RESPONSE OF ELK AND STONE'S SHEEP TO PRESCRIBED FIRE IN NORTHEAST BC

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HABITAT CONSERVATION TRUST FOUNDATION

MULTI-YEAR PROJECT REPORT

1. **PROJECT NAME** RESPONSE OF ELK AND STONE'S SHEEP TO PRESCRIBED FIRE IN NORTHEAST BC

2. **HCTF PROJECT FILE # CAT13-7-354**

3. **FISCAL YEARS** (1 APRIL 2010 TO 31 MARCH 2013)
   FOR CONTINUING PROJECTS, FINAL REPORT

4. **LOCATION**
   a) Distance from a known place: 215 km from Fort St John
   b) Longitude (degree/minute/seconds): between 121°51' and 124°31'
   c) Latitude: (degree/minute/seconds): between 57°11' and 57°15'

5. **PROJECT EXECUTIVE SUMMARY**

The Peace-Liard Prescribed Burn Program in northern British Columbia (BC) uses fire intensively to create, maintain, and enhance habitats for large game species. The Peace Region of BC is internationally known for its abundance of ungulates and predators. To quantify the influence of prescribed burns in the Besa-Prophet area of northern BC, we focused our efforts on two focal species: elk (*Cervus elaphus*), which contribute the largest ungulate biomass to a globally significant predator-prey system; and Stone's sheep (*Ovis dalli stonei*), which are highly dependent on traditional ranges and which have high ecological and economic values.

Specific objectives of the three-year study were to monitor seasonal movements of elk and Stone's sheep in relation to burned areas; to determine how the age and vegetative quality of burns influence the use of burns; to identify any seasonal range overlap in the use of burned areas by these two focal species; and to quantify the interactive effects of prescribed burning on the two species. We compared vegetation response in burned areas with unburned areas using measures of forage quantity (biomass) and quality (digestibility and protein). At a fine scale, we clipped and collected vegetation in plots along high, mid, and low-elevation transects. At the landscape scale, we used remote-sensing imagery to estimate burn extent and regrowth over a two-year period. We also monitored animal response to burns at both the fine scale (fecal pellet transects) and the landscape scale (global positioning satellite (GPS) - collared individuals and monthly flights to record animal distribution by species).

With the reduction in shrubs following prescribed fire, burned communities increased herbaceous cover. Species diversity increased to almost that of unburned areas by one year after burning. Vegetation biomass continued to increase two years after burning and the rate of forage growth was higher on burned areas than unburned control areas. Forage digestibility increased following burning and was highest one year after fire. Crude protein was higher in the new growth on burned areas, but returned to pre-burn levels by one year after fire. The availability of high-quality forage for ungulates (quantity x quality) was higher on south-aspect sites than west-facing sites. Both Stone's sheep and elk selected for south aspects and to be close to burns,

which were most important in winter and late winter. Averaged across individuals, the proportional use of burned areas was 45% in Stone's sheep and 80% in elk in late winter. Currently, the two species tend to occupy different niches on the landscape because Stone's sheep use steeper slopes at higher elevations with extensive use of rock/rock crust areas. Fire, however, has the potential to change predator-prey interactions by altering the distribution of ungulates that increase their use of higher quality forage in burned areas. We recommend continued monitoring of expanding elk populations to ascertain if they move into the steeper and higher elevations used by Stone's sheep in response to on-going burning.

This study comprises the graduate thesis by Krista Sittler at the University of Northern British Columbia (UNBC). The research was conducted in collaboration with the BC Ministry of Environment, which implemented the prescribed burns that allowed us to quantify the influence of fire relative to unburned areas.

7. BACKGROUND AND STUDY AREA

The Peace Region of BC is internationally known for its abundance of ungulates and predators. This assemblage of wildlife has been influenced by the mosaic of different successional stages of vegetation across the landscape, many of which occur because of the natural fire regime and the use of prescribed fire. Prescribed fire is an accepted habitat enhancement technique in northeastern BC (Backmeyer et al. 1992, AMEC 2002). The Ministry of Environment (MOE, with operations recently moved to Ministry of Forests, Lands and Natural Resource Operations, MFLNRO) in the Peace Region has been using prescribed burning as a management tool to enhance wildlife populations for more than 30 years. Prescribed burns now represent 41% of the total area burned in the region and 23% of all fires (Lousier et al. 2009). Perhaps nowhere in North America is prescribed burning as extensive as it is in the Peace Region where typically 7800 ha are burned annually.

The Muskwa-Kechika Management Area (MKMA) in northern BC covers approximately 6.4 million ha. It includes areas protected as provincial parks and special management zones where resource development is permitted as long as wildlife and wilderness values are maintained. Within the MKMA, the Besa-Prophet study area includes the 204,245-ha Besa-Prophet Pre-tenure Planning Area, and portions of the surrounding region including part of Redfern-Keily Provincial Park for a total of 740,800 ha (Fig. 1). The Besa-Prophet Pre-tenure Planning Area is designated as a special management zone where exploration and/or extraction of natural resources is permitted if concerns for wildlife populations are addressed prior to development. The study area is located between $57^{o}11'$ and $57^{o}15'$ N, and $121^{o}51'$ and $124^{o}31'$ W, south of the Prophet River and including the Besa River, within the Muskwa Ranges and Rocky Mountain Foothills. It is characterized by repeated east-west drainages and south-facing slopes.

There are primarily 3 biogeoclimatic zones in the Besa-Prophet study area (Meidinger and Pojar 1991). The Boreal Altai Fescue Alpine (BAFA) zone above approximately 1600 m consists of permanent snowfields, rock, mat vegetation, and grasslands (Demarchi 1996). The spruce-willow-birch (SWB) zone at mid-elevations (~1300-1600 m) in the subalpine is characterized by an abundance of willow (*Salix* spp) and scrub birch (*Betula glandulosa)*, as well as some balsam fir (*Abies lasiocarpa*) and white spruce often in krummholz form, and various grasses, sedges and fescues (*Festuca* spp.). The boreal white and black spruce zone (BWBS; *Picea glauca* and *P. mariana*) occurs at lower elevations. Valleys at ~800-1300 m are lined with white spruce, some lodgepole pine (*Pinus contorta*) and trembling aspen (*Populus tremuloides*) on dry sites, and black spruce, willow-birch communities on poorly drained sites.

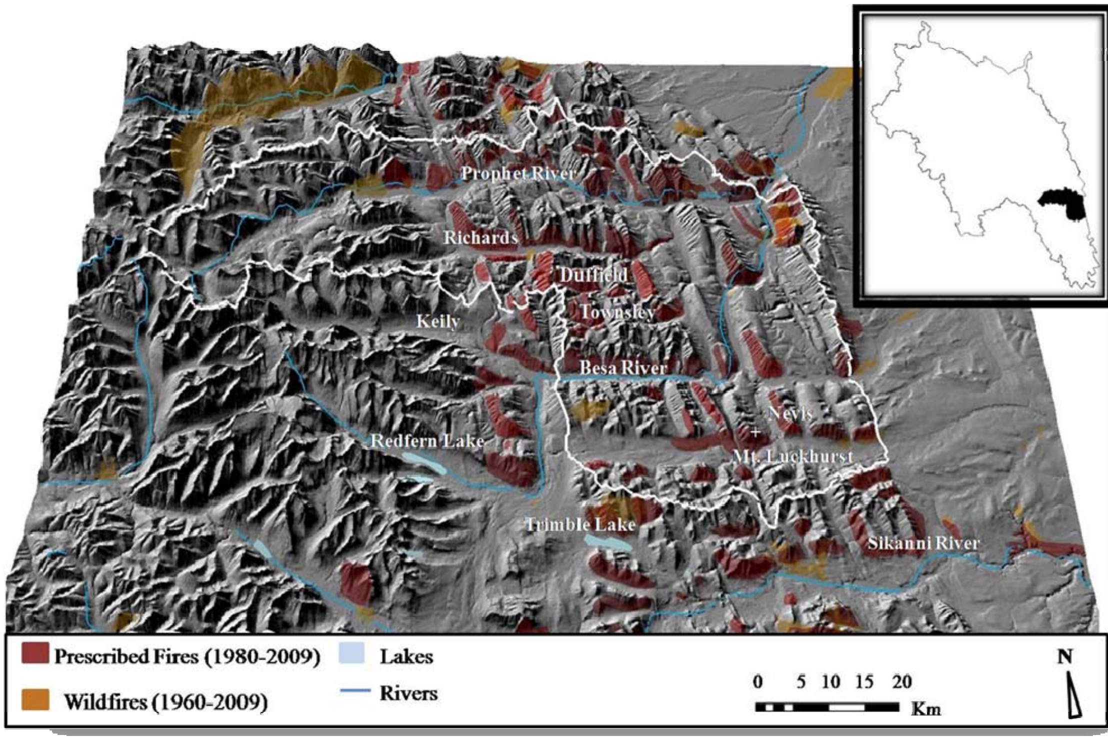

Figure 1. Besa-Prophet study area in the Muskwa-Kechika Management Area (shown in black box) in northern British Columbia, with major drainages, landforms, and wild and prescribed fires. The Besa-Prophet pre-tenure planning area is outlined in white.

There also are numerous slopes that have been burned by the BC Ministry of Environment and local guide outfitters to enhance forage production for ungulates (Fig. 2). Repeatedly burned south-facing slopes are dominated by fuzzy-spiked wild rye (*Elymus innovatus*), fireweed (*Epilobium angustifolium*), tall bluebells (*Mertensia paniculata*), and alpine sweet-vetch (*Hedysarum alpinium*); as the burned slopes age, aspen, balsam poplar (*Populus* balsamifera) and willows dominate the shrub layers (Lay 2005). Previously burned west-facing slopes are typically dominated by scrub birch, willows, and shrubby cinquefoil (*Potentilla fruticosa*). Dwarf shrubs such as ligonberry (*Vaccinium vitis-idea*) and bearberry (*Arctostaphylus uva-ursi*) form mats on the ground.

Because of the variety in vegetation, the numerous south-facing slopes that are often blown free of snow during winter, and the lack of access to the area, the Besa-Prophet study area supports one of the largest intact and diverse predator-prey systems in North America. Ungulates include moose Stone's sheep, elk, moose (*Alces americanus*), caribou (*Rangifer tarandus*), and a few mountain goats (*Oreamnos americanus*) and deer (*Odocoileus* spp.). Large predators capable of preying on these ungulates include wolves (*Canis lupus*), grizzly bears

(*Ursus arctos*), black bears (*U. americanus*), cougars (*Felis concolor*), coyotes (*Canis latrans*), and wolverines (*Gulo gulo*).

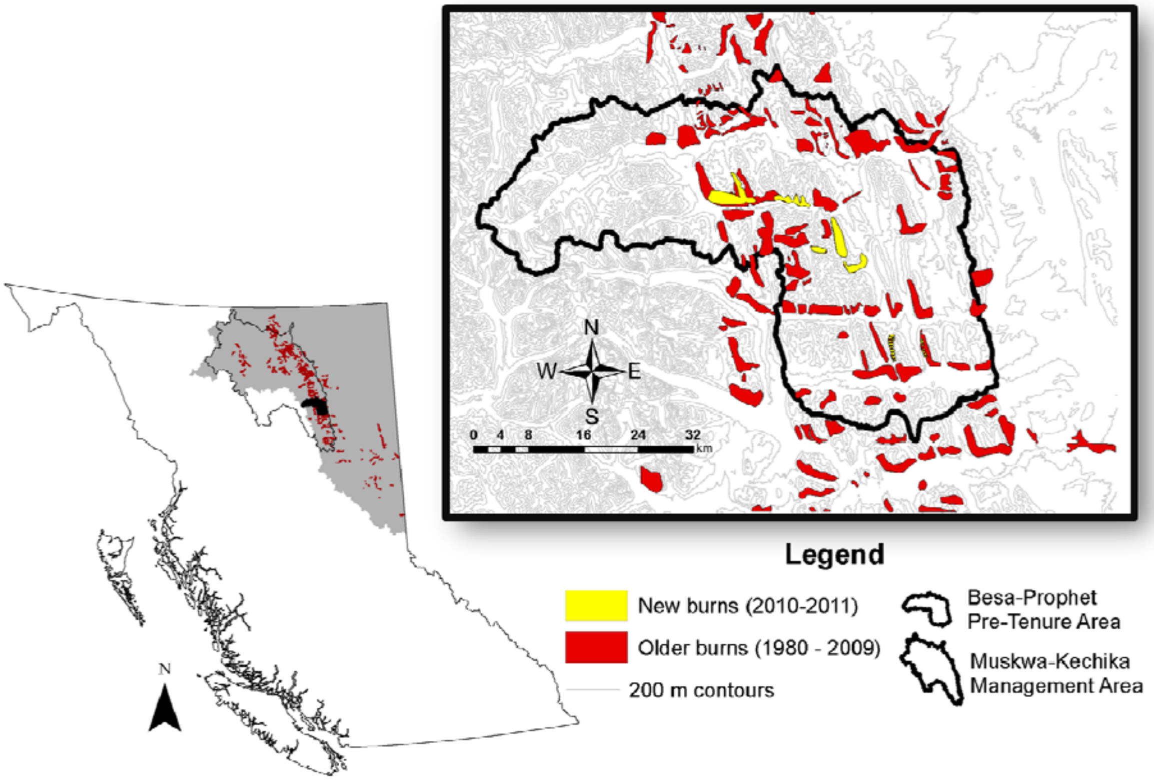

Figure 2. Besa-Prophet study area (outlined black box) in northern British Columbia. Gray area is the Peace Region, with prescribed burns implemented since 1980. New burns were implemented in 2010 and 2011 as part of the Peace-Liard Prescribed Burn Program.

8. ACTIVITIES/TECHNIQUE(S)

1. Monitor seasonal movements of elk and Stone's sheep in relation to burns

<u>Radio-collared animals</u>:

At the beginning of this project in March 2010, 12 Stone's sheep were captured by aerial netgunning and fitted with Global Positioning Satellite (GPS) collars (Advanced Telemetry Systems, Isanti, MN) programmed to acquire animal locations at 6-hour intervals over a 2-year battery life. Two of the collars were redeployed in 2011 after they were recovered: one animal had slipped the collar soon after capture and the other was killed after 6 months. The original collars were scheduled to drop off in mid-March 2012; the two more recently deployed collars were scheduled to drop from animals in late July 2012. Of these, 11 collars were recovered after helicopter transport within close proximity (one animal had died in an avalanche after 13 months of data collection). and one animal was presumed missing from collar failure. Of the 14 adult female Stone's sheep fitted with collars in this study, there were 2 confirmed mortalities.

Thirteen elk were captured in 2010 and fitted with GPS collars having a one-year battery life. There was 1 elk mortality and 2 elk that went missing during the first year of the study. In summer 2011, we retrieved collars from 9 elk after the collars were released from the animals; another elk collar was retrieved after netgunning the animal. Because the elk collars had only a 1-year battery, 13 additional elk were collared in 2011 so that elk locations could be collected over a 2-year period. Six of these elk were collared in February 2011; the remaining 7 collars were deployed in April 2011. All of these collars were scheduled to drop from the animals in late July 2012. Following periodic monitoring flights, one of the collared elk was noted as 'missing', presumably from collar failure, within 3 months. Twelve dropped collars were retrieved in early September 2012.

Upon collar retrieval, we incorporated all GPS locations of collared individuals into a Geographic Information System (GIS) using ArcMap (ESRI 2010). We calculated monthly and seasonal movement rates for individual Stone's sheep and elk by measuring the Euclidean distance between consecutive GPS locations, and then averaged across individuals to obtain average movement rates by species. We quantified seasonal ranges for Stone's sheep and elk by first determining the 95th longest distance moved by each individual in each season. We buffered each use point by this distance, assuming that the animal could have moved anywhere within that available area. We considered the area enclosed by all buffered use points to be its seasonal range. We averaged across individuals to obtain average sizes of seasonal ranges by species.

We defined five seasons for our analyses based on the life history, behaviour, and movements of Stone's sheep and elk (Table 1).

Table 1. Seasons, dates and biological rationale for grouping data from radio-collared Stone's sheep and elk in the Besa-Prophet area, northern British Columbia.

Season	Date	Biology
Spring	16 May – 15 June	Parturient females become solitary prior to birthing; onset of plant greening
Summer	16 June – 15 August	Plant green-up through peak vegetation biomass to start of senescence
Fall	16 August – 31 October	Senescence of vegetation
Winter	1 November– 28 February	Declines in movement rates; usually snow cover
Late winter	1 March – 15 May	Lowest movement rates; usually smallest range size

Animal distribution flights:

In June 2011, we began monthly fixed-wing flights over a one-year monitoring period to record the distribution of groups of elk and Stone's sheep, supplementing data from GPS collared individuals. This information was acquired along a designated 2-hour route over an area that encompassed all GPS-collared animals as well as 24 burns of varying size and age (Fig. 3) to help quantify spatial and temporal use of burns by elk and Stone's sheep in the Besa-Prophet area. For all animal groups observed, we recorded the location, elevation and dominant land cover (burn versus non-burn – alpine, rocks, conifer stand, valley bottom, mineral lick), as well as group size and sex if possible. We then compared animal numbers and group sizes by species, and locations by elevation (high, mid, low) on burned and unburned areas.

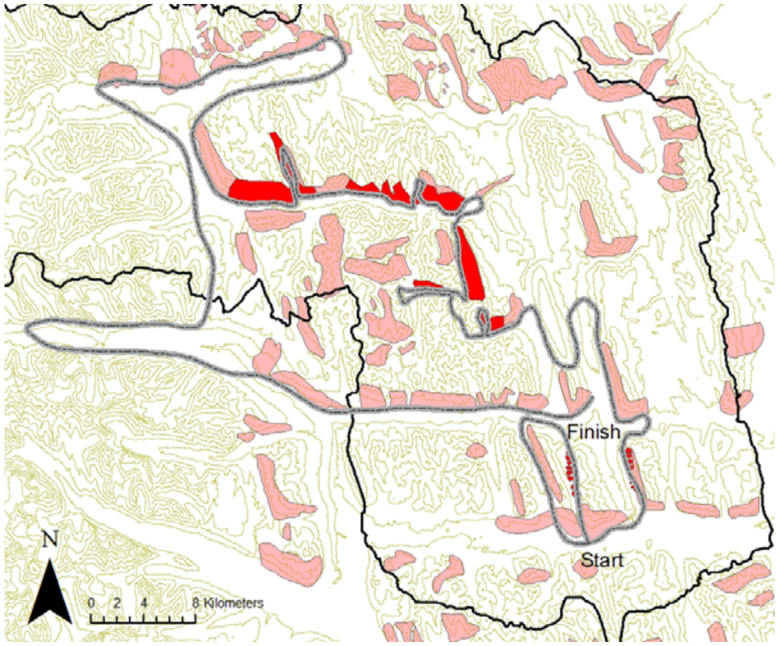

Figure 3. Flight route (in gray) for animal distribution flights in the Besa-Prophet area (black line designates the southern extent of the Besa-Prophet pre-tenure planning area). Red polygons are 2010 and 2011 prescribed burns implemented as part of this study; pink polygons are areas burned previously.

2. Determine how the age and vegetative quality of burns influence their use

<u>Prescribed burns:</u>

In conjunction with our study, prescribed burning was conducted in the spring of 2010 (between 15 May and 01 June) at 4 sites: Luckhurst, on the west side of Luckhurst Mountain in the southeast corner of the Besa-Prophet study area; Nevis, on the western slope above Nevis Creek located on the mountain just east of Luckhurst; Richards; a south-facing slope above Richards Creek; and Townsley, another south-facing slope in the Townsley Creek drainage (Fig. 4). The burns were implemented by BC provincial wildlife biologist Rob Woods as part of the Peace-Liard Prescribed Burn Program using a delayed aerial ignition device system (Rothermel 1984). This method allows for multiple ignition sites, resulting in a mosaic of unburned patches within a larger burned area. All sites had been burned previously except Luckhurst, for which the new burn extended the area of previous burns. The 2010 burns ranged in size from 150 – 1000 ha (Table 2). The burn on Luckhurst occurred 2 weeks later than the other sites because of excess snow accumulation on the site. These 4 2010 burns were monitored in our subsequent vegetation sampling research.

Three more prescribed burns were implemented between 22 May and 2 June 2011, ranging in size from 200 – 700 ha (Table 2), further to the east on Richards Creek, on a west-facing slope south of Richards Creek, and on a site bordering Duffield Creek (Fig. 4). A fourth prescribed burn was planned, but was not implemented because of inclement weather. All 7 prescribed burns completed for this study were on south- and west-facing slopes. The locations of the burns were identified and prioritized based on the potential to produce/increase early seral vegetation and took into account the locations of radio-collared elk and Stone's sheep and existing burns on the landscape.

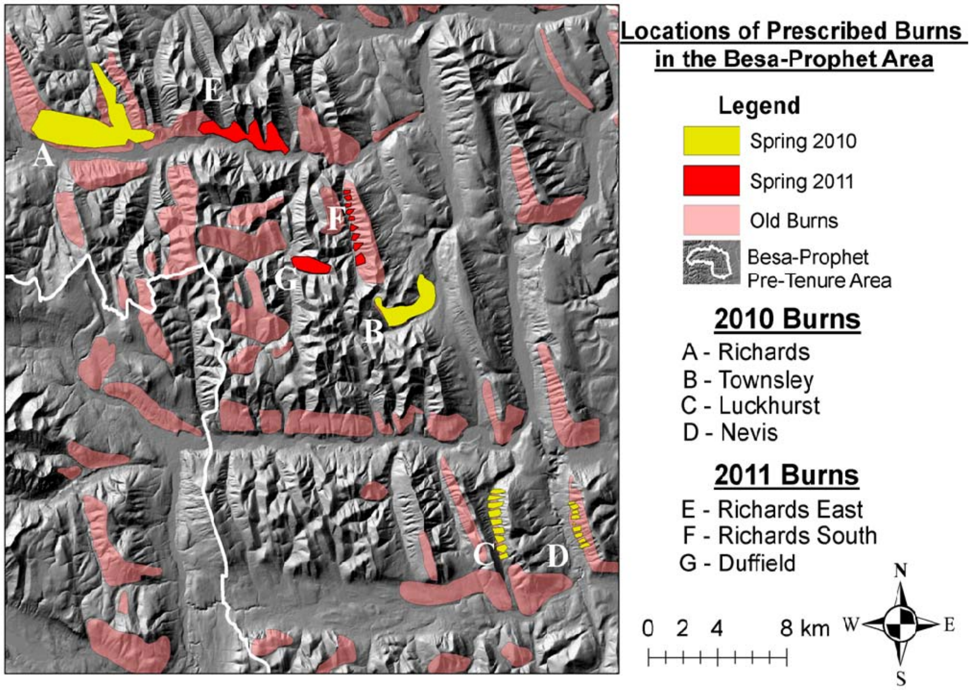

Figure 4. Locations of prescribed burns dating back to 1980 in the southeast corner of the Besa-Prophet study area, northern British Columbia. Red blocks are prescribed fires implemented in spring 2010 and yellow blocks were implemented in spring 2011.

Table 2. Descriptions and history of the prescribed burns implemented in the Besa-Prophet study area, northern British Columbia, in 2010 and 2011.

Site	Area (ha)	Aspect	Date Burned	Years Burned
Richards	1000	South	15 May 2010	1981, 1985, 1987, 1991, 2002, 2010
Townsley	370	South	16 May 2010	1987, 2010
Luckhurst*	150	West	01 June 2010	1984, 1987, 2001, 2010*
Nevis	300	West	16 May 2010	1984,1987, 2001, 2010
Richards East	700	South	22 May 2011	1981, 1985, 1987, 2011
Richards South	500	West	02 June 2011	1987, 2011
Duffield	200	South	03 June 2011	1987, 1990, 2011

*2010 burn was a new burn adjacent to the previously burned area

Burn severity and extent:

Burn severity is typically measured as above- or below-ground loss of organic matter (Stock 1987, Keeley 2009). In early May 2010 while sampling vegetation for a pre-burn baseline on the sites to be burned, we installed 9 burn pins along 50-m (vegetation) transects at high, mid, and low elevations to measure the subsequent intensity of burning. The cross-bar of each pin was placed even with the height of the litter and vegetation biomass (Fig. 5). Within a week following the prescribed burning, we revisited burned areas to measure the depth of each burn and retrieve the burn pins.

Figure 5. Depths of burn pins were used to measure the amount of fuel consumed as an index of the intensity of a burn.

We used remote-sensing imagery (multi-spectral Landsat Thematic Mapper and Enhanced Thematic Mapper — TM/+ETM) to determine broad-scale changes in vegetation and to quantify burn extent. The entire Besa-Prophet study area is located on path 50 row 20; the northwestern half can also be found in path 51 row 20 and the southern portion can be seen on path 49 row 20. We used the delta-Normalized Burn Ratio (dNBR), which is correlated with the amount of pre-burn vegetation photosynthetic activity, as an indication of how much vegetation was killed/consumed by the fire (Miller and Thode 2007). dNBR is derived by subtracting a post-fire from a pre-fire multi-spectral NBR Landsat TM/+ETM image (Fig. 6). Post-fire images were within 3 weeks of the prescribed burns.

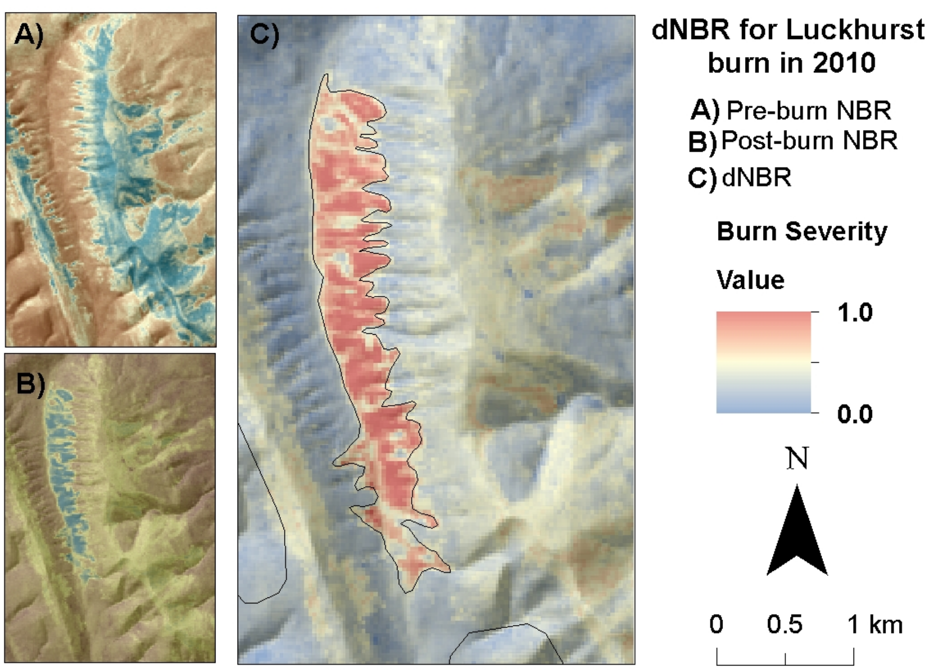

Figure 6. Delta-Normalized Burn Ratio (dNBR) showing the change in vegetation before and after prescribed burning at the Luckhurst site, Besa-Prophet study area, northern British Columbia. The difference between the pre- and post-fire images (C) indexes the extent of the burn and corresponds well with the area visually estimated from a helicopter (outlined in black).

Vegetation monitoring:

Prior to implementing the 2010 prescribed fires, we selected 4 unburned (control) areas to be as similar as possible to the burned (treatment) areas in pre-burn vegetation, elevation, aspect and slope. We identified potential areas using Geographic Information Systems (GIS) in ArcMap 9.3 (ESRI 2010) and then confirmed similarities visually from a helicopter. Vegetation sampling occurred on each of the 8 mountain areas (4 chosen for burning and 4 similar controls), which were accessed by helicopter, prior to burning (May 2010) and in the first and second summers (July) and winters (early May) following burning. May samples indexed late-winter forage and July samples represented peak forage biomass in summer.

To control for the effect of elevation on vegetation response to fire, each burned and unburned area was stratified by an elevational gradient. We established 3 50-m line-intercept transects at high, mid, and low elevations (Table 3). We used line-intercept to quantify percent cover of trees, shrubs, forbs, grass, rock/soil, and bare ground. Within 3 1x1-m plots along each transect, we recorded vegetation by species and height, and then clipped a 0.25-m^2 quadrat to estimate plant biomass (Fig. 7). This resulted in 9 clipped quadrats per area (or 36 samples from the 4 burned areas and 36 samples from the unburned control areas) during each sampling session (May 2010, July 2010, May 2011, July 2011, May 2012). We calculated percent cover from line-intercept data, forage volume from the product of plant height and cover within 0.25-m^2 quadrats, species diversity based on species numbers and relative proportions in 1x1-m plots using Simpson's Diversity Index (Krebs 1999), and species richness as the number of species within 1 m x1-m plots.

Table 3. Geographic information for vegetation transects and exclosures on burned and unburned (control) areas at 4 sites in the Besa-Prophet study area. UTM zone = 10.

	Burned					Control				
ID	Easting	Northing	Elevation (m)	Slope (°)	Aspect (°)	Easting	Northing	Elevation (m)	Slope (°)	Aspect (°)
Luckhurst										
High	476324	6363040	1580	35	280	477193	6359494	1636	28	213
Mid	467215	6363080	1500	30	280	477062	6359371	1530	29	234
Low	476116	6363102	1430	35	280	476792	6359196	1427	13	240
Exclosure	476273	6362978	1550			477057	6359539	1573		
Nevis										
High	484312	6361090	1500	32	240	481598	6360918	1575	32	250
Mid	451259	6361056	1454	32	260	481424	6360869	1483	31	250
Low	481192	6360861	1381	19	255	481256	6360796	1381	15	250
Exclosure	481274	6360943	1413			481333	6360800	1418		
Richards										
High	451895	638500	1436	23	182	457763	638945	1410	15	183
Mid	451870	6383260	1334	23	187	457764	6383758	1300	35	175
Low	451843	6382953	1227	27	177	457760	6383591	1203	28	187
Exclosure	451902	6383411	1406			457745	6383923	1395		
Townsley										
High	470039	6373563	1737	22	200	468510	6373033	1751	33	230
Mid	469986	6373475	1663	37	200	468441	6372902	1650	36	222
Low	469905	6373509	1579	34	200	468473	6372720	1543	27	200
Exclosure	469968	6373509	1673			468464	6372980	1694		

Figure 7. Sampling plant biomass in 0.25-m^2 quadrats within 1x1-m plots along vegetation transects in May (Richards low-elevation control) and in July (Townsley high-elevation control), 2010.

To monitor vegetation change at the landscape scale, we extracted the Normalized Difference Vegetation Index (NDVI) values from Landsat satellite images. NDVI is related to leaf area and vegetation biomass (Tucker and Sellers 1986; Purevdorj et al. 1998). This index is one of the most widely used spectral vegetation indices and has been used to characterize post-fire vegetation (Hope et al. 2007). We downloaded scenes at maximum green-up in July-August 2010 (year of the burns initiated during our study) and 2012 (2 years after the burns) to quantify changes in vegetation biomass.

<u>Range exclosures</u>:

To distinguish between the impacts of fire and the impacts of grazing and browsing on vegetation, we placed a permanent range exclosure (24x24x6 ft) at mid-elevation on each of the 8 different mountain areas (Table 3, Fig. 8). The exclosures were constructed by Mike Hammett of Sikanni River Outfitters with welded 2-inch square hollow steel tubing and woven wire fencing, and weighed ~1200 lbs each. They were heli-transported on 2-3 June 2010. Because of the extreme slopes on many of the sites (>35°), we placed them with one corner facing uphill to help prevent excess snow build-up in winter.

We measured ground cover (on 3 parallel 7-m line-intercept transects) within the exclosure and on a paired same-sized area 5 m outside each exclosure. We quantified species cover, height, and biomass (same methods as above) in 1 plot on each transect. These samples represented an additional 24 clipped samples from burned areas and 24 samples from unburned control areas.

Figure 8. Range exclosures constructed at Sikanni River Outfitters and transported by an A-STAR B2 helicopter to burned and unburned areas at 4 mid-elevation sites (Luckhurst, Nevis, Richards, and Townsley) in the Besa-Prophet study area of northern British Columbia, June 2010.

Vegetation lab analyses:

All plant samples were dried in a drying oven at 50°C for 5 days and then weighed to the nearest 0.01 g to quantify plant biomass. Forage (grass/forb) samples were ground using a Wiley mill with a 1-mm mesh screen before doing nutritional analyses. To index forage quality (digestibility), we used sequential detergent analyses to separate plant samples into neutral detergent fiber, acid detergent fiber, lignin, and ash (Van Soest 1994). Subsamples of ground plant samples also were analyzed for elemental nitrogen at the Ministry of Environment Analytical Chemistry Lab, Victoria, BC. We estimated percent dietary crude protein as the total nitrogen (g N/g forage) multiplied by 6.25 (Robbins 1993). We used equations in Hanley et al. (1992) to estimate digestible dry matter and digestible protein and multiplied those values by biomass to obtain the amount (g) of digestible dry matter and digestible protein available to ungulates per unit area.

Fecal pellet transects:

As an index of fine-scale animal use of burns (in addition to GPS-collared individuals and distribution surveys of groups of animals), we counted fecal pellet groups($\geq$ 5 pellets) along 100-m transects (4 m wide) at the same elevations as the vegetation transects on each of the 8 mountain areas. All pellet groups were removed from the transects after the quantification of seasonal use to avoid double counting in subsequent counts.

Statistical analyses:

We used the transects as the sampling unit for our vegetation analyses; data collected in the 3 plots within each transect were averaged. Data were transformed as needed to meet the assumptions of normality and equality of variances. All means were presented ± 1 standard error (SE) unless otherwise noted. All analyses were performed in Stata 12.0 (StataCorp 2011). Level of significance for all tests was set at $\alpha = 0.05$.

We used a mixed-effects model (xtmixed; Rabe-Hesketh and Skrondal 2008) to examine the effects of burning (versus unburned), elevation (high, mid and low), site (Luckhurst, Nevis, Richards and Townsley), and year (2010- 2011, 2011-2012) on forage biomass and volume, percent cover of forage and shrubs, species diversity, digestibility, g digestible dry matter, crude protein, and g digestible protein; observations were nested within transect. To examine how burned vegetation changed yearly compared to pre-burn conditions, we ran the xtmixed model with winter data from burned areas only for pre-burn (2010), the year of the burn and one year after the burn with the same parameters. To assess the relative magnitude of post-burn forage growth compared to unburned forage growth, we used an analysis of variance (ANOVA) with a difference variable calculated from the seasonal change in biomass and forage volume (i.e., July 2011 - July 2010, May 2012 - May 2011). We included elevation and site in that model. We also used ANOVA to test how vegetation height differed among burned versus unburned areas, elevation and site at the end of the study. To test for effects of grazing on biomass, forage volume, and species diversity, we used the same xtmixed approach as above, replacing elevation with grazed (non-exclosures) versus ungrazed (exclosures).

We examined count data (species richness, Stone's sheep and elk pellet counts) using a mixed-effects model with a poisson distribution (xtmepoisson) with independent variables burned (versus unburned), site, elevation, and year as described above. To assess if Stone's sheep and elk animal counts during the fixed-winged flights varied by elevation or burning, we used a generalized linear model with a poisson distribution and compared summer counts (June – Aug) to winter counts (Nov – May).

3. Identify seasonal range overlap in the use of burned areas by the 2 species

We quantified resource availability for each radio-collared animal at two nested spatial scales: at the seasonal movement scale and the seasonal range scale, as defined above. Within the area of seasonal movement potential (95^{th} longest distance movement), we characterized availability using 5 random points for each telemetry location. Within each animal's seasonal and annual range, we determined the proportion of resources available. In this report, we present summaries of use versus availability of land-cover classes within the area of seasonal movement potential, with emphasis on the use of burned areas.

Land cover in the Besa-Prophet study area was originally delineated into 15 classes using an August 2001 Landsat ETM satellite image with 80% accuracy across classes(>200 field assessment sites; Fig. 9), which was used in previous habitat analyses for elk and Stone's sheep (Walker et al. 2007, Gillingham and Parker 2008) . We believe that this classification is more valid in understanding animal use of the landscape than trying to use the BC biogeoclimatic ecosystem classification (BEC) system. There are only 3 BEC zones in this area (BWBS, SWB, and BAFA; as noted above), and very little ground-truthing of the classes and variants within these zones. Previous attempts to correlate the BEC classes with on-the-ground vegetation showed considerable error associated with the BEC classes because there were so few plots sampled in a very diverse area. Satellite imagery also allows for an exact quantification of the areas burned, including patches within prescribed blocks. We combined some of these classes into 10 classes that were biologically meaningful for both Stone's sheep and elk, using the raster calculator in ArcMap 9.3 (ESRI 2010).

We then updated this classification using PCI (Geomatica Inc. 2010) by overlaying each of the 7 2010-2011 prescribed burns implemented for our study and called this class New burn, resulting in a total of 11 land-cover classes (Table 4). The burn extents for these new burns were derived from a combination of the delta Normalized Burn Ratio (dNRB) from Landsat imagery (e.g., Fig. 6) and helicopter GPS routes. Final land-cover classes in the Besa-Prophet study area are shown in Figure 10. Of note, there are 3 different burn classes: 'Burn shrub', which includes older burns dominated by deciduous shrubs, 'Burn grass' (younger burns still grass-dominated), and 'New burn' (recent burns conducted for our study in 2010 and 2011).

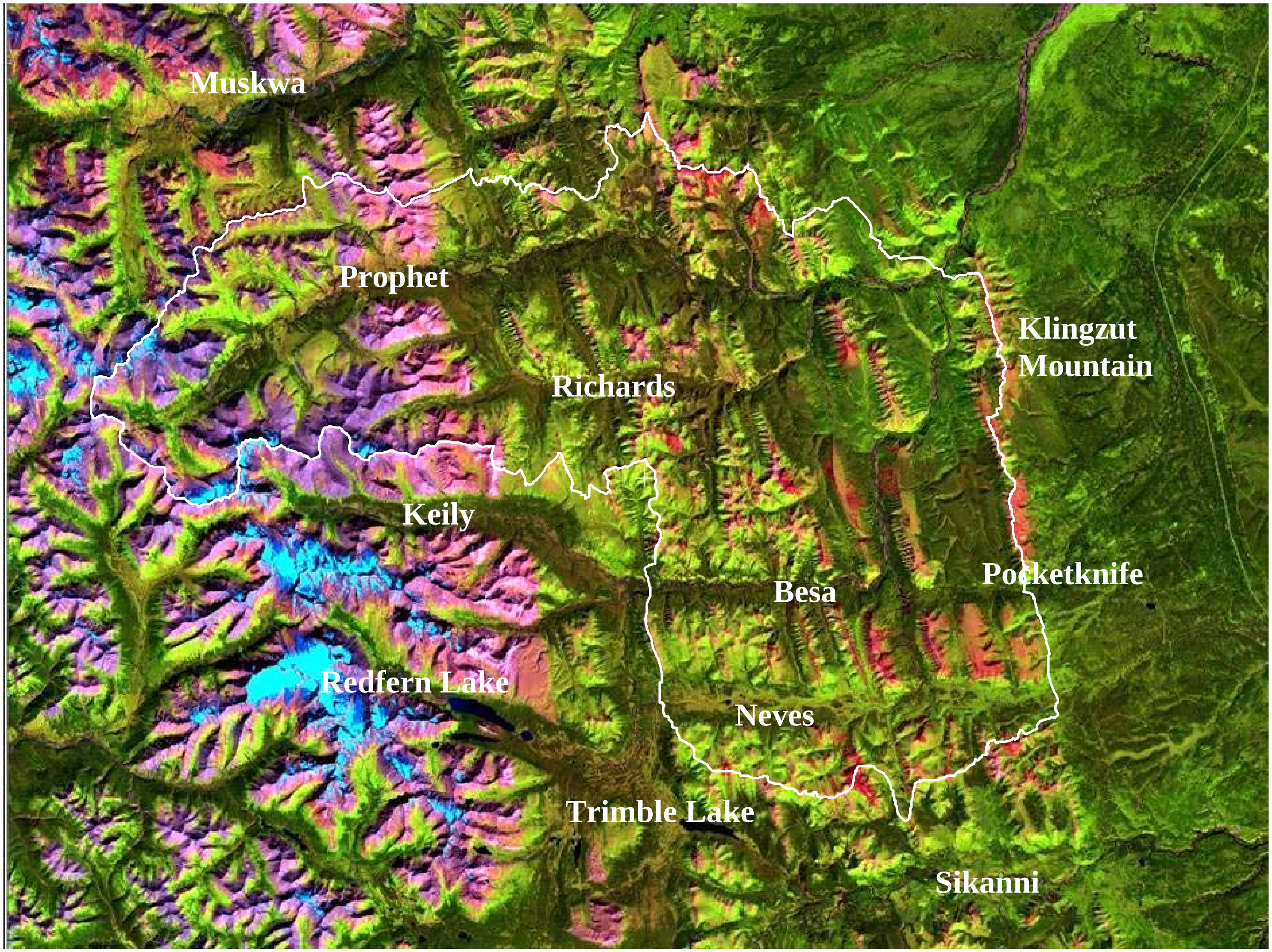

Figure 9. Remote-sensing satellite image of the Besa-Prophet study area including outline of the Besa-Prophet Pre-tenure Planning Area and notable drainages and landscape features.

Table 4. Description of 11 land-cover classes and their percent cover in the 740,800-ha Besa-Prophet study area, northern British Columbia, based on Lay's (2005) original 15 cover classes. New burns implemented in 2010 and2011 were overlaid as a new class.

Land-cover class	% of study area	Original classification	Description
Carex	6.0	*Carex*	Sedge wetland characterized by large open areas at low elevation (<1600 m), dominated by *Carex* spp. and intermittent willow (*Salix* spp.) shrubs.
Low shrub	5.7	Shrub <1600 m	Deciduous shrub communities <1600 m in elevation, characterized by willow (*Salix spp.*), scrub birch (*Betula glandulosa*) and some cinquefoils *(Potentilla* spp.).
Conifer	27.8	Pine + spruce + stunted spruce	Mature and growing coniferous stands of lodge pole pine (*Pinus contorta),* white spruce *(Picea glauca)* and potentially some fir (*Abies lasiocarpa).*
Rock /rock crust	22.4	Rock + rock crust	Rocky areas generally at high elevation including talus slopes, steep outcrops, scree slides, bedrock and rocks covered with black crustose lichen (e.g., *Melanelia haptizon*).
Non-vegetative	1.4	Snow + water	Permanent water bodies or water courses, and glaciers or snowfields.
Subalpine	9.2	Shrub ≥1600 m + subalpine spruce	Deciduous shrub communities ≥1600 m; spruce (*Picea glauca*) and shrub (*Salix* spp. and *Betula* spp.) transition area at mid to high elevation.
Riparian	11.8	Riparian spruce + gravel	Wet areas in low elevations (<1600 m) with spruce (*Picea gluaca* or *Picea mariana* in poorly drained sites), often with standing water in spring and summer; gravel bars along rivers and streams and dried river beds.
Alpine	5.4	Dry alpine + wet alpine	Herbaceous vegetation >1600 m in elevation. Dry alpine tundra dominated by *Dryas* spp.; wet alpine tundra dominated by *Cassiope* spp. and sedge (*Carex* spp.) meadows.
Burn shrub	7.0	Burn-deciduous	Older burns and disturbed areas containing deciduous shrubs (<2 m) and regenerating stands of *Populus tremuloides* and *Populus balsamifera*. Small stands of *Pinus contorta* may also be associated.
Burn grass	3.0	Burn - *Elymus*	Recent burns and disturbed areas characterized by open grass meadows dominated by *Elymus innovatus*, most often found on south-facing slopes.
New burn	0.26	na	The seven new burns conducted in the spring of 2010 and 2011.

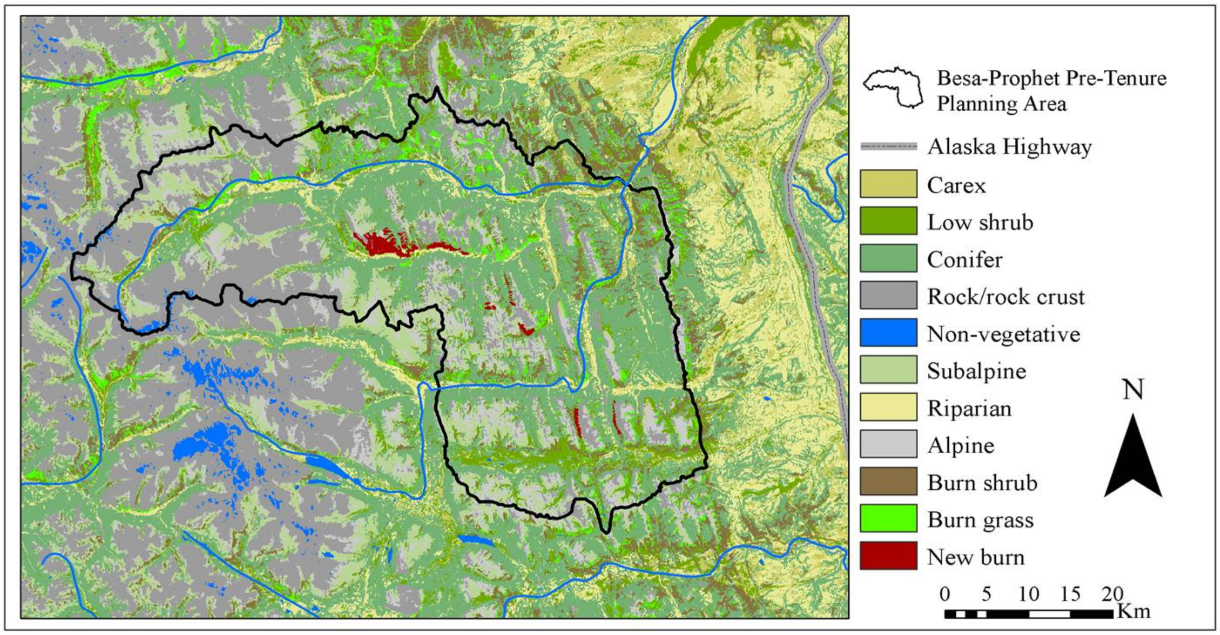

Figure 10. Land-cover classification in the Besa-Prophet study area, northern British Columbia. The Besa-Prophet pre-tenure planning area is outlined in black.

4. Define the interactive effects of prescribed burning on the 2 species

We defined resource use and selection by Stone's sheep and elk based on variables related to topography (slope, elevation, aspect, ruggedness), land cover, and distance to burns. Topographical variables were obtained from a BC Terrain Resource Information Management digital elevation model (1:20,000 DEM). We converted aspect (in radians) into 2 continuous variables of northness and eastness. For any pixel with a zero slope, we set northness and eastness both equal to zero. We used the vector ruggedness measure (VRM; Sappington 2007) to define terrrain ruggedness, ranging from 0 (even terrain) to 1 (rugged terrain). VRM provided a quantitative measure of ruggedness that was independent of slope and these two variables were used to distinguish 2 different, yet biologically meaningful, components of Stone's sheep and elk habitats. We used the land-cover classes shown in Figure 10. Historical locations of prescribed burns were provided as a polygon layer by the BC Ministry of Forests, Lands and Natural Resource Operations. To quantify the distance to a burn from any animal use point, we generated a raster surface (25 x 25 m) representing straight-line distance to the nearest burn of any age (Euclidean Distance Spatial Analyst tool in ArcMap 9.3; ESRI 2010).

We developed a set of 6 candidate models that we thought would describe Stone's sheep and elk resource selection, using different combinations of variables related to topography, land cover, and distance to burns (Table 5). We developed these models sets based on previous knowledge of resource selection by Stone's sheep (Walker et al. 2007) and elk (Gillingham and Parker 2008) and to better understand the influence of prescribed burns on the selection strategies of Stone's sheep and elk. We used logistic regression to quantify selection coefficients that would differentiate between used and available resources (Manly et al. 2002). The GPS locations of Stone's sheep and elk represented 'use'. We defined availability (the area from which animals could select resources) based on the 95th longest distance moved by each individual in each season. We buffered each use point by this seasonal distance, assuming that the animal could have moved anywhere within that available area. We assigned 5 random points in the buffered area around each use point as available.

Table 5. Biological rationale for candidate models to describe seasonal resource selection of Stone's sheep and elk in the Besa-Prophet study area of northern British Columbia. Elevation was modeled as a quadratic (elevation + elevation^2); aspect was modeled as 2 continuous variables (northness and eastness), and land cover was defined as one of 11 classes in Table 4.

Model Parameters	Biological Rationale
Land cover + Elevation + Slope + Aspect + Distance to burns + Ruggedness	Saturated model (all parameters) hypothesized to best describe selection by Stone’s sheep.
Land cover + Elevation + Slope + Aspect + Distance to burns	Saturated model (all parameters) hypothesized to best describe selection by elk.
Land cover + Slope + Aspect	Land cover and slope position drive selection. Both species select more for land-cover class and specific slope and aspect than other resource attributes, especially in winter.
Land cover + Distance to burns	Land cover and proximity to a burn drive selection. Topography and elevation are not as important to Stone’s sheep or elk as are land-cover classes and proximity to a burn.
Distance to burns + Elevation	Proximity to a burn and elevation drive selection. Stone's sheep may not select to be on a burn, but rather close to a burn and at high elevation (in contrast to elk).
Distance to burns + Ruggedness	Proximity to a burn and ruggedness of the terrain drive selection. Stone's sheep may not always select to be on a burn, but rather close to a burn and in rugged terrain (in contrast to elk).

Within an information theoretic approach, we used Akaike’s information criterion (AICc) corrected for small sample size to rank the models describing seasonal resource selection by each individual (Burnham and Anderson 2002). Akaike weights (w_i) give an estimate of the relative probability that the top model is the best amongst the suite of candidate models. A single model was chosen as the top model if $w_i \geq 0.95$. If the top model had an associated $w_i < 0.95$, we averaged the selection coefficients (β_i) from the suite of top candidate models for which $\Sigma\ w_i \geq 0.95$. We used the k-fold cross-validation procedure and an averaged Spearman’s rank correlation (r_s) to evaluate the predictive ability of each top model (Boyce et al. 2002). Level of significance was set at $\alpha = 0.05$. After determining the best seasonal model for each animal, we averaged models across individuals to obtain seasonal global selection models for both Stone’s sheep and elk. We used 95% confidence intervals to determine if the selection coefficients were different than zero. We assumed selection for a resource if $\beta_i > 0$ and CI did not include zero; and selection against a resource if $\beta_i < 0$ and CI did not include zero. We compared selection strategies across each of the 5 defined seasons.

9. Measures of Results

Movements and Ranges of Stone's Sheep and Elk

We obtained a total of 21,769 GPS locations from 11 collared Stone's sheep and 37,054 GPS locations from 22 collared elk between 2010 and 2012 (Fig. 11). We calculated fix success as the number of fixes acquired by each collar relative to the number that should have been taken at 6-h intervals over the duration the collar was deployed. Average fix success rate was 88.5 ± 3.0 % (mean ± SE) for Stone's sheep (range = 64.8 to 96.1 % across individuals) and 90.4 ± 2.2 % for elk (range = 65.5 - 98.5 %). Lowest GPS fix rates were for an elk in coniferous cover along the Besa River and for a Stone's sheep collared on Nevis.

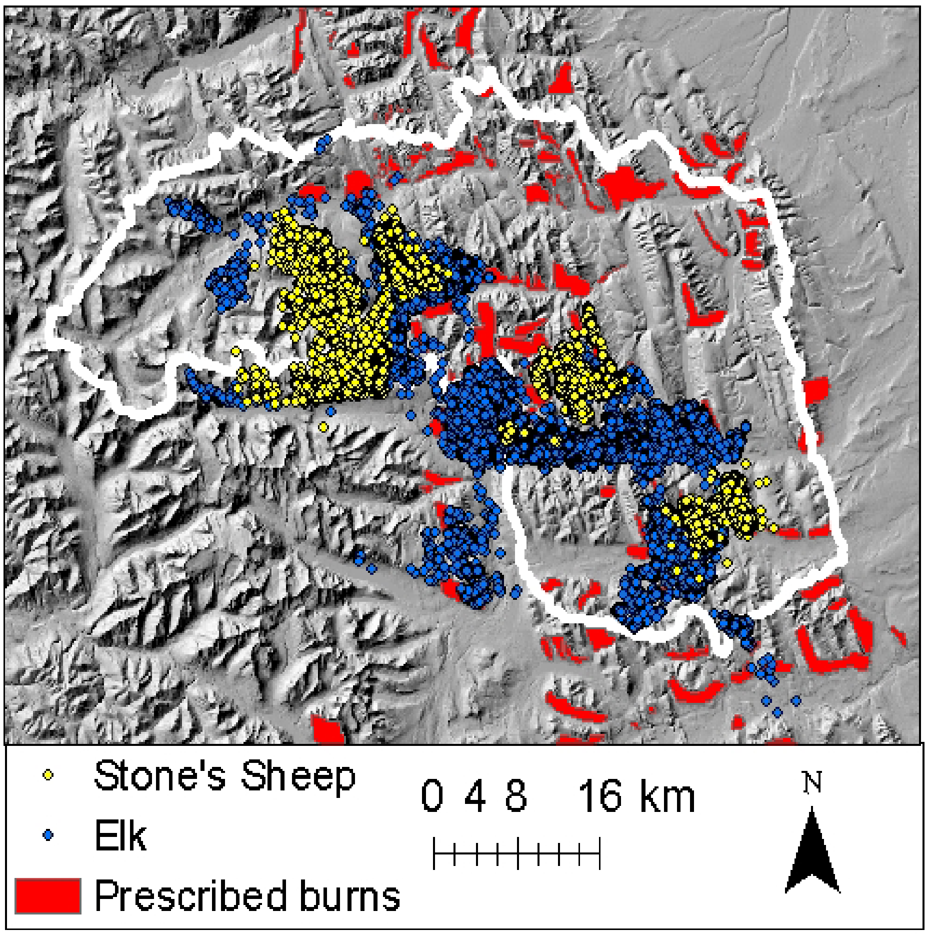

Figure 11. Locations of 11 GPS-collared Stone's sheep and 22 elk in relation to prescribed burns in the Besa-Prophet study area, northern British Columbia, from January 2010 to July 2012. The Besa-Prophet pre-tenure planning area is outlined in white.

Stone's sheep and elk showed similar patterns in average monthly and seasonal rates of movement (Fig. 12), with highest rates in summer (Stone's sheep: 62-165 m/h, elk: 62-147 m/h) and lowest rates in winter and late winter (Stone's sheep: 20-65 m/h, elk: 16-68 m/h). Movement rates were similar between the 2 species from winter through spring, but in summer and fall, average movement rates of Stone's sheep were higher than those of elk (Fig. 12). The longest straight line distance traveled by sheep in 6 hours was 7.9 km and occurred in the summer of

2011 in the Richards area. In contrast, the longest straight-line distance traveled by an elk occurred in the winter of 2010 in the Nevis area and was 9.9 km / 6 hours.

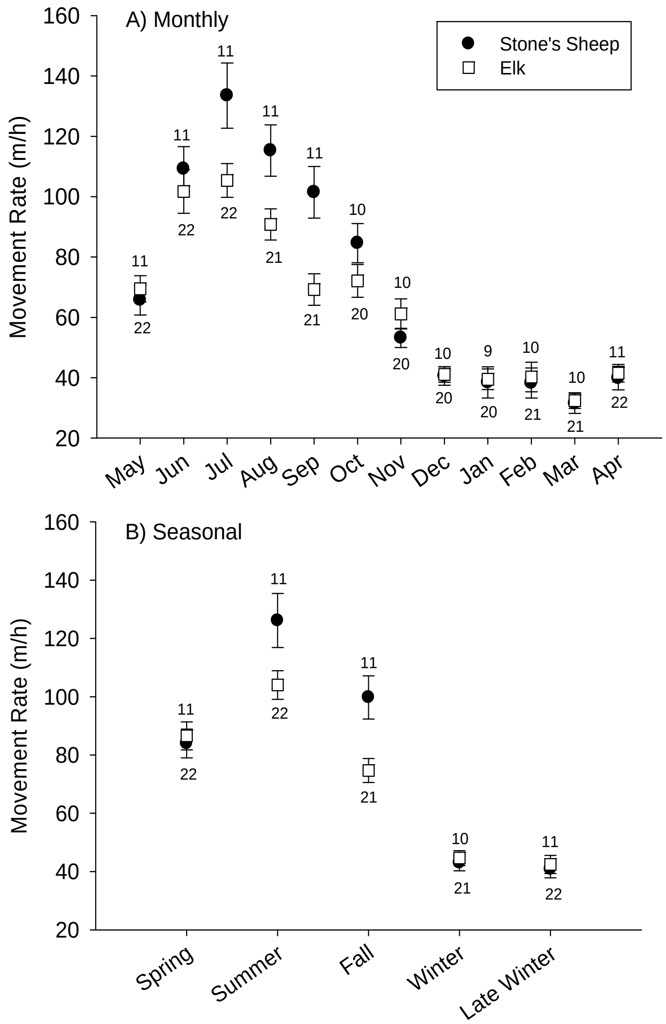

Figure 12. A) Monthly and B) seasonal movement rates (mean ± SE) of female Stone's sheep and female elk in the Besa-Prophet study area of northern British Columbia between 2010 and 2012. Movement rates were averaged for each individual and then averaged across individuals in each month and season. The number of individuals used to calculate means and standard errors are above error bars for Stone's sheep and below error bars for elk.

Sizes of annual ranges were highly variable among individuals of both species, resulting unexpectedly in an average annual range that was very similar in size between Stone's sheep (196.4 ± 36.4 km^2, range = 34-376 km^2) and elk (183.5 ± 17.2 km^2, range = 64-343 km^2). Previous studies in this area found that ranges of Stone's sheep (36 km^2, Parker and Walker 2007) were less than one-third the size of elk ranges (191 ± 70 km^2, Gillingham and Parker 2008). Because our analytical methods for quantifying range size were slightly more conservative than previous studies that used minimum convex polygon techniques, the large area determined as average range size for Stone's sheep in our study was even more surprising. We believe the discrepancy is largely due to differences among groups of collared Stone's sheep. Animals that used the Luckhurst and Townsley areas had ranges similar in size to those documented by Parker and Walker (2007) for Stone's sheep in these areas previously. However, Stone's sheep collared for our study in the Richards Creek area moved across the valley, using slopes on both sides of the Richards Creek drainage and encompassing a much larger area (Fig. 13). The smallest annual ranges recorded by species were 32.5 km^2 for a Stone's sheep on Nevis Mountain (included with the Luckhurst group, Fig. 13) and 64.1 km^2 for an elk along the Besa River.

The seasonal ranges for both Stone's sheep and elk were largest in summer and smallest in winter and late winter (Fig. 13). Sizes of summer ranges were most variable among individuals, coinciding with highest movement rates during that season, and ranged from 22 km^2 to 318 km^2 in Stone's sheep, and from 47 km^2 to 338 km^2 in elk. The smallest seasonal ranges were 10 km^2 for a Stone's sheep in late winter at Nevis and 4 km^2 for an elk in winter along the Besa River. Among different groups of Stone's sheep, Richards animals had higher movement rates and larger seasonal ranges than Townlsey or Luckhurst animals in spring, summer and fall.

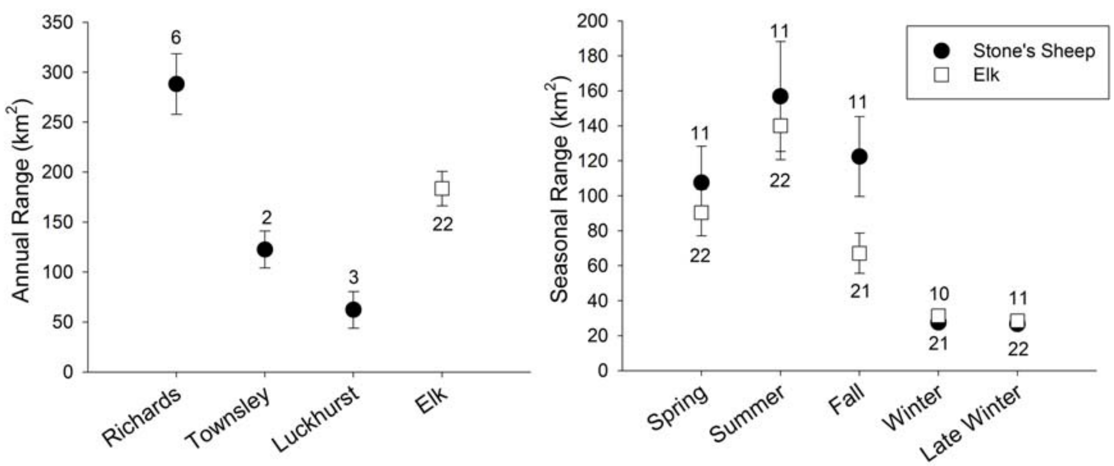

Figure 13. Annual and seasonal range sizes (mean ± SE) used by GPS-collared female Stone's sheep and elk in the Besa-Prophet study area in northern British Columbia between 2010 and 2012. Range sizes were calculated for each individual and averaged across individuals. Annual ranges are shown for elk and 3 different groups of Stone's sheep. Numbers of individuals used to calculate average size of seasonal ranges are shown above error bars for Stone's sheep and below error bars for elk.

Burned areas (Burn shrub, Burn grass and New burn) covered an average of 10% (range = 6-19%) of the annual ranges of individual Stone's sheep and 14% (9-17%) of the annual ranges of individual elk. Within seasons, animals used ranges with even higher amounts of burned land cover. Burned areas averaged 36% and 30% of elk ranges in late winter and winter, respectively, and 29% and 23% of Stone's sheep ranges during the same seasons. Of the burn classes, New burn comprised the highest percent cover within a seasonal range, and this occurred for both species in late winter (Stone's sheep: 17%; elk: 15%). Winter ranges also included large amounts of New burn (Stone's sheep: 12%; elk: 13%). The amount of New burn was lowest on summer ranges (Stone's sheep: 2%; elk: 4%).

Plant Response to Prescribed Fire: Forage Quantity and Quality

Burn Severity and Species Diversity:

Approximately 1,820 ha were burned in 2010 at the 4 different sites on which we monitored vegetation over the 2 summers and winters after burning (Table 2). Across areas, burn severity was highest at the Luckhurst site, where the average depth of burn was 8.3 ± 0.23 cm at high elevation, 4.06 ± 1.25 cm at mid elevation (with 8 pins that did not burn) and 6.31 ± 0.91 cm at low elevation. Similarly at the landscape level, dNBR was also highest at Luckhurst (Table 6).

Table 6. Average burn severity (measured at 2 spatial scales) and average normalized difference vegetation index (NDVI, representing landscape-level vegetation biomass) in July 2010 and July 2012 following prescribed burning in May 2010 at 4 sites (Luckhurst, Nevis, Richards and Townsley) in the Besa-Prophet study area, northern British Columbia. Burn severity was measured as average depth of burn (DOB) using pins along transects and as delta-normalized burn ratio (dNBR) derived from Landsat imagery.

Site	DOB ± SD (cm)	dNBR ± SD (min - max)	NDVI ± SD (July 2010)		NDVI ± SD (July 2012)	
			Burn	Control	Burn	Control
Luckhurst	6.2 ± 3.8	0.71 ± 0.17 (0.13 - 1.00)	0.24 ± 0.07	0.45 ± 0.04	0.33 ± 0.08	0.41 ± 0.06
Nevis	0.2 ± 0.8	0.51 ± 0.18 (0.11 - 0.99)	0.34 ± 0.06	0.43 ± 0.07	0.32 ± 0.08	0.40 ± 0.08
Richards	4.9 ± 2.3	0.52 ± 0.11 (0.37 - 0.76)	0.24 ± 0.07	0.33 ± 0.09	0.36 ± 0.09	0.34 ± 0.07
Townsley	3.2 ± 2.5	0.67 ± 0.10 (0.34 - 0.84)	0.27 ± 0.09	0.33 ± 0.07	0.34 ± 0.07	na

* NDVI was not measured at the Townsley area in July 2012 because of poor imagery.

We identified 71 different plant species while sampling the 1 m x 1-m plots during the summer; of these, 57 species were on south-facing slopes and 48 were on west-aspect slopes. The most common species observed on south-facing burned slopes were fuzzy-spiked wildrye, sweet vetch, fireweed and tall bluebell. On the west-aspect burns, most frequently observed species were fireweed, scrub birch and bunchberry (*Cornus canadensis*). After burning, there were 7 different species (*Astragulus alpinus, Botyrchium lunaria Saxifrage lyallii, Silene uralensis, Taraxacum* spp., *Stellaria longipies*, and *Geranium richarsonni*) identified in burned areas that were not identified in unburned areas. Elevation did not affect species richness (all $z \leq 1.59$, $P \geq 1.12$). Both the burned and unburned areas at the Townsley site were the most diverse and rich areas (Fig. 14).

Species diversity was lowest in burned areas the summer following burning, but was almost comparable to that on unburned sites by one year after the prescribed fires (Fig. 14). As expected, burning reduced shrub cover at all sites. The fires top-killed or severely damaged the above-ground portions of shrubs, but new basal growth was observed on all sites. Vegetation height (typically shrub height) was lower in burned areas (38.5 ± 10.3 cm) than unburned areas (73.5 ± 9.4 cm) 2 winters after burning ($F_{1,23} = 11.31$, $P = 0.004$). The length of time that burned areas will remain herb-dominated depends on site-specific characteristics such as grazing (Fuhlendorf *et al.* 2008), soil moisture and fertility, and fire-return interval (Baker 2009).

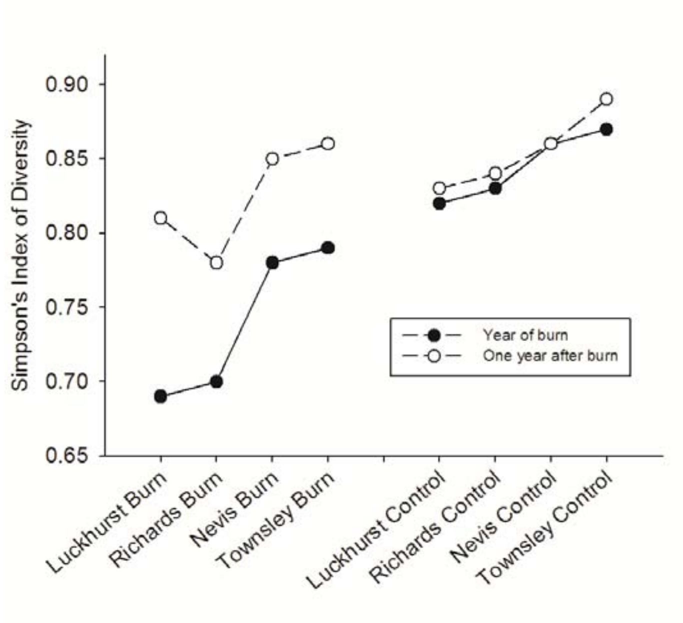

Figure 14. Simpson's index of plant diversity in summer the year of the burn (July 2010) and one year after burning (July 2011) on burned and control areas at 4 sites (Luckhurst, Richards, Nevis and Townsley) in the Besa-Prophet area in northern British Columbia.

Forage Quantity: Biomass and Volume

The effect of burning on forage biomass was scale-dependent. At the fine-scale along the 50-m transects, we observed a 60% decrease in forage biomass in the year of the burn compared to pre-burn levels (z = -3.42, P = 0.001). By the second winter after spring burning, forage biomass had rebounded to pre-burn levels (z = 0.68, P = 0.494). We did not detect a difference in forage biomass between burned areas and controls in the second summer, but more forage grew back on burned areas (18 to 28 g/0.25m^2) than on control areas (15 to 16 g/0.25m^2, $F_{1,23}$ = 6.89, P = 0.017). Forage biomass on the 2 south-facing sites (Richards and Townsley) did not differ from each other (both $z \leq 1.17$, $P \geq 0.241$) and there was always more forage on these sites than on the 2 west-facing sites (Luckhurst and Nevis) in both seasons (all $z \geq 3.87$, $P \leq 0.001$; Figure 15).

At the landscape level, vegetation biomass (based on NDVI values) was higher in control areas than in burned areas across all areas in the year of the burn (i.e., first summer, July 2010). No satellite images were available for 2011, but in 2012 the vegetation biomass on south-facing burned areas had increased (from 0.26 to 0.35) to control levels. West-facing areas (with the exception of Nevis which did not change) also increased vegetation biomass over this time but had not reached control levels by 2 years post-burn (Table 6). This suggests that forage biomass may not have peaked during the short duration of our study.

Forage volume, which provides another metric of forage quantity related to potential bite size, followed patterns similar to forage biomass. South-facing slopes on average had more than 3 times more forage volume than west-facing slopes in both seasons (all $z \geq 3.98$, $P \leq 0.001$). There was 213% more forage volume produced on burned areas than control areas from the first to second summer after burning ($F_{1,23}$ = 15.38, P = 0.001). Lower elevations had 1.5 – 2 times more forage biomass and forage volume than upper elevations.

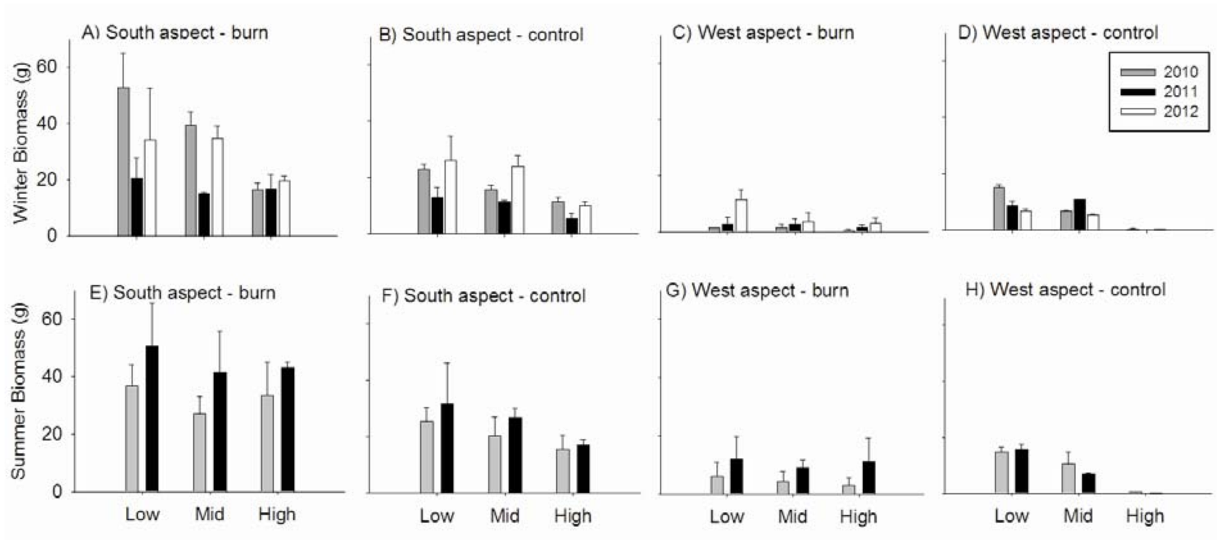

Figure 15. Average winter (A-D) and summer (E-H) forage biomass (g/0.25 $m^2 \pm$ SE) in burned and unburned control areas at high, mid, and low elevation on south-aspect (Richards and Townsley) and west-aspect (Luckhurst and Nevis) sites in the Besa-Prophet study area, northern British Columbia. Prescribed burning occurred after vegetation sampling in May 2010.

Forage Quality: Digestibility and Protein

Forage quality, as measured by digestibility and crude protein, was enhanced by burning. The greatest difference in digestibility of the forage between burned and unburned areas (both seasons $z \geq 2.02$, $P \leq 0.044$) occurred during the year of the burn, when burned areas were 4-5 % more digestible in both seasons. In winter, digestibility was not different between the pre-burn year and the year of the burn ($z = 1.06$, $P = 0.289$), but there was a 16.6 % increase one year after burning ($z = 5.35$, $P \leq 0.001$). Digestibility did not differ among sites in summer; in winter Luckhurst had the highest digestibility (Table 7). Also in winter, forage was 3% more digestible at high elevations than low elevations ($z = 2.85$, $P = 0.004$). Because the quantity of forage biomass was less, however, high elevations generally had lower amounts of digestible dry matter than low elevations in both seasons ($z \geq 2.17$, $P \leq 0.030$).

Crude protein also was 1.5-3 % higher on burned areas than unburned areas in both seasons (both $z \geq 2.19$, $P \leq 0.029$). In the winter immediately after burning, crude protein of forage on burned areas was more than 2 times higher than pre-burn levels ($z = 2.60$, $P = 0.009$). By the second winter after burning though, crude protein had declined to pre-burn levels ($z = 0.55$, $P = 2.60$). On the burned area at Luckhurst, crude protein was 5 times higher than the unburned area in late winter the year of the burn (Table 7). Elevation did not influence crude protein levels in either season (all $z \leq 0.79$, $P \geq 0.432$).

Of importance, burned areas greened up in late winter / spring earlier than unburned control areas did, resulting in higher digestibility and higher crude protein in the forage measured in May. The Luckhurst burn in particular was extremely hot; it severely burned the vegetation down to the soil leaving many bare spots over the winter and resulting in a slow return in 2011. The highest protein values recorded were in May 2011 on the Luckhurst burn. This is likely because no winter vegetation remained and the clipped vegetation included newly emerging vegetation without vegetation left from the previous winter.

Table 7. Comparison of average forage digestibility (% ± SE) and crude protein (% ± SE) on burned versus unburned (control) areas. Samples were collected prior to prescribed burning (pre-burn - early May 2010), the year of burning (July 2010, May 2011), and one year after burning (July 2011, May 2012) at 4 sites (Luckhurst, Nevis, Richards and Townsley) in the Besa-Prophet area, northern British Columbia.

Forage digestibility					
Area	Preburn	July 2010	May 2011	July 2011	May 2012
Luckhurst					
Burn	54.19 ± 2.22	63.09 ± 1.29	55.85 ± 1.57	60.89 ± 1.11	56.00 ± 0.37
Control	47.18 ± 6.00	56.07 ± 1.65	46.22 ± 1.83	59.29 ± 0.00	57.71 ± 2.47
Nevis*					
Burn		66.42 ± 0.42	48.55 ± 1.15	59.37 ± 0.88	53.39 ± 0.29
Control		62.14 ± 0.10	45.54 ± 0.21	61.75 ± 0.86	48.11 ± 1.13
Richards					
Burn	43.02 ± 0.81	63.24 ± 0.24	48.13 ± 0.93	59.46 ± 0.92	55.62 ± 0.67
Control	43.46 ± 1.46	56.51 ± 0.83	46.58 ± 3.28	58.04 ± 1.60	54.58 ± 2.58
Townsley					
Burn	44.83 ± 1.12	65.29 ± 0.44	43.98 ± 1.25	59.32 ± 0.73	54.28 ± 1.83
Control	45.76 ± 1.30	63.39 ± 0.91	41.56 ± 1.57	57.97 ± 2.28	54.39 ± 1.63

Forage crude protein					
Area	Preburn	July 2010	May 2011	July 2011	May 2012
Luckhurst					
Burn	5.77 ± 0.43	19.13 ± 1.67	26.19 ± 5.10	17.82 ± 1.14	12.34 ± 3.36
Control	4.85 ± 0.55	12.82 ± 1.17	5.28 ± 0.16	13.52 ± 0.82	5.45 ± 0.78
Nevis					
Burn	5.41 ± 0.91	13.29 ± 0.74	6.38 ± 0.91	12.51 ± 1.05	5.58 ± 1.65
Control	5.03 ± 0.20	13.01 ± 0.44	6.29 ± 0.92	14.20 ± 0.38	4.56 ± 0.06
Richards					
Burn	5.92 ± 0.53	15.99 ± 0.43	6.47 ± 0.63	14.45 ± 0.17	5.49 ± 0.16
Control	4.98 ± 0.39	13.70 ± 1.13	5.71 ± 1.06	14.65 ± 0.08	5.33 ± 0.49
Townsley					
Burn	6.16 ± 0.71	16.23 ± 0.51	6.18 ± 0.57	12.70 ± 1.16	4.49 ± 0.97
Control	5.01 ± 0.39	14.15 ± 0.60	5.26 ± 0.64	13.54 ± 0.42	4.78 ± 0.18

* Samples not available.

Stone’s Sheep and Elk Response to Burning: Resource Use and Selection

Animal Distribution Flights:

During the year of monthly fixed-winged flights, a total of 372 Stone's sheep and 1018 elk were recorded. We always recorded Stone's sheep and elk more often in winter than in summer. Other species recorded during the flights were plains bison, black bears, grizzly bears, moose, caribou, mountain goats, and wolves.

Relative specifically to the 4 prescribed burns and their control areas for which we monitored vegetation, the number of Stone's sheep observed across seasons was 7.5 times higher on burns than on control areas; the number of elk was 13.9 times higher on burns than on unburned areas (both $z \geq 2.08$, $P \leq 0.037$). Stone's sheep were usually observed at mid and high elevations, while elk were observed at all elevations throughout the year. All individuals in winter were observed on burned areas (Fig. 16). Between summer (Jun-Aug) and winter (Jan-May), mean group size increased from 5 ±2 to 16±5 individuals/group for Stone's sheep and 4 ± 1 to 26±7 individuals/group for elk. The largest group of Stone’s sheep recorded was 38 animals and the largest herd of elk was 115 animals; both groups were on the Richards burn in winter.

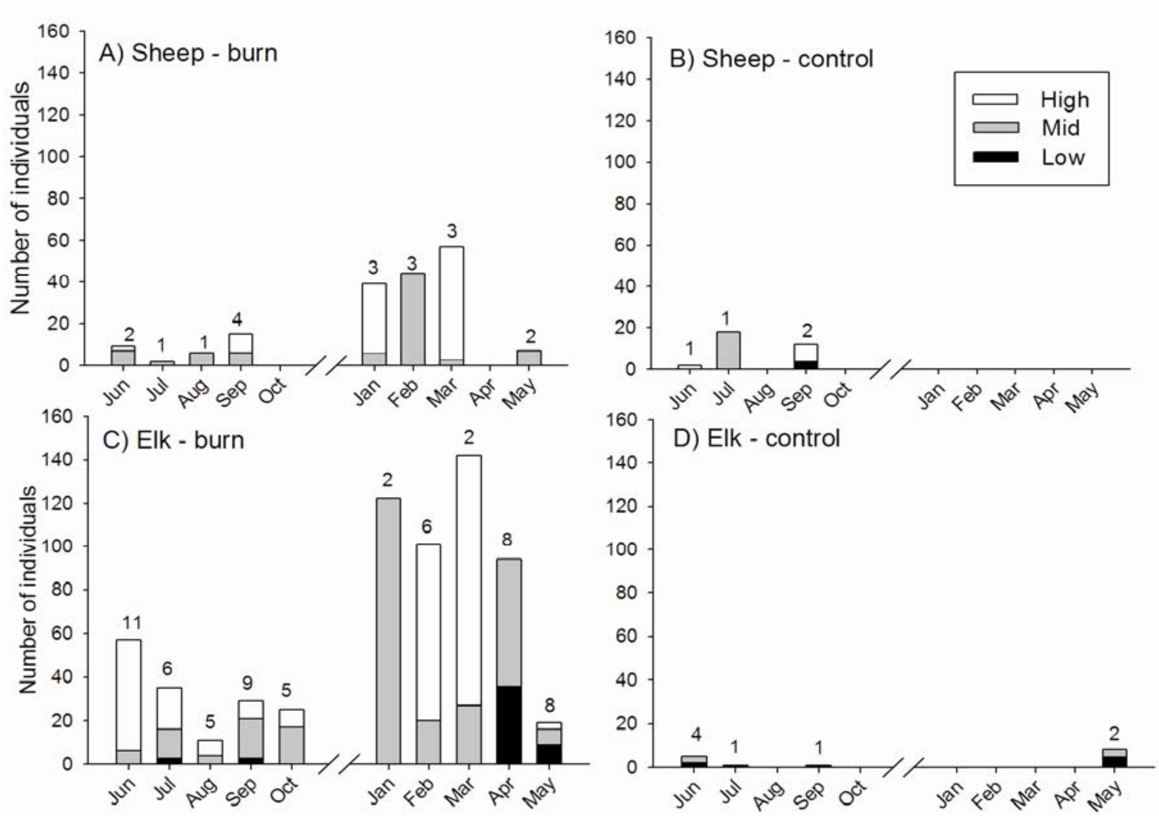

Figure 16. Number of individual Stone's sheep and elk observed on a burn or in an unburned control area at different elevations (high, mid, and low) during monthly animal distribution flights in the Besa-Prophet study area, northern British Columbia (June 2011 - May 2012). Number of animal groups is noted above each bar.

Fecal Pellet Transects:

We counted a total of 1613 pellet groups along the transects (covering a total area of 48,000 m^2) during our study; 504 were Stone's sheep and 902 were elk. Other fecal deposits along the transects were from plains bison, deer, ptarmigan (*Lagopus* spp.), domestic horse, black bear, grizzly bear, moose, and wolf. Prior to burning at the start of this study, pellet collections represented historical use. Townsley had the highest number of sheep pellet groups followed by Nevis, Luckhurst and Richards. Townsley and Richards Creek generally had more elk use than Nevis and Luckhurst (all $z \geq 3.80$, $P \leq 0.001$).

Prescribed burning at the 4 sites changed use by Stone's sheep (Table 8). Use, as indexed by fecal pellets, was always higher on burned areas than unburned areas in both seasons (both $z \geq 2.39$, $P \leq 0.017$). Higher elevations had higher counts than lower elevations (both $z \geq 3.10$, $P \leq 0.002$). The most extreme change in use was in the winter on the high transect of the Luckhurst burn where 3 Stone’s sheep pellet groups were observed in the 2010 pre-burn survey, 46 were observed in 2011, and 84 were counted in 2012. In both seasons sheep use was highest at Luckhurst and lowest at Richards.

Burning also changed elk use (Table 9). In winter, burned areas always had higher elk use than control areas ($z = -2.14$, $P = 0.033$). South-aspect sites (Richards and Townsley) had significantly more elk use than west-facing sites (Luckhurst and Nevis) (both $z \geq 3.50$, $P < 0.001$). In summer, Richards had the highest elk pellet group counts while Nevis had the lowest, but burned areas were not different from unburned areas (z = 1.16, $P = 0.248$).

Range Exclosures:

In the short duration of our study, we were unable to detect differences in forage quantity (biomass, forage volume, forage cover) or species diversity between vegetation on the inside and the outside of the range exclosures across the 4 sites (all $z \leq 1.20$, $P \geq 0.231$). There was more forage biomass though in the exclosures in burned areas than in unburned areas in both seasons (both $z \geq 2.19$, $P \leq 0.028$). Luckhurst had the lowest forage quantity among sites (all $z \geq 4.99$, $P \leq 0.001$) and Townsley had the highest diversity of all sites (all $z \geq 2.36$, $P \leq 0.018$). These 8 x 8-m range exclosures were less variable than the 50-m transects. It is likely, therefore, that if elk numbers continue to increase, there will be increased grazing pressure on burned sites that can be quantified by comparison to the vegetation inside the exclosures. Although we did not detect consistent differences across sites in plant composition or productivity due to grazing, we did record 6 times more forage biomass inside the exclosure than outside by one winter after the burn on Richards, where we observed the highest elk use.

Table 8. Stone's sheep pellet groups collected in May (representing winter use) and July (representing spring-summer use) at high, mid, and low elevations on burned and unburned (control) areas at 4 sites in the Besa-Prophet study area, northern BC. Fecal samples recorded and removed in May 2010 represent multiple-year accumulation prior to the commencement of our study.

Site	Winter 2010		Summer 2010		Winter 2011		Summer 2011		Winter 2012	
	Burn	Control	Burn	Control	Burn	Control	Burn	Control	Burn	Control
Luckhurst										
High	3	5	1	1	46	1	37	3	84	1
Mid	4	1	0	0	3	0	8	0	11	0
Low	0	1	0	0	6	0	7	0	2	0
Nevis										
High	12	2	0	0	8	10	0	0	5	7
Mid	2	4	1	0	5	7	5	2	8	2
Low	14	2	0	0	3	0	1	0	0	0
Richards										
High	1	0	0	1	0	0	0	1	0	0
Mid	0	1	0	0	0	0	0	0	0	1
Low	0	0	0	0	0	0	0	0	0	0
Townsley										
High	30	15	8	0	45	19	5	4	8	4
Mid	30	0	2	0	0	0	1	0	0	0
Low	1	0	0	0	2	0	0	0	0	0

Table 9. Elk pellet groups collected in May (representing winter use) and July (representing spring-summer use) at high, mid, and low elevations on burned and unburned (control) areas at 4 sites in the Besa-Prophet study area, northern BC. Fecal samples recorded and removed in May 2010 represent multiple-year accumulation prior to the commencement of our study.

Site	Winter 2010		Summer 2010		Winter 2011		Summer 2011		Winter 2012	
	Burn	Control	Burn	Control	Burn	Control	Burn	Control	Burn	Control
Luckhurst										
High	0	0	0	1	4	1	0	0	5	0
Mid	1	1	0	1	0	0	2	0	1	1
Low	0	6	0	1	0	3	0	3	0	7
Nevis										
High	2	0	0	0	1	0	0	0	0	0
Mid	0	8	0	0	0	1	0	0	2	1
Low	1	8	1	0	5	0	2	0	5	0
Richards										
High	87	32	7	0	55	8	16	1	44	0
Mid	12	59	7	1	13	17	4	0	6	2
Low	16	2	1	0	22	10	0	0	3	0
Townsley										
High	42	67	3	3	39	30	5	11	12	8
Mid	60	30	0	1	14	8	0	0	10	1
Low	21	10	1	1	19	2	2	0	1	1

Resource Selection and Use:

The models that best predicted resource selection by Stone's sheep and elk individuals were typically the saturated models (including all variables — Land cover, elevation, slope, aspect, ruggedness, and distance to burns) or an average of several models. They varied among animals and seasons. Predictive ability (r_s) across individuals averaged 0.90 (range = 0.72 to 0.97) for Stone's sheep and 0.86 (range = 0.66 to 0.98) for elk.

From the global selection models (the average of top individual models for each species in each season), it is apparent that both Stone's sheep and elk selected for south aspects year round and tended to avoid Conifer stands relative to their availability. Apart from these similarities, selection for topographical attributes and land-cover classes often differed between the 2 species.

Stone's sheep always selected for steeper more rugged terrain (Fig. 17). In most seasons, they selected for higher elevations and for Alpine (Fig. 18). Elk did not have a consistent selection strategy for topographic features. They selected for higher elevations in winter, but showed no selection in the other seasons. They selected for steep slopes only in late winter and spring (Fig. 17). Elk individuals were divided in their selection for or against ruggedness across seasons, with average selection usually being for non-rugged areas. Elk avoided the Alpine and Rock/rock crust areas throughout the year, and usually selected for the Subalpine (Fig. 18).

Both species selected to be close to a burn (Fig. 17). Stone’s sheep selected specifically for burns in fall, winter and late winter. Elk selected for burns throughout the year, with highest selection for the older Burn shrub areas (Fig. 18).

These selection strategies for topography and land cover resulted in the highest frequency of use by female Stone’s sheep in Rock/rock crust areas; 70% of locations (averaged across individuals) in summer was in that land-cover class (Fig. 19). The next highest proportion of locations was in the Alpine class in summer and fall (22-28%). Stone's sheep rarely used *Carex*, Low shrub, Non-vegetation or Riparian classes in any season (all use < 0.1 %). They used all 3 burn classes to some degree in every season except summer, when there was essentially no use. Proportional use of burns (all 3 burn classes combined) was 34 to 46% in winter and late winter, respectively. Highest use among burn classes in the 2 winter seasons occurred on New burns (18-28%).

The proportional use of burned areas by collared female elk was high and consistent. The proportion of locations in the 3 burn classes combined (averaged across individuals) ranged from 39% in summer to 80% in late winter. Use of Burn shrub (15-35%, depending on season) and New burn (18-29%) by elk was always higher than use of Burn-grass (5-21%) in each season. Each of the 3 burn classes was used more than it was available in all seasons except fall when use (5.1%) of Burn-grass was similar to its availability (5.9%). The next highest proportions of locations of collared elk were in Conifer (12-20%) and Subalpine (16-31%) cover in summer, fall, and winter. *Carex*, Non-vegetation, Alpine and Rock/rock crust classes were rarely used by elk (Fig. 20).

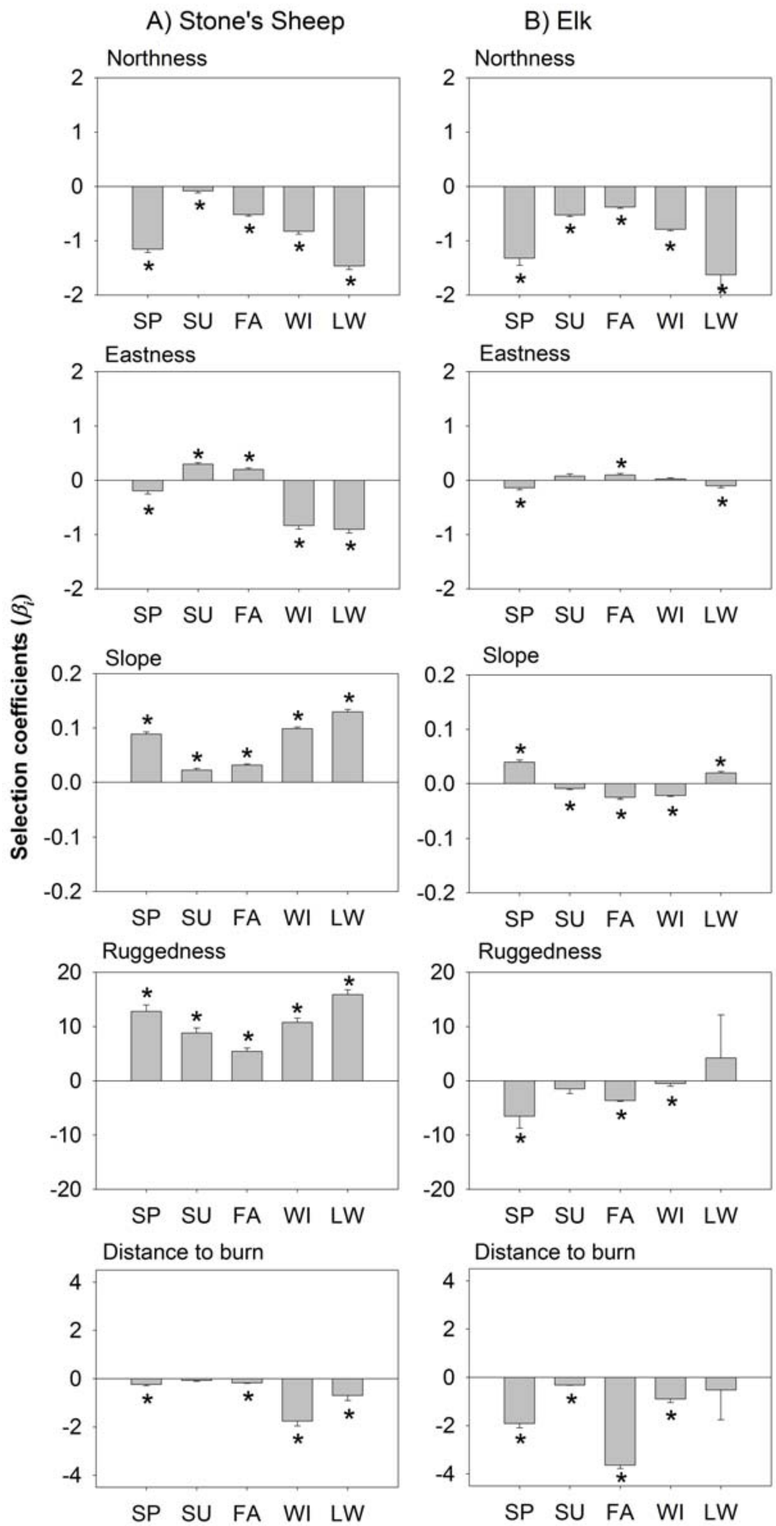

Figure 17. Selection coefficients (β_i ± SE) for aspect, slope, ruggedness, and distance to burns from the best global resource selection models by season for A) Stone's sheep and B) elk in the Besa-Prophet study area of northern British Columbia, 2010-2012. SP = Spring, SU = Summer, FA = Fall, WI = winter, LW = late winter; as defined in Table 1. * indicates each seasonal β_i is different from zero based on 95% confidence intervals.

A) Stone's sheep B) Elk

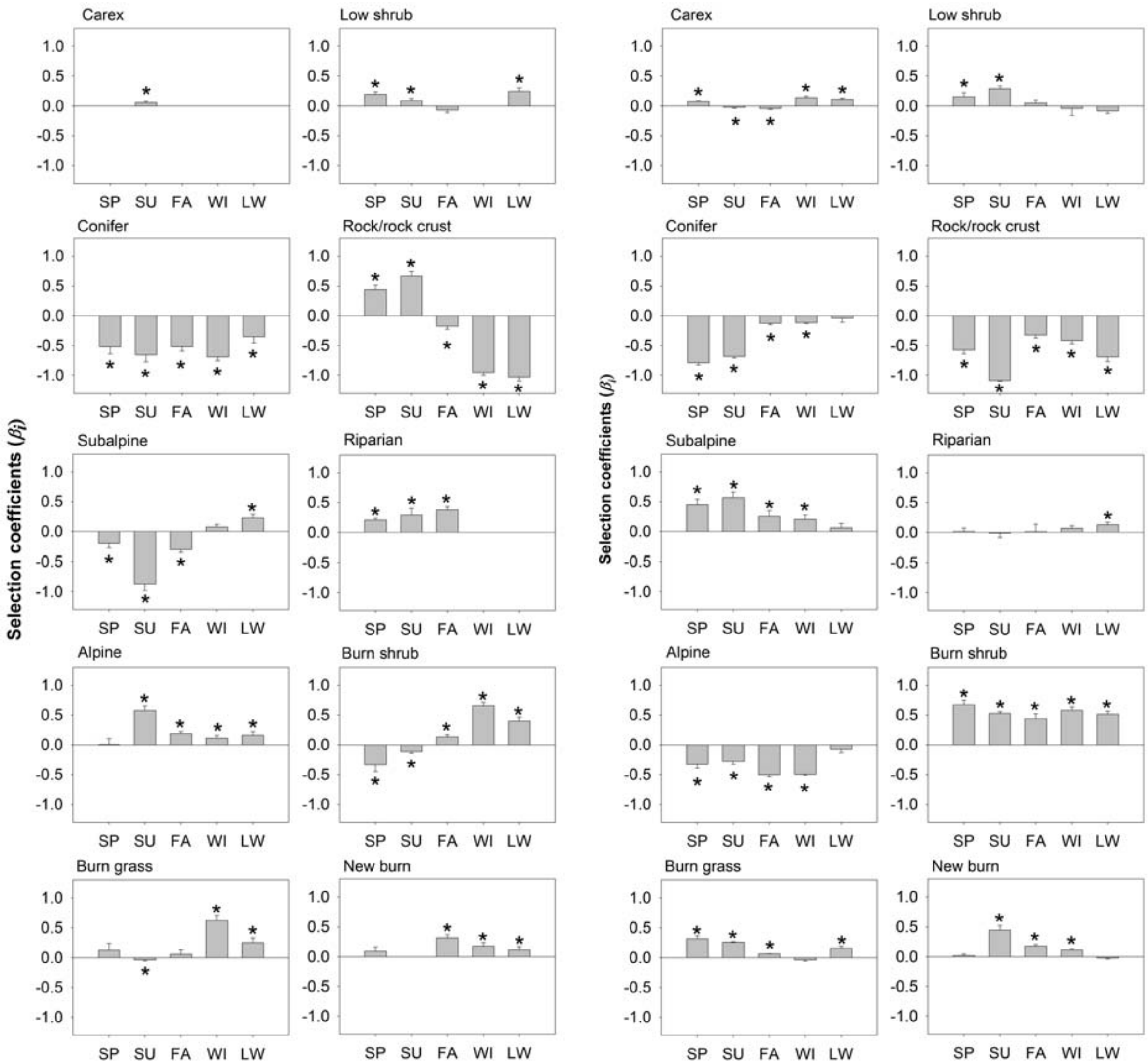

Figure 18. Land-cover classes and their selection coefficients ($\beta_i \pm$ SE) from the best global resource selection models by season for A) Stone's sheep and B) Elk in the Besa-Prophet study area of northern British Columbia, 2010-2012. SP = Spring, SU = Summer, FA = Fall, WI = winter, LW = late winter; as defined in Table 1. Seasons for which an attribute could not be incorporated into a model are not shown. * indicates each seasonal β_i is different from zero based on 95% confidence intervals.

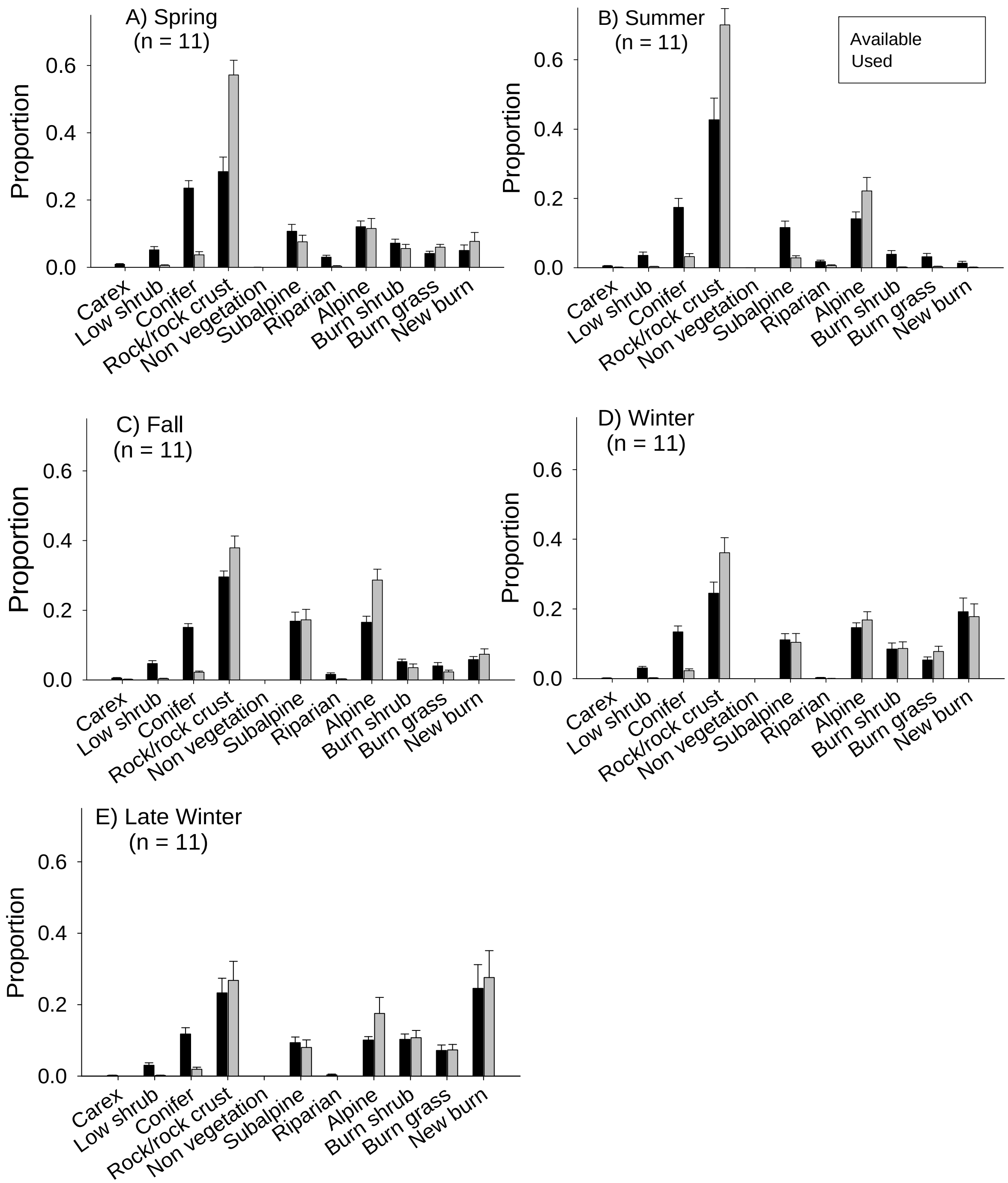

Figure 19. Proportional use (mean ± SE) by GPS-collared Stone's sheep of different land-cover classes in relation to their availability in the Besa-Prophet study area, northern British Columbia, 2010-2012. n is the sample size of individuals.

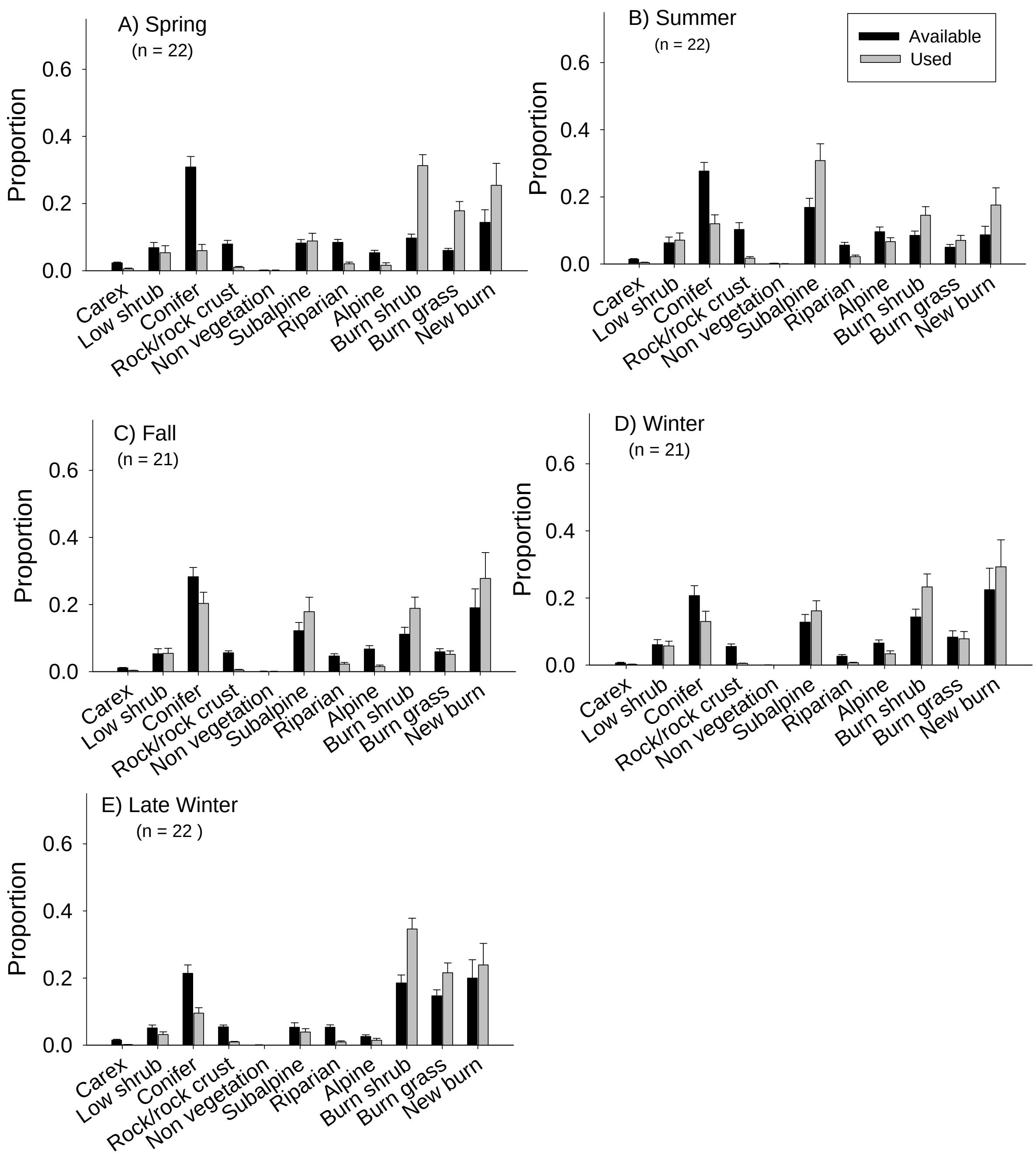

Figure 20. Proportional use (mean ± SE) by GPS-collared elk of different land-cover classes in relation to their availability in the Besa-Prophet study area, northern British Columbia, 2010-2012. n is the sample size of individuals.

The selection strategy used by both species to be close to a burn resulted in Stone's sheep being closest in winter (102 ± 29 m) and late winter (103 ± 53 m) and farthest away in summer (3399 ± 807 m) (Fig. 21). Elk were less than an average of 350 m away from a burn in all seasons except summer (1357 ± 493 m). Straight-line distance from a GPS location to a burn ranged from 0 m (i.e., on the burn) to 17.5 km for Stone's sheep and 20.2 km for elk; both of these longest distances were in summer. Stone's sheep and elk in the Besa-Prophet study area used burns up to 28 years old (Fig. 22). Most Stone's sheep locations were in younger burns (< 3 years), whereas elk more commonly used burns of all ages.

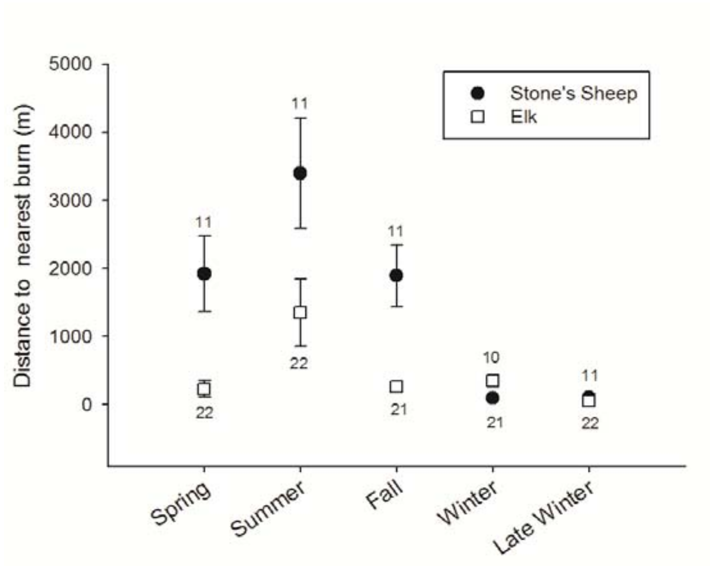

Figure 21. Distance to the nearest burn from locations of GPS-collared female Stone's sheep and elk in the Besa-Prophet study area of northern British Columbia, 2010-2012. The numbers of individuals used to calculate means and standard errors is shown above error bars.

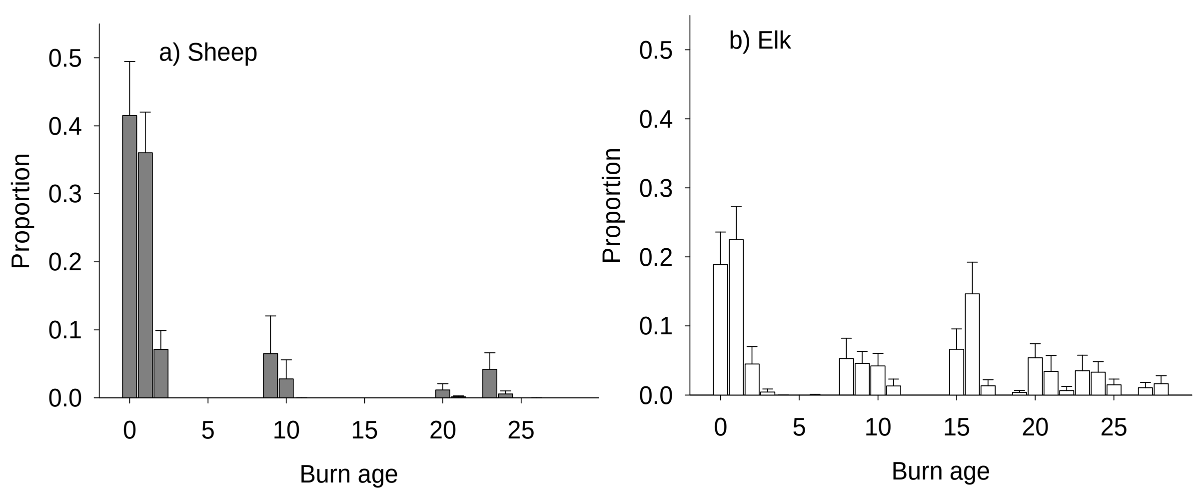

Figure 22. Proportional use of different aged prescribed burns by 11 GPS collared female Stone's sheep and 22 GPS-collared female elk in the Besa-Prophet study area of northern British Columbia, 2010 - 2012.

Stone's sheep and elk showed similar seasonal patterns in the use of elevation. Both species were at lowest elevations in late winter and moved up in elevation from spring to summer, when variation among individuals was highest (Fig. 23). Stone's sheep were at lowest elevation in April (1639 ± 19 m) and moved up in elevation each month until reaching their highest elevations in July (1864 ± 29 m) and August (1860 ± 26 m). This elevational movement occurs has they track the highest nutrient quality in newly emerging plants (Walker et al. 2006). Elk were at their lowest elevation (1396 ± 22 m) in May, moved up summer, and were at their highest elevations in November (1588 ± 17 m). Stone's sheep were always at higher elevations than elk.

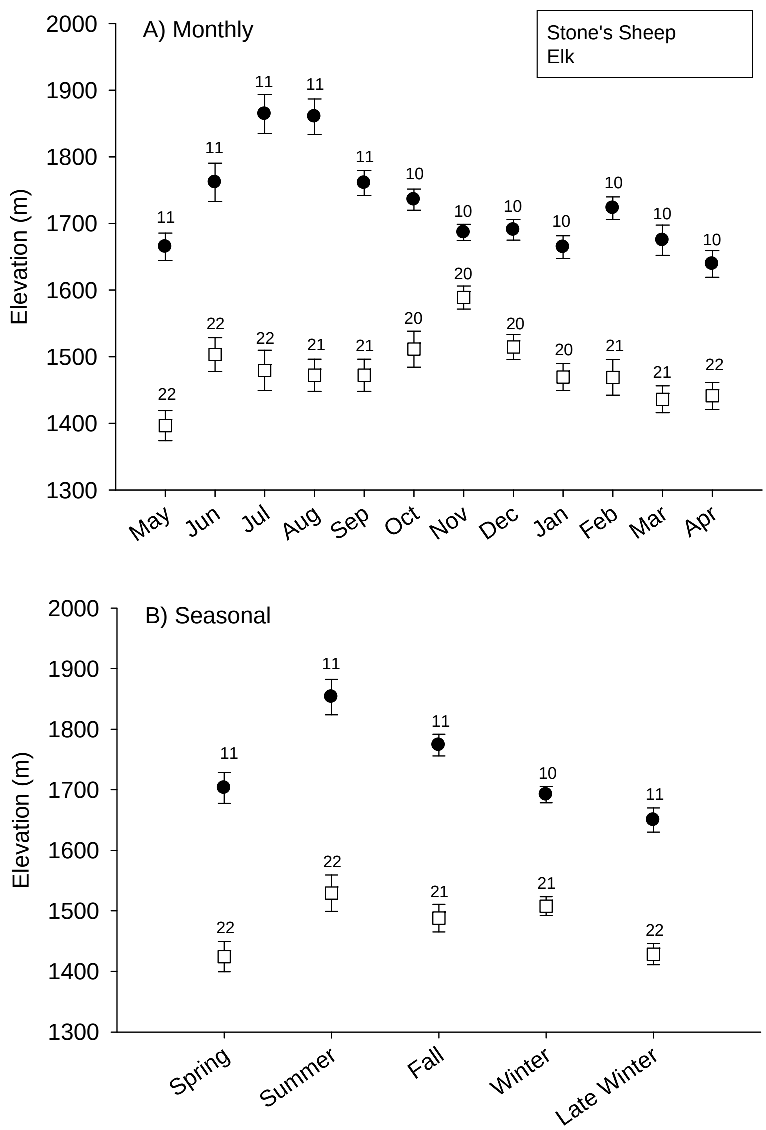

Figure 23. Elevations used by GPS-collared female Stone's sheep and elk by month (A) and season (B) in the Besa-Prophet study area of northern British Columbia, 2010-2012. The numbers of individuals used to calculate means and standard errors are shown above error bars.

The two species also showed similar seasonal patterns in the use of slope. Both species used steepest areas in late winter and spring and flatter areas in summer and fall (Fig. 24). The steepest location used by a collared individual was 61.3° for Stone's sheep in spring and 50.6° for elk in late winter. Stone's sheep used steeper slopes than elk in every month and each season.

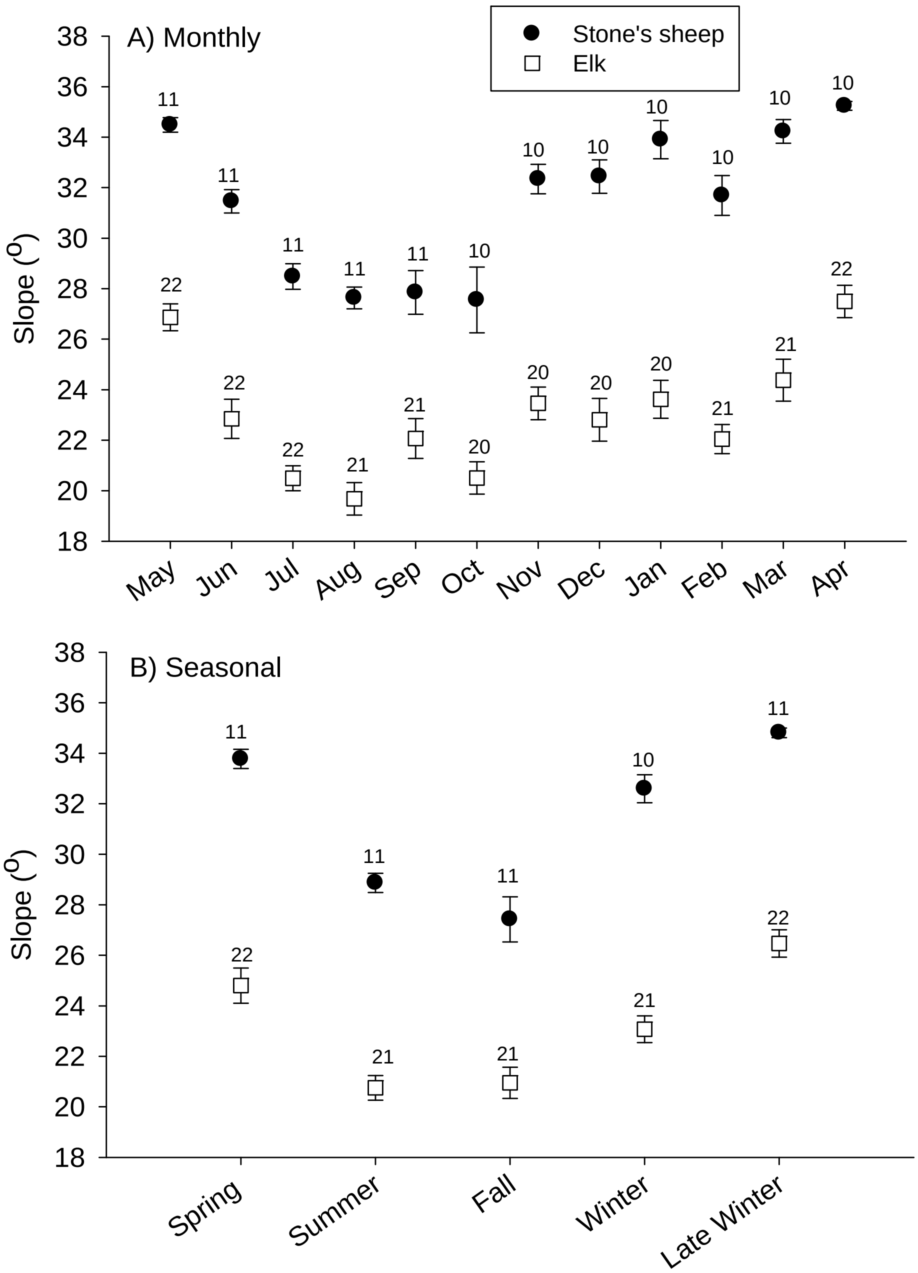

Figure 24. Slopes used by GPS-collared female Stone's sheep and elk by month (A) and season (B) in the Besa-Prophet study area of northern British Columbia, 2010-2012. The numbers of individuals used to calculate means and standard errors are shown above error bars.

Elk and Stone's sheep appear to partition their use of the Besa-Prophet landscape. Both species do select and use burns at similar times of the year. However, they currently occupy different niches because Stone's sheep use steeper slopes at higher elevations (Fig. 25). Stone's sheep also tend to be in rugged terrain at high elevation. In contrast, when elk are in rugged terrain, they are generally at lower elevations.

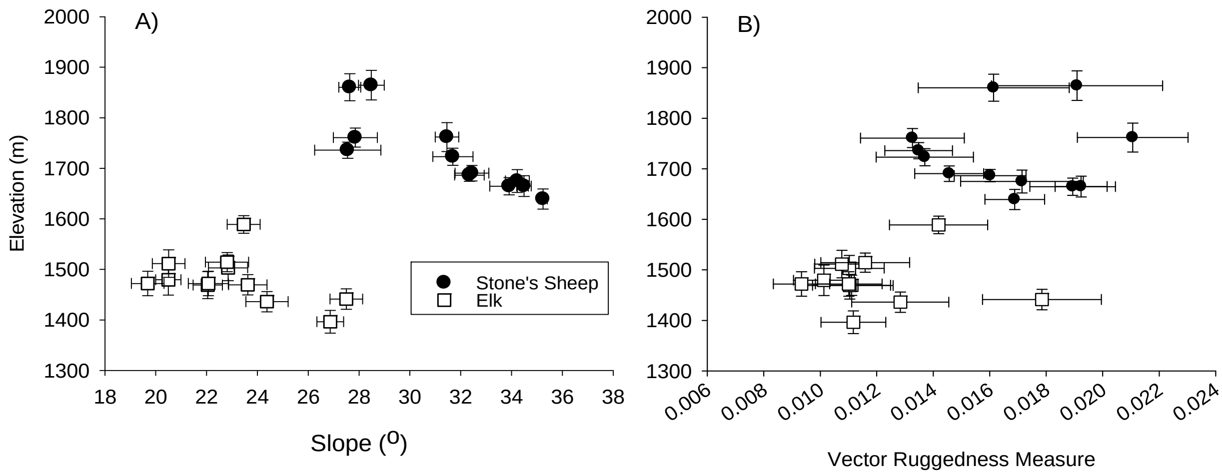

Figure 25. Differential use of elevation, slope, and terrain ruggedness by GPS-collared female Stone's sheep and elk in the Besa-Prophet study area of northern British Columbia, 2010-2012. Topographical attributes were averaged for each individual and then averaged across individuals.

Our data from the large Richards burn suggest similar partitioning between Stone's sheep and elk based on inherent preferences for elevation and slope. Figure 26 shows the use of the Richards prescribed burn by Stone's sheep and elk between 1 November and 15 May (2010-2012). Elk tended to distribute themselves across the burn at all elevations, whereas Stone's sheep remained at higher elevations and on rocky outcrops within the burned area.

Each prescribed fire is unique and the resulting plant and animal responses related to forage quantity and quality are variable (Baker 2009, Fuhlendorf et al. 2008). This complexity is inherent in our findings on the 4 burns that we monitored intensively for vegetation attributes and animal use. The 2 south-facing burns (Richards and Townsley) had high forage biomass and, based on pellet counts, had more historic and current elk use. The Richards burn, with the highest forage biomass and highest availability of digestible dry matter, sustained the largest groups of both elk and Stone's sheep (observed during survey flights). This use is already reflected in the difference in forage availability inside and outside the range exclosure. Townsley, as the steepest south-facing slope, also had the highest plant diversity and richness. The two west-facing sites (Luckhurst and Nevis) had the lowest forage biomass. Nevis had the lowest burn severity, resulting in the retention of many shrubs (both live and dead), and had the lowest animal use (both fecal pellets and flight observations). Luckhurst had the highest burn severity, which resulted in the lowest shrub and forage cover, and the lowest availability of digestible dry matter. The early regrowth in late winter, however, had the highest digestibility and crude protein content. Use by Stone's sheep (based on pellet counts) was highest post-burn on Luckhurst, presumably because unlike elk that require much larger large amounts of forage, they are able to selectively forage and choose the most nutritious parts of plants. Both Stone's sheep and elk track the phenology of plants. By foraging on burns when new growth is early and then shifting to unburned areas a few weeks later as new growth occurs, the time that animals have access to new high-quality forage is extended appreciably.

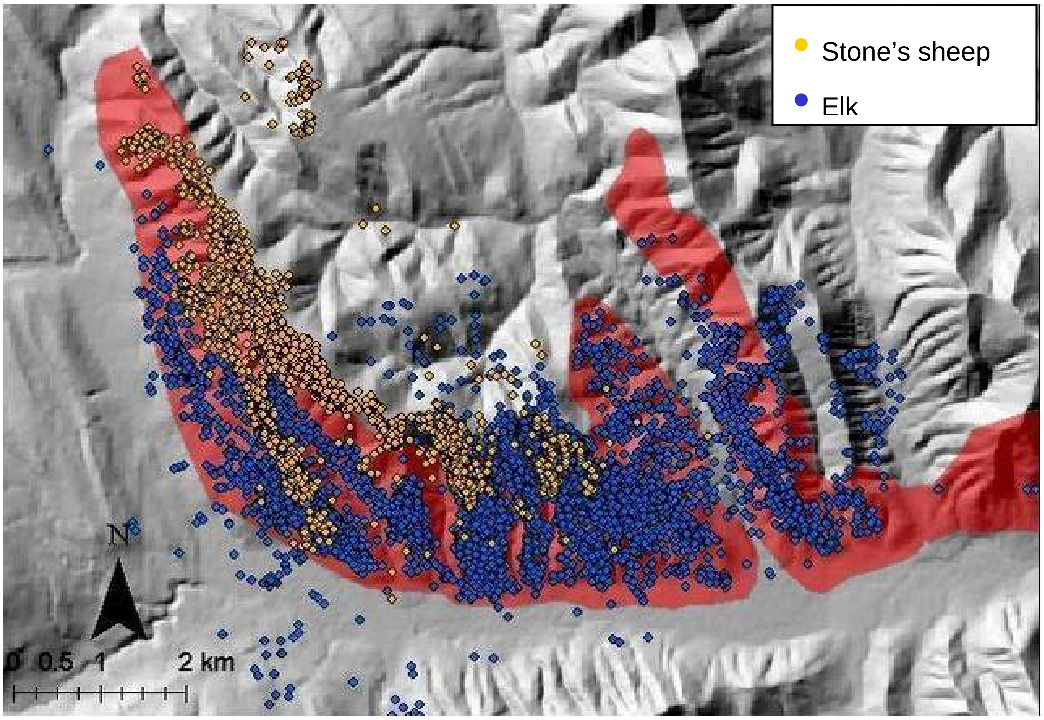

Figure 26. Winter and late winter distribution of GPS-collared Stone's sheep and elk in relation to the Richards prescribed burn (polygon in red) in the Besa-Prophet study area, northern British Columbia, 2010-2012.

10. Benefits/Risks

Our study provides information on how elk and Stone's sheep are currently sharing a heterogenous landscape, shaped by its topography and by the prescribed burning program. According to government survey reports, Stone's sheep populations in the Besa-Prophet area have been relatively stable during the last 20 years for which survey data are available. There are no specific census data for elk in the area, but from anecdotal accounts, elk populations are increasing.

Prescribed burning, by altering animal distribution in response to burned areas, influences ungulates at a larger scale than the footprint of the burns themselves. Fire has the potential to change complex predator-prey interactions. As increasing elk populations augment total ungulate biomass, there is increasing potential for interspecies interactions and subsequent increases in predator populations. We recommend monitoring of elk populations to ascertain if they are moving, in response to the nutrient flush provided by on-going burning, into the steeper and higher elevations used by Stone's sheep.

It is important that the permanent vegetation transects that have been established in burned and unburned areas continue to be monitored to assess the trends in forage quantity and quality over time and to provide more information on the frequency of beneficial burning. These transects could also be used as bench marks of future climate change. The long-term impacts of grazing should be quantified over time by continuing to monitor the grazing exclosures in place on the burned and unburned control sites.

This project complements work being conducted by Sonja Leverkus on movements of bison in response to burns in the Fort Nelson area (linked to HCTF project #7-352). The 2 wildlife studies (elk/Stone's sheep, bison) together help quantify the influence of fire on the 3 largest grazing species of northern BC.

11. ACKNOWLEDGMENTS

Support for this study was provided by the Habitat Conservation Trust Foundation ($183,000) and other contributors ($90,000) including University of Northern British Columbia, BC Ministry of Environment, Wildlife Conservation Society, Wild Sheep Foundation, Wild Sheep Society of BC, Northeastern BC Wildlife Fund, Northern Scientific Training Program, and Association of Canadian Universities for Northern Studies.

We extend special thanks to Rob Woods, with BC Ministry of Environment, who implemented the prescribed burns and captured /collared all of the animals monitored in this study. In addition to his efforts, we thank pilots from Bailey Helicopters (Pete Bryant, Sean Stone, Sean Whitford, Aaron Gillingham), Qwest Helicopters (Zonc Dancevik, Cam Allan, Mike Koloff, Tim Gray), Altoft Helicopter Services (Rob Altoft), and Guardian Aerospace (Eric Stier). We appreciate the help and accommodation provided by Sikanni River Outfitters, especially Mike Hammett who designed and fabricated the range exclosures for this study with help from Chris Shipman. We also acknowledge those who lent assistance in the field sampling vegetation (Mike Gillingham, Becky Cadsand, Libby Williamson-Ehlers, Krista Desmond, Bobbie Harbicht, Sandy Sittler) and retrieving radio-collars (Morgan Anderson, Doug Heard, Fraser MacDonald, Rob Woods, Alicia Goddard, Brad Culling), or in the lab (Scott Emmons, Ping Bai, Shannon O'Keefe). We also are grateful to Mike Gillingham for ecological and analytical contributions.

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13. Extension/Public Information/Participation/Partners

Video

Prepared for Wildlife Conservation Society
Available at Canadian Geographic Link (5th star from the west):
http://canadiangeographic.ca/magazine/dec12/arctic_research_map.asp

Presentations

Response of boreal vegetation to prescribed fire: Implications for Stone's sheep and elk in the northern Rockies. Canadian Section of the Wildlife Society's Annual Conference, 8-10 March 2013, Canmore, Alberta.

Response of Rocky Mountain elk and Stone's sheep to prescribed fire in the northern Rockies. The Wildlife Society's 18th Annual Conference, 5-10 November 2011, Waikoloa, Hawaii.

Elk and Stone's sheep response to prescribed fire. Habitat Conservation Trust Foundation Workshop, 28-29 October 2011, Kelowna, British Columbia.

14. Photographic Record

Please see following figures showing photographs taken during our study.

HCTF USE ONLY –Report Accepted by:

Controller, Habitat Conservation Trust Foundation Date

Townsley Creek (above) and Richards Creek (below) from south-facing control sites in July 2010.

Nevis Creek from the west-facing Nevis control site in May 2011.

Summer (July 2010) following burning on the west-facing Luckhurst site.

Range exclosure and vegetation sampling one year after prescribed burning at Townsley site in July 2011.

Late winter (May) and summer (July) vegetation sampling at Townsley control site in July 2010.

Stone’s sheep on the Luckhurst burn in July 2010; elk on the Richards burn in March 2012.

Krista Sittler at the Richards burn in May 2011.

Kathy Parker on the Townsley control site in May 2012.