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Artifact Ingestion in Sea Ducks Wintering at Northeastern Lake Ontario

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Abstract.—The incidence of lead shot ingestion in waterfowl has declined in the lower Great Lakes (LGL) following the 1999 Canada-wide ban on use of toxic shot for waterfowl hunting, but few data exist on ingestion frequencies of spent shot or fishing weights for sea ducks wintering at the LGL. Artifact ingestion was evaluated in 269 Buffleheads (*Bucephala albeola*), 224 Common Goldeneyes (*B. clangula*) and 256 Long-tailed Ducks (*Clangula hyemalis*) collected at Lake Ontario during winter 2002-03 and 2003-04. Long-tailed Ducks ingested total shot (lead and steel shot combined) more frequently (6.6%) than did Common Goldeneye (1.8%) and Bufflehead (0.4%). Lead shot was ingested by Long-tailed Ducks (5.1%) and Buffleheads (0.4%), but not by Common Goldeneyes. One Long-tailed Duck, 0.1% of all specimens, ingested one lead fishing weight. Substrate type influenced artifact ingestion frequency and diving ducks that specialize on prey associated with hard substrates may continue to ingest artifacts more than ducks using soft substrate marshes. The results suggest lead toxicosis from spent shotgun pellets is presently non-existent to low in sea ducks wintering at northeastern Lake Ontario and that further restrictions on use of lead fishing tackle may have little implication for sea ducks in this region. *Received 12 March 2010, accepted 14 July 2010.*

Key words.—*Bucephala albeola*, *Bucephala clangula*, Bufflehead, *Clangula hyemalis*, Common Goldeneye, Great Lakes, lead, Long-tailed Duck, shot, waterfowl.

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The toxicological effects of lead ingestion by waterfowl have been widely studied (Bowles 1908; Bellrose 1959; Sanderson and Bellrose 1986). Toxicosis from lead ingestion can cause morbidity and mortality in birds (Scheuhammer *et al.* 2003). Lead is available to waterfowl mainly through spent shotgun shell pellets and fishing weights (Thomas 1997). Waterfowl may ingest shotgun shell pellets and fishing weights when foraging for grit to aid in grinding food in the gizzard (Beer and Stanley 1965; Moore *et al.* 1998). The use of shotgun shells containing lead shot was banned for waterfowl hunting in the United States in 1991 (Samuel and Bowers 2000) and in 1999 in Canada (Rodrigue and Reed 1999; Stevenson *et al.* 2005). To further reduce availability of lead to waterbirds, lead fishing weights were banned within Canadian national parks and national wildlife areas in 1997 (Canadian Wildlife Service 1997; Anderson *et al.* 2000). Currently, Canada-wide options are being investigated to minimize the risk to waterbirds from lead fishing weights and jigs (Scheuhammer *et al.* 2003).

Spatial and temporal availability of shotgun shell pellets and fishing weights is primarily related to wetland substrate type and intensity of hunting and fishing activity (Bellrose 1959; Longcore *et al.* 1982; Moore *et al.* 1998). Flint (1998) conservatively estimated that spent lead shot remains available to waterfowl in silt sediments for at least three years. However, Demendi and Petrie (2006) suggested that most lead shot was inaccessible to waterfowl in Great Lakes lacustrine wetlands one year after use of lead shotgun shells for waterfowl hunting was banned in Canada. Hard substrates (i.e. rock and clay) may allow spent shot and fishing weights to accumulate and remain available for longer periods of time compared to softer, silt substrates (Thomas *et al.* 2001). Availability of spent shot and fishing weights likely varies throughout the LGL because substrates vary from silt sediments to limestone rock (Barton and Hynes 1978; Barton 1986).

Following the introduction and proliferation of zebra mussels (*Dreissena polymorpha,* circa 1986) and quagga (*D. bugensis*, circa 1991) mussels (hereafter dreissenid mussels) to the LGL, numbers of sea ducks, including Buffleheads (*Bucephala albeola*), Common Goldeneyes (*B. clangula*), Long-tailed Ducks (*Clangula hyemalis*) and scoters (*Melanitta* spp.) increased > 10-fold at many locations during migration and winter (Wormington and Leach 1992; Hamilton and Ankney 1994; Petrie and Knapton 1999). Sea ducks often eat dreissenid mussels and other macroinvertebrates during autumn and winter at the LGL, although some species, such as Long-tailed Ducks, consume dreissenid mussels to a greater extent than other sea ducks (Ross *et al.* 2005; Schummer *et al.* 2008a). Diet composition can influence grit intake in waterfowl (Trost 1981; Gionfriddo and Best 1996), so interspecific, as well age, sex and year, differences in diet might influence artifact ingestion (Pain 1991; Mateo *et al.* 2000).

Evidence suggests that the incidence of lead ingestion has decreased in some waterfowl at the LGL since the 1999 lead shot ban in Canada (Demendi and Petrie 2006). However, lead shot and lead fishing weights still remain available and are ingested by diving ducks and swans at some locales (Moore *et al.* 1998; Anderson *et al.* 2000; Figuerola *et al.* 2005; Demendi and Petrie 2006; Bowen and Petrie 2007). Although Buffleheads, Common Goldeneyes and Long-tailed Ducks are widespread and common at Lake Ontario during winter (Prince *et al.* 1992), there are no published data on incidences of artifact ingestion for these three sea ducks at the LGL.

Northeast Lake Ontario is one of the most important areas for waterfowl in the lower Great Lakes (LGL) because it provides more than 6,000 ha of coastal wetlands for migrant dabbling ducks and abundant foraging habitat for sea ducks throughout winter (Dennis *et al.* 1984; Prince *et al.* 1992; Schummer *et al.* 2008b). Waterfowl hunting and recreational fishing are common activities on the LGL (Environment Canada 2006) and lead may still be available to wildlife within wetland substrates at many locales, particularly at traditional hunting and fishing areas (Scheuhammer *et al.* 1998; Stevenson *et al.* 2005; Demendi and Petrie 2006; Bowen and Petrie 2007). In this study our objectives were to determine: 1) the proportions of Buffleheads, Common Goldeneyes and Long-tail Ducks that had ingested spent shot (lead and non-toxic) and fishing weights while over-wintering at northeastern Lake Ontario, 2) the raw number of artifacts ingested per individual of these ducks species, 3) interspecific and intraspecific (age and sex) plus annual differences in artifact ingestion, 4) differences in the incidence and types (lead shot, non-toxic shot, fishing weights) of artifact ingestion among ducks collected over silt, gravel and rock substrates (i.e. use of ducks as biomonitors of shot availability in various habitats), and 5) how our results compared to those of other waterfowl artifact ingestion studies conducted within the LGL and elsewhere in North America. Our goal was to interpret if spent lead shot and fishing weights were potentially problematic to sea ducks wintering at our study site four years after the ban of lead shotgun shells for waterfowl hunting in Canada.

METHODS

Study Site

The study was conducted at Lake Ontario, along the southeastern shore of Prince Edward County (Fig. 1). The western bays (43°55'N, 77°02'W) are silt substrate, the Prince Edward Point (43°45'N, 76°51'W) area is limestone rock ledge substrate and the bays and shoreline between Prince Edward Point and Point Petre (43°50'N, 77°09'W) are limestone rock ledges and gravel bays (Barton 1986). Dominant substrate type was determined where ducks were collected using direct observations and nautical maps. A substantial portion of Lake Ontario remains ice-free most years and provides winter habitat for sea ducks and other waterfowl species (Prince *et al.* 1992; Assel 2003; see Schummer 2005 for more detailed information).

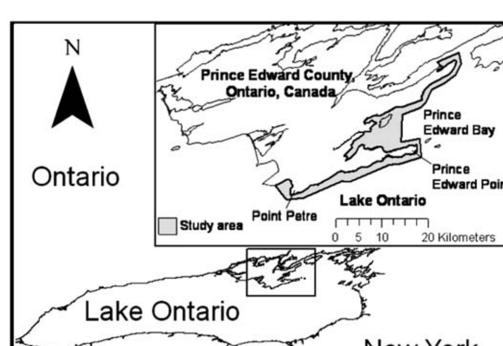

Figure 1. Study area including Prince Edward Bay and shoreline from Prince Edward Point through Point Petre, Lake Ontario, Canada.

Specimen Collection and Dissection

Under the authority of a Canadian Wildlife Service Scientific-Capture Permit (No. CA 0166), we collected 269 Buffleheads, 224 Common Goldeneyes and 256 Long-tailed Ducks from December through March 2002-2003 and 2003-2004 (Table 1) as part of a separate study of habitat use, diets, nutrient reserve dynamics and contaminant burdens in these species. Ducks were collected by shooting over decoys, jump shooting from shore, pass shooting and floating into flocks with a canoe and shooting. All specimens were double-bagged, frozen, and transported to the University of Western Ontario in London, Ontario. At the lab, sex was determined for each bird by internal examination of reproductive organs and age by the presence or absence of a bursa of fabricius. Gizzards were dissected and contents were frozen in individual glass vials. Contents of vials were thawed and food was manually separated from grit, shot and other artifacts. Visual inspection and a magnet were used to separate lead from non-toxic shot. A scalpel was used to make an indentation to confirm lead shot (Daury *et al.* 1994; Bowen and Petrie 2007).

Statistical Analysis

Log-likelihood ratio tests were used to make comparisons of the proportion of Buffleheads, Common Goldeneyes and Long-tailed Ducks containing shot by species, year (2002-03, 2003-04), age (juvenile, adult), sex (male, female) and substrate (silt, gravel, rock; Sokal and Rohlf 1981; SAS Institute 2002). Results of statistical analyses were considered significant when $P \leq 0.05$.

RESULTS

Of 749 ducks collected, 6.6% of Long-tailed Ducks (N = 256), 1.8% of Common Goldeneyes (N = 224) and 0.4% of Buffleheads (N = 269) contained ingested shot (both lead and non-toxic combined). The only artifact found in Buffleheads was a single lead pellet ingested by an adult male. Common Goldeneyes did not ingest lead shot and individuals ingesting artifacts had an average of 1.5 steel pellets per individual (max. = 2 pellets). Ingestion of lead shot ranged from 1 to 42 pellets per Long-tailed Duck containing shot (N = 17; $\bar{x}$ = 3.44 [SE ± 2.29] pellets). Overall, four of the 256 (1.6%) Long-tailed Ducks collected contained more than one lead pellet; gizzards from these individuals contained two, four, five and 42 lead pellets. One of 749 (0.1%) total ducks collected contained a lead fishing weight. An adult female Long-tailed Duck collected over silt substrate ingested a single, egg-shaped slip sinker (~1/8 oz.). For each species, proportions of individuals ingesting shot did not differ between collection years ($P > 0.05$; Table 2), so data were pooled across periods for subsequent analyses. Shot ingestion frequencies differed among species for lead, non-toxic shot and total shot; Long-tailed Ducks had the highest ingestion frequencies for all artifact types (Table 2). There were no differences in proportions of shot ingestion by sex or age for Buffleheads and Common Goldeneyes, but a greater percentage of adult Long-tailed Ducks (9.1%) ingested shot relative to juveniles (2.2%; Table 2). Sea ducks collected over rock (N = 429) and gravel (N = 194) substrates contained both lead (3.5%) and non-toxic shot (2.1%) but ducks collected over silt (N = 116) substrate only contained non-toxic shot (1.7%; Table 2).

DISCUSSION

Despite bans on use of toxic shot for waterfowl hunting in the U.S. and Canada,

Table 1. Number of Buffleheads, Common Goldeneyes and Long-tailed Ducks collected by species, year, sex and age at northeastern Lake Ontario, December-March, 2002-2004.

Species	Year	Adult male	Adult female	Juvenile male	Juvenile female	Total
Bufflehead	2002-2003	79	23	29	8	139
	2003-2004	47	17	35	31	130
	Total	126	40	64	39	269
Common Goldeneye	2002-2003	38	21	19	30	108
	2003-2004	42	18	25	31	116
	Total	80	39	44	61	224
Long-tailed Duck	2002-2003	40	37	10	27	154
	2003-2004	34	54	17	37	142
	Total	74	91	27	64	256

Table 2. Percentage of Buffleheads, Common Goldeneyes and Long-tailed Ducks containing shot by species, age, sex and substrate at northeastern Lake Ontario, December - March, 2002 - 2004.

Species	Lead shot present (%)	Non-toxic shot present (%)	Total shot present (%)	N
Sex				
Bufflehead	0.4	0.0	0.4	269
Common Goldeneye	0.0	1.8	1.8	224
Long-tailed Duck	5.1	2.0	6.6	256
$G_{statistics}$	G = 23.17, df = 2, $P < 0.0001$	G = 8.09, df = 2, $P = 0.04$	G = 20.20, df = 2, $P < 0.0001$	
Age Bufflehead				
Juvenile	0.0	0.0	0.0	
Adult	0.6	0.0	0.6	103
$G_{statistics}$	G = 0.96, df = 1, $P = 1.00$	*a*	G = 0.96, df = 1, $P = 1.00$	166
Common Goldeneye				
Juvenile	0.0	1.0	1.0	105
Adult	0.0	2.5	2.5	119
$G_{statistics}$	*a*	G = 0.83, df = 1, $P = 0.62$	G = 0.83, df = 1, $P = 0.62$	
Long-tailed Duck				
Juvenile	2.2	0.0	2.2	91
Adult	6.7	3.0	9.1	165
$G_{statistics}$	G = 2.76, df = 1, $P = 0.15$	G = 4.45, df = 1, $P = 0.11$	G = 5.30, df = 1, $P = 0.04$	
Sex Bufflehead				
Male	0.5	0.0	0.5	190
Female	0.0	0.0	0.0	79
$G_{statistics}$	G = 0.69, df = 1, $P = 1.00$	*a*	G = 0.69, df = 1, $P = 1.00$	
Common Goldeneye				
Male	0.0	2.4	2.4	124
Female	0.0	1.0	1.0	100
$G_{statistics}$	*a*	G = 0.67, df = 1, $P = 0.63$	G = 0.67, df = 1, $P = 0.63$	
Long-tailed Duck				
Male	3.0	3.0	5.9	101
Female	6.5	1.3	7.1	155
$G_{statistics}$	G = 1.65, df = 1, $P = 0.26$	G = 0.87, df = 1, $P = 0.65$	G = 0.13, df = 1, $P = 0.80$	

a - no shot present for statistical test.

Table 2. (Continued) Percentage of Buffleheads, Common Goldeneyes and Long-tailed Ducks containing shot by species, age, sex and substrate at northeastern Lake Ontario, December - March, 2002 - 2004.

Species	Lead shot present (%)	Non-toxic shot present (%)	Total shot present (%)	N
Substrate				
Silt	0.0	1.7	1.7	116
Gravel	0.5	1.0	1.6	194
Rock	3.0	1.1	3.9	439
$G_{statistics}$	$G = 9.52$, $df = 2$, $P = 0.04$	$G = 0.30$, $df = 2$, $P = 0.89$	$G = 3.51$, $df = 2$, $P = 0.18$	

a - no shot present for statistical test.

birds may still acquire lead shot from incomplete compliance or previously deposited lead remaining accessible (Sanderson and Bellrose 1986). One year after lead shot was banned for waterfowl hunting in Canada, less than 1% of Lesser Scaup (*Aythya affinis*) collected in the LGL region of Ontario contained lead shot (Demendi and Petrie 2006). Also, we found low incidences of lead shot ingestion (ranging from 0 to 5%) in our large sample of wintering sea ducks four years after the ban of lead shot for waterfowl hunting in Canada. Frequencies of lead shot ingestion in our and other studies in the LGL region (Demendi and Petrie 2006; Bowen and Petrie 2007) were lower than those recorded for Common Goldeneyes (7.8%), Canvasbacks (*Aythya valisineria*; 8.9%), Lesser Scaup (7.6%) and Ring-necked Ducks (*Aythya collaris*; 19.3%, Anderson *et al.* 1987) prior to the ban of lead shot. Thus, post-ban results suggest LGL waterfowl have lower exposure to lead relative to waterfowl sampled prior to the bans of lead shot for waterfowl hunting.

Differences in habitat use and diets among sea ducks may explain greater frequency of shot ingestion by Long-tailed Ducks relative to Buffleheads and Common Goldeneyes. Long-tailed Ducks feed in water up to 31m deep while Buffleheads and Common Goldeneyes feed in shallower (≤10m) nearshore areas at Lake Ontario (Schummer *et al.* 2008b). Lead shot has a greater maximum travel distance relative to steel resulting in deposition farther offshore in deeper water where it may remain available to Long-tailed Ducks (Bellrose 1959; Pain 1991). Alternatively, lead shot may become depleted nearshore due to greater foraging pressure relative to areas farther from shore (Schummer *et al.* 2008b). Consumption of prey with shells or bones is often related to higher grit ingestion because it aids digestion of these hard materials (Gionfriddo and Best 1996). Diets of Long-tailed Ducks consisted of dreissenid mussels (39%) and other molluscs (40%), whereas Buffleheads and Common Goldeneyes ate fewer prey with hard exoskeletons (Schummer *et al.* 2008a). Thus, Buffleheads and Common Goldeneyes may have had lower grit ingestion rates relative to Long-tailed Ducks resulting in reduced levels of shot ingestion. Previous studies also suggest that Buffleheads have relatively low incidence (0.0-1.7% of individuals) of lead shot ingestion (Reid 1948; Anderson *et al.* 1987). Other studies of Long-tailed Ducks, at Chesapeake Bay and Lake Michigan (where soft-bodied amphipods were a major prey item), found no lead shot in gizzards (Peterson and Ellerson 1977; Skeratt *et al.* 2005). Possibly, foraging on hard-bodied prey in deep water, offshore areas resulted in greater shot ingestion in Long-tailed Ducks at our study area.

Because waterfowl diets can vary by sex and age (Krapu and Reinecke 1992) and dietary differences may result in different grit ingestion among individuals (Gionfriddo and Best 1996), shot ingestion rates also might vary within species. For Buffleheads and Common Goldeneyes in this study, shot ingestion frequencies were similar between sexes and age classes. Neither of these species exhibited sex- or age-related differences in foraging behavior or diet at our study area, especially for hard-bodied prey such as dreissenid mussels and gastropods (Schummer 2005; Schummer *et al.* 2008a). We did observe different frequencies of shot ingestion between juvenile and adult Long-tailed Ducks, which may have resulted from age-related differences in habitat use and foraging behavior. Schummer (2005) reported that Long-tailed Duck flocks located farther from shore had a higher proportion of adults, whereas those in shallow, nearshore areas typically had a higher proportion of juveniles. Age-related differences in shot ingestion may result from adult Long-tailed Ducks feeding farther from shore and in deeper water than juveniles where shot availability was possibly greater than near shore.

Substrate can affect the time spent shot is accessible to waterfowl (Bellrose 1959; Longcore *et al.* 1982; Moore *et al.* 1998). Assuming shot ingestion reflects its availability in habitats where birds were collected, we found that incidence of lead, but not steel, shot ingestion differed among substrates. Previous studies using waterfowl as biomonitors of shot availability in silt substrates found that lead shot ingestion declined greatly after the lead shot ban in Canada (Demendi and Petrie 2006). At our study area, silt, gravel and rock substrates were available in December and early-January, but only expanses of gravel and rock substrates were available after ice covered the shallow nearshore, silt-dominated habitats. These attributes, along with consistent habitat use by ducks at our study area (Schummer *et al.* 2008b), suggests ingestion frequencies reflect artifact availability within habitats where ducks were collected. We did not find lead shot in ducks collected in areas with silt substrate, but did find ducks had ingested steel shot at the same locations. Thus, lead ingestion over gravel and rock substrates may reflect prolonged availability of shot on harder substrates (Bellrose 1959; Longcore *et al.* 1982).

Lead may be available to waterfowl at areas previously heavily hunted (especially if they have predominantly hard bottom substrates where shot residence times are longer than in silt or organic substrates) and through the loss of lead fishing weights (Anderson *et al.* 2000; Samuel and Bowers 2000; Franson *et al.* 2003; Demendi and Petrie 2006). Our findings suggest that use of lead fishing weights is not problematic for sea ducks in this area of Lake Ontario because only one of 749 ducks ingested a single lead fishing weight. Further, lead artifact ingestion was rare to non-existent in Buffleheads and Common Goldeneyes. Longcore *et al.* (1982) suggested that 5% was an acceptable incidence threshold for lead shot ingestion for American Black Ducks (*Anas rubripes*) and Mallards (*Anas platyrhynchos*). About 2% of Long-tailed Ducks in our study had ingested >1 lead pellet, a number deemed necessary to cause substantial mortality in waterfowl (Bellrose 1959; Cook and Trainer 1966; Rattner *et al.* 1989). Ducks foraging over limestone rock substrate more commonly ingested lead shot than did those feeding over silt or gravel bottoms. One adult female Long-tailed Duck foraging over limestone rock substrate ingested 42 lead pellets, which indicates that lead persists and can be abundant at some locales at Lake Ontario. Other sea ducks, such as White-winged Scoters (*Melanitta fusca*) and Black Scoters (*Melanitta nigra*), that frequently forage offshore within limestone rock substrates in areas where hunting traditionally occurred, also may have relatively higher and prolonged risk of ingesting lead while wintering or staging at northeastern Lake Ontario or other similar Great Lakes locales. Lead toxicosis may continue to affect some individual ducks, but our results suggest that lead shot related health issues are likely not problematic to the LGL population of sea ducks four years after the ban of lead shot for waterfowl hunting in Canada.

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