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ENVIRONMENTAL HEALTH | RESEARCH ARTICLE

Lead exposure through consumption of small game harvested using lead-based ammunition and the corresponding health risks to first nations in Alberta, Canada

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Abstract: The harvesting of game birds, such as grouse, with small arms using lead ammunition continues to be common practice in Alberta, Canada. Grouse are routinely consumed as a subsistence traditional food by First Nations in Alberta and the use of lead ammunition increases the potential lead exposure through the consumption of residual bullet or shot fragments in the edible portion of the meat. After removal of visible shot and ammunition fragments, similar to how the samples would be prepared for consumption, impacted and non-impacted grouse breast meat samples were analyzed to characterize the lead content. Using publicly available consumption rates, the potential lead exposures from consumption of both impacted and non-impacted grouse breast meat were estimated and the corresponding health risks were predicted. Comparison of the predicted health risks revealed a significantly higher risk ($p< 0.05$) for the consumption of ammunition-impacted meat.

ABOUT THE AUTHOR

Intrinsik Corp has significant expertise in the completion of Traditional Food Studies. Traditional or country foods are those foods harvested from the land or water, and include fish, large and small game animals, sea mammals, birds and plants. Our scientists, led by Claire McAuley, have completed numerous studies alongside First Nations across Canada. Swan River First Nation (SRFN) have completed investigations of their traditional food quality including moose, vegetation (medicines, teas, and berries), small mammals and fish. As part of these studies, Intrinsik (working with SRFN) evaluated risks from ingestion of harvested subsistence foods and provided assurances as to the quality and safety of locally sourced foods. The Traditional Food Studies involved the submission of food samples by trained community harvesters and analysis of trace contaminants (both organic and inorganic) and, in order to evaluate health risk, they involved the integration of community consumption rates obtained through surveys and interviews.

PUBLIC INTEREST STATEMENT

Traditional foods play an important nutritional, social, cultural and economic role for First Nations in Alberta, Canada. Hunting and subsistence harvesting are integral in food collection for many First Nations and small game is often harvested using lead-based ammunition, resulting in potential lead exposures when consumed. At low exposure levels, lead may affect the intellectual and behavioural developmental of infants and children and cause increased blood pressure in adults, presenting an elevated health risk to First Nations members. This study assessed the potential health risks from consumption of grouse meat impacted by ammunition through the use of measured lead concentrations in grouse meat harvested with leaded ammunition. The results identified that meat impacted by lead-based ammunition had significantly higher lead concentrations and supported the consumption of non-impacted meat as a good quality alternative to store-bought meats, highlighting the benefits of using unleaded ammunition.

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Keywords: heavy metal; lead; traditional food; dietary exposure; ammunition; First Nations

1. Introduction

Traditional foods are an integral component of good health among Canada's First Nations. Commercial foods are comparatively expensive and not always as nutrient-dense as traditional foods therefore any decrease in traditional food consumption can have a negative effect on the diet, and nutritional status, of First Nations communities. For these reasons, the continued consumption of traditional foods is recommended and encouraged. The increasing awareness of the nutritional and other benefits of traditional foods is an opportunity for First Nations to both remain connected with their culture and to identify and consume more economical, accessible and nutritious foods. When forced to fill the dietary gap left by the removal or decline of traditional foods is often not easy in northern communities where alternative food options may not be available, are of poor quality, or are very expensive (McAuley & Knopper, 2011; Van Oostdam et al., 2005).

Encroachment from industrial activity into traditional hunting and harvesting areas has led to the need to travel further and thus the requirement for transportation and fuel. Harvesting of small game (small mammals and birds) requires fewer hunting resources (such as quads, snowmobiles, high powered rifles) and often does not require the same amount of time as big game hunting. Through the use of snares and small arms, small game can be harvested at more locations, as these species have more general habitat requirements and smaller home ranges than larger game. Grouse, both ruffed grouse (*Bonasa umbellus*) and spruce grouse (*Falcipennis canadensis*), are important sources of protein and are some of the more popular traditional foods consumed among First Nation members in Alberta, Canada (Chan et al., 2016).

Lead-based ammunition has been, and continues to be, used in the hunting of small game, including grouse. Lead-based ammunition is typically less expensive than lead-free alternatives, more widely available, generally considered by hunters to have greater killing effectiveness (Trinogga, Fritsch, Hofer, & Krone, 2013) and less sensitive to the skill of the shooter (Tsuji & Nieboer, 1997). However, impacts from the use of lead ammunition to the environment, wildlife and human health have been widely documented. Exposure to lead can cause a multitude of adverse physiological effects to humans, including cardiovascular, renal, cerebrovascular, central and peripheral nervous, cognitive and neurobehavioural, haematological, reproductive, skeletal, and immunological effects (Agency for Toxic Substances and Disease Registry [ATSDR], 2007; Bellinger et al., 2013; Joint Expert Committee on Food Additives [JECFA], 2011). However, the greatest scientific evidence indicates that low levels of lead exposure may cause adverse effects on the intellectual and behavioural developmental of infants and children. For adults, low-level lead exposure is most strongly associated with an increase in blood pressure.

It has been demonstrated that consistent consumption of wild game hunted using lead ammunition can cause substantial increases in blood lead levels due to the intake of lead residues that may contaminate the meat (Kosnett, 2009). Radiographic evidence has shown that lead ammunition used to kill wild game fragments into numerous small metallic particles upon impact in the tissues of the animal (Andreotti, Borghesi, & Aradis, 2016; Hunt et al., 2009; Knott, Gilbert, Hoccom, & Green, 2010; Pain et al., 2010). These fragments can be widely dispersed in the tissues. In deer, Hunt et al. (2009) observed that the maximum distance between fragments was up to 45 cm. Despite the removal of visible lead shot and fragments, often these fragments would be too small to be detected and thus are unlikely to be removed from the meat prior to consumption (Andreotti et al., 2016; Hunt et al., 2009; Knott et al., 2010; Pain et al., 2010). A recent dietary study of First Nations in Ontario, Canada, indicated that the consumption of traditional foods, predominantly wild game, constituted 73% of dietary lead intake, despite only accounting for 1.8% of the average caloric intake (Juric et al., 2018). This demonstrates the large influence that the use of lead-based ammunition has on exposure to lead through diet.

Lead is also known to cause deleterious effects to wildlife. Historically, attention has been given to the adverse health effects of lead ammunition to waterfowl in the United States. The ingestion of spent lead shot in the environment resulted in widespread poisoning of waterfowl, which led to the ban of the use of lead shot for waterfowl hunting in the United States in 1991 (Scheuhammer, 2009). In addition to waterfowl, scavengers that eat viscera of large game left behind by hunters may also be exposed to lead residues in the animal tissues in cases where lead ammunition had been used, which has contributed to lead poisoning and mortality (Legagneux et al., 2014). In Canada, lead shot was banned for the hunting of migratory birds in 1999; however, lead shot is still sold and has been identified as potentially the greatest unregulated source of lead knowingly discharged into the environment (Bellinger et al., 2013).

There is widespread consensus among scientists across North America and Europe regarding the risks posed by lead-based ammunition to the health of humans and wildlife, and the need to eliminate the use of lead-based ammunition with the use of non-toxic alternatives (Bellinger et al., 2013; Bernhoft et al., 2014). According to a literature review conducted by Arnemo et al. (2016) on the impacts of lead ammunition on the environment and health, over 99% of the peer-reviewed scientific papers that were found highlighted concerns regarding the use of lead ammunition.

The current study was aimed at understanding the potential health risks presented to First Nations members from the consumption of lead-impacted grouse meat relative to non-impacted grouse meat harvested in Alberta, Canada. The objectives of this study were to: a) examine lead concentrations measured in grouse meat that are impacted and not impacted by lead ammunition; b) estimate lead exposure from the consumption of impacted and non-impacted grouse meat by First Nations members; and, c) assess the health risks from consumption of impacted and non-impacted grouse meat.

2. Methods

2.1. Sample collection and laboratory analysis

Grouse muscle samples were collected by First Nation harvesters trained in sample collection, documentation and storage. The samples were collected according to the sampling procedures outlined at a community capacity building workshop. Grouse were harvested from traditional hunting areas in Alberta as part of the regular hunting activity of the First Nation community.

Thirteen (13) grouse were included in the assessment. Grouse were harvested between mid-October 2016 and mid-January 2017. Twelve (12) grouse were harvested using a 0.22 calibre rifle and one was harvested using a shot gun. All grouse were harvested using lead ammunition. Harvesters collected full breasts from eight grouse. Five whole grouse were also collected. Whole animals were collected by harvesters who had not completed the sample collection workshop. All samples (grouse breasts and whole grouse) were submitted to Maxxam Analytics (Maxxam) for total metals analysis by inductively coupled plasma mass spectrometry (ICP-MS), which included lead analysis. The whole animal samples were dissected by the lab to reduce the potential for contamination during collection.

Samples were visually inspected by the lab and identified as impacted or non-impacted depending on the location of the ammunition impact. Photos of both impacted and non-impacted samples are included as Figures 1 and 2, respectively. Of the 13 grouse harvested, three were impacted in a single breast by ammunition during the harvest, four grouse were impacted in both breasts, and six grouse were not impacted in either breast. For the samples (*i.e.*, impacted in a single breast), the lab split the grouse breasts into impacted and non-impacted sides. For the ten

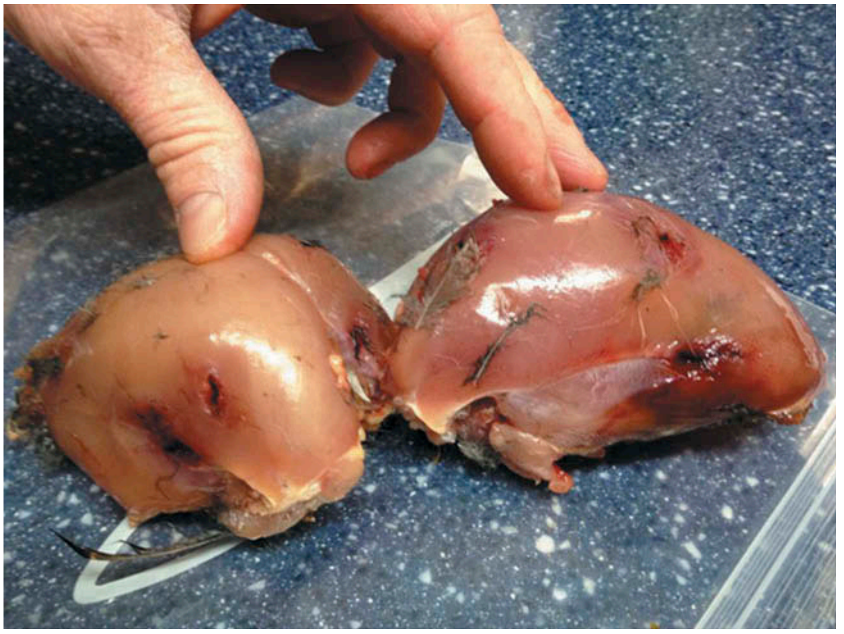

Figure 1. Impacted grouse sample.

Figure 2. Non-impacted grouse sample.

grouse with both sides impacted or not-impacted, the samples were analyzed as one. As a result, seven impacted and nine non-impacted breast meat samples were analyzed by the lab. Prior to analysis, the lab removed all visible lead shot and/or fragments, if impacted, to simulate how the grouse meat would be consumed. Each sample was homogenized to allow for total metals analysis.

A quality assurance/quality control (QA/QC) target of 10% of the total number of tissue samples to be submitted as duplicate samples was set for the program. Therefore, at least one duplicate sample for each tissue type was submitted as a blind duplicate for laboratory analysis. The QA/QC target of 10% was met, as three duplicates were submitted for 16 samples, equaling 19%.

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Additionally, the Maxxam Quality Control Reports were reviewed to ensure that the lab-generated QA/QC results were within their data quality objectives and met high standards of quality. In addition to the duplicate analyses, the lab completed their own QA/QC using spiked samples, internal duplicates and recovery tests of certified reference materials with all the results showing acceptable levels.

2.2. Consumption rates

Grouse are routinely consumed as a subsistence traditional food by First Nations. In order to calculate potential exposures to lead from the ingestion of grouse meat, it is necessary to determine the rates of consumption. The consumption estimates used in this human health risk assessment (HHRA) were obtained from the First Nations Food, Nutrition and Environment Study (FNFNES) (Chan et al., 2016) (Table 1). The FNFNES sought to gather information on the diets of First Nations peoples living on-reserve in Alberta (Chan et al., 2016). Food consumption patterns were obtained by 24-hour food recall surveys and a food frequency questionnaire between September and December 2013. More than 600 First Nations members from ten communities participated in the province-wide study. As part of the study, "consumer-only" consumption rates for average and heavy consumers (95th percentile) of grouse meat were determined for adult (≥19 years) First Nations living in Alberta. By using "consumer only" consumption rates, which exclude individuals reporting no consumption, potential exposures and the corresponding health risks to First Nations members who consume the most grouse muscle are unlikely to be underestimated.

Unfortunately, Chan et al. (2016) only provides grouse consumption rates for adult First Nations members and not for earlier life stages (infants and young children) who are especially susceptible to the intellectual and behavioural developmental effects of lead exposure.

2.3. Exposure assessment

The exposure assessment is aimed at estimating the level of exposure to lead that might be received by adult First Nations members through the consumption of impacted and non-impacted grouse meat. Consideration was also given to the amount of exposure typically received through the diet to arrive at estimates of total dietary exposures. The rate of exposure is expressed as the amount of lead taken in per unit body weight per unit time (*e.g.*, mg chemical per kg body weight per day or mg/kg bw/day). Daily intakes were calculated for the average and heavy consumer in the form of estimated daily intakes (EDIs) that are protective of long-term or chronic exposure (*i.e.*, repeated exposure over the course of several weeks, months or longer).

The magnitude of lead exposure depends mainly on the lead content of the grouse tissue and on the consumption rate and body weight of the consumer.

This assessment considered an adult consumer (≥ 20 years) with a body weight of 70.7 kg as recommended by Health Canada (2012a). Statistical analysis of the lead concentration data was completed to generate the 95th percent upper confidence limit (95UCLM), a representative lead concentration that reflects a reasonable maximum long-term exposure. The primary purpose of this statistical analysis was to determine representative exposure point concentrations (EPCs) for

Table 1. Consumer-only consumption rates for grouse muscle from the FNFNES results for Alberta

Consumer Type	Consumption Rate[a] (g/day)
Average consumer	5.7
Heavy consumer (95th percentile)	31.8

Note: [a] Values were obtained from Chan et al. (2016) and represent "consumer-only" consumption rates for all First Nations in Alberta.

estimating potential risks associated with exposure to lead from the consumption of grouse. The EPC is an estimate of a reasonable upper limit value of the mean chemical concentration in the medium, determined for each exposure unit (United States Environmental Protection Agency [US EPA], 2013). The use of the 95UCLM lead concentration as the EPC, in combination with the 95th percentile grouse muscle consumption rate, provides a potential estimate of exposure that would be considered a “reasonable worst-case” scenario. The EPC term used herein is an upper bound limit on expected concentrations of lead in grouse.

Exposure estimation was facilitated through the use of a consumption risk assessment equation. The equation incorporates techniques and procedures developed by various regulatory agencies (*e.g.*, US EPA, Canadian Council of Ministers of the Environment [CCME] and Health Canada) and published by academic and scientific literature sources to predict or calculate exposure.

The chronic EDI for lead through the consumption of grouse was calculated for the adult, as follows:

$$EDI_{Grouse} = \frac{C_{Grouse} \times IR_{Grouse}}{BW}$$

Where:

EDI_{Grouse} = Estimated daily intake of lead from grouse consumption (mg/kg bw/day)

C_{Grouse} = Concentration of lead in grouse muscle (mg/kg ww)

IR_{Grouse} = Ingestion (consumption) rate of grouse muscle (kg/day)

BW = Body weight (kg)

Cumulative dietary exposures were estimated by summing the $\mathrm{EDI}_{\mathrm{Grouse}}$ with the average dietary intake of the general adult Canadian population (0.00012 mg/kg bw/day; Health Canada, 2011). The average dietary intake of lead by Canadians decreased rapidly between 1981 and 2000 due to the discontinued use of lead solder in food cans in Canada in the 1980s and imported products in the 1990s, but has remained stable at approximately 0.0001 mg/kg bw/day in Canadian adults since 2007 (Government of Canada, 2016a, 2016b). Because the primary contributors to the dietary intake of lead by the Canadian general population are beverages (such as beer, wine, coffee, tea and soft drinks), cereal-based foods and vegetables, it was assumed as part of the current assessment that any exposure to lead through grouse meat consumption ($\mathrm{EDI}_{\mathrm{Grouse}}$) would occur over and above the “background” dietary intake of 0.00012 mg/kg bw/day for lead.

The cumulative dietary exposures were calculated for the average and heavy consumers, as follows:

$$EDI_{Total} = EDI_{Grouse} + EDI_{Background}$$

Where:

EDI_{Total} = Estimated daily intake of lead from diet (mg/kg bw/day)

EDI_{Grouse} = Estimated daily intake of lead from grouse consumption (mg/kg bw/day)

$EDI_{Background}$ = Estimated daily intake of lead from “background” dietary intake (mg/kg bw/day)

2.4. Toxicity assessment

The toxicity assessment is concerned with identifying the level of chronic exposure at which adverse health effects would not be expected to occur in adults. These levels are commonly referred to as exposure limits. Exposure limits are routinely adopted from regulatory agencies and leading scientific authorities in Canada and elsewhere. However, Health Canada, along with several other agencies (Advisory Committee for Childhood Lead Poisoning Prevention [ACCLPP], 2012; JECFA, 2011; US EPA, 2004), no longer supports the premise that lead is a threshold toxicant. Consequently, Health Canada and the US EPA have retracted their oral exposure limits for lead. In light of the lack of a regulatory-derived oral exposure limit, an alternative exposure limit was sought to assess the potential health risks from lead due to dietary exposure.

In 2011, the World Health Organization's Joint Expert Committee for Food Additives (JECFA 2011) published a comprehensive analysis of the health effects associated with exposure to lead. For adults, the Committee concluded that exposure to 0.0012 mg/kg bw/day was associated with a population level increase in systolic blood pressure of 1 mmHg and the risk to health at this exposure level was deemed by the Committee to be "negligible" (JECFA, 2011). On this basis, Wilson and Richardson (2013) proposed a toxicological reference value (TRV) for lead of 0.0013 mg/kg bw/day that is associated with 1 mmHg increase in systolic blood pressure in adults. This TRV also is considered protective of a 1 IQ point decrement in the developing fetus of women who are pregnant and women of childbearing age.

2.5. In the current assessment, the potential risks posed to adults from lead exposures associated with the consumption of lead-impacted grouse were calculated using the TRV proposed by Wilson and Richardson (2013). risk characterization

In the risk characterization, the potential health risks that could be presented to the First Nations members are quantified by comparing the exposure estimate (EDI_{Total}) determined as part of the exposure assessment to the corresponding exposure limit for adults (0.0013 mg/kg bw/day) identified as part of the toxicity assessment. The risk estimates are expressed as a hazard quotient (HQ). The HQ values are calculated, as follows:

$$HQ = \frac{EDI}{TRV}$$

Where:

EDI = Estimated daily intake (mg/kg bw/day)

TRV = Toxicological reference value (0.0013 mg/kg bw/day)

As only the oral exposure pathway was considered in the assessment, an HQ of 0.2 was used as a benchmark to assess the risks associated with exposure to lead through the ingestion pathway. An HQ of 0.2 assumes an exposure of 20% of the allowable level to come from the diet and 80% to come from other sources (air, water, soil and consumer products) (Health Canada, 2010). HQ values were calculated for impacted and non-impacted grouse samples.

3. Results

3.1. Sample collection and laboratory analysis

Results of the analyses of lead concentrations in grouse muscle were divided into impacted and non-impacted. Table 2 presents the results for the seven impacted and nine non-impacted samples, along with a comparison to lead concentrations measured in grouse in the FNFNES (Chan et al., 2016). Lead concentrations in the grouse samples collected for the FNFNES more closely resemble the concentrations found in the impacted grouse samples collected for the

Table 2. Lead concentrations in grouse muscle with and without impacts from ammunition

Grouse Muscle	*Mean (mg/kg ww)*	*Minimum (mg/kg ww)*	*Maximum (mg/kg ww)*	*95UCLM (mg/kg ww)*	*Detection Limit (mg/kg ww)*	*Number Detected*	*% Non-detect*
Impacted	0.968	0.0428	3.59	1.92	0.002	7/7	0%
Non-impacted	0.013	Non-detect (<0.002)	0.0594	0.0399	0.002	8/9	11%
FNFNES (Chan et al., 2016)	0.963	–	8.66	–	0.02	–	0%

Note:— Indicates that the value was not presented.
95UCLM = 95th percent upper confidence limit of the mean.

present study. This finding is not unexpected as the FNFNES acknowledges that the higher concentrations of lead in grouse were likely the result of contamination from lead-based ammunition.

The Student's t-test, assuming unequal variance and a one-tailed distribution at a significance level of 0.05, was used to compare the concentrations of lead in the impacted grouse samples to the concentrations found in the non-impacted grouse samples. The t-test analysis revealed that lead concentrations are significantly greater, at $p < 0.05$, in the impacted vs unimpacted grouse muscle samples.

3.2. Exposure assessment
Results of the exposure assessment are presented in Table 3 for impacted and non-impacted grouse muscle. As shown, lead exposure from the consumption of impacted grouse muscle is estimated to be approximately 48 times greater than from the consumption of non-impacted grouse muscle.

3.3. Risk characterization
For average consumers, a HQ of 0.21 was calculated for the consumption of lead-impacted grouse meat and 0.095 was calculated for non-impacted grouse meat. HQ values of 0.76 and 0.11 were calculated for heavy consumers of impacted and non-impacted grouse meat, respectively (Table 4). The HQ for impacted grouse muscle exceeded the benchmark value of 0.2 for both the average and heavy consumers, indicating that there may be a potential for adverse health effects from exposure to lead. In contrast, it is not anticipated that consumption of the non-impacted grouse meat would result in unacceptable health risks as the HQ is less than 0.2.

4. Discussion
Based on Canada's Food Guide (Health Canada, 2012b) with the adult recommended daily intake of 225 g (*i.e*., three servings of 75 g of traditional meats and wild game per day), adults can ingest 16 servings of impacted grouse muscle per year before exceeding the benchmark HQ of 0.2. This can be approximated as four servings per season for adults. However, if the grouse muscle is not impacted by ammunition, for example, if the ammunition enters the head as opposed to the body of the grouse, then the breast meat will not be affected by the metals found in ammunition and adults may continue to consume non-impacted grouse muscle in amounts that exceed reported consumption rates in the FNFNES.

Table 5 provides the daily benchmark consumption rate and the number of both adult 225 g portions and birds per year as calculated using the measured concentrations in the impacted and non-impacted grouse muscle. As a grouse breast is roughly ¼ to ⅓ of a pound (~ 115–150 g) depending on the size of the bird, each grouse should be considered 1 to 1.5 portions (225–300 g).

Table 3. Predicted lead exposure from consumption of impacted and non-impacted grouse muscle

					EDI (mg/kg bw/day)		
Consumer Type	**Grouse Muscle**	**Lead Concentration[a] (mg/kg)**	**Consumption Rate[b] (kg/day)**	**Body Weight (kg)**	EDI_{Grouse}[c]	$EDI_{Background}$[d]	EDI_{Total}
Average adult	Impacted	1.92	0.0057	70.7	0.00015	0.00012	0.00027
	Non-Impacted	0.04	0.0057	70.7	0.0000032	0.00012	0.00012
Heavy adult (95th percentile)	Impacted	1.92	0.0318	70.7	0.00086	0.00012	0.00098
	Non-Impacted	0.04	0.0318	70.7	0.000018	0.00012	0.00014

Notes:
[a] Calculations are based on the 95UCLM of the lead concentrations measured in impacted and non-impacted grouse muscle.
[b] Consumption rates were adopted from Chan et al. (2016) for average and heavy (95th percentile) of adult First Nations consumers in Alberta.
[c] In accordance with Health Canada (2010) guidance, that lead was assumed to be 100% bioavailable.
[d] Based on the findings of Health Canada (2011) Total Diet Study in Vancouver (September 2007), which represents the most recent, publicly available data on dietary intakes of lead by Canadians.

Table 4. Predicted hazard quotients for the consumption of impacted and non-impacted grouse muscle

Consumer Type	Impacted Grouse Muscle	Non-Impacted Grouse Muscle
Average adult	**0.21**	0.095
Heavy adult (95th percentile consumption rate)	**0.76**	0.11

Note:
Bolded and shaded values indicate an exceedance of the HQ benchmark of 0.2.

Table 5. Benchmark grouse consumption quantities equating to an HQ = 0.2[a], incorporating the contribution of lead from the background diet

Grouse Muscle	*Age Group*	*Benchmark Consumption Rate (g/day)*	*Number of 225 g Portions per Year*	*Number of Birds per Year*
Impacted	Adult	5.2	8	6–8
Non-impacted	Adult	247.5	400	300–400

Note:
[a] Based on measured lead concentrations in grouse muscle.

$$\textit{Benchmark consumption rate} = \frac{\left[(0.2^{*}TRV) - EDI_{Background}\right]^{*}BW}{Concentration_{Grouse}}$$

Where:

$EDI_{Background}$ = Estimated daily intake (0.00012 mg/kg bw/day)

TRV = Toxicological reference value (0.0013 mg/kg bw/day)

BW = Body Weight (70.7 kg)

$Concentration_{Grouse}$ = Lead concentrations in the grouse samples (1.92 mg/kg impacted and 0.04 mg/kg non-impacted)

5. Conclusion

Lead shot was the primary ammunition type used in the hunting and harvesting activities in the collection of animals for the study. Statistically significant differences in lead concentrations were noted between animals impacted by ammunition and those that were not. Lead levels were higher in animals where the bullet impacted the tissues. The findings of this paper suggest that the consumption of meat impacted by lead shot should be limited and the use of non-toxic alternatives, such as steel or copper ammunition, should be considered as substitutes, particularly when non-toxic alternatives have been demonstrated to be as effective as conventional lead ammunition in terms of ballistics and kill effectiveness (Ponder, 2014; Trinogga et al., 2013).

The study reaffirmed the importance of traditional food consumption by First Nations by demonstrating that the lead levels in unimpacted samples were low. The results identify that muscle tissue that is not impacted by lead shot is a good quality alternative to store-bought meats. The study also identified the significant impact that lead shot can have on lead concentrations in the meats, despite any limitations associated with the small sample size, which could present risks to human health when consumed. The study also highlighted the benefits of the substitution of an alternate ammunition type, and the benefits of precise aim through a headshot.

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