Spring diet of American black bears (Ursus americanus) in a moose (Alces alces) – woodland caribou (Rangifer tarandus caribou) system in northern Ontario, Canada

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Spring diet of American black bears (*Ursus americanus*) in a moose (*Alces alces*) – woodland caribou (*Rangifer tarandus caribou*) system in northern Ontario, Canada

A.A.D. McLaren, S.E. Jamieson, M. Bond, A.R. Rodgers, and B.R. Patterson

Abstract: American black bears (*Ursus americanus* Pallas, 1780) are opportunistic foragers, and across most of their range in North America, their diet is predominantly vegetation with limited consumption of vertebrates and invertebrates. However, they are also predators of ungulates, especially neonates, with regional variation in the amount of predation pressure they exert. We used scat analysis to examine the diet of black bears during the calving season in a moose (*Alces alces* (Linnaeus, 1758)) – woodland caribou (*Rangifer tarandus caribou* (Gmelin, 1788)) system in the Boreal forest of northern Ontario, Canada. Bears consumed herbaceous plants (46.5%), fruits and (or) seeds (20.0%), moose (3.3% adults; 4.3% calves), American beaver (*Castor canadensis* Kuhl, 1820; 8.5%), and insects (mostly ants; 4.2%). Bears had the highest consumption of moose and beaver in early spring, before switching to a more vegetation-dominated diet. We did not detect evidence of caribou consumption. Based on our results, black bear consumption of moose, particularly neonates, may warrant further investigation.

Key words: American black bear, *Ursus americanus*, predation, scavenging, moose, woodland caribou, neonate, calving, ungulate, beaver, berries, vegetation, ants, scat analysis, diet.

Résumé : Les ours noirs d'Amérique (*Ursus americanus* Pallas, 1780) s'alimentent de manière opportuniste, et dans la majeure partie de leur aire de répartition en Amérique du Nord, leur régime alimentaire est principalement constitué de plantes, en plus d'une consommation limitée de vertébrés et d'invertébrés. Ce sont toutefois aussi des prédateurs d'ongulés, de leurs nouveau-nés en particulier, l'ampleur de la pression de prédation qu'ils exercent variant d'une région à l'autre. Nous avons utilisé l'analyse d'excréments pour examiner le régime alimentaire des ours noirs durant la saison de mise bas dans un système à orignaux (*Alces alces* (Linnaeus, 1758)) et caribous des bois (*Rangifer tarandus caribou* (Gmelin, 1788)) dans la forêt boréale du nord de l'Ontario (Canada). Les ours consomment des plantes herbacées (46,5 %), fruits et (ou) graines (20,0 %), orignaux (3,3 % d'adultes; 4,3 % de veaux), castors (*Castor canadensis* Kuhl, 1820; 8,5 %) et insectes (principalement des fourmis; 4,2 %). La consommation d'orignaux et de castors par les ours est la plus importante au début du printemps, avant qu'ils ne passent à une alimentation dans laquelle les plantes sont plus prédominantes. Nous ne relevons aucun signe de consommation de caribous. À la lumière de nos résultats, il serait pertinent d'examiner plus en profondeur la consommation d'orignaux, en particulier les nouveau-nés, par les ours noirs. [Traduit par la Rédaction]

Mots-clés : ours noir d'Amérique, *Ursus americanus*, prédation, détritivorie, orignal, caribou des bois, nouveau-né, mise bas, ongulé, castor, baies, végétation, fourmis, analyse d'excréments, régime alimentaire.

Introduction

Indirect methods of assessing diets of wide-ranging species can offer practical insights into their feeding behaviour and ecology. For terrestrial consumers, scat analysis is a common method used to estimate their diet and impact on prey populations, particularly when there is interest in use of specific prey items (Putman 1984; Klare et al. 2011). American black bears (*Ursus americanus* Pallas, 1780) are generalist omnivores with scat analyses revealing that much of their diet consists of plants, including forbs, graminoids, and fruits, a pattern that is consistent across their range in North America (Schwartz and Franzmann 1991; Boileau et al. 1994; Bull et al. 2001; Benson and Chamberlain 2006; Baldwin and Bender 2009; Greenleaf et al. 2009; Popp et al. 2018). Given their opportunistic foraging behaviour, the diet of black bears can be variable by season and may also include a variety of animals and insects (Holcroft and Herrero 1991; Noyce et al. 1997; Mosnier et al. 2008). In some areas, a large portion of black bear diet consists of animal matter, particularly ungulates (Jacoby et al. 1999). Because black bears are known scavengers (Raine and Kansas 1990) and may also skin their mammalian prey (Wilton 1983; Wilton et al. 1984; LeCount 1987; Schwartz and Franzmann 1991; Svoboda et al. 2011), insights into black bear diet that rely on indirect methods (e.g., scat analysis) may produce biased results. However, field studies provide corroborating evidence that black bears do predate ungulates (Ballard et al. 1979; Wilton 1983; Austin et al. 1994; Veitch and Krizan 1996; Patterson et al. 2013; Leclerc et al. 2014).

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Indeed, grizzly bears (*Ursus arctos* Linnaeus, 1758) are formidable predators of ungulates, including of adults (Ballard et al. 1981; Ballard 1992; Bertram and Vivion 2002; Gau et al. 2002; Wyman 2002; Brockman et al. 2017), but documented predation of adult ungulates by the smaller bodied black bear appears to be rare (Barmore and Stradley 1971; Austin et al. 1994; Svoboda et al. 2011), and potentially even fatal to the attacker (Obbard et al. 2000). Conversely, neonates are particularly vulnerable to black bear predation due to their limited mobility following birth (Franzmann et al. 1980; Crête and Desrosiers 1995; Linnell et al. 1995; Barber-Meyer et al. 2008; Carstensen et al. 2009; Mahoney et al. 2016; Severud et al. 2019). Previous studies have shown neonate predation by black bears on several ungulate species including mule deer (*Odocoileus hemionus* (Rafinesque, 1817)) (Bull et al. 2001), white-tailed deer (*Odocoileus virginianus* (Zimmermann, 1780)) (Mathews and Porter 1988; Kunkel and Mech 1994; Carstensen et al. 2009), elk (*Cervus canadensis* (Erxleben, 1777)) (Barber-Meyer et al. 2008; Murrow et al. 2009), moose (*Alces alces* (Linnaeus, 1758)) (Schwartz and Franzmann 1991; Patterson et al. 2013; Severud et al. 2015), and woodland caribou (*Rangifer tarandus caribou* (Gmelin, 1788)) (Crête and Desrosiers 1995; Pinard et al. 2012; Mahoney et al. 2016). In some areas, predation by bears on juvenile ungulates is considered opportunistic, occurring mainly during incidental encounters with vulnerable neonates (Kunkel and Mech 1994; Bastille-Rousseau et al. 2011), but in other areas, bears may focus on ungulate prey and predation is a significant source of juvenile mortality (Franzmann et al. 1980; Bertram and Vivion 2002; Carstensen et al. 2009; Pinard et al. 2012; Mahoney et al. 2016), which can be particularly true when densities of black bears are high (Zager and Beecham 2006). For example, Carstensen et al. (2009) found that in north-central Minnesota, USA, black bears were the most abundant predator in the area and were responsible for 45% of white-tailed deer fawn mortalities, a similar pattern to that found for black bear predation on moose calves in eastern Alaska, USA (Bertram and Vivion 2002) and caribou calves in Newfoundland, Canada (Mahoney et al. 2016). Overall, evidence suggests that black bears are opportunistic predators with regional variation in predation on adult ungulates and their neonates (Zager and Beecham 2006).

Black bears are known to consume and prey on ungulates in the central Great Lakes – St. Lawrence region of Ontario, Canada, based on diet studies (Wilton et al. 1984; Popp et al. 2018) and intensive field research (Patterson et al. 2013). However, there is limited information about bear predation on ungulates in the Boreal forest (see Austin et al. 1994; Obbard et al. 2000), and spatial and temporal variation in phenology and abundance of food may preclude extrapolation from other areas (Romain et al. 2013). Although research in the Boreal forest of Ontario has shown grey wolf (*Canis lupus* Linnaeus, 1758) predation on ungulates is common, particularly on moose (Moffatt 2012; Vander Vennen et al. 2016; Found et al. 2017), knowledge of the prevalence of ungulates in the diet of black bears remains elusive. This is especially important given that the Boreal forest in Ontario overlaps with the range of woodland caribou, a species at risk in Canada (COSEWIC 2002; COSSARO 2007). Given the uncertainty and ongoing concern regarding predation by bears, especially on calves, our objective was to examine the diversity and proportion of food items consumed by bears in a region of Ontario where both moose and caribou are present. Specifically, we wished to examine the proportion of adult and neonate ungulates in the spring diet of black bears, a period of relatively high use of ungulates by black bears elsewhere (Wilton et al. 1984; Bull et al. 2001; Benson and Chamberlain 2006). Because of the generally low prevalence of ungulates in the diet of black bears across their range in North America, we expected moose and caribou to make up a low proportion of the diet of bears in northern Ontario.

Materials and methods

Study area

We conducted our study in the Ogoki-Nakina forest of the Boreal Shield ecozone in northern Ontario (centroid: 87.7°W, 50.5°N; Fig. 1). The study area was dominated by black spruce (*Picea mariana* (Mill.) Britton, Sterns & Poggenb.), jack pine (*Pinus banksiana* Lamb.), white spruce (*Picea glauca* (Moench) Voss), balsam fir (*Abies balsamea* (L.) Mill.), white birch (*Betula papyrifera* Marshall), and trembling aspen (*Populus tremuloides* Michx.), as well as tamarack (*Larix laricina* (Du Roi) K. Koch) and white cedar (*Thuja occidentalis* L.) (Crins et al. 2009). Human disturbance in the area was high, with 41 km of roads per 100 km^2 and 28% of the area was commercially harvested for timber (Thompson et al. 2015). The area consisted of a mixed predator–prey system with moderate densities of wolves (0.67/100 km^2), black bears (12.5/100 km^2), and moose (10.7/100 km^2), and a low density of caribou (minimum 0.45/100 km^2); white-tailed deer were scarce (MNRF 2014).

Sample collection and processing

We collected bear scats opportunistically from roads in the Ogoki-Nakina forest between late May and late June in 2012 ($n = 421$) and 2013 ($n = 218$) during ungulate parturition season; no scats were collected prior to peak calving dates (moose: 13 May (Patterson et al. 2016); caribou: 21 May (Walker et al. 2021)). We recorded the global positioning system (GPS) location and collection date for all scats and stored them at –20 °C in individual plastic bags until analysis. To minimize sampling multiple scats from the same bear (i.e., if foraging in the same location for a period of time), we subsampled scats that were collected on the same day and within 5 m of each other (i.e., within the error associated with the GPS unit) by selecting only the first scat encountered, resulting in 17 scats being eliminated from our analysis.

To process bear scats for identification of food items, we thawed whole scats and then rinsed them individually with water for approximately 5 min through a coarse-grain mesh sieve (1.168 mm; W.S. Tyler Canada Ltd., St. Catharines, Ontario, Canada) to remove large debris and then in a small-grain mesh sieve (0.589 mm; W.S. Tyler Canada Ltd., St. Catharines, Ontario, Canada) to retain small food items (see Baldwin and Bender 2009; Di Domenico et al. 2012).

We squeezed all excess water from the cleaned scats, spread them out to air-dry overnight, after which they were oven-dried at 50 °C for 24–48 h (see Romain et al. 2013). Once dried, we spread the scats onto trays containing 4 × 5 cell grid sheets, allowing thorough hand-sorting of undigested food items and estimation of the proportion of food items per scat based on coverage of each grid cell (one cell = 5%; 2 cm × 2 cm). We classified sorted contents into one of the following categories: grass/herbaceous vegetation (hereafter, herbaceous plants), moss, lichens, fruits and (or) seeds, insects, birds, eggs, mammals, garbage and (or) debris (i.e., indigestible material), or unknown (e.g., highly digested or unrecognizable material). Only mammalian contents of scats were identified to species. When we were unable to macroscopically identify mammalian species, we made hair impression mounts and (or) whole hair mounts and examined the cuticular scale pattern and morphological characteristics of the hairs using a 4×–40× microscope (Zeiss Primo Star, Carl Zeiss Canada Ltd., Toronto, Ontario, Canada). We identified the species with aid of a reference guide (Adorjan and Kolenosky 1969) and (or) compared them with hairs in our reference collection. Ungulate hairs were further classified into adult or calf. When ungulate hairs could not be definitively identified to species by the methods above, we analyzed the hairs molecularly by extracting DNA from 80 to 100 mg of entire hair shafts (or from tissue if attached to hair) using the Qiagen DNeasy tissue kit and eluted

Fig. 1. Ogoki-Nakina forest study area in northern Ontario, Canada, where American black bear (*Ursus americanus*) scats were collected from roads during May and June of 2012 and 2013 for dietary analysis. Figure was created using ArcGIS version 10.3.1 and assembled from the following data shapefiles: MNR Road Segment, Ontario Hydro Network (OHN) 500K Waterbody, Great Lakes, and Canada Boundary. Map data provided by the Ontario Ministry of Natural Resources and Forestry under the Open Government Licence – Ontario (https://www.ontario.ca/page/open-government-licence-ontario).
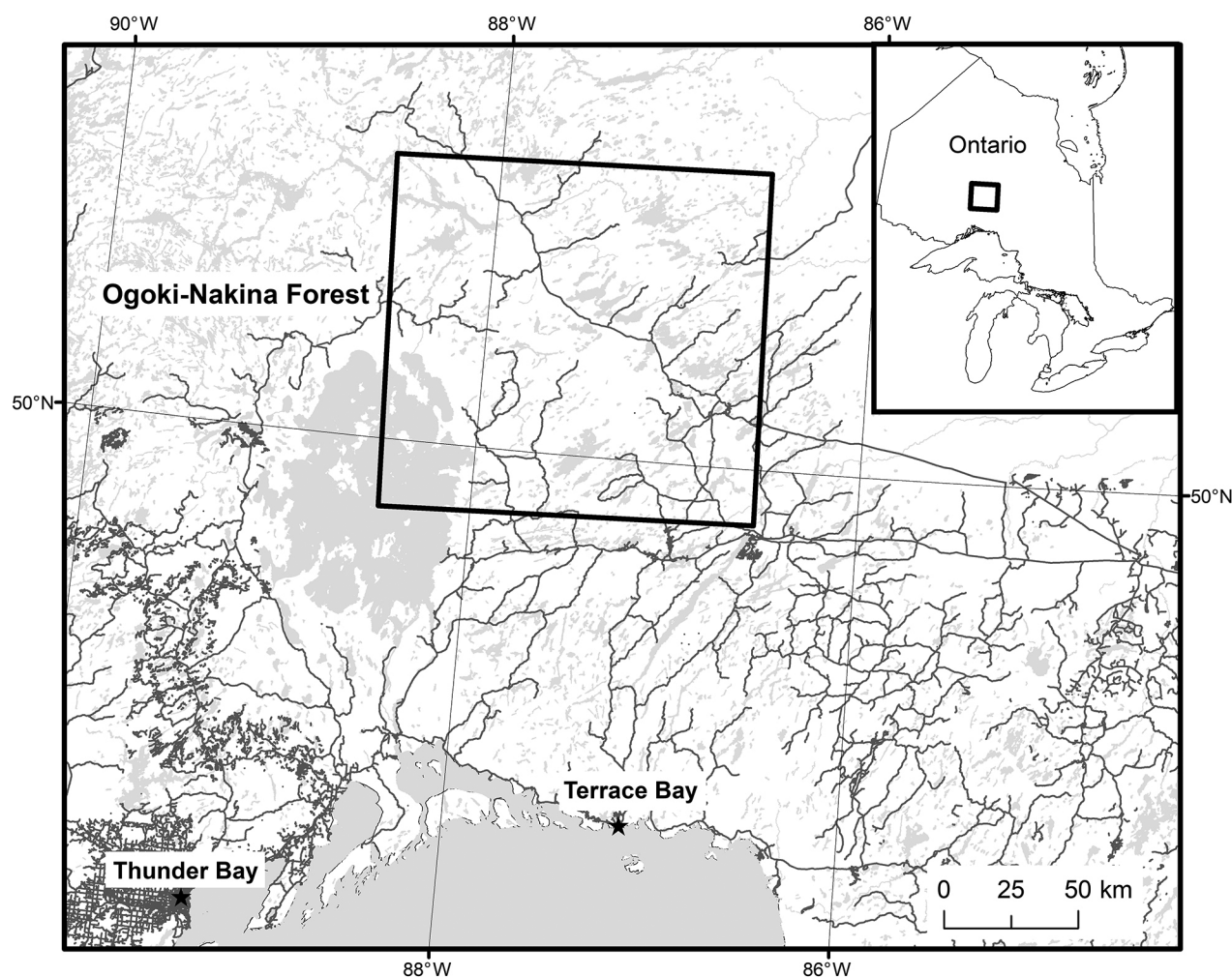
in 100 μL of TE buffer (0.1 mol/L). Eight microlitres of DNA were used to amplify and sequence approximately 400 bp of the mitochondrial cytochrome *b* gene using primers Gludg-L (Palumbi et al. 2002) and CB2-H (Kocher et al. 1989). Trimmed sequences were entered into the BLAST algorithm on GenBank, using default parameters, to determine sequence identity.

Data analysis

We calculated two main statistics to describe black bear diet: percent frequency of occurrence and percent volume. We defined percent frequency of occurrence as the number of scats containing a particular food item divided by the total number of scats analyzed. Percent volume is a more informative statistic because it calculates proportions of individual food items in the scats rather than a simple count of occurrence. However, the proportion of food items in scats can be influenced by differences in digestibility between plant and animal matter (Hatler 1972; Pritchard and Robbins 1990; Hewitt and Robbins 1996). Therefore, we calculated percent volume as the cumulative proportion of each scat containing a particular food item divided by the total number of scats analyzed, and applied correction factors (CF) calculated for captive grizzly bears (Hewitt and Robbins 1996) to account for digestibility differences. There are no CFs

derived specifically for black bears, but because they have similar digestive and metabolic efficiencies as grizzly bears (Pritchard and Robbins 1990), we deemed these CFs as appropriate for our analysis (Klare et al. 2011). Preliminary analysis showed that moss was commonly ingested by bears in our study area, yet a bear-derived CF for moss was not available. Moss has been shown to have a digestibility of one-eighth of grass in other non-ruminants (e.g., lemmings: Batzli and Cole 1979; Rodgers and Lewis 1986). Therefore, we estimated a CF for ingested mosses by dividing the CF for herbaceous material derived from grizzly bears by eight. Similarly, there were no CFs for birds and their eggs available for bears, so we used values derived from another omnivore, raccoons (*Procyon lotor* (Linnaeus, 1758)) (Greenwood 1979). No CFs were available for garbage and debris, so we excluded these items from calculations of percent volume. We also binned scats by week collected and calculated percent volume with correction factors to assess phenology in the diet. All analyses were conducted in R version 3.5.1 (R Core Team 2018).

Results

We identified 17 different categories of dietary items in bear scats (excluding garbage and unknown items; Supplementary

Fig. 2. Percent frequency of occurrence (*a*) and percent volume (*b*) of various dietary items found in American black bear (*Ursus americanus*) scats (*n* = 622) collected opportunistically from roads in northern Ontario, Canada, from late May to late June of 2012 and 2013. Correction factors (CF) were applied to estimates of percent volume to account for variable digestibility of ingested matter.
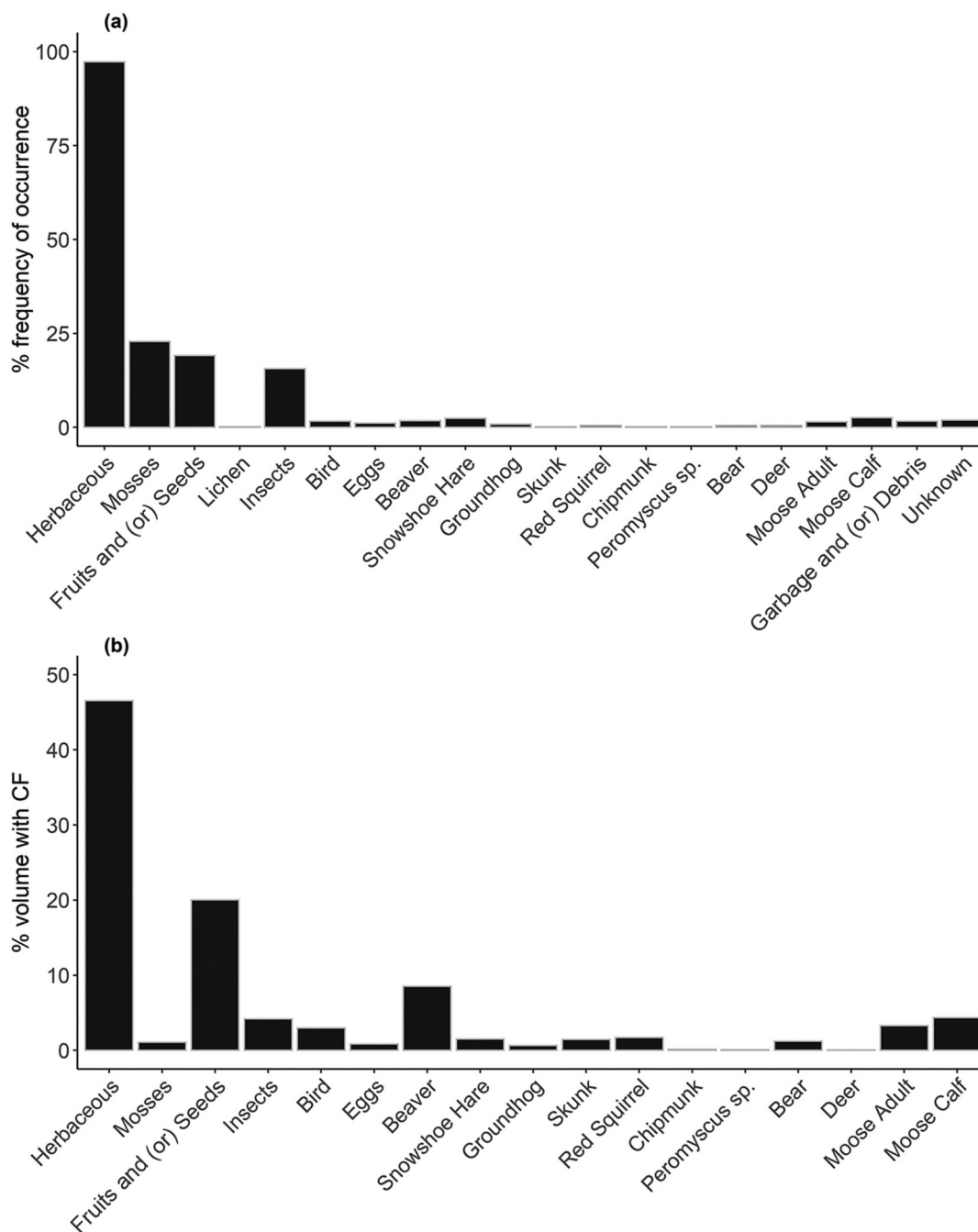

Fig. S1[1]). Of the 622 scats analyzed, 99.4% contained vegetation matter and 27.5% contained animal matter. Only 4 scats (<1% of scats sampled) lacked any vegetation matter and were composed exclusively of mammal remains (American beaver, *Castor canadensis* Kuhl, 1820: *n* = 1; red squirrel, *Tamiasciurus hudsonicus* (Erxleben, 1777): *n* = 1; moose + snowshoe hare (*Lepus americanus* Erxleben, 1777): *n* = 1; striped skunk (*Mephitis mephitis* (Schreber, 1776)) + snowshoe hare: *n* = 1). The most frequently occurring food item in scats was herbaceous plants (97.3%), followed by mosses (22.8%), fruits

and (or) seeds (e.g., cranberry (genus *Vaccinium* L.), wild strawberry (genus *Fragaria* L.); 19.1%), and insects (predominately ants; 15.6%) (Fig. 2*a*). Though we did not seek to identify all species of herbaceous plants found in scats, common horsetail (*Equisetum arvense* L.) was conclusively identified in 30% of scats. All other dietary items occurred in <3.0% of the scats.

Based on volume (Fig. 2*b*), bears consumed mostly herbaceous plants (46.5%), as well as fruits and (or) seeds (20.0%), beaver (8.5%), and insects (4.2%). A total of 25 scats contained remains of

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Fig. 3. Weekly percent volume with correction factors (CF) of various dietary items found in American black bear (*Ursus americanus*) scats collected in northern Ontario, Canada, from late May to late June of 2012 and 2013. Data were pooled by year and binned by week of collection (late May: $n = 19$; June week 1: $n = 171$; June week 2: $n = 201$; June week 3: $n = 228$; June week 4: $n = 3$). Items that made up <5% of the weekly diet by volume were grouped into the Other category.
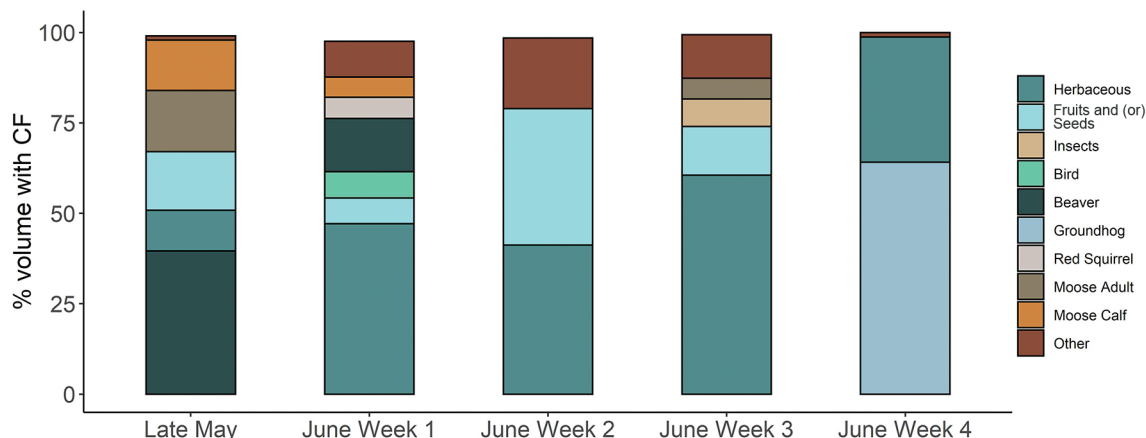
moose, and by volume, 3.3% and 4.3% of moose consumption was adults and calves, respectively. White-tailed deer contributed minimally to the diet (0.04%; $n = 3$ scats) and no caribou were detected in any of the bear scats.

Our sampling was conducted opportunistically rather than uniformly, but given the available temporal distribution, scats collected in late May and the first week of June contained 37.5% moose (18% adults, 19.5% calves) and 54.3% beaver by volume, while scats collected in mid- to late June contained <6% weekly of each beaver and moose (Fig. 3). This was opposite to the presence of vegetation in the diet with scats collected in late May containing 11.2% herbaceous plants by volume and then increasing to >40% weekly in June. Insects also increased in the diet through spring (0.67% in late May to 7.6% in late June). Diet results in the last week of June were biased due to low sample size ($n = 3$) and therefore we deemed them of limited biological inference.

Fifteen scats contained bear hair, with proportions per scat varying from ≤2% ($n = 12$) to >30% ($n = 3$). We presumed the scats containing ≤2% bear hair was the result of grooming, but included the remaining three scats in our analysis because they contained the remains of cubs (hair and claws) and represented evidence of cannibalism among bears in our study area (1.2% of diet by volume).

Discussion

Our results revealed that approximately 70% of the overall spring diet of bears in northern Ontario consisted of herbaceous plants and fruits, while the proportion of ungulates in the diet was <10%, approximately equal to the proportion of beaver in the diet. This is similar to other black bear diet research that has found that vegetation accounted for most of their diet with low occurrence of vertebrates (Maehr and Brady 1984; Schwartz and Franzmann 1991; Boileau et al. 1994; Bull et al. 2001; Benson and Chamberlain 2006; Mosnier et al. 2008; Greenleaf et al. 2009). But using the available temporal distribution of scat samples, our results also showed a relatively large amount of moose and beaver in the diet in early spring, before bears switched to a more vegetation-dominated diet. Spring can be an energetically challenging time for bears, because they emerge from hibernation in poor body condition and food availability can be low (Pelton 2003). Herbaceous plants are protein-rich and can allow bears to gain mass following hibernation (Rode et al. 2001), but animal matter can be an important source of highly digestible protein (Pritchard and Robbins 1990; Boileau et al. 1994; Bull et al. 2001;

Obbard et al. 2010), even if it makes up only a small portion of the overall diet.

Consumption of ungulates

Due to concern of potential bear predation, particularly of calves, we collected scat samples during the period of highest mortality risk of caribou and moose neonates (4–5 weeks following birth; Patterson et al. 2013; Walker et al. 2021). Despite predation by bears being an important cause of caribou mortality in other areas of the Boreal forest (e.g., Pinard et al. 2012; Mahoney et al. 2016), we failed to detect consumption of either juvenile or adult caribou through our scat analysis, supporting that black bear predation on caribou likely varies regionally (Zager and Beecham 2006). Additionally, low caribou densities combined with inter-individual variability in habitat selection patterns of bears (Latham et al. 2011; Lesmerises and St-Laurent 2017) may have resulted in limited encounters between bears and caribou in our study area. Caution is warranted, however, because increasing habitat modification within the Boreal forest of northern Ontario could increase favourable habitat for bears, increasing their presence in caribou range (Brodeur et al. 2008; Mosnier et al. 2008; Pinard et al. 2012). Even incidental or occasional predation on caribou in our study area may have significant impacts because of their low abundance and rate of increase (Bastille-Rousseau et al. 2011; Latham et al. 2011).

We detected a low proportion of adult moose and calves in the scats when pooled across the sampling period, similar findings to other black bear diet studies using scat analyses (Mosnier et al. 2008; Romain et al. 2013; Popp et al. 2018); however, temporal examination of bear diet revealed higher amounts of moose in scats in late May compared with the month of June. Moose calves made up a slightly larger proportion of the spring bear diet than adult moose, and though we cannot discern with certainty consumption resulting from predation from that of scavenging, Schwartz and Franzmann (1991) suggested that adult moose presence in spring scats of bears was due to scavenging, whereas calf hair was the result of predation. Researchers have documented black bears predating adult elk (Barmore and Stradley 1971), white-tailed deer (Svoboda et al. 2011), and even adult moose (Austin et al. 1994), but most evidence suggests that predation by black bears on large, adult ungulates, like moose, is rare (Ballard 1992). At least some of the presence of adult moose hair in the bear scats that we analyzed was likely the result of scavenging wolf kills. Through a concurrent spring diet analysis of wolves in our study area, Found et al. (2017) showed that approximately

78% of prey biomass of wolf scats was adult moose, suggesting wolf-killed moose carcasses may have been available for scavenging by bears in the area. Additionally, spring consumption of winter-killed moose is possible (Hatler 1972; Raine and Kansas 1990; Baldwin and Bender 2009). Based on kill site investigations of GPS-collared wolf packs (*n* = 14) in our study area, moose were the primary winter prey of wolves (Vander Vennen et al. 2016) and it is conceivable that bears may have scavenged remains from these sites upon den emergence in the spring. In contrast, the limited mobility of moose neonates in spring would make them susceptible to predation. In their study of moose calf survival in central Ontario, Patterson et al. (2013) found that just over half of all predation-related calf mortalities were due to black bears. Though black bear densities of the central Ontario study sites were greater than in our region, their results still suggest that bears in our study area may have opportunistically preyed on moose calves that they encountered. The availability of wolf-killed moose and the vulnerability of moose calves immediately following birth may explain the pulse in moose consumption we detected in early spring. Therefore, it is important to note that the overall low proportion of moose in the diet does not necessarily indicate that bear predation is of limited importance to moose in the Boreal forest, especially given the level of calf consumption we detected.

Additional protein sources and minor dietary components

Unexpectedly, our analysis revealed that beaver was the most commonly eaten mammal in spring by bears, particularly in late May with less use as spring progressed. Consumption of beaver by black bears has been documented elsewhere (Holcroft and Herrero 1991; Smith et al. 1994; Lesmerises et al. 2015), including in other regions of Ontario (Romain et al. 2013; Popp et al. 2018). Given that there is almost complete use of carcasses of beavers killed by wolves (98%; Gable et al. 2016), we suggest that bears likely had an active role in predating rather than scavenging beavers, with predation events possibly occurring when beavers were feeding on land following ice-out in spring, a time that they are particularly vulnerable to predators (Gable et al. 2016) and coinciding with the start of our scat sampling period. It is also possible that they predated beavers in their lodges (see Smith et al. 1994).

The need to replenish body condition after hibernation likely explains the variety of additional animal species (both invertebrate and vertebrate) that we detected in the bear scats. We found insects, particularly ants, frequently in small proportions, as has been reported elsewhere (MacHutchon 1989; Holcroft and Herrero 1991; Schwartz and Franzmann 1991; Hellgren 1993; Boileau et al. 1994; Bull et al. 2001; Benson and Chamberlain 2006; Greenleaf et al. 2009). Ants and their larvae are rich in protein and fat and are the type of high-energy food required by bears after emergence from hibernation (Noyce et al. 1997). The timing of insect emergence likely contributed to the temporal trend of insect use that we detected. Additional sources of protein consumed by bears in our study area included birds and eggs. Bears are known nest predators (DeWeese and Pillmore 1972; Heard Tardell and Doerr 1982) and the presence of feathers and eggshells in scats that we collected indicate possible nest predation (Schwartz and Franzmann 1991). Similar to other black bear studies, we also documented a low proportion of snowshoe hare in the diet (Lachapelle et al. 1984; Raine and Kansas 1990; Lesmerises et al. 2015).

Our scat analysis revealed some interesting secondary results. Moss was found in 23% of scats, coinciding with pieces of wood, ants, ungulate hairs, maggots, and (or) herbaceous plants, leading us to believe that moss may have been consumed incidentally during (*i*) raiding of ant nests in moss layers (Lafleur et al. 2002), (*ii*) consumption of prey cached under moss (A.A.D. McLaren and B.R. Patterson, personal observations), or (*iii*) while targeting protein-rich herbaceous plants. There is little energy available in moss due to very limited digestibility (Glime 2014); thus, we suggest that despite frequently occurring in scats, moss was not actively fed upon for nutrition by bears. In addition, we detected bear cub hair (one scat containing up to 90%) and claws in three scats, which we suggest was the result of intraspecific predation and infanticide by males, given documentation of it elsewhere across black bear range, similarly in spring upon den emergence, and during the breeding season (LeCount 1987; Bull et al. 2001; Garrison et al. 2007; Lesmerises et al. 2015).

Methodological limitations

Some caveats are warranted regarding our approach and interpretation of results. First, we cannot definitively ascertain whether ungulate prey in scats was the result of predation, scavenging, or a combination of both, a problem acknowledged by other researchers assessing diet through scat analyses (Lesmerises et al. 2015; Popp et al. 2018). We documented the presence of maggots in some scats, suggesting that in some cases, consumed prey was scavenged or cached as opposed to having been recently predated (Hatler 1972; Messier et al. 1986; Holcroft and Herrero 1991). In addition to our own observation from central Ontario of a bear caching a wolf pup it predated (A.A.D. McLaren and B.R. Patterson, personal observations), bears have been found elsewhere to also cache their kills (Crête and Desrosiers 1995; Svoboda et al. 2011), making the presence of maggots in scats an unreliable method of separating bear predation from scavenging. Second, our methods relied largely on the detection of prey hair in scats, but bears are known to evert the hide of their prey (Ballard et al. 1979; Wilton 1983; Wilton et al. 1984; LeCount 1987; Schwartz and Franzmann 1991; Svoboda et al. 2011). However, Austin et al. (1994) detected prey hair in bear scats even when the hide of the consumed carcass was everted, likely because some parts of the carcass retained pieces of hide and hair. Third, consumption of meat can lead to liquified scats (Svoboda et al. 2011), which may lessen their persistence on the landscape, particularly during periods of rain, and such scats may not have been found by our field crews. Therefore, we may have underrepresented actual bear predation risk to ungulates, something a more intensive field research effort could demonstrate (Schwartz and Franzmann 1991; Garneau et al. 2008; Leclerc et al. 2014). Despite limitations, diet interpretation based on a large sample size of scats collected across a large spatial scale provided us with the best means to non-invasively examine bear diet during a specific season when other biological samples were not available to allow more comprehensive analytical approaches (e.g., stable isotope analysis).

Management implications

Although we did not detect black bear consumption of caribou in our study area, losses to predators can have important effects on low-density populations of ungulates (Bastille-Rousseau et al. 2011). Additional data collected over a broader temporal scale may improve our understanding of the relationship between bears and caribou in the region. Moose represented a low proportion of the overall diet of black bears but made up a significant portion of the diet in early spring. If this consumption was additive to that of wolf predation on moose, especially of calves, then it may represent an important limiting factor for moose populations in the area, particularly for regions experiencing declines in moose abundance. Further research may be warranted to supplement our non-invasive methodology of assessing black bear use of ungulates in the Boreal forest of Ontario.

Acknowledgements

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