Seasonal ingestion of toxic and nontoxic shot by Canada geese

Stephen DeStefano, Christopher J. Brand, and Michael D. Samuel

Abstract We used rates of ingested shot and elevated blood-lead levels (≥0.18 ppm) to estimate the proportion of Canada geese (*Branta canadensis*) exposed to lead on 3 study areas in Manitoba, Minnesota, and Missouri. Lead exposure was prevalent on all areas and was common after the hunting season closed, when up to 15% of geese could have been exposed to lead shot. However, the proportion of steel shot ingested by geese has increased during the past 2 decades. We suggest that lead exposure is still a source of indirect hunting mortality in Canada geese but project that the prevalence of lead exposure in the Eastern Prairie Population and other waterfowl populations will decrease as nontoxic shot regulations persist and hunters use steel or other nontoxic shot.

Key words *Branta canadensis*, Canada geese, lead poisoning, lead shot, nontoxic shot, shot ingestion, steel shot, waterfowl

Regulations requiring the use of nontoxic shot such as steel for hunting waterfowl were first established in some areas of the United States in 1976 (U.S. Fish and Wildl. Serv. 1988) and nationwide in 1991. Lead toxicosis continues to cause mortality in waterfowl populations, however, because waste lead pellets from previous hunting seasons are still available. The problem of lead poisoning should diminish with time as steel shot replaces lead shot in the environment.

As hunters continue to use steel shot, newly deposited waste shot will be steel rather than lead, and thus steel shot will be available to be ingested by waterfowl rather than lead shot. Studies in Missouri (Humburg and Babcock 1982), Texas (Moulton et al. 1988), Illinois (Anderson and Havera 1989), and the Mississippi Flyway (Anderson et al. 1987) have compared ingestion rates of lead and steel shot in waterfowl after the establishment of nontoxic shot regulations. However, there have been few attempts to evaluate effectiveness of conversion to nontoxic shot in reducing lead shot ingestion.

During 1986–1988, we determined the prevalence and distribution of lead exposure in Canada geese (*Branta canadensis*) of the Eastern Prairie Population (EPP; DeStefano et al. 1991, 1992). Data on ingestion rates of lead and steel shot and lead concentrations in blood were collected at major breeding, migration, and wintering areas in EPP range. We estimate seasonal prevalence of lead exposure based on shot ingestion frequencies and elevated blood-lead concentrations, and we evaluate the extent to which nontoxic shot has reduced lead exposure in EPP Canada geese.

Study areas and methods

Major concentrations of EPP Canada geese occurred at Oak Hammock Wildlife Management Area (WMA), Manitoba and Lac Qui Parle WMA, Minnesota during fall migration, and at Swan Lake National Wildlife Refuge (NWR), Missouri during late fall and winter. Steel-shot zones were established at Swan Lake and Lac Qui Parle in 1978 and 1980, respectively (Humburg and Babcock 1982, Bengtson 1984). Nontoxic shot was not required at Oak Hammock.

At Oak Hammock, Lac Qui Parle, and Swan Lake, 1- to 2-ml blood samples were collected in heparinized

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vacutainers by jugular venipuncture of geese captured in cannon or rocket nets. At Oak Hammock and Swan Lake, blood samples were also collected from unclotted blood pooled in the body cavity of hunter-killed geese. Procedures for handling and bleeding geese followed those adopted at the National Wildlife Health Center (Madison, Wisc.). Lead concentrations in blood were determined by atomic absorption spectrophotometry. We considered geese to be recently exposed to lead if lead concentrations were 0.18 ppm in whole blood (Friend 1987, DeStefano 1989, DeStefano et al. 1991).

We believe that blood samples are a more sensitive and accurate method for determining lead exposure than ingested shot in gizzards, are a better physiological indicator of lead poisoning, and more accurately depict lead exposure in the population. Blood samples do not, however, indicate how much steel shot is ingested, and thus we relied on gizzard samples to determine the extent of steel shot ingestion.

We collected ≥ 50 gizzards/week/area from Canada geese at Oak Hammock, Lac Qui Parle, and Swan Lake during hunting seasons in 1986–1987 and 1987–1988. Procedures for identifying ingested shot were described by DeStefano (1989) and DeStefano et al. (1991). Wear on ingested lead and steel shot was rated and categorized from 0 (no wear) to 5 (extremely well worn or eroded, often resulting in a thin disklike shape).

We calculated 30-day and seasonal lead-shot ingestion rates for each refuge and time from estimates of mean ingestion rates ($\hat{I}$ = number of geese with ingested shot/total number sampled), hunting vulnerability ($\hat{H}$ = proportion of hunter-killed geese exposed to lead/proportion of live-captured geese exposed to lead), shot retention rates ($\hat{R}$ = mean number of days shot was retained in the gizzard), and the time of interest (T = time in days). Cumulative lead exposure ($\hat{E}$) was calculated by the formula:

$$\hat{E} = 1 - (1 - (\hat{I}/\hat{H}))^{T/\hat{R}} \qquad (1)$$

This equation is similar to the cumulative survival formula, where the usual mortality rate is replaced by the estimated probability of lead ingestion ($\hat{I}/\hat{H}$) and the survival time is replaced by the number of exposure intervals ($T/\hat{R}$). Sanderson and Bellrose (1986:3–5) used an alternate procedure ($[\hat{I}/\hat{H}] \times [T/\hat{R}]$) to estimate annual shot ingestion rate, but their procedure fails to consider that birds can ingest lead shot during >1 period and therefore overestimates population exposure. We also calculated the variance of estimated exposure from 1,000 Monte Carlo simulations using random numbers from the standard errors (SE) of each estimated parameter ($\hat{I}$, $\hat{H}$, and $\hat{R}$). The mean and SE for $\hat{I}$ and $\hat{H}$ were determined separately for each refuge or time period. $\hat{R}$ (20 days, SE = 1) was estimated from previous research (Bellrose 1959:281, Pain 1992:8).

A similar procedure was followed to estimate exposure rates based on blood samples from captured geese. In this calculation, $\hat{H}$ was considered to be a constant (1.0) because samples did not require correction for hunter vulnerability. The proportion of geese with elevated blood-lead levels (≥0.18 ppm) was used to estimate the ingestion rate ($\hat{I}$). In addition, the retention period ($\hat{R}$) was estimated from published sources (Finley et al. 1967; Roscoe et al. 1979; Franson et al. 1986; Mautino and Bell 1986, 1987; Roscoe 1986; Pain and Rattner 1988; Scheuhammer 1989; Sanderson et al. 1992) as the mean time that blood lead remains above the background level ($\bar{x}$ = .48 days, SE = 6). Lead-shot ingestion rates and proportion of geese with elevated blood-lead levels for each refuge or time were estimated using the combined samples from 1986–1987 and 1987–1988.

We compared the proportions of ingested steel and lead shot to develop a simple measure of the effectiveness of nontoxic shot regulations in reducing lead exposure. We assumed that waterfowl do not differentiate between steel and lead shot and that ingested steel shot replaces lead shot that would otherwise have been ingested (Anderson et al. 1987). We compared data from: (1) our 3 study areas, (2) Bengtson's (1984) study and ours at Lac Qui Parle, and (3) White and Stendell's (1977) study, Humburg and Babcock's (1982) study, and ours at Swan Lake.

Results and discussion

We collected 108 blood samples from hunter-killed Canada geese and 2,334 blood samples from live-captured geese at Oak Hammock and Swan Lake (Table 1). Although lead exposure was not different in hunter-killed than live-captured geese at either Oak Hammock or Swan Lake (χ^2 = 0.66 and 1.76, 1 df, P = 0.41 and 0.19, respectively), a test of the pooled data indicated that hunter-killed birds had a higher prevalence of lead exposure than live-captured geese (χ^2 = 3.04, 1 df, P = 0.08). On average, lead exposure was 1.7 times more prevalent among hunter-killed than live-captured geese.

Thirty-day exposure rates determined by lead-shot ingestion were highest following hunting at Swan Lake, intermediate at Swan Lake during fall (before and during hunting season) and at Oak Hammock, and lowest at Lac Qui Parle (Table 2). However, the data from post-hunting at Swan Lake were extremely

Table 1. Prevalence of elevated blood-lead concentrations in blood samples collected from hunter-killed and live-captured Canada geese at Oak Hammock Wildlife Management Area, Manitoba and Swan Lake National Wildlife Refuge, Missouri, 1986–1988. Geese were live-captured just before and during the waterfowl hunting season.

Area	Sample collection	No. samples	Elevated[a] No.	Elevated[a] %
Oak Hammock	Hunter-killed	79	8	10.1
	Live-captured	990	75	7.6
Swan Lake	Hunter-killed	29	3	10.3
	Live-captured	1,344	66	4.9

[a] Containing ≥0.18 ppm lead in whole blood.

variable due to low sample size (n = 16 gizzards). Exposure rates determined by blood lead were higher than those computed for shot ingestion except for the post-hunting period at Swan Lake, when blood lead provided a lower estimated exposure. Blood-lead exposure rates were highest at Swan Lake post-hunting followed by Oak Hammock, Swan Lake before and during hunting, and Lac Qui Parle. Because of the long period that geese generally stayed at Swan Lake (about 1 Dec–5 Mar), seasonal blood-lead exposure at this area may have been as high as 15% of the EPP. Geese that spent a long period at Oak Hammock may also have had a relatively high risk (10%) of lead exposure, especially compared with birds that resided at Lac Qui Parle.

Average category of wear on ingested lead and steel shot was rated at $\bar{x}$ = 3.9 (SE = 0.16; n = 65) and $\bar{x}$ = 2.1 (SE = 0.31, n = 43), respectively. Lead shot seemed to be more highly eroded and worn by gizzard action than steel (t = 5.18, 64 df, P < 0.001), and therefore less likely to be detected in gizzards than steel shot.

In our study, 64% of all ingested shot was lead and 36% was steel (DeStefano et al. 1991). However, at Lac Qui Parle and Swan Lake, ingested steel shot was common. No ingested steel was found at Oak Hammock, the only study area where lead shot was still legally used.

The proportion of gizzards at Lac Qui Parle with ingested shot that contained steel pellets increased (χ^2 = 7.27, 1 df, P = 0.007) from 38% (13 of 34 gizzards) in 1981–1983 (Bengtson 1984) to 81% (13 of 16 gizzards) in 1986–1988 (this study). At Swan Lake NWR, proportions of Canada goose gizzards with ingested shot that contained steel pellets were 19% (4 of 21) in 1974, 46% (59 of 129) during 1978–1981; and 60% (22 of 37) during 1986–1988 (White and Stendell 1977, Humburg and Babcock 1982, and this study, respectively). A higher proportion of steel shot was present in goose gizzards in the second study at Swan Lake than in the first (χ^2 = 5.28, 1 df, P = 0.02). Although the proportions of steel shot ingested in the second and third studies were not different (χ^2 = 2.17, 1 df, P = 0.14), the overall trend indicated that increasing proportions of ingested shot were steel (χ^2 test for trend, χ^2 = 8.15, 1 df, P = 0.004).

Estimated 30-day and seasonal lead-exposure rates based on elevated blood-lead concentrations were 1.3–2.1 times higher than estimates of exposure based on shot ingestion, excluding the post-hunting season at Swan Lake when few gizzards were sampled. This discrepancy in estimated lead-exposure rates was probably because shotgun pellets in waterfowl gizzards are frequently undetected (Anderson and Havera 1985, Friend 1987, DeStefano et al.

Table 2. Rates of lead exposure (proportion of birds with ingested shot or elevated blood lead concentrations for a specified number of days) for Eastern Prairie Population Canada geese based on lead shot ingestion and elevated blood-lead concentrations (≥0.18 ppm lead in whole blood).

				Population exposure rate					
				Shot ingestion			Elevated blood lead		
Area[a]	Arrival	Departure	Total days	n	30-day (2 SE)	Season (2 SE)[b,c]	n	30-day (2 SE)[b]	Season (2 SE)[b,c]
OH	1 Sep	31 Oct	61	1,029	2.28 (1.88)	4.51 (3.40)	990	4.82 (0.11)	9.54 (0.20)
LQP	15 Sep	30 Nov	76	516	0.50 (0.70)	1.28 (1.77)	1,140	1.04 (0.23)	2.60 (0.58)
$SL_{PRE+HUNT}$	15 Oct	15 Dec	61	590	2.29 (2.02)	4.65 (3.85)	1,344	3.10 (0.03)	6.20 (0.06)
SL_{POST}	16 Dec	10 Mar	84	16	18.21 (22.16)	39.46 (42.96)	1,193	5.34 (0.30)	14.26 (0.76)

[a] Areas: OH = Oak Hammock Wildlife Management Area (WMA), Manitoba; LQP = Lac Qui Parle WMA, Minnesota; and SL = Swan Lake National Wildlife Refuge, Missouri before and during ($SL_{PRE+HUNT}$) and after (SL_{POST}) the waterfowl hunting season.

[b] Mean exposure rate.

[c] Seasonal rate of exposure for the population is based on total days spent at each study area.

1991). Estimates of population exposure rate based on blood-lead concentrations were probably closer to actual exposure. Seasonal exposure based on blood-lead concentrations (Table 2) indicated that a potentially large proportion (15%) of EPP geese could have been exposed to lead during the fall and winter. Even the simple prevalence estimates based on blood-lead exposure showed that lead ingestion was still common 8 years after establishment of steel shot zones (DeStefano et al. 1991).

Steel shot is becoming more prevalent in goose gizzards in areas where steel has been used for an extended period. We believe that use of nontoxic shot for hunting waterfowl is reducing the number of birds that would otherwise suffer lead poisoning. With continued use of nontoxic shot, the incidence of lead poisoning should continue to decline with time. In addition, generations of birds yet to hatch may affect the removal of lead pellets through their feeding activities—this may very well play a role in ridding the environment of some waste lead shot (C. D. Stutzenbaker, Tex. Parks Wildl. Dep., Port Arthur, Tex., pers. commun., 1993).

Although our approach takes a simplistic view of the dynamic processes of shot ingestion and lead poisoning in waterfowl, we believe that our major conclusions are accurate: that a relatively large proportion of birds are still subjected to lead exposure throughout the year, but use of steel shot is substantially reducing the effect of lead poisoning. We project that the prevalence of lead exposure in the EPP and other populations of geese and ducks will continue to decrease as nontoxic shot regulations remain in effect and hunters use steel or other nontoxic shot rather than lead shot.

Management implications

Conversion to nontoxic shot on specific areas appears to substantially decrease lead exposure in EPP Canada geese, and nationwide use of nontoxic shot for hunting waterfowl should further reduce the effect of lead poisoning. Elimination of lead exposure will take time, however, because high densities of lead pellets have built up over several decades in some areas (Humburg and Babcock 1982, Bengtson 1984, Sanderson and Bellrose 1986, DeStefano 1989). Agricultural tillage can help reduce shot densities, but pellets remain available to birds even on cultivated land, and some buried pellets are brought to the surface during plowing (Fredrickson et al. 1977, Humburg and Babcock 1982, DeStefano 1989). On some important waterfowl areas where shot densities are high, restoration (including dredging) may be necessary to eliminate lead shot from the wetland substrate or adjacent fields, but this may not be feasible or may violate wetlands regulations. In addition, violation of nontoxic shot regulations adds some lead shot to the environment every year (Bengtson 1984, Simpson 1989), and lead shot is still used in many parts of Canada. Continued and strengthened law enforcement and public education regarding appropriate shot use is needed to further reduce availability of lead shot and subsequent lead exposure in waterfowl populations.

Acknowledgments. Funding was provided by the U.S. Fish and Wildlife Service, and research was conducted through the National Wildlife Health Center in cooperation with the Manitoba Department of Natural Resources, Minnesota Department of Natural Resources, and Missouri Department of Conservation. We thank J. E. Austin, J. Coluccy, M. P. Conrad, J. DiMatteo, M. M. Gillespie, S. J. Madsen, L. M. Mechlin, numerous agency personnel and goose hunters, and owners of goose-cleaning operations for assistance with sample collection. D. L. Finley and M. R. Smith analyzed blood samples, and J. R. Runningen processed x-ray films. We also thank D. H. Rusch for his insight and input. The Oregon Cooperative Wildlife Research Unit provided support during manuscript preparation, and D. D. Humburg, G. C. Sanderson, R. J. Steidl, and C. D. Stutzenbaker reviewed the text. The Wisconsin Cooperative Wildlife Research Unit conducts research in cooperation with the U.S. Fish and Wildlife Service, the University of Wisconsin-Madison, the Wisconsin Department of Natural Resources, and the Wildlife Management Institute.

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Associate Editor: Rotella.