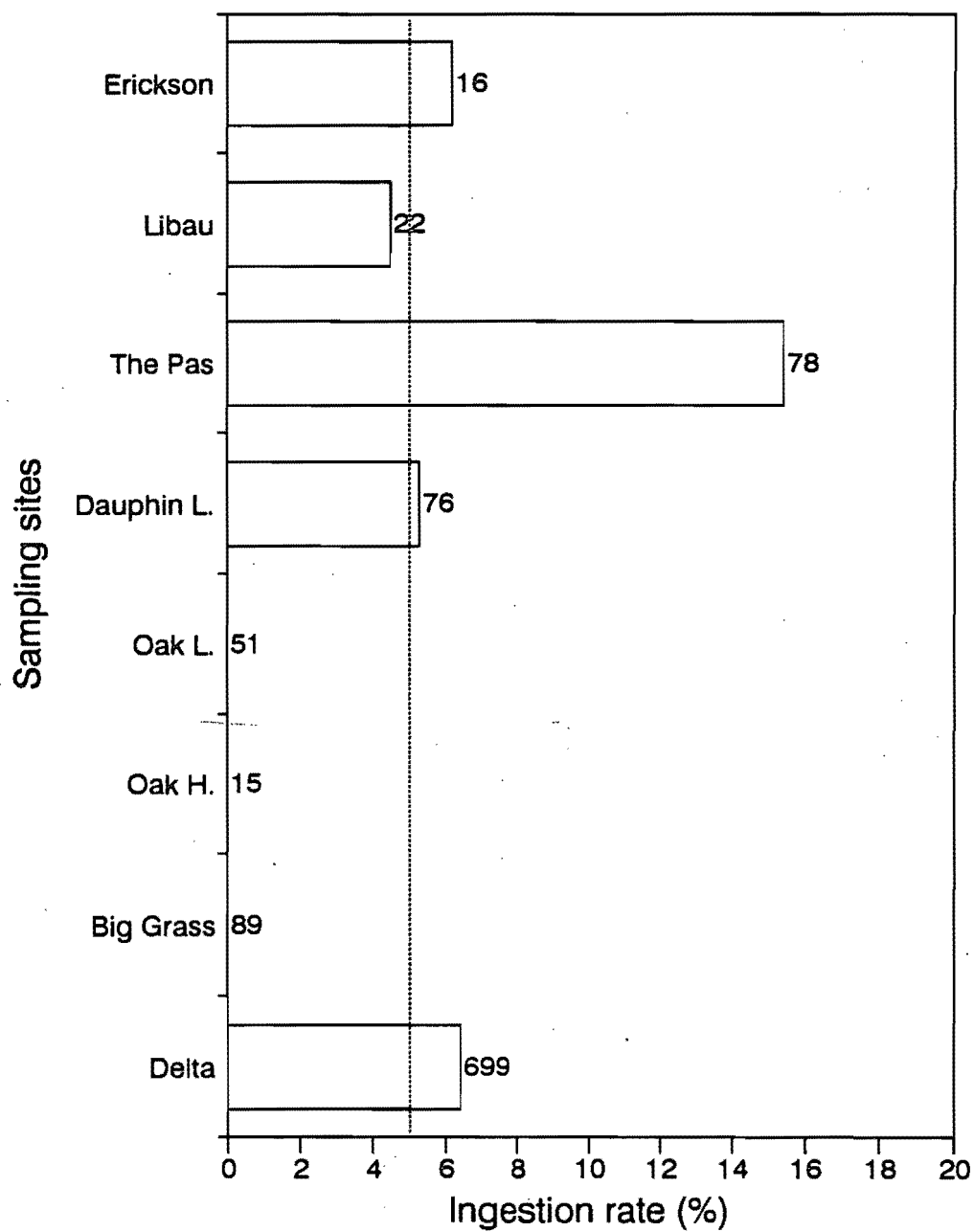


Figure 3. Ingestion rate in Mallards from various locations in Manitoba (summer and fall data combined).

Table 1. Summary of shot ingestion frequencies for duck species at each sample area in Manitoba during the summer (1979-85).

Species	Area																				
	Delta			Big Grass			Oak Hammock			Oak Lake			Dauphin Lake			Pasqua River			Pasqui Lake		
	N <sup>1</sup>	# <sup>2</sup>	%	N	#	%	N	#	%	N	#	%	N	#	%	N	#	%	N	#	%
Mallard	306	25	8.2	89	0	0.0	4	0	0.0	44	0	0.0	70	3	4.3	49	8	16.3	16	3	18.8
B-w Teal	51	4	7.8	6	0	0.0	27	0	0.0	81	0	0.0	3	0	0.0	-	-	-	3	0	0.0
N. Pintail	20	3	15.0	3	0	0.0	6	2	33.3	4	0	0.0	-	-	-	2	0	0.0	1	0	0.0
Unknown ducks	4	0	0.0	-	-	-	3	0	0.0	10	0	0.0	1	0	0.0	1	0	0.0	1	0	0.0
Total dabblers	381	32	8.4	98	0	0.0	40	2	5.0	139	0	0.0	74	3	4.2	52	8	15.4	21	3	14.3

<sup>1</sup>N = Sample size

<sup>2</sup># = Number of ducks having lead shot in their gizzard

Table 2. Summary of shot ingestion frequencies for duck species at each sample area in Manitoba during the fall (1979-85).

Species	Area																				
	Delta			Oak Hammock			Oak Lake			Libau			The Pas			Dauphin Lake			Erickson		
	N <sup>1</sup>	# <sup>2</sup>	%	N	#	%	N	#	%	N	#	%	N	#	%	N	#	%	N	#	%
Mallard	393	20	5.1	11	0	0.0	7	0	0.0	22	1	4.5	13	1	7.7	6	1	16.7	16	1	6.3
B-w Teal	32	1	3.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
N. Pintail	63	1	1.6	-	-	-	2	0	0.0	-	-	-	3	0	0.0	-	-	-	-	-	-
Unknown Ducks	503	28	5.6	5	0	0.0	5	0	0.0	9	0	0.0	61	2	3.3	-	-	-	4	0	0.0
Total Dabblers	991	50	5.0	16	0	0.0	14	0	0.0	31	1	3.2	77	3	3.9	6	1	16.7	20	1	5.0
Canada Goose	30	3	10.0	102	7	6.9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Snow Goose	61	3	4.9	88	2	2.3	-	-	-	1	0	0.0	-	-	-	-	-	-	-	-	-
Total Geese	91	6	6.6	190	9	4.7	-	-	-	1	0	0.0	-	-	-	-	-	-	-	-	-

<sup>1</sup>N = Sample size

<sup>2</sup># = Number of ducks having lead shot in their gizzard

Table 3. A comparison of the frequencies of ingested shot in gizzards of waterfowl at Delta Marsh during the summers of 1948 and 1949 with those collected in the summers of 1979 and 1980.

Species	Age	Year						Fisher's exact test probability
		1948 and 1949*			1979 and 1980			
		N <sup>1</sup>	# <sup>2</sup>	%	N	#	%	
Mallard	Juvenile	211	56	27	43	10	23	—
	Adult	326	41	13	68	4	6	—
	All ages	537	97	18	174**	21	12	0.078
Blue-winged Teal	Juvenile	501	25	5	42	1	2	—
	Adult	48	2	4	4	0	0	—
	All ages	549	27	5	85**	4	5	1.000
Northern Pintail	Juvenile	223	50	22	10	3	30	—
	Adult	168	12	7	9	2	22	—
	All ages	391	62	16	26**	5	19	0.588

\* Summarized from Elder 1950. Ducks were fluoroscoped live.

\*\* Includes 1979 un-aged birds and is greater than sum of Juvenile and Adult samples.

<sup>1</sup>N = Sample size

<sup>2</sup># = number of ducks having lead shot in their gizzard

Table 4. Lead shot ingestion frequencies for waterfowl taken at sites in Saskatchewan.

Species	Area																	
	Kindersley			Last Mountain			Ponass Lake			Little Manitou			Moose Mountain			Quill Lakes		
	N <sup>1</sup>	# <sup>2</sup>	%	N	#	%	N	#	%	N	#	%	N	#	%	N	#	%
Mallard	58	1	1.7	85	0	0.0	80	4	5.0	166	6	3.6	88	2	2.3	171	6	3.5
Northern Pintail	13	0	0.0	5	0	0.0	5	0	0.0	3	0	0.0	1	0	0.0	15	0	0.0
American Wigeon	1	0	0.0	7	2	28.6	6	0	0.0	9	1	1.1	6	0	0.0	3	0	0.0
Blue-winged Teal	-	-	-	1	0	0.0	-	-	-	1	1	100.	3	0	0.0	4	0	0.0
Gadwall	4	0	0.0	5	0	0.0	17	0	0.0	14	0	0.0	3	0	0.0	2	0	0.0
Northern Shoveler	-	-	-	2	0	0.0	1	0	0.0	-	-	-	4	0	0.0	3	0	0.0
Green-winged Teal	-	-	-	1	0	0.0	4	0	0.0	-	-	-	-	-	-	8	0	0.0
American Black Duck	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	0	0.0
Total dabblers	76	1	1.3	106	2	1.9	113	4	3.5	193	8	4.1	10	2	1.9	207	6	2.9
Redhead	-	-	-	3	1	33.3	7	0	0.0	6	0	0.0	3	0	0.0	15	2	13.3
Lesser Scaup	-	-	-	-	-	-	-	-	-	-	-	-	1	0	0.0	4	0	0.0
Canvasback	-	-	-	-	-	-	2	0	0.0	2	0	0.0	-	-	-	4	0	0.0
Ring-necked Duck	-	-	-	-	-	-	-	-	-	-	-	-	1	0	0.0	-	-	-
Total divers	0	0	-	3	1	33.3	9	0	0.0	8	0	0.0	5	0	0.0	23	2	8.7
Canada Goose	34	1	2.9	41	1	2.4	108	1	0.9	18	0	0.0	20	0	0.0	113	2	1.8
Snow Goose	15	0	0.0	18	0	0.0	4	0	0.0	12	0	0.0	66	0	0.0	32	1	3.1
White-fronted Goose	12	0	0.0	27	0	0.0	-	-	-	9	0	0.0	9	0	0.0	25	0	0.0
Ross' Goose	-	-	-	1	0	0.0	-	-	-	2	0	0.0	-	-	-	1	0	0.0
Unknown	2	0	0.0	107	5	4.7	1	0	0.0	-	-	-	-	-	-	42	0	0.0
Total geese	63	1	1.6	194	6	3.1	113	1	0.9	41	0	0.0	95	0	0.0	213	3	1.4

<sup>1</sup>N = Sample size

<sup>2</sup># = number of ducks having lead shot in their gizzard

Table 5. Sample sizes at each of the Alberta sites sampled during 1987 gizzard collection (no lead pellets were found in any gizzard).

Site	Species											Total
	Mallard	B.-wing Teal	Gr.-wing Teal	N. Shoveler	Canvasback	Redhead	N. Pintail	Am. Wigeon	Gadwall	Lesser Scaup	Common Goldeneye	
Beaverhill <sup>1</sup> Lake West	57	4	1	4	84	13	25	6	8	17	1	220
Beaverhill <sup>2</sup> Lake East	50	-	-	-	2	1	31	4	-	8	-	99
Beaverhill <sup>3</sup> Lake North	79	-	-	-	23	1	7	-	-	-	-	110
Bittern <sup>4</sup> Lake	69	-	-	-	-	1	19	2	3	4	-	98
Cooking <sup>5</sup> Lake	8	3	1	-	-	-	3	-	7	17	-	39
Rush Lake <sup>6</sup>	8	-	4	-	-	-	-	-	5	-	-	17
Big Hay <sup>7</sup> Lake	13	-	-	-	-	-	-	1	-	-	-	14
Hay Lake <sup>8</sup>	11	-	-	-	-	-	7	-	-	-	-	18
Demay <sup>9</sup> Lake	10	-	-	-	-	-	-	-	-	-	-	10
Manawan <sup>10</sup> Lake	-	-	-	-	-	-	1	-	2	-	-	3
Camrose <sup>11</sup>	6	-	-	-	-	-	-	2	3	-	-	11
Tofield <sup>12</sup>	21	-	-	-	-	-	-	-	3	-	-	24
Namaka Lake	24	-	-	-	-	-	-	-	4	-	-	28
McGregor Lake	16	-	-	-	-	-	-	-	-	-	-	16
Weed Lake	11	-	-	-	-	-	-	-	2	-	-	13
Bossano	7	-	-	-	-	-	-	-	-	-	-	7
Total	390	7	6	4	109	16	93	15	40	46	1	727

<sup>1</sup> Numbers in superscript refer to locations in Figure 1.

Table 6. Density of lead pellets in Prairie marshes.

Site	N <sup>1</sup>	Year	Pellets/ha	Pellets/m <sup>2</sup> ± S.D.
<b>Manitoba</b>				
Delta	840	1981	65,865 - 902,120	6.6 - 9.0
Reader Lake	50	1989	210,973 - 409,029	21.1 - 40.9
Chatique Lake	4	1989	1,517,711 - 2,316,393	151.8 - 231.6
Oak Hammock Marsh	180	1989	—	—
Oak Hammock Field	21	1989	867,264 - 1,466,967	86.7 - 146.7
Netley Marsh	70	1981	84,573 - 197,441	8.4 - 19.7
Otter Lake	70	1981	690,120 - 969,367	69.0 - 96.9
Whitewater Lake	70	1981	1,046 - 34,742	0.1 - 3.5
Minnedosa Pothole	60	1988	—	—
<b>Saskatchewan</b>				
Ponass Lake	70	1988	1,046 - 34,742	0.1 - 3.5
Valeport Marsh	210	1988	4,408 - 23,988	0.4 - 2.4
Crawford Lake	70	1988	—	—
Indi Lake	70	1988	—	—
Stalwart Marsh	70	1988	—	—
<b>Alberta</b>				
Bittern Lake	70	1988	—	—
Beaverhill Lake	210	1988	—	—
Whitford Lake	70	1988	—	—
Smokey Lake	70	1988	—	—
Cooking Lake	20	1988	—	—

N<sup>1</sup> = Sample size

## Discussion

The density of lead pellets in the substrate of water bodies may be a useful indicator of lead ingestion and may provide a method of identifying areas of concern, this of course depending on environmental conditions (e.g. siltation rate, water depth) and species considered. In areas where only upland hunting occurs, lead density may also serve as an indicator of ingestion if waterfowl feed extensively in hunted fields. Substrate type influences the availability of lead shot to waterfowl: lead pellets are unable to sink out of reach of waterfowl in wetlands with a hard substrate and remain available for ingestion, especially if natural sources of grit are absent. Many studies indicate that spent shot pellets sink into the sediment over the winter and are less available to waterfowl by the next summer. Most of these studies (Bellrose 1959; White and Stendell 1977; Browne 1978; U.S. Fish & Wildlife Service 1979-80) were undertaken in areas from which most waterfowl are absent during the summer. Depending on the consistency of the substrate and the feeding habits of the species present, pellets may remain accessible to waterfowl even after settling into the sediment. Dabbling ducks (Anatini) usually feed in water less than 40 cm deep and sift through the top 3 cm of sediment. Northern Pintails and Mallards puddle for seeds that resemble shot pellets and are likely to find expended shot. In Manitoba, Northern Pintails, Mallards and Blue-winged Teals showed altogether a higher incidence of lead pellet ingestion in summer than in fall. This may be due to a high proportion of waterfowl migrants in fall, staying in areas where lead pellets are present only for short periods.

Sample collection methods varied from summer to fall, which may have introduced bias. During the summer, birds were lured to baited traps for banding, and any casualties were examined for lead ingestion. This trapping would select adults at a higher rate than hunting. Poisoned birds may be less able to survive the stress presented by trap conditions, which might be expected to inflate the ingestion rates for the summer samples. However, a comparison of summer ingestion rates at Delta Marsh in 1979-80 with those for live fluoroscoped birds of 1948 and 1949 (Table 3) showed no significant difference. It is noteworthy that ingestion rates have not increased over time, indicating that the availability of a given pellet deposited over sediment probably decreases over time.

Estimates of shot ingestion in the fall sample may also tend to be inflated because of the increased vulnerability to hunting of lead intoxicated birds (Bellrose 1959). The magnitude of such effects in either the summer or fall samples is unknown, but both tend to inflate the ingestion rate. The date of marsh freeze-over influences shot ingestion (Bellrose 1959). The early freeze-up in Manitoba should favour lower fall ingestion rates as birds move southward to follow unfrozen water. More extensive summer samples should be collected to reach firmer conclusions about the prevalence of lead ingestion during non-hunting periods. It is necessary to consider summer ingestion when assessing the incidence of lead poisoning at any

given site.

Manitoba waterfowl hunters have a tradition of shooting over water, and these areas also serve as feeding, loafing and roost sites for ducks and geese. Samples from Oak Hammock Marsh were taken in managed hunting areas in which the marsh is closed to all shooting and effort is concentrated in adjacent dry land areas. Pellets found in waterfowl gizzards at Oak Hammock were probably deposited in previous years or were ingested in surrounding fields. Geese are exposed to lead when feeding in grain fields at Oak Hammock Managed Hunting Area. Oak Hammock was designated a non-toxic shot zone commencing in the 1991 hunting season, because of the high ingestion rates and some die-offs of geese in this area. No hunting is permitted at Big Grass Marsh refuge, and no lead was found in gizzards from this site. This area was included in the survey because of the heavy hunting in the 100-km<sup>2</sup> block within which it lies, which also includes Delta Marsh. The different hunting practices and waterfowl feeding behaviours at each site in Manitoba are reflected by significant differences in lead ingestion.

Ingestion rates in Saskatchewan are generally low. In Saskatchewan, hunters tend to shoot waterfowl landing in fields or on flight lines over land (pass shooting). Birds and hunters are more dispersed in Saskatchewan than in Manitoba, which limits the amount of lead shot deposited on any one area. Many of the hunted fields are cultivated in the fall, decreasing the availability of lead to grazing birds. All of these factors combine to lower the lead ingestion frequency in Saskatchewan. Mallards at Ponass Lake had a higher ingestion level than in other parts of Saskatchewan (Table 3), probably because the area is traditionally used as a marsh hunting area for non-residents. Further sampling to improve the sample size would help to verify the findings in this area.

Diving ducks (Aythyini) often tend to accumulate large numbers of pellets through their feeding habits, but lead-poisoning die-offs are infrequent due to their protein-rich diet (U.S. Fish & Wildlife Service 1986). The low ingestion rates for divers throughout Saskatchewan confirm the similar findings for dabbling ducks and indicate that little lead is being deposited in wetlands in the province. Similarly, ingestion rates for geese were well below the level of concern. Unlike some sites in Manitoba where geese had high ingestion rates in areas where duck ingestion was low, hunting effort over fields does not appear to be concentrated enough to pose problems for geese in Saskatchewan.

Hunters in Alberta do not traditionally use specific points, passes, islands or feeding and loafing areas on marshes and lakes as vantage points. Over-water shooting is uncommon in Alberta or is used opportunistically, with hunters rarely returning to the same site. This minimizes the accumulation of lead in most wetlands. Also, most of the lakes surveyed have extremely soft substrates, which allow the pellets to slowly sink out of reach of feeding ducks. Most lakes frequented by ducks

have limited access, and few hunters are equipped with waders or boats. Wetland areas are generally avoided by both ducks and hunters, following intensive activity in these areas on opening day. Hunting intensity tends to be low and dispersed in Alberta as a result of these combined considerations, which in turn decrease the likelihood that waterfowl will ingest lead shot. However, it does not preclude the appearance of local problems, as shown by the Incent Marsh data.

## Conclusion

It seems unlikely that a large-scale problem of lead contamination will develop at the sites assessed in Alberta in the immediate future. Specific sites (field or wetland) may, depending on the local environmental conditions, put waterfowl at risk of lead contamination due to spent lead shot. Based on the results obtained in Manitoba, it seems more likely that pellet ingestion will occur in summer, when waterfowl feed in wetlands. Hunting practices and intensity should be monitored to determine if spent lead pellets are likely to accumulate with a resulting increase in their availability to waterfowl.

The situation in Saskatchewan is similar to the one in Alberta, with few sites exhibiting waterfowl or sediment samples with high lead pellet frequency. Ponass Lake showed a frequency of lead shot in Mallard gizzards of 5%, requiring further sampling. Waterfowl at other sites showed high lead pellet ingestion, but sample size is limited. Additional studies should be conducted in Saskatchewan and Alberta on a limited number of species, in summer, with an objective of having sample sizes over 40 for all sites.

Of the three provinces, Manitoba presented the highest lead pellet ingestion rates and the highest number of sites that showed lead pellets in waterfowl gizzards and in soil samples. Non-toxic shot is already mandatory for hunting in Oak Hammock Managed Hunting Area, and a five-year project was started in 1991 to follow lead pellet availability in heavily hunted fields adjacent to the marsh, under different tillage methods. The Pas, Dauphin Lake and Delta Marsh areas are problematic and require further attention. Additional sampling is required to increase sample sizes at other sites.

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## LEAD INGESTION BY WATERFOWL IN ONTARIO

Adapted from: Dennis, 1990

### Abstract

Waterfowl gizzards were collected at various hunting locations in Ontario from 1980 to 1983 inclusively, and from some of these areas again in 1989 and '90. Gizzards were fluoroscoped and, if pellets were detected, dissected to determine pellet composition, and to separate out shot-in pellets. Blood samples were collected as part of a separate study in 1981 and 1982 and analyzed by hematofluorometry for elevated protoporphyrin levels. Ring-necked Ducks were collected in 1982 and '83 and assessed for elevated blood protoporphyrin to clarify previous findings that showed a high incidence of lead pellet ingestion with no apparent ill-effects.

Ingestion rates for five sites exceeded the 5.0% rate for dabbling ducks, but only two of these (Napanee and Lake St. Clair) had adequate sample sizes. Eight sites exceeded 5.0% for diving ducks, including two areas (Tiny/Wye Marshes and Cornwall) over 10.0%. Diving ducks, however, may be somewhat resistant to lead-poisoning, and 5.0% may not be indicative of a problem for this group of birds. Elevated protoporphyrin levels did not closely match ingestion rates. Lake St. Clair Mallards had higher protoporphyrin levels during the hunting season than before it (8.9% vs 3.8%), but only 7.2% had ingested lead. Conversely, only 2.6% of Long Point Mallards had elevated protoporphyrin vs 4.1% with ingested lead. Ring-necked Ducks also showed discrepancies between protoporphyrin levels and ingestion rates (38.0% and 12.7% respectively). Current data indicate that lead poisoning has limited occurrence in Ontario, but additional sampling may be required to confirm the situation in some areas. The Lake St. Clair area was zoned for non-toxic shot use beginning in 1990 to resolve the problem evident there.

### Introduction

Two contributing factors to the susceptibility of waterfowl to lead poisoning are: large numbers of available shot as a result of intense shooting pressure, and a diet deficient in certain amino acids, oligo-elements and vitamins (e.g. corn). Southern Ontario includes areas where these two factors are present. However, waterfowl loss to lead poisoning has not been extensive, primarily because of the relatively small number of wintering birds on a corn diet. During the last two decades, reported losses in Ontario have been limited. These include a few hundred Canada Geese and some Tundra Swans at Lake St. Clair in spring in the early 1970s, and a few hundred Mallards and American Black Ducks in 1975 on the fallout area of a former Royal Canadian Air Force skeet range near Aylmer. In the late 1980s

hundreds of Mallards and some American Black Ducks and Canada Geese were also killed by lead poisoning in the southern marshes at Lake St. Clair.

From 1980 to 1989, the Canadian Wildlife Service (CWS), in cooperation with the Ontario Ministry of Natural Resources (OMNR), conducted studies to document lead ingestion rates and their effects on Ontario waterfowl. This report summarizes the results of studies on lead ingestion and its effect on blood protoporphyrin concentration in Ontario waterfowl. Blood protoporphyrin is involved in heme synthesis and accumulates in blood as a result of lead interference.

## Methods

During 1980 and 1981, 4930 waterfowl gizzards were collected by OMNR and CWS staff at various waterfowl hunting locations throughout Ontario (Figure 1). In 1982, a CWS contractor collected 527 Mallard gizzards from the Lake St. Clair area; in 1983, 304 waterfowl gizzards were collected by contract at the Rondeau provincial hunting unit. Gizzards were collected in 1982 and 1983 because of the combination of small samples in earlier collections, high lead ingestion rates and the area's importance to waterfowl. All gizzards were appropriately labelled and frozen until examination for lead shot presence. In the January following each year of collection, a gizzard examination session was held at the CWS office in London. CWS, OMNR and University of Western Ontario staff participated.

Prior to analysis, all gizzards other than those from the Rondeau area were fluoroscoped at the University of Western Ontario Medical School and divided into three categories:

- (a) shot absent,
- (b) shot present,
- (c) objects present requiring further investigation.

Only gizzards in categories (b) and (c) were dissected, as exploratory dissections indicated that the fluoroscope assessments were essentially 100% accurate for category (a). All gizzards from the Rondeau area were also dissected. During dissections, care was taken to detect any shot that were shot into the gizzard rather than ingested by the bird.

Gizzards were also collected in 1989 and 1990 from some districts sampled previously in 1980-83. These included areas such as: Walpole Island, Rondeau Bay and Holiday Beach, because of their close proximity to Lake St. Clair; Prince Edward County, where earlier sampling hinted at high ingestion rates; and Holland Marsh and Lillabelle Lake, where gizzards were voluntarily collected by OMNR staff. The same methodology was followed for these subsequent samples as in the original study. We used Fisher's exact test to compare the lead ingestion rates found in the two periods of data collection at Rondeau, Holland Marsh, Prince Edward County and Lillabelle

Lake areas. Dabbling ducks and diving ducks were compared independently. Additional gizzard samples were collected in 1990 in the vicinity of Lake St. Clair.

During the autumn of 1981, blood samples from 304 Mallards were collected by Dr. C.D. Ankney of the University of Western Ontario under contract to CWS. Birds were captured as part of a waterfowl banding study conducted at the OMNR public hunting area near Long Point. The blood samples were screened in a hematofluorometer originally designed to detect lead intoxication in humans. The hematofluorometer was modified by the manufacturer to evaluate protoporphyrin concentration in waterfowl blood (after Roscoe et al. 1979). Roscoe (1979) indicates that finding a blood protoporphyrin level above 40  $\mu\text{g}/\text{dl}$  would suggest a duck had ingested the equivalent of at least one lead pellet approximately two days to one month prior to testing.

Blood samples were also collected by CWS staff from 474 Mallards during August and September 1982 as part of a pre-season banding operation at the St. Clair National Wildlife Area (NWA) on Lake St. Clair. Samples were analyzed by hematofluorometry as above. An additional 503 blood samples were collected from Mallards caught at Lake St. Clair during the 1982 hunting season. Weight, sex and age were recorded for all birds that were blood-sampled in 1981 and 1982.

Gizzard analysis in 1980 and 1981 showed that Ring-necked Ducks had high levels of ingested lead, but casual observations suggested that few Ring-necked Ducks bagged by hunters showed any overt signs of lead poisoning (such as reduced body weight). Because of these contradictions, further studies specifically directed at Ring-necked Ducks were initiated during the autumn of 1982. Seventy-one Ring-necked Ducks were collected during the autumns of 1982 and 1983 by staff members of CWS and the University of Western Ontario. Blood samples were obtained immediately upon retrieval of each bird. The technique was modified from that used with the hematofluorometer, because it was impossible to obtain blood from the brachial veins of the dead birds. Blood samples were usually obtained by severing the jugular vein and dripping between 1 and 2 ml into a heparinized vacutainer tube. Gizzards were dissected for ingested shot and blood samples were screened using the hematofluorometer. Sex, age and weight data were recorded in the field and retained with the blood and gizzard samples.

## Results

Table 1 provides a detailed breakdown of Ontario lead ingestion rates for dabbling ducks by species, by OMNR districts and by local areas for the years 1980-83. Waterfowl gizzards examined contained a variety of objects, including pieces of steel or aluminum, steel shot (all in birds collected near the U.S. border), and, in one gizzard, a small piece of gold. Five sites had ingestion rates for dabbling ducks above 5%, but only two of these had good sample sizes. The two sites indicating frequent ingestion of lead are Prince Edward County and Lake St. Clair. Dabbling

ducks with the highest mean ingestion rates were Mallards and American Black Ducks. Table 2 presents dabbling duck, Canada Goose, and Brant ingestion rates for various areas in Ontario in 1989. Table 3 shows detailed information on Mallards from the 1982 Lake St. Clair gizzard samples. St. Luke's Marsh had the highest ingestion rate at 10.0%, followed by Bradley's and Walpole Island at 7.5% and 5.5% respectively. Waterway Camp was just below 5%. Tables 4 and 5 present data for local areas on Lake St. Clair sampled in 1990. These results emphasize the problem of lead poisoning in this area. Only data from a small sample of dabbling ducks from Walpole Island showed ingestion rates under the 5% threshold. The results of statistical tests comparing ingestion rates in dabbling ducks between the 1980-83 period and 1989 are shown in Table 6. There was no change in ingestion rates during this time period at the four sites examined. However, it should be noted that the sample sizes are quite small for all but Rondeau in the second round of sampling. Given that there was no difference between the two samples, we pooled the data on Mallards from 1980-83, 1989 and 1990 and calculated a new ingestion rate based on the combined data (Figure 2). This figure generated an image of the average lead ingestion rate by this group in all areas considered.

In 1980-83, 7 out of the 9 areas with a sample size over 40 showed ingestion rates over 5% for diving ducks, including 3 areas that exceeded 10.0% (Table 7). These included Huronia and Cornwall districts. Data from gizzard samples of diving and sea ducks examined from four OMNR districts visited in 1989 are provided in Table 8. We found no statistical difference in the ingestion rates of diving ducks between the two sampling periods (Table 6).

The incidence of elevated protoporphyrin ( $>40 \mu\text{g/dl}$ ) in Mallards immediately prior to the 1982 hunting season at Lake St. Clair averaged 3.8% (Table 9). The incidence of elevated protoporphyrin in Mallards at Long Point during the 1981 hunting season represented 2.6% of the sample versus 4.1% for ingested shot (Table 10). Conversely, at Lake St. Clair, more birds had elevated protoporphyrin levels than had ingested lead (8.9% of the sample compared to 7.2%, respectively; see Tables 11 and 1). A higher proportion of adult female Mallards had ingested lead shot compared to adult males at Lake St. Clair in 1982 (Fisher's exact test two-tail:  $N=278$   $p=0.00135$ ). The same result was found in juvenile Mallards (Fisher's exact test two-tail:  $N=249$   $p=0.00314$ ). Surprisingly, the proportion of adult male Mallards with elevated levels of protoporphyrin was higher than for females (Fisher's exact test one-tail:  $N=114$   $p=0.0475$ ), but the data on juveniles failed to show a difference (Fisher's exact test one-tail:  $N=389$   $p=0.286$ ).

Data for Ring-necked Ducks collected during the autumn of 1982 and 1983 are shown in Table 12 and were included in Table 7. These analyses of blood protoporphyrin showed 27/71 Ring-necked Ducks (38.0%) with elevated lead levels, although only 12.7% of them had lead shot in their gizzard. Ingestion rates for Ring-necked Ducks across Ontario are very high at 22.7% (Table 7,  $N=379$ ).

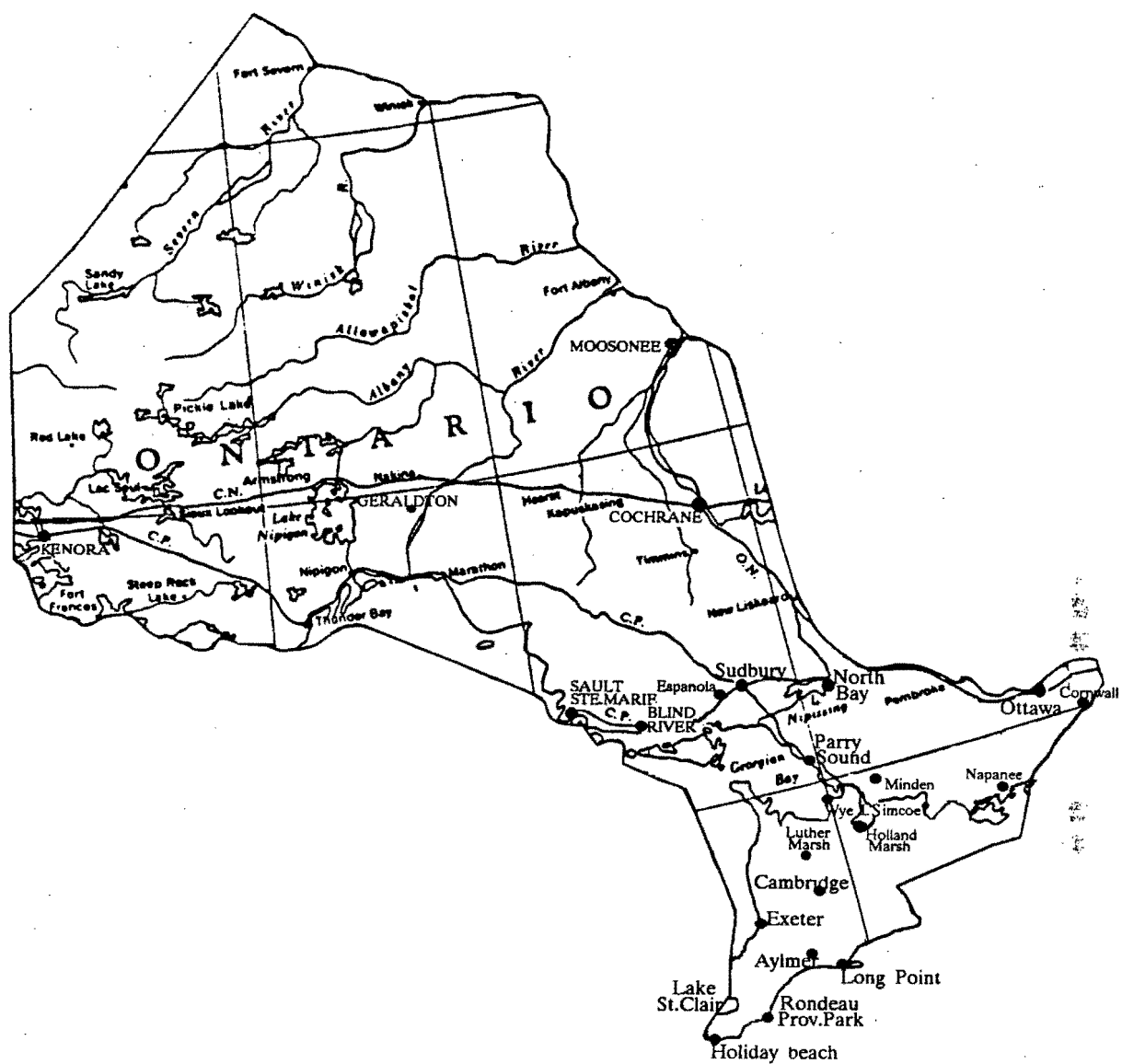
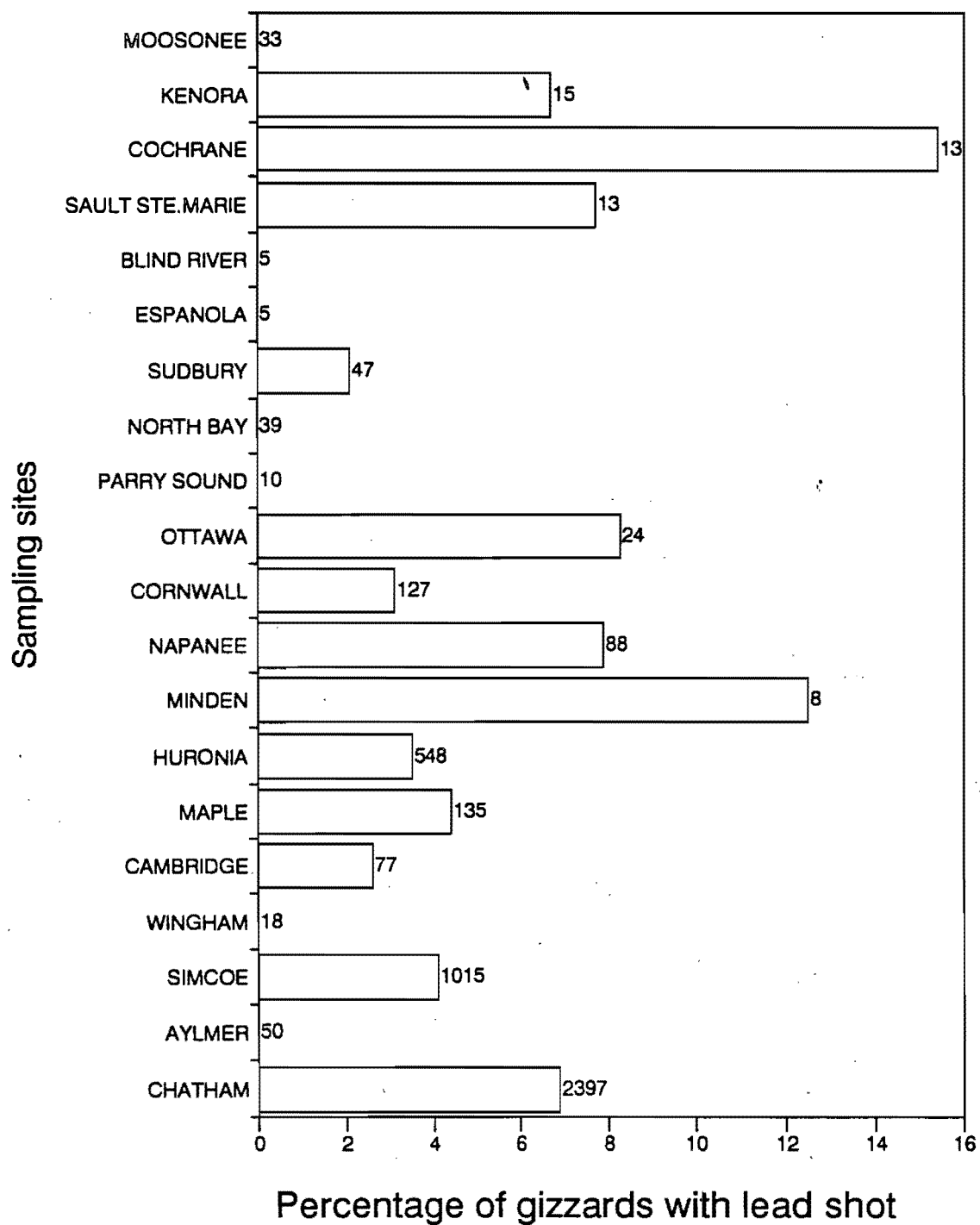


Figure 1. Location of sampling sites (filled circles) in Ontario.



<sup>1</sup> Numbers reflect sample size

<sup>2</sup> Data for Chatham include 1990

Figure 2. Lead ingestion rates in Mallards and American Black Ducks in 1981-83.

Table 1. Lead ingestion rates for dabbling ducks and Canada Geese in various areas of Ontario in 1980-83.

OMNR District	Area	Sample size (number with ingested shot)										Total gizzards	% gizzards with lead
		MALL <sup>1</sup>	ABDU	GADW	NOPI	AGWT	BWTE	AMWI	NSHO	WODU	CAGO		
Chatham	Lake St. Clair	733 (52)	2 (1)									735(53)	7.2
	Holiday Beach	14		2	2	5		1		2	8	34(0)	0.0
	Rondeau	182 (9)	52 (5)	19	12 (1)	52	72 (1)	37	1	32 (1)		459(17)	3.7
Aylmer	Elgin & Oxford Co.	47	3		6	1	1		1	27 (1)	6	92(1)	1.1
Simcoe	Long Point vicinity	1013 (42)	2			2						1017(42)	4.1
Wingham	Exeter vicinity	17	1		4							22(0)	
Cambridge	Luther Marsh	73 (2)	4	7	4	8	4	12		1		113(2)	1.8
Maple	Darlington Park, Holland Marsh, Lake Simcoe & others	115 (6)	20	8	7	56	21	10	1	35	6	279(6)	2.2
Huron	Tiny & Wye Marsh, Matchedash Bay & other local areas	487 (17)	61 (2)	13	20 (1)	61	132	38	2	159 (1)	2	975(21)	2.2
Minden	Various locations	5 (1)	3							9		17(1)	5.9
Napanee	Prince Edward County	71 (7)	17		6	7	6	4		14	5	130(7)	5.4
Cornwall	Dundas Co., Lake St. Francis, St. Lawrence River	102 (3)	25 (1)	28	18	6	26	15	8	5		233(4)	1.7
Ottawa	Constance Lake & Larose Forest	17 (1)	7 (1)				20	2		30		76(2)	2.6
Parry Sound	Ben's Lake, Rainy Lake, Bartlett Lake, Foley Twp.	3	7							2		12(0)	
North Bay	Lake Nipissing	30	9							1	1	41(0)	0.0
Sudbury	Various locations	34	13 (1)							13		60(1)	1.7
Espanola	Foster and Porter Twp.	3	2							1		6(0)	
Blind River	Various locations	2	3							17		22(0)	
Sault Ste. Marie	St. Mary's River and vicinity	10 (1)	3		2	4	2			1	2	24(1)	4.2
Cochrane	Lillabelle Lake and Glackmeyer Twp.	11 (2)	2									13(2)	15.4
Geraldton	Kanagamis Lake					1		2				3(0)	
Kenora	Various locations	15 (1)								1		16(1)	6.3
Moosonee	James Bay	23	10		18	9	2	2(1)				64(1)	1.6
All districts	All areas	3007 (144) 4.8%	246 (11) 4.5%	77 0%	99 (2) 2.0%	212 0%	286(1) 0%	123(1) 1.0%	13 0%	350(3) 1.0%	30 0%	4443(162)	3.6

<sup>1</sup> Abbreviations of waterfowl names are listed on page 77.

Table 2. Lead ingestion rates for dabbling ducks, Canada Geese and Brant in various areas of Ontario in 1989.

OMNR District	Area	Sample size (number with ingested shot)												Total Gizzards	% gizzards with lead
		MALL x ABDU Hybrid	MALL	ABDU	GADW	NOPI	AGWT	BWTE	AMWI	NSHO	WODU	CAGO	ATBR		
Chatham	Holiday Beach		27											27(0)	0.0
	Rondeau		55(2)	7	2	12	43	9	19	2	18			167(2)	1.2
Maple	Holland Marsh		9	2			20	6(1)						37(1)	2.7
Napanee	Prince Edward County		4	2	3	1	1	5				2	1	18(0)	0.0
Cochrane	Lillabelle Lake	1	11(1)	1		1	1	9	3					27(1)	3.7
Temagami	New Liskeard		10(1)	2				1	1					14(1)	7.1

Abbreviations of waterfowl names are listed on page 77.

Table 3. Lead shot incidence in Mallard gizzards from the Lake St. Clair area during the 1982 hunting season.

Location	Sample size (number with ingested shot)					% with ingested Shot
	Adult male	Adult female	Immature male	Immature female	Total gizzards	
Walpole Island Hunt Club	23(1)	38(4)	8	22	91(5)	5.5
Waterway Camp	7	6	3	5(1)	21(1)	4.8
St. Luke's Marsh	9	15(3)	1	15(1)	40(4)	10.0
Bradley's	70(1)	108(14)	71	123(13)	372(28)	7.5
Near St. Clair National Wildlife Area	0	2	1	0	3(0)	0.0
Total gizzards	109(2)	169(21)	84(0)	165(15)	527(38)	7.2
% with ingested shot	1.8	12.4	0.0	9.1	7.2	

Table 4. Lead ingestion rates for dabbling ducks near Lake St. Clair, 1990.

Species Location	Sample size (number with ingested shot)									Total	% with lead
	MALL	MALL X ABDU	ABDU	GADW	NOPI	AGWT	BWTE	AMWI	WODU		
Walpole Island		10(1)		4(0)	16(0)	41(0)	2(0)	16(1)	12(0)	101(2)	2.0
Walpole Reserve	1095(70)		146(12)							1241(82)	6.6
Mud Creek, Mitchell Bay & vicinity	162(13)		11(3)							173(16)	9.2

Abbreviations of waterfowl names are listed on page 77.

Table 5. Lead ingestion rates for diving ducks near Lake St. Clair, 1990.

Species Location	Sample size (number with ingested shot)						Total gizzards	% gizzards with lead
	REDH	RNDU	COGO	CANV	BUFF	RUDU		
Walpole Island	31(4)	66(10)	1	6	2	1	107 (14)	13.1

Table 6. Results of the statistical tests on ingestion rates of dabbling and diving ducks between 1980-83 and 1989.

OMNR district	Area	DABBLING DUCKS		DIVING DUCKS	
		Sample size	Probability of Fisher's exact test	Sample size	Probability of Fisher's exact test
Chatham	Rondeau	628	0.120	140	0.477
Maple	Holland Marsh	317	0.595	124	1.000
Napanee	Prince Edward County	148	0.598	108	1.000
Cochrane	Lillabelle Lake	41	0.232	48	0.0625

Table 7. Lead ingestion rates for diving ducks and sea ducks in various areas of Ontario in 1980-83.

OMNR District	Area	Sample size (number with ingested shot)															Total Gizzards	% with lead
		REDH	RNDU	GRSC	LESC	Scaup app.	COGO	COME	RBME	HOME	Merg app.	CANV	BUFF	OLDS	RUDU	Scoter app.		
Chatham	Lake St. Clair		71(12)														71(12)	16.9
	Holiday Beach		1		2		2(1)						3				8(1)	12.5
	Rondeau	18(3)	36(4)	3(1)	10		7					21	12				107(8)	7.5
Aylmer	Elgin & Oxford Co.																	
Simcoe	Long Point vicinity											1					1(0)	0
Wingham	Exeter vicinity																	
Cambridge	Luther Marsh	9(2)	17(4)	1	1								1				29(6)	20.7
Maple	Darlington Park, Holland Marsh, Lake Simcoe & others	4	8	27(1)	10(1)		11	14	2	6	9		20				111(2)	1.8
Huron	Tiny & Wye Marsh, Matchedash Bay & other local areas	34(3)	147(47)	53(7)	133(9)	25(7)	161	1	9	31		1	106(1)	20	1	22(1)	744(75)	10.1
Minden	Various locations									1							1(0)	0
Napance	Prince Edward County	3(1)	9			17(2)	7	1		3			7	1		3	51(3)	5.9
Cornwall	Dundas Co., Lake St. Francis, St. Lawrence River	18(3)	11(2)			9	2									1	41(5)	12.2
Ottawa	Constance Lake & Larose Forest	2(1)	28(12)	1	2												33(13)	39.4
Parry Sound	Ben's Lake, Rainy Lake, Bartlett Lake, Foley Twp.		1				1			2							4(0)	0
North Bay	Lake Nipissing		4			13(1)	5			3							25(1)	4.0
Sudbury	Various locations		18(2)			5(2)	8	12		2			2				47(4)	8.5
Espanola	Foster and Porter Twp.										3						3(0)	0
Blind River	Various locations																	
Sault Ste. Marie	St. Mary's River and vicinity	2	14(2)	20(3)	13		7		1	4			6	1		3	71(5)	7.0
Cochrane	Lillabelle Lake and Glackmeyer Twp.		1(1)		2												3(1)	33.3
Gerardton	Kanagamis Lake			1													1(0)	0
Kenora	Various locations		4		14	33(2)	2			2			1				56(2)	3.6
Moosonee	James Bay						1									1	2(0)	0
Total	All areas	93(14) 15%	379(86) 23%	106(12) 11%	187(10) 5%	119(16) 13%	220(1) 0%	29(0) 0%	12(0) 0%	57(0) 0%	12(0) 0%	23(0) 0%	165(1) 1%	23(0) 0%	1(0) 0%	32(1) 3%	1409 (138)	9.8

Abbreviations of waterfowl names are listed on page 77.

Table 8. Lead ingestion rates for diving ducks and sea ducks in various areas of Ontario in 1989.

OMNR District	Area	Sample size (number with ingested shot)											Total gizzards	% with lead
		REDH	RNDU	GRSC	LESC	Scaup spp.	COGO	RBME	CANV	BUFF	RUDU	Scoter spp.		
Chatham	Rondeau	2	17(3)	1	2				4(1)	4	1	2	33(4)	12.1
Maple	Holland Marsh		2							1			3(0)	0.0
Napanee	Presqu'ile, Amherst Island, Hay Bay, Bay of Quinte					35(3)	7	1		10		4	57(3)	5.3
Cochrane	Lillabelle Lake		6		1		38						45(0)	0.0

Abbreviations of waterfowl names are listed on page 77.

Table 9. Incidence of elevated ( $>40 \mu\text{g/dl}$ ) protoporphyrin levels by age and sex in Mallards sampled at Lake St. Clair immediately prior to the 1982 hunting season.

Age/Sex	Protoporphyrin levels		
	$<40$	$>40$	(%)
Adult male	33	2	(5.7)
Adult female	84	1	(1.2)
Immature male	209	7	(3.3)
Immature female	130	8	(5.8)
Total	456	18	(3.8)

Table 10. Incidence of elevated ( $> 40 \mu\text{g/dl}$ ) protoporphyrin levels by age and sex in Mallards sampled at Long Point during the 1981 hunting season.

Age/Sex	Protoporphyrin levels		
	$< 40$	$> 40$	(%)
Adult Male	70	2	(2.8)
Adult Female	30	1	(3.2)
Immature Male	98	2	(2.0)
Immature Female	106	3	(2.8)
TOTAL	304	8	(2.6)

Table 11. Incidence of elevated ( $> 40 \mu\text{g/dl}$ ) protoporphyrin levels by age and sex in Mallards sampled at Lake St. Clair during the 1982 hunting season.

Age/Sex	Protoporphyrin levels		
	$< 40$	$> 40$	(%)
Adult male	67	12	(15.2)
Adult female	34	1	(2.9)
Immature male	221	22	(9.1)
Immature female	136	10	(6.8)
Total	458	45	(8.9)

Table 12. Ring-necked Duck data for 71 samples in which free protoporphyrin and ingested shot were measured.

Age/Sex	Mean body weight in grams (sample size)		No. with elevated protoporphyrin (i.e. $> 40 \mu\text{g}/100 \text{ ml}$ )*	
	Without Shot	With Shot	Without Shot	With Shot
Adult Male	791 (14)	800 (1)	2 (14)	1 (1)
Adult Female	663 (3)	775 (2)	0 (3)	1 (2)
Immature Male	777 (24)	720 (7)	7 (24)	7 (7)
Immature Female	706 (18)	712 (2)	9 (18)	0 (2)

\* A greater number of birds without shot than those with shot had free protoporphyrin levels above  $40 \mu\text{g}/100 \text{ ml}$ .

( ) Sample size

# List of abbreviations

Code	English name	Latin name
ABDU	American Black Duck	<i>Anas rubripes</i>
AGWT	Green-winged Teal	<i>Anas crecca</i>
AMWI	American Wigeon	<i>Anas americana</i>
ATBR	Atlantic Brant	<i>Branta bernicla hrota</i>
BUFF	Bufflehead	<i>Bucephala albeola</i>
BWTE	Blue-winged Teal	<i>Anas discors</i>
CAGO	Canada Goose	<i>Branta canadensis</i>
CANV	Canvasback	<i>Aythya valisineria</i>
COGO	Common Goldeneye	<i>Bucephala clangula</i>
COME	Common Merganser	<i>Mergus merganser</i>
GADW	Gadwall	<i>Anas strepera</i>
GRSC	Greater Scaup	<i>Aythya marila</i>
HOME	Hooded Merganser	<i>Lophodytes cucullatus</i>
LESC	Lesser Scaup	<i>Aythya affinis</i>
MALL	Mallard	<i>Anas platyrhynchos</i>
Merg	Merganser	<i>Mergus spp.</i>
NOPI	Northern Pintail	<i>Anas acuta</i>
NSHO	Northern Shoveler	<i>Anas clypeata</i>
OLDS	Oldsquaw	<i>Clangula hyemalis</i>
RBME	Red-breasted Merganser	<i>Mergus serrator</i>
REDH	Redhead	<i>Aythya americana</i>
RNDU	Ring-necked Duck	<i>Aythya collaris</i>
RUDU	Ruddy Duck	<i>Oxyura jamaicensis</i>
WODU	Wood Duck	<i>Aix sponsa</i>

## Discussion

The incidence of high protoporphyrin levels in Mallards at Lake St. Clair was lower prior to the hunting season (3.8%) than during the hunting season (8.9%). This indicates that shot was generally picked up from the current season's deposition (confirming Solman 1966).

During gizzard analysis, it was discovered that a fair proportion of the shot present had been shot into the gizzard rather than ingested. Ingested shot normally have a bright, slightly abraded texture over their entire surface area. Shot-in shot were readily identified by wound channels through the gizzard walls and a bright, abraded area on only one portion of the pellet's surface. These abrasions are caused by contact with tissue and gizzard contents only on the pellet's leading surface during penetration. In addition, shot-in shot often had indentation marks from contact with other shot while in the gun barrel. In total, gizzards with shot-in shot accounted for approximately 50% of the gizzards with shot present (categories (b) and (c)). In the early stages of gizzard analysis, some shot-in shot were probably considered to be ingested; ingested percentages are, perhaps, slightly inflated.

In the gizzards from samples of Mallards from Lake St. Clair, adult males and immature males both show surprisingly low lead ingestion rates (Table 3). Banders operating in traditional baited sanctuaries have observed sex ratios heavily biased to adult males (D. Dennis, pers. obs.). It may be that baited sanctuaries attract adult males in disproportionate numbers, leaving them less exposed to lead shot deposited by hunting.

The blood analysis at Long Point and Lake St. Clair provided interesting additional information concerning the rates of lead uptake in birds. Hunter-killed samples may be biased towards birds that are already suffering from lead poisoning, as such birds are less wary and more vulnerable to predation (Bellrose 1959).

The contradiction between lead shot ingestion and protoporphyrin level data in adult Mallards at Lake St. Clair raises questions regarding the protoporphyrin results. It is often observed that a proportion of the population of lead-poisoned ducks has a concentration of protoporphyrin lower than 40  $\mu\text{g}/\text{dl}$ , because protoporphyrin can diffuse from erythrocytes *in vivo* and be cleared from the plasma by the liver (Roscoe et al. 1979). However, a higher proportion of the population with a high protoporphyrin concentration than that carrying lead shot remains unexplained.

At Long Point, most birds were sampled from the population using baited areas in the OMNR management unit; at Lake St. Clair, logistical considerations required that sampling encompass a wider geographic area. Gizzards were sampled from four

major locations: St. Luke's Marsh, Bradley's, Waterway Camp and Walpole Island Hunt Club. St. Luke's Marsh probably provides the most valid sample of trapped birds because of its proximity to the St. Clair NWA. Birds sit in legally baited sanctuaries at Bradley's, and are shot as they fly over flooded cornfields. Although this area is within 2 km of St. Clair NWA, birds using this area likely have lower exposure to lead shot, as they are not feeding in hunted marshes. The remaining two sample sites are approximately 13 and 25 km distant and are unlikely to be used by birds using the St. Clair NWA. Lead ingestion rates may vary greatly within a relatively small area, depending on local management and substrate. Sample sizes need to be large to accurately assess the lead ingestion rate in a given area.

Diving ducks appear to be more resistant to lead poisoning. It was hypothesized that their soft, high-protein diet resulted in reduced absorption of lead into the blood, but this hypothesis was rejected after 38.0% of the samples of Ring-necked Ducks showed elevated protoporphyrin (Table 12). In fact, 30% of the ducks having a protoporphyrin level over 40  $\mu\text{g}/\text{dl}$  did not have shot in their gizzards, while 25% of those with lead shot in their gizzards had protoporphyrin levels below 40  $\mu\text{g}/\text{dl}$ . It should be noted that the threshold value of 40  $\mu\text{g}/100\text{ ml}$  was defined for Mallards and may be different for other species.

Body weights for Ring-necked Ducks with and without elevated protoporphyrin levels are similar, corroborating the theory that this species is less susceptible to the effects of lead toxicosis than dabbling duck species. Further investigation concerning the suspected resistance of diving ducks to lead poisoning should include biochemical and physiological analyses.

## Conclusions

Lead poisoning of waterfowl appears to occur in limited areas of Ontario. A few of these areas would require additional sampling to confirm lead contamination problems. The large area bordering Lake St. Clair was zoned for non-toxic shot use beginning in the 1990 hunting season to mitigate the lead poisoning problem in this area. Due to the variability and contradictory results of protoporphyrin analyses, this technique seems to be of limited use for the identification of lead contamination problems.

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## QUEBEC SUMMARY OF LEAD SHOT INGESTION RATE IN WATERFOWL

Adapted from: Lemay et al. 1989

### Abstract

Gizzards were collected from hunters in 10 regions across the province of Quebec in 1987 and 1988. Lead pellets were isolated from other gizzard contents using a hydraulic separator, and shot-in pellets were distinguished from ingested shot. Assessment of lead contamination was based primarily on the results from dabbling ducks. Only 3 of the 10 regions had ingestion rates above 5.0% - Trois Rivières (8.4%), Montreal (6.8%) and the Outaouais (9.1%). These areas all have the highest hunting intensity. All other regions with reasonable sample sizes were below 3.0%. Within one of the low-ingestion regions (Abitibi-Temiscamingue), Lac Rouyn accounted for most of the pellet ingestion for dabbling ducks (57.1%) and diving ducks (97.5%). This site should be investigated further, as the ingestion rate for dabblers (4.9%) is close enough to the threshold to indicate a potential problem.

Lead contamination in Quebec appears to be confined mostly to the area along the St. Lawrence River between Montreal and Trois Rivières, where hunting activity is intense. Areas along the Ottawa River should be investigated further as sample sizes are somewhat small. These areas could be considered for non-toxic shot zoning.

### Introduction

A study was undertaken in Quebec by the Ministère du Loisir, de la Chasse et de la Pêche (MLCP) (Department of Recreation, Hunting and Fishing) to determine the incidence of lead ingestion in waterfowl hunting areas around the province during the years 1987 and 1988. Results from the study are summarized here, based on the publication "Incidence de la grenaille de plomb dans les gésiers de canards, d'oies et de bernaches récoltés au Québec" (Incidence of lead shot in the gizzards of ducks and geese harvested in Quebec) by André B. Lemay, Raymond McNicoll and Réginald Ouellet (published in May 1989) and from the examination of data provided by the MLCP.

### Methods

Waterfowl gizzards were collected from hunters in 10 regions in the province. Figure 1 is a map showing the regions and their names. Species were identified, aged and sexed by examining wing and tail feathers collected at the same time as the gizzard. Gizzards were cut open and their contents examined. Lead pellets were separated from other contents by water pressure using a hydraulic separator (after

Brewer 1981). Shot-in versus ingested pellets were distinguished by visual examination of the pellets as well as the gizzard walls. Two years of data were collected: the 1988 survey was conducted to verify the findings in problem areas identified in 1987, and to improve the sample sizes in those areas with little data retrieved in the first year. Data for 1987 and 1988 have been combined here to provide overall ingestion rates for the province. Pooling the data provides more accurate ingestion rates than averaging the results from two separate years, especially in those areas where sample sizes are small.

## Results and discussion

In 1987 and 1988, respectively, 3315 and 5539 waterfowl gizzards were collected. Waterfowl were considered in four categories: dabbling ducks, dominated in the sample by the Mallard (N=1750) and American Black Duck (N=2420); diving ducks dominated by the Ring-Necked Duck (N=546), Lesser Scaup (N=522), Common Goldeneye (N=306) and Greater Scaup (N=216); sea ducks, dominated by the Black Scoter (N=85) and White-winged Scoter (N=87); and geese, dominated by the Greater Snow Goose (N=269) and Canada Goose (N=289). Dabbling ducks are generally considered to be the most susceptible to the effects of lead poisoning, as well as having the best sample sizes, so emphasis will be placed on the results for this group.

When the sampling regions are considered separately, only 3 of the 10 regions stand out as potentially problematic for lead poisoning of dabbling ducks. Trois-Rivières (region 04), Montreal (region 06) and the Outaouais (region 07) showed ingestion rates of 8.4%, 6.8% and 9.1%, respectively (Table 1 and Figure 2). All other regions showed ingestion rates below 3.0%, except for Estrie (region 05), for which the sample size is small. Species with the highest ingestion rates are also those most frequently taken by hunters. Mallards, Black Ducks and Mallard × Black Duck hybrids had, altogether, an ingestion rate of 10.5% in region 04, 8.9% in region 06 and 13.7% in region 07. This group of species accounted for 88.6% of the total pellets ingested in region 04, 91.9% in region 06 and 90.1% in region 07. Mallards, Black Ducks and hybrids represented 71.2%, 69.6% and 60.2% of the dabbling ducks sampled in the three regions, respectively, so the ingestion rate is greater than the proportion of each species in the sample.

It is interesting to note that two of these three areas include portions of the St. Lawrence River between Montreal and Trois-Rivières, where the greatest hunting intensity in the province occurs. Most of the ducks with ingested lead shot in the Trois-Rivières zone were collected in a narrow zone along the St. Lawrence where hunting effort is greatest. The rest of this region lies within areas receiving only light hunting use (Figure 3). The situation within the Montreal zone is different, as 47% of ducks with ingested shot were from Venise-en-Québec, close to Champlain Lake. In the Outaouais region, the sampling effort was concentrated along the Ottawa River:

11 sites showed Mallard-Black Duck-hybrid ingestion rates over 5% (Figure 4) and 6 sites did not. These 6 sites, all with sample sizes under 10, were Angers, Baie Perras, Luskville, Baie Maclaren, Calumet and Laiches. Areas of heavy hunting effort are suspect for lead poisoning, as lead is deposited in high concentrations in these areas; lead is more dispersed, and therefore less likely to be picked up by waterfowl, in areas of less intensive hunting effort. It would be interesting to look at the results for each of these three regions in specific hunting locations to verify this theory.

In addition to the Venise-en-Québec site, this study did isolate another specific hunting location within the broader regions surveyed, which contributed extensively to the problem of lead ingestion. Lac Rouyn in region 08 (Abitibi-Témiscamingue) accounted for 45/49 or 91.8% of the pellets ingested by all species in that region, although it represented only 47.9% of the sample in that region. Interestingly, this area was less noticeably a problem for dabbling ducks than divers. Only 57.1% of the pellet ingestion for dabblers in region 08 occurred at Lac Rouyn (1987 data only), as opposed to 97.5% of the ingestion for diving ducks. It would be interesting to verify the hypothesis that the water at Lac Rouyn is slightly too deep for most dabblers to access the bottom, but is shallow enough to still provide access to pellets by diving ducks. Although the ingestion rate of 4.9% for dabbling ducks at Lac Rouyn (Table 2) is close enough to the 5% level to merit further investigation for non-toxic shot zone status, region 08 as a whole does not show levels high enough to cause concern.

A case similar to Lac Rouyn occurred in the Bas St-Laurent-Gaspésie-Iles-de-la-Madeleine zone (region 01), where all gizzards with ingested lead shot in 1988 came from Iles-de-la-Madeleine sites. Those results tend to confirm data obtained by Nadeau (1987). However, the overall ingestion rate in dabbling ducks of this region is still low, at 1.8% for the two years combined.

Similarly, regions 01, 02, 03, 09 and 10 show very low ingestion rates (Figure 2) and are probably not causing significant mortality. All of these areas, with the exception of region 03, receive little, or no, hunting pressure and likely have very small amounts of lead deposited. Region 03 has moderate hunting activity along the St. Lawrence shoreline, although this is not reflected by an elevated rate of pellet ingestion.

As in other jurisdictions in North America, ingestion rates for diving ducks are much higher than those for dabblers. Diving ducks seem to have an inherent resistance to lead poisoning, as significant blood lead levels do not result in weight loss or other symptoms of lead poisoning. However, ingestion rates such as 34.6% in the Outaouais and 32.5% for Lac Rouyn indicate the potential for lead poisoning to exist in those areas, and further investigation of effects on waterfowl should be considered. Geese and sea duck species had generally very low lead ingestion rates.



Figure 1. Sampling zones.

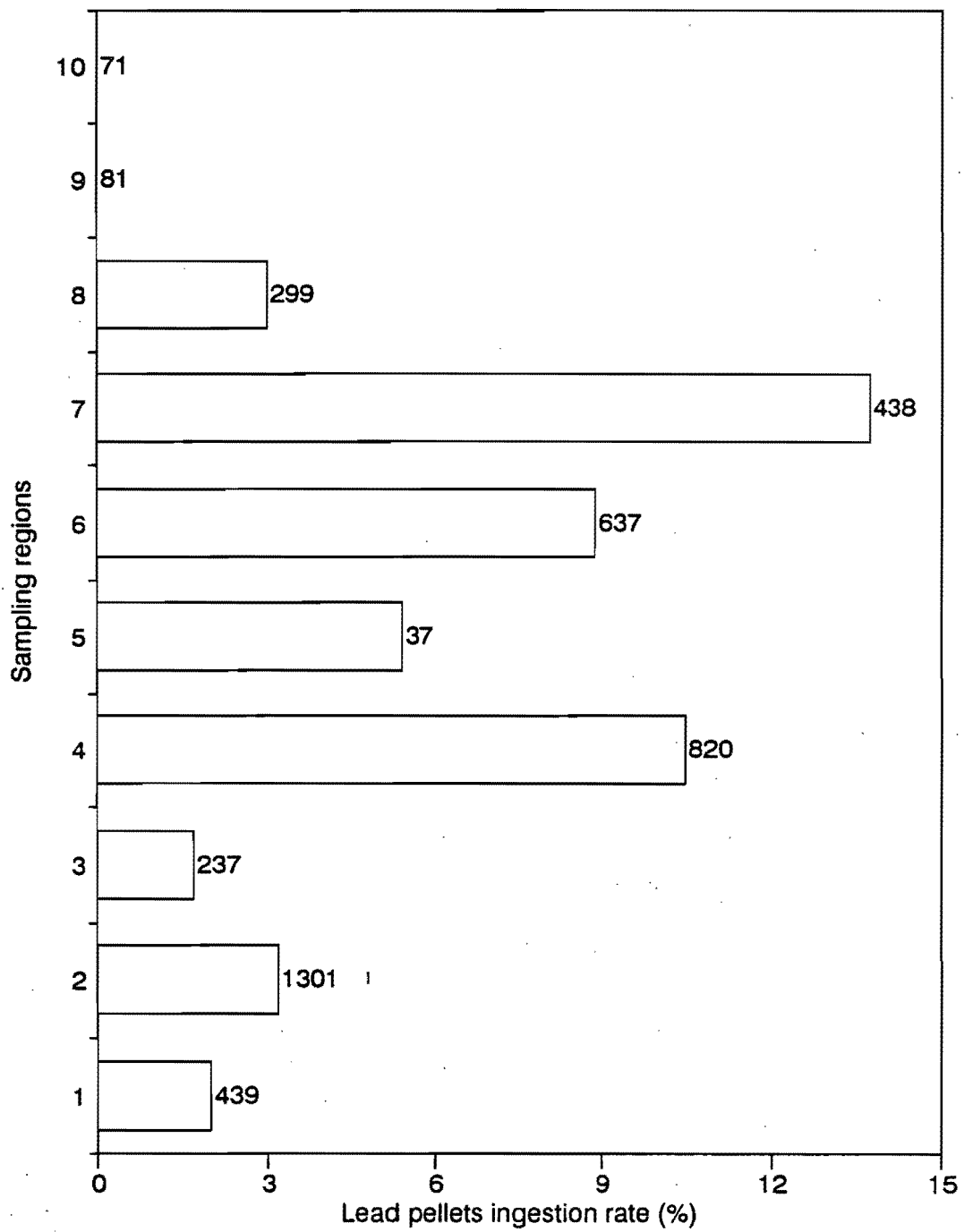


Figure 2. Ingestion rates in Mallards, American Black Ducks and hybrids in the 10 sampling regions during the 1987 and 1988 hunting seasons (numbers indicate sample size; refer to Table 1 for sampling regions).

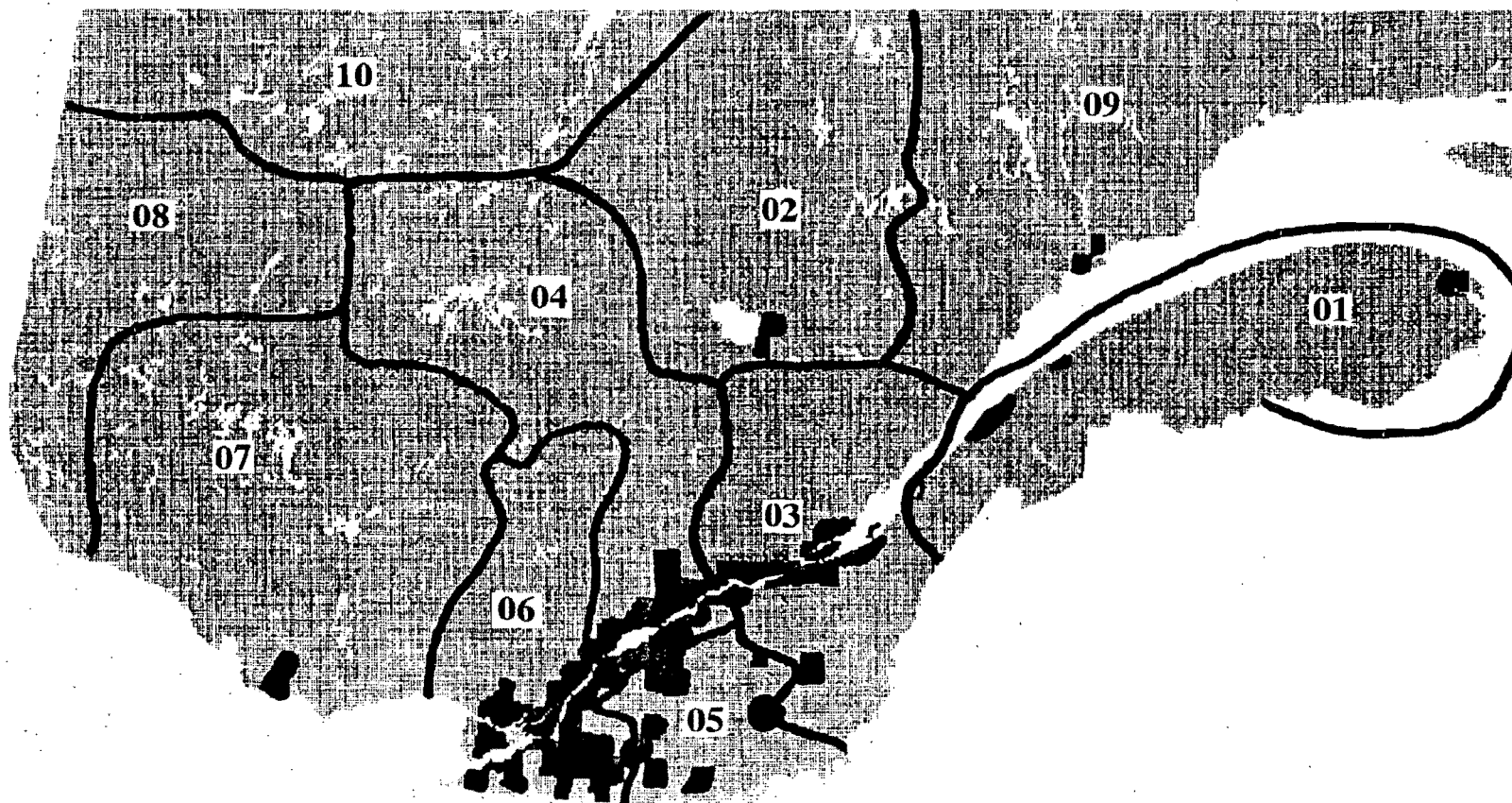


Figure 3. Intensity of waterfowl hunting per zone (Dark areas represent an intensity of hunting superior to 500 hunter-days in a 10 minute  $\times$  10 minute block; Data are for the period 1972-88).

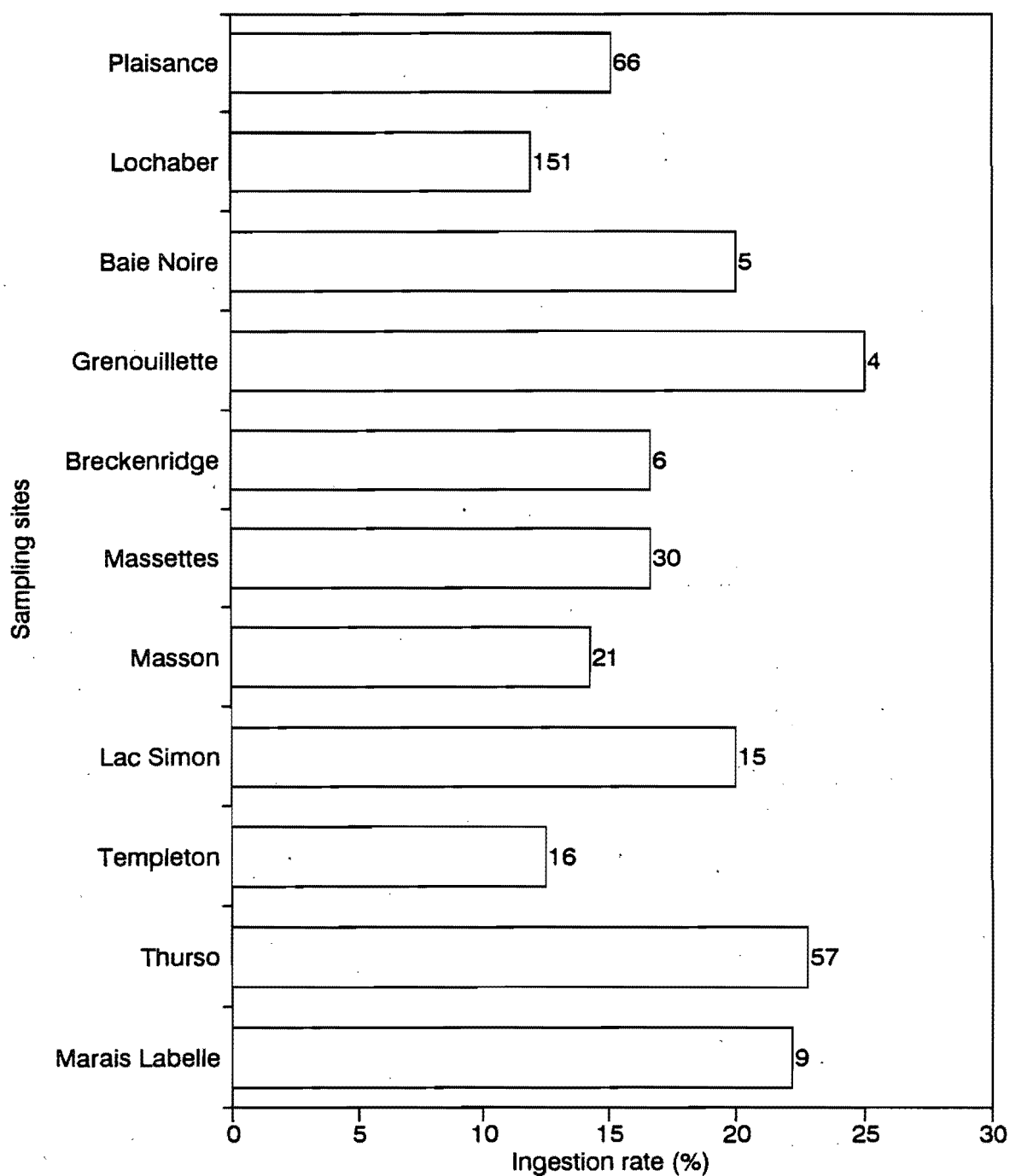


Figure 4. Ingestion rates in Mallards, American Black Ducks, and hybrids at various sites in the Outaouais region in 1988.

Table 1. Analysis of waterfowl gizzards in Quebec for ingestion of lead pellets during the 1987 and 1988 hunting seasons (pooled data).

Species	Sampling regions									
	01	02	03	04	05	06	07	08	09	10
<b>DABBING DUCKS</b>										
Mallard	40 (1)	348 (10)	55 (2)	433 (45)	19 (2)	398 (39)	251 (36)	177 (4)	2	27
American Black Duck x Mallard	24 (1)	65 (4)	11	28 (2)	1	29 (1)	12 (2)	10 (1)	4	6
American Black Duck	375 (7)	888 (28)	171 (2)	359 (39)	17	210 (17)	175 (22)	112 (4)	75	38
Gadwall		1	6 (1)	24 (1)		26 (1)	3			
American Wigeon	15	8	4	26 (1)		32	13	14	1	3
Green-winged Teal	106	113 (2)	98	156 (5)	9 (1)	100 (3)	44	20	51	4
Blue-winged Teal	8	31	5	13	2	22	53 (1)	11	1	
Northern Shoveler			4	24 (2)		5	2			
Northern Pintail	38 (2)	36	25 (1)	59 (2)		34	8 (1)	5 (1)	20	17 (1)
Wood Duck	6	12		30	12	59 (1)	166 (4)	9		
<b>TOTAL DABBLERS</b>	<b>622 (11)</b>	<b>1502 (44)</b>	<b>379 (6)</b>	<b>1152 (97)</b>	<b>60 (3)</b>	<b>915 (62)</b>	<b>727 (66)</b>	<b>358 (10)</b>	<b>154</b>	<b>95 (1)</b>
% gizzards with lead	1.8	2.9	1.6	8.4	5.0	6.8	9.1	2.8	0	1.1
<b>DIVING DUCKS</b>										
Redhead			3	5		10 (1)				
Canvasback				1		2				
Greater Scaup	4 (3)	4 (1)	38	63 (6)		91 (2)	2	11 (6)	3	
Lesser Scaup		26 (3)	160	87		105 (5)	33 (14)	94 (31)	17	
Ring-necked Duck	12	52 (1)	31	55 (6)	10 (1)	66 (6)	188 (74)	128 (15)	4	
Common Goldeneye	19	24 (1)	70 (2)	66		74	3	31 (3)	19	
Barrow's Goldeneye	3		8	2		3 (1)		3	4	
Bufflehead		1	2	9		6	3	45		
Ruddy Duck			2	1						
Common Merganser				6		6	1	24	5	1
Red-breasted Merganser	1	1	6	5	1	4	5	2	4	
Hooded Merganser	3	7	4	18	1	7	19	17 (1)	2	
<b>TOTAL DIVING DUCKS</b>	<b>42 (3)</b>	<b>115 (6)</b>	<b>324 (2)</b>	<b>318 (12)</b>	<b>12 (1)</b>	<b>374 (15)</b>	<b>254 (88)</b>	<b>355 (56)</b>	<b>58</b>	<b>1</b>
% gizzards with lead	7.1	5.2	0.6	3.8	8.3	4.0	34.6	15.8	0.0	0.0

Table 1. (continued)										
Species	01	02	03	04	05	06	07	08	09	10
<b>SEA DUCKS</b>										
Oldsquaw	1		2	6		7		1	29	
Common Eider	7		4	1		1			19	
Black Scoter	2	8	11	35		21		5 (1)	3	
White-winged Scoter	1	5	14	35 (1)		27	1	1	3	
Surf Scoter	3	2	10	13		20 (1)		1		
<b>TOTAL SEA DUCKS</b>	<b>14</b>	<b>15</b>	<b>41</b>	<b>90 (1)</b>		<b>76 (1)</b>	<b>1</b>	<b>8 (1)</b>	<b>54</b>	
% gizzards with lead	0.0	0.0	0.0	1.1		1.3	0.0	12.5	0.0	
<b>GEESE</b>										
Lesser Snow Goose			3							52 (1)
Greater Snow Goose	1	2	203 (2)	42 (2)		18		2		1
Canada Goose	17	126 (1)	32	26		39 (2)	1	29 (1)	4	15
Brant				2		4				
<b>TOTAL GEESE</b>	<b>18</b>	<b>128 (1)</b>	<b>238 (2)</b>	<b>70 (2)</b>		<b>61 (2)</b>	<b>1</b>	<b>31 (1)</b>	<b>4</b>	<b>68 (1)</b>
% gizzards with lead	0.0	0.8	0.8	2.9		3.3	0.0	3.2	0.0	1.5
<b>UNKNOWN DUCKS</b>	<b>9 (1)</b>	<b>30</b>	<b>5</b>	<b>46 (5)</b>		<b>27 (2)</b>		<b>2 (1)</b>		<b>2 (1)</b>
<b>GRAND TOTAL</b>	<b>705 (15)</b>	<b>1790 (51)</b>	<b>987 (10)</b>	<b>1676 (117)</b>	<b>72 (4)</b>	<b>1453 (82)</b>	<b>983 (154)</b>	<b>754 (69)</b>	<b>270</b>	<b>166 (2)</b>
% gizzards with lead	2.1	2.8	1.0	7.0	5.6	5.6	16.7	9.2	0.0	1.2

( ) Number of gizzards with at least one lead pellet

Regions: 01=Bas St-Laurent-Gaspésie-Iles-de-la-Madeleine 02=Saguenay-Lac St-Jean 03=Québec 04=Trois-Rivières 05=Estrie 06=Montréal  
07=Outaouais 08=Abitibi-Témiscamingue 09=Côte-Nord 10=Nouveau-Québec

Table 2. Ingestion rates for Lac Rouyn or region 08 as compared to region 08 as a whole. Data for Lac Rouyn are 1987 data only. Both pooled (1987+1988 data) and 1987 data are presented for comparison.

Dabbling ducks											
Year	Region	Mallard	American Black duck x Mallard	American Black Duck	American Wigeon	Green-winged Teal	Blue-winged Teal	Northern Pintail	Wood Duck	Total dabblers	% gizzards with lead
1987	Lac Rouyn	36 (1)	5 (1)	20 (2)	8	3	10			82 (4)	4.9
	Rest of region 08	81 (1)	4 (0)	42 (2)	3	12	1	1	6	150 (3)	2.0
1988	Rest of region 08	60 (2)	1	50	3	5		4 (1)	3	126 (3)	2.4
1987 + 1988	Region 08	177 (4)	10 (1)	112 (4)	14	20	11	5 (1)	9	358 (10)	2.8

Diving ducks												
Year	Region	Greater Scaup	Lesser Scaup	Ring-necked Duck	Common Goldeneye	Barrow's Goldeneye	Bufflehead	Common Merganser	Red-breasted Merganser	Hooded Merganser	Total divers	% gizzards with lead
1987	Lac Rouyn	8 (5)	28 (18)	64 (12)	9 (3)	3	3	2		3 (1)	120 (39)	32.5
	Rest of region 08		9 (0)	22 (1)	10 (0)	0	5	3	2	6	57 (1)	1.7
1988	Lac Rouyn	2 (1)	52 (13)	8 (1)							62 (15)	24.2
	Rest of region 08	1	5	34 (1)	12		37	19		8	116 (1)	0.8
1987 + 1988	Region 08	11 (6)	94 (31)	128 (15)	31 (3)	3	45	24	2	17 (1)	355 (56)	15.8

## Conclusions

Ingestion rates indicate that there may be a problem with lead poisoning of waterfowl along the St. Lawrence River between Montreal and Trois-Rivières. Further investigation of the Outaouais should be undertaken to increase the sample size in order to confirm the high lead ingestion rates obtained all along the Ottawa River. Results from the current study indicate that a problem is likely, despite relatively low hunting effort in this area. Lac Rouyn and Venise-en-Québec sites require investigation, as high rates of lead ingestion in ducks from those sites affected their whole regions. The majority of Quebec, however, does not show evidence of an extensive problem with lead pellet ingestion, particularly the northern two-thirds of the province, which supports very little hunting activity, other than along the James Bay coast.

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## SPENT LEAD SHOT IN THE MARITIME PROVINCES: AVAILABILITY TO AND INGESTION BY WATERFOWL

Adapted from: Hanson 1989; Bateman et al. 1989; Schwab and Daury 1989; Daury 1991; and Bateman and Barrow 1992.

### Abstract

Sediment samples from 14 heavily hunted marshes were collected in 1988-89 using a 15 cm diameter core sampler. Samples were examined for the presence of lead both visually and using a metal detector. Pellet densities ranged from 3.5 - 5.7 pellets/m<sup>2</sup> in New Brunswick, 0.9 - 8.6 in Nova Scotia and 4.8 - 9.1 in PEI.

Blood samples from waterfowl collected in 1988-89 were assessed for lead content using protoporphyrin levels for samples from New Brunswick, and atomic absorption spectrophotometry for samples from Nova Scotia and PEI. Elevated lead levels were found for 8.0% of Black Ducks in New Brunswick, 5.0% in Nova Scotia and 28.0% in PEI. These levels were not significantly higher than unhunted sites in Nova Scotia, but were statistically higher in PEI. Sullivan's Pond, Dartmouth, NS had elevated lead levels in 76% of the sample. As no hunting is permitted in this urban site, the most likely source of lead is from tetraethyl lead in gasoline, or from lead shot picked up from other areas.

Gizzards were collected from various sites in the three provinces from 1987 to 1990. Gizzards were dissected and examined for the presence of ingested lead. In 1991, birds were live-fluoroscoped to detect lead pellets. For the species group comprising Mallards, Black Ducks and their hybrids in New Brunswick, the ingestion rate was 8.2%, while 7.6% of fluoroscoped birds contained lead. The figures for Ring-necked Ducks were 17.9% and 11.2%. (A complementary 1992 study of ten fresh water marshes along the Saint John River determined that 9% of all waterfowl scanned contained pellets.) Ingestion rates for Black Ducks in Nova Scotia were 6.0%, and 14.3% of fluoroscoped birds showed lead near the gizzard. Nine percent of PEI Black Ducks fluoroscoped indicated lead presence, although sample sizes were small. Fluoroscoped Ring-necked Ducks in Nova Scotia and PEI ranged from 20% presence in the former to 59% in the latter.

All three studies indicate the likelihood of a lead contamination problem in parts of each of the three provinces. Additional studies to improve sample sizes in some areas would help to finalize areas requiring remedial action, but would be costly and time-consuming. Effort might be better directed at hunter education and development and promotion of non-toxic alternative shot.

## Introduction

In 1987, Acadia University and the Canadian Wildlife Service (CWS) initiated a study in Nova Scotia on the frequency of lead shot ingestion by waterfowl at two specific sites. The Eastern Canadian Waterfowl Advisory Committee recommended in 1988 that studies be carried out throughout eastern Canada to determine the importance of lead shot ingestion to eastern waterfowl populations. In the Atlantic Region, a cooperative study involving CWS, New Brunswick Department of Natural Resources and Energy, Nova Scotia Department of Lands and Forests, Prince Edward Island Department of Community and Cultural Affairs, Atlantic Veterinary College of the University of Prince Edward Island and Acadia University was initiated in 1988. Three aspects of the lead shot problem were investigated: the abundance of lead pellets in sediments, the frequency and abundance of lead pellets in waterfowl gizzards, and the frequency of high lead levels in blood. Newfoundland was not included in the study because there was no indication of lead poisoning in that province and hunting intensity is light in most areas.

## Methods

### Sediment sampling

#### *New Brunswick*

Ten heavily hunted marshes that were also used extensively by waterfowl were selected for sampling. There were two sites at New Horton, five at Germantown, two at Babbitts Meadow and one at Grassy Island (Table 1). Sampling stations were located in the marsh on a random-stratified basis. Additional samples were taken from areas with the highest shooting intensity. Two to five samples were taken at each sampling station. Sampling was restricted to water depths less than 135 cm. Each sample was taken with a core sampler 15 cm in diameter and 30 cm deep. The top 15 cm of the core was placed in a plastic bag, labelled and taken to the laboratory for analysis.

Each core sample was washed into a sieving box (mesh size=1 mm) to remove water-soluble sediments. The remaining sediments and vegetation were examined for the presence of lead shot visually, and with a lead detector (Model 4900/D, Geoquest Inc.). A 95% confidence interval of lead shot density (pellets/m<sup>2</sup>) was calculated, based on the assumption that each core sample containing pellets had only one pellet.

#### *Nova Scotia and Prince Edward Island*

Four heavily hunted marshes that were also used extensively by waterfowl were selected for sampling (Figure 1). Wallace Bay Impoundments 1, 2 and 3 (NS), and Johnston's River and Fullerton's Marsh, Queens County (PEI), were sampled systematically. The number of core samples taken was consistent for a given marsh

between years, but varied between marshes (5 to 12). The core sampler used was identical to that used in New Brunswick. The top 10 cm of each core sample was placed in a plastic bag and labelled. These samples were later cut in half and each half was sieved to detect lead shot presence.

The frequencies of lead pellets in core samples were compared between provinces, using a chi-square test. The density of pellets was evaluated with a 95% confidence interval based on a Poisson distribution, since occurrence of pellets in core samples is an uncommon event. Another value of the interval was also calculated to compare it with values from New Brunswick, where longer core samples were taken. We assumed that the frequency of lead pellets was proportional to the volume sampled. The occurrences of lead pellets in core samples from different sites were compared using Fisher's exact test.

### Tissue analysis

#### *New Brunswick*

Blood samples were collected from seven species of waterfowl (Tables 2 and 3) that were bait-trapped or captured with an airboat. One to two millilitres of blood was collected from the alar vein using a 3 ml Monoject syringe fitted with a 22 gauge, 1.8 cm needle. The sample was immediately transferred to a 110 x 13 mm vacutainer prepared for trace element determination. Both the syringe and the vacutainer were treated with sodium heparin. Blood samples were placed on ice and transferred to a refrigerator as soon as possible. Samples were shipped weekly to CWS facilities in London, Ontario, where blood protoporphyrin levels were determined using a hematofluorometer calibrated for waterfowl blood (AVIV hematofluorometer Model Z pp meter). Lead levels in blood samples were considered to be elevated if protoporphyrin levels exceeded 40 ug/dl (Roscoe et al. 1979).

#### *Nova Scotia and Prince Edward Island*

In summer through early fall, flightless juvenile American Black Ducks were collected at three hunted marshes and two unhunted marshes. Blood samples from Black Ducks and Ring-necked Ducks able to fly were collected at six hunted marshes and two unhunted marshes (Figure 1). After the 1988 hunting season, American Black Duck blood samples were collected at two sites in Prince Edward Island and at two sites in Nova Scotia, from birds captured in baited traps. Blood samples were collected from the brachial vein of each bird with a heparinized syringe, and stored in vacutainers prepared for trace element determination. Blood samples were frozen and shipped to the Atlantic Veterinary College for determination of lead content with an atomic absorption spectrophotometer. Blood samples were collected from American Black Ducks captured using trained retriever/pointer dogs, night lighting techniques and bait traps during summer, and with bait traps during January 1989. Lead levels in blood samples were considered to be elevated, if lead content was greater than 200

ppb (Dieter 1978). Comparison of blood lead levels between hunted and unhunted marshes was achieved using Fisher's exact test.

### Incidence of lead pellets in gizzards

#### *New Brunswick*

Nine marshes were selected for investigation, based on the need for lead information (potential lead problem expected) and how efficiently ducks could be captured. Hunters were asked to contribute the gizzard and a wing from each duck killed, which were then used to determine the sex, age and species of each bird. Gizzards from waterfowl carcasses encountered during the course of the study were also collected. All gizzards were frozen prior to their examination. Gizzards were cut open and their contents washed into large, shallow, white pans. Vegetation and water-soluble materials were decanted, and the remaining gizzard contents visually examined for the presence of lead shot. Ingested pellets were distinguished from embedded pellets by their external appearance. In 1991, birds were fluoroscoped alive for detection of lead pellets. We used a chi-square test to compare the frequency of lead pellet in the body between three categories (non-flying young, flying young and flying adult).

#### *Nova Scotia and Prince Edward Island*

In 1987, hunters were contacted directly as they were leaving Wallace Bay National Wildlife Area, NS, and gizzards were collected from harvested ducks. At Port Joli, NS, hunters were asked to keep gizzards of birds killed and keep records of the bird species for each gizzard. From 1988 to 1991, collection and analysis of gizzards in PEI and Nova Scotia were similar to the New Brunswick methods.

### **Results**

#### Sediment sampling

Prince Edward Island showed a frequency of lead pellets in the sediments higher than Nova Scotia ( $\chi^2=60.4$   $p<0.001$ ) and New Brunswick ( $\chi^2=44.5$   $p<0.001$ ), respectively. Results from New Brunswick and Nova Scotia were not significantly different from each other ( $\chi^2=1.34$   $p=0.247$ ).

#### *New Brunswick*

The density of lead pellets at the 10 sample sites ranged from 0 to a maximum of 15.6 pellets/m<sup>2</sup>. The most contaminated sites were Babbits Meadow Pond and Grassy Island (Table 1). Those two sites showed frequencies of lead shot in core samples significantly greater than all other sites pooled together (two-tail Fisher's exact test, Babbits Meadow Pond:  $df=1$   $N=785$   $p<0.001$ ; Grassy Island:  $df=1$   $N=785$   $p<0.001$ ). The density of pellets in the top 15 cm of sediments in the New Brunswick marshes sampled averaged 35,000-57,000 pellets/ha (3.5-5.7 pellets/m<sup>2</sup>).

### *Nova Scotia and Prince Edward Island*

The density of lead pellets in the top 10 cm of sediments at the five sample sites ranged from 0.9 to 8.6 pellets/m<sup>2</sup> in Nova Scotia and from 4.8 to 9.1 pellets/m<sup>2</sup> in Prince Edward Island. The most contaminated sites were Fullerton's Marsh and Johnston's River in Prince Edward Island and Martinique Beach in Nova Scotia (Table 1). Wallace Bay impoundment #2 showed a frequency of lead pellets in core samples significantly lower than all other sites pooled together (Fisher's exact test, two-tail - df=1 N=2113 p=0.004). The density of spent lead shot in the top 10 cm of sediments averaged 60,000-83,000 pellets/ha and 93,000-121,000 pellets/ha in the top 15 cm in Prince Edward Island. In Nova Scotia, the density of spent lead shot in the top 10 cm of sediments averaged 32,000-46,000 pellets/ha, and 46,000-60,000 pellets/ha in the top 15 cm of sediments.

### Tissue analysis

#### *New Brunswick*

Blood samples were analyzed for 377 ducks in New Brunswick during 1988 (Tables 2 and 3). Eight percent (15/196) of the American Black Duck samples had elevated blood protoporphyrin levels, indicating exposure to lead. Blood samples from Mallards, Wood Ducks, and Northern Pintails also indicated lead exposure.

#### *Nova Scotia and Prince Edward Island*

Blood samples were collected from 274 American Black Ducks during summer and early fall 1988 and 1989 in Nova Scotia (N=193) and Prince Edward Island (N=81) (Table 2). Elevated lead levels (>200 ppb) were found at all sites except East Amherst in Nova Scotia and Black Pond (Kings County) in Prince Edward Island. Hunted sites in Nova Scotia did not show blood lead levels statistically different from unhunted sites (Fisher's exact test, one-tail - df=1 N=165 p=0.895). However, hunted sites in Prince Edward Island did show blood lead levels statistically higher than unhunted sites (one-tail Fisher's exact test, df=1 N=59 p=0.042).

Post-hunting season blood samples were collected from 94 American Black Ducks in Prince Edward Island (N=47) and Nova Scotia (N=47) (Table 4). Seventy-six percent of samples from Sullivan's Pond in Dartmouth were contaminated with lead. As no hunting is allowed at this location, the lead may have been picked up as shot from other areas, or may have come from gasoline. Vernon River, Prince Edward Island, showed an incidence of waterfowl blood lead levels in the winter sample (5.9%) above what is considered background exposure (Table 4).

### Lead pellets in Gizzards and in fluoroscoped ducks

A fluoroscopy analysis of the frequency of lead pellets in the area of the gizzard of live American Black Ducks (Table 6) in 1991 in the three provinces showed that there was no difference between flightless young, young able to fly and adults ( $\chi^2$ : N=458 df=2 p=0.833). Species with good sample sizes (N $\geq$ 40) and

high ingestion rates from 1988 through 1989 were Ring-necked Ducks and the group formed by American Black Ducks, Mallards and hybrids. Northern Pintails in Nova Scotia and Prince Edward Island had frequency of pellets in their gizzards over the 5% threshold (Table 7). Figure 2 shows the overall fraction of contaminated American Black Ducks (presence of lead shot in gizzard by fluoroscopy or manual examination of gizzard content) in samples from each county in the Maritime provinces for which sample size was good.

#### *New Brunswick*

The analysis of 560 American Black Duck gizzards (Table 5) and of 331 fluoroscoped American Black Duck-Mallard hybrids collected from 1988 through 1991 (Table 6) showed an ingestion rate of 8.2% and a frequency of lead pellets in live birds of 7.6%. For Ring-necked Ducks, those numbers rose to 17.9% and 11.2% , respectively. Data on other species are too few to be conclusive. The most contaminated American Black Ducks were from White Birch/Sackville, Germantown and Evandale, with four other sites showing ingestion rates over 5%. For Ring-necked Ducks, all sites except one showed ingestion rates or pellet frequencies in the gizzard region of over 10%.

#### *Nova Scotia and Prince Edward Island*

From 1987 through 1991, a total of 813 American Black Duck gizzards were assessed (Table 8) and 152 birds fluoroscoped alive in Nova Scotia (Table 8), and 302 and 96 (Table 9), respectively, in Prince Edward Island. For Ring-necked Ducks, 119 gizzards were examined and 44 birds fluoroscoped in Nova Scotia (Table 8), and 72 gizzards examined and 18 birds fluoroscoped in Prince Edward Island.

#### *American Black Duck*

Among sites examined in Nova Scotia that had good sample sizes, only Wallace Bay NWA and East Amherst showed ingestion rates or frequency of lead pellets in the area of the gizzard over the 5% threshold. If we consider sites altogether, 6% of American Black Ducks ingested lead shot, and 14.3% of live birds contained lead pellets in the gizzard area.

In Prince Edward Island, most of the sites exhibited high ingestion rates or high frequency of lead pellets in the gizzard area greatly exceeding the 5% threshold, but sample sizes were generally small. However, 9% of all American Black Ducks had lead shot in the area of the gizzard.

#### *Ring-necked Ducks*

In Nova Scotia, sample sizes were low for most of the sites, except for East Amherst, where Ring-necked Ducks had a frequency of lead shot in the area of the gizzard of 20%. In Prince Edward Island, the only site with a good sample size, Pisquid Pond, showed a frequency of lead pellets in the gizzard area of 59% for Ring-necked Ducks.

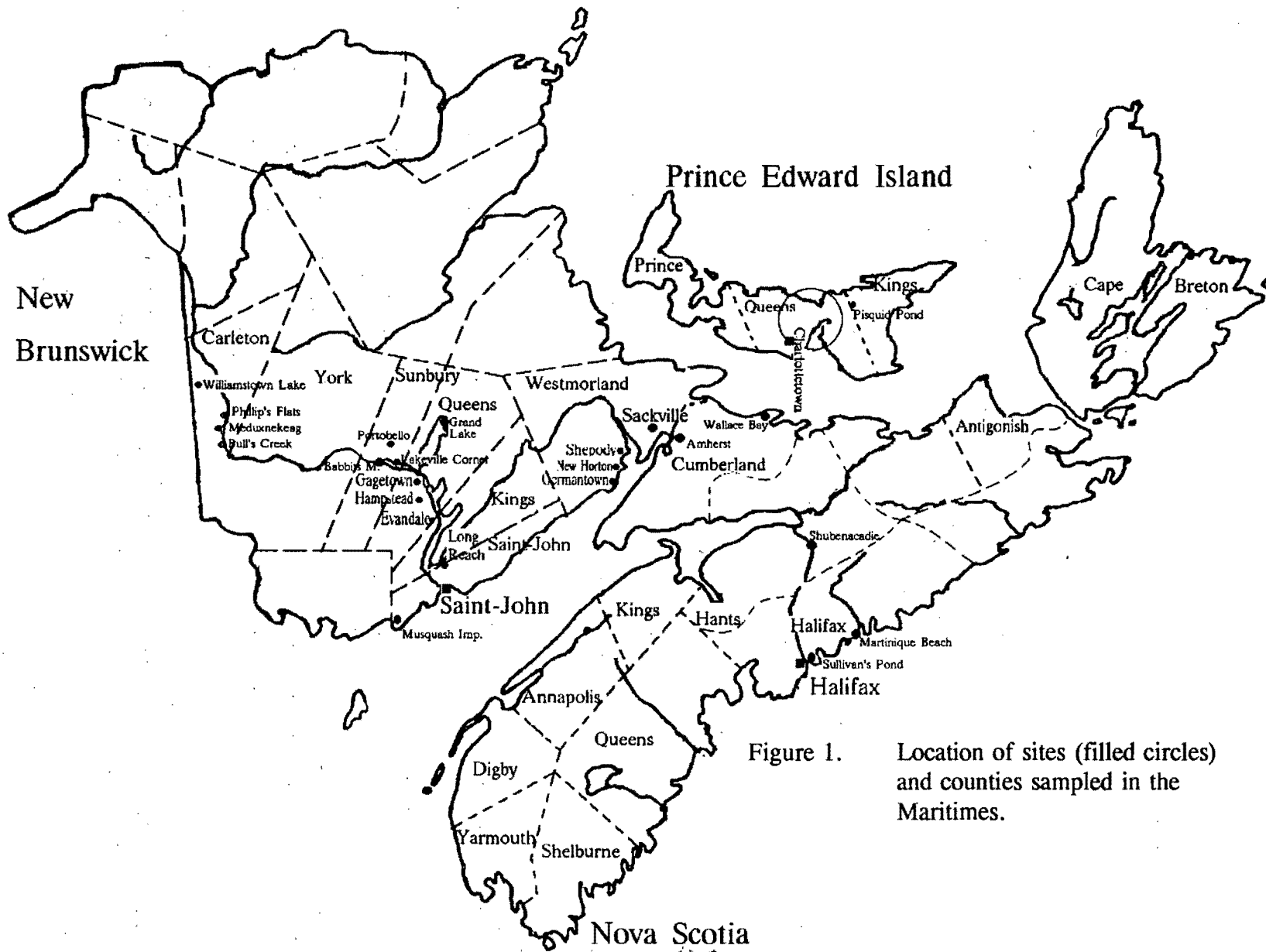


Figure 1. Location of sites (filled circles) and counties sampled in the Maritimes.

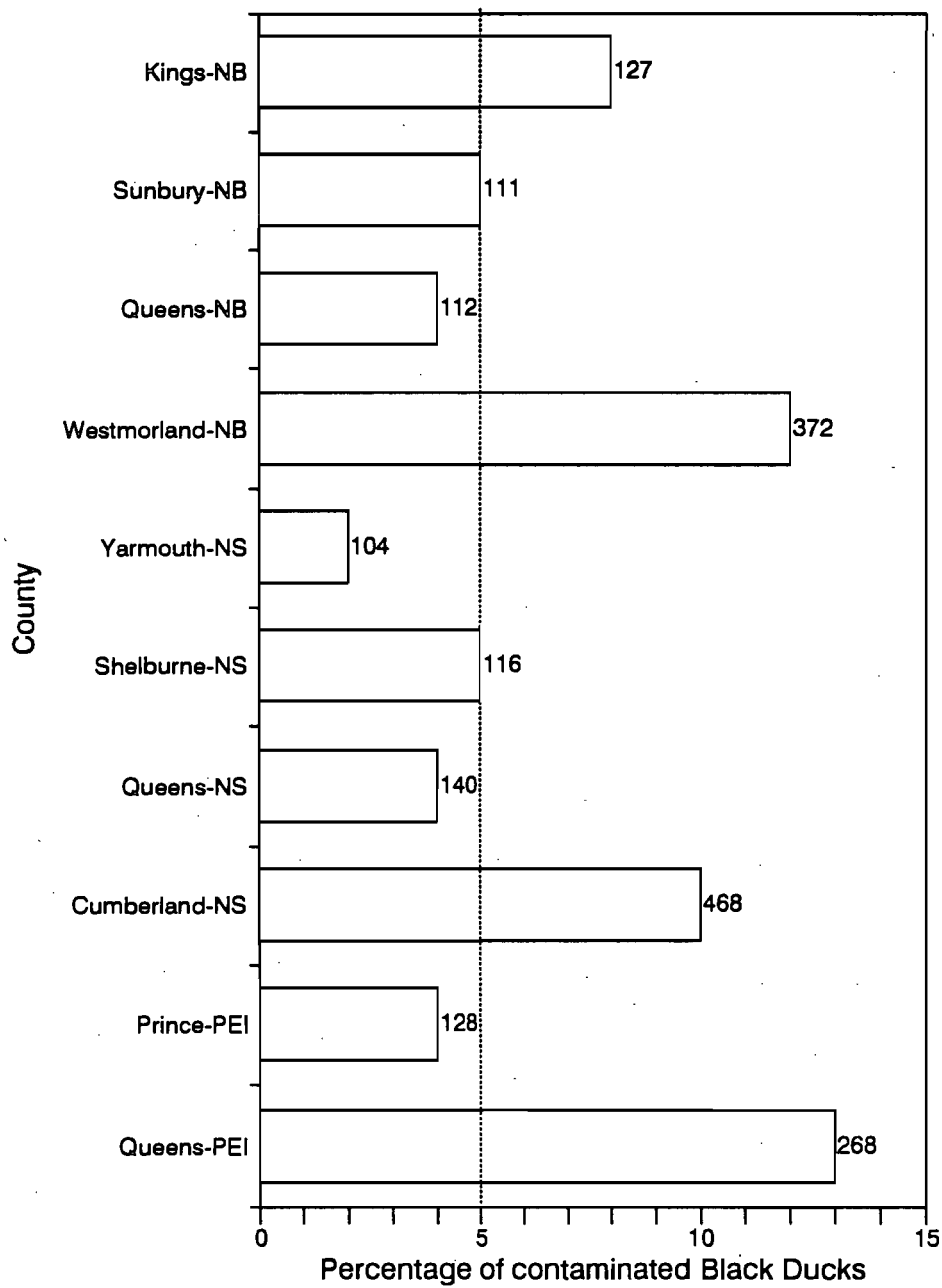


Figure 2. Percentage of American Black Ducks containing lead (from gizzard examination and fluoroscopy) by county.

Table 1. The incidence of lead shot in sediment samples collected in New Brunswick<sup>1</sup>, Nova Scotia<sup>2</sup> and Prince Edward Island<sup>2</sup> marshes in 1988.

Marsh	No. of sample sites	No. of cores	% cores with one or more lead shot	95 % confidence interval <sup>3</sup> of Lead shot density (pellets/m <sup>2</sup> for a 15-cm-deep core sample)
New Horton A - NB	49	130	3	0.7-4.4
New Horton C - NB	34	170	3	0.7-3.9
Germantown A - NB	18	55	9	2.2-12.1
Germantown A - NB	10	20	5	0.56-15
Germantown B - NB	25	75	4	0.8-6.6
Germantown C - NB	12	60	2	0.2-5.3
Germantown D - NB	9	45	0	0-4.6
Babbits Meadow - NB	10	50	4	0.6-8.1
Babbits Meadow Pond - NB	22	95	22	8.2-19.1
Grassy Island - NB	17	85	24	8.6-20.6
Fullerton's Marsh - PEI	95	643	13	9.5-13.5 (5.9-9.1) <sup>4</sup>
Johnston's River - PEI	80	511	11	7.8-11.9 (4.8-8.0)
Martinique Beach - NS	21	210	10	5.9-11.9 (3.7-8.6)
Wallace Bay Imp. # 1 - NS	193	1145	7	4.9-7.0 (3.2-4.9)
Wallace Bay Imp. # 2 - NS	58	406	3	1.7-4.1 (0.9-2.9)
Wallace Bay Imp. # 3 - NS	41	352	5	3.0-6.3 (1.8-4.6)
Missouri (Humberg and Babcock 1982)				9-37
Maine (Longcore et al. 1982)				10
Illinois (Esslinger and Klimstra 1983)				11
Delta Marsh, Manitoba (Hochbaum and Pochailo 1987)				9
Massachusetts (Windingstand and Hinds 1987)				16

<sup>1</sup> New Brunswick data from Hanson (1989)

<sup>2</sup> PEI and NS data include 1988 and 1989 data (Daury 1991)

<sup>3</sup> Intervals are presented for locations not in the Maritimes

<sup>4</sup> Intervals in parentheses refer to 10-cm-long core samples

Table 2. Results from American Black Duck and Ring-necked duck blood samples analyzed for elevated lead level in blood (>200 ppb) collected during summer and early fall 1988 and 1989.

Province	Location	American Black Duck			Ring-necked Duck		
		No. of birds sampled	No. with elevated lead	% of samples with elevated lead	No. of birds sampled	No. with elevated lead	% of samples with elevated lead
NS <sup>1</sup>	Amherst Point - no hunting	28	2	7.1	0	0	0
	East Amherst - hunting	33	1	3	33	0	0
	Eastern Shore - hunting	30	2	6.7	0	0	0
	Wallace Bay - hunting	102	6	5.9	36	4	11.1
	Total (hunting sites only)	165	9	5	69	4	5.8
PEI <sup>1</sup>	Black Pond - no hunting	22	0	0	0	0	0
	Fullerton's Marsh - hunting	24	9	37.5	0	0	0
	Deroche Point - hunting	4	1	25	1	1	100
	Johnston's River - hunting	31	10	32.3	11	2	18.2
	Total (hunting sites only)	59	20	28	12	3	25
NB <sup>2</sup>	Total	196	16	8.1	0	0	0

<sup>1</sup> NS and PEI data are from Daury (1991)

<sup>2</sup> NB data from Hanson 1989 are % of protoporphyrin levels > 40 ppm.

Table 3. Results from blood samples analyzed for elevated protoporphyrin (>40 ug/dl) in other species of waterfowl in New Brunswick.

Species	No. of samples	No. with elevated lead	% with elevated lead
Mallard and Mallard × American Black Duck hybrid	30	1	3
Wood Duck	43	4	9
American Wigeon	5	0	0
Northern Pintail	9	2	22
Blue-winged Teal	52	0	0
Green-winged Teal	42	0	0
Total	181	7	3.9

Data from Hanson 1989

Table 4. Results from American Black Duck blood analyzed for elevated lead levels (>200 ppb) collected in Prince Edward Island and Nova Scotia after the 1988 hunting season.

Province	Location	No. of birds sampled	No. with elevated lead	% of sample with elevated lead
PEI	North River	30	1	3.3
	Vernon River	17	1	5.9
	Total	47	2	4.2
NS	Shubenacadie	22	1	4.5
	Sullivan's Pond, Dartmouth	(25)	(19)	(76)
	Total (not including Sullivan's Pond)	22	1	4.5

Data from Daury 1991

Table 5. Incidence of lead shot ingestion for American Black Ducks and Ring-necked Ducks in New Brunswick, 1988-91.

New Brunswick	American Black Duck gizzard: 1988-91	Fluoroscoped American Black Ducks	% of contaminated American Black Ducks	Ring-necked Duck gizzards: 1988-91	Fluoroscoped Ring-necked Ducks	% of contaminated Ring-necked Ducks
White Birch/Sackville	101(19)	67(7)	15	61(9)	33(3)	13
Shepody NWA	112(10)	92(7)	8	131(31)	41(5)	21
Musquash	34(0)		0	50(5)		10
Gagetown	70(5)		7	19(4)		21
Portobello	111(5)		5	114(18)		16
Grand Lake	42(0)		0	70(16)		23
Long Reach	30(0)		0	9(4)		44
Evandale	60(7)	37(3)	10	87(10)		11
Total	560(46)	196(17)	8	541(97)	74(8)	17

Data from Hanson 1989; and Bateman and Barrow 1992

Table 6. Frequency of lead pellets in fluoroscoped ducks from selected marshes in New Brunswick, Nova Scotia and Prince Edward Island in the summer of 1991 (Bateman and Barrow 1992).

Province	Site	Species															
		American Black Duck-Mallard-Hybrid				Ring-necked Duck				Wood Duck				Northern Pintail			
		NFY <sup>1</sup>	FY <sup>2</sup>	AD <sup>3</sup>	% total	NFY	FY	AD	% total	NFY	FY	AD	% Total	NFY	FY	AD	% Total
N B	White Birch	5	81(9)	8(2)	11.7	25(4)	5	3	12.1		1	14	0		2(1)		50
	New Horton	1	35(1)	3	2.6	9(2)	8(1)	6	13.0		1		0				
	Germantown	14	44(7)	3	11.5	18(2)			11.1			13	0				
	Musquash Imp.		7	1	0	4	1	1	0								
	Hampstead		32(3)	9	7.3										1(1)		100
	Meductekeag R.	6	12	5	0							1	0				
	Bull's Creek	2	25(1)	3	3.3							1	0				
	Phillip's Flats	3	9		0												
	Williamstown L.		8(1)	15(1)	8.7												
N S	East Amherst B	18	83(11)	7(2)	17.6	9(1)	5(2)		21.4			11(1)	9.1	9(3)	4	4	17.6
	East Amherst A	23	3		0												
	Wallace Bay	2	15(3)	1	17.6	19(1)		11	3.3			3	0				
P E I	Suffolk Pond	28	4(2)	5	21.6					2		1	0				
	Fullerton's Marsh		3(1)	1	25												
	Johnston's R.		5(2)	1(1)	50		1		0			1	0				
	Tenmile House	16	17(7)	5	30.4												
	Glenfinnan					3			0								
	Pisquid Imp.		4	2(1)	16.7		1(1)		100								
	Mt. Stewart	9	2(1)	2	23.1		1		0								
	Deroche Point		5(1)	1(1)	33.3	2	2		0								

Data from Bateman and Barrow 1992

<sup>1</sup>NFY = non-flying young

<sup>2</sup>FY = flying young

<sup>3</sup>AD = adult

Table 7. Incidence of ingested lead shot in waterfowl gizzards collected from hunters in New Brunswick, Nova Scotia, and Prince Edward Island in 1988 and 1989.

Species	New Brunswick <sup>1</sup>			Nova Scotia and Prince Edward Island <sup>2</sup>		
	No. of gizzards	(no.)	%	No. of gizzards	(no.)	%
		with lead shot			with lead shot	
Canada Goose	11	(0)	0	71	(1)	1.5
Wood Duck	38	(1)	2.6	24	(0)	0
Green-winged Teal	120	(0)	0	583	(5)	0.9
American Black Duck	370	(19)	5.1	748	(38)	5.1
American Black Duck x Mallard Hybrid	32	(2)	6.2	23	3	13.0
Mallard	30	(1)	3.3	39	(3)	7.7
Northern Pintail	13	(0)	0	53	(4)	7.5
Blue-winged Teal	67	(0)	0	8	(0)	0
Shoveler	1	(0)	0	1	(0)	0
Gadwall				6	(0)	0
American Wigeon	37	(0)	0	41	(1)	2.4
Ring-necked Duck	177	(31)	17.5	76	(13)	17.1
Greater Scaup	4	(1)	25			
Lesser Scaup	2	(0)	0	3	(0)	0
Common Eider	66	(0)	0	1	(0)	0
Oldsquaw	2	(0)	0			
Black Scoter	4	(0)	0			
Surf Scoter	2	(0)	0			
White-winged Scoter	13	(0)	0			
Common Goldeneye	73	(2)	2.7	8	(0)	0
Barrow's Goldeneye	3	(0)	0	1	(0)	0
Bufflehead	18	(0)	0	5	(0)	0
Common Merganser	18	(0)	0	7	(0)	0
Red-breasted Merganser	10	(0)	0			

<sup>1</sup> Data from Hanson (1989)

<sup>2</sup> Data from Daury (1991)

Table 8. Incidence of lead shot ingestion for American Black Ducks and Ring-necked Ducks in Nova Scotia, 1987-91.

County	Sample sites	American Black Duck gizzard: 1987-91	Fluoroscoped American Black Ducks	% of contaminated American Black Ducks	Ring-necked Duck gizzards: 1988-91	Fluoroscoped Ring-necked Ducks	% of contaminated Ring-necked Ducks
Cumberland	West Amherst	32 (0)		0			
Cumberland	Missaguash	19(0)		0	3(0)		0
Cumberland	East Amherst	116(13)	134(19)	13	45(9)	14(3)	20
Cumberland	Wallace Bay NWA	182(15)	18(3)	9	57(5)	30(1)	7
Annapolis		8(0)		0			
Antigonish		15(1)		7			
Cape Breton		1(0)		0			
Colchester		2(0)					
Digby		5(1)		0			
Halifax		65(1)		20	1(1)		100
Hants		2(0)		0			
Kings		6(1)		17			
Queens		140(5)		4	5(0)		0
Shelburne		116(5)		5			
Yarmouth		104(2)		2	8(2)		25
Total		813(44)	152(22)	7	119(17)	44(4)	13

Data from Bateman et al. 1989; Schwab and Daury 1989; Daury 1991; and Bateman and Barrow 1992

Table 9. Incidence of lead shot ingestion for American Black Ducks and Ring-necked Ducks in Prince Edward Island, 1988-91.

County	Sample sites	American Black Duck gizzard: 1988-91	Fluoroscoped American Black Ducks	% of contaminated American Black Ducks	Ring-necked Duck gizzards: 1988-1991	Fluoroscoped Ring-necked Ducks	% of contaminated Ring-necked Ducks
Kings	Pisquid Pond	1(0)		0	51(28)	8(7)	59
Kings	Other in Kings County	21(1)		5	2(1)		50
Queens	Suffolk Pond		24(7)	29			
Queens	Fullerton's Marsh		4(1)	25			
Queens	Tenmile House		37(9)	24			
Queens	Glenfinnan	24(3)		12		3 (0)	0
Queens	Pisquid Impoundment	4(0)	6(1)	10	4(2)	1 (1)	60
Queens	Mount Stewart	5(0)	13(3)	17		1 (0)	0
Queens	Deroche Point	2(0)	6(2)	25	3(1)	4 (0)	14
Queens	Johnston's River	12(3)	6(3)	33		1 (0)	0
Queens	Dromore Pond				12(11)		92
Queens	Mermaid	2(0)		0			
Queens	Marshfield	1(0)		0			
Queens	Mount Hebert	1(0)		0			
Queens	Woods Creek, East River	9(0)		0			
Queens	Other in Queens County	92(2)		1			
Prince		128(5)		4			
Total		302(14)	96(26)	9	72(43)	18(8)	57

Data from Bateman et al. 1989; Daury 1991; and Bateman and Barrow 1992

## Discussion

### Sediment Sampling

Reliable estimates of spent lead shot densities in sediment are difficult to obtain. Very large sample sizes are required for reasonable confidence intervals of  $\pm 10\%$ . Results of sediment sampling are, however, useful as one of the indices to identify whether lead shot poses a problem on a given wetland. Lead shot was retrieved from samples in all except one marsh (Germantown D) sampled in the Maritime provinces (Table 1). Frequency of occurrence of lead shot in samples suggests that lead shot is relatively more available to waterfowl at Grassy Island (NB), Babbits Meadow Pond (NB), Fullerton's Marsh (PEI), Johnston's River (PEI) and Martinique Beach (NS).

For all sites combined, pellet density in 15-cm core samples in New Brunswick marshes was similar to that obtained for Nova Scotia, but lower than that obtained for Prince Edward Island. The most contaminated sites showed values similar to the mean contamination showed in three other studies. However, methodology was not the same in all studies (Table 1). Comparison between New Brunswick data and those from other Maritime provinces should be made cautiously, since a larger volume of sediment per sample was analyzed in New Brunswick, and the results could have been influenced by temporal variation in the rate of pellet deposition.

### Tissue Analysis

Blood samples collected before and during the hunting season and analyzed for lead contamination showed that high blood lead levels were over the 5% incidence threshold in three of the four marshes in Nova Scotia, three of the four marshes in Prince Edward Island and all sites combined in New Brunswick (Table 2). Finding lead-contaminated American Black Ducks during the summer suggests that ducks are ingesting lead in brood-rearing areas.

Analysis of results of American Black Duck blood samples collected in January from other sites in Nova Scotia and Prince Edward Island indicate a lower incidence of lead ingestion than for samples collected during summer (Table 4). Lead shot appears to be less available on feeding areas and habitat used by wintering American Black Ducks than on summer habitat. An extremely high incidence of lead contamination in ducks sampled from Sullivan's Pond is thought to be related to automotive contamination (gasoline tetraethyl lead) in this urban pond. However, one site in Prince Edward Island did have over 5% of the population with high blood lead levels in winter. Environment Canada's Environmental Protection Directorate is further investigating the source of lead in this area.

Blood samples collected from species other than the American Black Duck in New Brunswick suggested that Wood Ducks and possibly Northern Pintails also have access to large amounts of spent shot (Table 3). Teal showed no ingestion of lead pellets. Sample sizes were small, however, particularly for the Northern Pintail.

#### Lead pellets detected by fluoroscopy of the gizzard area of live ducks

Overall, the incidence of lead shot in American Black Ducks (as found in studies of gizzard content and fluoroscopy studies) in New Brunswick (8%), Nova Scotia (7%) and Prince Edward Island (9%) were over the 5% ingestion rate (Table 5, 8 and 9) established as the lowest level of concern by the Canadian Wildlife Service (CWS 1990). Subsequent studies in both New Brunswick (Barrow 1993) and Nova Scotia (W.R. Barrow, pers. comm.) also showed overall ingestion rates greater than 5% in the waterfowl sampled.

In all provinces, lead shot was present much more often in Ring-necked Ducks than in American Black Ducks.

#### **Summary and conclusions**

The frequency of lead shot in sediment samples was significantly high at 5 of the 15 heavily hunted marshes sampled: Babbits Meadow Pond (NB); Grassy Island (NB); Martinique Beach (NS); and Fullerton's Marsh and Johnston's River marshes (PEI). Only 6 of the 24 values obtained by Bellrose (1959) in various sites in north America were higher than the ones shown for the above sites. Estimates of pellet density were not precise, because of the large number of samples required for precision. Calculated pellet densities ranged from 0 to 15.6 pellets/m<sup>2</sup>. Density of lead pellets in the sediments is indicative of hunting pressure, but availability to waterfowl depends on the species, bottom firmness, water depth and current, siltation rate and ice cover.

Analyses of blood samples collected from American Black Ducks suggest that lead ingestion is unacceptably high in most heavily hunted marshes sampled in Nova Scotia and Prince Edward Island which are used as brood rearing habitat. Overall, 8% percent of American Black Ducks sampled in New Brunswick were contaminated by lead. A lower incidence of lead ingestion was indicated by blood samples from wintering American Black Ducks in Nova Scotia and Prince Edward Island. Analyses of gizzards and fluoroscopy of live birds suggest unacceptably high levels of lead shot ingestion in birds from several hunted marshes in the three provinces. For Ring-necked Ducks, lead pellet frequency in gizzards was very high, ranging from 17.9% to 59% in the three provinces. While immediate action may be taken to alleviate the problem of lead contamination in waterfowl in identified sites, marshes for which the sample size is small may also be at risk. Public education about the drawbacks of lead shot, and opportunities for use of alternative non-toxic shot, should be encouraged throughout the Atlantic provinces.

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## CONCLUSIONS

J.S. Wendt

This collection of papers has given a Canada-wide overview of the exposure of waterfowl to lead, which in most cases probably reflects an exposure to lead shot from hunting. A first, broad look was provided in the wing bone study by Dickson and Scheuhammer. The more detailed examinations at specific sites, with alternative methodologies, provided additional information.

The areas where lead exposure in waterfowl was indicated include parts of every province, although the areas of potential concern indicated in Newfoundland, Saskatchewan, and Alberta were small and isolated. In the other provinces, lead exposure was generally greater in more populated, or more heavily hunted, regions. Lead exposure in areas hunted primarily by aboriginal people were not properly represented, because aboriginal people are not included in the national harvest survey sample frame.

The studies in this report emphasised our incomplete understanding of the lead poisoning problem, and raised several important questions, such as:

- 1.) What significant sources of lead for waterfowl exist other than lead shot? The paper by Dickson and Scheuhammer suggests that mining operations in some areas may have caused lead exposure. Fishing sinkers are another source of lead that may be widespread in some areas frequented by waterfowl, and may be especially important as a source of lead for fish-eating birds.
- 2.) What is unusual about the toxicology of lead in diving ducks? The paper by Dickson and Scheuhammer indicated that 48% of the Ring-necked duck sample had "elevated" levels of lead in their bones, and 28% had more than 20 mg/kg. This concentration is significantly higher than what was found in dabbling ducks. Dennis remarked on the high indication of lead exposure in diving ducks. Hanson et al. had low samples for diving ducks, but very high exposure (59% occurrence in gizzards) was indicated at a site in PEI. Contrasting with this evidence of high exposure is a relative lack of reports of lead poisoned diving ducks.
- 3.) What are the ramifications of lead shot for raptors and other carnivores? Elliot et al. looked at the exposure of Bald Eagles to lead, but there is not an extensive literature on the effects of dietary lead on raptors, or on the exposure of Canadian raptors to lead. Presumably fishing weights can be a source of lead to Ospreys and Bald Eagles, and bullets and pellets from hunting upland species such as mammals can be a source to other raptors. Neither of these sources is controlled at present in Canada.

In Canada, the current solution to waterfowl contamination by lead shot ingestion is the mandatory use of non-toxic shot in areas where the problem has been shown to be significant. The papers in this report show that this approach must be applied much more broadly than is the case in 1993, if the risk of lead poisoning in waterfowl is to be reduced to acceptable levels.