Incidence of Artifact Ingestion in Mute Swans and Tundra Swans on the Lower Great Lakes, Canada

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Incidence of artifact ingestion in Mute Swans and Tundra Swans on the lower Great Lakes, Canada

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Although lead poisoning is common in swans, no information exists on the prevalence of lead artifact ingestion in swans using the lower Great lakes (LGL). We examined artifact ingestion (lead and non-toxic) in Mute Swans *Cygnus olor* and Tundra Swans *Cygnus columbianus* collected on the LGL in Ontario (1999–2003) following the 1999 ban on use of lead shot for waterfowl hunting in Canada. A larger proportion of Mute Swans (19.8% of 243 birds) contained artifacts than did Tundra Swans (6.5% of 77 birds), possibly due to the fact that Mute Swans feed exclusively in aquatic habitats. Overall, 14% of Mute Swans contained non-toxic shot, 6% contained lead shot and 1.6% contained fishing tackle; 4% of Tundra Swans contained non-toxic shot and 2.6% contained lead shot. Adult Mute Swans (22.7%) had a higher incidence of artifact ingestion than did cygnets (8.9%), but there were no age-related differences in Tundra Swans. No sex-related differences in artifact ingestion were detected in either species. Given the overall frequency of shot ingestion in Mute Swans (20% of birds), lead toxicosis probably was a significant mortality factor for this species on the LGL before the lead shot ban. As only 1.6% of Mute Swans and no Tundra Swans contained any form of fishing tackle, angling related injuries and mortalities are likely lower in the LGL than has been reported for swans in Europe. Presently, lead toxicosis is likely having a low to moderate effect on Mute Swans and a minimal effect on Tundra Swans on the LGL.

Key words: artifact ingestion, Mute Swans, Tundra Swans, lead poisoning, Great Lakes

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INTRODUCTION

Lead toxicosis in waterfowl is most frequently caused by ingestion of spent shotgun pellets and lead fishing weights in aquatic habitats (O'Halloran *et al.* 1989, Wilson *et al.* 1998, Anderson *et al.* 2000). Such artifacts are picked up from the substrate during foraging or as grit to aid in the mechanical breakdown of food in the gizzard. Breakdown of ingested lead artifacts facilitates absorption of lead into the blood stream resulting in lead toxicosis (O'Halloran *et al.* 1989, Havera *et* *al.* 1992). In addition to mortality, sub-lethal consequences of lead poisoning include impaired body condition and altered behaviour which can compromise survival and reproductive success (Hohman *et al.* 1990, Havera *et al.* 1992, Blus 1994, Mateo *et al.* 1997).

Lead toxicosis has been a common mortality factor in waterfowl (Longcore *et al.* 1982, Sears 1988, Schwab & Daury 1989), especially swans (Birkhead & Perrins 1986, Wilson *et al.* 1998, O'Halloran *et al.* 2002). Lead poisoning has been reported in Mute Swans *Cygnus olor*, Black Swans *C. atratus*, Whooper Swans *C. cygnus*, Bewick's Swans *C. columbianus*, and Tundra Swans *C. columbianus* (Wilson *et al.* 1998). Swans may be particularly prone to lead ingestion as their long necks and bills enable them to forage deep in wetland substrates, thereby accessing recently deposited lead, as well as older sources of lead (Wilson *et al.* 1998). Swans also ingest sediment while eating aquatic plant tubers, further increasing their likelihood of ingesting shot and fishing tackle (Blus 1994).

Concern over lead poisoning in waterfowl resulted in a ban on use of lead shot for waterfowl hunting in the United States (U.S.) and Canada in 1991 and 1999, respectively. Lead sinkers weighing less than 50 grams were also prohibited in Canadian national parks and national wildlife areas in 1997 (Canadian Wildlife Service 1997). Although artifact ingestion frequencies have been studied in swans in Europe (Sears 1988, O'Halloran *et al.* 1989, O'Halloran *et al.* 1991, Sears & Hunt 1991, Brown *et al.* 1992), and in ducks in North America (Longcore *et al.* 1982, Hohman *et al.* 1990, Daury *et al.* 1994, Tsuji *et al.* 1998, Anderson *et al.* 2000, Franson *et al.* 2003), limited research has been conducted in Canada since the 1999 lead shot ban (but see Demendi & Petrie 2006), and no studies have been preformed on swans on the lower Great Lakes (LGL).

Lead poisoning has been well documented in Mute Swans in their native Eurasian range (Hardman & Cooper 1980, Sears 1988, O'Halloran *et al.* 1989, Sears & Hunt 1991, O'Halloran *et al.* 2002). Before the ban on use of lead fishing weights in Britain in 1987, 50–60% of Mute Swans found dead or sick were diagnosed as lead poisoned (Sears 1989). Following the ban, lead poisoning in the same areas dropped considerably as only 16% of birds found dead or sick had elevated blood lead levels (Sears 1989). However, recent studies in the UK indicate Mute Swans continue to consume large quantities of fishing tackle and that some birds still have elevated blood lead levels (Kelly & Kelly 2004). The Mute Swan is an exotic species in Canada and its populations have been expanding rapidly on the LGL since the 1980's (Petrie & Francis 2003). Because Mute Swans are a resident species on the LGL and do not feed in fields (Beyer *et al.* 1998), all artifacts they consume must originate from LGL aquatic habitats. Therefore, Mute Swans are an excellent sentinel species for studying the present availability of lead artifacts in aquatic habitats on the LGL.

Lead poisoning was identified in wintering populations of Tundra Swans before the ban on use of lead shot (Bartonek *et al.* 1991). Also, despite the switch from lead shot to non-toxic shot (e.g. steel, bismuth, and tungsten), large numbers of Trumpeter Swans continue to succumb to lead toxicosis in British Columbia, Canada (Wilson *et al.* 1998, Ruth Shea, personal communication). Because Tundra Swans have somewhat similar foraging behaviour to Trumpeter Swans, they could also continue to consume large quantities of lead shot (or other artifacts) despite the lead shot ban (Grant *et al.* 1997, Petrie *et al.* 2002, Badzinski 2003). The LGL is the first major staging area in spring and last one in fall for a large portion of the Eastern Population of Tundra Swans (Petrie & Wilcox 2003). Despite the importance of staging grounds for Tundra Swans (Petrie *et al.* 2002, Badzinski 2003) and the high recreational hunting and fishing activity in these areas (Knapton *et al.* 2000), it is not known if Tundra Swans consume large quantities of toxic artifacts.

Previous studies pertaining to artifact ingestion in swans have been based on the collection of dead, moribund and entangled birds (Irwin 1975, Birkhead 1982, Bartonek *et al.* 1991, O'Halloran *et al.* 1991, Brown *et al.* 1992, Kelly & Kelly 2004).

In this study, we collected seemingly healthy birds to identify the incidence (% of individuals) of toxic and non-toxic shot and tackle ingestion by Tundra and Mute Swans on the LGL. We predicted that, despite the lead shot ban in 1999, individuals of both species would continue to ingest toxic shot due to their ability to forage deep in wetland substrates. We also predicted that incidence of fishing tackle ingestion in Mute Swans would be highest during summer when sport fishing is prominent.

STUDY AREA

Long Point and Lake St. Clair support two of the largest populations of Mute Swans on the Canadian side of the LGL (Petrie and Francis 2003) and also provide important spring and fall staging habitat for Eastern Population Tundra Swans (Petrie *et al.* 2002, Petrie & Wilcox 2003). Mute Swans were collected on wetlands associated with Long Point, Lake Erie and Lake St. Clair/ Detroit River from March 2001 until December 2003 (Fig. 1). Tundra Swans were collected in agricultural fields and wetlands associated with Long Point during spring and fall, 1999–2001. Long Point is a 35 km sandspit that extends into the eastern basin of Lake Erie and encompasses 24 000 ha of marsh habitat (Petrie 1998). Long Point's wetlands provide staging habitat for hundreds of thousands of migratory waterfowl, and have the highest waterfowl use of all coastal wetlands on the LGL (Petrie 1998). Lake St. Clair and its surrounding area contain 18 880 ha of wetlands, and is also considered to be a very important staging area for waterfowl (Dennis *et al.* 1984). Long Point and Lake St. Clair are both used extensively by waterfowl hunters and sport fishermen.

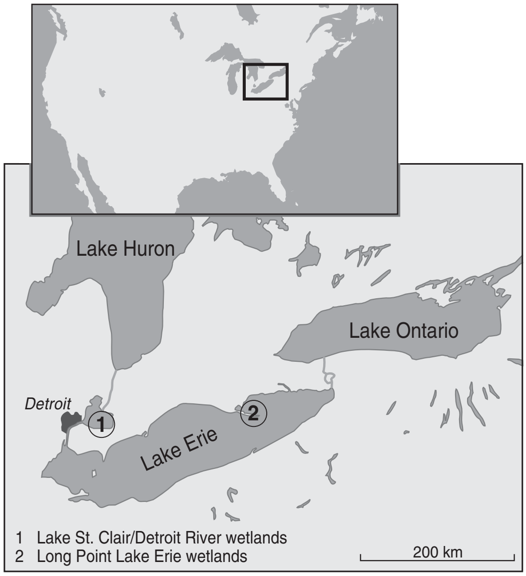

Figure 1. Location of Mute Swan (1, 2) and Tundra Swan (2) collection sites on the lower Great Lakes, Ontario.

METHODS

As part of two separate nutrient reserve dynamic studies, Tundra Swans (n = 77) and Mute swans (n = 243) were collected by shotgun and rifle at various sites (see study area) during daylight hours. Collected birds were tagged for identification and frozen upon return to the laboratory. After thawing, the sex of each bird was determined by internal examination of ovaries/testes. Age was determined by plumage characteristics and the presence/absence of a bursa. Gizzard contents were removed and thoroughly washed with water to remove ingesta. Grit was then manually examined using tweezers to identify any artifacts present in each sample. Steel was differentiated from lead using a magnet, and verification of lead was determined by making indentations in pellets/sinkers using a scalpel (Tsuji *et al.* 1998). All other shot (non-malleable and non-magnetic) was considered to be non-toxic (e.g. Bismuth, Tungsten). Manual examination of gizzards can underestimate incidence of artifacts by 20–25% (Anderson & Havera 1985). Therefore, all samples were manually examined a second time by a different observer using the same technique described above. Deformed pellets and those that were encased in feathers (indication they were shot in and not ingested) were not included in the analysis (Anderson & Havera 1985).

Due to the possible confounding effects of differences in collection location (Lake Erie vs. Lake St. Clair), season (Tundra Swans could only be collected in spring and fall), time (Tundra Swans were collected in 1999–2001, Mute Swans were collected in 2001–2003), and site (aquatic vs. agricultural fields), as well as the fact that our Tundra Swans sample size was small ($n = 77$), we decided not to perform interspecific statistical comparisons. Likelihood ratio tests were used to test for differences in relative ratios of toxic vs. non-toxic artifact ingestion between sexes, ages, and seasons for Mute Swans; Tundra Swan ingestion rates were too low to perform toxic vs. non-toxic comparison. Season, sex, and age-related differences in total (toxic and non-toxic combined) Mute and Tundra Swan artifact ingestion were evaluated using Fisher's exact tests.

RESULTS AND DISCUSSION

Mute Swan artifact ingestion

Mute Swans collected at Long Point, Lake Erie had a similar frequency of artifact ingestion to those collected in the Lake St. Clair/Detroit River region ($G = 2.341$, $P = 0.126$) so birds from the two sites were combined for subsequent analyses. Adult male (23.9% of 109 birds) and female (21.3% of 89) Mute Swans had similar artifact ingestion frequencies ($G = 0.056$, $P = 0.813$), which is likely due to the fact that they have similar feeding habits (Bailey 2003). Adult Mute Swans (22.7% of 198) had a higher incidence of artifact ingestion than cygnets (8.9% of 45) ($G = 4.763$, $P = 0.029$), likely due to the fact that many of the collected cygnets were very young and therefore may have been less capable of reaching artifacts (i.e. structurally smaller). Also, Mute Swan cygnets consume primarily the leaves of *Elodea canadensis* and *Potamogeton* spp. from the water column, whereas adults consume higher quantities of rhizomes and tubers from the substrate where artifacts are more readily available (Bailey 2003).

Although there were no significant seasonal differences in Mute Swan artifact ingestion frequencies ($P > 0.05$ for all comparisons), birds collected during the breeding period (Apr-Jun) did appear to have the highest frequencies (Table 1). Before the ban on lead fishing weights in the UK, Mute Swan artifact ingestion was highest in summer, a period which corresponded with the fishing season (Sears 1988). Following the ban on lead weights in the UK, rates of artifact ingestion were consistent throughout the annual cycle (Sears 1989). Because shot was the predominant artifact ingested by Mute Swans in this study, seasonal variation is most likely due hyperphagia during the breeding season (Ciaranca *et al.* 1997). There were no significant seasonal differences in cygnet artifact ingestion ($G = 2.22$, $P = 0.136$); however, evidence does suggest that cygnets have a higher frequency of ingestion later in the year (16.7%, Nov–Mar) than earlier in the year (7.4%, Jul–Oct) (Table 2). This is likely due to the fact that cygnets approach adult structural size in late fall (Ciaranca *et al.* 1997), and their dietary intake is probably similar to adults at that time, thereby increasing their susceptibility to artifact ingestion.

A study done on Lesser *Aythya affinis* and Greater Scaup *A. marila* on the LGL showed a much lower post-ban artifact ingestion frequency (3% of 869 birds; Demendi and Petrie 2006) than we found in Mute Swans (20%). These ingestion frequency differences are likely due to the fact that; (1) Mute Swans are structurally much larger than Scaup, enabling them to forage deep in the substrate where artifacts tend to settle, (2) swans tend to consume substrate while selecting macrophyte tubers which may increase artifact ingestion rates, (3) Scaup primarily consume bivalves which might reduce their requirement for grit, thereby reducing their likelihood of consuming artifacts, and (4) Mute Swans tend to forage in nearshore areas where waterfowl hunters and fishermen also tend to congregate. Therefore, although Mute Swans are a good sentinel species for artifact availability in aquatic habitats on the LGL, their frequency of artifact ingestion is not necessarily indicative of what duck species consume. It has

Table 1. Percentage of adult Mute Swans containing non-toxic shot, toxic shot and other artifacts throughout the annual cycle on the lower Great Lakes, 2001–2003.

Artifact	Breeding (Apr–Jun) *n* = 99	Brood (Jul–Aug) *n* = 48	Fall (Sep–Nov) *n* = 22	Winter (Dec–Mar) *n* = 29	Entire year *n* = 198
Non-toxic shot	23.8	6.3	13.6	3.4	15.7
Toxic shot	9.5	2.1	0	10.3	6.7
Non-toxic artifacts[a]	0	6.3	0	3.4	2.0
Total	33.3	14.7	13.6	17.1	22.7

[a]Primarily fishing tackle.

Table 2. Percentage of Mute Swan cygnets containing non-toxic shot, toxic shot or other artifacts on the lower Great Lakes, 2001–2003.

Artifact	Early (Jul–Oct) *n* = 27	Late (Nov–Mar) *n* = 18
Non-toxic shot	3.7	11.1
Toxic shot	3.7	5.6
Non-toxic artifacts[a]	0	0
Total	7.4	16.7

[a]Primarily fishing tackle.

been suggested that Mute Swans have a high frequency of artifact ingestion (Wilson *et al.* 1998), but previous studies have been based on the collection of dead and moribund birds. Our results (22.7% of seemingly healthy adults) confirm that Mute Swans are in fact prone to artifact ingestion as they had one of the highest ingestion frequencies ever reported for waterfowl (Bellrose 1959, Havera *et al.* 1992).

Mute Swans had a higher frequency of non-toxic shot (13.9% of 243 birds) than both lead shot (6.2%) ($G = 7.56$, $P = 0.006$) and other artifacts (1.6%, primarily fishing tackle) ($G = 21.63$, $P < 0.001$); toxic shot was more prevalent than other artifacts ($G = 3.98$, $P = 0.046$). Therefore, non-toxic shot was the more prevalent artifact consumed by Mute Swans shortly after the lead shot ban. Although individual Mute Swans contained a limited number of artifacts (mean 5, range 1–102, mode 1)(Fig. 2), it has been suggested that swans *Cygnus* spp. have an inherent sensitivity to lead and that it takes a limited number of toxic artifacts to cause health-related problems and death (Birkhead & Perrins 1986, Wilson *et al.* 1998). High overall frequency of artifact ingestion by adults and juveniles (Tables 1 and 2) suggests that lead toxicosis may have been a significant mortality factor for Mute Swans on the LGL before the ban. The rate of Mute Swan population increase on the LGL has accelerated since the early 1990s, when the U.S. lead shot ban came into effect (Petrie & Francis 2003), suggesting a possible reduction in lead toxicosis mortality. Similarly, the banning of lead shot and lead fishing weights between 0.06 and 28.36 g in the UK probably led to a reduction in lead toxicosis (Owen 1992) and to an increase in Mute Swan numbers (Delany *et al.* 1992, Kirby *et al.* 1994). Because adherence to toxic shot regulations appears to be high on the LGL (Demendi & Petrie 2006), the frequency of lead shot ingestion will likely continue to decrease over time as previously deposited lead continues to settle into the substrate and becomes inaccessible to foraging waterfowl.

In the UK, Mute Swans are often injured or killed through the ingestion of, or entanglement with, fishing line, hooks and/or sinkers (Birkhead 1982, Kelly & Kelly 2004). Only 4 of 243 Mute Swans collected in this study (1.6%) contained any form of fishing tackle and only one bird contained a lead sinker. Therefore, consumption or entanglement with fishing tackle does not appear to be an important mortality factor for Mute Swans on the LGL. We suggest that low incidence of tackle consumption or entanglement on the LGL can be attributed to a lower density of anglers relative to the UK (there are over 3 million anglers in England and Wales alone, Kelly & Kelly 2004).

Tundra Swan artifact ingestion

Only 5 of 77 Tundra Swans collected contained artifacts and all birds that contained items had 2 artifacts or fewer (Fig. 2); 3 (3.9%) contained non-toxic shot, 2 (2.6%) contained toxic shot and no birds contained fishing tackle (Table 3). Low Tundra Swan artifact ingestion relative to Mute Swans can likely be attributed to the fact that Tundra Swans have short residence times on the LGL and they tend to forage in agricultural fields (Petrie *et al.* 2002). Limited evidence suggests that male Tundra Swans (9.1% of 44) may have higher ingestion rates than females (3.0% of 33) ($G = 1.241$, $P = 0.265$), and unlike Mute Swans, adult Tundra Swans (6.9% of 58) had similar artifact ingestion rates to cygnets (5.3% of 19) ($G = 0.066$, $P = 0.798$). Similar age-related ingestion frequencies can likely be attributed to the fact that cygnet Tundra Swans were collected during spring and fall migration and therefore, were already close to adult size and likely consumed similar foods.

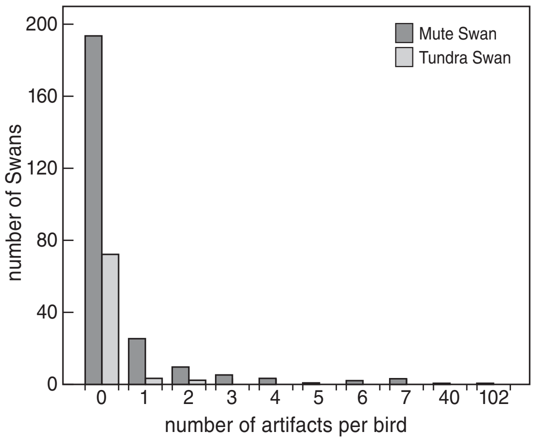

Figure 2. Number of artifacts contained within Mute Swans and Tundra Swans collected on the lower Great lakes, 1999–2002.

Conclusions

A unique feature of this study is that we collected seemingly healthy birds for analysis and did not rely on dead or moribund birds as has been the case in other swan artifact ingestion studies. Mute Swans collected in this study had one of the highest overall frequencies of artifact ingestion ever reported for a waterfowl species. Given the high present-day incidence of shot ingestion, lead toxicosis was likely a significant mortality factor for Mute Swans before the lead shot ban. Although lead shot is still ingested by Mute Swans (6% of birds contained lead), it does not appear to be affecting population growth and will most likely

Table 3. Percentage of adult and cygnet Tundra Swans containing non-toxic shot, toxic shot and other artifacts during spring and fall migration through the lower Great Lakes, 1999–2001.

Artifact	Spring		Fall		Entire year	
	Adults $n = 21$	Cygnets $n = 14$	Adults $n = 37$	Cygnets $n = 5$	Adults $n = 58$	Cygnets $n = 19$
Non-toxic shot	0	0	8.1	0	5.2	0
Toxic shot	0	7.1	2.7	0	1.7	5.3
Non-toxic artifacts[a]	0	0	0	0	0	0
Total	0	7.1	10.8	0	6.9	5.3

[a]Primarily fishing tackle.

continue to decline as previously deposited lead shot becomes inaccessible to foraging swans. Tundra Swans had a relatively low overall incidence of artifact ingestion (6.5%) and lead consumption does not appear to be a problem for Tundra Swans on the LGL since only 2.6% of birds contained toxic artifacts. As only 1.6% of Mute Swans and no Tundra Swans contained any form of fishing tackle, angling related injuries and mortalities are likely lower than has been reported for swans in Europe.

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REFERENCES

Anderson F.C., Havera S.P. & Zercher B.W. 2000. Ingestion of lead and non-toxic shotgun pellets by ducks in the Mississippi Flyway. J. Wildl. Manage. 64: 848–857.

Anderson W.L. & Havera S.P. 1985. Blood lead, protoporhyrin, and ingested shot for detecting lead poisoning in waterfowl. Wildl. Soc. Bull. 13: 26–31.

Bailey M.L. 2003. Mute Swan dietary intake in relation to reproduction on the lower Great Lakes. Honors Thesis, Univ. Western Ontario, London, Ontario.

Badzinski S.S. 2003. Influence of Tundra Swans on aquatic vegetation and staging waterfowl at Long Point, Ontario. Ph.D. Dissertation. Univ. Western Ontario, London, Ontario.

Bartonek J.C., Serie J.R. & Converse K.A. 1991. Mortality in Tundra Swans, *Cygnus columbianus*. Wildfowl Supp. No. 1: 356–358.

Bellrose F.C. 1959. Lead poisoning as a mortality factor in waterfowl populations. Illinois Nat. Hist. Surv. Bull. 27: 235–288.

Beyer W.N., Day D., Morton A. & Pachepsky Y. 1998. Relation of lead exposure to sediment ingestion in Mute Swans on the Chesapeake Bay, USA. Environ. Toxicol. Chem. 17: 2298–2301.

Birkhead M. 1982. Causes of mortality in the mute swan *Cygnus olor* on the River Thames. J. Zool. 198: 15–25.

Birkhead M.E. & Perrins C.M. 1986. The Mute Swan. Croom Helm, London, UK.

Blus L.V. 1994. A review of lead poisoning in swans. Comp. Biochem. Physiol. 108: 259–267.

Brown M.J., Linton E. & Rees E.C. 1992. Causes of mortality among wild swans in Britain. Wildfowl 43: 70–79.

Canadian Wildlife Service. 1997. Regulations amending the wildlife area regulations, P.C. 1997–1294, SOR/ 97–439. Canada Gazette Part II 131: 2805–2809.

Ciaranca M.A., Allin C.C. & Jones G.S. 1997. Mute Swan (*Cygnus olor*). In: Poole A. & Gill F. (eds) The Birds of North America, No. 273. AOU, Washington, D.C.

Daury R.W., Schwab F.E. & Bateman M.C. 1994. Prevalence of ingested lead shot in American Black Duck, *Anas rubripes*, and Ring-necked Duck, *Aythya collaris*, gizzards from Nova Scotia and Prince Edward Island. Can. Field Nat. 108: 26–30.

Delany S., Greenwood J.J.D., & Kirby J. 1992. The national Mute Swan Survey 1990. 1992. JNCC Report No. 74. JNCC, Peterborough.

Demendi M. & Petrie S.A. 2006. Shot ingestion in scaup on the Lower Great Lakes after nontoxic shot regulations in Canada. Wildl. Soc. Bull. 34:1101- 1106.

Dennis D.G., McCullough G.B., North N.R. & Ross R.K. 1984. An updated assessment of migrant waterfowl use of Ontario shorelines of the southern Great Lakes. In: Curtis S.G., Dennis D.G. & Boyd H. (eds) Waterfowl Studies in Ontario. Can. Wildl. Serv. Occas. Pap. No 54: 37–42.

Franson J.C., Hansen S.P., Creekmore T.E., Brand C.J., Evers D.C., Duerr A.E. & DeStefano S. 2003. Lead fishing weights and other fishing tackle in selected waterbirds. Waterbirds 26: 345–352.

Grant T.A., Henson P. & Cooper J.S. 1997. Feeding behaviour of Trumpeter Swans, *Cygnus buccinator*. Wildfowl 48: 6–15.

Hardman J.A. & Cooper D.R. 1980. Mute Swans on the Warwickshire Avon – A study of decline. Wildfowl 31: 29–36.

Havera S.P., Whitton R.M & Shealy R.T. 1992. Blood lead and ingested and embedded shot in diving ducks during spring. J. Wildl. Manage. 56: 539–545.

Hohman W.L., Pritchert R.D., Pace R.M., Woolington D.W. & Helm R. 1990. Influence of ingested lead on body mass of wintering canvasbacks. J. Wildl. Manage. 54: 211–215.

Irwin J.C. 1975. Mortality factors in Whistling Swans at Lake St. Clair, Ontario. J. Wildl. Dis. 11: 8–12.

Kelly A. & Kelly S. 2004. Fishing tackle injury and blood lead levels in Mute Swans. Waterbirds 27: 60–68.

Kirby J., Delany S. & Quinn J. 1994. Mute swans in Great Britain – a review, current status and long term trends. Hydrobiologia 280: 467–482.

Knapton R.W., Petrie S.A. & Herring G. 2000. Human disturbance of waterfowl on Long Point Bay, Lake Erie. Wildl. Soc. Bull. 28: 923–930.

Longcore J.R., Corr P.O. & Spencer H.E. 1982. Lead shot incidence in sediments and waterfowl gizzards from Merrymeeting Bay, Maine. Wildl. Soc. Bull. 10: 3–10.

Mateo R., Martinez-Vilalta A. & Guitart R. 1997. Lead shot pellets in the Ebro Delta, Spain: densities in sediments and prevalence of exposure in waterfowl. Environ. Poll. 96: 335–341.

O'Halloran J., Myers A.A. & Duggan P.F. 1989. Some sublethal effects of lead on mute swan *Cygnus olor*. J. Zool. 218: 627–632.

O'Halloran J., Myers A.A. & Duggan P.F. 1991. Lead Poisoning in Mute Swans, *Cygnus olor*, in Ireland: a review. Wildfowl Supp. No. 1: 389–395.

O'Halloran J., Smiddy P., Quishi X., O'Leary R. & Hayes C. 2002. Trends in Mute Swan blood lead levels: evidence of grit reducing lead poisoning. Waterbirds 25, Special Publication 1: 363–367.

Owen M. 1992. Progress on lead free shot in the UK: 1991. Wildfowl 34:223.

Petrie S.A. 1998. Waterfowl and Wetlands of Long Point Bay and Old Norfolk County: Present Conditions and Future Options for Conservation. Long Point Waterfowl and Wetlands Research Fund, Port Rowan, Ontario.

Petrie S.A., Badzinski S. & Wilcox K.L. 2002. Population trends and habitat use of Tundra Swans staging at Long Point, Lake Erie. Waterbirds 25, Special Publication 1: 143–149.

Petrie S.A. & Francis C.M. 2003. Rapid increase in the lower Great Lakes population of feral mute Swans: A review and a recommendation. Wildl. Soc. Bull. 31: 407–416.

Petrie S.A. & Wilcox K.L. 2003. Migration chronology of eastern population Tundra Swans. Can. J. Zool. 81: 861–870.

Schwab F.E. & Daury R.W. 1989. Incidence of ingested lead shot in Nova Scotia waterfowl. Wildl. Soc. Bull. 17: 237–240.

Sears J. 1988. Regional and seasonal variations in lead poisoning in the Mute Swan, *Cygnus olor* in relation to the distribution of lead and lead weights in the Thames area, England. Biol. Conserv. 46: 115–134.

Sears J. 1989. A review of lead poisoning among the River Thames Mute Swan *Cygnus olor* population. Wildfowl 40: 151–152.

Sears J. & Hunt A. 1991. Lead poisoning in Mute Swans, *Cygnus olor*, in England. Wildfowl Supp. No. 1: 383–388.

Tsuji L.J., Young J. & Kozlovic D.R. 1998. Lead shot ingestion in several species of birds in the Western James Bay Region of Northern Ontario. Can. Field Nat. 112: 86–89.

Wilson L.K., Elliott J.E., Langelier K.M., Scheuhammer A.M. & Bowes V. 1998. Lead poisoning of Trumpeter Swans, *Cygnus buccinator*, in British Columbia, 1976–1994. Can. Field Nat. 112: 204–211.

SAMENVATTING

Watervogels kunnen door het opnemen van hagelkorrels en vislood loodvergiftiging oplopen. Na maatregelen in Europa werd het in 1999 ook in Canada verboden om watervogels met loden hagelkorrels te bejagen. Als vervangend materiaal werd gebruikgemaakt van niet-giftige stoffen als staal, bismut en wolfraam. Dit artikel beschrijft de opname van hagelkorrels en visgerei door Knobbelzwanen *Cygnus olor* en Fluitzwanen *C. columbianus* op de Grote Meren in Canada in de jaren direct na het instellen van het verbod. Van de Knobbelzwanen had 19,8% van de 243 onderzochte vogels voorwerpen in de maag. Bij de Fluitzwaan, die niet alleen in water voedsel zoekt maar ook veel op het land, lag dit percentage aanzienlijk lager (slechts 6,5% van de 77 vogels). De voorwerpen bestonden bij de Knobbelzwaan uit niet-giftige hagel (14% van de vogels), loden hagelkorrels (6%) en visgerei (1,6%). Bij de Fluitzwaan was het aandeel respectievelijk 4%, 2,6% en 0%. Oude Knobbelzwanen hadden vaker voorwerpen opgenomen dan jonge vogels (respectievelijk 22,7% en 8,9%). Bij de Fluitzwaan bestond geen verschil tussen beide leeftijdsklassen. Evenmin bestonden er bij beide soorten verschillen in opname tussen de seksen. Aangezien veel Knobbelzwanen hagelkorrels in de maag hadden, lijkt het waarschijnlijk dat loodvergiftiging een belangrijke doodsoorzaak bij deze soort in het Grote Merengebied is geweest vóór het verbod op schieten met loodkorrels. Verwondingen of verhoogde sterfte door visgerei lijken in het Grote Merengebied een minder grote rol te spelen dan in Europa. Al met al wijzen de waarnemingen erop dat loodvergiftiging tegenwoordig een laag tot matig effect heeft op Knobbelzwanen in het Grote Merengebied, en een minimaal effect op Fluitzwanen. (JS)

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