Carcasses of Shot Richardson's Ground Squirrels May Pose Lead Hazards to Scavenging Hawks

LOREN D. KNOPPER,[1] *National Wildlife Research Centre, Canadian Wildlife Service, Carleton University Campus, Ottawa, ON K1A 0H3, Canada*
PIERRE MINEAU, *National Wildlife Research Centre, Canadian Wildlife Service, Carleton University Campus, Ottawa, ON K1A 0H3, Canada*
ANTON M. SCHEUHAMMER, *National Wildlife Research Centre, Canadian Wildlife Service, Carleton University Campus, Ottawa, ON K1A 0H3, Canada*
DELLA E. BOND, *National Wildlife Research Centre, Canadian Wildlife Service, Carleton University Campus, Ottawa, ON K1A 0H3, Canada*
DONALD T. McKINNON, *Planning and Evaluation Branch, Saskatchewan Environment, Regina, SK S4S 5W6, Canada*

Abstract

*Shooting and using poison baits (e.g., strychnine, zinc phosphide) are current management options for controlling Richardson's ground squirrels (*Spermophilus richardsonii*; RGS). Bullets used for shooting RGS contain lead, fragment upon impact, and RGS carcasses are not usually recovered after being shot. For these reasons, we hypothesized that scavenging birds of prey may be at risk of lead poisoning. To test this, we took radiographs of 15 shot RGS and analyzed the area around the path of the bullet for lead. Lead levels ranged from 0.01 to 17.21 mg/carcass (median = 3.23 mg), and fragments appeared as dust. Two common scavenging hawks (Swainson's and ferruginous hawks [*Buteo swainsonii, B. regalis*]) consume eviscerated RGS carcasses and would consequently ingest this amount of lead per feeding. In a previous study, an estimated 5.71 mg/kg of lead, eroded in vivo from ingested lead shot, was lethal to bald eagles (*Haliaeetus leukocephalus*). Fitting the residue values to a normal distribution and based on the mass of an average raptor, we determined that roughly 1 in 5 RGS carcasses had lead levels that exceeded this value. Based on the average amount of lead in carcasses, and assuming that uptake of lead from the carcass is as high as that of eroded lead, we suggest that hawks would have to eat roughly 6.5 carcasses, taking an average of 23 days of feeding on an uninterrupted supply of shot carcasses, to attain a lethal dose of lead. Uncertainties remain, but shot RGS carcasses appear to be an appreciable source of lead that could prove fatal to scavenging hawks. This hazard could be avoided with the collection and disposal of shot carcasses and with the use of (green) ammunition.* (JOURNAL OF WILDLIFE MANAGEMENT 70(1):295–299; 2006)

Key words

bullet fragments, hawks, hollow-point bullets, lead, pests, radiographs, Richardson's ground squirrels, Spermophilus richardsonii.

Shooting and using poison baits (e.g., strychnine, zinc phosphide) are current management options for controlling RGS. Strychnine baits are known to cause primary poisoning of songbirds (Fagerstone and Hegdal 1998; D. T. McKinnon, Saskatchewan Environment, unpublished data) and possible secondary poisoning to birds of prey that scavenge poisoned carcasses. Prairie species like Swainson's and ferruginous hawks, for example, scavenge RGS carcasses (Chesser 1979, Schmutz et al. 1989, Bechard and Schmutz 1995), and much of their diet is composed of these rodents. Generally speaking, RGS make up to 71 and 50% of the prey items taken by Swainson's and ferruginous hawks, respectively, but the value is expected to be much greater for ferruginous hawks living east of the Rocky Mountains (Bechard and Schmutz 1995, England et al. 1997). Shooting has therefore been portrayed as the more ecologically benign management option.

There is evidence that ingesting lead from bullets can result in wildlife mortality. The ingestion of lead bullet fragments in shot carcasses of large mammals is a significant source of mortality in wild California condors (*Gymnogypus californianus*; Meretsky et al. 2000). In Japan, Steller's sea eagles (*Haliaeetus pelagicus*) and white-tailed sea eagles (*H. albicilla*) have died from eating lead bullet fragments found in the carcasses of deer (Kurosawa 2000). Hollow-point bullets are the main ammunition type used for shooting RGS and other rodent species (see http://www.DiscoverTheOutdoors.com; http://www.Outdoorlife.com). These bullets are usually made of lead, and because they have hollowed tips to maximize tissue damage, they are prone to fragment upon impact. Considering that RGS are not generally recovered after being shot, we hypothesized that their carcasses may pose a risk of lead exposure and poisoning to scavenging birds of prey. To test this, radiographs were taken of shot RGS to identify bullet fragmentation, and areas that contained fragments were analyzed for lead. Using Swainson's and ferruginous hawks as examples, we calculated possible acute and chronic lead exposure from feeding on shot carcasses and compared these doses to known lethal doses of metallic lead administered to raptors in past studies.

Methods

Fifteen RGS were shot once, by one individual, using a 0.22 calibre rifle and hollow-point, rimfire ammunition (Federal American Eagle, Mexico) at an average distance of 40 m. Carcasses were frozen and sent to the National Wildlife Research Centre (Canadian Wildlife Service, Ottawa, Ontario, Canada) for analysis.

Radiographs

Richardson's ground squirrels carcasses were partially thawed at room temperature and gently washed to remove debris adhering to the carcass. Carcasses were blotted dry and placed on a Kodak Lanex fine-screen X-OMAT cassette (Kodak Inc., Rochester, New York) containing a sheet of Konica SR-G Medical film (Konica, Tokyo, Japan). Radiographs were taken using a portable X-ray machine (#HF8015, Minxray Inc., Northbrook, Illinois; 15mA, 52KVp, 0.04 sec exposure, 23-in focal plate-film distance),

[1] *E-mail: loren.knopper@jacqueswhitford.com*

and film was developed using Kodak GBX developer and fixer (Kodak Inc.).

Dry radiographs were placed on a light table and inspected for evidence of bullet fragmentation. The area containing fragments adjacent to the path of the bullet was removed (Fig. 1), and after being cut into smaller 10- to 20-g pieces, the entire section containing bone, hair, and tissue was analyzed for lead (see below), yielding a lead burden value for each individual carcass. The left hind legs and haunch of 2 randomly selected individuals (areas containing no visible fragments on the radiograph) were removed and analyzed to indicate normal background body burdens of lead.

Lead Analysis

Lead was analyzed according to Neugebauer et al. (2000) with modification to accommodate this study. Twelve ml of nitric acid (70% Fisher Trace Metal Grade) was added to each 50-ml polypropylene tube (SCP Science) containing a sample. Tubes were covered with plastic watch glasses (SCP Science, Baie d'Urfé,

Figure 1. Radiograph of a Richardson ground squirrel (#8–9.44 mg lead) shot with a 0.22 rimfire hollow-point bullets. Radiograph was digitized using an Epson 4870 photo scanner. The entire area within the solid white lines was analyzed for lead.

Quebec, Canada) and left overnight at room temperature. Two standard reference materials were prepared at this time and included in the analysis. Tubes were placed in a DigiPREP Jr. (SCP Science) digester for 2 hours at 70°C, followed by an hour at 85°C, followed by 2 hours at 95°C. This stepwise increase in temperature eliminated boiling-over of the samples. Samples were adjusted to a volume of 50 ml by adding reverse osmosis purified water and allowed to cool overnight at room temperature. Samples were mixed, and visible fat was removed and allowed to settle for 24 hours. Approximately 4 ml of digested sample was removed with a disposable plastic transfer pipette, placed in a glass acid-washed test tube, and capped until lead analysis by Flame Atomic Absorption Spectrophotometry (AAS). Overall accuracy was measured by spike recovery from 2 different standard reference materials; lobster hepatopancreas (TORT-2: National Research Council of Canada, Ottawa, Ontario, Canada) and bone meal 1486 (National Institute of Standards and Technology, Gaithersburg, Maryland). Average accuracy for lead analysis was 116.3 ± 6.1%.

Results

The radiographs showed that 14 of 15 RGS carcasses had visible bullet fragments. Fragments appeared as minute debris (lead dust) rather than larger pieces of bullet (Fig. 1). A median value of 3.23 mg lead was found in the carcasses, and values for individuals ranged from 0.01 mg (the carcass with no observable fragments) to 17.21 mg (actual individual values: 0.01, 0.02, 0.06, 0.71, 1.36, 1.60, 1.63, 3.23, 3.29, 3.84, 5.47, 9.44, 9.71, 14.11, 17.21 mg). Approximately 0.01 mg of lead was found in the hind limbs. The distribution of lead among all of the carcasses was not normally distributed, so data were log $_{10}$ transformed. The log $_{10}$–transformed data closely approximated normality (Lilliefors = 0.02) but were significantly skewed to the left (skew = −1.29, skew/standard error skew = −2.2).

Discussion

An ancillary study conducted for us by the Royal Canadian Mounted Police (RCMP) Forensic Laboratory Service showed that hollow-point bullets fired from a standard 0.22 calibre rifle into a water bullet recovery tank lost approximately 0.20 of their mass in the form of fragments (W. Sopiro, RCMP Forensic Laboratory Service, unpublished data). Like the carcasses of large mammals, these fragments were much larger than those retained in the RGS carcasses from the present study. This implies that larger fragments have enough momentum to exit a small carcass, leaving only the smaller dust-like fragments behind. We suggest that this dust-like lead debris could also be an appreciable source of lead exposure that could result in acute and chronic lead poisoning in scavenging raptors.

Acute Exposure

We are aware of only 2 studies in which raptors were orally dosed with metallic lead and the amount of lead that eroded in vivo concomitantly measured. Stendell (1980) fed American kestrels (*Falco sparverius*) laboratory mice (*Mus musculus*) that contained 1 no. 9 lead shot (~49 mg) and found that shot in regurgitated castings was approximately 2% lighter than the preingestion mass. No adverse effects were observed in these kestrels. Pattee et al. (1981) administered 10, 20, 30, 80, or 156 # 4 lead shot (~200 mg per pellet) to 1 of 5 bald eagles. The birds given 10, 20, and 30 shot died within 20 days, the bird given 80 shot died 133 days after dosing, and the bird given 156 shot became blind and was euthanized. For 2 of the birds, all of the shot administered was recovered in castings, and the average amount of lead eroded in vivo was between 0.8 and 1.0% of the ingested dose. Body mass of these eagles was not given by Pattee et al. (1981), but the average mass from other studies was approximately 3.5 kg (McVey et al. 1993). Accordingly, it can be assumed that the lowest lethal dose of lead shot given to eagles was 571.4 mg/kg, but since no more than 1% of the shot was eroded in vivo, the actual lethal dose was 5.7 mg/kg.

Swainson's and ferruginous hawks have average body masses of roughly 1.0 (693–1,367 g; England et al. 1997) and 1.5 kg (977–2,074 g; Bechard and Schmutz 1995), respectively. Both species eviscerate RGS before consuming the entire carcass (Schmutz et al. 1989, Bechard and Schmutz 1995, England et al. 1997). Based on the range of lead values we measured, hawks in this size range would ingest 0.003 (background) to 24.8 mg lead/kg from eating a single RGS carcass. Looking at the distribution of RGS lead levels, we can ask what proportion of the shot population carried lead levels that exceeded the actual lethal dose to eagles. For simplicity sake, based on a 1-kg raptor, and accepting that the log $_{10}$ lead levels in RGS carcasses are normally distributed, a z-score calculation (Rohlf and Sokal 1969) tells us that an estimated 1 in 5 shot RGS carcasses contained lead levels that exceeded our derived lethal dose. Presumably more carcasses would contain lead levels that exceeded the derived lethal dose for smaller individuals, whereas the opposite would be true for larger individuals. In assessing the risk associated with this level of lead ingestion, 2 critical assumptions are that lead dust in carcasses is absorbed as efficiently as lead from lead shot after ingestion by raptors, and that lead sensitivity in eagles and buteos is similar. We believe these to be reasonable assumptions. The fine-lead particles we observed have a large surface area to facilitate dissolution and uptake and are found throughout the muscle, making them less likely to be regurgitated in casts, and since eagles and hawks are closely related species with similar digestive physiologies, oral lead sensitivity is likely similar. We recognize that similar phylogeny does not necessarily signify similarities in sensitivity to toxicants (Mineau 1991), but presently, we have no other basis for our comparisons. Thus, the carcasses of shot RGS appear to be an appreciable source of lead that could prove acutely fatal to scavenging hawks.

Chronic Exposure

Not all RGS carcasses we examined contained potentially lethal levels of lead. Carcass 12, for example, had the same lead levels as the hind legs, which indicate normal ambient lead burdens. If hawks are randomly choosing shot RGS carcasses in respect to lead levels, over time they would consume the average amount of lead that we measured in carcasses (1.32 mg/carcass based on the mean of the log $_{10}$ distribution). Again for simplicity based on a 1-kg hawk, and using the following equation for daily food requirements (g/day, dry weight) of avian species (Nagy 1987),

$$y = 0.648\ x^{0.651}$$

where x equals body mass (g), we determined that the average adult hawk would require approximately 60 g/day (dry weight) to sustain itself. When converted to wet weight values, assuming 68% water content (Jorgensen et al. 1991), hawks would need to consume 190 g/day to meet their metabolic requirements. We were unable to ascertain the average mass of the gastrointestinal tract of RGS used in this study (i.e., stomach, small and large intestines), but Howald (1997), in a study to quantify pesticide residue in Norway rats (*Rattus norvegicus*), determined that the gastrointestinal tract made up 10–15% of rat body mass. The average mass of RGS carcasses was 780 g. Assuming the gastrointestinal tract of RGS is also 10–15% body mass, the average mass of eviscerated carcasses would be approximately 660 g. Thus, assuming a diet exclusively comprised of scavenged-shot RGS, the average 1-kg adult hawk would have to eat an RGS carcass every 3.5 days to meet its nutrient demands. This means that to exceed the estimated lethal dose of lead, almost 6.5 carcasses would have to be eaten, taking an average of 23 days of feeding on an uninterrupted supply of shot carcasses. This is a worse-case scenario assuming that hawks are solely feeding on shot carcasses, and that all the metallic lead contained in the carcasses is eroded and assimilated by the hawk, but since both raptor species are opportunistic; indeed, Chesser (1979) reported that ferruginous hawks appeared regularly when shooting began in prairie dog towns and scavenged shot carcasses within minutes. Harmata and Restani (1995) reported similar RGS scavenging behavior in golden eagles (*Aquila chrysaetos*), and since RGS are commonly shot throughout prairie provinces and states for control and recreation, it seems reasonable to expect that enough carcasses will be available to be scavenged. The exact number of ground squirrels shot during control and recreation activities is impossible to determine but to illustrate the point that carcasses will be available to scavenge; in 2002 and 2003, an organized shooting event was held over a 12-week period in Saskatchewan, Canada, in an attempt to control RGS numbers and in both years combined, just over 100,000 RGS were shot (S. Klein, Saskatchewan Wildlife Federation, Saskatoon, Canada, personal communication). In a study of the effects of recreational shooting on prairie dog colonies, Vosburgh and Irby (1998) reported that 229 black-tailed prairie dogs (*Cynomys ludovicianus*) were shot over a 5-month period in 1994 at 10 colonies in Montana. In 1995, during a 3-month shooting period, 518 prairie dogs were shot.

The above scenarios only consider lethality to adult birds as a possible endpoint of lead exposure. There are also numerous possible sublethal effects from lead ingestion like lethargy, dehydration as a result of watery feces (Rattner et al. 1989), blindness (Pattee et al. 1981), and myocardial damage (Langelier et al. 1991) that cannot be overlooked. Chicks fed carcasses containing lead would undoubtedly be at risk, as would mammalian species (e.g., badgers, foxes) and other birds of prey (e.g., red-tailed hawks [*Buteo jamaicensis*], burrowing owls [*Speotyto cunicularia*]) that also scavenge shot carcasses.

Management Implications

Our results suggest that carcasses of shot RGS may constitute a significant source of elevated lead exposure, meaning that birds of prey scavenging these carcasses may be at high risk of lead poisoning. Presently, we are unaware of any data that have been collected on hawk mortality due to scavenging-shot RGS. Dead birds are difficult to find and are rapidly scavenged and removed from fields, which makes field-based estimates of mortality difficult (Balcomb 1986, Mineau and Collins 1988). Regardless, it appears that any possible risk of lead poisoning to hawks could be almost entirely eliminated with the collection and disposal of shot carcasses from fields. The use of (green) ammunition such as steel, tungsten-nylon used by the U.S. military (U.S. Army Environmental Center, Aberdeen Proving Ground, Maryland), or polymer (used for indoor shooting) would also eliminate the risk of lead poisoning, but it may be some time before this type of ammunition is widely available or accepted.

Acknowledgments

We thank W. Sopiro of the RCMP Forensic Laboratory Service in Ottawa for his assistance, L. Moore (Saskatchewan Environment, Lloydminster, Saskatoon, Canada) and B. Shepard (Lloydminster, Saskatoon, Canada) for their help in collecting the RGS used in this study, and our colleagues for their comments on previous drafts.

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Associate Editor: Block.