# Observational Description of Alpine Ungulate Use at Mineral Licks in Southwest Alberta, Canada

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**ABSTRACT** Mineral licks are a unique resource utilized by all ungulate species in North America. The location of a mineral lick can have significant bearing on population distribution. Research on alpine ungulate mineral licks in Alberta has been limited to sampling elemental content of licks and documenting bighorn sheep (*Ovis canadensis*) attraction to man-made mineral licks (e.g., natural gas salty deposits). However, no observational studies of natural mineral licks have been conducted in the southwest region of Alberta. Current guidelines suggest a minimum forested buffer distance of 100 m from licks and restricted industrial activity, mainly helicopter seismic activity, in alpine ungulate zones from 1 July to 22 August. We demonstrate why mineral licks should be a special management concern and not simply a general categorization in industrial operating guidelines. From 2010–2012, we identified, monitored, and assessed 9 alpine mineral licks in southwest Alberta. Initial visits by both bighorns and mountain goats (*Oreamnos americanus*) generally began before licks became snow-free, while routine use commenced shortly after snowmelt, peaking in use during late June and July. Mountain goat licks were essentially visited daily at all times; bighorn licks were visited slightly less, usually during daylight hours. Analysis of animal collar and aerial survey data show both bighorns and mountain goats have high spatial fidelity to lick location. In light of the intensity with which alpine ungulates use mineral licks in southwest Alberta, both the lick itself and the proximity to surrounding topographic cover and food and water resources should be considered in land use decisions. Mineral licks are an essential component of alpine ungulate habitat. The long-term integrity and productivity of alpine ungulate populations throughout their range in North America would benefit from having mineral licks managed around guidelines that are specific to the timing of use and the species involved.

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Natural mineral licks are unique habitat features that are essential to the diet of all North American ungulate species (Jones and Hanson 1985). Ungulates use mineral licks to compensate for dietary deficiencies, typically during late spring and early summer (Jones

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and Hanson 1985) when they are required to make a quick transition from their winter diet to lush green spring forage, which tends to be extremely high in potassium, carbohydrates, and protein but low in fiber (Ayotte 2004). The chemical properties of spring forage reduce the digestive efficiency of the rumen and impair absorption (Kreulen 1985). Forage digestibility is further compromised for species like moose (*Alces alces*) and mountain goat (*Oreamnos americanus*) because they consume forages high in plant defense compounds (Ayotte et al. 2006). Lick soils provide the necessary elements to help stabilize the rumen, as well as supplement demands of lactation and growth (Kreulen 1985, Ayotte et al. 2006).

The location of a mineral lick on the landscape will strongly influence the movement and distribution of ungulate populations (Heimer 1974, Simmons 1982, Watts and Schemnitz 1985). Unlike forage vegetation patterns, which are non-static and vary with natural disturbance patterns over time, mineral licks are a static resource that may be used by many generations of a population over long periods of time. Since these small, localized areas are of significance to the ecology of all ungulate species, their preservation on the landscape is critical. Developing management guidelines that safeguard mineral licks and recognize the importance of preserving connectivity around these habitat features is therefore needed (Dormaar and Walker 1996, Rea et al. 2004).

Currently, Alberta's timber harvest guidelines list mineral licks under the "other species/ sensitive site" section of the document. In this section, mineral licks are universally managed with amphibian sites, bat hibernacula, nesting areas, and wolverine dens — all of which require a forested buffer distance of 100 m (AESRD 2012, 2013). A similar approach was taken as part of the Enhanced Approval Process for industrial activities, such as oil and gas development. Although timing restrictions are in place for bighorn sheep (*Ovis canadensis*) and mountain goat range to protect critical periods like lambing, no restrictions or suggestions are in place for activity in and around mineral licks. Both bighorn sheep and mountain goats are sensitive to a wide variety of human disturbances. The type and level of disturbance can alter the behavior of bighorn sheep and mountain goats to the degree where it can displace them from desirable foraging areas, migration corridors, and secure resting areas (Schoenecker and Krausman 2002, Keller and Bender 2007, St-Louis et al. 2012, Côté et al. 2013). A lack of mineral-lick-specific guidelines is at least in part due to the state of research on mineral licks in Alberta, which has been limited to date. A study conducted in 1992 sampled the elemental content of licks in southern Alberta (Dormaar and Walker 1996); however, species-use data was not collected. One study documented bighorn sheep attraction to man-made mineral licks (e.g., natural gas salty deposits) along the eastern slopes of Alberta (Morgantini and Bruns 1988), but no studies of natural mineral licks have been conducted in the southwest region of Alberta. As a result, our understanding of temporal and spatial use of habitat surrounding mineral licks is limited.

Our objectives were to document lick locations, conduct site assessments, and establish a monitoring approach that would allow us to determine species composition, and timing, and intensity of lick use by bighorns and mountain goats. We hypothesized that the peak period of use for alpine ungulates using mineral licks would be largely driven by plant phenology (the variable timing of seasonal plant growth in the alpine). We expected to see annual variation in the date in which a lick is first visited during the season (based on spring condition and snow pack) and we expected to see consistency in the timing of peak use among years.

## STUDY AREA

The study was conducted in southwest Alberta, Canada (Fig. 1). The western boundary conformed to the Alberta and British Columbia (BC) provincial border, which is also the Continental Divide, while the northern boundary was defined using the northern extent of Wildlife Management Unit (WMU) 402 (upper polygon). The southern boundary was the south boundary of Waterton Lakes National Park (lower dark polygon), which is also the Alberta and Montana border. The eastern boundary was restricted to precipitous terrain within WMUs 400 (central polygon), 402, and Waterton Lakes National Park. The Municipality of the Crowsnest Pass (49°60'N, 114°43'W) is centrally located in the study area.

The study area falls within the Rocky Mountains Natural Region of Alberta, which includes the alpine, subalpine, and montane natural sub-regions. The alpine and subalpine regions receive significant precipitation (~560 mm annually) and the growing season is short and cool in summer (Archibald et al. 1996). Open stands of Engelmann spruce (*Picea engelmannii*), subalpine fir (*Abies lasiocarpa*), and subalpine larch (*Larix lyallii*) generally occur at higher elevations and young, closed stands of fire-successional lodgepole pine (*Pinus contorta*) reside at lower elevations. Dynamic microclimates occur throughout the region as a result of varying aspect, elevation, and substrate (Natural Regions Committee 2006). Soils in the subalpine are dominantly brunisols or regosols, while soils under forest cover at lower elevations consist primarily of luvisols or brunisols (Archibald et al. 1996).

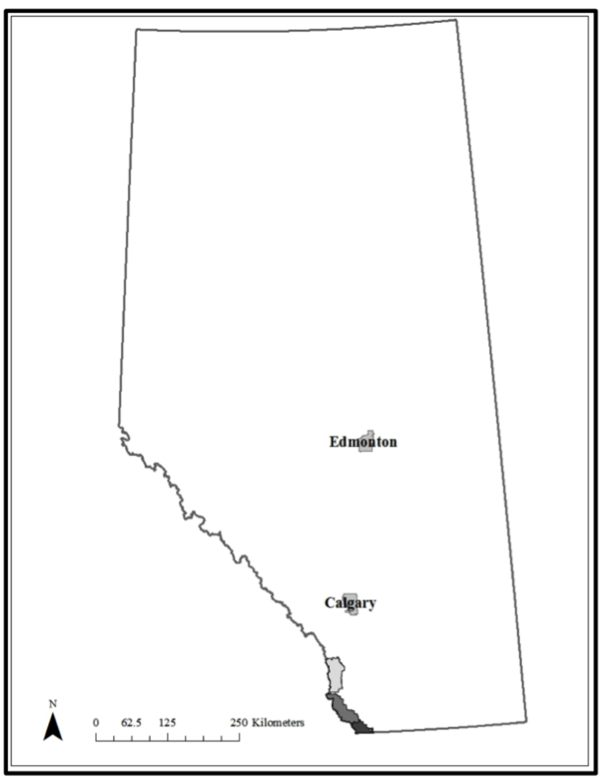


**Figure 1.** Study area within the province of Alberta, Canada. Wildlife Management Unit 402 (upper polygon), WMU 400 (central polygon) and Waterton Lakes National Park (lower polygon).

## METHODS

### Mineral lick site characteristics

We compiled a list of mineral licks from two sources: 1) through a survey of local outdoorsmen, area biologists, and area foresters (Anatum Ecological Consulting Ltd.) and 2) licks identified in Waterton Lakes National Park (B. Johnston, Parks Canada, personal communication). Initially, we visited all potential locations to confirm whether a mineral lick existed. When a lick was located, we gathered the following data: site location, animal sign, lick type, soil type, number of game trails, and the plant community surrounding the lick. We also identified whether there was probable risk of human disturbance. Soil and water samples were collected in 2013 to provide a baseline summary of elemental concentrations at mineral licks. Soil samples were collected from the area of the lick believed to have the highest use (i.e., cavities, excavations, smoothly licked, or chewed areas). All soil samples were analyzed using a digestion technique described by Horvath (2009), the Strong Acid Leachable Metals in soil method. Samples were dried at

≤60°C, sieved, and digested using a strong acid digestion that dissolves most elements that could become environmentally available (K. Beaudet, Maxxam Analytics Inc., personal communication).

**Timing and duration of mineral lick use**

We collected data on bighorn sheep and mountain goat use of mineral licks using remote trail cameras. We placed Reconyx PC800 and PC900 motion-triggered trail cameras at bighorn sheep and mountain goat mineral lick sites from 1 April to 31 October, 2011–2013. We programmed the cameras to obtain 3 photos per trigger at a 5-second interval between photos. The 5-second interval between images allowed time for animals to move into and about the frame, increasing the potential to confidently classify and count the number of animals in a given group. A 5-minute quiet period was set between triggers (set of 3 photos), as this significantly reduced the amount of incoming image data while still providing sufficient observational detail.

To ensure we captured the first wildlife visit at each site, we deployed our cameras in late March to early April each year. To verify that cameras were in the appropriate positions at that time of year (as the sites were still completely snow covered), we put out camera stands and security boxes the previous fall. This was advantageous as we could predetermine where the stand or security enclosure should be placed (i.e., avoiding direct sun, having the ability to clear obstructing vegetation, choosing appropriate distance and height) while the mineral lick was still detectable and snow-free. At sites where no trees were available for mounting cameras, we used portable camera stands. The portable stands were constructed of aluminum tubing and were collapsible for ease of transport. Cameras were placed on trees or stands at a distance of 10 m or less from a mineral lick to ensure animals would be within detection and infrared range.

We created a custom image database to process our camera data (Microsoft Access Version 2010). The database automatically loaded the image number, date, time, and temperature. We manually entered species and minimum group size from a single trigger event (set of 3 consecutive images). Minimum group size was determined by counting the greatest number of animals in the set of 3 photos. As bighorn sheep and mountain goats often visited in large groups, we recognized that outlying individuals could have been missed in images, so our results represent a minimum group size. Bighorn sheep and mountain goat visits were determined when the time between visits was >30 minutes. These visitations included repeat visits and same group visits.

**Spatial fidelity**

We compared mountain goat aerial survey locations (collected from 2004–2013) to 6 mineral licks that we monitored in Waterton Lakes National Park and WMUs 400 and 402. The timing of mountain goat aerial surveys paralleled the timing of mountain goat mineral lick and summer range use. The summer range of mountain goat nursery herds averages 18–25 $km^2$ while male goat range averages 3–4 $km^2$ (Festa-Bianchet and Côté 2008). Singer and Doherty (1985) reported strong fidelity to small annual home ranges by goats when influenced by a mineral lick (females 8.9 $km^2$, males 6.3 $km^2$). We assumed that a 3-km radius around each mineral lick represented the mineral lick zone, which is likely lick influenced fidelity, and a 5-km radius represented summer home range of those goats that used a particular lick on a recurring basis. We plotted aerial survey points collected from 2004–2013 and tallied those goat counts within a 3-km and 5-km radius of each mineral lick (ArcMap 10.1, software by ERSI).

To build upon our evaluation of alpine ungulate fidelity to mineral licks, we conducted a retrospective analysis of bighorn sheep

**Figure 2.** Unstable slope mineral licks were used by bighorn sheep and mountain goats, where they consumed clay at cavities.

movements in relation to mineral licks that we monitored. Site fidelity to mineral licks by wild sheep has been shown to be as high as 100% by ewes (Heimer 1974). Female sheep, in particular, will focus their summer activity around mineral licks (Heimer 1974, Simmons 1982). Bighorn ewe summer range averages 30 km$^2$ in size (Festa-Bianchet 1986). Our data on sheep movement came from 2 studies. First, we used movement data from 3 Global Positioning System (GPS) collared bighorn sheep from our Yarrow-Castle research (Jokinen et al. 2008). Second, we used data from 3 of 13 bighorn sheep that were collared in the Waterton Lakes National Park region (K. Keating, unpublished). These sheep were chosen because they clearly visited the mineral licks that we monitored and we wanted to illustrate bighorn use of the mineral lick zone over time.


**Figure 3.** Site 60 represents an example of a timber flat surface mountain lick in southwest Alberta. Note the hard packed lick area surrounded by vegetation and forest cover. These licks contained a slight seep at the source and were saturated throughout the season.

## RESULTS

### Mineral lick site characteristics

Across the study area, 9 alpine ungulate mineral licks were monitored using trail cameras. Of these, 3 were primarily used by bighorns, 5 by mountain goats, and 1 was shared equally between both species. A few bighorns passed through one of the mountain goat licks (site 78) but did not visit with regularity or for an extended time. Two bighorn licks and 3 mountain goat licks were monitored for 2 seasons, while the other 2 bighorn and 3 mountain goat licks were monitored for 1 season (including the shared lick).

When conducting field assessments at alpine mineral licks, animals were often present during the months of July and August. Goats used mineral licks at all hours of the day and bighorn tended to target morning and afternoon periods, thus there was no favorable time when disturbance of the animals could be avoided.

Alpine licks were usually located in rocky areas having little to no vegetation nearby; therefore, an organic layer was essentially absent and the disturbed area lacked hedging, typical of forest mineral licks (Jokinen et al. 2015). Alpine licks in our study region tended toward 3 distinct varieties. We termed the 3 lick types as unstable steep slope, timber flat surface, and rock face (Fig. 2–4).

Unstable, steep-slope licks (Fig. 2) were located on rocky slopes, having granule to boulder sized fragments, no vegetation, and contained deep cavities dug by bighorns or goats to access clay substrate. The surface of these licks eroded and changed in appearance each year with spring run-off. Timber flat surface licks were located at a lower elevation, at the forest edge, and somewhat removed from alpine ungulate escape terrain. Vegetation and forest flanked these licks; however, an organic layer was present but thin at the disturbance. Because these licks were located at the fringe of alpine ungulate habitat, they were often shared with forest ungulates, resulting in more frequent carnivore detections (Fig. 3). We documented instances where carnivores caused bighorn sheep and mountain goats to flee; however, confrontations were only observed at timber flat surface licks. Rock face licks were located along cliff faces, well within escape terrain and were obscure, as the rocky terrain seldom offered clues of animal use (Fig. 4). Essentially, animals frequenting a cliff area helped identify the location of a rock lick.

Alpine mineral licks were at elevations averaging 1,918 m (SE = 38.90) and 128 $m^2$ (SE = 13.26) in size (Table 1). Elevation at bighorn sheep licks averaged 1,874 m; elevation at mountain goat licks averaged


**Figure 4.** Site 78 is an example of a rock face lick used by mountain goats in southwest Alberta.

1,954 m. Hedging was insignificant at the majority of alpine licks in this study, as the substrate was primarily rock and there was little to no organic layer. Hedging occurs when trampling of hooves abruptly carve at the organic layer bordering a lick. Evidence for rubs was sporadic due to the lack of vegetation at most of the alpine licks; however, bighorn rams often rubbed their horns on Krumholtz conifers. Most of the alpine licks held moisture throughout the season and it appeared to be the seeping water at rock face licks that functioned as the mineral channel.

Game trails leading away from the alpine licks were extremely apparent in the direction of the escape terrain and remained recognizable until they reached solid rock faces. Rock face licks often lacked evidence of game trails

**Table 1.** Description of alpine ungulate mineral licks assessed in southwest Alberta, 2011−2013.

| Site | Elev (m) | Hedging[c] | Digs[d] | Beds[e] | Rubs[f] | Browse[g] | Lick Type | Lick Soil | Soil Type | Lick Area ($m^2$) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1[a] | 1,647 | Yes | No | No | No | Yes | Dry | Dry | Sand/ Cobble | 108.6 |
| 9 | 1,683 | No | Yes | Yes | No | No | Unstable Steep Slope | Moist | Clay | 450.0 |
| 12 | 1,893 | No | No | Yes | No | Yes | Timber Flat Surface | Moist | Sandy Loam | 100.0 |
| 13 | 2,260 | No | Yes | Yes | No | No | Unstable Steep Slope | Moist | Boulder/ Gravel/Clay | 225.0 |
| 60[b] | 1,943 | No | No | Yes | No | Yes | Timber Flat Surface | Moist | Silt/Loam | 80.0 |
| 78 | 1,720 | No | No | Yes | No | No | Rock Face | Moist | Rock | 12.0 |
| 81[b] | 2,205 | Yes | No | Yes | No | Yes | Timber Flat Surface | Moist | Sandy Loam | 11.0 |
| 83 | 1,959 | No | Yes | Yes | No | No | Unstable Steep Slope | Moist | Boulder/ Gravel/Clay | 144.0 |
| 84 | 1,950 | No | No | Yes | No | No | Rock Face | Moist | Rock | 25.0 |

[a] This site holds water early in the season but dries up after snowmelt, not a typical seeping lick
[b] This site hosts both alpine and forest species
[c] Hedging: an abrupt edge created by trampling of hooves on an organic layer
[d] Dig: cavities or excavations created by ungulates
[e] Beds: sign of bedding depressions
[f] Rubs: sign of horn or antler rubbing
[g] Browse: sign of whether vegetation immediately surrounding lick is browsed

because they were located on solid rock faces. The immediate area surrounding an alpine lick can provide evidence needed to determine the species using it. During the peak season of lick use, alpine licks almost always had a distinct barn-like odor, and fresh urine, scat, and tracks were observed. Clumps of molted hair on the ground or snared along vegetation of game trails were also found. Bedding areas were typically observed at alpine licks.

We monitored a bighorn lick (site 1) that likely resulted from several years of cattle mineral block placement at its location. Cattle graze within the forest reserve in our study area and the lessee had placed a mineral block at this lick location in 2012. Bighorn sheep and cattle were observed visiting the site at the same time in 2012. Although mineral blocks were not placed at site 1 each year, the minerals likely leach to the surface making them available to animals when water pools in the area during spring melt and precipitation. Bighorn visitations were comparable during year 1 of monitoring site 1, when no mineral block was available; however, domestic cattle occurrences increased substantially from year 1 to year 2 (the year a mineral block was on site).

Bighorn sheep mineral licks tend to contain higher concentrations of soil elements when compared to mountain goat mineral licks (Fig. 5). The mineral lick having both bighorn and goats visiting had the highest concentrations of calcium and magnesium. In general, soil elemental values were relatively similar between lick types, with exception of calcium and sodium levels observed at rock face licks (Fig. 6). Calcium and sodium

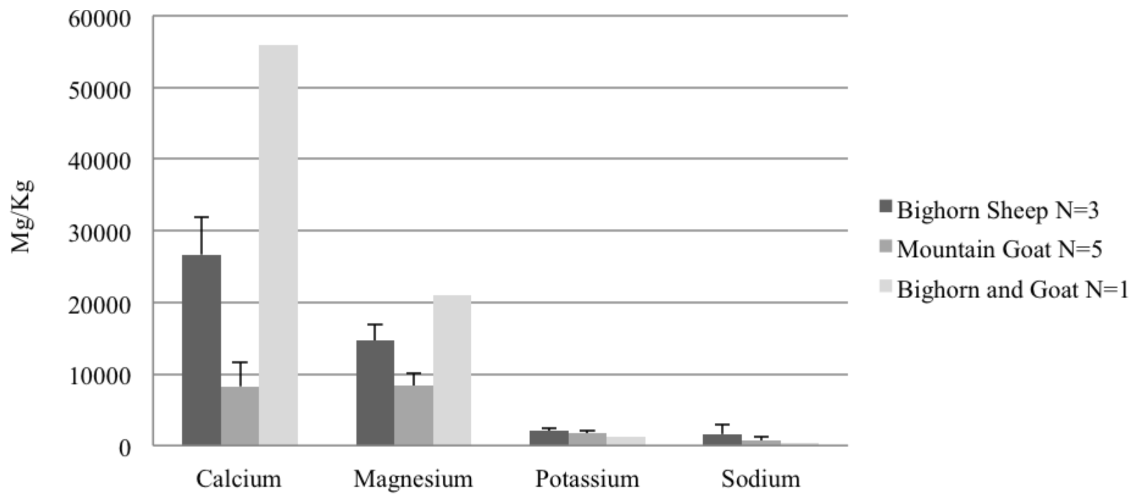


**Figure 5.** Mean (+SE) concentration of soil elements at bighorn sheep and mountain goat mineral licks in southwest Alberta, 2013.

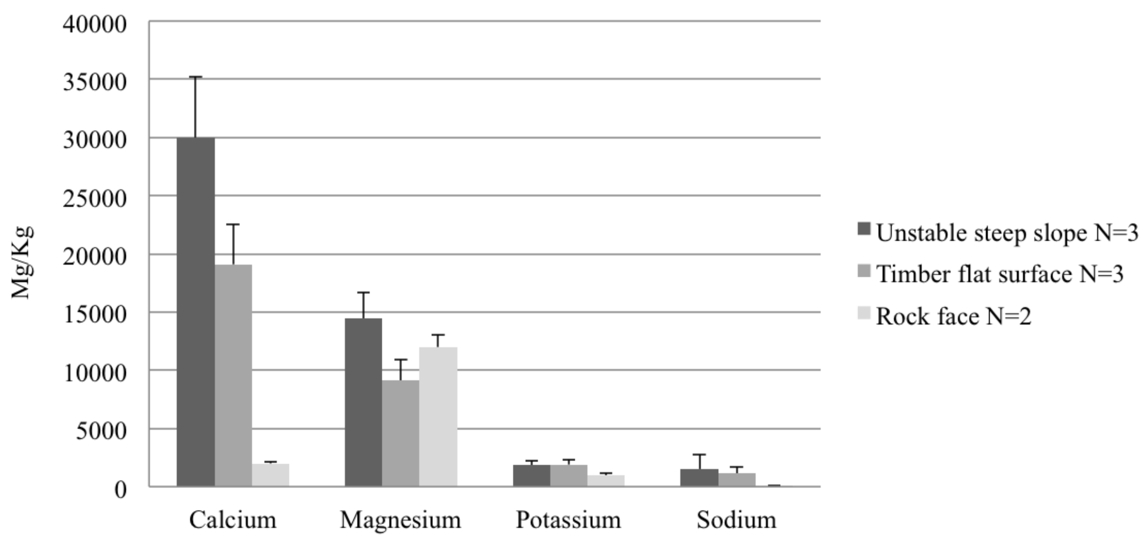


**Figure 6.** Mean (+SE) concentration of soil elements among 3 mountain ungulate lick types in southwest Alberta, 2013.

values were less at rock face licks (2,000 and 84 mg/kg, respectively) when compared to unstable steep slope (30,000 and 1,520 mg/kg, respectively) and timber flat surface licks (19,100 and 1,125 mg/kg, respectively).

## Timing of use

*Annual initiation.* — Mountain ungulate use of alpine licks began once the snowpack receded from surrounding terrain and likely coincided with animals shifting from winter to summer range. The earliest use of a mountain goat lick was 15 May. The earliest recorded use of a bighorn sheep lick was 1 April, though use may have actually been initiated prior to this as the site was snow-free when we started camera monitoring at this site (Table 2). Mineral licks that were visited regularly by bighorn sheep were snow-free up to 2 months prior to those mineral licks that were primarily visited by mountain goats, making them available earlier in the season compared to mountain goat licks. Bighorn sheep mineral licks tend to be situated on exposed slopes that are largely snow-free by late April and, as a result, are utilized by bighorns prior to lambing. The peak lambing

**Table 2.** Mineral lick snow-free date, date of first visit by bighorn sheep adults lambs and mountain goat adults and kids in southwest Alberta, 2011−2013.

| | Snow-free date | | | Bighorn sheep first visit | | | Lamb first visit | | |
|---|---|---|---|---|---|---|---|---|---|
| Site | 2011 | 2012 | 2013 | 2011 | 2012 | 2013 | 2011 | 2012 | 2013 |
| 1 | 30 March[a] | 04 April[a] | -- | 01 April | 06 April | -- | 22 June | 16 June | -- |
| 9 | -- | 26 April[a] | 05 May | -- | 27 April | 04 April | -- | 01 June | 29 May |
| 78 | -- | early May | -- | -- | 02 June | -- | -- | 05 Oct. | -- |
| 81 | -- | -- | 18 June[a] | -- | -- | 18 June[a] | -- | -- | 27 June |
| 83 | -- | -- | 16 May[a] | -- | -- | 19 May | -- | -- | 06 June |

| | Snow-free date | | | Mountain Goat first visit | | | Kid first visit | | |
|---|---|---|---|---|---|---|---|---|---|
| Site | 2011 | 2012 | 2013 | 2011 | 2012 | 2013 | 2011 | 2012 | 2013 |
| 12 | 16 July | 06 July | -- | 21 June[b] | 22 May | -- | 04 July | 29 June | -- |
| 13 | mid-June | 16 June | -- | 20 June[b] | 15 May | -- | 20 June[b] | 10 June | -- |
| 60 | 08 July | 13 July | -- | 21 June | 12 June | -- | 28 June | 15 June | -- |
| 78 | -- | early May | -- | -- | 30 May | -- | -- | 30 June | -- |
| 83 | -- | -- | 16 May[a] | -- | -- | 17 May | -- | -- | 10 June |
| 84 | -- | -- | 22 June[a] | -- | -- | 28 June | -- | -- | 30 June |

[a] camera set on this date and lick was snow-free by this time
[b] camera set on this date and still snow covered
-- not surveyed this year

period in southern Alberta occurs during the first 2 weeks of June (Jokinen et al. 2008).

*Persistent and peak use.* — We found there to be 2 distinct timeframes associated with persistent use at alpine mineral licks. On average, licks at lower elevations having less snowfall, and greater exposure to winds and sunlight experienced habitual visitation by early May (i.e., bighorn licks) (Table 3A1). In contrast, those licks at high elevation and typically sheltered and having high wind-deposited snow were used consistently by early July, immediately after snows dissolved from the lick (i.e., mountain goat licks) (Table 3B1). Sites 78 and 83 were an exception to this, as they were snow-free earlier than most mountain goat licks and goats appeared to visit these 2 sites by late May or early June. Although visits started as early as May, and despite being snow-free by early May (Table 2), constant use at site 78 did not occur until July.

Bighorn sheep licks had the highest number of visits during the months of May and June (Table 3A2), while visits to mountain goat licks did not begin until the latter part of June (Table 3B2). Site 83 (monitored in 2013) was one exception to this 2-month range in the onset of mineral lick use by bighorn sheep and mountain goats. Site 83 was the only site where both bighorn sheep and mountain goats visited regularly despite the environment being more typical of bighorn sheep licks (i.e., exposed to wind, sun, less snowfall overall). Mountain goat use at site 83 was initiated in May, peaked during June and July, and tended to slow during the month of August. Peak use at bighorn sheep and mountain goat mineral licks in the study area occurred during late June and July, respectively. Mountain goats visited mineral licks on a daily basis during the months of July and August.

**Table 3A1.** Mean (+SE) number of days during the months of May through October when bighorn sheep visited an alpine lick in southwest Alberta, 2011−2013. Only 1 bighorn sheep lick was monitored in 2011. One lick was not monitored May 2013.

| Year | # of sites | May | June | July | Aug | Sept | Oct |
|---|---|---|---|---|---|---|---|
| 2011 | 1 | 18 | 14 | 16 | 8 | 4 | 3 |
| 2012 | 2 | 20 (8) | 20 (10) | 16 (9) | 19 (5) | 16 (3) | 7 (3) |
| 2013 | 3 | 19 (10) | 20 (5) | 21 (5) | 19 (4) | 13 (4) | 13 (4) |

**Table 3A2.** Mean (+SE) number of mineral lick visitations by bighorn sheep in southwest Alberta during the months of May through October, 2011−2013. A visitation was determined when time between visits was greater than 30 minutes. Only one bighorn lick was monitored in 2011. One lick was not monitored May, 2013.

| Year | # of sites | May | June | July | Aug | Sept | Oct |
|---|---|---|---|---|---|---|---|
| 2011 | 1 | 36 | 32 | 30 | 9 | 4 | 3 |
| 2012 | 2 | 88 (67) | 100 (87) | 78 (67) | 71 (39) | 41 (16) | 10 (1) |
| 2013 | 3 | 82 (61) | 81 (25) | 65 (20) | 53 (12) | 32 (7) | 34 (16) |

*Time of day and duration of use.* — Bighorn sheep utilized mineral licks less at night than in the morning and afternoon (Fig. 7). At some bighorn licks, night visitation was almost non-existent, whereas goats were visiting some licks in equal amounts throughout the day. The average visit duration was variable by time of day (Fig. 8) but both bighorn and mountain goats remained at mineral licks for longer periods during daylight hours. Day bedding areas were usually located upslope from a lick or individuals bedded at the lick itself during visitations. Bighorn sheep visited mineral licks an average of 3 times (SE = 0.54) during a single day, while mountain goats visited at a slightly higher frequency, averaging 5 visitations (SE = 0.58) per day.

The maximum group size observed at a lick for both bighorn sheep and mountain goats was 24 individuals. Bighorn sheep and mountain goats both visited in large group sizes and seldom visited a mineral lick alone (Fig. 9). On average, bighorn sheep visited in larger group sizes when compared to goats, with exception of the nighttime period.

In general, we avoid flying mountain goat aerial surveys during the afternoon, as goats tend to take cover when temperatures are highest. Despite this, mountain goats visited licks on a daily basis during the warmest months and visitations were slightly higher

**Table 3B1.** Mean (+SE) number of days during the months of May through October where mountain goat visited an alpine lick in southwest Alberta, 2011−2013. Two sites were not monitored May, 2011. A camera malfunctioned at 1 site July−August, 2012. During 2013, 1 site was not monitored in May and its camera was removed mid-September.

| Year | # of sites | May | June | July | Aug | Sept | Oct |
|---|---|---|---|---|---|---|---|
| 2011 | 3 | 0 | 8 (2) | 30 (1) | 27 (2) | 8 (1) | 8 (6) |
| 2012 | 4 | 3 (2) | 11 (2) | 29 (2) | 21 (5) | 18 (4) | 4 (1) |
| 2013 | 2 | 9 | 13 (11) | 24 (4) | 10 (1) | 0 | 3 |

**Table 3B2.** Mean (+SE) number of mineral lick visitations by mountain goats in southwest Alberta during the months of May through October, 2011−2013. A visitation was determined when time between visits was greater than 30 minutes. Two sites were not monitored May 2011. A camera malfunctioned at 1 site July−August 2012. During 2013, 1 site was not monitored in May and its camera was removed mid-September.

| Year | # of sites | May | June | July | Aug | Sept | Oct |
|---|---|---|---|---|---|---|---|
| 2011 | 3 | 0 | 43 (29) | 211 (38) | 174 (54) | 27 (9) | 23 (19) |
| 2012 | 4 | 3 (3) | 61 (28) | 119 (17) | 104 (43) | 86 (30) | 9 (4) |
| 2013 | 2 | 24 | 74 (71) | 105 (55) | 22 (3) | 0 | 18 |

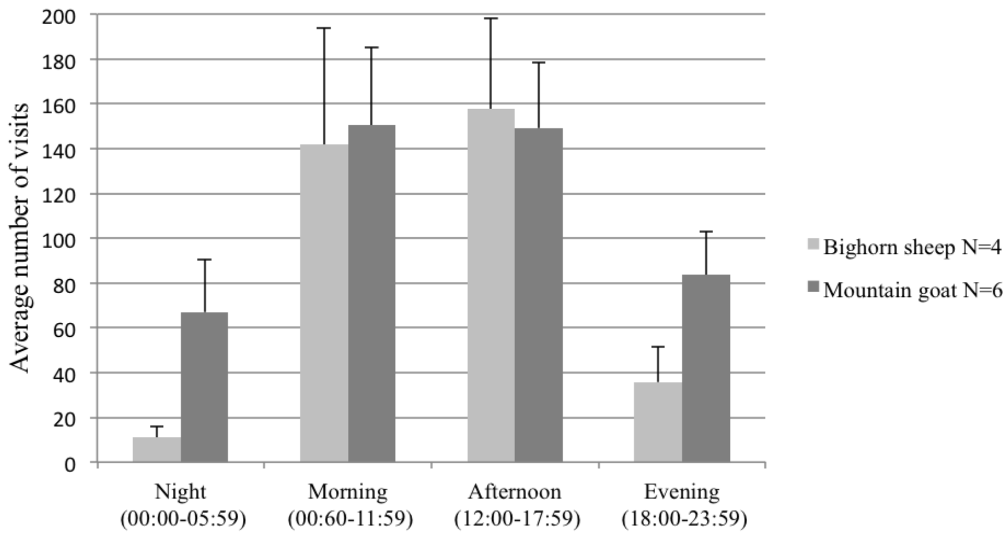


**Figure 7.** Seasonal mean (+SE) number of bighorn sheep and mountain goat visitations (by time of day) at alpine mineral licks in southwest Alberta, 2011–2013. A visitation was determined when time between visits was greater than 30 minutes.

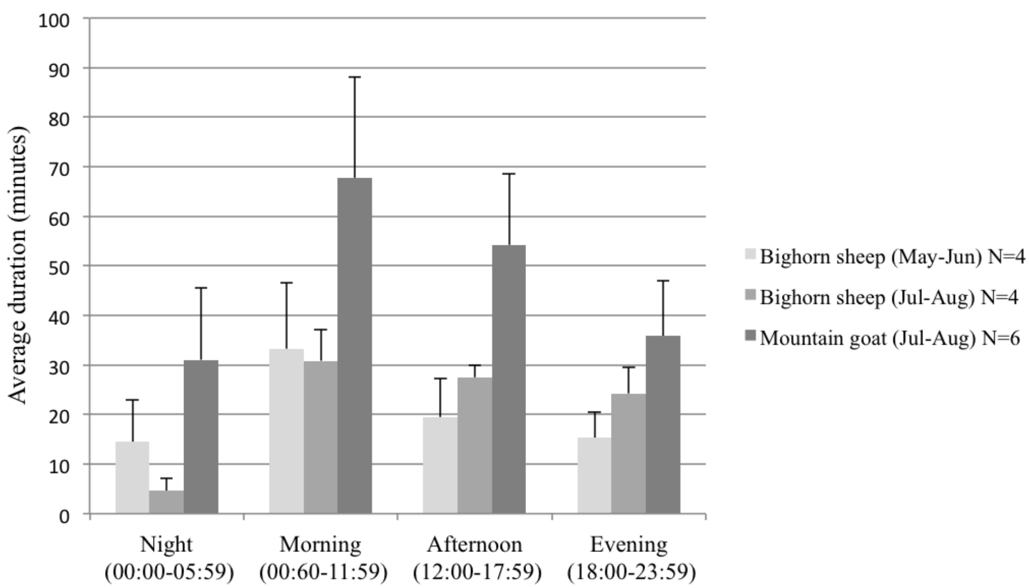


**Figure 8.** Mean (+SE) duration of mineral lick visits (by time of day) by bighorn sheep (May–Jun/Jul–Aug) and mountain goats (Jul–Aug) during peak season, in southwest Alberta, 2011–2013. A visitation was determined when time between visits was greater than 30 minutes.

during the afternoon period at some licks. We observed instances where afternoon sun was shadowed by the mountain, creating tolerable afternoon temperatures at the mineral lick, even during the warmest times of the day.

**Spatial fidelity of mountain goats in relation to alpine mineral licks**

We assessed mountain goat aerial survey counts that were within a 3-km and 5-km radius around each monitored mineral lick, but we concede that we likely did not capture every mountain goat mineral lick available within these survey regions, particularly WMU 400. Only 1 of the 6 mountain goat mineral licks that we monitored was located within this

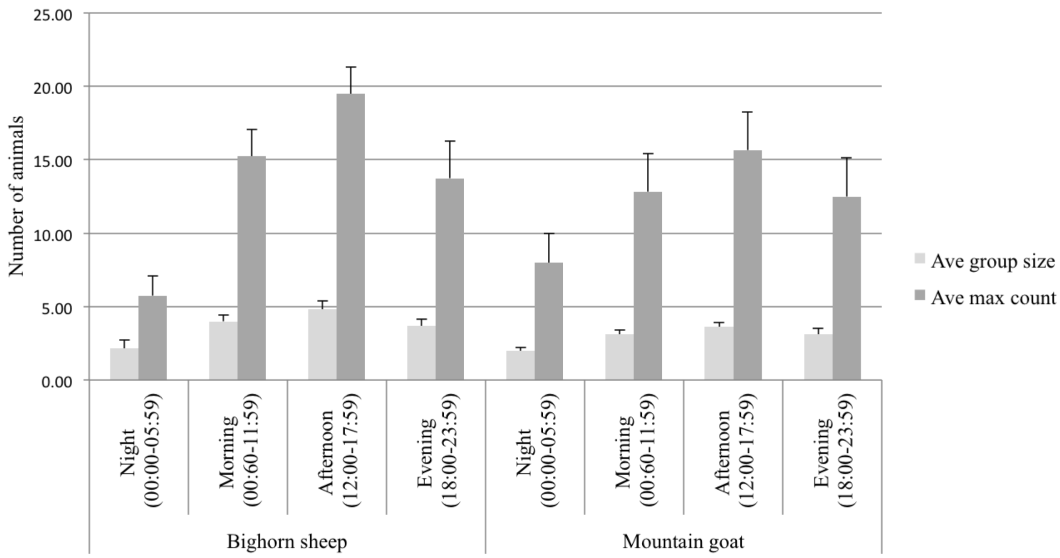


**Figure 9.** Mean (+SE) group size and maximum count of bighorn sheep and mountain goats at mineral licks by time of day in southwest Alberta, 2011−2013. Our maximum counts represent a minimum group size.

unit. According to summer goat aerial survey counts in WMU 400, an average of 22% of the mountain goat population is observed within 3 km of site 12 (Table 4A).

Three mountain goat mineral licks (i.e., sites 78, 83 and, 84) were monitored within Waterton Lakes National Park. Two of these were rock face licks and likely serve small, localized herds. On average, 64% of the mountain goat population in Waterton Park is observed within 5 km of these 3 mineral licks (Table 4B).

In WMU 402, 47% of the goats in that population are located within 3 km of sites 13 and 60 (Table 4C). Similar to Waterton Park, greater than half of the goat population in WMU 402 (58%) was observed within 5 km of a mineral lick, on average. Site 13 is located approximately 4 km from the BC boundary although we feel that the majority of the goats occupying this area remain on the Alberta side of the divide. Site 60 is located 1 km from the BC boundary and we are certain that goats in this area commonly use both sides of the Continental Divide.

**Spatial fidelity and movement of bighorn sheep in relation to alpine mineral licks**

In the Yarrow-Castle region (southern half of WMU 400), a GPS-collared bighorn sheep ewe maintained a distance of 3 km or less from site 9 from April-July 2004 (Fig. 10). This ewe's home range was approximately 25 $km^2$, condensing to a spring and summer range of 8 $km^2$, focusing around the mineral lick zone. The ewe did visit the lick during September; however, she began to extend her movements outside the 3-km range during this time (Fig. 11).

Two additional GPS-collared bighorn sheep ewes migrated to the mineral lick from a separate mountain complex in the study area during 2003 and 2004 (Jokinen et al. 2008). These ewes traveled 17 km to reach the lick from their respective range. One of those individuals migrated 2 consecutive years during the same timeframe, utilizing the same stopover in both instances (Fig. 12). Both ewes traveled to the mineral lick on separate occasions; however, both utilized the stopover before spending time inside the 3-km mineral lick zone (Fig. 13). In addition to GPS collared individuals, 7 very high frequency collared bighorns (and several unmarked bighorns) were observed utilizing the mineral lick during the study (Jokinen et

**Table 4A.** Mountain goat aerial survey counts associated with mineral lick 12 in Wildlife Management Unit 400 of southwest Alberta, 2004–2011.

| Year | Date surveyed | Total goat count (entire WMU) | % <3km of lick (site 12) | % 3-5km of lick (site 12) | % 0-5km of lick (site 12) |
|---|---|---|---|---|---|
| 2004 | 13 July | 207 | 25 | 0 | 25 |
| 2005 | 07 July | 248 | 21 | 11 | 32 |
| 2007 | 29 June | 193 | 22 | 17 | 39 |
| 2008 | 03 July | 218 | 13 | 16 | 29 |
| 2011 | 28 July | 146 | 30 | 3 | 33 |
| Mean | | 202 | 22 | 9 | 32 |

**Table 4B.** Mountain goat aerial survey counts associated with mineral licks 78, 83, and 84 in Waterton Lakes National Park, Alberta, 2004–2011.

| Year | Date surveyed | Total goat count (in WLNP) | % <3km of lick (sites 78, 83, 84) | % 3-5km of lick (sites 78, 83, 84) | % 0-5km of lick (sites 78, 83, 84) |
|---|---|---|---|---|---|
| 2004 | 14 July | 80 | 35 | 23 | 58 |
| 2005 | 04 July | 93 | 42 | 11 | 53 |
| 2007 | 26 June | 74 | 51 | 26 | 77 |
| 2008 | 01 June | 106 | 48 | 24 | 72 |
| 2011 | 25 July | 126 | 38 | 20 | 58 |
| Mean | | 96 | 43 | 21 | 64 |

**Table 4C.** Mountain goat aerial survey counts associated with mineral licks 13 and 60 in Wildlife Management Unit (WMU) 402 of southwest Alberta, 2006–2013.

| Year | Date surveyed | Total goat count (entire WMU) | % <3km of lick (sites 13 and 60) | % 3-5km of lick (sites 13 and 60) | % 0-5km of lick (sites 13 and 60) |
|---|---|---|---|---|---|
| 2006 | Not available | 142 | 42 | 8 | 50 |
| 2009 | 12 July | 186 | 57 | 3 | 60 |
| 2010 | 26 June | 148 | 36 | 28 | 64 |
| 2013 | 19 July | 173 | 51 | 5 | 56 |
| Mean | | 162 | 47 | 11 | 58 |

al. 2008) and in subsequent years following the study.

We observed similar migratory behavior in the Waterton bighorn sheep population. For example, a 9-year-old GPS-collared ram traveled approximately 10 km from his typical range to end his northbound journey at site 83 (Fig. 14). Not only did bighorn sheep rams make extensive movements for short visits to the mineral lick but they also spent considerable amounts of time in the mineral lick zone, utilizing the lick over several days (Fig. 15). Ram 06−08 spent 6 days in the mineral lick zone and appears to have visited the lick on 2 occasions. This ram's greatest step-lengths were made while traveling to and from the mineral lick and it appears that he visited the lick a second time before leaving the area. Bighorn ewes also made dedicated movements to the mineral lick zone (Fig. 16). Ewe 06−03 traveled approximately 18 km during one day to spend the next 5 days in and around the mineral lick zone of site 83.

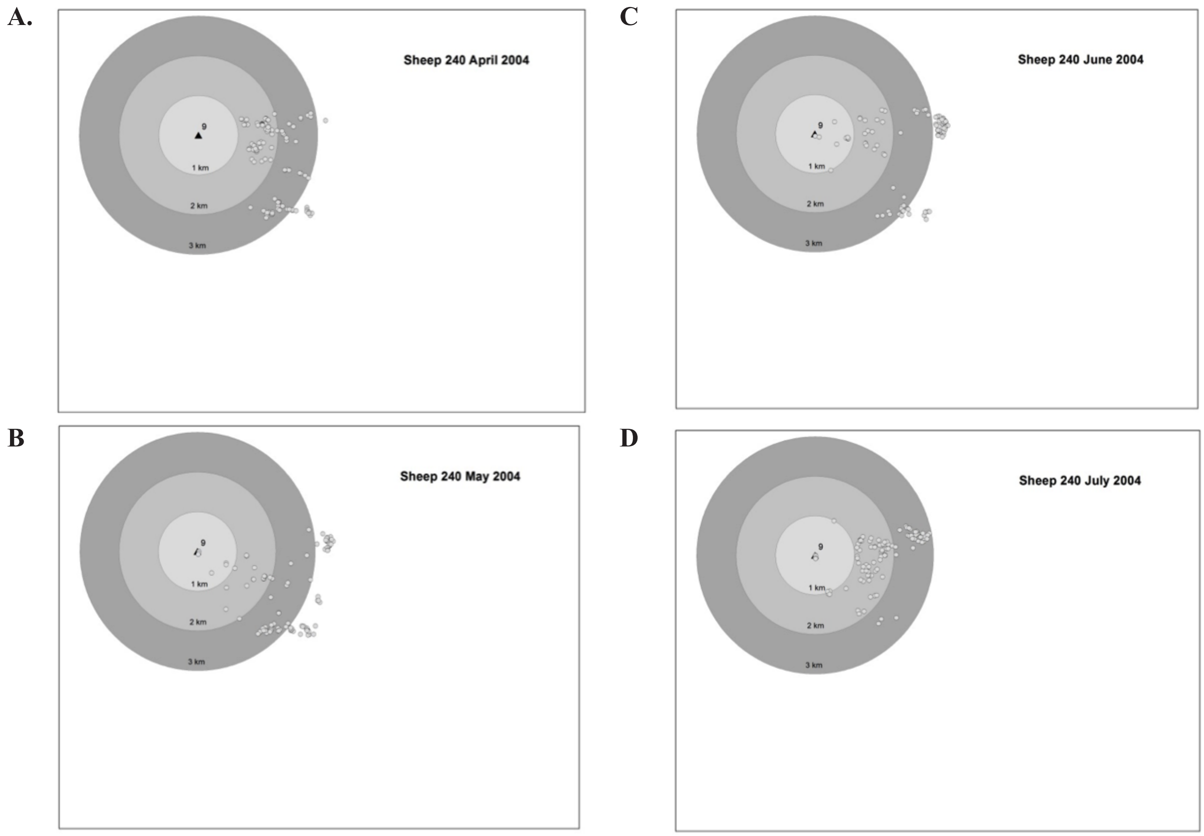


**Figure 10.** Bighorn sheep ewe (240) monthly movements in relation to lick 9 during April (A), May (B), June (C) and July (D) 2004 in the Yarrow-Castle region of southwest Alberta.

## DISCUSSION

For several decades, wildlife managers have realized that natural mineral licks are a special habitat feature on the landscape. This study is among the first to monitor bighorn sheep and mountain goat mineral lick use where observation is uninterrupted over time (i.e., using trail cameras), having the ability to capture every visit by any animal in a population. Most studies have relied on visual observation and GPS collar data from select individuals. Our trail camera monitoring provides an improved understanding of when mountain ungulate populations use mineral licks. For a habitat feature to be recognized as requiring special attention, collecting data such as we have on bighorn sheep and mountain goat mineral licks, is an essential first step to making informed decisions when land use considerations arise.

Based on our observations, alpine ungulate mineral licks are not as common on the landscape as forest mineral licks. Bighorn sheep and mountain goats visit mineral licks in sizable numbers and they are habitually visiting on a daily basis and multiple times throughout the day. Therefore, each bighorn and mountain goat lick on the landscape should inevitably hold high value as a significant habitat feature encompassed by critical summer range.

### Mineral lick site characteristics

Bighorns generated the greatest number of camera triggers at site 1 and we consider site 1 to be an important bighorn sheep mineral lick even though it may originate from a man-made source. Bighorn sheep notoriously frequent artificial mineral sources and, in our region, we have observed bighorn sheep licking vehicles, roadsides, railways, oil and gas structures and

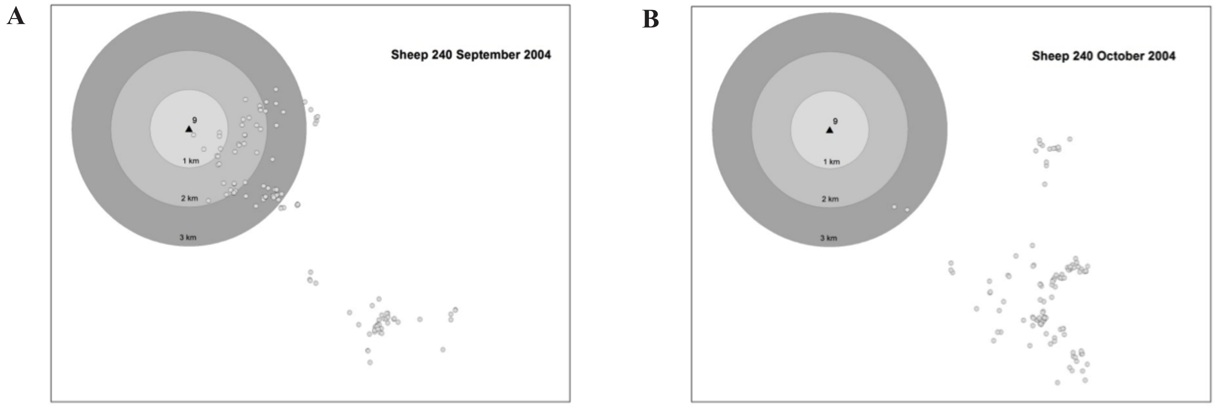


**Figure 11.** Bighorn ewe (240) monthly movements in relation to lick 9 during September (A) and October (B) 2004 in the Yarrow-Castle region of southwest Alberta.

areas where humans have urinated. Some National Parks in the United States have urged visitors not to urinate along hiking trails because goats have become aggressive towards humans in those areas where they have become habituated to urine salt deposits (U.S. Forest Service 2014).

Alpine ungulates in our region may encounter artificial mineral sources along the Continental Divide because it is legal to place mineral blocks out as an attractant for wild species in British Columbia. This practice is illegal in Alberta. We observed mineral blocks along mountain ridges on the BC side of the divide. Ungulates can establish an attraction to these areas years after the mineral block has been depleted since the minerals seep into the substrate below and leach back to the surface over time. Mincher et al. (2008) bring up the important point that the introduction of man-made mineral blocks to bighorn sheep can interfere with natural mineral lick use, which can limit bighorn intake of minor elements that are only available from a natural mineral source.

Mountain goat licks in our study had roughly half the amount of calcium and sodium concentrations as bighorn sheep licks. Calcium and sodium levels were lower at rock face licks compared to other licks; however, rock face lick values were generated from water samples rather than soil samples. Our alpine ungulate mineral lick elemental analyses resulted in higher concentrations than those reported by Ayotte (2004) in BC, in which the highest reported calcium (15,419 mg/kg) concentration was half that of our average for bighorn licks, though it was similar in concentration to our mountain goat licks. The highest concentrations of magnesium (3,225 mg/kg), sodium (118 mg/kg) and potassium (418 mg/kg) reported by Ayotte (2004) at his sheep and mountain goat licks were all less than our concentrations. Magnesium concentrations in our region are more than double than those reported by Ayotte (2004).

Rock face licks may serve as a concentrated source of magnesium for goats as other elements at rock face licks were extremely low in concentration. It appears that the seep (drinking) at rock face licks provide ungulates with mineral elements. Ayotte et al. (2006) mention that inflow waters at wet licks are particularly high in magnesium. Magnesium may be sought after by ungulates when high levels of dietary potassium (a result of consuming lush spring vegetation) inhibit nutrient absorption (Jones and Hanson 1985, Heimer 1988, Ayotte et al. 2006).

Site 78 was 1 of 2 rock face licks that we suspect served a local population of goats. This lick was snow-free by early May as it was located on a relatively steep, south-facing

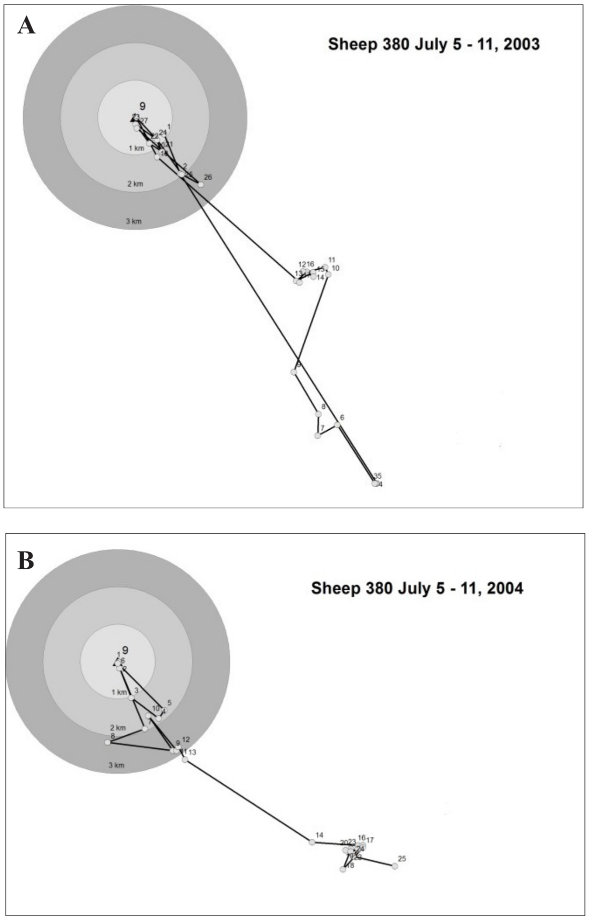


**Figure 12.** Bighorn ewe (380) movement and stopover in relation to lick 9 during July 2003 (A) and July 2004 (B) in the Yarrow-Castle region of southwest Alberta.

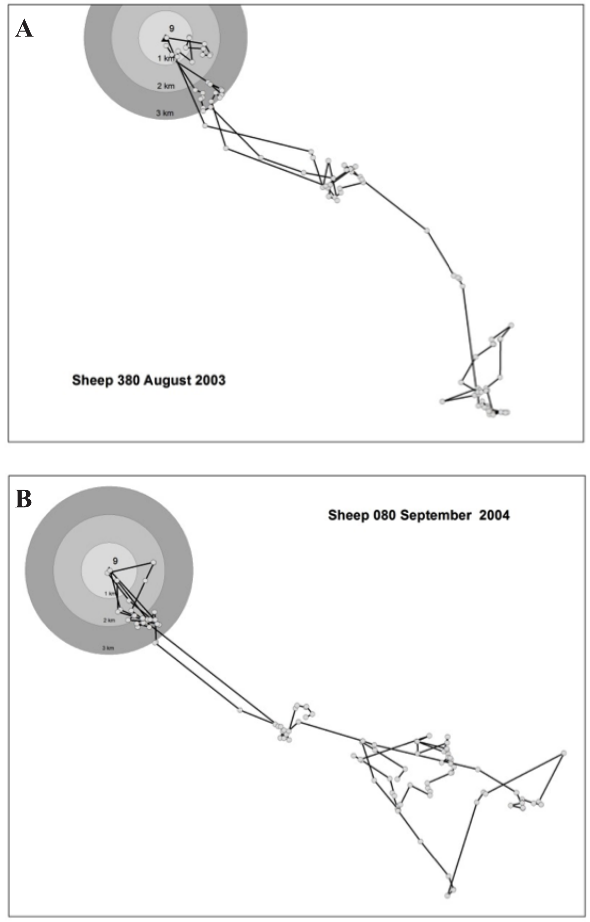


**Figure 13.** Bighorn movements and stopovers in relation to lick 9 by ewe #380 (A) August 2003 and ewe #080 (B) September 2004 in the Yarrow-Castle region of southwest Alberta.

rocky bluff. However, mountain goats did not visit site 78 with regularity until July, visiting daily in July and August. This delay could be related to seasonal migration or it may be magnesium driven during the onset of lactation or change in emerging vegetation.

Researchers in BC found mountain goats accessing minerals by digging cavities under trees where the subsoil was completely dry (Poole et al. 2010); however, we are unaware of any tree licks occurring in our region.

### Timing of use

Nearly all alpine ungulates fed for an extended period during each mineral lick visit. Bighorn sheep and mountain goats are herd species; therefore, the number of animals in a herd influences the duration of a particular visit (i.e., the larger the herd, the greater potential for an extended visit time, as some animals bed while others feed at the lick).

In this study, animals repeatedly visited alpine ungulate mineral licks, usually immediately after snow receded during early spring and summer. This suggests that snow cover and thawing temperatures dictated animal arrival at the majority of the mineral licks in our region. As snow recedes, available forage begins to green-up and animals migrate onto their summer range. On average, bighorn sheep mineral licks were snow-free 2 months prior to mineral licks that were visited by

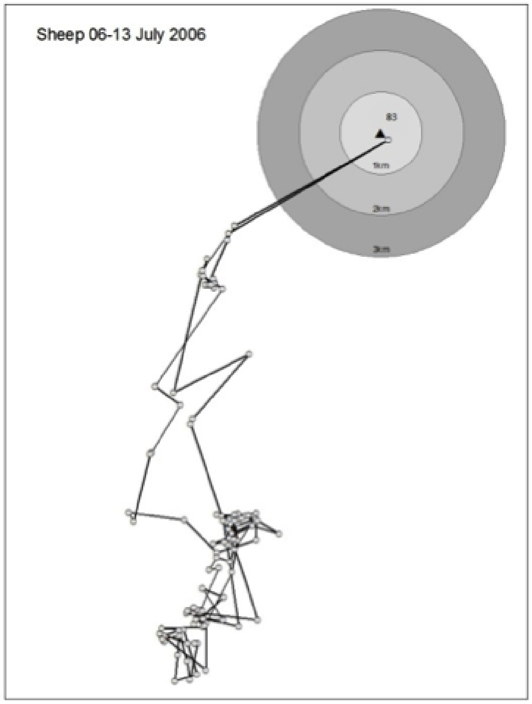


**Figure 14.** Bighorn ram (06–13) movement in relation to lick 83 during the month of July 2006 in Waterton Lakes National Park.

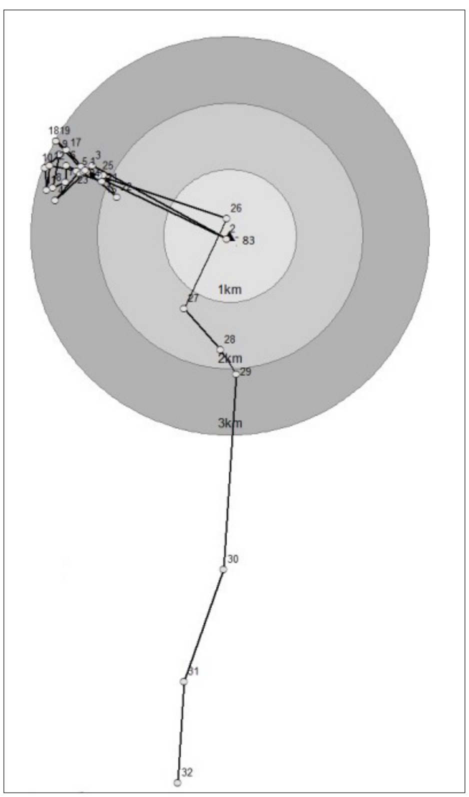


**Figure 15.** Bighorn ram (06–08) movement in relation to lick 83 over a 1-week period during June 2006 in Waterton Lakes National Park.

mountain goats, therefore bighorn licks tended to be used sooner. However, mountain goats utilized site 83 in a similar pattern to what we observed with bighorn sheep but this area did green-up sooner than most other mountain goat licks because of its location (i.e., front-range, having less snowfall, exposed to sun and wind). This lick had twice the calcium concentration of other bighorn and goat mineral licks and was composed of a clay substrate. Kreulen (1985) and Ayotte et al. (2006) discuss how carbonates and clay minerals help stabilize the rumen with early season foraging.

Our region holds a variety of habitat types and many front-range mountainous areas, which support bighorn sheep but do not provide mountain goats with appropriate habitat conditions. We have not observed mountain goats in the mineral lick zone of any bighorn licks in our region, with the exception of site 83 that is used by both species. It is interesting to note however, that we have observed bighorn sheep in the mineral lick zone of 2 mountain goat licks, but bighorn were never detected at the licks over a 2-year period. Alpine ungulates may be initially driven to mineral licks by dietary and lactation demands (Hebert and Cowan 1971, Ayotte et al. 2008) but access (i.e, snowmelt) may delay mineral lick use for some populations. We observed mountain goats accessing minerals during snow melt directly downslope of site 12 weeks prior to the lick being snow-free (water seeping overtop the lick area and flowing downslope). However, once the lick was partially free of snow, the goats shifted their visitations to the mineral lick.

Rea et al. (2013) observed a unique instance in which moose were using mineral licks during winter months. Due to heavy snow cover and freezing temperatures in our study area, we presumed bighorn sheep and mountain goats are unable to access mineral licks during winter. Installing cameras prior to initial visits proved to be a challenge, as safety and logistical issues (e.g., avalanche

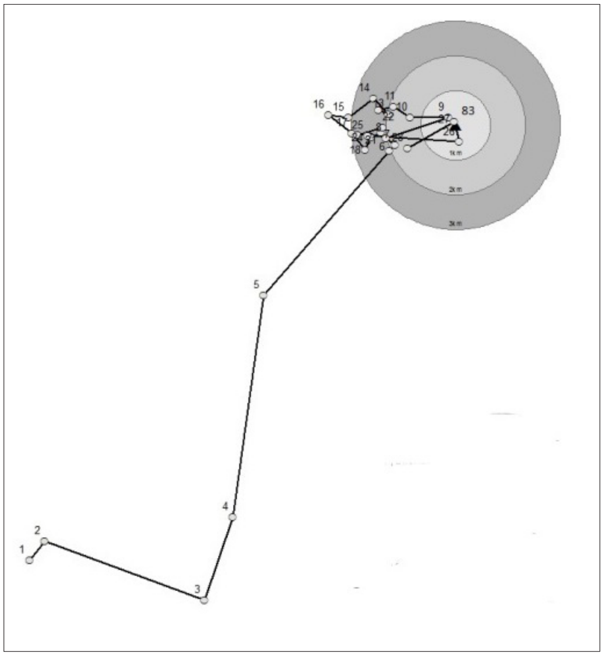

**Figure 16.** Bighorn ewe (06–03) movement in relation to lick 83 over a 1-week period during July 2006 in Waterton Lakes National Park.

conditions, access, etc.) influenced our ability to access licks in late winter or early spring. Therefore, because of a limited sample of licks at which we could collect data for initial use in multiple years, we were unable to effectively test our prediction that initial use would vary among years.

Our data suggested that, overall, bighorn sheep preferred to visit mineral licks during morning (0600-1200 hours) and afternoon (1200-1800 hours); they visited in groups, averaging 4–5 individuals; they remained at mineral licks for 15–30 minutes on average (often bedding nearby); and visited an average of 3 times per day. Their use was constant during the months of May through July with peak use occurring in June and use continuing to the end of August and moderately into October.

Overall, our data provide evidence that mountain goats travel to and from mineral licks at all times of the day and night, their use is constant, and visits are longer than 45 minutes on average. Mid- to late July was the peak period for mountain goats and lick use was constant to the end of August and continued well into September at some sites. Group size varied from 1 individual up to 24; goats often bedded nearby, visiting an average of 5 times throughout the day; and visitations virtually occurred daily during July and August.

At the intensity that mineral licks are being used by bighorn sheep and mountain goats, the mineral lick itself is not only critical, but the lick's proximity to surrounding topographic cover (for bedding, security, rearing), food and water resources is fundamental.

**Spatial fidelity and movement**

The draw of a mineral lick to a bighorn sheep or mountain goat population influences how individuals delineate their summer range. The immediate landscape surrounding a mineral lick will be used by those ungulates utilizing lick areas for foraging and cover on summer range (Simmons 1982, Singer and Doherty 1985). In northern BC, Stone's sheep (*Ovis dalli stonei*) and mountain goats were documented as traveling a minimum of 3 km from their foraging habitat to lick areas (Ayotte et al. 2008); while along the Rocky Mountains of BC, some individual goats were observed visiting multiple licks during a season, traveling up to 17 km to visit licks (Poole et al. 2010). In addition, Poole et al. (2010) found that during 2 consecutive years, collared mountain goats inhabited the slopes neighboring a mineral lick during the summer season. In Washington State, mountain goats traveled up to 29 km along mountain ridges to visit mineral licks. The author identified goats having 4 movement patterns associated with lick use (Rice 2010). Rice (2010) found some goats to be migrants, traveling far distances but remaining in the vicinity of the lick for a month on average, while other goats included the lick as a component of their usual range.

Both bighorn sheep and mountain goats in our study appear to draw on an area of about 3 km (i.e., mineral lick zone) from a mineral lick for other habitat needs during the summer months or while they are visiting a mineral lick. The degree to which bighorn and mountain goats use each mineral lick likely depends on whether other habitat needs are located nearby. Simmons (1982) and Singer and Doherty (1985) found mineral licks influenced the shape of wild sheep and mountain goat summer range and movements. A GPS-collared bighorn sheep ewe (240) in the Yarrow-Castle region maintained a spring and summer range (April through July) of 8 $km^2$ revolving around site 9. The ability to relate mountain goat aerial survey observations and bighorn sheep collar data in relation to alpine mineral licks provided an example of how these alpine ungulates utilize the range surrounding a mineral lick. Maintaining connectivity between mountain passes, ridges, and stopovers traditionally used to access lick regions and mountain ranges adjacent to licks should be considered in land-use planning. This should be of particular interest along the Continental Divide where these alpine ungulate populations occupy both Alberta and BC. Investigating mountain goat distribution and range use along the Continental Divide could provide both jurisdictions with a unified management strategy.

## MANAGMENT IMPLICATIONS

To ensure the long-term integrity and productivity of Alberta's ungulate populations, industrial and recreational guidelines must provide adequate protection to mineral licks, based on research findings that are specific to licks and the species that rely on them. We present information on the timing of use of mineral licks and spatial movement around mineral licks, further supporting the idea that mineral licks should evolve into a special management classification, rather than simply a general categorization in industrial operating ground rules.

The Alberta Fish and Wildlife Division (2001) suggest that industrial activity, whether ground or air based, should occur between 1 July and 22 August in sheep and goat zones. This timeframe has been suggested to avoid birthing time periods and hunting seasons, but it does not consider the animal's dependency on mineral licks throughout the periods of nearly constant summer use that we identified in our study. The timeframe recommended for industrial activity could impact an alpine ungulate population utilizing a mineral lick and surrounding summer range. Human disturbances displace mountain ungulates (Schoenecker and Krausman 2002, Keller and Bender 2007, St-Louis et al. 2012, Côté et al. 2013). Disturbances may be intermittent on the landscape but the cumulative effects of disturbances can have serious consequences to a population (Schoenecker and Krausman 2002). When industrial activity is conducted during summer months in bighorn sheep and mountain goat range, managers should consider mineral licks and industrial activity should be directed accordingly using mineral lick specific restrictions.

Alberta's timber harvest guidelines list mineral licks under the "other species/sensitive site" section of the document. In this section, mineral licks are universally managed with amphibian sites, bat hibernacula, nesting areas, and wolverine dens, all receiving a forested buffer distance of 100 m (AESRD 2012). Corbould et al. (2010) investigated the effects of forest disturbance on low-elevation mountain goat lick use and found that forest removal treatments (conducted during the winter) along trails leading to mineral licks did not have a behavioral effect on goats. Although, lick and trail use by goats declined post timber harvest (at both treatment and control licks), while carnivore detections increased. Their treatments included a buffer of 150 m on either side of the trail leading to the lick and then clearcutting the buffer a few years afterwards. Authors postulated that forest removal might have an indirect effect, increasing mortality risk (Corbould et al. 2010). In our study region, the principal threat from timber harvest to bighorn sheep and mountain goats is the access it creates, especially to off-highway vehicles. St-Louis et al. (2012) found goats to be highly disturbed when off-highway vehicles approached directly and at high speeds. Based on our data, a buffer distance of 100 m is inadequate in most instances.

Bighorn sheep and mountain goat mineral licks are often located at the fringe of what is typical of their range because licks are often low-lying. Therefore, it is important for managers to understand where alpine ungulate mineral licks are located, as they are seldom high on the mountain and there may be instances where mountain ungulates are overlooked where in fact they could be directly impacted by human influences. Creating a universal buffer distance for bighorn and mountain goat mineral licks is a complex undertaking but our observational data provide awareness to the issue. Marking and tracking movements of individuals in a population would provide a better sense of effective buffer distances at alpine ungulate mineral licks. Furthermore, each alpine mineral lick is unique to the setting in which it is located and industrial or recreational regulation may require site-specific forethought. Consequently, it is critical that all alpine ungulate mineral licks in a region are pinpointed and that the location and mineral lick zone receive special consideration when land use planning.

Guidelines have been established for when industrial activity occurs in bighorn sheep and mountain goat range (AESRD 2012). A 2-km buffer from position of known animals is the suggested distance if helicopter activity should occur in bighorn and mountain goat terrain (Côté 1996; Hurley 2004). If mineral licks were to be integrated into this 2-km rule for aerial based activity, an additional 3-km mineral lick zone buffer could be considered. Based on the evidence that bighorn sheep and mountain goats in our study area concentrate use around mineral licks (i.e., based on trail camera, aerial survey and, animal collar data), adding 3-km to the 2-km rule would allow the majority of the population utilizing the mineral lick and surrounding mountain range to go relatively undisturbed. It also ensures that travel corridors regularly used by the animals between the lick and the nearby mountain range are undisturbed by rotary wing aircraft.

A timing restriction on industrial and or recreational disturbance in relation to alpine mineral licks or critical summer range would be most effective. A seasonal timing restriction that is designed to avoid activity near mineral licks during the peak months of May through August would be an appropriate standard. This incorporates the snow-free period, the lambing or kidding season, as well as the peak use period by bighorn sheep and mountain goats at mineral licks. Bighorn sheep and mountain goat mineral lick use somewhat decreases by September but does not cease; therefore, industrial activity in close proximity to mineral licks during the months of September and October should be conducted with this understanding. Preserving corridors between summer range and mineral licks from short and long-term disturbance is paramount. Managers need to consider the consequences of newly constructed roadways or off-highway vehicle trails when in close proximity to bighorn sheep and mountain goat summer range. Keller and Bender (2007) reported how road and human disturbance negatively affected bighorn use of a mineral lick, while St-Louis et al. (2012) found that off-highway vehicles can cause high levels of disturbance in mountain goats while on summer range. Special management considerations (closures, regulations, or gates) may be necessary for those bighorn and goat summer range areas already affected by disturbance.

Future research on the role of mineral licks and alpine ungulate populations should focus on seasonal range use and identifying traditional travel routes associated with them. Collaring a proportion of the mountain goat population would provide necessary range use information and those marked individuals would be identifiable at mineral lick sites. This research would be of particular value along the Continental Divide, where evaluating the potential impacts of recreational and industrial development on goat seasonal ranges, mineral licks and corridors would benefit the conservation and management of mountain goats across both provinces.

Alpine ungulate licks are intermittent on the landscape and alpine species are conditioned to exploiting these areas, including the summer range and corridors associated with them. These areas hold biological significance and this is why mineral licks require a conscientious approach to ensure their preservation for wildlife.

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