

# Scat analysis as a preliminary assessment of moose (*Alces alces andersoni*) calf consumption by bears (*Ursus* spp.) in north-central British Columbia

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## Abstract

*Scat analysis as a preliminary assessment of moose (Alces alces andersoni) calf consumption by bears (Ursus spp.) in north-central British Columbia.* Moose (*Alces alces andersoni*) population numbers have decreased by 50–70% in some parts of northern British Columbia (BC), Canada. Predation of moose calves by bears may be affecting moose populations in this area, but has gone undocumented. A total of 1,381 bear scats were collected during the spring and summer of 2014 and 2015. Hairs extracted from the scats were identified to species through hair scale imprints made in thermoplastic film, with the specific purpose of identifying the frequency of occurrence of moose calf hairs in scats. Only 27 scats (~2%) contained moose calf hair. We discuss possible explanations for our findings.

Key words: *Alces alces andersoni*, Moose neonate, Diet, Feces, Hair analysis, Predation

## Resumen

*Análisis de heces para la evaluación preliminar del consumo de becerros de alce (Alces alces andersoni) por osos (Ursus spp.) en la zona centroseptentrional de la Columbia Británica.* La población de alce (*Alces alces andersoni*) ha disminuido entre el 50% y el 70% en algunos lugares del norte de la Columbia Británica, en Canadá. La depredación de becerros de alce por osos puede estar afectando a la población de alces en esta zona; sin embargo, no se ha documentado. Se recolectaron 1.381 heces de oso durante la primavera y el verano de 2014 y 2015. Con el propósito de determinar la frecuencia de presencia de pelo de becerro de alce en las heces, se identificaron las especies a las que pertenecían los pelos extraídos de las heces a través de las impresiones de las escamas de los mismos en películas termoplásticas. Solo 27 heces (~2%) contenían pelos de becerros de alce. Analizamos las posibles explicaciones de los resultados.

Palabras clave: *Alces alces andersoni*, Neonato de alce, Dieta, Heces, Análisis de pelo, Depredación

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## Introduction

Bears (*Ursus* spp.) prey on ungulates (Singer et al., 1997; De Barba et al., 2014), principally throughout the calving season (Zager and Beecham, 2006; Patterson et al., 2012). Moose (*Alces alces*) calves are an important food source for bears during late May and June (Swenson et al., 2007), and both black bears (*Ursus americanus*) and grizzly (brown) bears (*Ursus arctos*) eat moose calves. Up to 90% of moose calf mortality by bears occurs before mid–July (Ballard et al., 1981) after which moose calf mortality by bears may decline as a result of increased mobility (Zager and Beecham, 2006) and decreased vulnerability of moose calves (Boertje et al. 1988), or shifts in bear diet to other food sources (Zager and Beecham, 2006).

Adult grizzly bears account for a wide range of reported moose calf mortalities: 39% in Alberta (Hauge and Keith 1981); 58% in the Yukon Territory (Larsen et al., 1989); and 39% to 79% in Alaska (Ballard et al., 1981; Boertje et al., 1987, 1988). Black bears are known to be responsible for a similar range of moose calf mortalities: 45% in eastern interior Alaska (Bertram and Vivion, 2002); and 60–70% in south–western interior Alaska (Garneau et al., 2007). Some authors, however, suggest that bear predation on moose neonates in some parts of Alaska is insignificant: 11% (LeResche, 1968), trace (Hatler, 1972).

Black bears can have a significant impact on moose calf mortality when bear numbers are  $> 0.2/\text{km}^2$  (Ballard, 1992). Furthermore, bear predation can influence the survival and recruitment of calves where moose population numbers are in decline relative to predator abundance (Boertje et al., 1988; Ballard, 1992; Gasaway et al., 1992). The effects of bear predation on moose calves can be exacerbated where moose numbers are relatively low ( $0\text{--}0.65/\text{km}^2$ ) and where wolves are present (Messier, 1994; Crête and Courtois, 1997).

It has been hypothesized that moose population declines in British Columbia (BC hereafter) may be due to a change in moose habitat due to a recent epidemic of mountain pine beetle (*Dendroctonus ponderosae* Hopkins, 1902) and subsequent salvage logging (Kuzyk, 2016). This salvage logging has led to dramatic increases in road densities and associated access for both hunters and predators which may have also contributed to the decline (Gorley, 2016). The role of predation in the declines of moose, however, has also been the topic of much conjecture. Most recently, a survival analysis from the interior of British Columbia reported high adult cow moose survival and suggested that current population declines may be more related to calf mortality and inferred that calves are likely being targeted and killed by bears (Mumma and Gillingham, 2019).

The extent to which bears consume moose or other prey has been studied using a variety of techniques, including observational studies (Landers et al., 1979; Hamer and Herrero, 1987; MacHutchon and Wellwood, 2003), analysis of data from neck–mounted cameras (Brockman et al., 2017), isotope analysis (Costello et al., 2016), fatty acid signatures

(Thiemann, 2008), feeding/kill site investigations (Franzmann et al., 1980; Ballard et al., 1981; Hamer and Herrero, 1987; MacHutchon and Wellwood, 2003), analysis of stomach (Landers et al., 1979) and intestinal contents (Wilton et al., 1984), and analysis of scat contents (Landers et al., 1979; Hamer and Herrero, 1987; Mattson et al., 1991; Hewitt and Robbins, 1996; MacHutchon and Wellwood, 2003; Munro et al., 2006). Since bears are known to consume the entire carcass of a moose calf before leaving the kill site (Boertje et al., 1988), we assumed that evidence of calf consumption from both predation and scavenging would be revealed through the identification of hairs found in scats as described in studies of wolf and bear predation on moose calves in Ontario (Voigt et al., 1976; Popp et al., 2018) and polar bear predation on marine mammals in Norway (Iverson et al., 2013).

We conjectured that rates of bear predation on moose calves in north–central BC would be similar to those reported in the bordering jurisdictions of Alaska, the Yukon Territory, and Alberta. We predicted that an analysis of bear scat contents collected during (May–June) and after (July) calving would indicate whether or not bears were preying on moose calves, reveal the frequency of occurrence of moose calves in scats, and help elucidate how bears might be impacting calf recruitment.

## Material and methods

### Study area

Our study area is on the interior plateau of BC between the Rocky and Coastal Mountains. The study area is located within the sub–boreal ecotype (Eastman, 1983) where decades of forest harvesting have caused extensive modifications to the landscape (Kuzyk, 2016). The forests contain stands of all ages, from recently logged clear cuts to maturing plantations and uncut forests. The uncut forests are dominated by coniferous forests of hybrid white spruce (*Picea engelmannii* x *Picea glauca*) and subalpine fir (*Abies lasiocarpa*). Secondary successional sites are pioneered by lodgepole pine (*Pinus contorta* var. *latifolia*) and trembling aspen (*Populus tremuloides*) (Meidinger and Pojar, 1991).

The area has a humid continental climate which is generally wet and cool, with precipitation evenly distributed throughout the year. Mean daily average temperatures are  $4.3^\circ\text{C}$  and range from a mean daily average of  $-7.9^\circ\text{C}$  in January, to a mean daily average of  $15.8^\circ\text{C}$  in July. Mean annual precipitation is 595 mm, with 205 cm of it falling as snow (Government of Canada, 2016).

Reported bear densities near our study area were between  $0.10\text{--}0.27/\text{km}^2$  for black bears and  $0.012\text{--}0.049/\text{km}^2$  for grizzlies (Mowat et al., 2002) prior to this study and appear to have remained relatively stable to the present (District Contact, Ministry of Forests, Lands and Natural Resource Operations and Rural Development MFLNRORD, unpublished data).

Wolf densities in our study area are 10–44/1000 km<sup>2</sup> (British Columbia MFLNRORD, 2014). Moose populations in north–central British Columbia (BC) around Prince George (PG) have declined from a density of 1.3 moose/km<sup>2</sup> during the late 1990s (Heard et al., 1999) and early 2000s (Walker et al., 2006) to 0.45 moose/km<sup>2</sup> in 2017 (Klaczek et al., 2017).

Other large carnivores inhabiting our study area include wolves (*Canis lupus*), and cougars (*Puma concolor*) (Kuzyk et al., 2018). In addition to moose, large ungulates in the area include mule deer (*Odocoileus hemionus*), white-tailed deer (*Odocoileus virginianus*), elk (*Cervus canadensis*), and caribou (*Rangifer tarandus*) (Kuzyk et al., 2018).

#### Field collections

Bear scats were collected opportunistically along roads and trails in 2014 (16 May–27 October) and 2015 (12 May–30 July). We collected bear scat samples in the later summer and fall of 2014 because we wanted to know if bears were eating older calves. We did not collect scats in August, September or October of 2015 because samples collected during this period in 2014 contained no hairs from moose calves, which was consistent with the literature. Many of the roads and trails from which we collected were sampled in both years. In May and June of 2015, we added collections from areas where collared cow moose were calving in the John Prince Research Forest (JPRF). There, we collected 58 scats with an aim towards comparing differences in the frequency of occurrence of calf hairs in scats located inside of known calving areas (a biased sample) to the rest of the study area.

Samples were collected and stored in Ziploc® freezer bags in the field. We collected what we considered to be fresh, recently deposited scats, but also collected some slightly older looking (e.g., covered in dust, dried out) samples. Our samples likely contained scats of both black and grizzly bears, but we did not attempt to distinguish between the two. A geo-reference and date of collection were recorded on each sample bag. All samples were stored in a freezer (–20°C) until analysis.

#### Scat analysis

In the laboratory, scats were thawed, homogenized by hand mixing, and the piles divided into two equal portions. One portion was inspected for the presence of remains from moose calves, while the other portion was refrozen for use as reference material. The scat portions examined for calf remains were autoclaved for 60' at 121°C (Schwab et al., 2011). The autoclaved samples were then washed over a 1mm sieve screen for 10" to 15" until the rinse water ran clear. We tested the sieve screen with known moose calf hairs to ensure hairs were retained by the sieve. Washed scats were then put into paper bags and oven dried (70°C) to a constant weight. Finally, scat contents were disentangled manually and examined for the presence of hair, bones, hooves, and other body parts.

Hairs and body parts were separated from the washed materials and sorted with tweezers. Species identification was difficult from bone fragments and hooves without DNA analyses or reference materials, so we focused our study on species identification using hair impressions as accomplished by others (Perrin, 1980; Cashman et al., 1992; Iversen et al., 2013; Popp et al., 2018). When hairs were present, we extracted all hairs from the scats and placed and stored them in petri dishes for imprinting and analysis.

Our protocol for identifying hair was modified from the methods of Kennedy and Carbyn (1981). Hairs were initially separated into color and size types by visual inspection at 100x magnification with a compound microscope. We then made imprints of the cuticular scale patterns of all separate hairs (or one or two from tufts of hair) by placing hairs between two pieces (89 mm x 139 mm) of thermal laminating plastic (Swingline® GBC®, Lincolnshire, Illinois), clamping them between two microscope slides, and heating them at 120°C in a drying oven (Fisher Scientific Model V602G, Dubuque Iowa) for 160". The same technique was used to make cuticular scale cast reference standards for hairs that we extracted from several dozen mammal study skins (including adult moose) previously collected in north–central BC and housed in a reference collection at the University of Northern BC. In addition, impressions were made of hairs from a calf moose collected in Jasper National Park, Alberta (The University of BC, Beaty Biodiversity Museum Catalogue # M000922 Collector: Ian McTaggart Cowan, 1944–MAY–27). All hair scale impressions were then examined under a compound microscope at 400x. Hairs were identified to species by comparing the impressions observed in thermoplastic film with known standards (Williamson, 1951). Adult and calf (neonate to three months old) moose hairs were distinguished using hair size, color, and cuticular patterns.

#### Statistical analysis

We applied statistical comparisons only to those samples (n = 1,319) collected in the May through July period that was consistent between the two years of collections. The  $\chi^2$ -test (Gould and Gould, 2002) was used to compare the proportions of scats with and without hair from moose calves collected in 2014 and 2015. The 2014 and 2015 records were combined and the  $\chi^2$ -test was used to compare the proportions of scats containing hairs from moose calves between the months of May, June, and July. For each of these three months, we reported the proportion of scats that contained hairs from moose calves. Dates of sample collections were recorded to day of the year where January 1 = day 1 and December 31 = day 365. The two-sample Wilcoxon rank-sum (Mann–Whitney) test was used to determine whether there was a difference between 2014 and 2015 in the days of the year when scats containing hairs from moose calves were collected. Significance of these statistical tests was assessed at  $\alpha = 0.05$  using STATA 12 (StataCorp, College Station, TX).

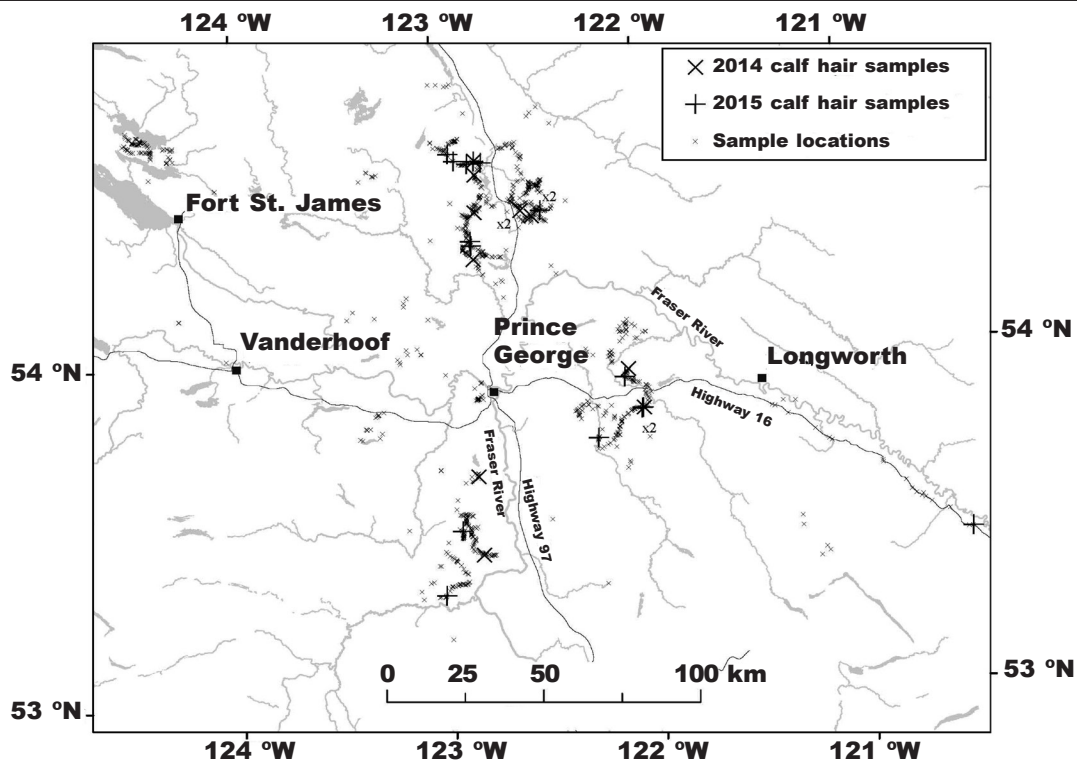


Fig. 1. Map of north-central British Columbia showing the locations of bear scats collected during May to October of 2014 and May to July of 2015: x, scats without hairs from moose calves; X, scats containing hairs from moose calves ( $n = 27$ ) collected in 2014 ( $n = 11$ ); +, scats containing hairs from moose calves collected in 2015 ( $n = 16$ ). ("x2" indicates symbols representing two nearby scats).

Fig. 1. Mapa de la zona centroseptentrional de la Columbia Británica en el que se muestran las localizaciones de las heces de osos recolectadas entre mayo y octubre de 2014 y entre mayo y julio de 2015: x, heces sin pelos de becerros de alce; X, heces con pelos de becerros de alce ( $n = 27$ ) recolectadas en 2014 ( $n = 11$ ); + heces con pelos de becerros de alce recolectadas en 2015 ( $n = 16$ ). ("x2" indica la presencia de dos heces cercanas).

Spatial relationships between the scats containing hairs from moose calves were described using the 'Generate Near Table' tool in ArcGIS (Version 10.4.1, ESRI 2016, Redlands, California) to calculate the distance between each point and its nearest neighbor. We described geographic clustering (grouping) of scats containing calf hairs using a circular buffer with a 6-km radius (to mimic 116 km<sup>2</sup> home range; Young and Ruff, 1982).

## Results

In addition to plant matter, 213 of our 1,319 scat samples contained hairs from various species of mammals, including bears, squirrels, hares, muskrat, various rodents, and ungulates (e.g., deer, elk, and moose; Reichert and Rea, unpublished data). Twenty-seven of the scats (2.05%) collected in the May through July periods of 2014 and 2015 contained hair from moose calves. The frequency of occurrence of moose calf

hairs within bear scats increased from May to July of each year (fig. 1). Two scats collected on June 3, 2015 contained hairs from adult moose (0.15%). In 2014, 11 of the 510 scats (2.16%) collected from May to July contained hair from moose calves, while in 2015, 16 of the 809 scats (1.98%) collected in the same months contained hair(s) from moose calves. There were no significant differences ( $\chi^2 = 0.0500$ ,  $df = 1$ ,  $P = 0.823$ ) in the frequency of occurrence of scats with and without hairs from moose calves collected between May (peak calving May 24, D. Aitken, unpublished data) through July 2014 and 2015.

The proportion of scats containing moose calf hairs was significantly different ( $\chi^2 = 7.1387$ ,  $df = 2$ ,  $P = 0.028$ ) between the months of May, June, and July (fig. 2). The greatest proportion of scats with hairs from moose calves were collected in July (3.2%) with fewer in June (2.3%) and May (0.3%). None of the 62 scats collected in the August to October 2014 period contained hairs from moose. Additionally, none of the 58 bear scat samples collected in June of

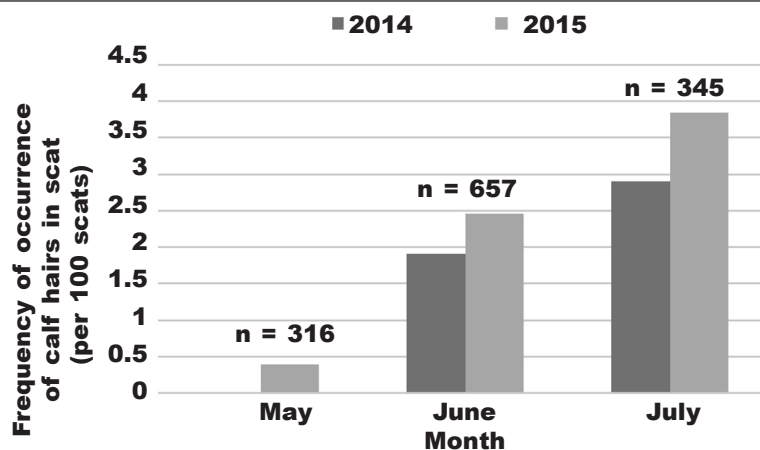


Fig. 2. Frequency of occurrence of scats containing moose calf hairs (out of every 100 scats collected) from May through July 2014 and 2015.

*Fig. 2. Frecuencia de heces con pelos de becerro de alce (por cada 100 heces recolectadas) entre mayo y julio de 2014 y 2015.*

2015 from the six calving grounds in the John Prince Research Forest contained calf hairs.

Calf hairs were observed in bear scats collected as early as 28 May (day 148) and as late as 30 July (day 211). There were no significant differences ( $z = 1.262$ ,  $P = 0.2071$ ) in the May, June, and July dates of collection of scats with hairs from moose calves between 2014 ( $n = 11$ ) and 2015 ( $n = 16$ ). Median date of collections of bear scats containing calf hairs for the two years was June 24 (day 175).

Several of the scats with calf hair were geographically clustered (fig. 3). Five of these clusters were located approximately 90 km north of Prince George, while another two clusters were located approximately 50 km east of Prince George. Seven of the 27 6-km diameter buffers we placed around scats with hairs contained a single scat with calf hair. Eleven of the 27 buffers did not overlap each other (fig. 3). Six locations on the map to the north and east of Prince George (includes overlapping buffers) contained more than 1 scat with calf hair ( $n = 1$ –5 scats) within a 6-km radius area (fig. 3).

## Discussion

Our examination of bear scats from north–central BC showed that bears consumed moose calves in both years of study. The frequency of occurrence of bear scats containing calf hair that we observed (~2%) was similar to that reported in Algonquin Park where most moose calf mortalities were attributable to black bears (Patterson et al., 2012) and where 1.7% of bear digestive contents examined in spring and summer contained moose calf hairs (Wilton et al., 1984). This is lower than what was reported in Alaska by Chatain (1950) where 5.7% of scats contained moose

calf hair, some of which LeResche (1968) speculated may have been from scavenging. Although some of the moose calves consumed by bears in our study may have been scavenged (possibly from previous bear kills; Boertje et al., 1988), both Franzmann et al. (1980) and Boertje et al. (1988) suggest that bears primarily kill, rather than scavenge calves.

Ballard et al. (1981) reported 90% of calf mortality due to bears occurred before 19 July. Furthermore, Larsen et al. (1989), and Boertje et al. (1988) reported that predation by bears on moose calves was focused between May and late July/early August, after which predation rates declined due to the decreased availability and increased mobility of calves or alternate food sources becoming more abundant and available to bears (Adams et al., 1995; Boertje et al., 1988; Zager and Beecham, 2006).

Unlike LeResche (1968) who reported bear predation occurrence to be highest in May and June with decreases in July, we found increasing evidence of calf hair in scats from May (during first estrous calving) to July. We do not know the exact dates that our bear scats were collected. We do not know, however, exactly when each scat was deposited by bears and, therefore, cannot be certain of the exact date of calf consumption. Since we drove and collected scats on some roads every two weeks, we feel confident that most scats collected in our study would have been less than two weeks old.

Backdating all scats that we collected containing calf hair by one to two weeks, better aligns our findings with expected predation events by bears that have been reported to eat calves of various ages also born in May and June in other jurisdictions (Ballard et al., 1981; Boertje et al., 1988; Swenson et al., 2007). This was true of both years, since we found no statistically significant difference between the dates on which scats with calf hairs were collected.

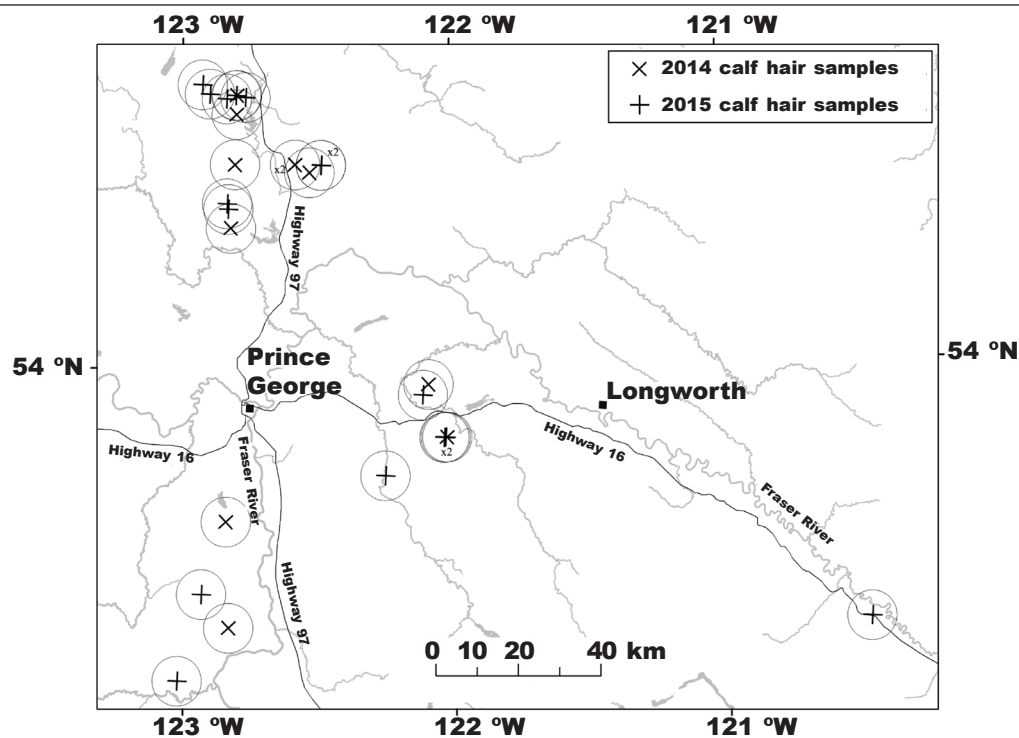


Fig. 3. Map of locations of bear scats containing moose calf hairs collected during the springs and summers of 2014 and 2015 in north-central British Columbia. Each scat location is buffered with a 6 km radius buffer that was used to estimate bear home range size (see Material and methods) and show overlap of possible home ranges relative to moose calf predation events. (x2 indicates symbols representing two nearby scats).

*Fig. 3. Mapa de las localizaciones de heces de osos con pelos de becerro de alce recolectadas durante la primavera y el verano de 2014 y de 2015 en la zona centroseptentrional de la Columbia Británica. Cada localización está rodeada por un radio de 6 km que se utilizó para estimar el tamaño del territorio del oso (véase el apartado "Material and methods") y mostrar posibles superposiciones de territorios relacionadas con episodios de depredación de becerros de alce. ("x2" indica la presencia de dos heces cercanas).*

Some bears specialize on killing calves (Boertje et al., 1988), with some taking up to one calf daily (French and French, 1990). We, therefore, examined scat locations for possible clusters of scats containing calf hairs. Because bears defecate up to eleven times per day (Roth, 1980), clustering could be indicative of a single bear eating one calf but leaving behind several separate scats with remains of a single calf. Our nearest neighbor analysis suggested that about one quarter of the scats that had moose calf hairs were geographically clustered to the north and east of Prince George. Three quarters of the 6-km home range buffers we placed around the scats with calf hairs included more than one (and up to 5) scat with hair, suggesting that individual bears could theoretically be responsible for multiple predation events on calves. The exact number of bears consuming calves could possibly be determined through DNA analysis of intestinal mucosa extracted from the surface of scats at the time of collection (Lonsinger et al., 2015), but was not an explicit objective of our study and was not within the budget constraints of the project.

None of the 58 scats collected in our six calving grounds to the northwest of Prince George were found to contain calf hairs. Even with this form of biased sampling, where we expected calves would more likely be eaten by bears, we observed lower than expected frequency of occurrences (0%) compared to the entire study area. This could have, however, been affected by the timing of our surveys since our data suggest bears were feeding on calves somewhat later in the season (after cows and calves had left the calving grounds) than anticipated.

We sampled primarily along roads and trails and were not able to document whether bears were eating calves far from roads and trails. Bear scat samples collected in Alberta with the use of scat detection dogs were highly concentrated on industrial-use roads (Wasser et al., 2004), suggesting our collections along roads should be fairly representative of scats (albeit not necessarily prey) from across the landscape. If moose are calving far from roads and trails and bears are also consuming calves far from roads and trails, we may be underestimating predation on calves. We may

also be underestimating calf predation if the reference proportion of the scat we did not analyze, by chance, contained evidence of calf predation not found in the portion we did assess.

Several jurisdictions that are multi-prey and multi-predator systems surrounding our study area have reported significant impacts of bears on moose calves (Alberta: Hauge and Keith, 1981; Yukon Territory: Larsen et al., 1989; Alaska: Bertram and Vivion, 2002). Consequently, we have no reason to believe that these findings do not apply to north-central BC given the relatively high density of bears. Therefore, alternative explanations for our findings of a small number of scats with moose calf hairs may be simply that the ratio of calves to bears is low, that other food types (mostly vegetation) are much more common in spring and summer diets of bears, or that our collection procedures were unable to capture an unevenly distributed prey base.

We determined that moose calves ( $n = 27$ ) appear to comprise a much larger proportion of the spring and summer bear diet than adult moose ( $n = 2$ ). If we scale our findings of 0.15% of bear scats containing adult moose hairs to a recently published mortality study of adult cow-only moose where 6.6% of cows were killed by bears (Mumma and Gillingham 2019), our 2% of scats with calf hairs could suggest bears may be responsible for up to 88% of calf mortalities in north-central BC. This is not unreasonable given the role that predators such as bears can have on moose calves (56–100% of moose calf mortalities; Zager and Beecham, 2006), but is likely an overestimation given bears preferentially prey on adult cow moose that are pregnant or defending calves (seven cows to one bull moose killed by bears; Boertje et al., 1988).

Developing a robust technique to age scats (e.g., travelling roads and trails and cleaning off all scats on a weekly basis) would help to pinpoint calf consumption dates better. Determining the species and individual identity of each bear from each scat and delineating the full range of diet items using genetic techniques for both could allow managers to determine the relative importance of moose calves in the diets of individual bears. However, DNA techniques would not distinguish between calf and adult moose, underscoring the importance of establishing baseline data from the present use of hair analysis. These parameters, combined with accurate estimates of: seasonal defecation rates of bears, moose and bear densities, spring and summer cow:calf ratios, moose to bear (both black and grizzly) ratios, and moose and bear home range sizes and overlap, could all help to establish more precisely the impacts of bears on moose. Finally, determining predation rates of bears on moose calves might help managers determine the overall impact of bears on a declining moose population, allowing them to weigh options about what, if anything, can be done to mitigate that impact.

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