**Lead shot incidence in Greater and Lesser Scaup on the Lower Great Lakes, one year after the ban of lead shot use for waterfowl hunting in Canada.**


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ABSTRACT

Use of toxic shot for waterfowl hunting was banned in the United States in 1991 and Canada in 1999 to reduce the incidence of lead toxicosis in waterfowl. The lower Great Lakes (LGL) are important migratory areas for Greater (*Aythya marila*) and Lesser Scaup (*A. affinis*) and both species contained high quantities of lead shot on the LGL prior to the ban (11% and 8% respectively). Greater and Lesser Scaup were collected from lakes Erie, Ontario and St. Claire during fall 1999 and spring 2000 to determine if toxic shot ingestion declined one year after the ban in Canada. There were no lake, season, sex or age related differences in proportion of Greater and Lesser Scaup that had ingested shot or any interspecific differences. The overall shot ingestion in was 0.6% toxic and 3.1% non-toxic shot. Extremely low lead shot ingestion (0.6% of birds) suggests that shot quickly becomes inaccessible to scaup on lacustrine areas of the Great Lakes and that toxic shot ingestion is not presently affecting scaup migrating through the LGL. Large pre-ban (8-11%) and post ban (3.7%) differences in overall ingestion suggests that pre-ban numbers may have been biased (elevated) due to the fact that lead increases harvest susceptibility. Low post-ban toxic shot ingestion are also indicative of high hunter compliance to shot regulations.

# INTRODUCTION

Lead shot was traditionally used for waterfowl hunting in Canada and the United States and this resulted in the accumulation of spent pellets in aquatic habitats (Rocke et al. 1997). Waterfowl periodically ingest lead when foraging in wetlands (Mateo et al. 2000) and this has caused many deaths in certain localities and among certain waterfowl species (Bellrose 1959; Sanderson and Bellrose 1986; Woebser 1981). Lead toxicosis also causes sublethal effects such as neurological damage (Dieter and Finlely 1979), reduced immune efficiency (Rocke et al. 1997) and reduced body weight (Sanderson and Bellrose 1986). Although birds can overcome the sublethal effects of lead poisoning, survival may be indirectly compromised. For example, waterfowl vulnerability to hunting and predation is increased as a result of altered behavior and habitat use (Sanderson and Bellrose 1986; Hohman et al. 1990; Moore et al. 1998).

Lead shot was banned for waterfowl hunting in the US in 1991 (Samuel and Bowers 2000) and in Canada in 1999 (Anderson et al. 2000) based on lethal and sub-lethal effects, and the possibility that lead ingestion had an impact on certain populations. Lead shot has been replaced with several non-toxic alternatives such as steel, bismuth and tungsten-matrix. Nevertheless, some wetland habitats still contain large quantities of previously deposited lead shot (Rocke et al. 1997). Toxic pellets should become inaccessible to waterfowl over time (Bellrose 1959), however, the rate at which lead shot sinks into the sediment depends largely on the type of substrate present (Bellrose 1959; CWS 1991).

In some waterfowl species and at certain localities, lead shot ingestion has declined, however, it has not in others. Lead exposure of live trapped Black Ducks (*Anas* *rubripes*) declined by 44% between 1986-88 and 1997-99 in Tennessee at Cross Creek National Wildlife Refuge and Tennessee National Wildlife Refuge (Samuel and Bowers 2000). Moore et al. (1998) reported a reduction from 27% in 1988-89 to 6% in 1992-93 of lead shot in the gizzards of diving duck (Canvasbacks, *Aythya valisineria*, and Lesser Scaup) at Catahoula Lake, Louisiana. Similarly, Anderson et al. (2000) found that lead shot incidence in Ring-Necked Ducks (*Aythya collaris*) and Greater and Lesser Scaup collected from the Mississippi flyway declined between 1977-79 and 1996-97 (Ring-necks, 20.4% to 12.7%; Greater and Lesser Scaup combined 8.8% to 4.3%). However, Canvasbacks and Mallards (*Anas platyrhynchos*) collected between 1977-79 and 1996-97 on the Mississippi flyway did not exhibit decreases in lead consumption (Canvasbacks 8.9% to 9.7%; Mallards 7.9% to 8.9%) (Anderson et al. 2000). Therefore, although it has been suggested that lead shot would become inaccessible to waterfowl and that non-toxic shot would become more prevalent over time (Samuel and Bowers 2000), incidence of lead shot ingestion remains high in some regions of the United States. In Canada, there has been no published work on lead ingestion by waterfowl since the 1999 ban on lead shot for hunting waterfowl.

The LGL provide important spring and fall migratory habitats for Greater and Lesser Scaup (Bellrose 1980; Dennis et al. 1984; Petrie and Knapton 1999). The, numbers of scaup staging and over wintering on the LGL has increased substantially since zebra mussels colonized in the mid 1980s (Petrie and Schummer 2002; Petrie and Knapton 1999). Large numbers of Lesser Scaup stage on lakes Ontario, Erie and St. Claire, whereas Greater Scaup tend to stage on Lakes Ontario and Erie (S. Petrie, *personal communication*). These lakes are also traditional waterfowl hunting areas and prior to the toxic shot ban, lead ingestion were high for Greater and Lesser Scaup. For instance, incidence of lead shot ingestion in birds harvested from Long Point in 1992 was 16% for Lesser and 11% for Greater Scaup (S. Petrie, unpublished data). Scaup collected throughout the LGL during 1980-83 also had a high lead shot ingestion (11% Greater Scaup; 5% Lesser Scaup; 14% Scaup spp.) (N. North, unpublished data). However, it is unknown how fast toxic shot becomes inaccessible to waterfowl on lacustrine wetlands and consequently, if migrating scaup continue to ingest lead on the LGL after the ban.

House sparrows (*Passer domesticus)* (Gionfriddo and Best 1995), Northern Bobwhites (*Colinus virginianus*) (Best and Stafford 2002) and Mallards (Trost 1981) increase their grit consumption when eating foods that are difficult to digest. There are conflicting views as to whether ducks consume shot because they confuse it with grit (Pain 1990; Mateo et al 2000) or if they actually actively select shot (Moore et al. 1998). Regardless, dietary composition influences the amount of grit consumed (Gionfriddo and Best 1995, 1996), which in turn influences shot ingestion (Pain 1990; Mateo et al. 2000). Therefore, since scaup diets have changed substantially since zebra mussels were introduced to the Great Lakes (Hamilton et al. 1994; Petrie and Knapton 1999), it is possible that shot ingestion have also changed since that time. Furthermore, since waterfowl diets can vary by season, sex and age (Krapu and Reinecke 1992 and references therein), shot ingestion may vary accordingly.

The objectives of this study were to (1) determine the relative proportion of toxic vs. non-toxic shot ingestion by Greater and Lesser Scaup on the LGL during the first year following the ban of lead shot for waterfowl hunting in Canada; (2) compare lead shot ingestion between birds collected prior to the ban to birds collected one year after the ban; (3) determine if birds with ingested lead shot are in poorer condition than those that ingested non-toxic shot and those without shot; and (4) determine if there are regional, seasonal, gender, age or species-specific differences in toxic and non-toxic ingestion by Greater and Lesser Scaup on the LGL.

## METHODS

Staging Greater and Lesser Scaup were collected by shotgun from lakes Ontario, Erie, and St. Claire (Fig 1), during fall 1999 and spring 2000 (Table 1) for a separate study of nutrient reserve dynamics and contaminant burdens. In the lab, gizzards were dissected out of the birds, cut open and all contents were removed and stored frozen in glass vials. Food was manually separated from grit, shot and other artifacts. All grit samples were manually searched twice for shotgun pellets and other artifacts. Steel shot was identified using a magnet and pellets that were non-magnetic but could be distorted by manual force (scalpel) were categorized as lead (Daury et al. 1994). Pellets that were not magnetic or malleable were categorized as non-toxic shot (e.g. tungsten-matrix, bismuth). Deformed pellets and those that were covered with feathers (indication they were shot in and not ingested) were excluded from the analysis (Anderson and Havera 1985).

There are different ways to determine if a bird has been exposed to lead; liver or other organ analysis (Rocke et al. 1997; Mateo et al. 1997), or analysis of blood for lead and protoporphyrin levels (Havera et al. 1992; Sanderson and Bellrose 1986). Although, blood lead levels provide a sensitive indicator of lead poisoning, lead shot ingestion provide a good indication of the degree of lead exposure in wild waterfowl populations

(Anderson and Havera 1985). Shot consumption identified in this study were compared to unpublished data from the 1980s (Canadian Wildlife Services) and early 1990s (Long Point Waterfowl and Wetlands Research Fund) to determine if there has been a decrease in lead ingestion on the LGL since the implementation of the lead shot ban in 1999.

Analysis of frequencies were used on the number of birds with ingested shot since the data did not satisfy the normality of residuals and homogeneity of variance required for parametric analysis (Sokal and Rohlf 1981) despite several transformations (square root, arcsine and arcsine-square root). Fisher's exact tests (Sokal and Rohlf 1981) were used to make pair-wise comparisons of the relative number of birds containing toxic shot (lead) and non-toxic shot (steel, tungsten-matrix, bismuth) by location (lakes Erie, Ontario, St. Claire), age (adult, juvenile), season (fall, spring) and sex (male, female) for both Greater and Lesser Scaup. The log-likelihood ratio test was used to determine seasonal, regional, age and sex related differences in the proportion of Greater and Lesser Scaup with ingested shot (Sokal and Rohlf 1981).

Because ingested lead can adversely affect bird condition (Sanderson and Bellrose 1986; Hohman et al. 1990), I had intended to compare the condition (levels of body fat) of birds that had consumed lead with all other birds collected. However, since only 0.6% (4 of 722) of the birds contained lead, I was unable to do this analysis.

## RESULTS

### Prior to lead shot ban

A higher proportion of Greater Scaup (11%, $n$ =106) collected during 1980-83 contained lead shot than Lesser Scaup (5%, $n$ = 187) (G = 4.181, d.f. = 1, $P$ = 0.041).

There were also 14% (*n* = 102) of scaup spp. with ingested lead shot, however, the birds were not identified to species. In comparison, there was no interspecific difference in proportion of Greater (11%, *n* = 27) and Lesser Scaup (16%, *n* = 55) harvested in 1992 with ingested lead shot (G = 0.4116, d.f. = 1, $P = 0.519$).

<u>After lead shot ban</u>

Only 3.1% of Greater and 4.2% of Lesser Scaup collected post-ban on the LGL contained shot. Shot ingestion during 1999-2000 did not vary interspecificly or intraspecifically by lake, season or age (P > 0.05 for all comparisons). Pooled likelihood ratio tests for sex differences between Greater and Lesser Scaup indicates that there is an interaction between species and sex. A higher proportion of Greater Scaup females and Lesser Scaup males contained shot than Greater Scaup males and Lesser Scaup females (Table 2).

The combined proportion of Lesser and Greater Scaup containing toxic and non-toxic shot on the LGL was low; out of 722 birds collected only 26 (3.7%) contained shot. Overall, 23 birds (3.1%) contained non-toxic, 3 birds (0.5%) contained toxic, and 1 bird (0.1%) contained both. There was no interspecific difference in the overall relative number of toxic and non-toxic shot ingestion (Greater Scaup, 0.7% toxic and 2.4% non-toxic; Lesser Scaup, 0.5% and 3.7%) ($P = 0.582$). Also, toxic and non-toxic shot ingestion did not vary intraspecifically by region, season, sex, or age (Table 3).

# DISCUSSION

## Shot Ingestion Prior to and Following the Lead shot Ban

Prior to the ban on toxic shot use for waterfowl hunting in Canada, scaup on the LGL had high proportion of birds with ingested lead shot. For instance, 10% of scaup harvested during 1981-83 (N. North, unpublished data) and 14% of scaup harvested during 1992-93 (S. Petrie, unpublished data) contained ingested shot. Greater and Lesser Scaup collected during 1999-2000 (one year after the ban) had a much lower incidence of ingested shot (3.7%). Of that 3.7%, 3.1% was non-toxic shot and only 0.6% was toxic shot. Although, there was a slight decline in number of waterfowl hunters in southern Ontario during the later part of the 20$^{th}$ Century (S. Petrie, *personal communication*), this does not explain the 300% decline of shot ingestion. Scaup underwent a dietary shift on the LGL in response to invasion of exotic zebra mussels in the mid-1980s. However, the shift has been largely from native gastropods to zebra mussels which are introduced mollusk (Ross et al. submitted, Petrie and Knapton 1999), each of which comprises a substantial proportion of calcareous shell. Therefore, this dietary shift alone also likely does not explain the substantial reduction in shot ingestion since lead was banned. Temporal differences in reported shot ingestion are more likely a function of the different types of shot that are available to waterfowl. It is well known that waterfowl suffering from lead toxicosis are in poor physical condition and are more susceptible to harvest (Bain 1980; Pace and Afton 1999; McCracken et al. 2000). Therefore, previous studies reporting lead ingestion in waterfowl from hunter harvested samples are potentially biased. I suggest that the low shot ingestion in this study are more reflective of ingestion as non-toxic shot does not influence condition or harvest susceptibility.

Relative Amount of Toxic and Non-Toxic Shot Consumed Following the Ban

There were no interspecific or intraspecific differences in relative shot ingestion of toxic and non-toxic shot ingestion between age, lake, season and sex (Table 3). Lack of statistical significance may simply be a function of extremely low shot ingestion. However, Greater and Lesser Scaup are closely related species which stage and winter on similar habitats (lakes, coastal bays and estuaries) and have similar feeding habits (Hener et al. 1996). Also, similar dietary items are likely consumed by both age classes and sexes during migration, which may also explain the lack of significance in shot consumption. Although, statistically there were no regional differences in the proportion of non-toxic and toxic shot, it might not mean that there are no differences in the availability of lead. For instance, lead availability in Lake Erie might be lower since no lead shot was found in either Greater or Lesser Scaup.

Prior to the ban, lead was the primary shot type used for waterfowl hunting in Canada. The low proportion of birds with ingested lead shot one year after the ban indicates that lead must quickly become inaccessible to waterfowl on the LGL. Although, several other post-ban studies indicate that waterfowl consume larger quantities of non-toxic shot (Anderson et. al 2000; Rocke et al. 1997), toxic shot consumption are higher than on the LGL. For instance, a higher proportion of Lesser Scaup (6%) salvaged from finishing nets in Lake Catahoula, Louisiana one year after the US ban contained ingested lead shot (Moore et al. 1998) than scaup (0.6%) on the LGL. Also, six years after the US ban, 61% of birds with ingested shot contained non-toxic shot and 75% (46) of the total number of pellets ingested were non-toxic (Anderson et. al. 2000). On the LGL, 86% (23) of birds with ingested shot contained non-toxic shot and

92% of the total number ingested shot was non-toxic just one year after the ban. This provides further support that lead shot quickly becomes inaccessible to waterfowl on the LGL.

As a result of the mandatory use of non-toxic shot, lead shot is no longer being deposited into wetlands, and its availability therefore declines over time. (Anderson et al. 2000). As lead shot sinks into the sediment its accessibility to waterfowl also declines over time; the rate at which it sinks can be influenced by wetland sediment type (Bellrose 1959). However, given that scaup on the LGL had a substantially lower lead shot ingestion than has been reported in other post-ban studies in the US (Moore et al. 1997; Anderson et al. 2000), sediment type alone likely does not explain these differences. The Great Lakes are the largest freshwater lakes in the world with large amounts of wind and wave energy and rapidly fluctuating water levels (seiches) (Keough et al 1999). Lead shot may become inaccessible more quickly in LGL lacustrine wetland systems as a result of wave action and fluctuating water level. In comparison, palustrine wetlands are non-tidal, surrounded by trees and shrubs and generally protected from intense wave action (Mitsch and Gosselink 1986). Therefore, the meteorological characteristics of large lacustrine wetlands may result in artifact settling in the substrate more quickly than in smaller more protected palustrine wetland. This is supported by the fact that anthropogenic substrate disturbance (tilling) reduced the availability of lead shot in palustrine wetlands where shot ingestion remained high after the ban (Thomas et al. 2001). Similarly, intense wave action may naturally reduce shot availability on large lacustrine wetlands.

## CONCLUSION

There are no intraspecific or interspecific differences in shot ingestion or the relative amount of toxic and non-toxic shot consumed by Greater and Lesser Scaup on the LGL. Lead shot appears to become inaccessible to waterfowl at a faster rate on the LGL than has been reported on other wetlands systems and wave action in these lacustrine habitats is possibly the primary factor contributing to the decline. Low toxic shot consumption indicates that lead toxicosis is presently inconsequential for scaup migrating through the LGL. I suggest that the substantial reduction in reported shot ingestion following the toxic ban is reflective of a pre-ban harvest bias. Therefore, post-ban shot ingestion (3.7%) probably provide a better indication of shot ingestion prior to the ban. Since, freshly deposited shot are the most accessible to waterfowl (Bellrose 1959) there would be a higher proportion of birds with ingested lead shot if hunters did not comply with shot regulations. Although, the switch to non-toxic shot in Canada was met with controversy, the low toxic shot consumption indicates that hunters are complying with the regulation.

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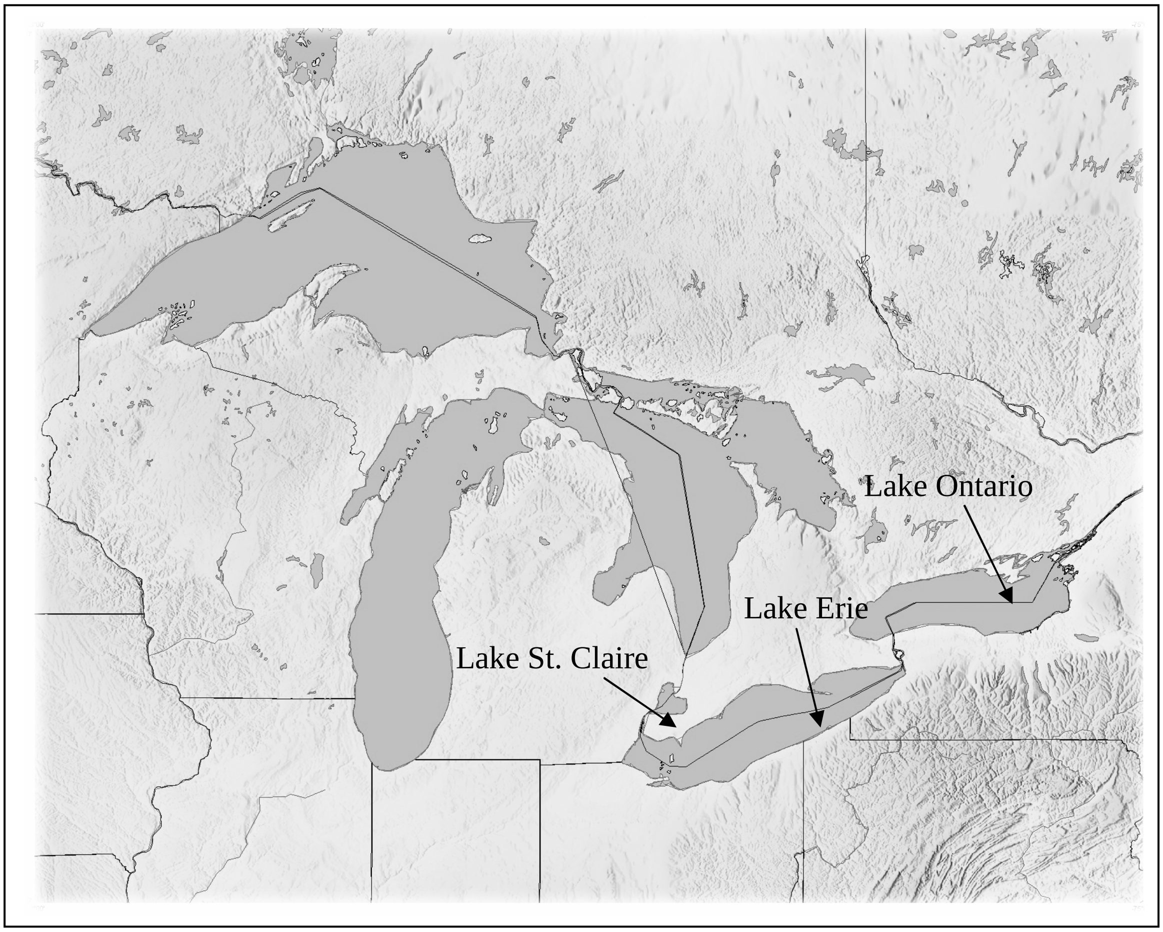


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**Figure 1. Greater and Lesser Scaup collection site on lower Great Lakes, 1999-2000.** Scaup were collected from: Long Point Bay and Port Dover area at Lake Erie; Bay of Quinte and Wolf Island at Lake Ontario; and Mitchell's Bay and St. Claire National Wildlife Area at Lake St. Claire.

**Table 1**. **Number of Greater and Lesser Scaup collected by species, season and lake on the lower Great Lakes, 1999-2000.**

| **Lake** | **Season** | **Species** | **Number of individuals collected** |
|---|---|---|---|
| Erie | Fall 1999 | Great Scaup | 112 |
| Erie | Fall 1999 | Lesser Scaup | 78 |
| Erie | Spring 2000 | Great Scaup | 71 |
| Erie | Spring 2000 | Lesser Scaup | 113 |
| Ontario | Fall 1999 | Great Scaup | 76 |
| Ontario | Fall 1999 | Lesser Scaup | 69 |
| Ontario | Spring 2000 | Great Scaup | 23 |
| Ontario | Spring 2000 | Lesser Scaup | 69 |
| St. Claire | Fall 1999 | Great Scaup | 2 |
| St. Claire | Fall 1999 | Lesser Scaup | 40 |
| St. Claire | Spring 2000 | Great Scaup | 5 |
| St. Claire | Spring 2000 | Lesser Scaup | 64 |

**Table 2. Percent of Greater (GS) and Lesser Scaup (LS) containing shot by lake, season, age and sex, 1999-2000.**

| | Shot Present (%) | *n* |
|---|---|---|
| Lake | | |
| GS Erie | 3.3 | 183 |
| GS Ontario | 4.0 | 99 |
| LS St. Claire | 0.0* | 7* |
| LS Erie | 2.6 | 191 |
| LS Ontario | 5.1 | 138 |
| LS St. Claire | 4.8 | 104 |
| $G_{heterogeneity}$ =1.796, d.f. = 4, $P$ = 0.773 | | |
| Season | | |
| GS Fall 1999 | 2.6 | 190 |
| GS Spring 2000 | 5.0 | 99 |
| LS Fall 1999 | 3.2 | 187 |
| LS Spring 2000 | 4.5 | 246 |
| $G_{heterogeneity}$ = 1.647, d.f. = 3, $P$ = 0.649 | | |
| Age | | |
| GS Juvenile | 4.7 | 149 |
| GS Adult | 2.1 | 139 |
| LS Juvenile | 4.2 | 144 |
| LS Adult | 3.8 | 288 |
| $G_{heterogeneity}$ = 1.562 d.f. = 3, $P$ =0.668 | | |
| Sex** | | |
| LS Male | 5.9 | 238 |
| GS Female | 4.5 | 156 |
| LS Female | 1.5 | 194 |
| GS Male | 2.3 | 132 |
| $G_{heterogeneity}$ = 7.048, d.f. = 3, $P$ = 0.070 | | |

* Sample size too small for statistical comparison

** $G_{pooled}$ = 6.451, d.f. = 1, $P$ = 0.011

**Table 3. Intraspecific and interspecific comparison (lake, age, season sex) in the shot type (% of birds) ingested by Greater and Lesser Scaup on the lower Great Lakes, 1999-2000.**

| | Greater Scaup | | Lesser Scaup | | |
|---|---|---|---|---|---|
| | Non-toxic | Toxic | Non-toxic | Toxic | Interspecific Comparison |
| Lake | | | | | |
| Erie | 4 | 0 | 5 | 0 | $P$ =1.000 |
| Ontario | 2 | 2 | 7 | 1 | $P$ = 0.236 |
| St. Claire | 0* | 0* | 4 | 1 | |
| | $P$ = 0.429 | | $P$ = 0.490 | | |
| Age | | | | | |
| Adult | 1 | 1 | 10 | 1 | $P$ = 0.295 |
| Juvenile | 5 | 1 | 6 | 1 | $P$ = 1.000 |
| | $P$ = 0.464 | | $P$ =1.000 | | |
| Season | | | | | |
| Fall 1999 | 3 | 1 | 6 | 1 | $P$ = 1.000 |
| Spring 2000 | 4 | 1 | 10 | 1 | $P$ = 1.000 |
| | $P$ = 1.000 | | $P$ = 1.000 | | |
| Sex | | | | | |
| Male | 1 | 1 | 13 | 2 | $P$ = 0.331 |
| Female | 6 | 1 | 3 | 0 | $P$ = 1.000 |
| | $P$ = 0.417 | | $P$ = 1.000 | | |

* Sample size too small for statistical comparison

[1] The numbers provided are the actual number of birds with ingested shot.