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Shot Ingestion in Scaup on the Lower Great Lakes After Nontoxic Shot Regulations in Canada

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Abstract

*Use of lead shot for waterfowl hunting was banned in the United States in 1991 to reduce the incidence of lead toxicosis in waterfowl. In 1999 Canada implemented a similar ban. The lower Great Lakes (LGL) are important migratory areas for greater (*Aythya marila*) and lesser scaup (*A. affinis*). Prior to the implementation of the Canadian ban, 11% and 8% of greater and lesser scaup harvested in the LGL, respectively, had ingested lead shot. We collected greater and lesser scaup on the Canadian side of lakes Erie, Ontario, and St. Clair during autumn 1999 and spring 2000 to determine if lead shot ingestion declined 1 year after the ban in Canada. There were no intraspecific (lake, season, sex, or age) or interspecific differences in proportion of birds containing ingested shot. Overall, only 0.6% of birds (*$n = 4$ *of 722) contained lead shot and only 3.1% contained nontoxic shot. The low frequency of toxic relative to nontoxic shot ingestion suggests that shot may quickly become inaccessible to scaup on lacustrine areas of the Great Lakes. Thus, the risk of lead toxicosis to scaup migrating through the LGL appears low at this time. Pre- and postban differences in overall ingestion frequencies (8–11% vs. 3.7%) suggests that preban numbers may have been biased (elevated) because lead shot ingestion can increase harvest susceptibility. However, recent scaup dietary shifts may also have contributed to overall declines in shot consumption. Low postban lead shot ingestion may also be indicative of high hunter compliance with nontoxic shot regulations in Canada.* (WILDLIFE SOCIETY BULLETIN 34(4):1101–1106; 2006)

Key words

Aythya affinis, Aythya marila, *Great Lakes, greater scaup, hunting, lead, lesser scaup, shot, toxicosis, waterfowl.*

The use of lead shot for waterfowl hunting in Canada and the United States resulted in the accumulation of spent pellets in aquatic habitats (Sanderson and Bellrose 1986, Rocke et al. 1997). Waterfowl may periodically ingest lead when foraging in wetlands (Bellrose 1959, Mateo et al. 2000). Ingestion of lead shot has been implicated in localized die-offs among some waterfowl species (Bellrose 1959, Sanderson and Bellrose 1986). Lead toxicosis also causes sublethal effects such as neurological damage (Dieter and Finley 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 still 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 United States in 1991 (Samuel and Bowers 2000) and in Canada in 1999 (Anderson et al. 2000). These policy decisions were based on the documented lethal and sublethal effects of lead toxicosis and the possibility that lead ingestion had population-level effects on certain waterfowl species (Canadian Wildlife Service [CWS] 1990). Although numerous studies have shown that lead shot consumption has declined since the United States' ban, the rates of decline reported are highly variable. Lead pellets should become inaccessible to waterfowl over time (Bellrose 1959, Samuel and Bowers 2000), but the rate at which lead shot sinks into the sediment largely depends on the type of substrate present (Bellrose 1959, Longcore et al. 1982). Thus, some wetland habitats may still contain large quantities of lead shot several years after its use for waterfowl hunting was banned (Rocke et al. 1997).

Lead exposure of live-trapped black ducks (*Anas rubripes*) declined from 11.7 to 6.5% between 1986–1988 and 1997–1999 in Tennessee, USA, at Cross Creek National Wildlife Refuge and Tennessee National Wildlife Refuge (Samuel and Bowers 2000). Moore et al. (1998) reported a frequency reduction from 27% in 1988–1989 to 6% in 1992–1993 of lead shot in the gizzards of diving ducks, including canvasbacks (*Aythya valisineria*) and lesser scaup (*Aythya affinis*), at Catahoula Lake, Louisiana, USA. Lead shot incidence also declined in ring-necked ducks (*Aythya collaris*; 19.3 to 6.9% of birds), greater (*Aythya marila*) and lesser scaup (7.7 to 2.4%), canvasbacks (8.9 to 2.9%), and mallards (*Anas platyrhynchos*; 6.3 to 2.8%) collected between 1977–1979 and 1996–1997 in the Mississippi Flyway. Therefore, although lead shot may have become less accessible to waterfowl and consumption rates have declined, certain waterfowl species continue to consume lead shot at some United States localities several years after the ban.

Previous studies have suggested that waterfowl be periodically monitored to evaluate rates of lead exposure following the implementation of nontoxic shot regulations (Samuel et al. 1992, DeStefano et al. 1995). However, in Canada, there has been no published work on lead ingestion by waterfowl since the 1999 ban on lead shot for hunting waterfowl.

The lower Great Lakes (LGL) provide important spring and autumn migratory habitats for greater and lesser scaup

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(Bellrose 1980, Dennis et al. 1984, Petrie and Knapton 1999). The numbers of scaup staging and overwintering on the LGL has increased substantially since zebra mussels (*Dreissena polymorpha*) colonized in the mid-1980s (Petrie and Knapton 1999, Petrie and Schummer 2002). Large numbers of lesser scaup stage on Lake Ontario, Lake Erie, and Lake St. Clair, whereas greater scaup tend to stage on Lake Ontario and Lake Erie (Badzinski and Petrie 2006). Concomitantly, these lakes also are traditional waterfowl hunting areas.

In 1992, before the lead shot ban, incidence of lead shot ingestion in birds harvested from Long Point, Lake Erie, Canada, was 16% for lesser ($n = 65$) and 11% for greater scaup ($n = 27$; S. Petrie, Long Point Waterfowl and Wetlands Research Fund, unpublished data). Scaup collected throughout the LGL during 1980–1983 had similar frequencies of lead shot ingestion (11% greater scaup, $n = 106$; 5% lesser scaup, $n = 177$; 14% scaup species, $n = 102$; N. North, Canadian Wildlife Service, unpublished data). However, the rate at which lead shot becomes inaccessible to waterfowl on these lacustrine wetlands is unknown. Thus, little was known regarding the lead shot ingestion risks for scaup that migrate through the LGL after the ban. In addition, lead shot have been replaced by several nontoxic (e.g., tungsten-matrix, bismuth) alternatives. Little information is available regarding waterfowl ingestion of nontoxic shot.

There also 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 it (Moore et al. 1998). Regardless, dietary composition can influence the amount of grit consumed (Trost 1981, Gionfriddo and Best 1995, 1996), which in turn influences shot ingestion (Pain 1990, Mateo et al. 2000). Because scaup diets have changed substantially since zebra and quagga mussels (*D. bugensis*) colonized the Great Lakes (Hamilton et al. 1994, Petrie and Knapton 1999, Ross et al. 2005), it is possible that the incidence of shot ingestion also has changed. Furthermore, because waterfowl diets can vary by season, sex, and age (Krapu and Reinecke 1992), shot ingestion may vary accordingly.

The objectives of this study were to 1) determine the relative proportion of lead versus nontoxic shot ingestion by greater and lesser scaup on the LGL during the first year following the ban on lead shot for waterfowl hunting in Canada, 2) compare lead shot ingestion before the ban to 1 year after the ban, and 3) determine if there are intraspecific (lake, season, sex, age) or interspecific differences in lead and nontoxic shot ingestion by greater and lesser scaup on the LGL.

Methods

Staging greater and lesser scaup were collected by shotgun from Lake Ontario (Bay of Quinte and Wolfe Island), Lake Erie (Long Point Bay and Port Dover area), and Lake St. Clair (Mitchell's Bay and St. Clair National Wildlife Area; Fig. 1) during autumn 1999 and spring 2000 (Table 1) for a separate study of nutrient reserve dynamics and contaminant burdens (CWS collection permit CA 0067). In the lab, we determined the sex of each bird by plumage characteristics and internal examination of ovaries or testes. We determined age by plumage characteristics and the presence or absence of a bursa. We removed gizzards, cut them open, and removed all contents and stored them frozen in glass vials. After thawing, we manually separated food from grit, shot, and other artifacts. We then manually examined grit using tweezers to identify any artifacts present in each sample.

We identified steel shot using a magnet and we categorized as lead pellets those that were not magnetic but could be distorted by manual force (scalpel; Daury et al. 1994). We categorized pellets that were not magnetic or malleable (along with steel) as nontoxic shot (e.g., tungsten-matrix, bismuth). We excluded from the analysis deformed pellets and those that were covered with feathers, which indicated they were shot in and not ingested (Anderson and Havera 1985). Manual examination of gizzards can underestimate incidence of artifacts by 20–25% (Anderson and Havera 1985, but see Longcore et al. 1982). Therefore, a different observer manually examined all samples a second time, using the same technique described above to ensure greater probability of identifying shot.

The data did not satisfy the normality of residuals and homogeneity of variance required for parametric analysis (Sokal and Rohlf 1981); therefore, we used Fisher's exact tests (Sokal and Rohlf 1981) to make pair-wise comparisons of the relative number of birds containing lead shot and nontoxic shot (steel, tungsten-matrix, bismuth) by location (lakes Erie, Ontario, St. Clair), age (adult, juvenile), season (autumn, spring), and sex (M, F) for both greater and lesser scaup. We used log-likelihood ratio tests to determine season, lake, age, and sex-related differences in the

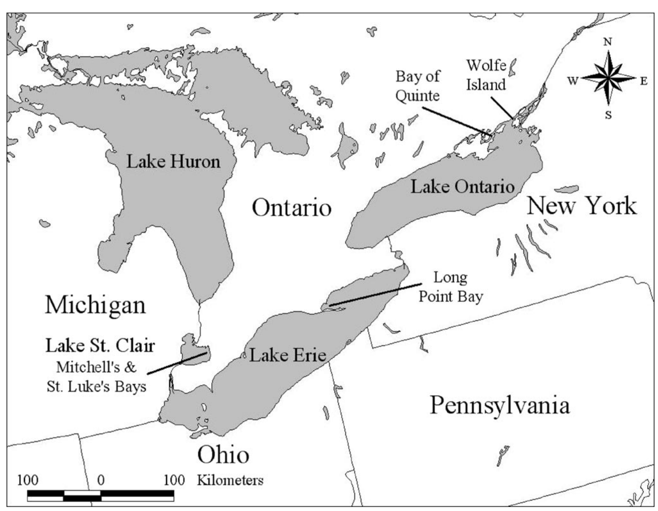

Figure 1. Geographic distribution of locations (Lake St. Clair: Mitchell's and St. Luke's bays, Lake Erie: Inner and Outer Long Point bays, and Lake Ontario: Bay of Quinte–Wolfe Island area) in Ontario, Canada, where lesser scaup and greater scaup were collected during autumn 1999 and spring 2000.

Table 1. Number of greater and lesser scaup collected by species, season, and lake on the lower Great Lakes, autumn 1999 and spring 2000.

Species	Season	Lake St. Clair	Lake Erie	Lake Ontario
Greater scaup	Autumn 1999	2	112	76
	Spring 2000	5	71	23
	Total	7	183	99
Lesser scaup	Autumn 1999	40	78	69
	Spring 2000	64	113	64
	Total	104	191	133

Table 2. Percentage of greater and lesser scaup containing shot by lake, season, age, and sex on the lower Great Lakes, 1999–2000.

	Shot present (%)	*n*
Lake		
Greater scaup		
Erie	3.3	183
Ontario	4.0	99
St. Clair	0.0[a]	7[a]
Lesser scaup		
Erie	2.6	191
Ontario	5.1	138
St. Clair	4.8	104
$G_{heterogeneity} = 1.796$, df = 4, $P = 0.773$		
Season		
Greater scaup		
Autumn 1999	2.6	190
Spring 2000	5.0	99
Lesser scaup		
Autumn 1999	3.2	187
Spring 2000	4.5	246
$G_{heterogeneity} = 1.647$, df = 3, $P = 0.649$		
Age		
Greater scaup		
Juvenile	4.7	149
Adult	2.1	139
Lesser scaup		
Juvenile	4.2	144
Adult	3.8	288
$G_{heterogeneity} = 1.562$, df = 3, $P = 0.668$		
Sex[b]		
Greater scaup		
M	2.3	132
F	4.5	156
Lesser scaup		
M	5.9	238
F	1.5	194
$G_{heterogeneity} = 7.048$, df = 3, $P = 0.070$		

[a] Sample size too small for statistical comparison.
[b] $G_{pooled} = 6.451$, df = 1, $P = 0.011$.

proportion of greater and lesser scaup with ingested shot (Sokal and Rohlf 1981). We compared incidence of shot consumption identified in this study to unpublished data from the 1980s (Canadian Wildlife Service) 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. We considered the results of statistical analyses to be significant when $P \leq 0.05$

Results

Only 3.1% of greater scaup and 4.2% of lesser scaup collected postban on the LGL contained shot (lead and nontoxic combined). Shot-ingestion frequencies during 1999–2000 did not vary within or between species by lake, season, or age ($P > 0.05$ for all comparisons; Table 2). Pooled likelihood ratio tests for sex differences between greater and lesser scaup indicated a Sex*Species interaction ($P < 0.5$); a higher proportion of greater scaup females and lesser scaup males contained shot than greater scaup males and lesser scaup females. The combined proportion of lesser and greater scaup containing lead and nontoxic shot on the LGL was low; of 722 birds collected only 26 (3.6%) contained shot. Overall, 23 birds (3.2%) contained nontoxic shot, 3 birds (0.4%) contained lead shot, and 1 bird (0.1%) contained both types of shot. There was no interspecific difference in the overall incidence of lead and nontoxic shot ingestion (greater scaup, 0.7% lead and 2.4% nontoxic; lesser scaup, 0.5% and 3.7%; $P = 0.582$). Also, lead and nontoxic shot ingestion did not vary intraspecifically by region, season, sex, or age (Table 3).

Discussion

Prior to the ban on lead shot use for waterfowl hunting in Canada, over 10% of the population of scaup staging on the LGL reportedly had consumed toxic shot. For instance, 10% of scaup (both species combined) harvested during 1981–1983 ($n = 385$; N. North, unpublished data) and 14% of scaup harvested during 1992–1993 ($n = 92$; S. Petrie, unpublished data) contained ingested lead shot. In contrast, only 3.7% of greater and lesser scaup collected during 1999–2000 (1 yr after the ban) contained ingested shot and only 0.6% contained lead shot. Although there was a 50% decline in number of waterfowl hunters in Ontario between the early 1980s and late 1990s (Boyd et al. 2002), this does not fully account for the observed decline in incidence of shot ingestion (from approx. 12% to 4% of harvested birds). There are 2 non–mutually exclusive explanations for the observed decline in shot-ingestion rates on the LGL. Temporal differences in reported shot ingestion could be 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 birds in poor condition are more susceptible to harvest (Bain 1980, Pace and Afton 1999, McCracken et al. 2000). Therefore, previous studies reporting lead-ingestion rates in waterfowl from hunter-harvested samples are potentially biased high; birds in our sample also were collected using decoys (also see Bellrose 1959, Anderson and Havera 1985, Sanderson and Bellrose 1986, DeStefano et al. 1995). We suggest that the low incidence of shot ingestion in this study likely is more representative of ingestion in the population because nontoxic shot does not influence condition or harvest susceptibility.

However, dietary composition can influence shot-ingestion rates (Pain 1990, Mateo et al. 2000) and scaup have undergone a dietary shift on the LGL since zebra mussels colonized in the mid-1980s. Although the shift has been largely from native gastropods to introduced zebra mussels (Petrie and Knapton 1999, Ross et al. 2005), each of which comprises a substantial proportion of alcareous shell, they possibly require different foraging methods. For instance, zebra mussels are sessile and tend to adhere to hard surfaces (rocks, native unionids, etc.), whereas native gastropods are mobile and can be associated with softer substrates where shot tends to accumulate. Consequently, dietary shifts from native gastropods to zebra mussels also may have contributed to observed declines in shot-ingestion rates.

We did not identify any inter- or intraspecific differences in the incidence of lead or nontoxic shot ingestion. Greater and lesser scaup are closely related species that stage and winter on similar habitats (lakes, coastal bays, and estuaries) and have somewhat similar feeding habits on the Great Lakes (Petrie and Knapton 1999, Ross et al. 2005, Badzinski and Petrie 2006). Also, similar food items tend to be eaten by both age classes and sexes during migration, which also may explain the lack of differences in shot consumption (Petrie and Knapton 1999, Ross et al. 2005, Badzinski and Petrie 2006).

Before the ban, lead was the primary shot type used for waterfowl hunting in Canada. Because of the ban, lead shot is no longer legally being deposited into wetlands, and its relative availability will decline over time (Anderson et al. 2000). However, the reported incidence of lead shot ingestion in scaup on the LGL was lower than has been reported in all other postban studies in the United States (Moore et al. 1998, Anderson et al. 2000). For instance, during the first year after the Canadian ban, 14% of scaup with ingested shot contained toxic shot and 8% of the total number of ingested pellets were toxic. In contrast, in the Mississippi Flyway 6 years after the United States ban, 41% of birds with ingested shot contained toxic shot and 26% of the total number of pellets ingested were nontoxic (Anderson et al. 2000). Also, 6% of lesser scaup salvaged from fishing nets in Lake Catahoula, Louisiana, 1 year after the United States ban contained ingested lead shot (Moore et al. 1998), versus 0.6% found in this study.

The low incidence of lead shot ingestion 1 year after the ban suggests that lead may quickly become inaccessible to waterfowl on the LGL. As lead shot settles into the sediment, its accessibility to waterfowl declines over time, and the rate at which it sinks can be influenced by wetland sediment type (Bellrose 1959). Longcore et al. (1982) found lower shot densities on sand as opposed to silt substrates and suggested that the continuous suspension, settlement, and resuspension of sand particles allows the relatively heavier shot to move deeper into sandy sediments, thereby becoming inaccessible to waterfowl more quickly. This process may explain the low overall rates of shot consumption in this study since many of the habitats used by scaup on the lower Great Lakes contain sandy substrates (S. Petrie, personal observation). Additionally, since lead is heavier than nontoxic shot alternatives, it is possible that it vertically redistributes more quickly within sandy substrates. Lastly, because the Great Lake lacustrine wetlands experience high winds, waves, and rapidly fluctuating water levels (seiches; Keough et al. 1999), lead shot may settle and become inaccessible more quickly there than in palustrine wetland systems (see Mitsch and Gosselink 1986). 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).

Table 3. Intraspecific and interspecific comparison (lake, season, age, sex) in the shot type (percent of birds) ingested by greater and lesser scaup on the lower Great Lakes, 1999–2000.

	Greater scaup		Lesser scaup		Interspecific comparison
	Nontoxic	Lead	Nontoxic	Lead	
Lake					
Erie	4[a]	0	5	0	$P = 1.000$
Ontario	2	2	7	1	$P = 0.236$
St. Clair	0[b]	0[a]	4	1	
	$P = 0.429$		$P = 0.490$		
Season					
Autumn 1999	3	1	6	1	
Spring 2000	4	1	10	1	
	$P = 1.000$		$P = 1.000$		
Age					
Adult	1	1	10	1	$P = 0.295$
Juvenile	5	1	6	1	$P = 1.000$
	$P = 0.464$		$P = 1.000$		
Sex					
M	1	1	13	2	$P = 0.331$
F	6	1	3	0	$P = 1.000$
	$P = 0.417$		$P = 1.000$		

[a] The numbers provided are the actual number of birds with ingested shot.
[b] Sample size too small for statistical comparison.

Management Implications

There were no intra- or interspecific differences in shot ingestion or in the relative frequency of lead and nontoxic shot ingested 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. We suggest that sandy substrates and severe meteorological conditions in these lacustrine habitats may be major contributing factors.

Despite the fact that the use of manual identification techniques may have resulted in some ingested shot being missed (see Longcore et al. 1982), we suggest that the low incidence of lead shot consumption indicates that lead toxicosis is presently not a threat for scaup migrating through the LGL. We suggest that the apparent substantial reduction in incidence of shot ingestion following the lead shot ban is reflective of a preban harvest bias. However, recent dietary shifts (native gastropods to zebra mussels) also may have contributed to the observed decline in shot consumption. Because recently deposited shot is most accessible to waterfowl (Bellrose 1959), there should be a higher proportion of birds with ingested lead shot if hunters did not comply with shot regulations. Although the switch to nontoxic shot in Canada was met with controversy, the low incidence of lead shot consumption in scaup suggests that hunters are complying with the regulation.

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