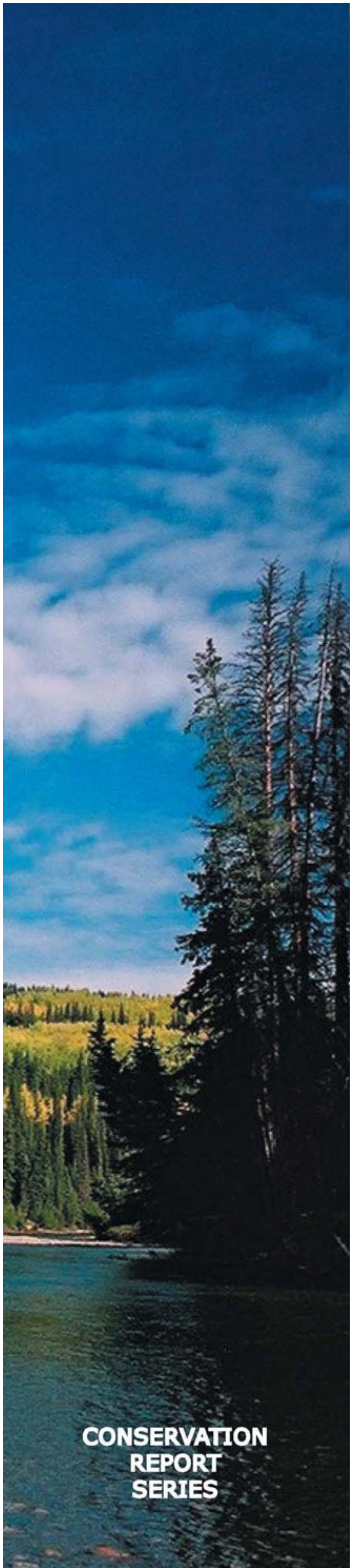

Frequency and Timing of Use of Mineral Licks by Forest Ungulates in Southwest Alberta

Alberta Conservation Association
Conserving Alberta's Wild Side

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EXECUTIVE SUMMARY

Mineral licks are a unique resource used by all ungulate species in North America. Research on mineral licks in Alberta has generally been limited to assays of elemental content and to documenting the attraction of bighorn sheep (*Ovis canadensis*) to human-made mineral licks (e.g., natural gas salty deposits). We monitored activity at mineral licks in forested zones in southwest Alberta to better understand their seasonal and daily use by ungulates. From 2010 to 2012, we identified and monitored the activity of elk (*Cervus canadensis*), deer (*Odocoileus* sp.) and moose (*Alces alces*) at nine mineral licks. The pattern of use was similar between years and among species. Visits typically increased as licks became snow-free in spring, with frequency of use peaking in July. Each of the four species used licks from May to October. Given the intense use of mineral licks by ungulates, we suggest that licks and other important spatial resources (e.g., calving grounds, migration routes, stopover areas) be mapped and factored into land-use plans, with the objective of decreasing disturbance to these resources during key seasonal periods. Limiting disturbance is particularly important for ungulates while they are occupying their summer ranges because they devote effort to gaining mass, raising their young, replenishing dietary needs (minerals licks) and avoiding predation. We suggest human disturbance (e.g., heighted road use and industrial activity) be avoided within 500 m of licks from May to August.

Key words: Alberta, elk, mineral lick, moose, mule deer, trail camera, white-tailed deer.

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1.0 INTRODUCTION

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 spring and early summer (Jones and Hanson 1985) as they transition from their winter diet to spring forage, which is extremely high in potassium, carbohydrates and protein, but low in fibre (Ayotte 2004). The chemical properties of spring forage reduce the digestive efficiency of the rumen and impairs absorption (Kreulen 1985). Forage digestibility is further compromised for species such as moose (*Alces alces*) and mountain goat (*Oreamnos americanus*) because they consume forage high in plant defence compounds (Ayotte et al. 2006). Lick soils provide the necessary elements to stabilize the rumen as well as supplement chemical needs exacerbated by 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 and weather over time, mineral licks are a static resource that may be used by many generations of a population. Because these small, localized areas are important resources for all ungulate species, their preservation on the landscape is vital (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. Under these guidelines, mineral licks are universally managed with amphibian sites, bat hibernacula, nesting areas and wolverine (*Gulo gulo*) dens—all receiving a forested buffer distance of 100 m (Environment and Sustainable Resource Development [ESRD] 2012; ESRD 2013). A similar approach was taken for the Enhanced Approval Process for industrial activities, such as oil and gas development.

Ungulate species are prone to flee when exposed to human disturbance (Stankowich 2008). Elk (*Cervus canadensis*) are particularly sensitive to and affected by off-road activity (Naylor et al. 2008), and they avoid areas within 500 m of roads (Paton 2012). Female reproductive success has been shown to decrease as human disturbance increases during the calving season (Phillips and Alldredge 2000). Female ungulates with young offspring are most affected by human disturbance (Stankowich 2008).

Previous work in Alberta has examined the elemental content of mineral licks (Dormaar and Walker 1996), although the frequency and timing of use by ungulates was not observed. Another study documented the attraction of bighorn sheep (*Ovis canadensis*) to human-made mineral licks (i.e., natural gas salty deposits) along the eastern slopes of Alberta (Morgantini and Bruns 1988), but no studies of ungulate use patterns at natural mineral licks in southwest Alberta have occurred to our knowledge.

Our objectives were to identify lick locations, characterize sites and monitor the frequency and timing of use by ungulates. We also assessed the movements of three cow elk monitored using Global Positioning System (GPS) collars to better understand their fidelity to and use of mineral licks. We hypothesized that the peak period of use by forest ungulates at licks would coincide with plant phenology (variable timing of plant growth and forage preferences). We expected to see consistency in the date that licks were first visited during the season (based on summer range migration), although we anticipated differences in initial seasonal use among species (forage and migration variability).

2.0 MATERIALS AND METHODS

2.1 Study area

The study was conducted in southwest Alberta, Canada (Figure 1). The study area boundary conformed to Wildlife Management Units (WMU) 400 and 402 (~2,530 km^2). These management units are largely delineated by the Alberta–British Columbia provincial border (the Continental Divide) along the western edge and the forest reserve boundary along the east. 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 subregions. The alpine and subalpine subregions receive significant precipitation (~560 mm annually) and the growing season is short and cool in the 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. The montane subregion is largely characterized by open forests of Douglas fir (*Pseudotsuga menziesii*), limber pine (*Pinus flexilus*), lodgepole pine and aspen (*Populus tremuloides*), intermixed with grassland. The montane climate is generally warmer and dryer when compared with the other subregions in the study area (Archibald et al. 1996). 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, whereas soils under forest cover at lower elevations consist primarily of luvisols or brunisols (Archibald et al. 1996).

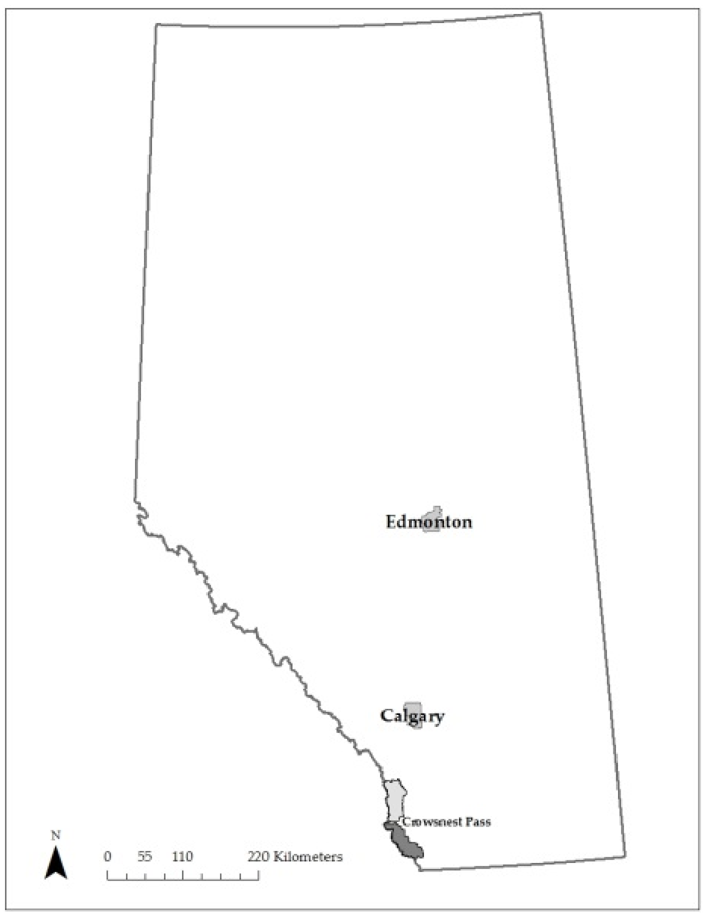


Figure 1. Study area within Alberta, Canada, defined by Wildlife Management Units 402 (lightly shaded polygon) and 400 (dark polygon).

2.2 Mineral lick site characteristics

We compiled a list of mineral licks through a survey of local recreationists, area biologists and area foresters, with help from Alberta Environment and Parks and Anatum Ecological Consulting Ltd. 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 leading to and from the site, and the plant community surrounding the lick. We also identified whether there was probable risk of human disturbance (e.g., distance to road or trail). An example of the field assessment form is provided in Appendix 1.

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 (e.g., cavities, excavations, smoothly licked or chewed areas) and from a reference site, which we defined as an area of exposed earth >10 m away from the lick. Samples were stored on ice in a hard-sided cooler to maintain an optimal temperature of ≤10°C to preserve the integrity of inorganic parameters (pers. comm., Kris Beaudet, Maxxam Analytics Inc.). Our samples were couriered to Maxxam's laboratory within seven days from time of collection. All soil samples were analyzed using a digestion technique described by Horvath (2009)—the Strong Acid Leachable Metals (SALM) in soil method. Samples were dried at ≤60°C, sieved and digested using a strong acid that dissolves most elements that could become environmentally available (pers. comm., Kris Beaudet, Maxxam Analytics Inc.). We removed outliers from the dataset and performed paired *t*-tests to determine if there were significant differences between the mean concentrations of elements found at mineral lick sites compared with reference sites. All analyses were performed in JMP (Version 10) at a significance level of $\alpha \leq 0.05$.

2.3 Timing and duration of mineral lick use

We collected mineral lick use data by elk, white-tailed deer (*Odocoileus virginianus*), mule deer (*Odocoileus hemionus*) and moose using remote trail cameras (Reconyx PC800 and PC900) between April 1 and October 31 of 2011 and 2012. We programmed the cameras to obtain three photographs per trigger at five-second intervals between photographs.

The five-second interval between images allowed time for animals to move into and about the frame, increasing our potential to confidently classify and count the number of animals in a given group. A five-minute quiet period was set between triggers (set of three photographs), because this significantly reduced the amount of incoming image data but still provided sufficient observational detail. Our mineral lick monitoring included alpine ungulate licks used by bighorn sheep and mountain goats, but those results are reported in another document (Jokinen et al. 2014).

To ensure that we captured the first wildlife visit at each site, we deployed our cameras in late March to early April each year, although we put out camera stands and security boxes the previous fall before snowfall to ensure that cameras were in appropriate locations. This approach allowed us to determine where to place the stand or security enclosure (e.g., 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. Cameras were placed on trees at a distance of ≤10 m from a mineral lick to ensure animals would be within detection and infrared range.

2.4 Image data management

We created a custom image database developed to process our camera data (Hasbani 2010). The Microsoft Access 2010 database automatically loaded the image (event), date, time and temperature. We manually entered species and minimum group size from a single trigger event (set of three consecutive images). Minimum group size was determined by counting the greatest number of animals in the set of three photographs. Because elk and mule deer often visited in groups, we recognize that outlying individuals could be missed in images, so our results represent a minimum group size. Visit events were considered independent when the time interval between camera triggers was greater than 30 min. These visitations may include repeat visits by the same individual or group of animals.

We were able to determine the monthly mean number of lick visits by each species using the information gathered by the trail-camera images. Since the cameras had the ability to monitor without interruption, we were able to further break down these visits into a night, morning, afternoon and evening period, including the duration of those visits.

2.5 Spatial fidelity

Site fidelity to seasonal ranges has been documented for elk (Boyce 1991; van Beest et al. 2013), white-tailed deer (Grovenburg et al. 2009), mule deer (Garrott et al. 1987) and moose (Welch et al. 2000). Tankersley and Gasaway (1983) suggested that spring and summer movement and distribution of moose is influenced by the location of mineral licks. Female ungulate summer range averages 53 km^2 for elk (Anderson et al. 2005), 9 km^2 for white-tailed deer (Grovenburg et al. 2009), 11 km^2 for mule deer (Bender et al. 2007) and 68 km^2 for moose (Dussault et al. 2005).

We conducted both a retrospective and real-time analysis of elk movements in relation to the mineral licks that we monitored. We used movement data from three GPS-collared cow elk to demonstrate their fidelity and use of mineral licks. The three elk were chosen because they clearly visited the mineral licks that we monitored, and we wanted to better understand their use of the mineral lick and surrounding mineral lick zone over time. Movement data for these elk were collected between 2007 and 2013 in our study region and were provided by Shell Canada Limited. The collared elk were part of a multi-partner research program to better understand wildlife species movement and habitat selection in southwest Alberta.

3.0 RESULTS

We monitored six mineral licks in 2011 and nine in 2012. All the licks were used by each species at least once, with one lick also used by a mountain goat. Six mineral licks were monitored for two seasons, and the remaining three mineral licks were monitored for one season.

3.1 Forest mineral lick site characteristics

In general, forest mineral licks are characterized by a disturbed area where vegetation at the periphery is sharply hedged to bare rock and subsoil. The disturbed area is often depleted of all vegetation, with moisture reaching the surface. Forest mineral licks occur in two forms: moist and loamy, commonly referred to as muck licks (Figure 2); and moist with a hard rock or sand substrate (Figure 3).

Figure 2. Lick 32 represents a muck lick in southwest Alberta. Note the loamy substrate, lack of vegetation in the disturbed area and heavy trampling by hooves.

Figure 3. Lick 72 represents a hard-substrate forest mineral lick in southwest Alberta.

An organic layer is rare at hard-substrate licks, and hedging is reduced, but the area is heavily trampled. Some of these sites have little forest canopy, but resilient springs maintain water throughout the summer season. Persistent ungulate use at mineral licks creates a network of heavily worn game trails departing in all directions (Figure 4), but these quickly wane into smaller and obscure forest paths.

Figure 4. Lick 49 has recognizable game trails (indicated by arrows) departing this muck lick in southwest Alberta.

Additional wildlife sign is often evident, such as tracks, scat, clumps of molted hair, antler rub trees, browsed shrubs, bedding sites, and bone fragments from hunter or carnivore kills. Hunter blinds were observed at three of the nine mineral licks. Forest mineral licks occurred at elevations averaging 1,778 m (standard error [SE] = 38.90) and averaged 94 m^2 (SE = 13.26) in size (Table 1).

Table 1. Description of nine forest mineral licks assessed in southwest Alberta, 2011 – 2012.

Lick	Elev (m)	Hedging[c]	Beds[d]	Rubs[e]	Browse[f]	Lick type	Lick soil	Soil type	Lick area (m^2)
11	1,773	Yes	No	Yes	Yes	Wet	Moist	Loam	128.1
32	1,909	Yes	No	Yes	Yes	Wet	Moist	Loam	92.4
46[a]	1,874	Yes	No	Yes	No	Wet/Dry[a]	Dry	Loam	24.2
49	1,790	Yes	No	No	Yes	Wet	Moist	Clay/Loam	78.0
58	1,660	Yes	No	No	Yes	Wet	Moist	Silt/Clay	141.1
60[b]	1,943	Some	Yes	No	No	Wet	Moist	Silt/Loam	80.0
65	1,776	Yes	No	Yes	Yes	Wet	Moist	Silt/Clay/Loam	52.3
72	1,661	Some	No	Yes	No	Wet	Moist	Silt/Loam	121.7
73	1,612	Yes	No	Yes	Yes	Wet	Moist	Clay/Loam	132.0

[a] This site holds water early in the season but dries up after snow melt.

[b] This is a unique site, hosting both alpine and forest species.

[c] Hedging: an abrupt edge created by trampling of hooves on an organic layer.

[d] Beds: sign of bedding depressions.

[e] Rubs: sign of horn or antler rubbing.

[f] Browse: sign of whether vegetation immediately surrounding lick has been browsed.

We observed hedging at all forest licks, although Licks 60 and 72 had limited hedging because of their rocky substrate. Lick 60 is used by both alpine and forest ungulates; it is situated outside the forest canopy at the fringe of alpine habitat and is the only forest mineral lick where beds were evident (created by mountain goats while visiting the lick).

All but one mineral lick held moisture throughout the season (May – October). Lick 46 lacked a spring; therefore, it dried up after snow melt. It was also the smallest in size (24 m^2), and animal visitations were short-lived when compared with all other licks. This lick is located on a well-drained pine forest bench (hairy wild rye [*Elymus innovates*], lodgepole pine ecosite) (Figure 5), whereas most licks were located in ecosites resembling higher moisture regimes (thimbleberry [*Rubus parviflorus*], subalpine fir, spruce species or horsetail [*Equisetum* sp.] and spruce species).

Figure 5. Lick 46 is an example of a lick in which a depression collects moisture early and late in the season but lacks a seep and therefore dries up mid-season.

We collected soil samples from mineral licks and reference sites between August 20 and September 11, 2013. There was a significant difference between licks and reference sites for mean concentrations of magnesium and sodium, whereas other concentrations were more similar (Table 2). Mean concentrations of sodium and magnesium at mineral licks were approximately 3.3 and 1.6 times higher, respectively, than concentrations at reference sites. The mean concentration of iron was highest among all elements at mineral licks, followed by calcium and magnesium (Table 2).

Table 2. Difference between mean concentrations (mg/kg) of soil elements at forest mineral licks (N = 9) and reference sites (N = 9) in southwest Alberta, 2013.

Element	Lick site		Reference site		Paired	
	Mean	SE	Mean	SE	*t*-value	*p*-value
Calcium	9,922.22	2,267.88	6,511.11	1,465.38	-1.27	0.24
Cobalt	7.69	0.58	6.16	0.85	-1.52	0.17
Copper	20.44	2.57	16.56	2.48	-1.07	0.32
Iron	27,777.78	2,385.01	22,888.89	1,946.82	-1.94	0.09
Potassium	1,622.22	164.80	1,520.00	235.43	-0.90	0.40
Magnesium	4,588.89	429.29	2,926.67	427.32	-3.14	0.01*
Manganese	392.22	79.32	276.33	56.72	-1.54	0.16
Molybdenum	3.00	0.93	3.40	1.28	0.75	0.48
Sodium	234.89	45.78	72.56	15.60	-3.28	0.01*
Phosphorus	821.11	52.40	1,130.00	197.42	1.61	0.15
Zinc	83.11	6.24	88.11	8.5	0.86	0.42

*Significant at $p \leq 0.05$; SE = standard error

3.2 Timing of use

We identifed elk, moose, mule deer, white-tailed deer and mountain goats using forest mineral licks. Several carnivore species were also deteced at mineral licks, including coyote (*Canis latrans*), wolf (*Canis lupus*), lynx (*Lynx canadensis*), cougar (*Felis concolor*), black bear (*Ursus americanus*), grizzly bear (*Ursus horribilis*) and wolverine. A porcupine (*Erethizon dorsatum*) regularly visited Lick 58 in 2011, and domestic cattle visited several forest mineral licks as they ranged freely within the forest reserve during the summer season. The earliest visit of a lick by a forest ungulate was April 23, but the lick was not snow-free until May 15 (Table 3).

Table 3. The earliest snow-free date and visit by elk, white-tailed deer, mule deer and moose at mineral licks in southwest Alberta, 2011 and 2012.

Site	Snow-free date		Elk first visit		White-tailed deer first visit		Mule deer first visit		Moose first visit	
	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
11[a]	Jun-28	Jun-30	Jul-03	Jun-29	Jul-30	Jul-06	Jul-17	Jun-21	Jun-28	Jun-14
32	Jun-26	Jun-21	Jun-22	Jun-01	NV	Jun-27	Jun-25	Jun-18	Jun-13	Jun-14
46[b]	Jun-19	May-22	Jun-19	May-22	NV	NV	Jul-03	Jun-04	Jun-29	Jun-17
49	–	Jun-12	–	Jun-13	–	Jun-08	–	Jun-13	–	May-31
58	Jun-05	May-18	Jun-17	Jun-20	NV	Jul-10	Jun-09	Jun-12	Jun-08	May-18
60	Jul-08	Jul-13	Jul-01	Jul-12	Jul-06	Jun-22	Jun-24	Jun-29	Jul-02	Jul-01
65[c]	Jun-23	May-31	NV	Jul-03	Jun-24	May-27	Jun-24	Jun-08	Jun-23	May-07
72	–	Apr-28	–	Apr-25	–	Apr-30	–	Apr-26	–	Apr-25
73	–	May-15	–	May-12	–	Apr-23	–	Apr-29	–	May-06

[a] Camera set on June 21 in 2011; first visit potentially missed in 2011.

[b] Unsure of exact date when snow melted because of lack of animal activity at this time.

[c] Camera set on June 23 in 2011; first visit potentially missed in 2011.

– Site not surveyed.

NV - not visited by species.

We found forest mineral licks were typically snow-free by late May or June. Lick 72 was an exception; it was snow-free earlier than most licks because of its easterly aspect and exposed location, and it was used by all species almost a month sooner than most licks. Most initial visits by ungulates at forest licks took place in the latter part of May or in June (Table 4). Not all mineral licks were visited before they were snow-free.

Table 4. Mean (standard error) number of days during May through October that forest ungulates visited a mineral lick in southwest Alberta in 2011 (N = 6) and 2012 (N = 9). Two sites during 2011 may be missing early detections because cameras were set up on June 21 and 23.

Month	Elk		White-tailed deer		Mule deer		Moose	
	2011	2012	2011	2012	2011	2012	2011	2012
May	0 (0)	3 (2)	0 (0)	3 (3)	0 (0)	5 (3)	0 (0)	2 (1)
June	2 (1)	8 (3)	1 (1)	6 (3)	4 (3)	10 (4)	4 (1)	11 (3)
July	8 (3)	10 (3)	9 (6)	8 (4)	10 (3)	14 (4)	13 (4)	16 (3)
August	8 (4)	8 (2)	9 (6)	4 (2)	8 (2)	12 (4)	13 (4)	12 (3)
September	3 (1)	4 (2)	3 (3)	4 (3)	5 (2)	9 (3)	6 (2)	8 (2)
October	0 (0)	1 (1)	0 (0)	1 (0)	1 (0)	3 (2)	2 (1)	5 (2)

Consistent use of licks did not typically occur until July (Table 5). Regular June visits were largely limited to more easterly and exposed sites as animals were migrating to their summer ranges.

Table 5. Mean (standard error) number of mineral lick visits by forest ungulates in southwest Alberta during May through October in 2011 (N = 6) and 2012 (N = 9). A visit was determined when the time between visits was greater than 30 minutes.

Month	Elk		White-tailed deer		Mule deer		Moose	
	2011	2012	2011	2012	2011	2012	2011	2012
May	0 (0)	9 (8)	0 (0)	7 (5)	0 (0)	22 (15)	0 (0)	4 (2)
June	5 (4)	22 (11)	2 (2)	14 (9)	9 (6)	48 (27)	5 (2)	28 (11)
July	18 (9)	20 (7)	22 (14)	17 (11)	18 (6)	52 (25)	32 (13)	44 (16)
August	15 (7)	12 (3)	16 (14)	6 (4)	11 (4)	40 (19)	26 (10)	30 (12)
September	3 (1)	6 (2)	5 (5)	6 (5)	6 (3)	22 (10)	10 (4)	15 (5)
October	0 (0)	1 (1)	1 (1)	1 (1)	1 (1)	5 (4)	2 (1)	10 (6)

Mule deer made the greatest number of visits, totalling 768 at Lick 72 during one season. Moose visited Lick 49 a total of 436 times during one season, elk visited Lick 72 a total of 206 times, and white-tailed deer visited Lick 73 a total of 196 times. Mineral lick visitations began to decrease noticeably in September, in comparison with the peak months of July and August.

3.3 Time of day and duration of use

Moose and elk used licks less frequently during the afternoon period than other times of the day (Figure 6). White-tailed deer visited mineral licks the least during the night period, whereas mule deer did not show a clear preference (Figure 6).

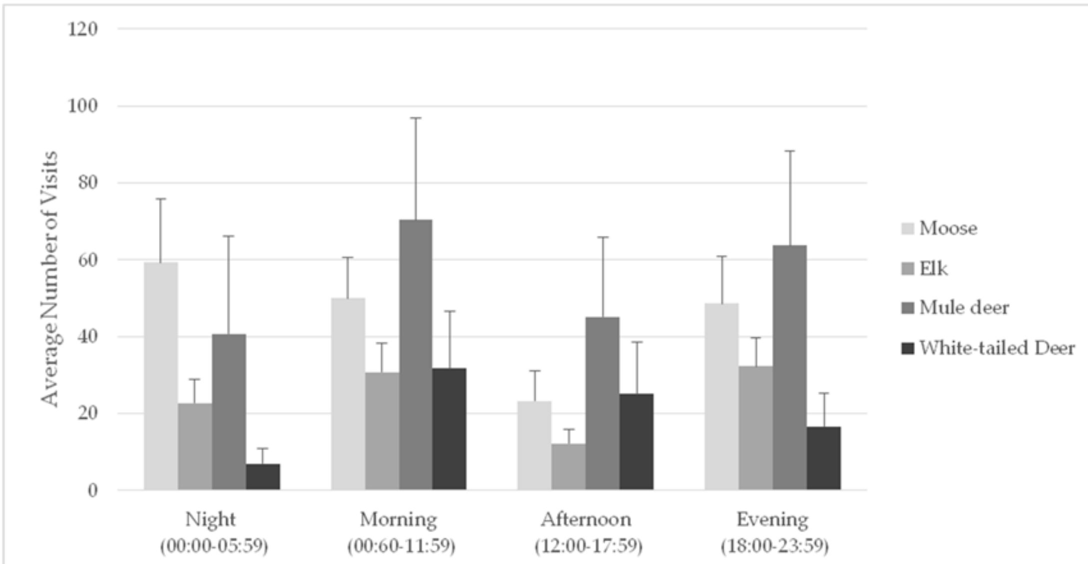


Figure 6. Seasonal mean (+ standard error) number of forest ungulate visitations (by time of day) at mineral licks in southwest Alberta in 2011 (N = 6) and 2012 (N = 9). A visitation was determined when the time between visits was greater than 30 minutes.

Moose visited mineral licks an average of 1.9 (SE = 0.18) times during a single day, whereas elk averaged 1.8 (SE = 0.16) visits per day; mule deer visited an average of 1.9 (SE = 0.31) times per day, and white-tailed deer visited an average of 1.5 (SE = 0.18) times per day. The maximum number of moose observed at a mineral lick was three, whereas the maximum elk count was eight individuals. The maximum number of deer observed at a mineral lick was five for both species.

Visit duration at mineral licks was relatively equal by time of day for all ungulates; however, elk appeared to spend less time at mineral licks during the afternoon than during other periods of the day (Figure 7).

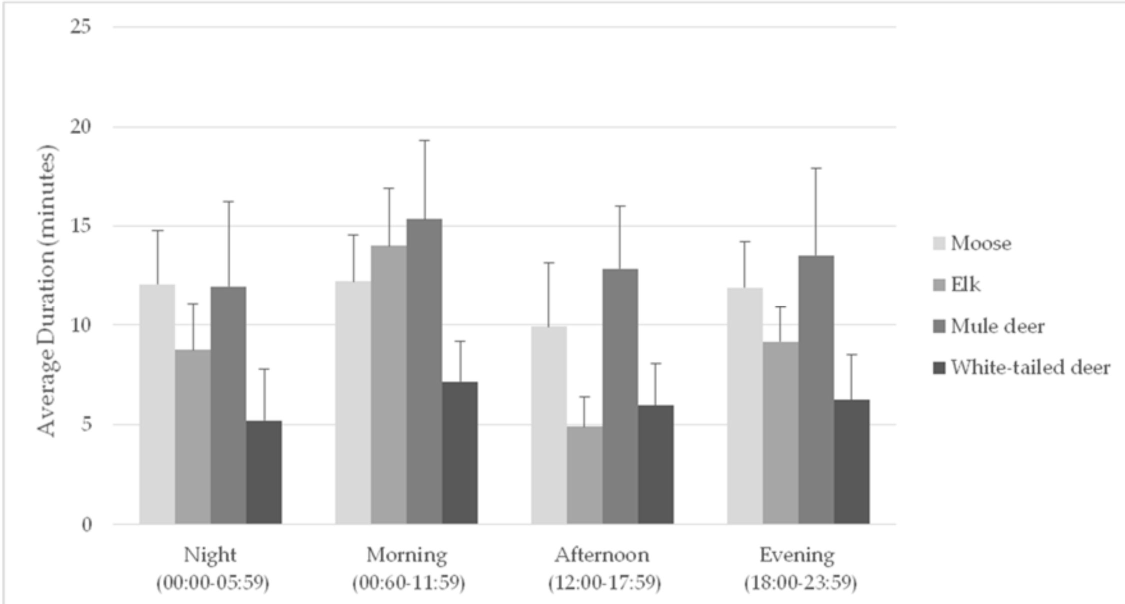


Figure 7. Mean (+ standard error) duration of mineral lick visits (by time of day) by forest ungulates in southwest Alberta in 2011 (N = 6) and 2012 (N = 9). A visitation was determined when the time between visits was greater than 30 minutes.

Ungulates occupied mineral licks the longest during the morning period, although moose had the least variability in visit duration. Each species generally visited a mineral lick more than once during a single day; however, we were not able to identify individuals.

3.4 Spatial fidelity and movement of elk in relation to mineral licks

During 2011 and 2012, we captured images of marked and collared elk at our forest mineral licks. Figure 8 shows a series of elk locations and movement patterns (two-hour fix rate) with lines connecting points in consecutive order over a one-week period when the cow elk used the lick or was near the lick. This illustration of elk use at Lick 72 occurred two years before our monitoring, but it provides an example of how collar data can be used retrospectively.

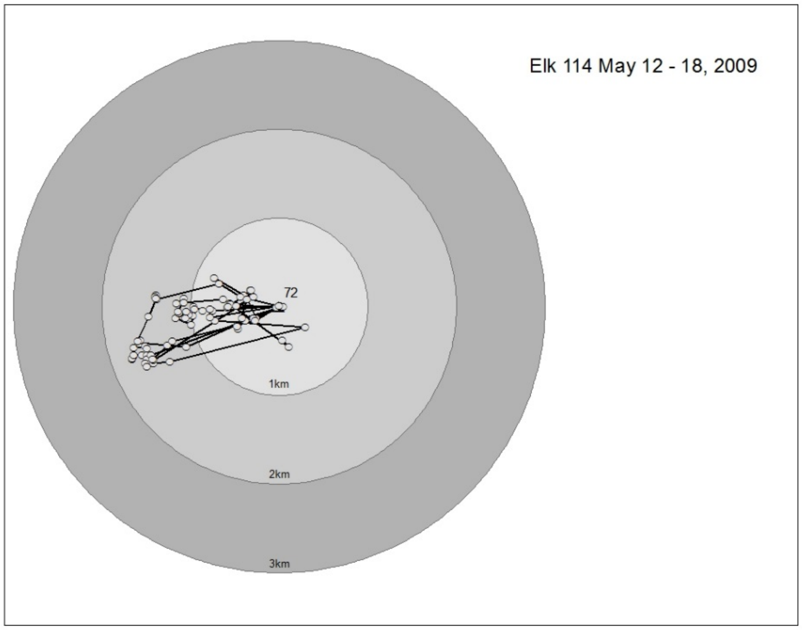
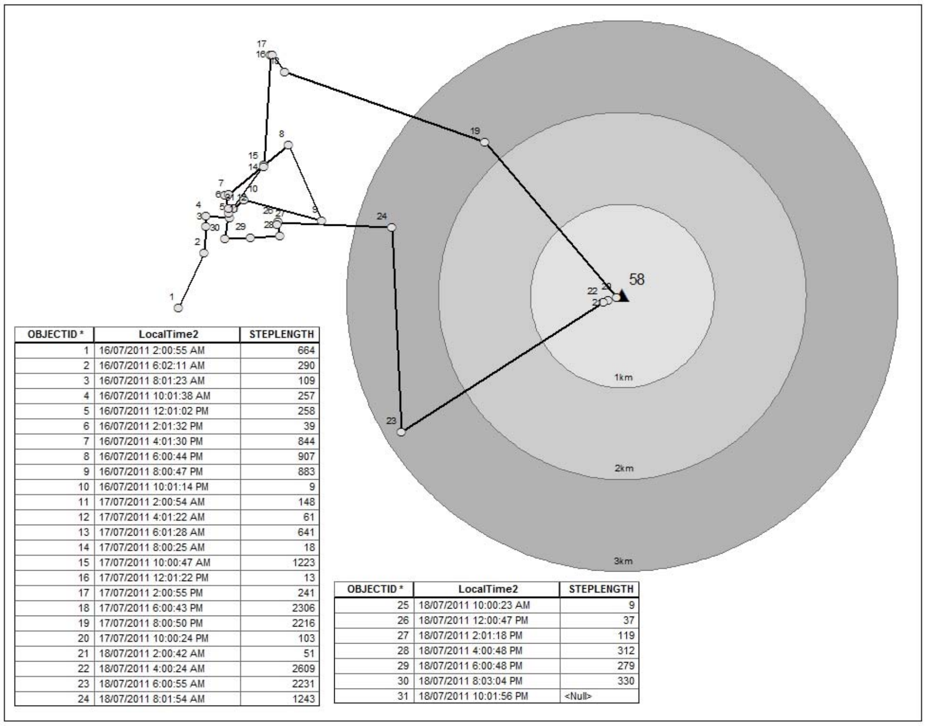


Figure 8. Movements of cow Elk 114 in relation to Lick 72 over a one-week period in southwest Alberta, May 2009.

Five locations were within 50 m of the mineral lick, and we considered these occurrences to be lick visits. We examined the movements (distance between each consecutive point) of Elk 114, and based on her five visits, she moved longer distances when travelling to and from the lick when compared with movements between visits. On average, the distance moved while travelling to the lick was 710 m, whereas the distance travelled after leaving the lick was 534 m. The average distance moved between visits (bedding, foraging) was 165 m.

Figures 9 and 10 show use of Lick 58 by a cow elk, including images of her visit to the site. The elk resided in a relatively small area, covering a few square kilometres over a couple of days in July. However, the cow elk deviates from this area to access Lick 58.



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3	16/07/2011 8:01:23 AM	109
4	16/07/2011 10:01:38 AM	257
5	16/07/2011 12:01:02 PM	258
6	16/07/2011 2:01:32 PM	39
7	16/07/2011 4:01:30 PM	844
8	16/07/2011 6:00:44 PM	907
9	16/07/2011 8:00:47 PM	883
10	16/07/2011 10:01:14 PM	9
11	17/07/2011 2:00:54 AM	148
12	17/07/2011 4:01:22 AM	61
13	17/07/2011 6:01:28 AM	641
14	17/07/2011 8:00:25 AM	18
15	17/07/2011 10:00:47 AM	1223
16	17/07/2011 12:01:22 PM	13
17	17/07/2011 2:00:55 PM	241
18	17/07/2011 6:00:43 PM	2306
19	17/07/2011 8:00:50 PM	2216
20	17/07/2011 10:00:24 PM	103
21	18/07/2011 2:00:42 AM	51
22	18/07/2011 4:00:24 AM	2609
23	18/07/2011 6:00:55 AM	2231
24	18/07/2011 8:01:54 AM	1243

OBJECTID *	LocalTime2	STEPLENGTH
25	18/07/2011 10:00:23 AM	9
26	18/07/2011 12:00:47 PM	37
27	18/07/2011 2:01:18 PM	119
28	18/07/2011 4:00:48 PM	312
29	18/07/2011 6:00:48 PM	279
30	18/07/2011 8:03:04 PM	330
31	18/07/2011 10:01:56 PM	<Null>

Figure 9. Movements of collared cow Elk 137 in relation to Lick 58 in southwest Alberta between July 16 and 18, 2011.

Figure 10. Images of collared cow Elk 137 while visiting Lick 58 in southwest Alberta on July 17 and 18, 2011.

On the evening of the July 17, the elk altered her typical behaviour and moved approximately 4.5 km to visit Lick 58. She spent a portion of the night at the lick, but before daybreak, she moved back to the range she had been using before visiting the mineral lick. Over the month of July, the cow elk made distinct movements toward both Licks 58 and 60 (Figure 11).

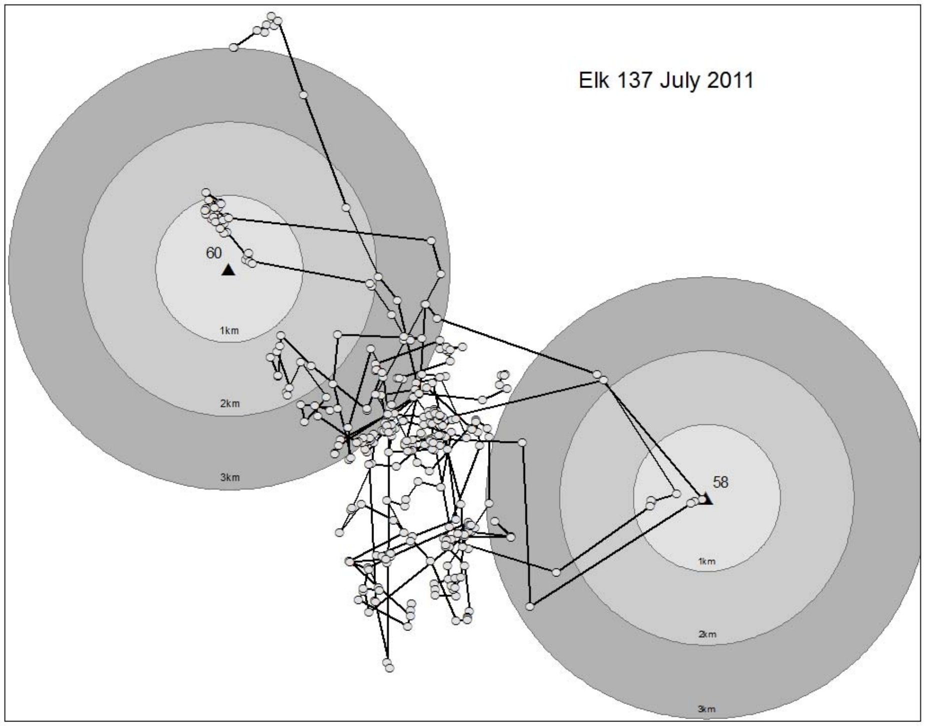
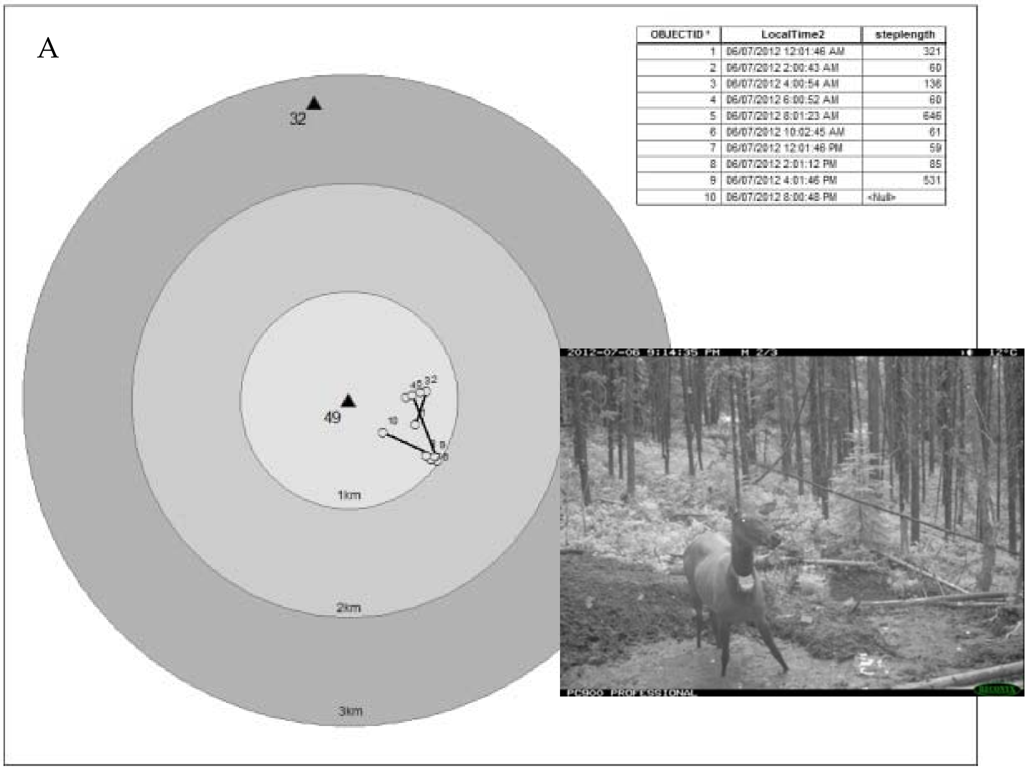


Figure 11. Movements of cow Elk 137 in relation to Lick 58 and Lick 60 in southwest Alberta in July 2011.

Cow Elk 173 regularly occupied an area east of Lick 49 but visited the lick on several occasions during July and August 2012. During these visits, she was compelled to cross a graveled secondary roadway (located 200 m directly east of Lick 49) because it was situated between her foraging/resting area and the mineral lick. She retreated to the east side of the roadway after spending time feeding at the lick (Figures 12A to 12E).



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4	06/07/2012 6:00:52 AM	60
5	06/07/2012 8:01:23 AM	646
6	06/07/2012 10:02:45 AM	61
7	06/07/2012 12:01:46 PM	59
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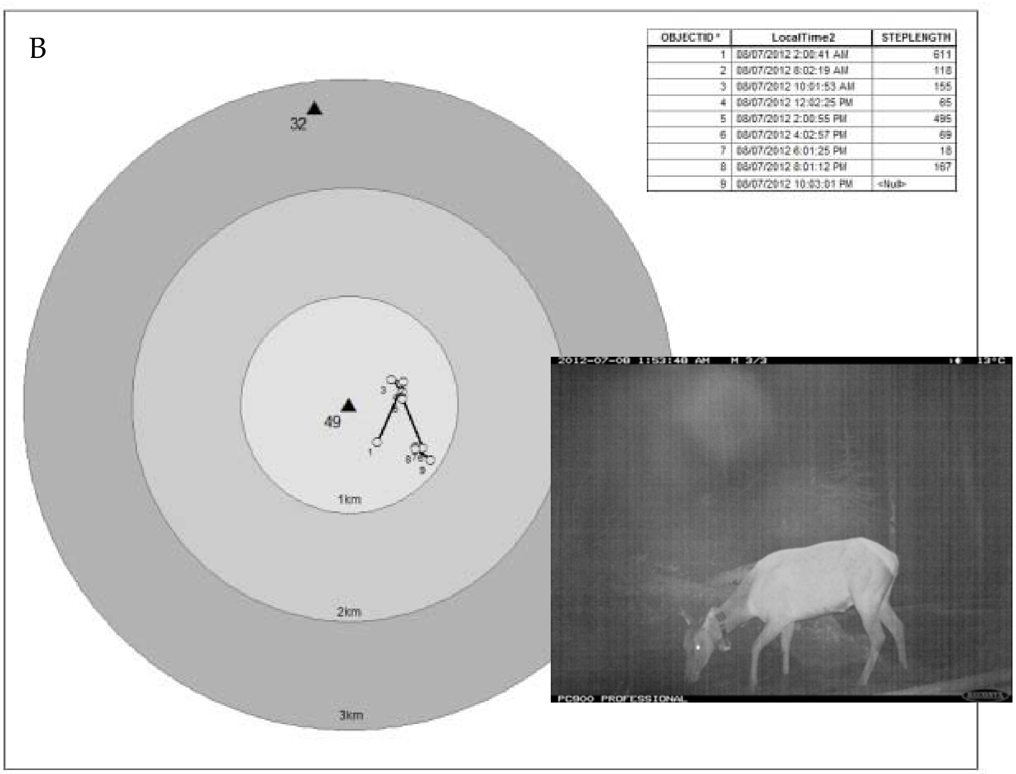
10	06/07/2012 8:00:48 PM	<Null>



OBJECTID *	LocalTime2	STEPLENGTH
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3	08/07/2012 10:01:53 AM	155
4	08/07/2012 12:02:25 PM	65
5	08/07/2012 2:00:55 PM	495
6	08/07/2012 4:02:57 PM	69
7	08/07/2012 6:01:25 PM	18
8	08/07/2012 8:01:12 PM	167
9	08/07/2012 10:03:01 PM	<Null>

C

OBJECTID *	LocalTime2	STEPLENGTH
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4	09/07/2012 6:01:41 AM	199.909696
5	09/07/2012 8:01:23 AM	46.743349
6	09/07/2012 10:01:51 AM	63.623681
7	09/07/2012 12:01:53 PM	52.854616
8	09/07/2012 2:00:56 PM	417.22184
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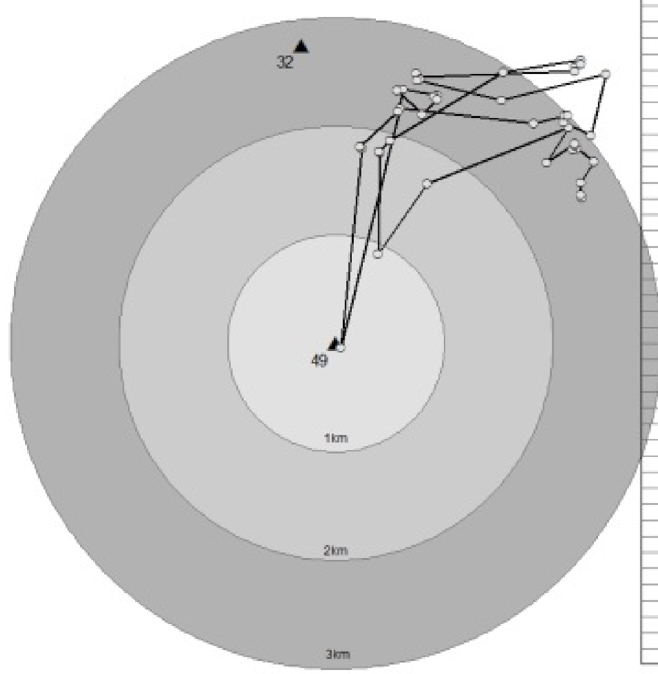
11	09/07/2012 10:02:20 PM	<Null>

D



OBJECTID *	LocalTime2	STEPLENGTH
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2	7/19/2012 2:01:52 AM	111
3	7/19/2012 4:00:54 AM	231
4	7/19/2012 6:01:48 AM	200
5	7/19/2012 8:01:25 AM	39
6	7/19/2012 10:01:22 AM	38
7	7/19/2012 12:01:27 PM	22
8	7/19/2012 2:00:53 PM	318
9	7/19/2012 4:02:54 PM	382
10	7/19/2012 6:01:50 PM	1405
11	7/19/2012 8:03:08 PM	789
12	7/20/2012 12:01:43 AM	943
13	7/20/2012 2:00:41 AM	7
14	7/20/2012 4:00:42 AM	146
15	7/20/2012 6:02:15 AM	1223
16	7/20/2012 8:00:55 AM	714
17	7/20/2012 10:01:54 AM	79
18	7/20/2012 12:02:36 PM	58
19	7/20/2012 2:01:41 PM	77
20	7/20/2012 4:01:41 PM	1450
21	7/20/2012 10:00:54 PM	39
22	7/21/2012 12:00:43 AM	61
23	7/21/2012 2:02:04 AM	26
24	7/21/2012 4:00:54 AM	801
25	7/21/2012 6:03:05 AM	993
26	7/21/2012 8:01:09 AM	588
27	7/21/2012 10:02:47 AM	274
28	7/21/2012 12:02:27 PM	67
29	7/21/2012 2:02:46 PM	29
30	7/21/2012 4:01:43 PM	327
31	7/21/2012 6:02:36 PM	1236
32	7/21/2012 8:01:24 PM	2273
33	7/21/2012 10:02:37 PM	1844
34	7/22/2012 12:00:52 AM	23
35	7/22/2012 2:00:41 AM	13
36	7/22/2012 4:01:22 AM	482
37	7/22/2012 6:00:52 AM	202
38	7/22/2012 8:00:55 AM	318
39	7/22/2012 10:02:24 AM	22
40	7/22/2012 12:01:46 PM	37
41	7/22/2012 4:01:24 PM	194
42	7/22/2012 6:01:51 PM	317
43	7/22/2012 8:00:54 PM	<Null>

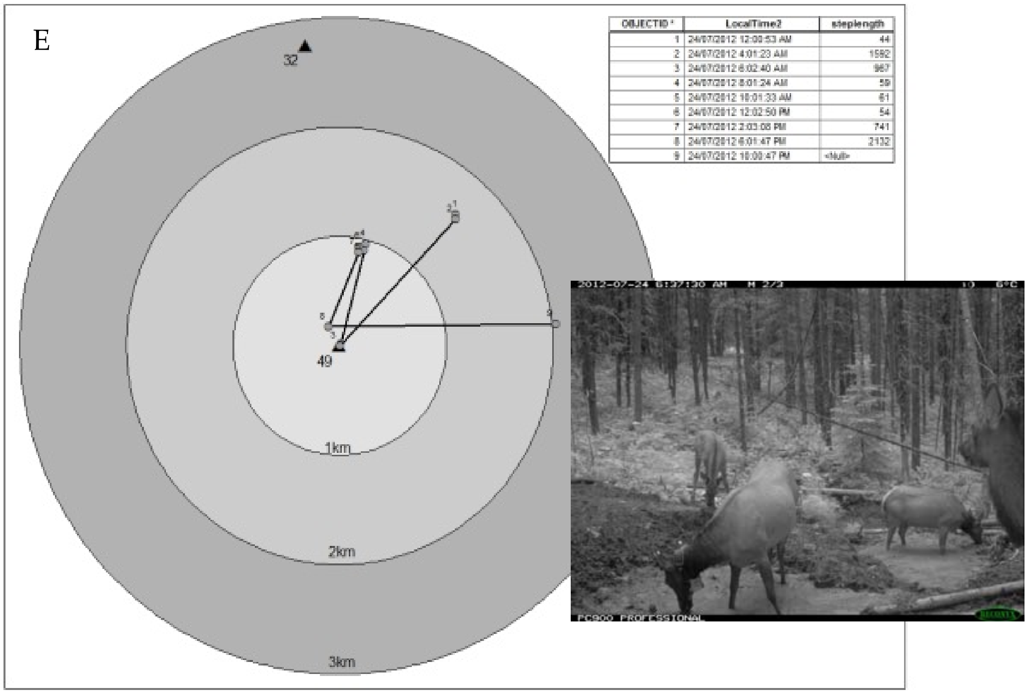

Figure 12. Summer range use and movements (A to E) of cow Elk 173 in relation to Lick 49 in southwest Alberta, 2012.

Based on camera images, this cow elk visited lick 49 a total of 13 times between July 6 and August 27, 2012. Figures 12A and12B illustrate how using a two-hour fix rate for elk could potentially miss visits at licks. The location data placed her on what would be the east side of the secondary roadway, but the camera data confirmed that she crossed the road and accessed the lick for a brief period.

During the peak-use months of July and August, cow Elk 173 seldom travelled outside a 3 km radius of the mineral lick. She and the remainder of the herd appeared to bed, feed and spend most days on the east side of the secondary roadway but regularly crossed during the crepuscular periods of the day to feed at the lick.

4.0 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 forest mineral lick use where observation is uninterrupted over time (i.e., using trail cameras), resulting in an ability to capture visits by any animal in a population. Most studies have relied on visual observations and GPS collar data from select individuals. Our trail-camera monitoring provides an improved understanding of when forest ungulate populations use mineral licks. For a habitat feature to be recognized as requiring special attention, collecting data such as we have collected in this study is an essential first step in making informed decisions when land-use considerations arise.

Visit frequency and timing is variable among sites, although forest licks are typically used by multiple species and visited on a daily basis during peak periods. Therefore, each mineral lick is a valuable key resource.

4.1 Mineral lick site characteristics

Forest mineral licks occur in a variety of landscapes. They are found under heavy tree cover, in open areas near the forest edge, in low lying areas, and high on hills and ridges. They are characterized by a seep and a heavily trampled area of rock, sand or mud. They typically consist of a loamy, silt or clay substrate, and their perimeters are often hedged.

Magnesium and sodium soil concentrations were significantly higher at our sampled mineral licks when compared with reference sites. Our elemental analyses showed higher concentrations of magnesium and sodium than those reported by Ayotte (2004) from high-use sites at forest licks in British Columbia. In Ayotte's (2004) study, the magnesium concentration was one-quarter that of our average concentration, and the sodium concentration was half of our average concentration. Ayotte et al. (2006) mentioned 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). Lavelle et al. (2014) found elk and deer visitations positively related to magnesium and sodium concentrations, but they suggested that elevated sodium is the draw for ungulates and that elevated magnesium concentrations are coincidental and potentially harmful.

Multiple species visited all forest mineral licks. Interspecific competition will likely occur when several different species are visiting one lick. We observed occurrences in which one species pushed the other off the lick, but other occasions in which three species tolerated each other and used a lick simultaneously (see inside cover photograph). Lick 60 received significant use by mountain goats, and goats visited for an extended period in large numbers. Therefore, instances like this will affect use of a site by other species (e.g., comfort level), particularly when some species can be aggressive in behaviour and occur in large numbers (e.g., goats).

It is possible that domestic cattle visiting mineral licks could impact the number of ungulate visitations, depending on the frequency of cattle use. Elk in our region have been documented to avoid cattle, particularly during elk calving season (Pruvot 2014). We observed several instances in which domestic cattle visited mineral licks (four of nine licks had cattle use). When multiple species are concentrating at communal sites such as mineral licks, there is a heightened risk of disease transmission among species (Lavelle et al. 2014). Mineral blocks and natural mineral lick sites that are visited by both domestic cattle and wild ungulates may exacerbate the transmission of pathogens (Pruvot 2014).

Predation risk is likely another factor that affects comfort level of ungulates using lick areas. From our observations, forest species are less likely to bed at a mineral licks when compared with alpine ungulates, and perhaps group size plays a role in vigilance (Festa-Bianchet and Côté 2008). We documented instances in which mountain goats demonstrated group defence at Lick 60, chasing off coyotes and standing ground with a cougar. We also observed instances in which deer and elk were frightened off the lick by coyotes.

4.2 Season and timing of use

Mineral licks were visited by animals repeatedly, usually after snow receded during early spring and summer. This behaviour suggests that snow cover and thawing temperatures are associated with animal arrival at most mineral licks in our region. As snow recedes, available forage begins to green-up, and animals migrate to their summer ranges (Boyce 1991). Furthermore, the calving and fawning season occurs simultaneously with green-up, and lactational demands amplify the dietary need for lick soils (Kreulen 1985; Ayotte et al. 2006). Rea et al. (2013) observed a unique instance in which moose were using mineral licks during winter months. Because of heavy snow cover and freezing temperatures in our study area, we believe ungulates are unable to access mineral licks during the winter season. Although we did not monitor throughout the winter season, our late winter and early spring monitoring did not reveal mineral lick use before spring thaw.

With the exception of the lower elevation licks (Licks 72 and 73), forest sites received little activity during May, but ungulates began visiting mineral licks with regularity in June. We observed visits at mineral licks over the entire sampling period from May to October, although the greatest intensity occurred in June through August. All ungulates were still visiting licks on occasion in September, and mule deer and moose continued to visit licks through October. On average, the night (00:00–06:00) hours were visited most frequently by moose. White-tailed deer largely avoided mineral licks during the night, whereas both moose and elk visited mineral licks the least during the afternoon (12:00–18:00) period. Street et al. (2015) indicated that moose increase activity during periods of low temperature and select for tall forest stands during summer afternoons to avoid the heat. The overall reduction of mineral lick use during the day period may also coincide with the time of day when ungulates feel most vulnerable and when human activity is highest.

Elk tended to visit in small groups, averaging three individuals, and visiting for 9 min on average. Deer commonly visited in pairs, with mule deer averaging 13 min per visit and white-tailed deer averaging 6 min. Moose visited licks singly and in pairs, spending an average of 12 min feeding. Ayotte et al. (2008) reported higher group sizes and visit durations for elk and moose in northern British Columbia. Their highest reported elk group size was 42 individuals with a visit time of 75 min. Their highest moose count was 6, and moose visits were always less than 40 min in length (Ayotte et al. 2008).

4.3 Spatial fidelity and movement

The draw of a mineral lick will influence how ungulates delineate their summer ranges (Tankersley and Gasaway 1983). The immediate landscape surrounding a mineral lick will be used by those ungulates using lick areas for foraging and cover (Simmons 1982; Singer and Doherty 1985). Furthermore, ungulates will travel several kilometres from their foraging habitat to access lick areas (Ayotte et al. 2008; Poole et al. 2010; Rice 2010).

We briefly investigated movement patterns of collared elk in relation to our known mineral licks. During a one-week period in May 2009, cow Elk 114 remained within a 2 km radius of Lick 72, visiting on five occasions and retreating to the same general area each time to presumably bed and forage. These distinct movements to and from the lick provide an example of how elk may use the immediate area surrounding a mineral lick for its daily requirements. All but one of these visits occurred during the crepuscular periods of the day. This lick is in an exposed location and is located 100 m from an off-highway-vehicle trail that appears to have sporadic use. Off-highway vehicles have been shown to cause elk to reduce their time feeding and increase their time travelling away from a disturbance (Naylor et al. 2008).

Lick 58 is located in an exposed area (cutblock) near a gravel road. Visit duration by elk was lower than the overall average, and elk visited the lick only twice in the afternoon over a two-year period. Ciuti et al. (2012) found both male and female elk moved faster when near gravel roads and during weekends. Cow Elk 137 appeared to summer between Licks 58 and 60, moving with purpose (longer step lengths and aimed movement) when visiting each of the licks.

Paton (2012) observed elk migration routes between winter and summer ranges that spanned from 15 to 64 km in our study area. Spring migration began the first week of May (in association with calving) and typically ended in June (Paton 2012). The herd in which cow Elk 173 was part of spent their summer months nursing their young and gaining summer mass adjacent to Lick 49, visiting it habitually. These elk had travelled approximately 18 km in a straight-line distance from their winter range during May and June to reach these summer grounds. During the peak months of July and August, Elk 173 and members of the herd occupied the area immediately to the east of Lick 49. The elk often bedded and foraged within a few kilometres of the lick; however, they had to cross Highway 940 (located 200 m from the lick) to access the lick each time. These visits took place during the crepuscular periods of the day when we assume vehicle traffic was lower. Ciuti et al. (2012) found elk in our study area showed a noticeable increase in activity (moving longer distances) during the crepuscular periods of the day.

5.0 CONSERVATION IMPLICATIONS

Mineral licks are highly valued and frequently used by forest ungulates during the spring and summer periods. This time period coincides with calving, as females are seeking safe zones for their young. To enhance the productivity and security of ungulate populations, we suggest that proactive steps be taken to limit the negative impacts of industrial activity and road use in relation to key wildlife resources such as mineral licks. Alberta's timber harvest guidelines list mineral licks under the "other species/sensitive site" section of the document. Mineral licks are universally classed along with amphibian sites, bat hibernacula, nesting areas and wolverine dens—all receiving a forested buffer distance of 100 m (ESRD 2012). We suggest that future land-use plans include specific actions for mineral lick sites rather than grouping them in a general category and the spatial buffer be upgraded along with seasonal and timing considerations.

5.1 Spatial buffer

Natural and human-made features and activity surrounding each mineral lick are often unique, which influences the species that are attracted to a site as well as frequency of use. The relative value of any one mineral lick is difficult to quantify based merely on its appearance or size. Hence, determining an appropriate buffer that encompasses the needs of all species with the potential to use a lick is challenging because each situation is somewhat unique. However, we suggest that a spatial buffer of 500 m is a reasonable minimum distance.

Elk movement and behaviour have been well studied in this area over the past 10 years. Elk have been shown to avoid areas <500 m from roads and to select areas with low road density when migrating and using stopovers (Paton 2012). Road use affects elk movement and leads to greater vigilance among individuals (Ciuti et al. 2012). Ciuti et al. (2012) found that elk in this area used more vigilant behaviour when <500 m from roads that have only moderate traffic levels (12 vehicles per day). Furthermore, ungulates visit mineral licks during and shortly after the calving season, and human disturbance during this sensitive period negatively impacts their reproductive success (Phillips and Alldredge 2000). We suggest that a 500 m spatial buffer is a minimum distance to avoid disturbing elk (and other ungulates) and heightening their level of vigilence.

5.2 Seasonal and daily disturbance

The implementation of seasonal disturbance restrictions is another tool that could be overlaid with spatial buffers to mitigate impacts from human disturbance near licks and other key resources. A seasonal timing restriction would ideally avoid heightened industrial activity near migration routes in spring, key calving and stopover sites, and forest mineral licks. Paton (2012) found spring elk migrations averaged 20 days but ranged from 2 to 65 days. Cow elk that took longer to migrate to their summer ranges often stopped along the way to calve. Elk in this area migrate in May and June annually (Paton 2012), and this migration coincides with the initial visitations we documented at mineral licks. We suggest that land-use planners map these key resources and overlay seasonal timing restrictions with a 500 m buffer to minimize industrial activity and road disturbance. These seasonal restrictions would be particularly effective in areas where roads already exist within 500 m of key resources such as licks, migration routes, stopovers and calving areas. We suggest spring restrictions from May through June along migration routes, stopovers and calving areas, and restrictions from May through August within 500 m of forest mineral licks. If seasonal and spatial buffer restrictions are not achievable, then a secondary measure would be to target any heighted disturbance activity from 12 p.m. to 6 p.m. on a daily basis. Our results showed that that this time period was used least by elk and moose.

Wildlife resources are intermittent on the landscape, and multiple species will habitually use high-value areas, such as licks, and the ranges and corridors associated with them. These areas hold spatial biological significance.

6.0 LITERATURE CITED

Alberta Environment and Sustainable Resource Development (ESRD). 2012. Alberta timber harvest planning and operating ground rules framework for renewal. Alberta Environment and Sustainable Resource Development, Forestry Division, Forest Management Branch. 98 pp.

Alberta Environment Sustainable Resource Development (ESRD). 2013. Enhanced approval process, integrated standards and guidelines. Alberta Environment and Sustainable Resource Development, Alberta Energy Regulator. 94 pp.

Anderson, D.P., J.D. Forester, M.G. Turner, J.L. Frair, E.H. Merrill, D. Fortin, J.S. Mao, and M.S. Boyce. 2005. Factors influencing female home range sizes in elk (*Cervus elaphus*) in North American landscapes. Landscape Ecology 20: 257–271.

Archibald, J.H., G.D. Klappstein, and I.G.W. Corns. 1996. Field guide to ecosites of southwestern Alberta. Natural Resources Canada, Canadian Forest Service, Northwest Region, Northern Forestry Centre, Edmonton, Alberta, Canada. Special Report 8.

Ayotte, J.B. 2004. Ecological importance of licks to four ungulate species in north-central British Columbia. MSc. Thesis, University of Northern British Columbia. 120 pp.

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 Mammology 87: 878–888.

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(4): 1041–1050.

Bender, L.C., L.A. Lomas, and T. Kamienski. 2007. Habitat effects on condition of doe mule deer in arid mixed woodland-grassland. Rangeland Ecology & Management 60(3): 277–284.

Boyce, M.S. 1991. Migratory behavior and management of elk (*Cervus elaphus*). Applied Animal Behavior Science 29: 239–250.

Ciuti, S., T.B. Muhly, D. Paton, A.D. McDevitt, M. Musiani, and M.S. Boyce. 2012. Human selection of elk behavioural traits in a landscape of fear. Proceedings of the Royal Society B 279(1746): 4407–4416.

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.

Dussault, C., R. Courtois, J.-P. Ouellet, and I. Gerard. 2005. Space use of moose in relation to food availability. Canadian Journal of Zoology 83: 1431–1437.

Festa-Bianchet, M., and S.D. Côté. 2008. Mountain goats. Ecology, behaviour and conservation of an alpine ungulate. Island Press, Washington. 265 pp.

Garrott, R.A., G.C. White, R.M. Bartmann, L.H. Carpenter, and A.W. Alldredge. 1987. Movements of female mule deer in northwest Colorado. Journal of Wildlife Management 51(3): 634–643.

Grovenburg, T.W., J.A. Jenks, R.W. Klaver, C.C. Swanson, and C.N. Jacques. 2009. Seasonal movements and home ranges of white-tailed deer in north-central South Dakota. Canadian Journal of Zoology 87(10): 876–885.

Hasbani, J.G. 2010. Reconyx image loader user guide. Software developed by Jean-Gabriel Hasbani for Alberta Conservation Association. 26 pp.

Heimer, W.E. 1974. The importance of mineral licks to Dall sheep in interior Alaska and its significance to sheep management. Proceedings of the Third Biennial Wild Sheep and Goat Council Conference 3: 49–63.

Heimer, W.E. 1988. A magnesium-driven hypothesis of Dall sheep mineral lick use: preliminary tests and management relevance. Proceedings of the Sixth Biennial Wild Sheep and Goat Council Conference 6: 269–279.

Horvath, S. (editor). 2009. British Columbia environmental laboratory manual. Water and Air Monitoring and Reporting, Environmental Quality Branch, Ministry of Environment, Victoria, British Columbia, Canada.

Jokinen, M.E., M.S. Verhage, R. Anderson, and D. Manzer. 2014. Observational description of alpine ungulate use at mineral licks in southwest Alberta, Canada. Proceedings of Nineteenth Biennial Wild Sheep and Goat Council Conference 19: 42–63.

Jones, R.L., and H.C. Hanson. 1985. Mineral licks, geophagy, and biochemistry of North American ungulates. Iowa State University, Ames, Iowa, USA.

Kreulen, D.A. 1985. Lick use by large herbivores: a review of benefits and banes of soil consumption. Mammal Review 15: 107–123.

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.

Morgantini, L.E., and E. Bruns. 1988. Attraction of bighorn sheep to wellsites and other man-made mineral licks along the eastern slopes of Alberta: a management concern. Proceedings of the Sixth Biennial Wild Sheep and Goat Council Conference 6: 135–140.

Natural Regions Committee. 2006. Natural regions and subregions of Alberta. Compiled by D.J. Downing and W.W. Pettapiece. Government of Alberta. Pub. No. T/852. 264 pp.

Naylor, L.M., M.J. Wisdom, and R.G. Anthony. 2008. Behavioral responses of North American elk to recreational activity. Journal of Wildlife Management 73(3): 328–338.

Paton, D.G. 2012. Connectivity of elk migration in southwestern Alberta. MSc. Thesis, University of Calgary, Calgary, Alberta, Canada. 163 pp.

Phillips, G.E., and A.W. Alldredge. 2000. Reproductive success of elk following disturbance by humans during calving season. Journal of Wildlife Management 64(2): 521–530.

Poole, K.G., K.D. Bachmann, and I.E. Teske. 2010. Mineral lick use by GPS radio-collared mountain goats in southeastern British Columbia. Aurora Wildlife Research, Nelson, British Columbia, Canada. 21 pp.

Pruvot, M. 2014. Eco-epidemiology of production limiting diseases at the wildlife-livestock interface: beef cattle and elk in southwestern Alberta, Canada. PhD. Thesis, University of Calgary, Calgary, Alberta, Canada. 296 pp.

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. 2013. 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: 36–41.

Rice, C.G. 2010. Mineral lick visitation by mountain goats, *Oreamnos americanus*. Canadian Field-Naturalist 124: 225–237.

Simmons, N.M. 1982. Seasonal ranges of Dall's sheep, Mackenzie Mountains, Northwest Territories. Arctic 35: 512–518.

Singer, F.J., and J.L. Doherty. 1985. Movements and habitat use in an unhunted population of mountain goats, *Oreamnos americanus*. Canadian Field-Naturalist 99: 205–217.

Stankowich, T. 2008. Ungulate flight responses to human disturbance: a review and meta-analysis. Biological Conservation 141: 2159–2173.

Street, G.M., A.R. Rodgers, and J.M. Fryxell. 2015. Mid-day temperature variation influences seasonal habitat selection by moose. Journal of Wildlife Management 79(3): 505–512.

Tankersley, N.G., and W.C. Gasaway. 1983. Mineral lick use by moose in Alaska. Canadian Journal of Zoology 61: 2242–2249.

van Beest, F.M., E. Vander Wal, A.V. Stronen, P.C. Paquet, and R.K. Brook. 2013. Temporal variation in site fidelity: scale-dependent effects of forage abundance and predation risk in a non-migratory large herbivore. Oecologia 173(2): 409–420.

Watts, T.J., and S.D. Schemnitz. 1985. Mineral lick use and movement in a remnant desert bighorn sheep population. Journal of Wildlife Management 49: 994–996.

Welch, I.D., A.R. Rodgers, and R.S. McKinley. 2000. Timber harvest and calving site fidelity of moose in northwestern Ontario. Alces 36: 93–103.

7.0 APPENDICES

Appendix 1. Mineral lick field assessment form.

please do not leave areas blank, cross them out if they do not apply		Page 1
Site Number		
Observer/s		
Date visited		
Elevation (m) *GPS derived*		
UTM (NAD 83) *GPS derived*		
Slope (%) *at lick itself*		
Aspect *at lick itself*		
Wildlife Observed at Lick	**Species:**	
	Count:	
sex/age composition if possible	**Group Composition:**	
record photo number	**Photos: Yes/No**	
Wildlife Observed in Area?	**Species/Count/Group Composition**	
if observed in general area of lick		
Wildlife Sign at Lick	**Droppings:** *fresh?* **Yes/No** *species?*	
	Hair: Yes/No *species?*	
digging within lick	**Lick Excavation/Hedging: Yes/No**	
provide rough count	**Beds: Yes/No**	
provide rough count	**Rubs: Yes/No**	
plant being browsed?	**Browse: Yes/No**	
	Tracks: Yes/No *species?*	
record photo number	**Photos: Yes/No**	
	Bone/Kill sites? Yes/No *species?*	
Lick Type *circle one*	**Dry / Wet / Rock / Tree**	
Lick Soil Type *circle one*	**Moist / Dry** *AND* **Silt / Clay / Loam**	
Area of Lick (*m2*)	**________meters ________meters**	*roughly pace disturbed soil/lick area*
Soil Sample	**Yes/No** *(taken from most active location)*	
record photo number	**Photos: Yes/No**	
Comments:		

Surrounding Trail System	**Trails Evident? Yes/No**	
level of wear, are the trails distinct?	**Visible Wear: High/Low**	
provide count of distinct trails	**Number of Well-Defined Trails Departing Lick**	
record photo number	**Photos: Yes/No**	
General Plant Community	**Overstory:**	
in Area	**Understory:**	
	Comments:	
record photo number	**Photos: Yes/No**	
Other Site Details	**Proximity to Water:**	
form, direction and distance		
	Proximity to Cover/Escape Terrain:	
form, direction and distance		
Risk of Human Disturbance	**Sign of Human Activity: Yes/No**	
cutblock, OHV, garbage etc	**Form of Disturbance:**	
use GPS to determine distance	**Distance of Lick from Disturbance/s**	*provide wpt, description & distance*
note greatest possible threat	**Threat:**	
	ie:timber harvest, OHV trail etc.	
provide possible remedy to threat	**Altering Level of Threat**	
	ie: ensure no harvest occurs between lick and escape terrain/summer range	
	ie: trail closure, trail unnecessary	
Candidate for monitoring?	**Yes/No**	
(based on scene observation)	**Why?**	
Is it currently monitored?	**Yes/No**	**Camera distance from lick? __________m**
N, E, W, S etc & compass degree	**Compass bearing taken camera towards lick**	
Additional Comments		
Are there any site specific concerns? Active logging in the area? Avalanche terrain? Poor/difficult access?		
Monitoring concerns? (theft/vandalism, nothing to secure camera to)		

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Alberta Government

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