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Year-round patterns of mineral lick use by Moose (*Alces americanus*), deer, and Elk (*Cervus canadensis*) in north-central British Columbia

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Abstract

Natural mineral licks are important to the physiological ecology of several species of ungulates in North America and abroad. Information on year-round patterns of mineral lick use by ungulates in Canada is poorly understood. We used camera traps to record patterns of mineral lick use by four ungulate species visiting five naturally occurring mineral licks located within the John Prince Research Forest and surrounding area, near Fort St. James, British Columbia, Canada. Our cameras detected over 1800 mineral lick visits by ungulates from February 2017 to January 2018. Mineral licks were visited year-round, however, most visits were made between May and September during morning hours. We observed variable lick visitations among sites, species, and sex and age classes. The species observed in descending number of lick visits included Moose (*Alces americanus*), White-tailed Deer (*Odocoileus virginianus*), Elk (*Cervus canadensis*), and Mule Deer (*Odocoileus hemionus*). Some licks were visited by all four species, while others were visited by fewer. Female ungulates were recorded at licks more frequently than males or juveniles, which likely reflected the underlying sex and age structure of the population. Elk spent more time at licks than Moose and deer and there was no difference in visit durations between Moose and deer. Most visits were made by single animals, but group visits were also observed. Our findings provide evidence that mineral licks are used year-round by ungulates and appear to be important habitat features on the landscape.

Key words: Camera trap; mineral licks; Moose; Elk; Mule Deer; White-tailed Deer; ungulates

Introduction

Mineral licks (also known as salt licks, mineral springs, and muck licks) are used by a variety of wildlife species (Jones and Hanson 1985). Formed commonly near groundwater springs, on exposed rock faces, along streams, or around tree roots or clay banks, licks are areas where soil solutes can concentrate (Jones and Hanson 1985; Shackleton 1999). Licks are generally classified as dry (e.g., rock faces, clay banks; Jones and Hanson 1985) or wet. Wet licks are frequented by Elk (*Cervus canadensis*) and Moose (*Alces americanus*; Fraser and Hristienko 1981; Parker and Ayotte 2004). Other ungulates, such as White-tailed Deer (*Odocoileus virginianus*) and Mule Deer (*Odocoileus hemionus*) also visit wet licks (Fraser and Hristienko 1981; Shackleton 1999; Jokinen *et al.* 2016) during the early spring and summer months, with little to no visitation in the winter, but see Rea *et al.* (2013a).

Many mineral licks have elevated concentrations of sodium, which is thought to be a key attractant for animals such as Moose (Fraser and Hristienko 1981; Fraser *et al.* 1982; Tankersley and Gasaway 1983) and Elk (Lavelle *et al.* 2014). Several studies have concluded that in addition to sodium, other elements in licks such as carbonates, magnesium, and iron may be attractants to animals (Cowan and Brink 1949; Kreulen 1985; Kennedy *et al.* 1995; Ayotte *et al.* 2006). Visitation to mineral licks by ungulates for sodium and other attractants is thought to be related to milk production (Ayotte *et al*. 2006), the demands of antler growth (Atwood and Weeks 2002), and elements required for improved rumen function (Ayotte *et al.* 2008).

Carbonates (Ayotte *et al.* 2006) and magnesium found in licks may act to combat dietary deficiencies and as compounds necessary for herbivores to regulate high levels of dietary potassium in spring compared to winter forages (Dormaar and Walker 1996; Shackleton 1999; Parker and Ayotte 2004; Jokinen *et al.* 2016). Rea *et al.* (2013a) found that iron concentrations were high at licks in northern British Columbia (BC). Iron could potentially act as an attractant for Moose populations that could use supplemental iron to defend against ticks and improve blood and muscle function (Rea *et al.* 2013a). Iron-rich soils are known to be used by both Snowshoe Hare (*Lepus americanus*; Rea *et al.* 2013b) and Black-tailed Jackrabbit (*Lepus californicus*; Arthur and Gates 1988). In addition to the importance of acquiring minerals, lick sites may also be used for non-dietary needs such as social gathering (Knight and Mudge 1967; Carbyn 1975; Fraser and Hristienko 1981; Atwood and Weeks 2002).

Mineral lick research has predominantly been conducted using daytime visual observations of animals at licks between April and September (Cowan and Brink 1949; Carbyn 1975; Fraser and Hristienko 1981; Ayotte 2004; Parker and Ayotte 2004; Ayotte *et al.* 2006, 2008), which has been termed the 'high use' period. Few studies have been conducted over continuous 24-hour periods (Tankersley and Gasaway 1983) or with camera traps (Atwood and Weeks 2002; Lavelle *et al.* 2014; Jokinen *et al.* 2016). In addition, year-round research into the use of licks using cameras (Rea *et al.* 2004, 2013a) is limited, resulting in an incomplete picture of seasonal patterns of use.

Licks that are used year-round by ungulates may be negatively impacted by land development activities. Because few policies exist that explicitly protect lick sites (Rea *et al*. 2004; Jokinen *et al*. 2016), year-round studies that can delineate time-of-day, season-of-year, and species-specific use patterns could be of value for forest and wildlife managers attempting to balance resource extraction with local wildlife management objectives (Dormaar and Walker 1996; Atwood and Weeks 2002; Parker and Ayotte 2004; Rea *et al.* 2004).

To better understand the daily and year-round seasonal use of mineral licks by ungulates in a managed forest, we installed video-enabled trail cameras at five mineral licks in and adjacent to the John Prince Research Forest in north-central BC, near Fort St. James. Cameras were monitored for one full year to determine which species were using the licks and if use patterns varied by species and among licks. Due to the presumed importance of mineral licks to ungulates, our null hypothesis was that mineral licks would be used by all ungulates equally and that time of day and season of use would not vary among species.

Methods

Study area

We established two wildlife video camera trap stations at each of five mineral licks in and adjacent to the John Prince Research Forest (JPRF; 16 500 ha, 54.833°N, 124.583°W) ~160 km northwest of Prince George, BC, Canada (Figure 1). The area is within the Sub-boreal Spruce Biogeoclimatic Zone, with the local geology comprised of limestone and ultramafic bedrock overlain predominantly by glacial till (Rea *et al.* 2013a). Mean daily average temperatures in the area (2014–2018) were 4.3°C and ranged from a monthly mean daily average of –6.5°C in January, to a monthly mean daily average of 16.7°C in July. Mean annual precipitation was 212.34 mm, with an average of 61.8 cm of it falling as snow (Environment and Climate Change Canada 2019). The maximum for mean monthly snow on the ground typically occurred in February and averaged 37.91 cm (SE 6.30) from 2014 to 2018. In 2017 and 2018, the maximum for mean monthly snow on the ground was 14.88 cm (January) and 58.04 cm (February), respectively (Environment and Climate Change Canada 2019).

Five wet mineral licks within or in close proximity to the JPRF that had been previously documented during field activities were monitored for one year (1 February 2017–31 January 2018). Sites were chosen based on their location within or proximity to the research forest with sites named according to a history of monitoring or their general location. All licks had been known to be used by Moose, some of which are known to migrate seasonally in and out of the research forest (to higher elevations in summer; Chisholm 2018). Deer had also been documented using the lick sites and are known to migrate seasonally in the province (D'Eon and Serrouya 2005), although nothing specific is known about local elevational movements by deer or the seasonal movements or migrations of Elk that inhabit the local area.

Data collection

Two digital passive infrared trail cameras (Trophy Cam HD Model 119477 and 119676, Bushnell Outdoor Products, Overland Park, Missouri, USA) were used at each mineral lick. We used two cameras per site to capture a wide angle of view and to reduce potential errors associated with possible camera malfunctions. Cameras were set on trees at ~1.5 m above ground along the edge of each mineral lick with each camera facing a different direction to maximize coverage of activity areas. Cameras were checked approximately once every three weeks to change memory cards, check batteries, and adjust camera position (sometimes cameras were bumped by animals). Video recording times were set at 20 s, with a 1 s delay be-

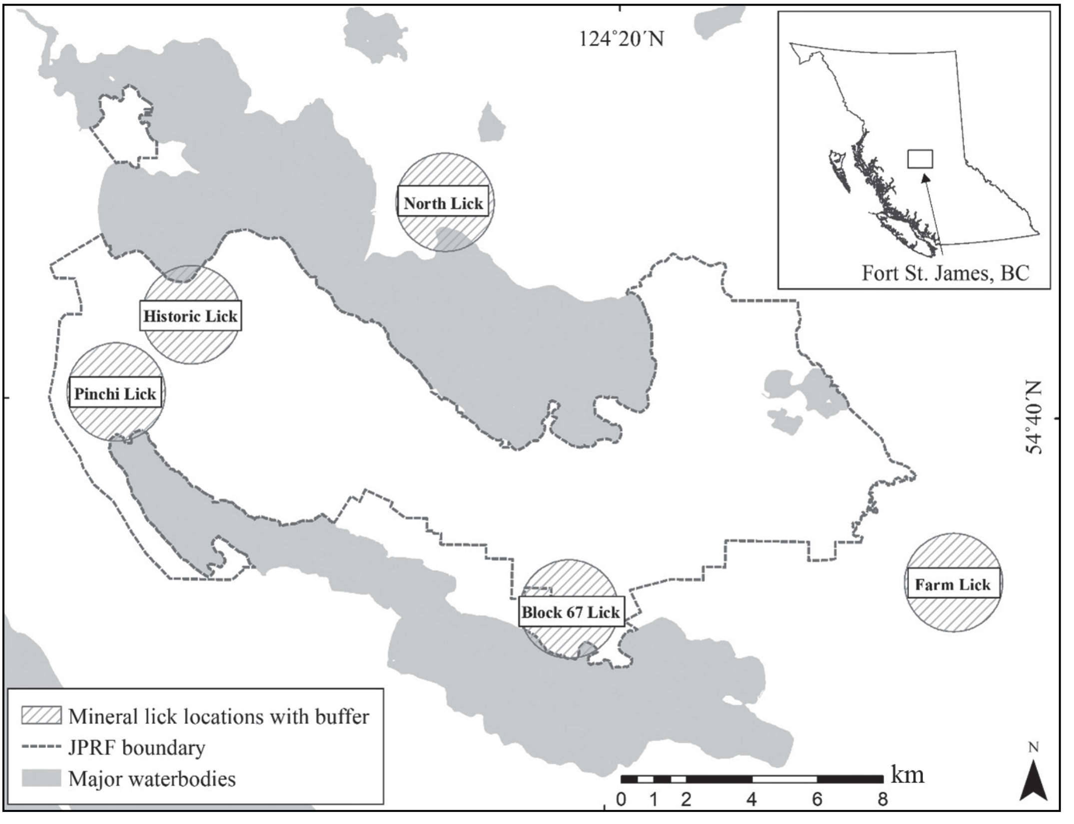

FIGURE 1. Location of five mineral licks within the John Prince Research Forest and surrounding area near Fort St. James, British Columbia (inset). Buffers added to disguise exact locations of licks.

tween videos to allow for near-continuous videos if an animal remained present and active in front of the camera. Date and time imprints were stamped on each video recording. All cameras were set to daylight savings time for the entire study.

Videos were downloaded, viewed, and information entered into a database. Date, time, temperature, and video number were recorded, then videos were scrutinized to identify the number of individuals, species, sex and age class, the time the animal came into view and left the camera view (in 24-h format) as well as other behaviours. It took 90–120 s to analyze each video.

Animal visits, as captured by cameras, were considered independent and were generally easy to define when different individuals and species were recorded. When the identification of individuals of a species was difficult, which was common in low light conditions, we used average visit times by each species to delineate visits. To determine average visit times for each ungulate species, we recorded how much time individual animals would spend at a lick during a single visit. We then averaged visit times and used the average lengths of these visits as cut-offs to delineate one independent visit from another where an animal of questionable identity moved into and out of the camera's field of view.

Data interpretation

Data were sorted for every ungulate visit. Overlapping dates taken from both cameras at each site were organized and selected to avoid duplicates. To determine length of stay, any data that overlapped from both cameras were merged into one entry, and time of departure was subtracted from time of entry. Data were then grouped for the entire study period, by month, and by day for analyses of trends and patterns.

Moose, Elk, Mule Deer, and White-tailed Deer adult males were identified using antler presence and antler pedicel scars in the months following antler shedding. Moose, Elk, and deer adult females were identified by lack of antlers and lack of antler scars, with female Moose being further identified by the presence of a vulva patch, if visible (Rea *et al.* 2013a). Juveniles were identified based on morphological differences and spotting patterns on coats of younger animals (Ayotte *et al.* 2008).

When animals stepped out of the view of the primary camera, if malfunctions in camera recordings occurred, if data files became corrupt, or if a camera was knocked out of alignment by an animal, data from the second camera at the site were used. During time periods when both cameras at a lick malfunctioned or were not operational (the last two weeks of December at the Farm Lick; Figure 1) we corrected these data to standardize the total number of visitations for that month. We did this by multiplying the number of individual visits during the part of the month in which the camera was recording with the number of days in that month (31 days for December) and then dividing that by the number of days the camera was functioning in that month (as per Rea *et al.* 2013a). This method assumed that the number of visits/day to the lick on the days of the month that the camera was functional equalled the number of visits/day to the lick on the days of the month that the camera malfunctioned.

Statistical testing

We used a series of Kruskal-Wallis (Van Hecke 2013) and multiple comparisons *P* value (two-tailed) tests to determine if there were differences in visit times by species. We used an alpha of 0.05 for all analyses. All statistical tests were completed in Statistica 9.0 (StatSoft 2009).

Results

Our cameras captured 1817 independent ungulate visits to the five mineral licks between 1 February 2017 and 31 January 2018. Most recordings were of Moose (n = 621), followed by White-tailed Deer (n = 547), Elk (n = 495), and Mule Deer (n = 154). The majority of mineral lick visits were by single animals: 84% of Moose, 79% of Mule Deer, and 66% of Elk and White-tailed Deer.

Species variability by site

Moose were recorded more often at the Block 67 Lick, the Historic Lick, and the Pinchi Lick, whereas White-tailed Deer were the dominant species recorded at the Farm Lick, and Elk made relatively more visits to the North Lick (Figure 2). The largest number of ungulate visits (n = 837) was recorded at the Farm Lick, with White-tailed Deer visits (n = 516) at this site accounting for 94% of all White-tailed Deer visits to all licks. Most Moose (n = 198) were recorded at the Farm Lick, accounting for 32% of the total Moose visits across all licks; 21% of all Elk and 12.4% of all Mule Deer visits were also recorded at the Farm Lick. There were 552 total ungulate visits recorded at the North Lick, of which 255 were Elk (comprising 52% of the total Elk visits across all licks), 185 were Mule Deer (accounting for 85% of Mule Deer visits across all licks); 22% of all Moose, and 5.2% of all White-tailed Deer visits occurred at the North Lick.

Our cameras recorded 270 ungulate visits at the Block 67 Lick, accounting for 26% of the total Moose visits, 21% of all Elk, 1.3% of all Mule Deer, and 0.5% of all White-tailed Deer visits to all licks. There were 93 ungulate visits recorded at the Historic Lick, accounting for 14% of all Moose, 0.4% of all Elk, and 1.3% of all Mule Deer visits to all licks. No White-tailed Deer were recorded at the Historic Lick. Only Moose and Elk were recorded 65 times at the Pinchi Lick, accounting for about 6% of Moose and Elk visits.

Seasonal trends

More ungulates (n = 308) were recorded at licks (all visits pooled for all licks) in June than any other

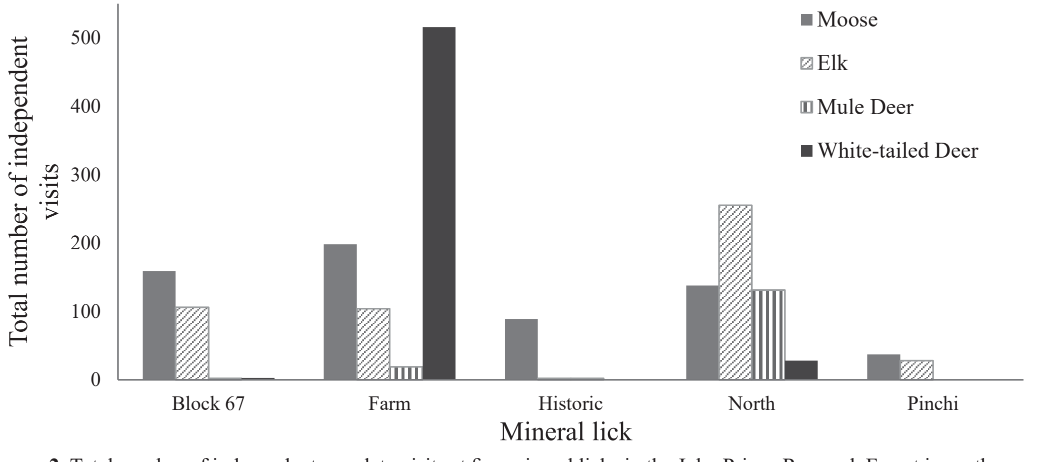

FIGURE 2. Total number of independent ungulate visits at five mineral licks in the John Prince Research Forest in north-central British Columbia, Canada, February 2017–January 2018. Note: No Mule Deer (*Odocoileus hemionus*) or White-tailed Deer (*Odocoileus virginianus*) were recorded at the Historic Lick and no White-tailed Deer were recorded at the Pinchi Lick.

month of the study period, followed by July (n = 278), August (n = 254), September (n = 240), and May (n = 220; Figure 3). The fewest number of visits were recorded in February (n = 35). Recordings of Moose and Elk were made in all months while White-tailed Deer were recorded from March to January and Mule Deer from May until November. Similar to trends using the pooled results, visits to licks by Moose peaked in June (n = 152; Figure 3). However, peak visits by other species were variable, with White-tailed Deer peaking in September (n = 143), Elk peaking in May (n = 90), and Mule Deer peaking in August (n = 61).

Visits to licks by ungulates outside of the high-use period of May–September (i.e., October–April) were mostly made by Moose (n = 230), with a peak in visits during December (n = 59; Figure 3). White-tailed Deer made 154 lick visits during the winter months, with a peak in April (n = 81). Elk were also recorded visiting licks during this period (n = 125) with a peak in March (n = 33). Mule Deer made eight visits to licks during October–April, with four in October and four in November.

Timing of visits

More ungulates visited licks over the entire year study period (combined visits) at 0700 than any other time of the day. Of the 116 independent visits to licks at 0700, 33% were Elk, 32% Moose, 28% White-tailed Deer, and 7% Mule Deer (Figure 4). The fewest ungulate visits (n = 47) across all licks occurred at 0100. Time of day was divided into four periods (morning: 0600–1159, afternoon: 1200–1759, evening: 1800–2359, and night: 0000–0559; as per Jokinen *et al.* 2016). Most visits combined occurred in the morning (n = 571), of which 41% were White-tailed Deer, 25% Moose, 22% Elk, and 12% Mule Deer. There were 476 ungulate visits during the evening, of which 43% were Moose, 35% Elk, 17% White-tailed Deer, and 5% Mule Deer. There were 389 ungulate visits during the afternoon, of which 45% were White-tailed Deer, 24% Moose, 22% Elk, and 9% Mule Deer. There were 365 ungulate visits during the night, of which 46% were Moose, 32% Elk, 14% White-tailed Deer, and 8% Mule Deer (Figure 4). Although there were fewer visits to licks during winter, the pattern of visits by ungulates by time of day was relatively unchanged, with fewer visits over a 24-h period made from 2100 to 0600, and at mid-day, with most visits occurring from 0600 to 1100 and from 1300 to 2000 (Figure 5).

Visit duration

Ungulates spent an average of 15:33 ± 24:48 (SD) min:sec at licks throughout the study period. The only significant differences in the amount of time spent at licks was between Elk (an average of 22 min per visit) and all other species (n = 1801, H_3 = 26.281, P < 0.0001), with specific pairwise differences between Elk and Moose (P < 0.0001), Elk and White-tailed Deer (P < 0.0001), and Elk and Mule Deer (P = 0.006; Figure 6). Moose made more visits to all the licks over the study period but spent less time on average (14:26 ± 26:31 min:sec) at licks when com-

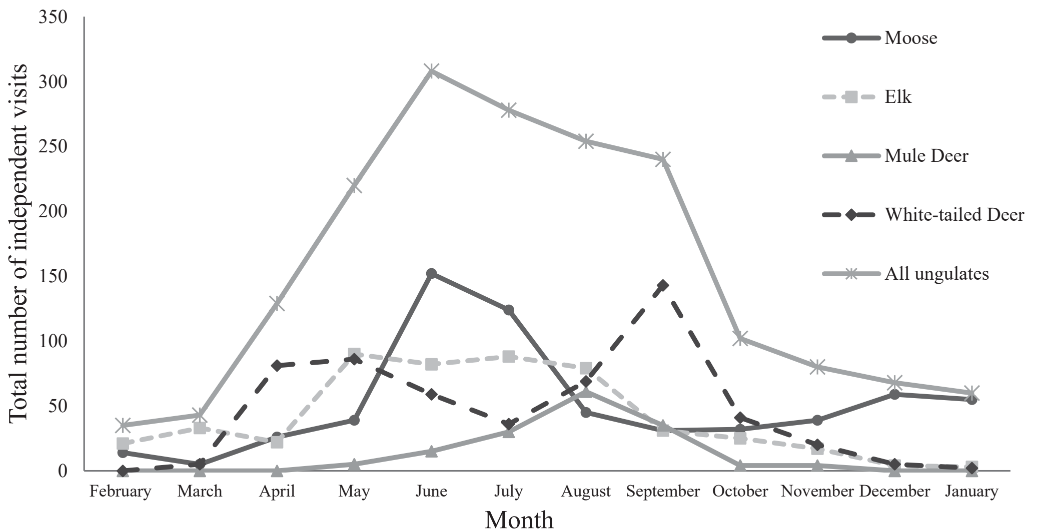

FIGURE 3. Total number of independent ungulate visits to mineral licks by month in the John Prince Research Forest in north-central British Columbia, Canada, February 2017–January 2018. Visits are pooled across all five licks.

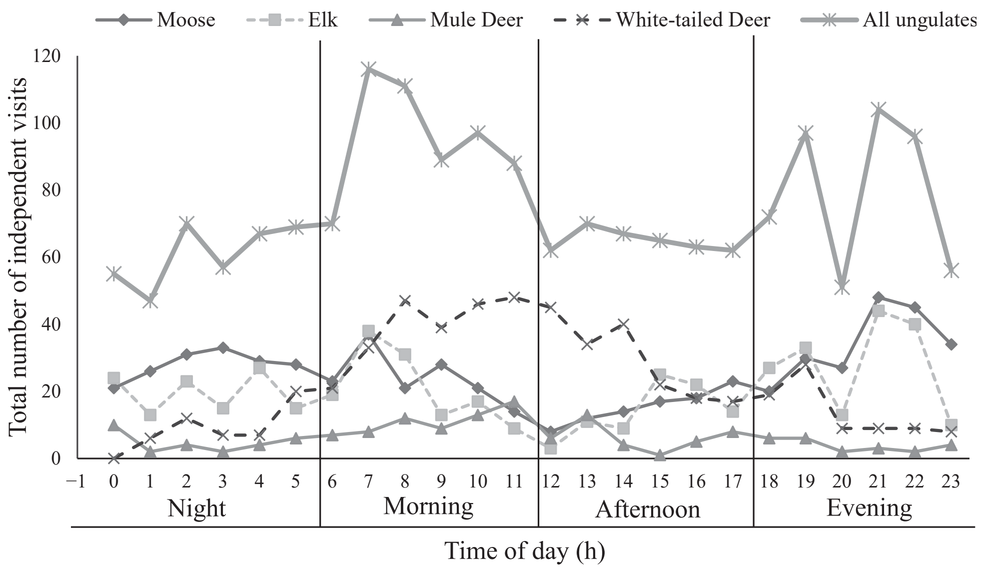

FIGURE 4. Total number of independent ungulate visits to mineral licks by time of day in the John Prince Research Forest in north-central British Columbia, Canada, February 2017–January 2018. Visits are pooled across all five licks.

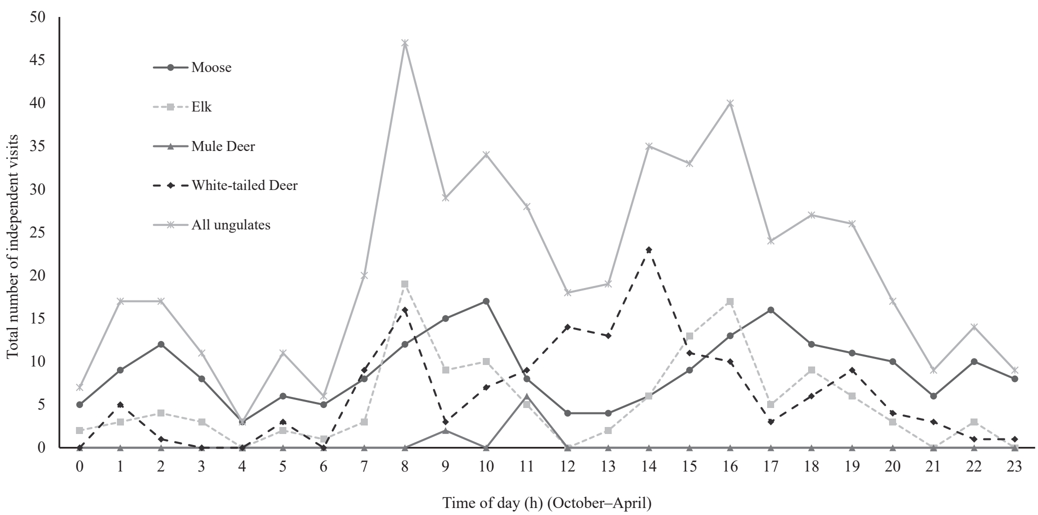

FIGURE 5. Total number of independent ungulate visits to mineral licks outside of the high-use period (i.e., October to December 2017 and January to April 2018) by time of day in the John Prince Research Forest in north-central British Columbia, Canada. Visits are pooled across all five licks.

pared to Elk. Mule deer spent nearly the same amount of time on average (11:49 ± 14:52 min:sec) at licks as White-tailed Deer (12:13 ± 17:29 min:sec), but were recorded having fewer visits on average.

The amount of time Moose spent at licks varied significantly among some licks (n = 608, H_4 = 29.54, P < 0.0001; Figure 7). Moose spent significantly more time per visit at the Farm Lick than the North Lick (P < 0.0001) or the Historic Lick (P = 0.03). The amount of time Elk spent at licks varied significantly among some licks (n = 496, H_4 = 68.43, P < 0.0001; Figure 7). Elk spent significantly more time per visit at the North Lick than at the Farm Lick (P < 0.0005), the Pinchi (P < 0.0001), or Block 67 (P < 0.0001) licks (Figure 7). The amount of time Mule Deer or White-tailed Deer spent at licks did not vary significantly among licks (n = 154, H_3 = 5.48, P = 0.14; n = 544, H_2 = 4.22, P = 0.12, respectively; Figure 7).

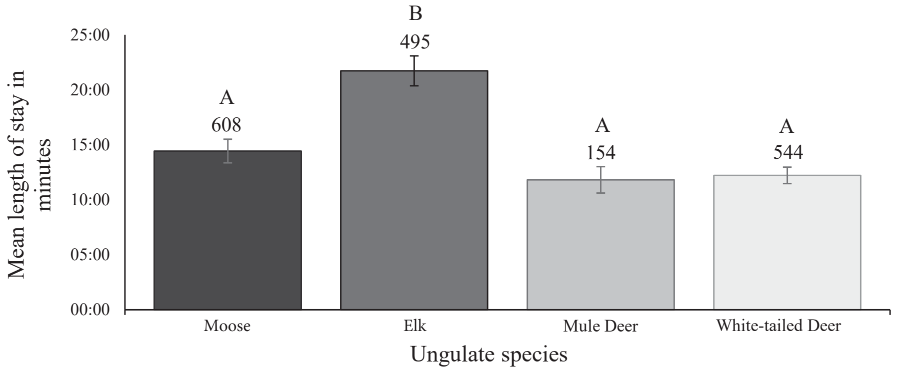

Figure 6. Mean (± SE) length of stay in min:sec for each species of ungulate visiting all mineral licks. The sample of independent visits from the beginning of February 2017 to the end of January 2018 is represented by the number above the error bar. If error bars share a common letter they were not statistically significantly different from one another ($P \geq 0.05$).

Sex and age classes

Female ungulates of all species (n = 1026) visited mineral licks more than males (n = 477) or juveniles (n = 298) throughout the study (Figure 8). Males generally visited the licks more than juveniles, but this trend was reversed for White-tailed Deer; Mule deer made up the fewest number of visitors to licks in all sex and age classes (Figure 8). Overall, the total number of visits to licks by female Moose was lowest in March (n = 5) and peaked in June (n = 77; Figure 9). In general, male Moose and juveniles followed a similar pattern as the females. Total visits by female Elk peaked in May (n = 47) and were lowest in December (n = 2; Figure 9). Male Elk followed a similar visitation pattern as female Elk over the course of the year and peaked in June (n = 47). Visits by juvenile Elk peaked in August (n = 22). Visits by female Mule Deer began to rise in April, peaked in August (n = 33), then decreased through to November (Figure 9). Visits by male Mule Deer peaked in July (n = 12) thereafter declining steadily towards winter. Total visits by juvenile Mule Deer peaked in August (n = 17) declining to October when visits stopped. Female White-tailed Deer visits peaked in April (n = 76) with a secondary peak in September, with male visits peaking in May (n = 25) with a secondary peak in August while juveniles visited most often in September (n = 76; Figure 9).

Discussion

With the use of cameras, we determined that over 1800 visits were made by ungulates in a one-year period to the five licks. The majority of visits were made by single animals, with most species visiting licks at various points throughout the year. Visits to licks were made in all months by Moose and Elk, while White-tailed Deer were recorded in every month except February. Mule Deer were recorded at licks in the summer and in October and November, but otherwise did not visit much outside of the high-use period of May to September.

The use of video cameras helped us determine visit lengths and the number of independent visits. With two cameras on each site, we were able to document time of entry and exit from licks by ungulates, giving us a better average length of stay for each animal, and thus a way to determine an independent visit. Additionally, we were able to record ungulate behaviour at lick sites, allowing us to see Moose cratering in the snow to access the lick and could help explain why Moose spent longer periods of time at licks in winter compared to other ungulates we studied. Video footage showed us Moose behaviour that included resting on, or adjacent to, snow-covered licks, behaviours that may otherwise have been missed with non-video cameras that only capture still images when triggered by movement. The use of video cameras may have helped to reduce gaps in our understanding by providing continuous recordings of Moose and other ungulate behaviour that still images could have missed. The audio in video mode also allowed us to hear vocalizations and to detect movements just outside of the camera view that were useful in understanding what was happening during each visit.

Seasonal trends

We recorded more visits to licks during the summer than during any other season. Moose visitations peaked in June, as previously found by Stepanova *et al.* (2017). Moose were also the dominant species recorded at licks in July, November, December, and January. The use of licks by Moose increased from February into May, peaked in June, and decreased in July, which corresponds to findings by Ayotte (2004) and coincides with early summer sodium deficiencies linked to spring plant phenology (Fraser and

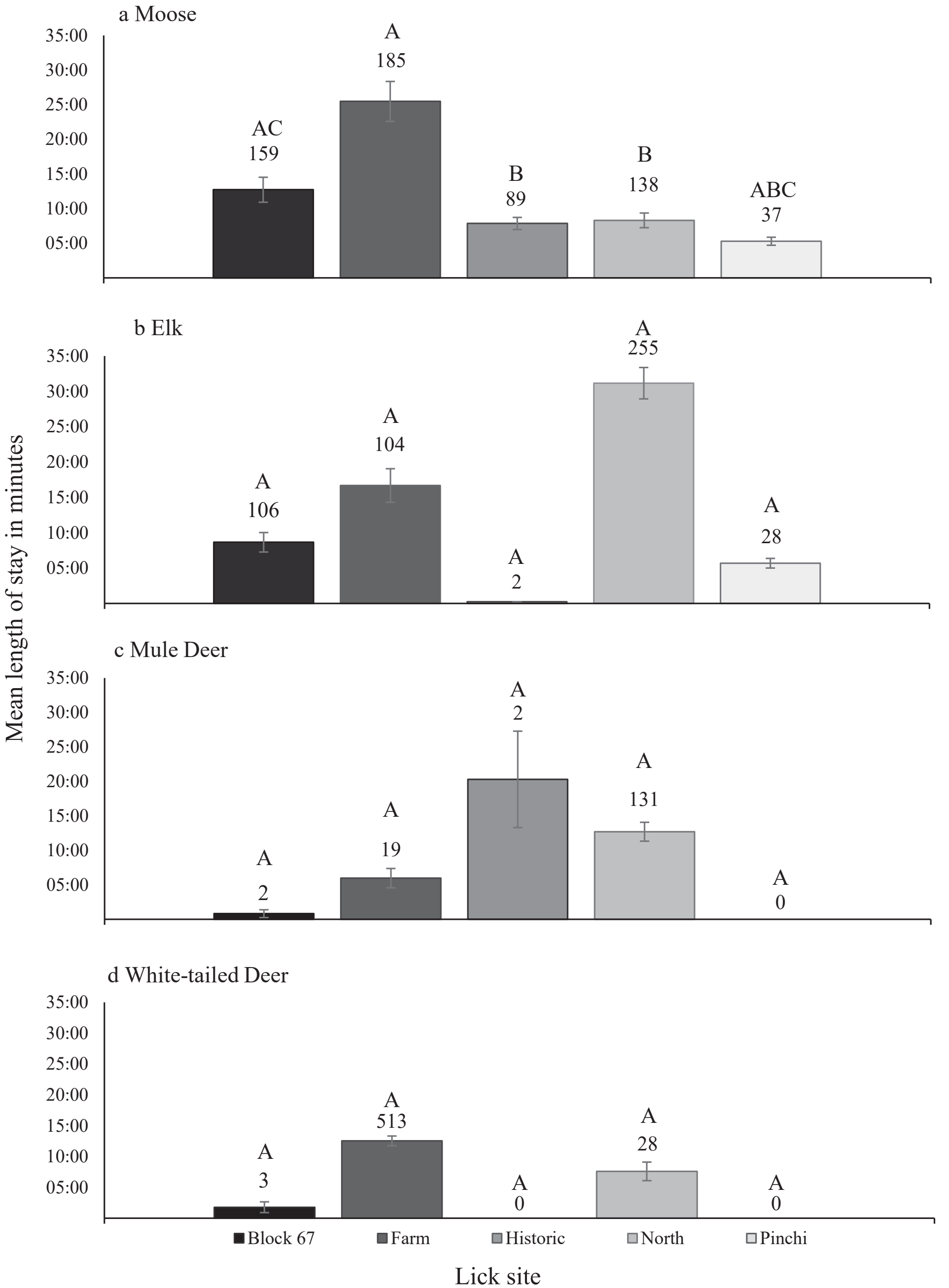

FIGURE 7. Mean (± SE) length of stay in minutes for a. Moose (*Alces americanus*), b. Elk (*Cervus canadensis*), c. Mule Deer (*Odocoileus hemionus*), and d. White-tailed Deer (*Odocoileus virginianus*) across all five licks from the beginning of February 2017 to the end of January 2018. Sample sizes (*n*) are represented by the numbers above the error bars. Note: No Mule Deer were recorded at the Pinchi Lick and no White-tailed Deer were recorded at the Historic or Pinchi Licks. Error bars sharing a common letter are not statistically significantly different from one another ($P \geq 0.05$).

Hristienko 1981; Ayotte *et al.* 2008) as well as calving, moulting, and antler growth (Tankersley and Gasaway 1983). Tankersley and Gasaway (1983) reported no winter lick use by Moose based on lack of tracks in January, April, and early May. However, our study and research done by Rea *et al.* (2013a) showed

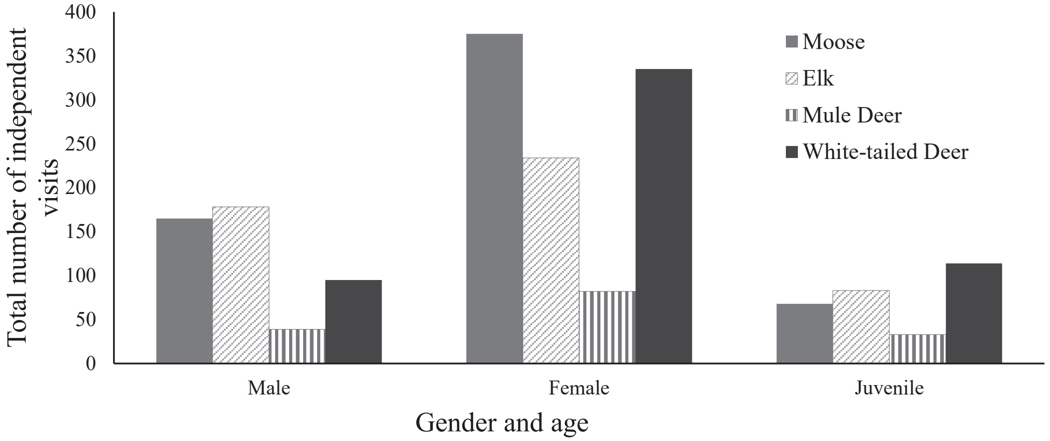

FIGURE 8. Total number of independent male, female, and juvenile ungulate visits recorded across all five licks from the beginning of February 2017 to the end of January 2018.

increased Moose visits to licks from October onward, which may be attributed to Moose satisfying mineral deficiencies in winter.

Elk visited licks most often in May and were the dominant ungulate at licks in February, March, May, and August. Other studies have also reported high use of licks by Elk in late May and early June following spring forage switching (Ayotte *et al.* 2008) and low elevation vegetation green-up (Parker and Ayotte 2004). Carbyn (1975) also reported an increase in Elk visits in June as large nursery bands passed through their study area following calving (Dalke *et al.* 1965). Rea *et al.* (2013a) reported no Elk in their study based at the Historic Lick in the JPRF during 2002–2005. However, we detected two Elk at the same Historic Lick and 495 Elk at all licks combined in the study area.

Mule Deer were recorded most often in August but were never the most common species at any of the licks. Carbyn (1975) reported peak Mule Deer lick use in June and July and Black (1955) recorded increased observations in April and May with a peak in June. Buss and Harbert (1950) found a striking correlation between lunar phases and Mule Deer visitation rates to lick sites, stating that between July and August, more Mule Deer were counted when the moon was nearly full, having changed their feeding patterns. Although we found a trend in increased early summer use, no such correlation occurred in August when the most Mule Deer were recorded.

White-tailed Deer visits to licks peaked in September, and they were the dominant species at licks in April, September, and October. Atwood and Weeks (2002) recorded more White-tailed Deer visitation between July and August, with another peak in September that they attributed to the minerals required for the growth of winter pelage. The increase in total number of White-tailed Deer visits in September may also be due to the increased number of fawns recorded accompanying does to licks (Atwood and Weeks 2002). Additional studies have reported White-tailed Deer usage of licks increasing from April to May (Weeks and Kirkpatrick 1976; Weeks 1978), May to June (Kennedy *et al.* 1995), and mid-July (Fraser and Hristienko 1981). Weeks and Kirkpatrick (1978) also reported White-tailed Deer use of licks continuing into December with no visits from December to March.

Although several other studies (Cowan and Brink 1949; Carbyn 1975; Fraser and Hristienko 1981; Tankersely and Gasaway 1983) have recorded ungulate use of licks in spring and summer, relatively few studies have looked at lick use year-round (Rea *et al.* 2013a). Snow cover is often assumed to deter ungulate use of licks (Fraser and Hristienko 1981; Jokinen *et al.* 2016), leading to the assumption that licks are not sought out by ungulates in the winter months. However, we recorded Moose excavating licks with their front legs before kneeling to access the material beneath the snowpack during the winter months. Rea *et al.* (2013a) also observed Moose cratering in the snow to access lick soil and water. Because some Moose in our study area do not make seasonal migrations, while others do (Chisholm 2018), there is potential for some animals to use these licks year-round.

Our findings corroborate suggestions by others that peak use of licks occurs in summer with lower use in winter (with February visits being lowest). But we recorded Moose and Elk at licks in every month of the year, and White-tailed Deer in every month but February. Mule Deer were recorded at licks from May to November, after which cameras detected no visits.

The snow may have been too deep for ungulates other than Moose to visit our licks regularly in mid-winter, which may have been the reason only Moose were detected in deep snow in the study by Rea *et al*. (2013a).

Ayotte *et al.* (2006) demonstrated that chemical composition of licks can vary throughout the year. As such, visits to different licks by ungulates throughout the year may be explained by foliage changes (Dalke *et al.* 1965; Carbyn 1975; Weeks 1978; Ayotte *et al.* 2006) and associated changing mineral requirements across different seasons. Chemical data for each of the licks we studied is being determined and will possibly enrich our ability to interpret what is driving ungulate visits.

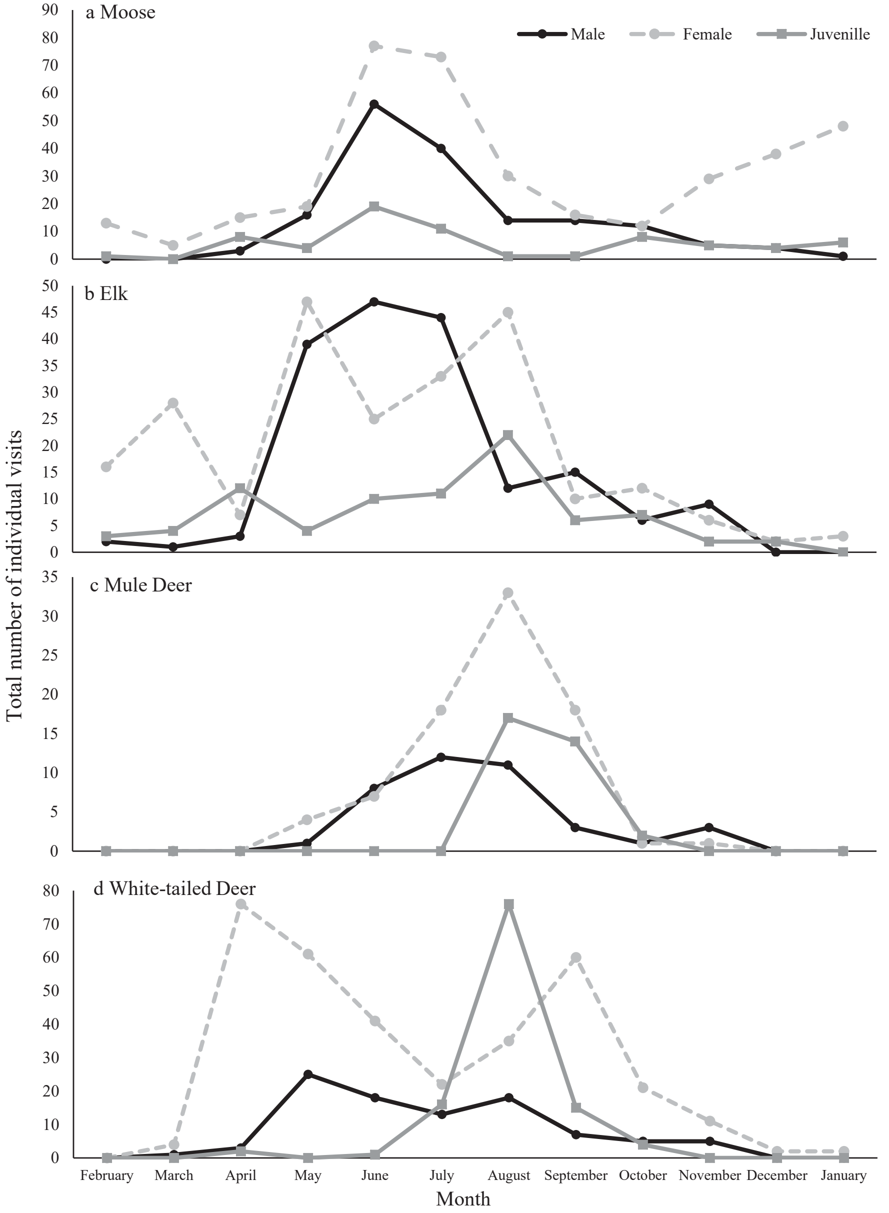

FIGURE 9. Total number of visits by male, female, and juvenile a. Moose (*Alces americanus*), b. Elk (*Cervus canadensis*), c. Mule Deer (*Odocoileus hemionus*), and d. White-tailed Deer (*Odocoileus virginianus*) pooled across all five licks in the John Prince Research Forest (JPRF) in north-central British Columbia, Canada from the beginning of February 2017 to the end of January 2018.

Time-of-day trends

Pooled visits to licks by all ungulate species revealed that peak visitations were during the morning and evening hours with fewer visits in the late afternoon and in the late night/early morning hours after midnight. This pattern was evident when data from all months of the study were combined and held true for the low-use season (October to April), albeit there were fewer visits to licks in the fall to spring months. These diurnal patterns varied by species, with Moose and Elk using licks more in the evening and morning hours while deer concentrated their use at midday. Concentrated use of licks by Moose and Elk in the evening and morning hours has been found by others (Fraser and Hristienko 1981; Tankersley and Gasaway 1983; Ayotte 2005; Rea *et al.* 2013a), although not all have found similar patterns (Carbyn 1975; Jokinen *et al.* 2016).

Mid-day peaks in lick use by deer have been found by others (Carbyn 1975; Fraser and Hristienko 1981), while some suggest deer visit licks throughout the day, but more during the morning hours (Jokinen *et al.* 2016) and after sunset (Wiles and Weeks 1986). The use of licks by different species may be partially attributable to which species are using the lick and whether or not interspecific interactions may modulate that use (Dalke *et al.* 1965; Fraser and Hristienko 1981). Although we detected no distinct patterns of use by one species being dependent on the presence of another, our cameras did record some species being chased out of licks by other species and suspect with more data collection and cameras adjusted to take longer videos, such patterns may emerge with further study.

Length of stay

On average, ungulates spent 15 min at licks per visit. Although Elk visits were on average significantly longer, visit times by Moose and deer were similar. There was a significant difference in the length of visits among licks for Moose and Elk, but not for deer. The average length of stays we found for Moose and Mule Deer were similar to averages found by Jokinen *et al.* (2016), but our average visit lengths for Elk and White-tailed Deer were nearly double those they found. A more detailed examination of the video data from cameras (including more years of video recordings) could perhaps reveal that the longer average visit lengths are an artifact of most visits being made by solitary animals, which might spend more time being vigilant as singletons, than if part of a group.

Ayotte *et al*. (2008) also reported that Elk made shorter visits to remote wilderness licks in comparison to Moose, Stone Sheep (*Ovis dalli stonei*), and Mountain Goat (*Oreamnos americanus*) and that the average length of stay for Moose was always >40 min; the longer length of stay for Moose was not attributed to bedding down near licks. Tankersley and Gasaway (1983) recorded average Moose visits as 15 min in one year of their study and 19 min in the next. Stepanova *et al*. (2017) reported that, on average, moose spent approximately 9 min engaged in geophagy while visiting licks. Wiles and Weeks (1986) found that the average length of stays for White-tailed Deer ranged from 20 to 25 min, whereas Fraser and Hristienko (1981) reported ~13 min. Black (1955) reported an average of 18 min spent at lick sites by Mule Deer.

Moose, Elk, and Mule Deer had longer visits to licks in the evening and White-tailed Deer spent more time at licks in the morning, which differed from findings by Jokinen *et al.* (2016), who reported Elk spending less time at licks in the afternoon but staying longer during the morning. Tankersley and Gasaway (1983) recorded longer visits by Moose between 2100–0459 with peaks around midnight and shorter visits at midday. Ayotte *et al.* (2008) found that Elk and Moose visit times were shorter in the morning than those during the day or evening. Moose and Elk spent less time at licks in the morning. Mule and White-tailed Deer spent less time at licks in the afternoon, which is interesting given deer visits to licks were most frequent in the afternoon, but actual time spent at licks during this period was lowest for both species.

Much of our results on length of stay differed from findings by Jokinen *et al.* (2016), who reported Elk as spending less time at licks in the afternoon but staying longer during the morning. Tankersley and Gasaway (1983) recorded longer visits by Moose between 2100 and 0459 with peaks around midnight and shorter visits at midday. Ayotte *et al.* (2008) found that Elk and Moose visit times were shorter in the morning than those during the day or evening. Several other studies (Carbyn 1975; Weeks 1978; Wiles and Weeks 1986; Rea *et al.* 2013a) provided information on how often ungulates visited during the day, but did not report length of stay. Dalke *et al.* (1965) and Atwood and Weeks (2002) report social interactions being sometimes responsible for the length of time spent at licks, that a more detailed examination of videos might reveal.

Pooled visit times suggest that the longest visits occurred in April and the shortest in January. Moose visits to licks were longest in February and March and shortest in December. Longer stays in February and March corresponded to times of the year when collared cow Moose in our study area began to move less (Scheideman 2018), suggesting they may have been less inclined to range far from licks that were used repeatedly. Videos of Moose recorded at the lick also suggest that Moose were forced to crater through snow to reach the lick and were bedding down near licks more frequently in February and March than at other times of the year.

Elk visits were longest in June and shortest in March. Mule Deer and White-tailed Deer visits were longest in July and April, respectively, with both deer species having the shortest visits in October. Variation in visit times by month have been described by others. Ayotte *et al.* (2008) recorded longer visits by Elk in late May and early June and variable visit lengths by Moose from spring into summer. Fraser and Hristienko (1981) also found that Moose visit lengths would vary at different times of the year, with shorter visits from July to October and longer visits in May and June. However, other studies have found that average visit lengths did not vary among months for Moose (Tankersley and Gasaway 1983) or White-tailed Deer (Wiles and Weeks 1986).

Explaining differences in lengths of stay for different species (or even different individuals) is difficult and could be related to several factors such as weather or predation risks (Carbyn 1975), social interactions (Dalke *et al.* 1965; Atwood and Weeks 2002), human activities (Dormaar and Walker 1996), or overall ungulate health (Tankersley and Gasaway 1983; Ayotte *et al.* 2008; Rea *et al.* 2013a). A more detailed analysis of various behaviours captured by the cameras may help address some of these questions, but would require increasing the length of the videos and the number of cameras at each lick. Combining camera data with collar data could also help to answer how seasonal migrations may factor into differential lick use.

Sex and age classes

The number of adult female ungulates we recorded visiting mineral licks was on average over three times the number of juveniles and twice the number of adult male ungulates. For all ungulates combined there were 29 juveniles and 46.5 males per 100 female ungulates. These patterns may be due in part to a differential need for females to obtain minerals from licks that are not required by males or juveniles but are most likely driven by differences in background sex and age class ratios on the landscape that are a result of hunting regulations that favour males. From census data collected in our study area, 35 juveniles and 26 adult male Moose were recorded per 100 females in 2017 (Klaczek *et al.* 2017), which compares poorly with our ratios of 18 juveniles and 45 males per 100 female Moose from our video records. The relative abundance of Elk, Mule, and White-tailed Deer were only recorded as "low" in the JPRF by Kuzyk *et al.* (2018), so demographic comparisons for these other ungulates cannot be made.

As our findings indicate, female Moose have been recorded visiting licks more often in the early summer to mid/late summer (Ayotte *et al.* 2008), primarily in June (Fraser and Hristienko 1981) and early July (Parker and Ayotte 2004). Adult male Moose visited our licks in nearly every month of the study (except March), and tended to visit licks earlier in the summer than females as has previously been found by others (Fraser and Hristienko 1981; Tankersley and Gasaway 1983; Rea *et al.* 2013a). Parker and Ayotte (2004) recorded a larger number of male Moose visits to licks in early July. Juvenile Moose were not recorded visiting licks during April and May (Rea *et al.* 2013a) or until the middle (Ayotte 2005) to end of June (Tankersley and Gasaway 1983).

Female Elk visits peaked in May and August, with Elk visiting licks the least in December. Ayotte *et al.* (2008) reported female Elk visits increasing in late May and peaking in late June for both males and females. Elk of all sex and age classes in our study increased visits to licks in May, but without a steep June peak, as reported by Ayotte *et al.* (2008). Differences in peak calving time and how lick use is tied to parturition and lactation demands can vary among regions (Dalke *et al.* 1965; Carbyn 1975; Parker and Ayotte 2004) and may help to explain differences in use, not only for Elk but for all species we recorded using licks.

We also detected differences in visitations between juvenile and male and female deer in our study as did Buss and Harbert (1950), Black (1955), Weeks and Kirkpatrick (1976), Weeks (1978), Kennedy *et al.* (1995), and Atwood and Weeks (2002). However, as with Elk, knowing the background sex and age class ratios of all species visiting licks is required before any attempt is made to attribute reasons to why there may be differences in visitation patterns between sex and age classes.

Conclusions

Our camera traps revealed that mineral licks were used by four species of ungulates year-round, use varied among lick sites, and ungulates using licks did so in different ways, allowing us to reject our null hypothesis that all ungulates used all licks equally and that time of day and season of use would not vary among species. Specifically, our cameras recorded differences in seasonal and daily patterns of use by different ungulates that all spent different amounts of time at various licks. Visits by different sex and age classes also varied among licks which may be attributed to differences in mineral requirements among adult males, adult females, and juveniles but was also likely influenced by background differences in the ratios of these sex and age classes due to fall hunting regulations that favour male harvest.

Why some licks were used more often and for longer periods by certain species remains unknown. Reasons for differential use of licks by species may include both site and landscape level factors such as the presence, density and quality of food and cover, the level of disturbance, the timing of parturition, the presence of other species (including predators) as well as the attributes of the lick itself (Dalke *et al.* 1965; Carbyn 1975; Atwood and Weeks 2002; Jokinen *et al.* 2016). The licks in our study do have slightly different mineral contents and concentrations (D.P.H. unpubl. data) which may help explain differential use by ungulates at different times of the year (Fraser and Hristienko 1981; Tankersley and Gasaway 1983; Atwood and Weeks 2002; Ayotte 2005; Ayotte *et al.* 2008), but requires further study.

The role of mineral licks in the physiological ecology of ungulates remains understudied. Data captured by our cameras, however, showed that mineral licks are important to at least four species of ungulates in north-central BC. A more detailed study of ungulate behaviour recorded by video at licks combined with data from collared animals could be used to study ungulate interactions within and among species at licks, help determine if some of the seasonal use patterns are due to seasonal migrations, and the importance of mineral licks for ungulates. The importance, seasonal use, and reasons for use of licks by ungulates are needed by land managers planning development activities such as forest harvesting in areas where licks are known to occur (Rea *et al.* 2004).

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Literature Cited

Arthur, W.J., and R.J. Gates. 1988. Trace element intake via soil ingestion in pronghorns and in black-tailed jackrabbits. Journal of Range Management 41: 162–166. https://doi.org/10.2307/3898955

Atwood, T.C., and H.P. Weeks. 2002. Sex and age-specific patterns of mineral lick use by white-tailed deer (*Odocoileus virginianus*). American Midland Naturalist 148: 289–296. https://doi.org/10.1674/0003-0031(2002)148[B0289:SAASPO]2.0.CO;2

Ayotte, J.B. 2004. Ecological importance of licks to four ungulate species in north-central British Columbia. M.Sc. thesis, University of Northern British Columbia, Prince George, British Columbia, Canada. https://doi.org/10.24124/2005/bpgub324

Ayotte, J.B., K.L. Parker, J.M. Arocena, and M.P. Gillingham. 2006. Chemical composition of lick soils: functions of soil ingestion by four ungulate species. Journal of Mammalogy 87: 878–888. https://doi.org/10.1644/06-mamm-a-055R1.1

Ayotte, J.B., K.L. Parker, and M.P. Gillingham. 2008. Use of natural licks by four species of ungulates in northern British Columbia. Journal of Mammalogy 89: 1041–1050. https://doi.org/10.1644/07-MAMM-A-345.1

Black, H.C. 1955. Salt use by Mule Deer in the Deschutes National Forest of central Oregon. M.Sc. thesis, Oregon State College, Corvallis, Oregon, USA. Accessed September 2018. https://ir.libraryoregonstate.edu/downloads/th83m263w.

Buss, I.O., and F.H. Harbert. 1950. Relation of moon phases to the occurrence of mule deer at a Washington salt lick. Journal of Mammology 31: 426–429. https://doi.org/10.2307/1375111

Carbyn, L.N. 1975. Factors influencing activity patterns of ungulates at mineral licks. Canadian Journal of Zoology 53: 378–384. https://doi.org/10.1139/z75-050

Chisholm, J. 2018. Seasonal movements and home range size of migratory and non-migratory moose (*Alces alces*) in north-central, British Columbia: implications for winter population surveys. Undergraduate thesis, University of Northern British Columbia, Prince George, British Columbia, Canada.

Cowan, I.M., and V.C. Brink. 1949. Natural game licks in the Rocky Mountain National Parks of Canada. Journal of Mammalogy 30: 379–387. https://doi.org/10.2307/1375213

Dalke, P.D., R.D. Beeman, F.J. Kindel, R.J. Robel, and T.R. Williams. 1965. Use of salt by elk in Idhao. Journal of Wildlife Management 29: 319–332. https://doi.org/10.2307/3798437

D'Eon, R.G., and R. Serrouya. 2005. Mule deer seasonal movements and multiscale resource selection using global positioning system radiotelemetry. Journal of Mammalogy 86: 736–744. https://doi.org/10.1644/1545-1542(2005)086[0736:mdsmam]2.0.co;2

Dormaar, J.F., and B.D. Walker. 1996. Elemental content of animal licks along the eastern slopes of the Rocky Mountains in southern Alberta, Canada. Canadian Journal of Soil Science 76: 509–512. https://doi.org/10.4141/cjss96-063

Environment and Climate Change Canada. 2019. Historical data - climate. Accessed June 2020. https://climate.weather.gc.ca/historical_data/search_historic_data_e.html.

Fraser, D., and H. Hristienko. 1981. Activity of moose and white-tailed deer at mineral springs. Canadian Journal of Zoology 59: 1991–2000. https://doi.org/10.1139/z81-271

Fraser, D., B.K. Thompson, and D. Arthur. 1982. Aquatic feeding by moose: seasonal variation in relation to plant chemical composition and use of mineral licks. Canadian Journal of Zoology 60: 3121–3126. https://doi.org/10.1139/z84-014

Jokinen, M.E., M. Verhage, R. Anderson, and D. Manzer. 2016. Frequency and timing of use of mineral licks by forest ungulates in southwest Alberta. Technical Report T-2016-101. Alberta Conservation Association, Lethbridge and Blairmore, Alberta, Canada. Accessed October 2018. https://www.ab-conservation.com/downloads/

report_series/Frequency_and_Timing_of_Use_of_Mineral_Licks_by_Forest_Ungulates_in_Southwest_Alberta.pdf.

Jones, R.L., and H.C. Hanson. 1985. Mineral Licks, Geophagy, and Biogeochemistry of North American Ungulates. Iowa State University Press, Iowa City, Iowa, USA.

Kennedy, J.F., J.A. Jenks, R.L. Jones, and K.J. Jenkins. 1995. Characteristics of mineral licks used by white-tailed deer (*Odocoileus virginianus*). American Midland Naturalist 134: 324–331. https://doi.org/10.2307/2426301

Klaczek, M., S. Marshall, A. Batho, and M. Anderson. 2017. Density and Composition of moose (*Alces alces*) within the Southern Omineca Region, central British Columbia. Winter 2016–2017. British Columbia Ministry of Forests, Lands and Natural Resource Operations, Prince George, British Columbia, Canada.

Knight, R.R., and M.R. Mudge. 1967. Characteristics of some natural licks in the Sun River area, Montana. Journal of Wildlife Management 31: 293–299. https://doi.org/10.2307/3798319

Kreulen, D.A. 1985. Lick use by large herbivores: a review of benefits and banes of soil consumption. Mammal Review 15: 107–123. https://doi.org/10.1111/j.1365-2907.1985.tb00391.x

Kuzyk, G., S. Marshall, C. Procter, H. Schindler, H. Schnwantje, M. Gillingham, D. Hodder, S. White, and M. Mumma. 2018. Determining factors affecting moose population change in British Columbia: testing the landscape change hypothesis. Ministry of Forests, Lands, Natural Resource Operations and Rural Development, Victoria, British Columbia, Canada.

Lavelle, M.J., G.E. Phillips, J.W. Fischer, P.W. Burke, N.W. Seward, R.S. Stahl, T.A. Nichols, B.A. Wunder, and K.C. VerCauteren. 2014. Mineral licks: motivational factors for visitation and accompanying disease risk at communal use sites of elk and deer. Environmental Geochemistry and Health 36: 1049–1061. https://doi.org/10.1007/s10653-014-9600-0

Parker, K.L., and J.B. Ayotte. 2004. Ecological importance of mineral licks in the Tuchodi Watershed, north-central British Columbia. Final Report, Natural Resources and Environmental Studies, University of Northern British Columbia, Prince George, British Columbia, Canada. Accessed 26 January 2021. http://web.unbc.ca/~parker/MKReports/FINAL%20LICK%20REPORT%20revised.pdf.

Rea, R.V., D.P. Hodder, and K.N. Child. 2004. Considerations for natural mineral licks used by moose in land use planning and development. Alces 40: 161–167.

Rea, R.V., D.P. Hodder, and K.N. Child. 2013a. Year-round activity patterns of moose (*Alces alces*) at a natural mineral lick in north central British Columbia, Canada. Canadian Wildlife Biology and Management 2: 37–41.

Rea, R.V., C.L. Stumpf, and D.P. Hodder. 2013b. Visitations by Snowshoe Hares (*Lepus americanus*) to and possible geophagy of materials from an iron-rich excavation in north-central British Columbia. Canadian Field-Naturalist 127: 26–30. https://doi.org/10.22621/cfn.v127i1.1403

Scheideman, M. 2018. Use and selection at two spatial scales by female moose (*Alces alces*) across central British Columbia following a mountain pine beetle outbreak. M.Sc. thesis, University of Northern British Columbia, Prince George, British Columbia, Canada. Accessed 26 January 2021. https://unbc.arcabc.ca/islandora/object/unbc:58851.

Shackleton, D. 1999. Hoofed Mammals of British Columbia. UBC Press, Vancouver, British Columbia, Canada.

Statsoft. 2009. Statistica for Windows, Version 9.0.

Stepanova, V.V., A.V. Argunov, R.A. Kirillin, and I.M. Okhlopkov. 2017. Time-study of moose (*Alces* L., 1758) geophagia activity in the Central Yakutia. Russian Journal of Theriology 16:185–190. https://doi.org/10.15298/rusjtheriol.16.2.07

Tankersley, N.G., and W.C. Gasaway. 1983. Mineral lick use by moose in Alaska. Canadian Journal of Zoology 61: 2242–2249. https://doi.org/10.1139/z83-296

Van Hecke, T. 2013. Power study of anova versus Kruskal-Wallis test. Journal of Statistics and Management Systems 15: 241–247. https://doi.org/10.1080/09720510.2012.10701623

Weeks, H.P. 1978. Characteristics of mineral licks and behavior of visitng white-tailed deer in southern Indiana. American Midland Naturalist 100: 384–395. https://doi.org/10.2307/2424838

Weeks, H.P., and C.M. Kirkpatrick. 1976. Adaptations of white-tailed deer to naturally occurring sodium deficiencies. Journal of Wildlife Management 40: 610–625. https://doi.org/10.2307/3800555

Wiles, G.J., and H.P. Weeks. 1986. Movements and use patterns of white-tailed deer visiting natural licks. Journal of Wildlife Management 50: 487–496. https://doi.org/10.2307/3801111

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