# HABITAT USE AND SELECTION BY MOOSE AND ELK IN THE BESA-PROPHET

**Part 4 of Project "An Ecosystem Approach to Habitat Capability Modeling and Cumulative Effects Management"**

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## *EXECUTIVE SUMMARY*

This research contributes to the large-scale ecosystem approach by the University of Northern British Columbia to quantify dynamics within focal predator-prey systems of the Muskwa-Kechika Management Area and to provide a baseline against which to monitor changes over time.

The overall goal of this project was to obtain preliminary information on habitat selection strategies of female moose and elk in the Besa-Prophet region of the Muskwa-Kechika Management Area. We used radio-telemetry data obtained from global positioning satellite (GPS) collars on 14 female moose and 13 female elk, remote-sensing imagery of vegetation communities, and assessments of predation risk from studies on grizzly bears (*Ursus arctos*) and wolves (*Canis lupus*) in the same area to assess habitat use and selection. We determined proportional use of different vegetation classes as well as of the biophysical zones and habitat suitability classes developed by the British Columbia Ministry of Environment for use in pre-tenure planning for the study area. We developed resource selection models to quantify the combinations of variables that moose and elk selected or avoided from what was available to them. These models showed that moose always selected for mid elevations, usually against steep slopes, and consistently for deciduous burns and *Carex* sedge areas. Moose also selected for stunted spruce sites in late winter, calving, and summer, and for the subalpine in summer, fall, and winter. Low shrub vegetation was favoured from fall through winter. In contrast, elk selected for mid elevations only in fall, and for both low and high elevations in late winter and summer. Other than during summer, elk selected most consistently for deciduous and *Elymus* grass burn habitats, as well as for the subalpine. Summer was the only season in which elk selected for stunted spruce, pine spruce, and riparian, and the only season in which elk selected against deciduous and *Elymus* burns, low shrubs, and the subalpine. Both moose and elk tended to avoid non-vegetated and alpine areas throughout the year and made trade-offs among forage quality, forage biomass, and predation risk. Seasonal ranges were largest for both species during summer.

This research provides a preliminary analysis of habitat use and selection by moose and elk, the two large-biomass prey species that help support wolf and grizzly bear populations in northern British Columbia. The findings help characterize the ungulate landscape of the Besa-Prophet area to better understand interactions within the large mammal predator-prey system.

## INTRODUCTION

This project on moose (*Alces alces*) and elk (*Cervus elaphus*) is one component of a large research effort to understand the interactions within the large mammal predator-prey systems of the Muswka-Kechika Management Area (MKMA) of northern British Columbia (BC). The overall study will build an information database for the Muskwa-Kechika, particularly by defining movements and specific habitat requirements for large ungulates and carnivores that use large portions of the landscape. We concentrated the study in the Besa-Prophet Pre-tenure Planning Area of the MKMA because of its abundant wildlife species and habitat diversity, and because of the likelihood of extrapolating some of the science to other areas of the Muskwa-Kechika.

Moose and elk often provide the majority of prey biomass for large predators in complex predator-prey systems of North America. As examples, elk support wolf (*Canis lupus*) populations in Yellowstone and Yukon (Hayes and Harestad 2000, Smith et al. 2003), moose are also common prey for wolves (e.g., Post et al. 2002, Vucetich et al. 2002), and both moose and elk provide a prey base for wolves and grizzly bears, *Ursus arctos*) in northern BC (Bergerud et. al. 1983, Bergerud and Elliott 1998, Parker and Milakovic 2007). Moose and elk are relatively profitable prey types in comparison to smaller ungulates or alternative prey for wolves and bears, and given sufficient densities, can enable large predator populations. Hence, moose and elk are keystone species in the functioning of large-scale large mammal systems. In multi-ungulate multi-predator systems, however, they are commonly not as studied as other species because they are less susceptible to disturbance than other species (e.g., Stone's sheep, *Ovis dalli stonei*), use smaller areas and, therefore, are not as subjected to landscape disturbance as some species (e.g., woodland caribou, *Rangifer tarandus caribou*), or have large populations that are less vulnerable to and better accommodate change. In addition, the requirements of moose and elk are assumed to be relatively well known (e.g., Franzman and Schwartz 1997, Toweill and Thomas 2002). Moose and elk also have the benefit of being high-profile game species, which are often managed to maintain or increase numbers. High numbers of high-biomass species have implications to their predators, and in turn other species in the same system.

This study provides preliminary information on moose and elk, and complements other projects on caribou (Parker and Gustine 2007), Stone's sheep (Parker and Walker 2007), and grizzly bears and wolves (Parker and Milakovic 2007) in the same area. Although the study was only an initial overview of seasonal habitat use and selection by moose and elk, it contributes to the conservation of the large mammal system for which the area is recognized, as well as to effective land-use planning. Moose and elk are highly visible species, with strong social and ecological values in the mountains of British Columbia. Knowledge of landscape use and habitat selection by these two species will help maintain ecosystem function and be used to document the impacts anthropogenic or environmental disturbance in the future.

## *PROJECT OBJECTIVES*

The overall goal of this study was to provide an initial description of habitat use and selection by moose and elk in the Besa-Prophet area. To do this we used global positioning satellite (GPS) radio-locations, remote-sensing imagery of vegetation communities, assessments of predation risk from concurrent studies on grizzly bears and wolves in the same area, and habitat selection modeling. These data and analyses are helpful in characterizing the ungulate landscape of the Besa-Prophet watershed. They contribute to a better understanding of interactions within the large mammal predator-prey system.

Specific objectives were to:

1) monitor seasonal movements and range use by moose and elk;

2) determine which habitat attributes are most important in habitat selection by moose and elk; and

3) assess habitat use relative to pre-tenure zones in the Besa-Prophet Pre-tenure Planning Area.

## *STUDY AREA*

The Muskwa-Kechika Management Area (MKMA) in northern BC covers approximately 6.4 million ha. It includes both protected areas as provincial parks and special management zones where resource development is permitted as long as wildlife and wilderness values are maintained (Fig. 1). Within the MKMA, the Besa-Prophet study area included the 204,245-ha Besa-Prophet Pre-tenure Planning Area, and portions of the surrounding region with part of Redfern-Keily Provincial Park for a total of 740,887 ha (Fig. 1). The study area was located between $57^o11'$ and $57^o15'$ N, and $121^o51'$ and $124^o31'$ 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. The underlying sedimentary rock formations are folded and faulted, and as is common along the eastern slopes of the Rockies, the area potentially contains significant oil and gas reserves. 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. Therefore, data from this study are an important baseline that can be used to help determine routes of access and the cumulative effects of that access. At this time there is relatively little access into the Besa-Prophet region. There are several permanent outfitter camps and one government-designated all-terrain vehicle (ATV) trail through the Neves (also referred to as Nevis) valley. The majority of human activity occurs during the summer and fall with the start of hunting seasons. Some snowmobile activity is present during winter.

There are primarily 3 biogeoclimatic zones in the Besa-Prophet study area: boreal white and black spruce (*Picea glauca* and *P. mariana*) at lower elevations, spruce-willow-birch (*Salix* spp., *Betula glandulosa*) at mid-elevations (~1300-1600 m), and alpine tundra above

approximately 1600 m (as in cover photo of Keily Creek and Besa River) (Meidinger and Pojar 1991). 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. There also are slopes that have been burned by the British Columbia Ministry of Environment and local guide outfitters to enhance ungulate populations, primarily Stone's sheep. The spruce-willow-birch zone of the subalpine area is characterized by an abundance of willow and scrub birch, as well as some balsam fir (*Abies lasiocarpa*) and white spruce often in krummholz form, and various grasses, sedges and fescues (*Festuca* spp.). Alpine areas consist of permanent snowfields, rock, mat vegetation, and grasslands (Demarchi 1996). Because of this 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, it supports one of the largest intact and diverse predator-prey systems in North America.



**Figure 1. Besa-Prophet study area in the Muskwa-Kechika Management Area of northern British Columbia.**

## *ACTIVITIES/TECHNIQUES/FINDINGS:*

### **Ranges and Movements**

Fifteen adult female moose and 14 adult female elk were fitted with GPS (global positioning satellite) collars (GTX, Advanced Telemetry Systems, Isanti, MN) in March 2003 and January 2005, respectively. Collars were programmed to record locations 4 times daily. Data were retrieved when collars were recovered at the end of a 1-year sampling period. We retrieved 14,534 GPS locations from 14 of the collared moose and 14,870 locations from 13 collared elk. The number of GPS locations recorded as a percentage of the number of attempted GPS locations was only $51 \pm 1.9\%$ (mean $\pm$ SE, range = 38-60%) for moose and $82 \pm 1.6\%$ (range = 68-93%) for elk.

We defined 5 seasons that are distinguished by biological and ecological characteristics for our analyses of range use and movements by moose and elk (Table 1). Distances moved between 6-h GPS fixes ranged from <1 m to 14.53 km (straight-line distance) by moose and <1 m to 10.34 km by elk, respectively. From the GPS locations that were obtained from consecutive 6-hr fixes, we calculated average monthly and seasonal movement rates for the individuals, and then averaged across individuals to obtain average moose and elk movement rates. Both species moved at lowest rates during winter and late winter (35-40 m/hr), and then increased movements to highest rates in summer (>100 m/hr) (Figs. 2 and 3). Elk usually tended to move at rates slightly higher than moose (repeated-measures ANOVA, $P = 0.049$), but these rates were significantly higher only during calving (elk = $93 \pm 27$ m/hr, mean $\pm$ SE; moose = $59 \pm 21$ m/hr) (Bonferonni confidence intervals).

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

| Season | Date | Biology |
|---|---|---|
| Winter | 1 November– 28 February | Formation often of sex-specific groups following rut |
| Late winter | 1 March – 15 May | Lowest movement rates; usually smallest range size |
| Calving | 16 May – 15 June | Parturient females become solitary; 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; males and females form mixed sex groups; females come into estrus |

## Moose Movement Rate
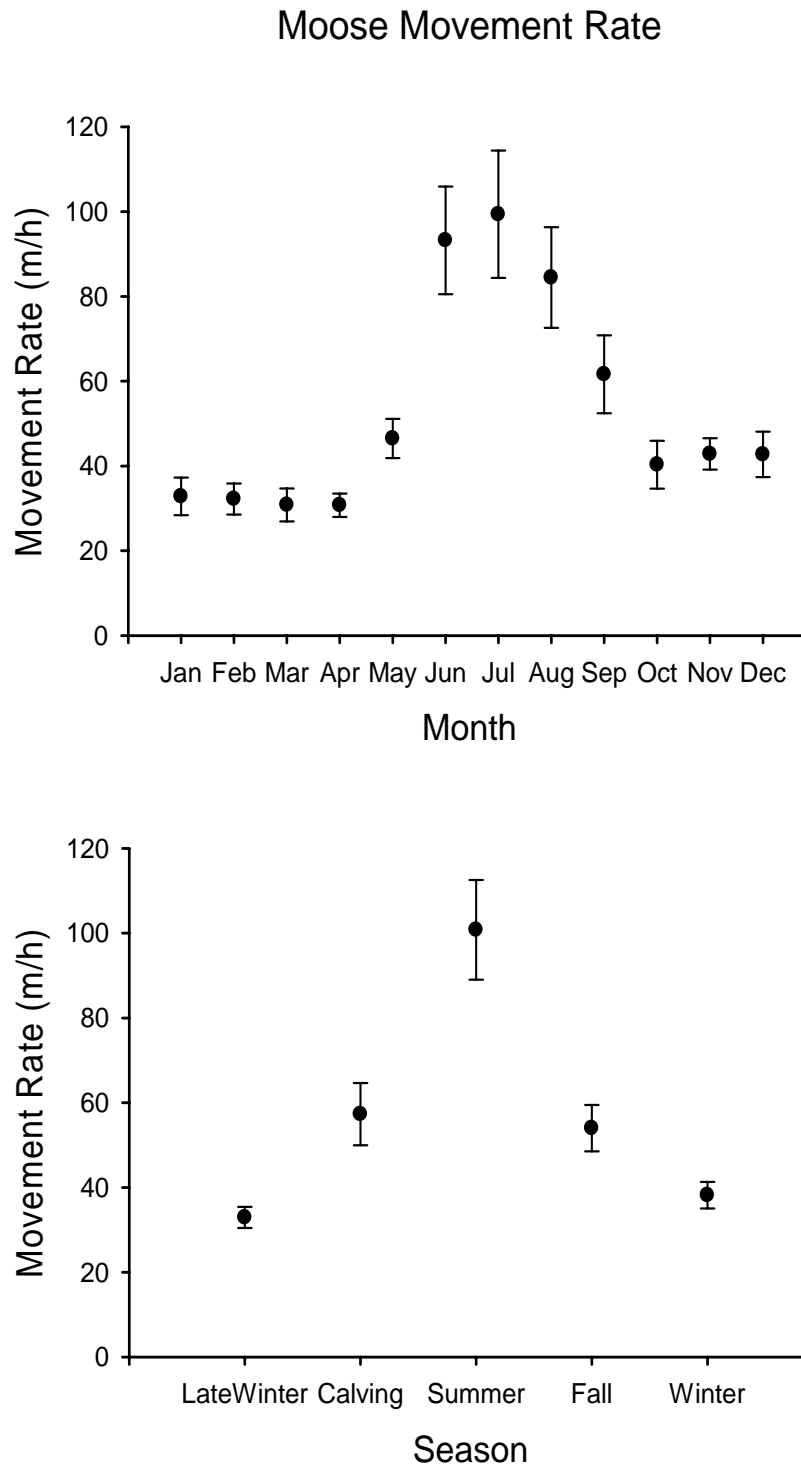


Figure 2. Movement rates (m/hr, mean ± SE) of adult female __moose__ (n = 14), averaged by individual and then averaged across individuals, by month and season (as defined in Table 1) in the Besa-Prophet area, March 2003 - March 2004.
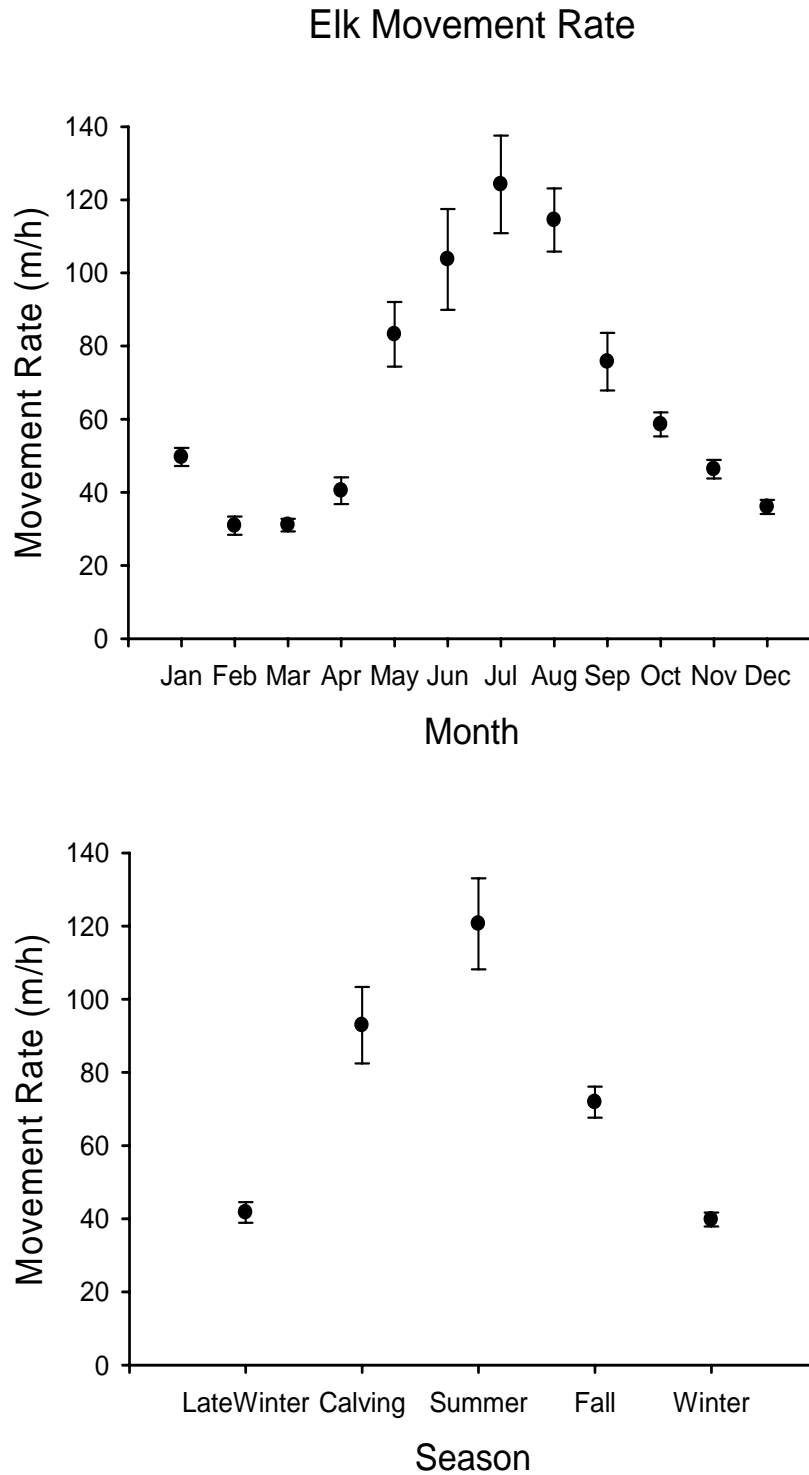
## Elk Movement Rate





**Figure 3. Movement rates (m/hr, mean ± SE) of adult female <u>elk</u> (n = 13), averaged by individual and then averaged across individuals, by month and season (as defined in Table 1) in the Besa-Prophet area, January 2005 - January 2006.**

We determined sizes of annual and seasonal home ranges using 100% minimum convex polygons (MCPs, Jennrich and Turner 1969) around GPS locations for each individual, as well as by fixed kernel analysis (Worton 1989). These calculations were done using the ArcView Animal Movement Extension (Hooge and Eichenlaub 2000) in ArcView (ESRI 2002). MCPs, which link use points on the outside edges of a convex polygon encompassing all points, tend to overestimate range sizes for animals that have infrequent movements away from a centralized area. Kernels, calculated from the 95% probability density of all locations, delineate core areas of use. This works well for species that have more than one area of concentrated use, but may exclude areas where movements take place between core areas and include substantial 'buffer' areas around high density locations. Small numbers of locations also tend to result in over-estimated kernel home range sizes (Seaman et al. 1999). As examples, we present data for 2 moose individuals in Figures 4 and 5. Both animals showed movements along valleys. For animal #658, most of the long valley movements were associated with summer (Fig. 4A, B) although there were also other far-ranging summer movements. Animal #810, which used a much smaller area more consistently, moved along its valley corridor throughout several seasons (Fig. 5A). The annual MCP for #658 was notably larger than that of #810, and incorporated an area far beyond most GPS locations (Fig. 4A). Annual kernels for both animals were much smaller than the MCPs, and did not include the valley corridors. In summer, both MCPs and kernels better captured the ranges used by the moose, with kernels appearing most appropriate for these 2 animals (Figs. 4B, 5B). Our calculations of sizes of seasonal ranges are probably more reflective of reality than one annual home range. We present data for both MCPs and kernels by season and an annual range to correspond with other studies on moose and elk, but it is important to recognize the limitations of both. We discuss our findings relative to MCPs.

Moose Ranges:  Most of the GPS-collared moose were in the southern portions of the Besa-Prophet Pre-tenure Planning Area of the MKMA (Neves and Besa valleys), and the western portion of Redfern-Keily Provincial Park (Keily Creek, Redfern Lake) (Fig. 6). Annual ranges for moose averaged 195 km$^2$, but were highly variable, ranging from a minimum of 39 to a maximum of 899 km$^2$ (Table 2). Seasonal ranges were typically smallest during the calving season (18 km$^2$), and more than 7 times larger during summer.

Elk Ranges:  Elk with GPS collars were concentrated in areas bordering the Besa River and Richards Creek (Fig. 7). Annual ranges for elk averaged 191 km$^2$, with high individual variation from a minimum of 50 km$^2$ to a maximum of 1000 km$^2$ (Table 3). Excluding animal #769 that made a large circular excursion away from the Besa River area in July, annual ranges averaged 123 km$^2$ ($\pm$ 19 SE, range = 50 - 250 km$^2$). In contrast to moose, seasonal ranges for elk were typically smallest during the winter and late winter seasons (~18 km$^2$) (as opposed to calving, 38 km$^2$). Similar to moose, seasonal ranges for elk were largest during the summer (118 km$^2$).
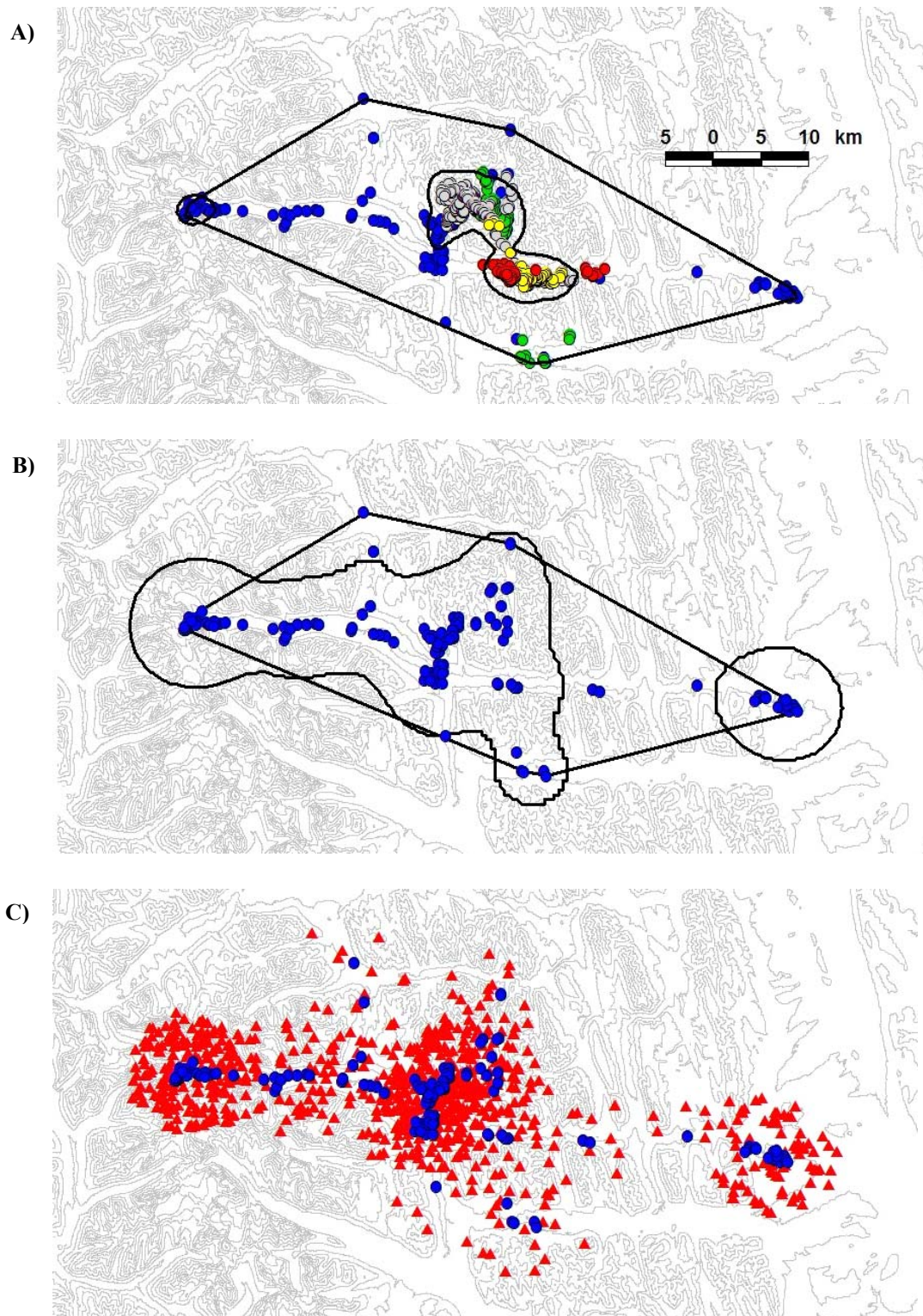
A)

B)

C)

**Figure 4. Locations for <u>moose</u> #658 showing A) all seasonal GPS locations on 200-m contours, annual 100% MCP and annual 95% fixed kernels, B) summer locations with summer MCP and kernels, and C) random points (▲) used to quantify availability in the summer habitat use (●) and selection analyses.**
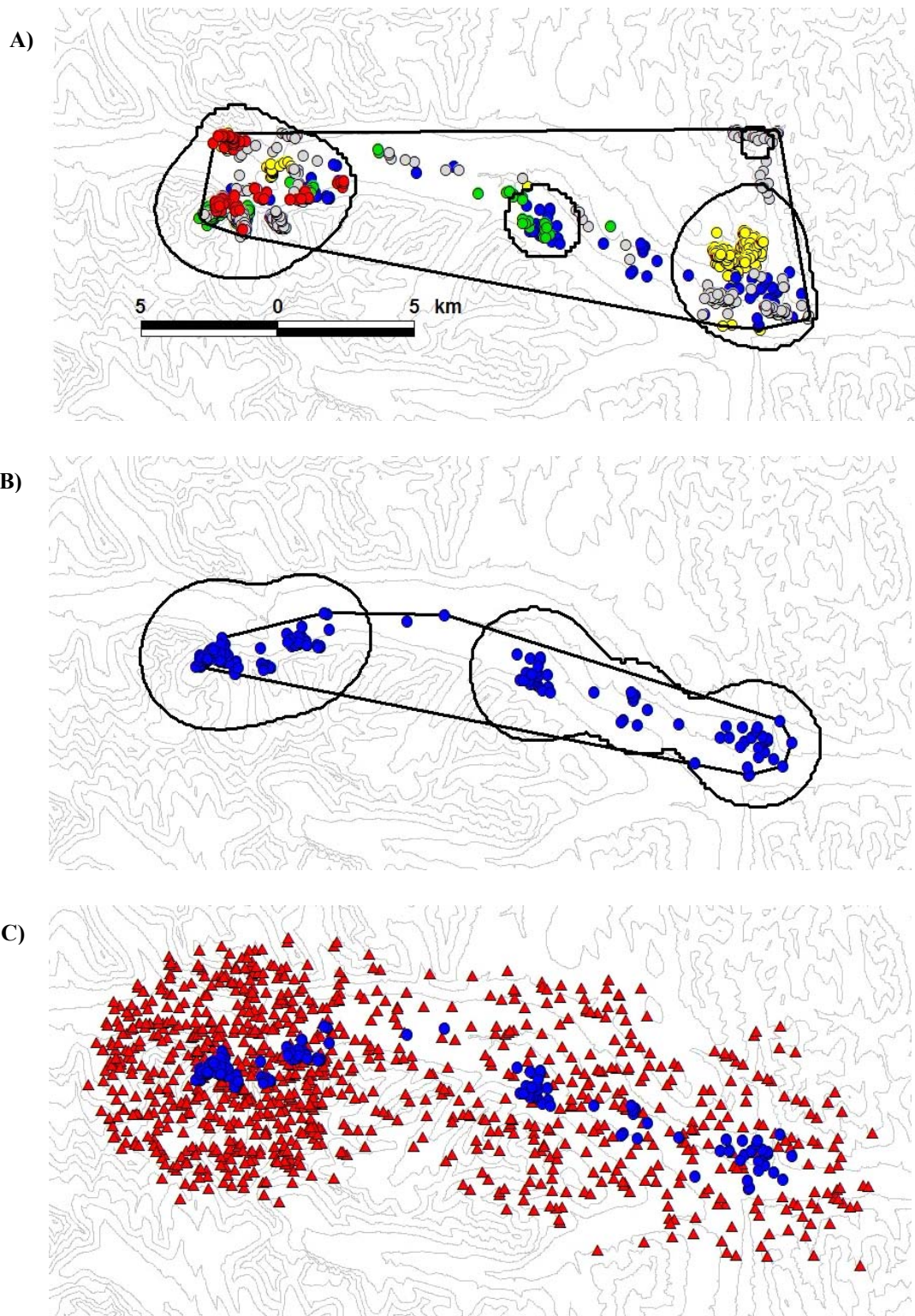
**A)**

**B)**

**C)**

**Figure 5. Locations for <u>moose</u> #810 showing A) all seasonal GPS locations on 200-m contours, annual 100% MCP and annual 95% fixed kernels, B) summer locations with summer MCP and kernels, and C) random points (▲) used to quantify availability in the summer habitat use (●) and selection analyses.**
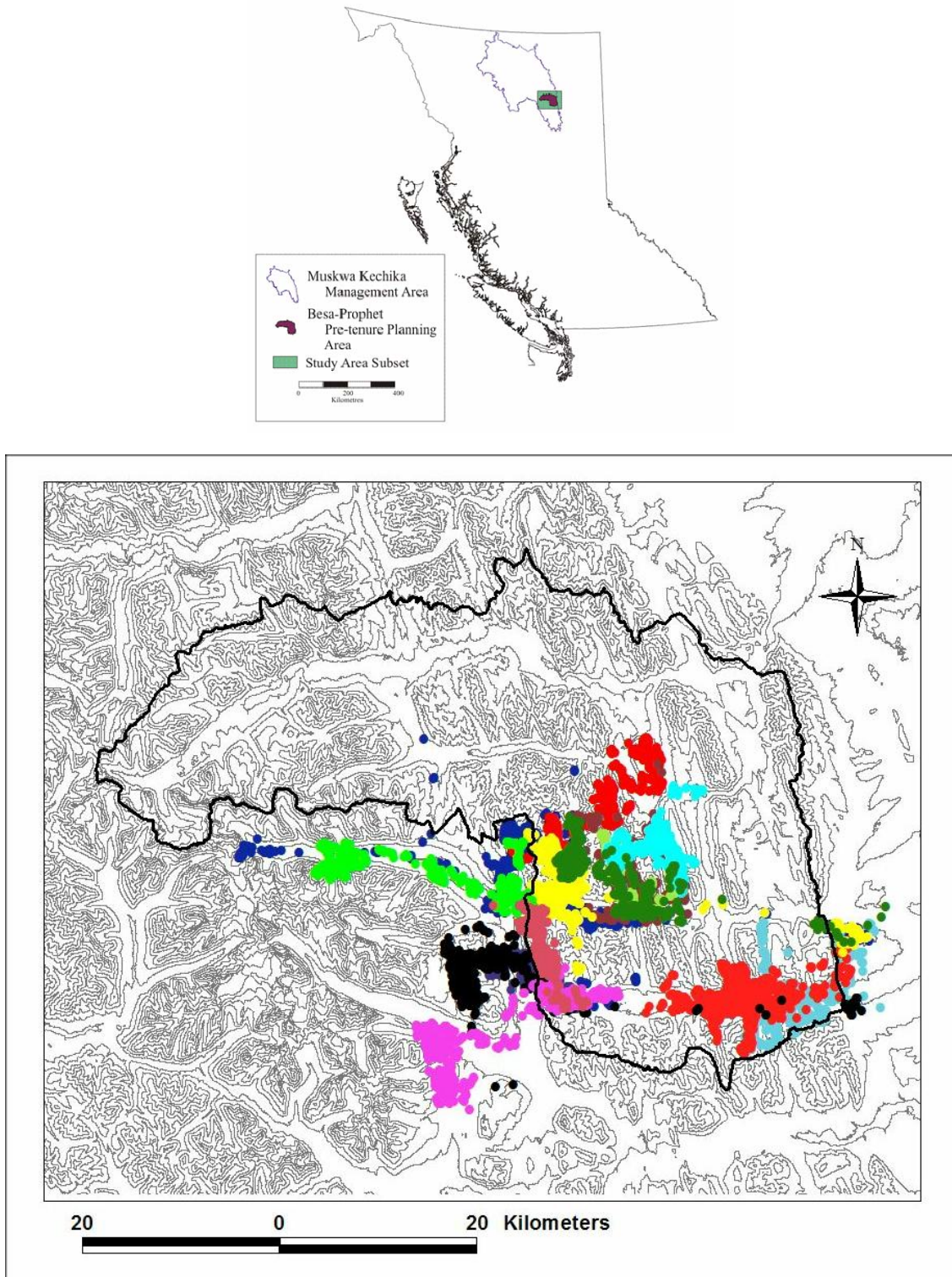
**Figure 6. Locations of GPS-collared female <u>moose</u> in relation to the the Besa-Prophet Pre-tenure Planning Area of the Muskwa-Kechika Management Area, northern British Columbia, March 2003 - March 2004. Each colour represents locations from a single individual relative to 200-m contours.**

**Table 2. Annual and seasonal range sizes (km$^2$) of 14 radio-collared female <u>moose</u> in the Besa-Prophet study area, as determined with 100% minimum convex polygons (MCP) and fixed kernel analysis (Kernel), March 2003 - March 2004. Seasons are defined in Table 1. *n* is number of GPS locations.**

| Moose # | Method | Annual km$^2$ | *n* | LateWinter km$^2$ | *n* | Calving km$^2$ | *n* | Summer km$^2$ | *n* | Fall km$^2$ | *n* | Winter km$^2$ | *n* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 598 | MCP | 207.6 | 979 | 18.0 | 225 | 7.8 | 86 | 111.6 | 119 | 51.5 | 171 | 11.8 | 378 |
|  | Kernel | 44.8 |  | 16.6 |  | 4.8 |  | 108.8 |  | 49.9 |  | 0.5 |  |
| 609 | MCP | 39.1 | 664 | 16.6 | 192 | 2.5 | 103 | 32.3 | 202 | 7.0 | 167 |  | 0 |
|  | Kernel | 17.1 |  | 8.0 |  | 1.6 |  | 13.1 |  | 4.7 |  |  |  |
| 650 | MCP | 141.5 | 1227 | 14.7 | 250 | 38.4 | 108 | 95.9 | 204 | 82.4 | 247 | 83.5 | 418 |
|  | Kernel | 73.0 |  | 12.6 |  | 43.2 |  | 11.1 |  | 59.6 |  | 74.2 |  |
| 658 | MCP | 899.4 | 1115 | 25.1 | 219 | 14.0 | 99 | 895.7 | 162 | 92.8 | 234 | 78.9 | 401 |
|  | Kernel | 113.7 |  | 6.3 |  | 10.5 |  | 772.4 |  | 22.4 |  | 33.3 |  |
| 698 | MCP | 84.2 | 1148 | 54.5 | 228 | 5.5 | 102 | 32.3 | 162 | 21.1 | 235 | 16.4 | 421 |
|  | Kernel | 73.5 |  | 83.2 |  | 3.5 |  | 15.2 |  | 11.0 |  | 8.8 |  |
| 708 | MCP | 152.4 | 892 | 42.3 | 177 | 37.3 | 64 | 70.4 | 140 | 23.4 | 177 | 54.3 | 334 |
|  | Kernel | 75.9 |  | 29.8 |  | 36.5 |  | 30.0 |  | 17.5 |  | 33.6 |  |
| 720 | MCP | 138.0 | 1267 | 36.8 | 267 | 46.7 | 100 | 66.5 | 195 | 49.5 | 261 | 42.4 | 444 |
|  | Kernel | 53.4 |  | 12.2 |  | 45.3 |  | 75.7 |  | 37.1 |  | 25.7 |  |
| 730 | MCP | 48.9 | 550 | 26.0 | 152 | 29.7 | 69 | 32.3 | 195 | 15.5 | 134 |  | 0 |
|  | Kernel | 34.7 |  | 20.9 |  | 27.7 |  | 19.2 |  | 2.6 |  |  |  |
| 744 | MCP | 374.6 | 1247 | 15.3 | 235 | 3.2 | 104 | 205.5 | 190 | 114.7 | 268 | 21.9 | 450 |
|  | Kernel | 40.8 |  | 10.0 |  | 3.3 |  | 126.4 |  | 43.1 |  | 7.0 |  |
| 769 | MCP | 148.0 | 860 | 46.2 | 190 | 6.7 | 86 | 89.9 | 91 | 14.4 | 83 | 75.8 | 410 |
|  | Kernel | 123.5 |  | 70.6 |  | 4.4 |  | 38.8 |  | 16.9 |  | 81.3 |  |
| 778 | MCP | 274.2 | 1192 | 23.9 | 241 | 5.3 | 86 | 128.5 | 176 | 127.6 | 252 | 22.6 | 437 |
|  | Kernel | 45.7 |  | 14.8 |  | 4.6 |  | 71.7 |  | 86.6 |  | 17.8 |  |
| 789 | MCP | 65.7 | 1108 | 30.0 | 211 | 29.6 | 101 | 11.7 | 160 | 12.5 | 225 | 20.9 | 411 |
|  | Kernel | 25.0 |  | 22.9 |  | 15.4 |  | 13.2 |  | 7.1 |  | 11.9 |  |
| 810 | MCP | 117.6 | 1262 | 68.7 | 312 | 9.3 | 102 | 58.0 | 194 | 27.2 | 266 | 111.4 | 388 |
|  | Kernel | 63.8 |  | 41.2 |  | 6.1 |  | 83.8 |  | 6.5 |  | 84.6 |  |
| 820 | MCP | 42.7 | 1023 | 8.7 | 170 | 10.3 | 71 | 28.6 | 154 | 16.3 | 226 | 11.0 | 402 |
|  | Kernel | 13.6 |  | 7.7 |  | 3.8 |  | 12.5 |  | 11.0 |  | 7.2 |  |
| Mean ± SE | MCP | 195.3 ± 59.7 |  | 30.5 ± 4.6 |  | 17.6 ± 4.1 |  | 132.8 ± 60.2 |  | 46.8 ± 11.0 |  | 45.9 ± 9.8 |  |
|  | Kernel | 57.0 ± 8.8 |  | 25.5 ± 6.4 |  | 15.1 ± 4.3 |  | 99.4 ± 52.8 |  | 26.9 ± 6.7 |  | 32.2 ± 8.9 |  |
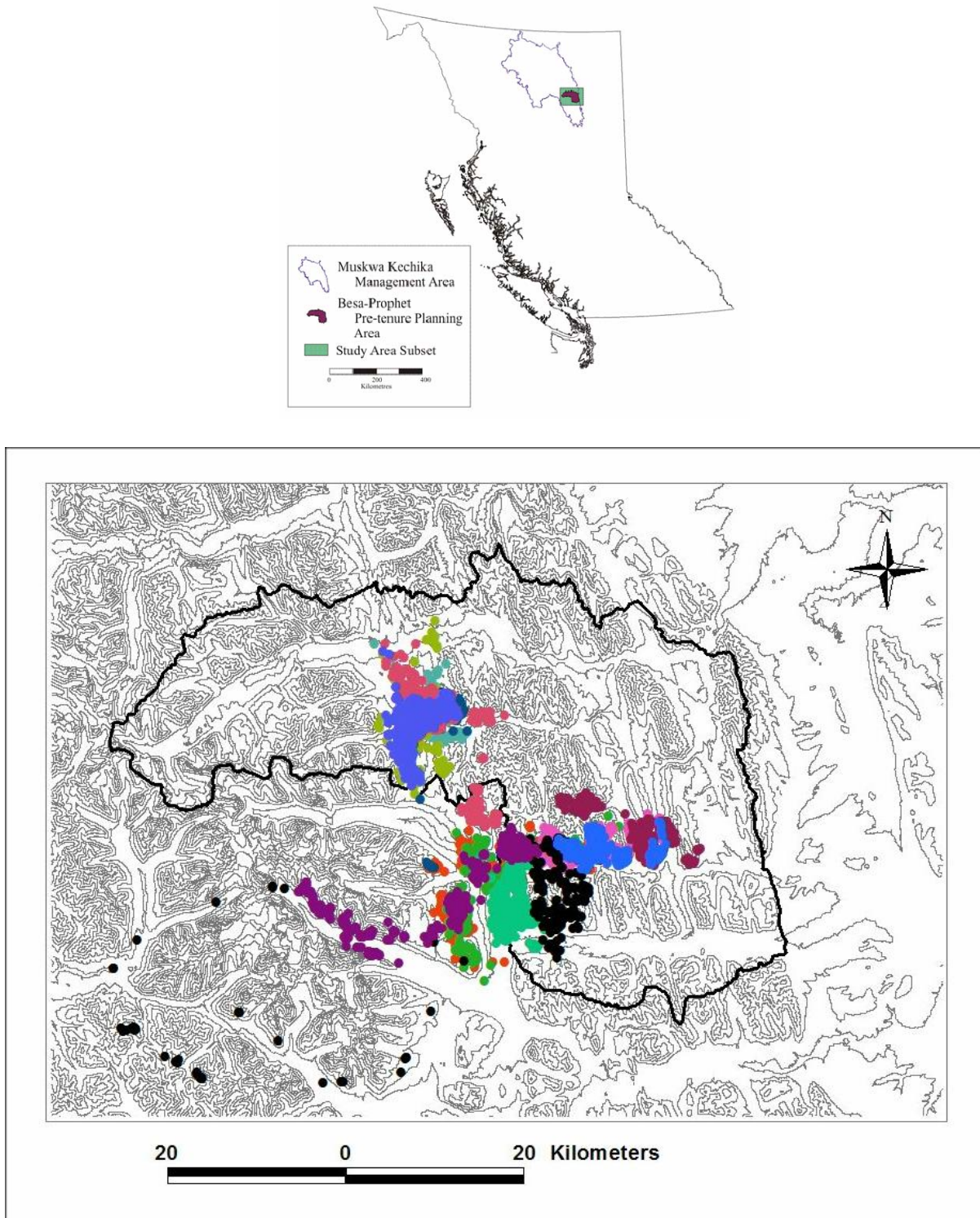
**Figure 7. Locations of GPS-collared female <u>elk</u> in relation to the the Besa-Prophet Pre-tenure Planning Area of the Muskwa-Kechika Management Area, northern British Columbia, January 2005 - January 2006. Each colour represents locations from a single individual relative to 200-m contours.**

**Table 3  Annual and seasonal range sizes (km$^2$) of 13 radio-collared female <u>elk</u> in the Besa-Prophet study area, as determined with 100% minimum convex polygons (MCP) and fixed kernel analysis (Kernel), January 2005 - January 2006.  Seasons are defined in Table 1.  _n_ is number of GPS locations.**

| Elk # | Method | Annual km$^2$ | _n_ | LateWinter km$^2$ | _n_ | Calving km$^2$ | _n_ | Summer km$^2$ | _n_ | Fall km$^2$ | _n_ | Winter km$^2$ | _n_ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 598 | MCP | 200.2 | 1140 | 33.0 | 267 | 46.0 | 86 | 76.2 | 189 | 102.7 | 221 | 26.6 | 377 |
|  | Kernel | 64.7 |  | 24.0 |  | 38.9 |  | 9.2 |  | 88.1 |  | 10.6 |  |
| 609 | MCP | 88.3 | 1041 | 3.0 | 240 | 42.0 | 84 | 33.4 | 180 | 40.8 | 181 | 24.4 | 356 |
|  | Kernel | 9.6 |  | 2.5 |  | 15.5 |  | 32.9 |  | 28.3 |  | 3.9 |  |
| 658 | MCP | 250.6 | 1142 | 12.6 | 261 | 44.4 | 95 | 55.6 | 209 | 98.8 | 216 | 39.8 | 361 |
|  | Kernel | 106.5 |  | 5.1 |  | 48.1 |  | 30.9 |  | 105.0 |  | 11.0 |  |
| 698 | MCP | 112.2 | 1179 | 63.0 | 274 | 24.9 | 100 | 29.2 | 208 | 64.6 | 202 | 16.6 | 395 |
|  | Kernel | 46.9 |  | 8.2 |  | 16.0 |  | 21.8 |  | 71.8 |  | 8.4 |  |
| 708 | MCP | 119.7 | 1301 | 6.0 | 287 | 37.3 | 104 | 36.0 | 232 | 64.3 | 261 | 14.2 | 417 |
|  | Kernel | 24.2 |  | 4.7 |  | 19.1 |  | 15.0 |  | 36.1 |  | 9.1 |  |
| 720 | MCP | 97.3 | 1148 | 6.1 | 258 | 22.7 | 93 | 82.7 | 194 | 40.9 | 219 | 17.8 | 384 |
|  | Kernel | 21.5 |  | 5.1 |  | 10.3 |  | 36.1 |  | 31.7 |  | 11.0 |  |
| 730 | MCP | 64.0 | 1117 | 16.0 | 246 | 44.4 | 83 | 37.8 | 205 | 31.1 | 205 | 27.5 | 378 |
|  | Kernel | 40.1 |  | 3.9 |  | 72.1 |  | 10.8 |  | 26.1 |  | 7.8 |  |
| 744 | MCP | 141.8 | 1198 | 8.6 | 259 | 38.7 | 86 | 59.5 | 208 | 70.1 | 223 | 19.3 | 422 |
|  | Kernel | 35.2 |  | 7.3 |  | 40.5 |  | 84.3 |  | 32.4 |  | 9.5 |  |
| 769 | MCP | 999.6 | 954 | 8.8 | 268 | 39.1 | 75 | 876.4 | 152 | 44.7 | 107 | 23.8 | 352 |
|  | Kernel | 88.5 |  | 5.1 |  | 33.8 |  | 393.5 |  | 34.9 |  | 6.5 |  |
| 778 | MCP | 65.8 | 1187 | 17.7 | 255 | 40.4 | 89 | 38.4 | 193 | 13.5 | 231 | 15.3 | 419 |
|  | Kernel | 26.1 |  | 2.8 |  | 54.5 |  | 14.2 |  | 8.0 |  | 4.5 |  |
| 789 | MCP | 50.5 | 1136 | 19.4 | 254 | 37.8 | 105 | 40.7 | 204 | 6.1 | 215 | 18.3 | 358 |
|  | Kernel | 27.5 |  | 6.3 |  | 23.5 |  | 13.5 |  | 5.3 |  | 18.9 |  |
| 810 | MCP | 214.7 | 1162 | 3.1 | 248 | 69.6 | 101 | 132.1 | 204 | 179.5 | 231 | 8.4 | 378 |
|  | Kernel | 76.9 |  | 0.4 |  | 63.6 |  | 70.3 |  | 174.1 |  | 2.8 |  |
| 820 | MCP | 75.8 | 1165 | 4.4 | 255 | 6.7 | 92 | 40.9 | 207 | 25.7 | 211 | 13.2 | 400 |
|  | Kernel | 25.6 |  | 3.1 |  | 7.3 |  | 18.4 |  | 21.5 |  | 10.6 |  |
| Mean ± SE | MCP | 190.8 ± 69.6 |  | 15.5 ± 4.6 |  | 38.0 ± 4.0 |  | 118.4 ± 63.7 |  | 60.2 ± 12.9 |  | 20.4 ± 2.2 |  |
|  | Kernel | 45.6 ± 8.2 |  | 6.0 ± 1.6 |  | 34.1 ± 5.8 |  | 57.8 ± 28.7 |  | 51.0 ± 13.2 |  | 8.8 ± 1.1 |  |

## Habitat Use and Selection

We used the GPS data from radio-collared individuals to describe the habitat associations for moose and elk on a seasonal basis in the Besa-Prophet area. We visually compared use to availability of different vegetation classes, but then determined resource selection for combinations of variables because habitat use occurs in response to multiple variables and not to vegetation class alone.

The vegetation classification system for the Besa-Prophet area was developed using remote-sensing imagery (Fig. 8) by Roberta Lay as part of her thesis at the University of Northern British Columbia (Lay 2005). Fifteen general vegetation associations were classified with a 2001 Landsat Enhanced Thematic Mapper image with 25-m resolution. For analyses on moose and elk, we amalgamated several of these associations, resulting in 10 vegetation classes, to ensure that we had sufficient samples sizes for our analyses. Classes were lumped according to similarity of vegetation and elevation, and associations relevant to moose and elk. The 10 classes were non-vegetated, *Elymus* burn, deciduous burn, subalpine, stunted spruce, pine spruce, riparian, alpine, low shrub, and *Carex* (Table 4). The 2 burn classes may also include other disturbed areas such as avalanche chutes, which could not be distinguished separately with remote-sensing imagery.

To determine use by animals, we pooled GPS locations by season in each year, and the data were then mapped on the remote-sensing data layers. To index available resources for each collared individual, we took all movement rates from the 6-hr GPS fixes and determined the 95th percentile rate with its corresponding distance travelled. Our reasoning was that 95% of the time, an animal typically moves within this movement potential. The movement potential, therefore, generally represents how far an animal could have moved and the movements shorter than the potential represent choices that the animal made. The remaining 5% of movements includes faster rates (longer distances travelled during the 6-hr GPS time frame) and much rarer events, and could be evoked by more non-typical conditions. We then assumed that for each location used by moose or elk, resources were accessible within the 95th percentile distance in any direction. Therefore, from a circle with this potential movement radius around each use point, we randomly selected 5 points as what was available to the animal (Gustine 2005), as shown in Figs. 4C and 5C. We believe this is a better representation of what was available to the animal around where it was located than selecting points from a very large MCP or a kernel based on density of use (Figs. 4, 5). To obtain overall use and availability across animals, we averaged the proportions of vegetation classes that were used by and available to each individual to reduce effects of uneven sample sizes among individuals.
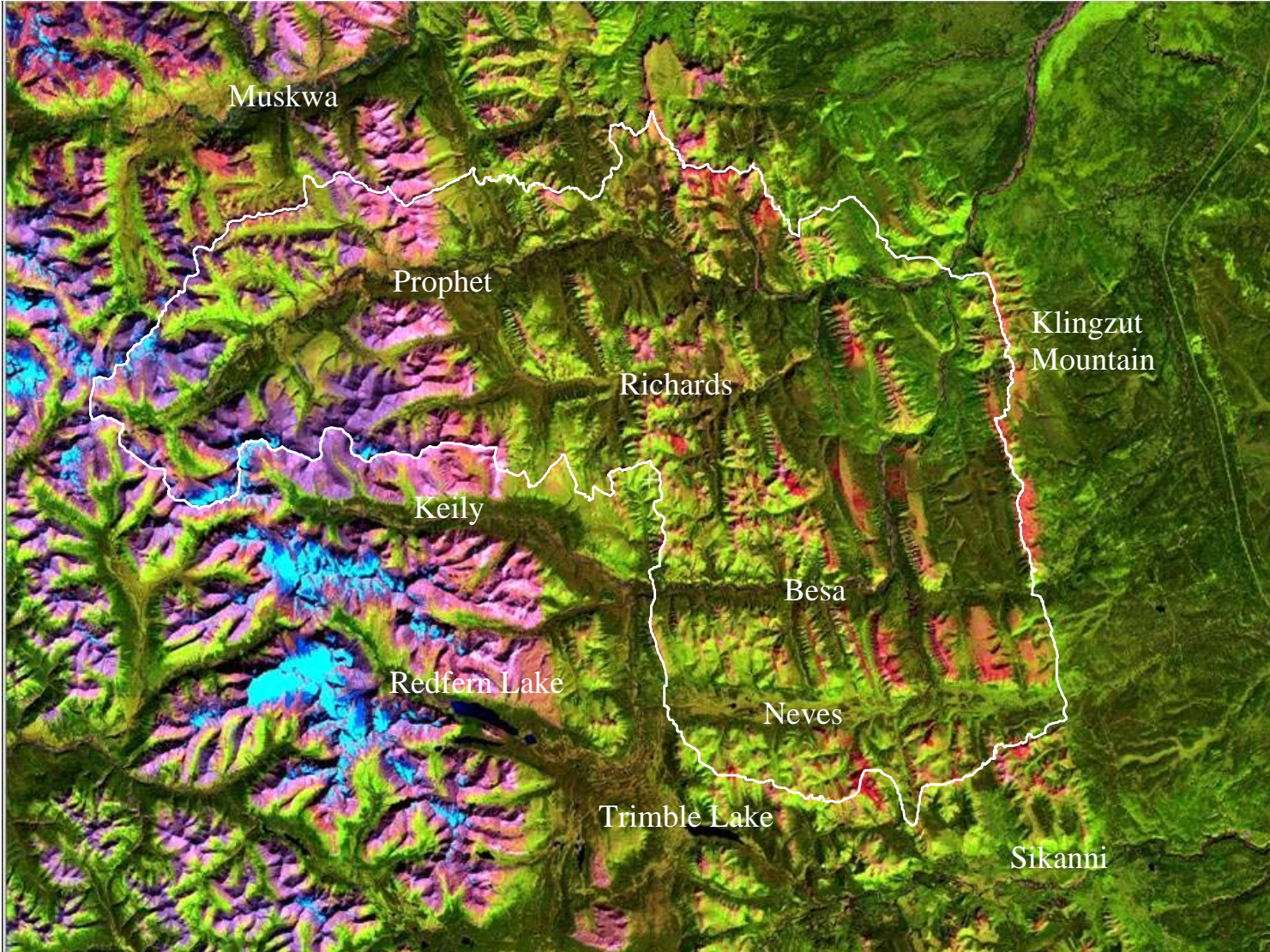
**Figure 8.** **Remote-sensing image of the Besa-Prophet study area including outline of the Besa-Prophet Pre-tenure Planning Area and notable drainages and landscape features.**

**Table 4.  Ten vegetation classes used in habitat analyses for moose and elk in the Besa-Prophet area, northern British Columbia.**

| Vegetation Class | Description |
| --- | --- |
| Non-vegetated | Rock; rock habitats with black, crustose lichens; permanent snow-fields or glaciers and water bodies. |
| *Elymus* burn | Recently burned and open disturbed sites dominated by *Elymus innovatus*; most often found on south facing slopes, except for avalanche slopes that may occur on steep slopes of other aspects; does not include tree cover. |
| Deciduous burn | Older burned and disturbed areas.  Contain *Populus tremuloides* and *Populus balsamifera* shrubs (<2 m) and trees (>2 m).  Can be associated with small stands of lodgepole pine (*Pinus contorta)*. |
| Subalpine | Deciduous shrubs ≥1600 m in elevation; spruce-shrub transition zone at middle to upper elevations with white and hybrid-spruce (*Picea glauca* and *P. glauca* x *engelmanni*), and dominated by birch (*Betula* spp.) and willow (*Salix* spp.). |
| Stunted spruce | Low productivity sites typically on north-facing slopes with *Picea glauca* of limited tree height, diameter and percent cover. |
| Pine spruce | White and hybrid spruce -dominated communities; lodgepole pine-dominated communities. |
| Riparian | Low elevation, wet areas with black (*Picea mariana*) and hybrid spruce; often with standing water in spring and summer; exposed gravel bars adjacent to rivers and creeks. |
| Alpine | Dry alpine tundra habitat >1600 m characterized by *Dryas* spp.; wet alpine tundra habitat >1600 m dominated by *Cassiope* spp. and sedge (*Carex* spp.) meadows. |
| Low shrub | Deciduous shrubs <1600 m dominated by birch and willow, some cinquefoil (*Potentilla fruiticosa*). |
| *Carex* | Wetland meadows dominated by sedges (*Carex* spp.) at elevations <1600 m, with intermittent *Salix* shrubs. |

Vegetation Classes Used by Moose:  We used 14,534 GPS locations to assess habitat use by 14 collared female moose.  From March to mid August (late winter, calving, and summer), most locations (28-36%) were in the pine-spruce vegetation class (Fig. 9).  This contrasts to the fall and winter period, when most locations were in subalpine vegetation (33-39%).  Although moose are stereotypically associated with riparian areas, there was relatively little use of this vegetation class (distinct from lowland shrub and *Carex*) in the Besa-Prophet (<6% of locations in each season).  Low shrub vegetation was used least (10%) by moose during the calving season, and most during winter (22%).  Use of the deciduous burn class was relatively consistent at 13-16% throughout the year.  As expected, moose avoided non-vegetated and alpine areas.

Vegetation Classes Used by Elk:  From 14,870 GPS locations from 13 GPS-collared female elk, the use of 3 vegetation classes was prominent: *Elymus* burn, deciduous burn, and subalpine (Fig. 10).  The 3 classes always totaled between 59 and 83% of use locations.  Highest use by elk occurred in the subalpine in all seasons except late winter, when they increased use of both burned habitats (~70% of locations).  In contrast, during summer when elk used the subalpine more than any other season (averaging 64% of locations), they spent less time in *Elymus* and deciduous burn vegetation classes.  Compared to moose, elk avoided the pine-spruce vegetation class during all seasons.  Highest potential for overlap between moose and elk may be during fall and winter, when both species used the subalpine more than other vegetation classes.

Elevations Used by Moose and Elk:  Given the general differences in the vegetation classes used by moose and elk (Figs. 9 and 10), we compared elevations used by the 2 species.  From early winter in November and December, until early May, both species moved down in elevation (Fig. 11).  Calving strategies, however, were very different between the species.  In June, moose were at lowest elevations ($1338 \pm 21$ m, mean $\pm$ SE) of the year, and after the calving season moved gradually upslope during summer and fall.  In June, elk returned to higher elevations ($1664 \pm 13$ m) and remained there in July; they then moved down to lowest elevations in September ($1427 \pm 21$ m) before moving back upslope in fall (Fig. 11).

Elk and moose used elevation differently among seasons (repeated-measures ANOVA, $P < 0.001$).  During calving and summer (May through August) and winter (November – February), elk used higher elevations than moose (elk = $1551 \pm 49$ m in calving, $1671 \pm 40$ m in summer, $1624 \pm 51$ m in winter; moose = $1333 \pm 81$ m in calving, $1397 \pm 53$ in summer, $1519 \pm 88$ in winter) (Bonferonni confidence intervals).  During calving and summer, the high elevations used by elk corresponded with the high use of subalpine.  From November - January, both elk and moose had most locations in the subalpine vegetation class, but it appears there may be elevational separation between the 2 species.  However, animal sample sizes were very small in this study and these elevational differences may simply be responses to different environmental influences in different years.
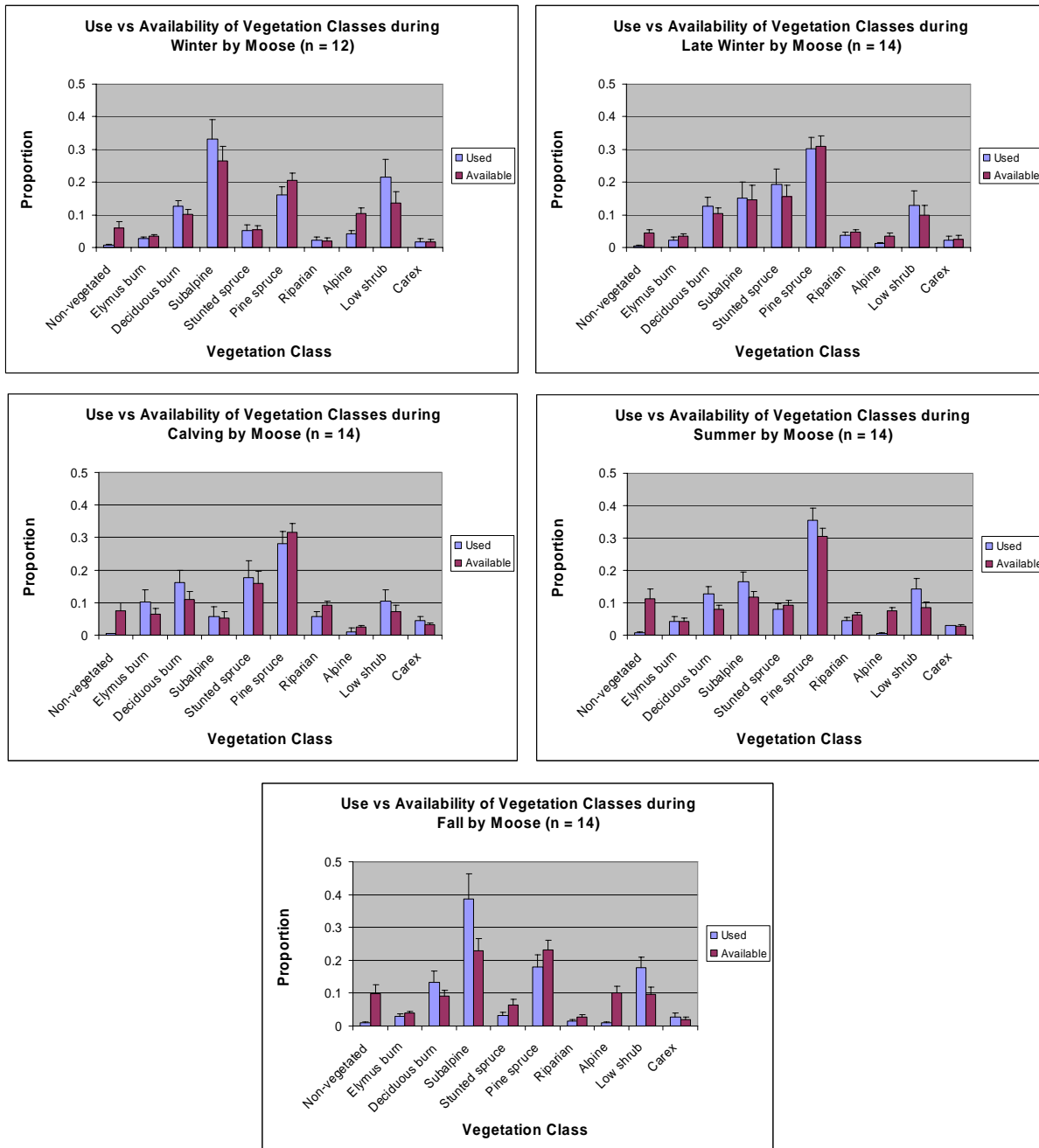
**Figure 9. Proportional use versus availability (+ SE) of vegetation classes for female <u>moose</u> in the Besa-Prophet area of northern British Columbia. Standard errors were determined from averages for each individual by season as defined in Table 1.**
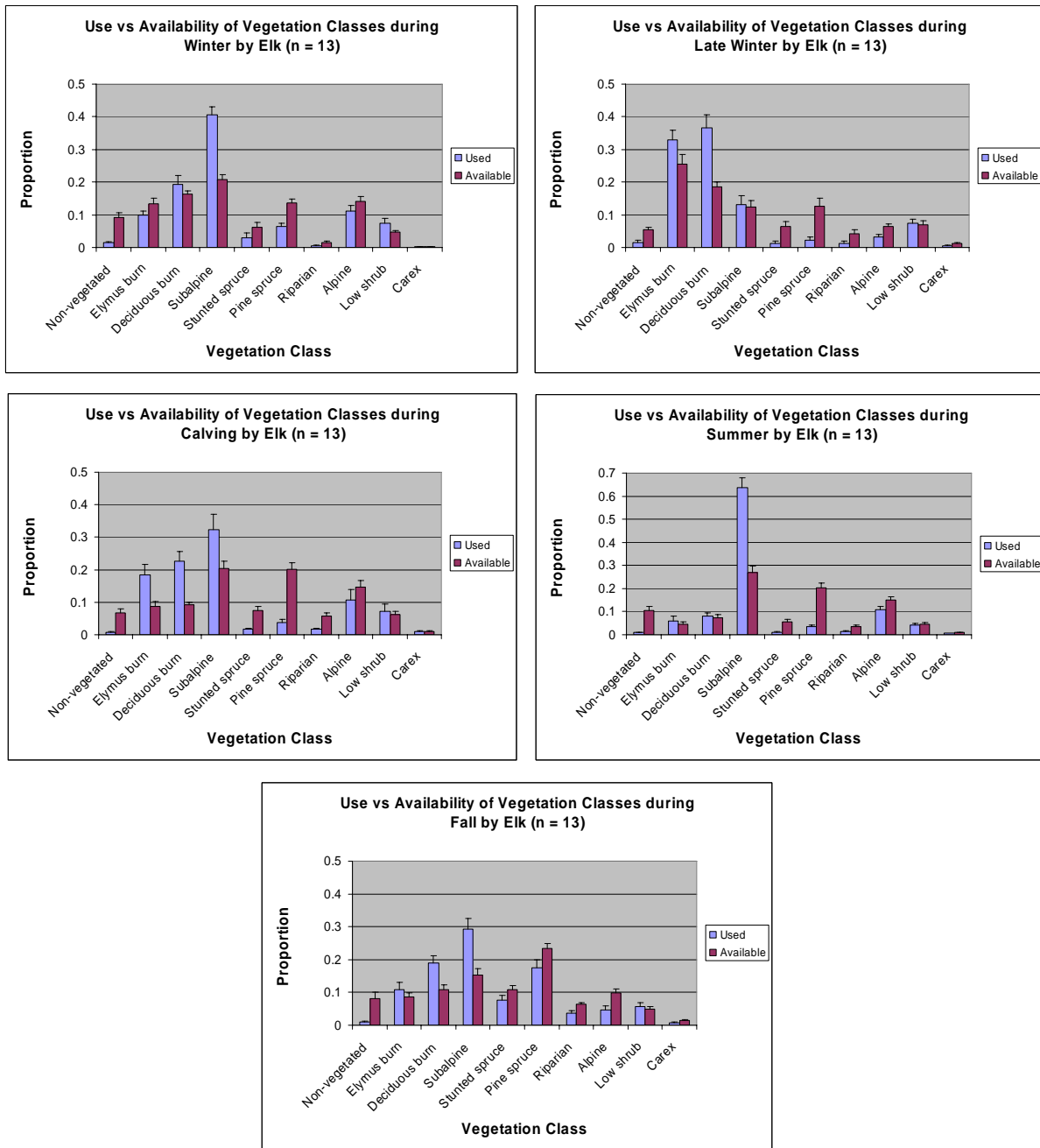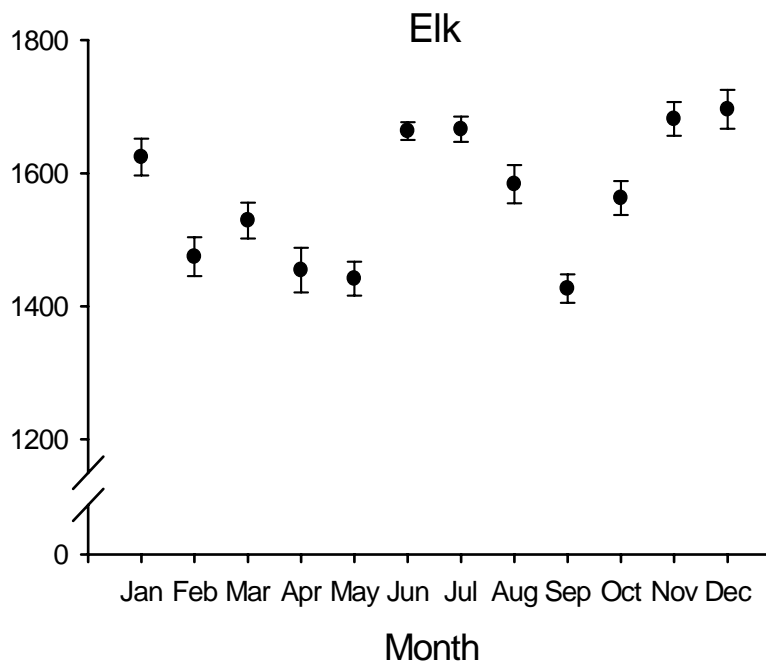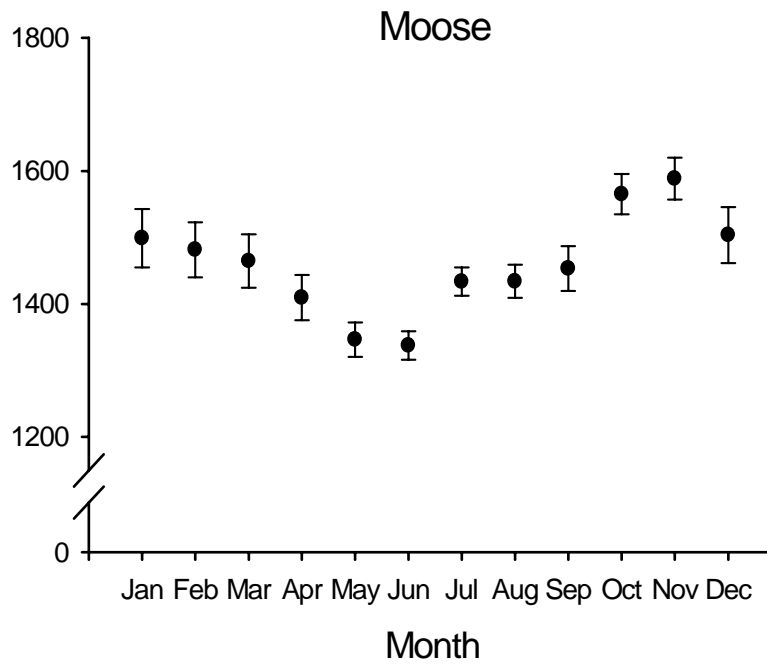
**Figure 10. Proportional use versus availability (+ SE) of vegetation classes for female elk in the Besa-Prophet area of northern British Columbia. Standard errors were determined from averages for each individual by season as defined in Table 1.**

**Figure 11.  Elevations (mean ± SE) used by GPS-collared female <u>moose</u> ($n$ = 14) and <u>elk</u> ($n$ = 13), averaged by individual and then averaged across individuals, by month in the Besa-Prophet area, northern British Columbia.**

Resource Section Models

For both moose and elk, resource selection functions (RSFs) help determine which particular attributes of habitat are selected for on a seasonal basis. The RSF models provide a broad-scale perspective of general selection patterns on the landscape (Boyce and McDonald 1999; Manly et al. 2002). They also accommodate any type of habitat variables (categorical and continuous) and easily incorporate spatial data acquired from Geographical Information Systems (GIS) or remote sensing (Boyce and McDonald 1999). We developed a suite of ecologically plausible models, chose the best model (Akaike's Information Criterion; Burnham and Anderson 2002), and evaluated the relative importance of each of the variables in the models (using selection coefficients). We also confirmed that models had validity by using k-fold cross validation procedures that assess predictability of each model using subsamples of the data (Spearman's rank correlation $r_s$, Boyce et al. 2002).

Our resource selection models typically included vegetation class (Table 4), elevation, slope, aspect, fragmentation, indices of forage biomass and quality, and an index of predation risk. We modelled aspect as 2 continuous variables (i.e., northness and eastness; Roberts 1986) to avoid introducing additional categorical variables. Northness values of 1.00 and -1.00 suggest selection for north and south aspects, respectively, whereas values near 0.00 suggest selection for east and west aspects. Eastness values show selection for east (i.e., 1.00) and west (i.e., -1.00) aspects; values of 0.00 show selection for northern/southern exposures (Palmer 1993). Fragmentation was an index assigned to each pixel based on the number of different vegetation class polygons in broad open and closed cover types (Gustine 2005) in a 7 x 7-pixel window; values were grouped into high, medium and low fragmentation classes, and used as an index of habitat diversity. During the spring and summer months, we extracted NDVI (Normalized Difference Vegetation Index) values, which are related to leaf area and plant biomass (Tucker and Sellers 1986, Ruimy et al. 1994). For all vegetation classes defined by Lay (2005) from remote-sensing imagery, plant biomass increased from June to July and August, and then declined in September (Fig. 12). Shrubs, burned and disturbed areas, and subalpine vegetation were highest in plant biomass; gravel bars were lowest. We mapped this index of relative biomass across the entire study area (e.g., the darkest green areas along south-facing slopes had the greatest biomass in July, whereas the lowest biomass (reddest areas) was on rocky areas and glaciers in Fig. 12). We also determined the rate of change in green-ness for each vegetation class from the change in NDVI between months (Fig. 13). Highest rates of change were between June and July for shrubs, burned and disturbed areas, and subalpine areas, and much less change occurred on gravel bars and riparian areas. Change was relatively stable from July to August, and was negative from August to September as plants declined in green-ness. We used this information as an index of forage quality (highest rates of green-up are likely the most digestible, best quality forage; Griffith et al. 2002, Oindo 2002), and mapped quality across the study area (e.g., the darkest green areas had the highest relative quality between June and July in Fig. 13).

To define predation risk to moose and elk, we used resource selection functions (RSFs) with logistic regression models by season within year for data from GPS-collared wolves and grizzly bears in the Besa-Prophet area. Grizzly bears and wolves are assumed to be the most significant large mammal predators in the Muskwa-Kechika Management Area (Bergerud and Elliott 1998). These data are the foundation for Brian Milakovic's PhD dissertation at the University of Northern British Columbia. The predation-risk models included slope, aspect, elevation, vegetation type, fragmentation, and distance to linear features (e.g., seismic lines).
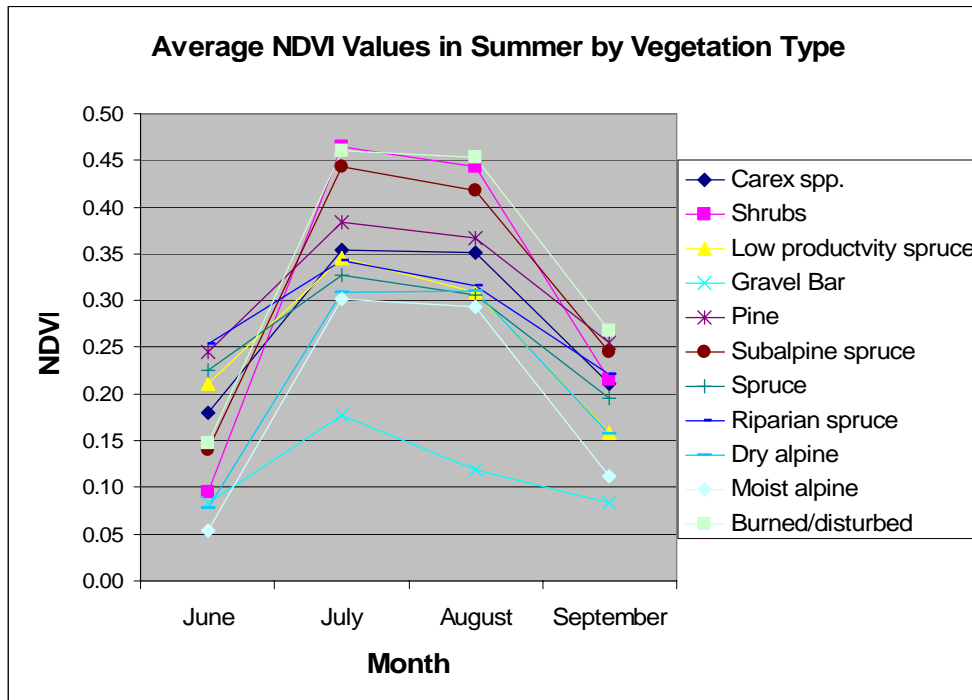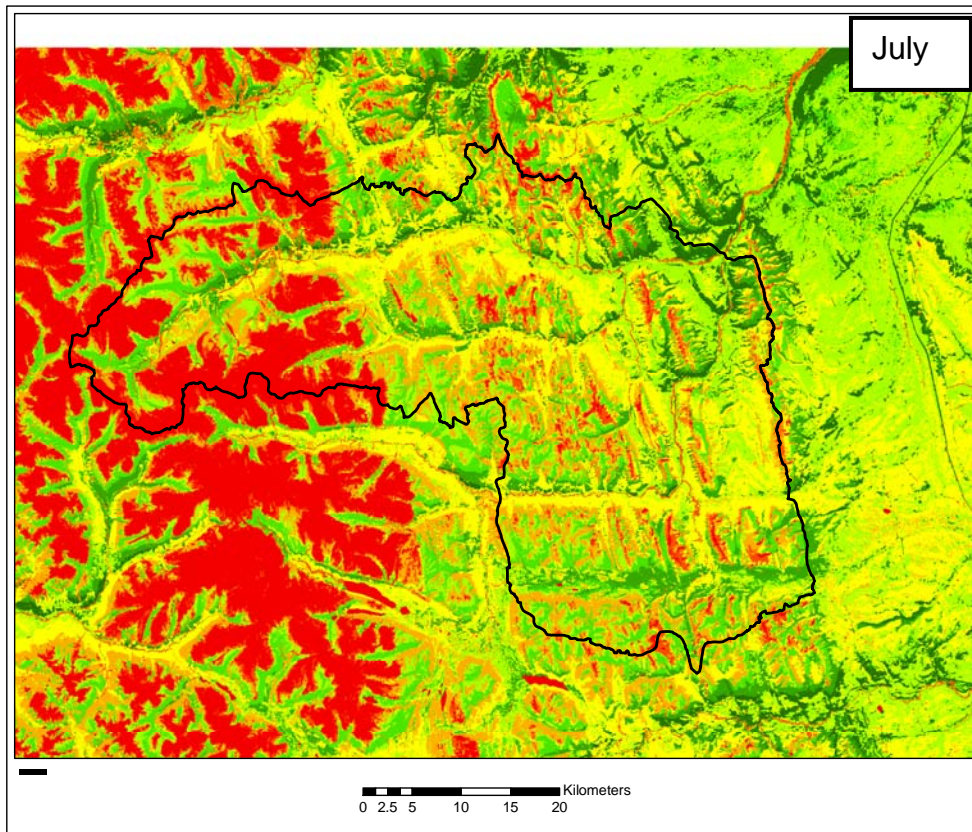
**Figure 12. Relative forage biomass, as indexed by NDVI, across the Besa-Prophet study area in July, and for comparison among vegetation classes from June through September.**
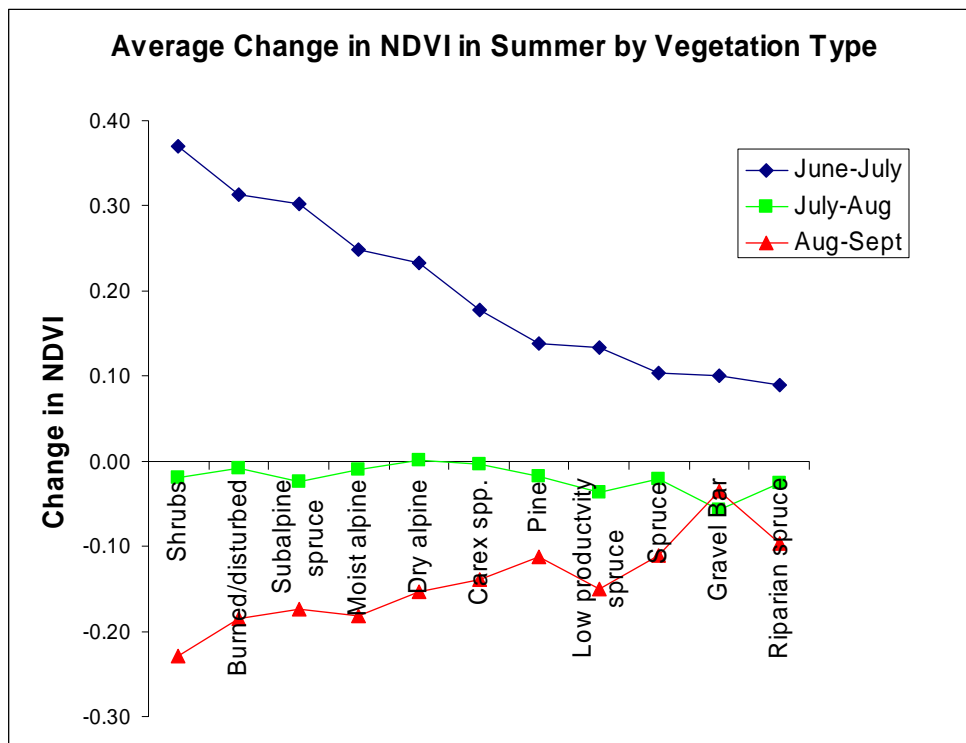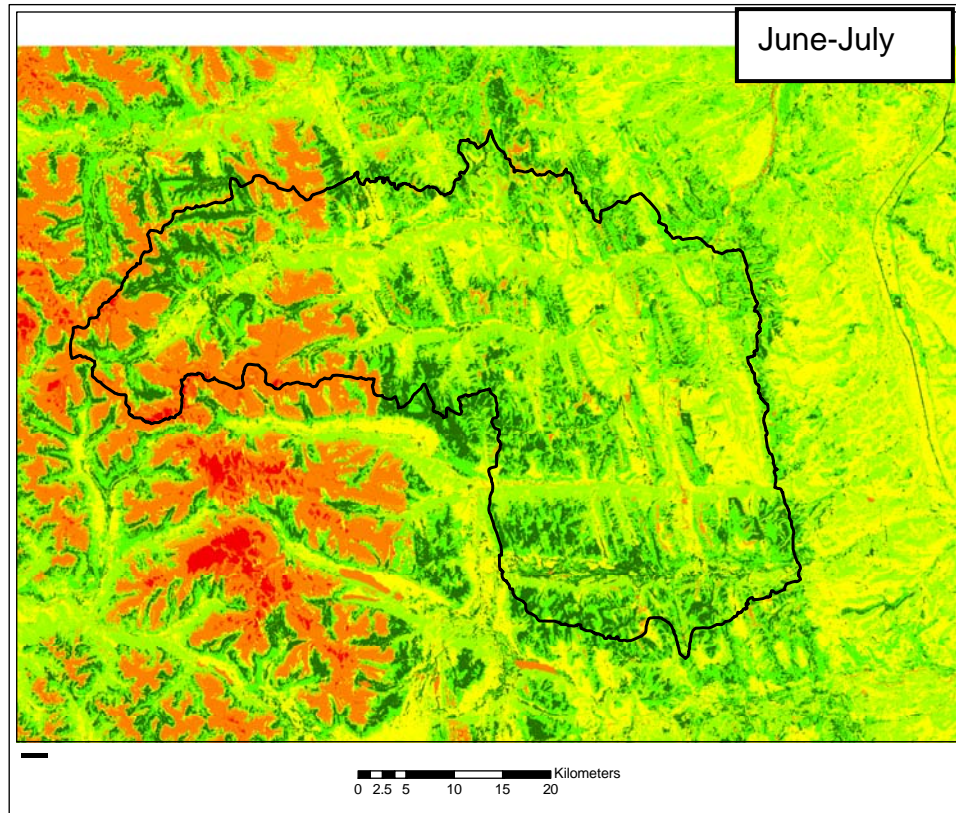
**Figure 13. Relative forage quality, as indexed by change in NDVI, across the Besa-Prophet study area in June-July, and for comparison among vegetation classes from June to September.**

For each use location, we selected 5 random locations from individual bear and wolf pack ranges, as defined by a 100% minimum convex polygon, to determine what predators were selecting.  We assumed that the predators could access any area of their range within the 6-hr sampling interval of the GPS collars, and therefore all areas were 'available' for selection by the animal.  In areas where data for wolf packs or bears were not available, we used a global model incorporating data from all bears or wolves to rank risk in those few parts of the landscape.  We incorporated models for all packs and bears per season and year in a GIS.

Resource selection function values from the predator-risk models are relative values that rank habitats based on a variety of topographical and vegetation features.  Because RSF values are relative to each data set (e.g., pack, season, and year) and species (i.e., grizzly bear and wolf), we normalized or standardized the values to define risk across packs and species within each season.  We then generated a risk surface to define which areas have the highest selection values for bears or wolves in each season.  Where pack boundaries of wolves overlapped, we assigned the lowest risk value to each GIS pixel because there generally tends to be less pack vigilance along boundary areas (Mech 1994).  We assumed that the risk of predation to moose and elk from wolves and grizzly bears was directly related to selection values from the RSF of those species.  Figure 14 is an example of grizzly bear risk in spring (e.g., the red areas across the study area had the highest bear risk).
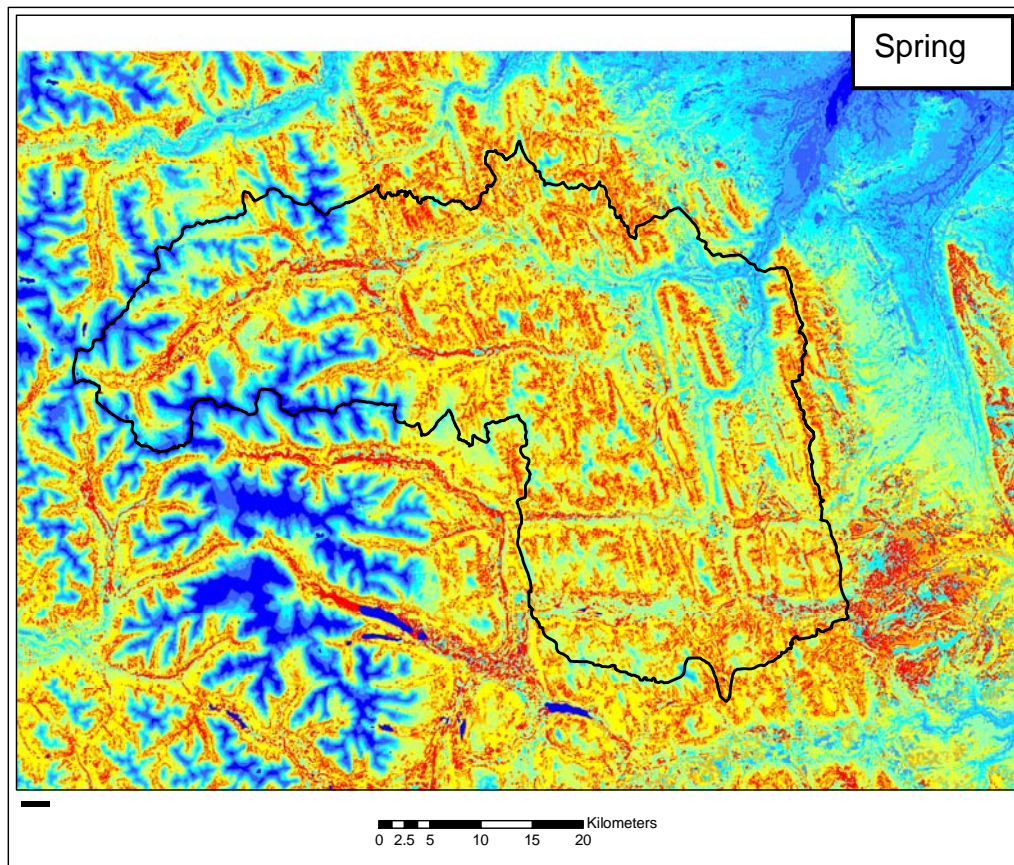


**Figure 14.  Relative predation risk from grizzly bears in spring across the Besa-Prophet study area.**

Resource Selection by Moose

Using the data from all collared individuals, the best resource selection model in each season for moose always included elevation, slope, aspect, and vegetation class. We averaged the top 2 models in each of the late winter, calving, and fall seasons, and 3 models in winter and summer to ensure that 95% of the weight of evidence for explaining selection by moose was captured by the final pooled model for each season (Akaike weight $w_i \geq 0.95$, Burnham and Anderson 2002). All models validated well ($r_s \geq 0.98$ in summer and fall, $r_s \geq 0.86$ in winter and calving, $r_s \geq 0.74$ in late winter). Moose always selected for mid elevations. They selected against steep slopes in all seasons but summer. From a forage perspective, moose selected for high forage quality during calving and summer, and against high forage biomass in summer and fall. As for predation risk, they appeared to select against high bear risk during calving, but their locations during summer were in areas of relatively high wolf risk.

Selection by moose was consistent across seasons for several vegetation classes (Table 4). Moose always selected against non-vegetated and alpine areas, and always for deciduous burns and *Carex* sedge areas. They selected for stunted spruce sites in late winter, calving, and summer, and then for the subalpine in summer, fall, and winter (Fig. 15). Low shrub vegetation was favoured from fall through winter. The only season when moose selected for riparian was in winter (Fig. 16). The selection of different vegetation classes generally corresponded with the highest use of vegetation classes presented in Figure 9, but the selection models also include the contributions of other variables. Relative importance of the vegetation classes selected by season given what was on the landscape is shown in Fig. 16.



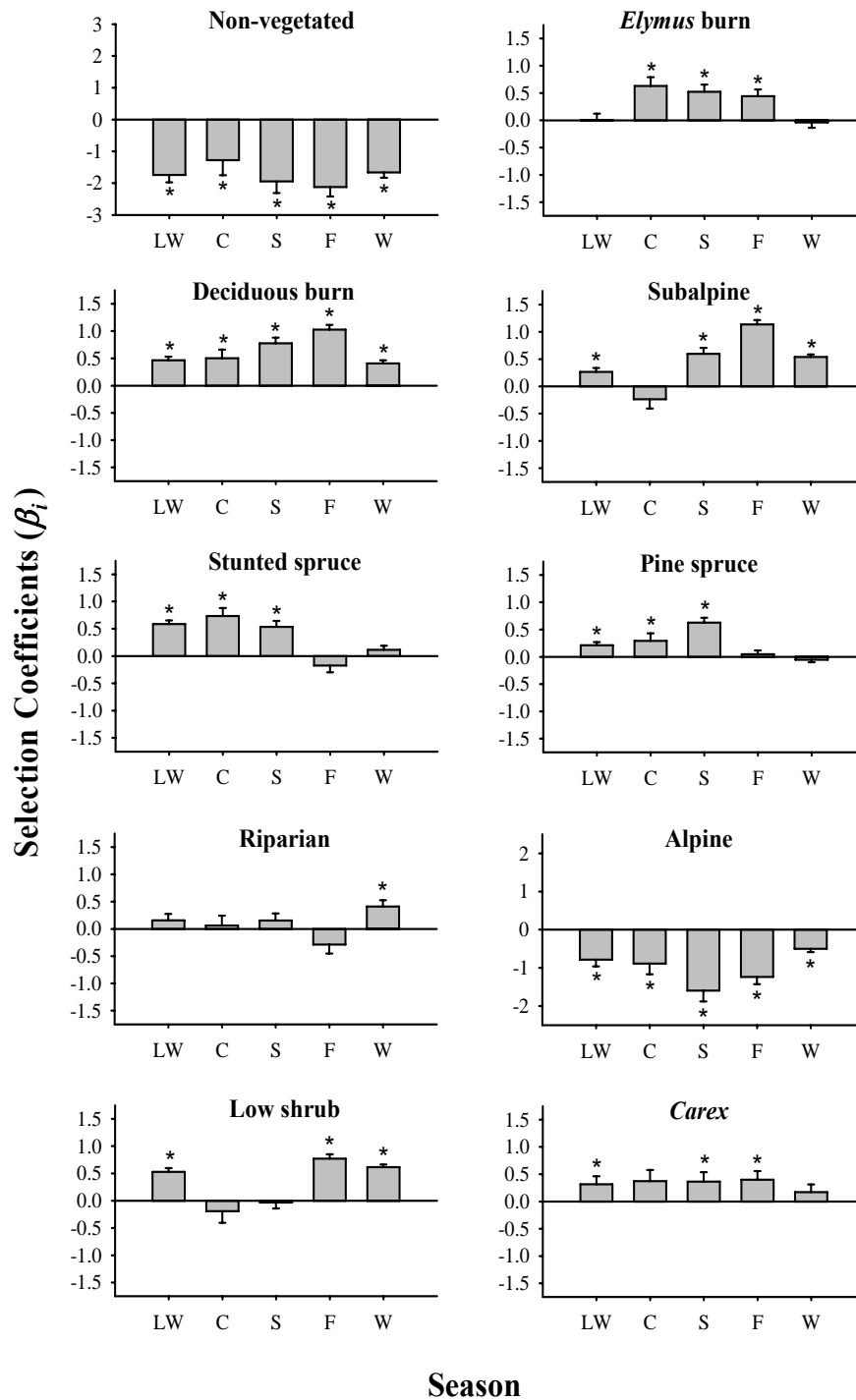**Fig. 15. Use of subalpine areas by moose in the Besa-Prophet study area, late June 2002.**

**Figure 16.** Relative habitat selection values ($\beta_i \pm$ SE) for <u>moose</u> in the Besa-Prophet study area based on resource selection models. Coefficients >0 show selection and <0 show avoidance. * indicates significant seasonal coefficients. LW = late winter, C = calving, S = summer, F = fall, W = winter (as defined in Table 1).

We also developed models for each individual moose, which showed seasonal variation in individual selection patterns for vegetation classes as well as differences among individuals. Most consistent was the selection for the subalpine in fall and winter. Given only one year of data and therefore relatively small sizes, we can not really quantify different strategies among individuals. Qualitatively, however, we believe that there are likely to be different strategies given different movement patterns by the animals. Six of the 14 collared moose had overlapping or contiguous seasonal ranges without long movements. Other animals exhibited noticeable directional movements away from previous areas of concentration a) in calving or early summer ($n = 3$), b) in late summer or fall ($n = 2$), c) in winter or late winter ($n = 2$), or d) during all seasons except calving ($n = 1$). Additional studies are needed to determine if there are indeed multiple seasonal strategies used by moose.

Resource Selection by Elk

We determined the best global models to describe the resources selected across all individual elk after averaging models during calving (n = 4) and fall (n = 3). One model was sufficient to explain selection (Akaike weight $w_i \geq 0.95$) by elk in each of the summer, winter, and late winter seasons. Models in all seasons validated well (all $r_s > 0.93$). Each of the best final seasonal models included aspect and vegetation class. Slope was important to elk in all seasons except calving. Elk selected against steep slopes in summer, winter, and fall, but for steep slopes in late winter. The use of slopes by elk and their position on slopes is known to vary by season (Skovlin et al. 2002). Elevation was only incorporated into 3 models (not winter or calving). Elk selected for low and high elevations in late winter and summer, and for mid elevations in fall. Relative to significant forage parameters, elk selected areas that were far from highest quality vegetation in summer, and relatively low in vegetation biomass during calving and fall. As for predation risk, they appeared to select against high wolf risk during winter, but their locations were close to areas of high wolf risk in late winter and calving and close to high bear risk in summer.

Selection of vegetation classes by elk showed considerable seasonable variation (Fig. 17), but summer tended to be distinctly different than the other seasons. Summer was the only season in which elk selected for stunted spruce, pine spruce, and riparian, and the only season in which elk selected against deciduous and *Elymus* burns, low shrubs, and the subalpine (Fig. 17). As with moose, elk tended to avoid non-vegetated and alpine areas throughout the year. Other than during summer, elk selected most consistently for the 2 burn habitats (Fig. 18) and the subalpine during the rest of the year, although *Carex* communities were also important from late winter though summer.

Given the prominent selection for (Fig. 17) and use of (Fig. 10) burned areas, we mapped the locations of the GPS collared elk relative to prescribed burn blocks. The mapped burn polygons do not accurately represent actual burned area on the ground, but rather outlines that are determined for protection purposes. In other words, these include the area within which prescribed burns must remain to avoid having to take subsequent management actions to contain fires. In the Besa-Prophet, often less than 50% of a polygon is actually burned (Rob Woods, Ministry of Environment, Fort St John, personal communication). This allows for the maintenance of forested benches and draws next to burned areas (Fig. 19). Collared elk in our study were recorded in 9 prescribed burn blocks (Fig. 20).
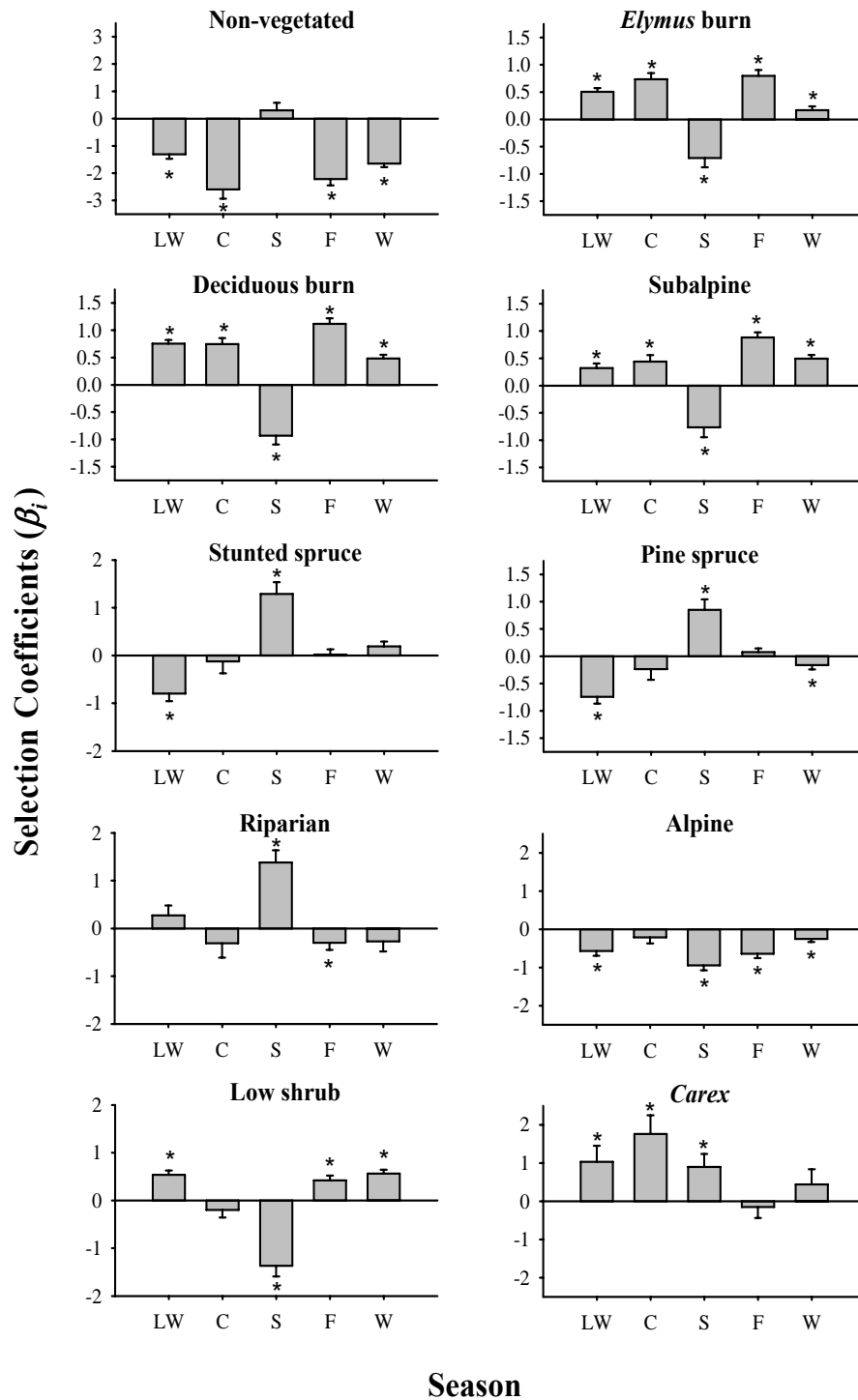
**Figure 17.** Relative habitat selection values ($\beta_i \pm$ SE) for <u>elk</u> in the Besa-Prophet study area based on resource selection models. Coefficients >0 show selection and <0 show avoidance. * indicates significant seasonal coefficients. LW = late winter, C = calving, S = summer, F = fall, W = winter (as defined in Table 1).

**Figure 18.  Use of burned vegetation classes by elk in the Besa-Prophet study area, May 2002.**



**Figure 19.  Typical prescribed burn on south-facing slopes bordering Richards Creek in the Besa-Prophet study area, August 2003.**
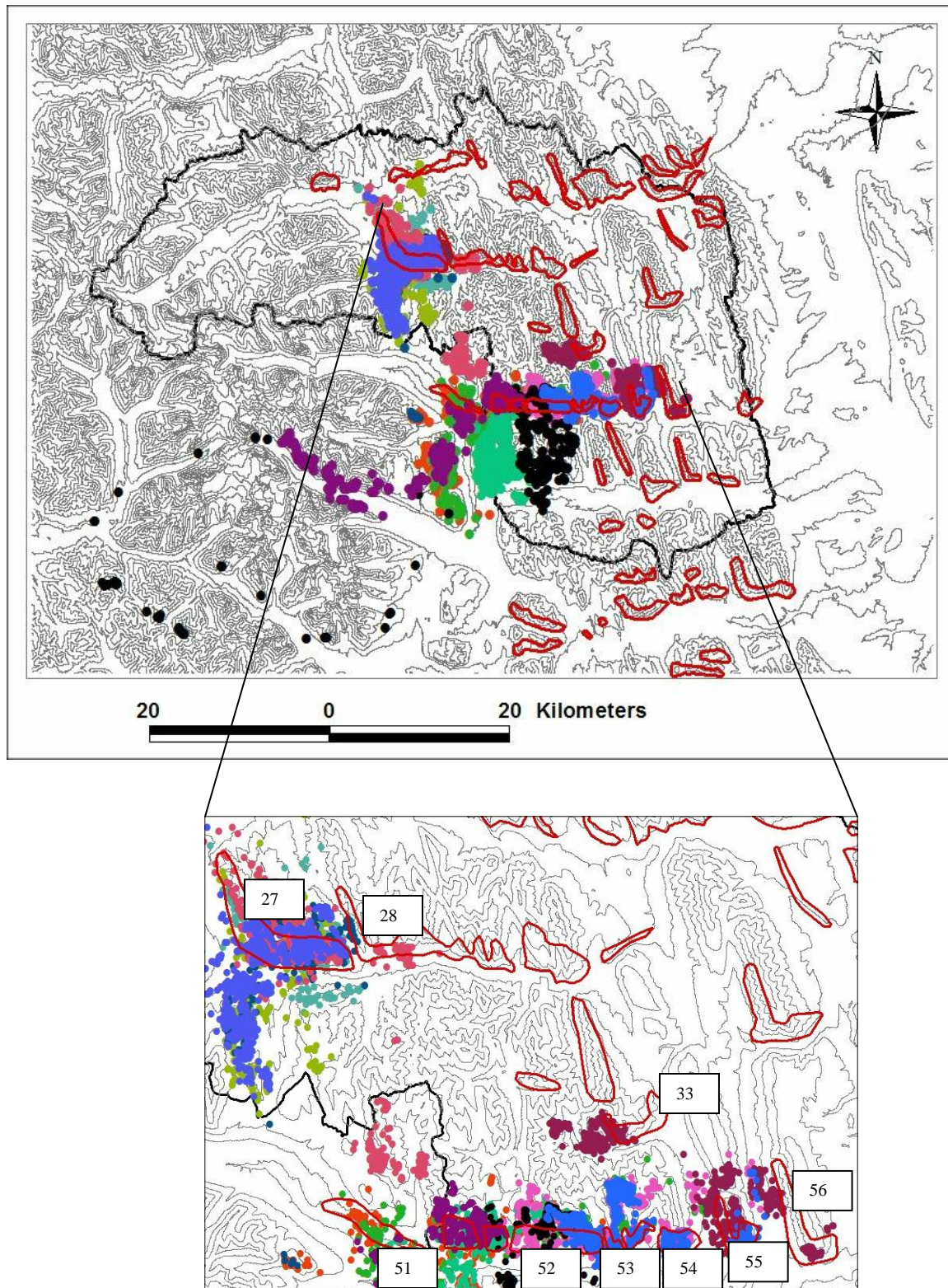
**Figure 20. Locations of GPS-collared female elk (Jan 2005 – Jan 2006) in relation to the Besa-Prophet Pre-tenure Planning Area (outlined in black) and prescribed burn blocks (outlined in red). Numbers are burn block labels.**

The sizes of prescribed burn blocks used by the collared elk ranged from approximately 300 to 1000 ha (Table 5).  Most of the 6,241 locations of elk occurred in blocks that had been treated most frequently, although this is confounded for some blocks by block size, the amount of area burned within the block, and undoubtedly the numbers of animals collared in a particular area.  Future studies should define which attributes of burned areas (e.g., treatment frequency, size of burn, location of burn) are most related to habitat selection by elk.

In our definition of vegetation classes (Table 4) and analyses of use (Fig. 10) and selection (Fig. 17) of the 2 burned vegetation classes by elk, we were unable to conclude that the 2 classes did not include some other disturbed vegetation (i.e., avalanche chutes).  Therefore, we are unable to determine precisely how much of the prescribed burn blocks were actually burned.  For all the elk locations within prescribed burn blocks, however, we determined what vegetation classes, as defined by satellite imagery (Table 4), were associated with the use locations.  Based on those elk locations, all vegetation classes were found in the prescribed burn polygons.  The majority of elk locations in the burn blocks were in the *Elymus* burn and deciduous burn vegetation classes, ranging from a high of 80% during late winter and calving, and between 55 and 69% for all other seasons.

**Table 5.  Description of prescribed burn blocks used by GPS-collared <u>elk</u> in the Besa-Prophet area, Jan 2005 – Jan 2006.**

| Block Label | Block size (ha) | Biogeoclimatic Zone | Years treated | Number of elk GPS locations |
|---|---|---|---|---|
| 27 | 1571 | SWB* | 1981, 1985, 1987, 1991, 2002 | 3422 |
| 28 | 1007 | SWB | 1981, 1985, 2005 | 56 |
| 33 | 374 | SWB | 1987 | 18 |
| 51 | 994 | SWB | 1984,1985,1987, 1991, 1995 | 819 |
| 52 | 623 | SWB | 1984,1985,1987, 1991, 1995 | 737 |
| 53 | 196 | SWB | 1984, 1989, 1991, 1995 | 156 |
| 54 | 289 | SWB | 1984,1985,1987, 1991, 1995 | 467 |
| 55 | 354 | SWB | 1987, 1989, 1991 | 544 |
| 56 | 698 | SWB | 1987, 1989, 1995, 2003 | 22 |
| Total | $n = 6,106$ | | | $n = 6,241$ |

* Spruce-willow-birch

## Habitat Use in Relation to Pre-tenure Plans

We compared the GPS use locations of the radio-collared moose and elk in this study with the habitat suitability index (HSI) models developed by Ministry of Environment staff (Rod Backmeyer, Fort St John) for moose and elk during winter. The HSI models were based primarily on literature review and local accounts of high-use areas, and were developed to help rank the Besa-Prophet landscape using classes from 1 (high value) to 6 (low value) during pre-tenure planning processes. The Besa-Prophet Pre-tenure Plan incorporates a roll-up map from the HSI modeling efforts to be used across species. It categorizes habitats into zones, as defined by physical and topographical features (Table 6). We present our findings relative to both the Plan and suitability (HSI) models.

**Table 6. Biophysical zones with wildlife value and management requirements in the pre-tenure planning areas of the Muskwa-Kechika Management Area (British Columbia Ministry of Sustainable Resource Management 2004). Not all biophysical zones are found in each plan area.**

| Code | Pre-tenure Biophysical Zone | Description |
|---|---|---|
| LEW | Wetlands – Low Elevation | Concentrated in valley bottoms and lowland areas. Consists of seasonal and year-round moisture saturated soils; watercourses and coniferous/deciduous forest patches can be dispersed throughout the wetland. Contains summer and critical winter habitat for moose, critical caribou habitat and high fisheries values. Various other wildlife species such as raptors, birds, rodents, furbearers, amphibians and reptiles inhabit this zone. High fisheries values are also found within this zone. The wetland zone is important for maintaining water quality and quantity. |
| HEW | Wetlands – High Elevation | Located in mid to high elevation valley bottoms. Consists of seasonal and year-round moisture saturated soils. Minimal if any coniferous forest within or adjacent to this zone. Contains summer moose habitat, critical caribou winter habitat and year-round furbearer habitat. |
| MOS | Mosaic | Contains a mixture of forested and open habitats interspersed with wetlands, meadows, and forested lowlands and hills. The zone provides a mixture of foraging and security cover for ungulates. It contains critical winter habitat for moose and caribou; as well the older forested stands provide habitat for furbearer species. |
| IS | Incised Stream | Consists of steep-sloped stream-banks with flat upland areas. Important values include riparian habitat, fish, wildlife movement corridor and water quality and quantity. A mixture of ungulate security and foraging cover primarily on the uplands with a minor component on the steep slopes. Critical moose and elk winter habitat on the upland region. |
| MWA | Warm Aspect Forest (moderate <45% slope) | Consists of both extensive tracks of coniferous tree species and open forested habitat on south-west aspect slopes of gentle to moderate sloped terrain and contains areas of old growth. Depending on the pre-tenure plan area, this zone can provide critical winter elk habitat depending on snow depths. Older forest stands are important year round habitat for a variety of furbearers, while younger willow stands provide critical winter moose habitat. Spring grizzly bear habitat is found on steeper slopes that experience early snowmelt. |
| CAF | Cool Aspect Forest (<45% slope) | Consists of wet and cool forests that occur on gentle to moderately sloped terrain. Some forest stands may be interspersed with smaller interconnected wetland complexes. Older forested stands contain critical |

| | | |
|---|---|---|
| | | winter caribou habitat and important year round habitat for a variety of furbearer species, while shrub areas provide critical moose habitat. Pockets of permafrost are found on north slopes in this habitat type. This zone is a wildlife movement corridor. |
| SWA | Steep Slope Warm Aspect (>45% slope) | Consists of open and forested habitat on steep, southwest facing slopes. A variety of terrain features and habitat types are found in this zone including: alpine meadows, old growth forested stands, parkland, young forests, cliffs, rock outcrops and talus slopes. Furbearers are found in this zone. Steeper slopes are primarily open and provide critical winter Stone's sheep habitat and important year round goat habitat. This zone also provides elk and moose winter habitat and birthing and rearing areas for Stone's sheep, mountain goat and caribou. Higher zone elevations have lower biological productivity. |
| SCA | Steep Slope Cool Aspect (>45% slope) | Consists of open and forested habitat on steep, northeast facing slopes, with pockets of permafrost found on north slopes. A variety of terrain features and habitat types are found in this zone including: alpine meadows, old growth forested stands, parkland, young forests, cliffs, rock outcrops and talus slopes. This zone is primarily mountainous terrain, highly visible throughout the plan area. Critical winter Stone's sheep habitat borders a large portion of this zone. Steep slopes offer security habitat for caribou, elk and moose. This zone is important as a wildlife movement corridor, for Grizzly bear denning and furbearer habitat. Higher zone elevations have lower biological productivity. |
| HEP | High Elevation Plateau | Consists of high elevation plateaus, often surrounded by steep open and treed terrain. The plateaus are primarily open and consist of vegetation types that are particularly sensitive to disturbance due to low biological productivity, shallow soils and low moisture and nutrient conditions. Isolated pockets of coniferous forest are found on some plateaus. These areas are prone to strong winter winds and provide critical winter caribou habitat especially during winters of high snowfall. |
| FFP | Forested Floodplain | Low elevation zone and adjacent to the River Zone. Forested Floodplain zone width is variable, dependent on valley bottom topography. Forest cover is dominated by conifers. May contain stable side/back water channels. Provides foraging, security and thermal cover for a diverse range of wildlife, including: elk, moose, bear, and a variety of furbearers, raptors and songbirds. |
| RFP | Major River Floodplain | A low elevation zone characterized by braided streams bordered by a multi-layered forest canopy and understory. Waterflow varies throughout the year with peak flows generally occurring late spring and early summer. Year to year, the active water channel can change location within the floodplain. The zone provides foraging, security and thermal cover for a diverse range of wildlife, including: elk, moose, bear, furbearers, raptors, and songbirds. High fisheries values exist in this zone. |
| G | Glacier | Consists of areas that have year-round accumulations of ice and snow that exclude the establishment of any vegetation. During summer months, various ungulate species may use accessible portions of glaciers to mitigate high ambient temperatures and/or to seek a reprieve from blood sucking insects. |
| R | River | Stream flow varies throughout the year with peak flows generally occurring late spring and early summer. Year to year, the active channel can change location within this zone. High fisheries values exist in this zone. May contain forested islands. |
| RB | River Breaks | Consists of actively eroding unstable steep-sloped banks of various heights and lengths bordering watercourses. |

## Moose

Moose were most frequently found in three pre-tenure zones during winter: the steep slopes with cool and warm aspects (SCA, SWA) and the low elevation wetlands (LEW) (Table 7, Fig. 21).  These zones included 80% of the moose GPS locations.  Of note was that even though the low elevation wetlands occurred on only 3.5% of the landscape, 16% of the moose use was in these areas (Table 7, Fig. 22).

Moose were observed in all winter habitat suitability classes (Table 7, Fig. 22).  We recognize that use of suboptimal habitats may be affected by animal density, but do not have information that would suggest over-utilization of the 'best' habitats.  Moose were found 4 times more than expected (from what was available on the landscape) in the highest class 1 areas, and more than twice the expected in class 2 areas.  Many of our collared animals concentrated in the low elevation wetlands on the valley floor of the Neves Valley, whereas others tended to frequent slightly higher elevations with steeper aspects (Fig. 21).  As noted in the Besa-Prophet Pre-tenure Plan (Phase I), the maintenance of wildlife values, particularly for moose during winter, is critical in the Neves corridor (Fig. 8).

**Table 7.  Pre-tenure zones (excluding the Upper Prophet) and final habitat suitability (FS) classes as a percentage of the Besa-Prophet Pre-tenure Planning Area compared to locations used by GPS-collared female _moose_ in winter (Nov 2003 – Mar 2004).**

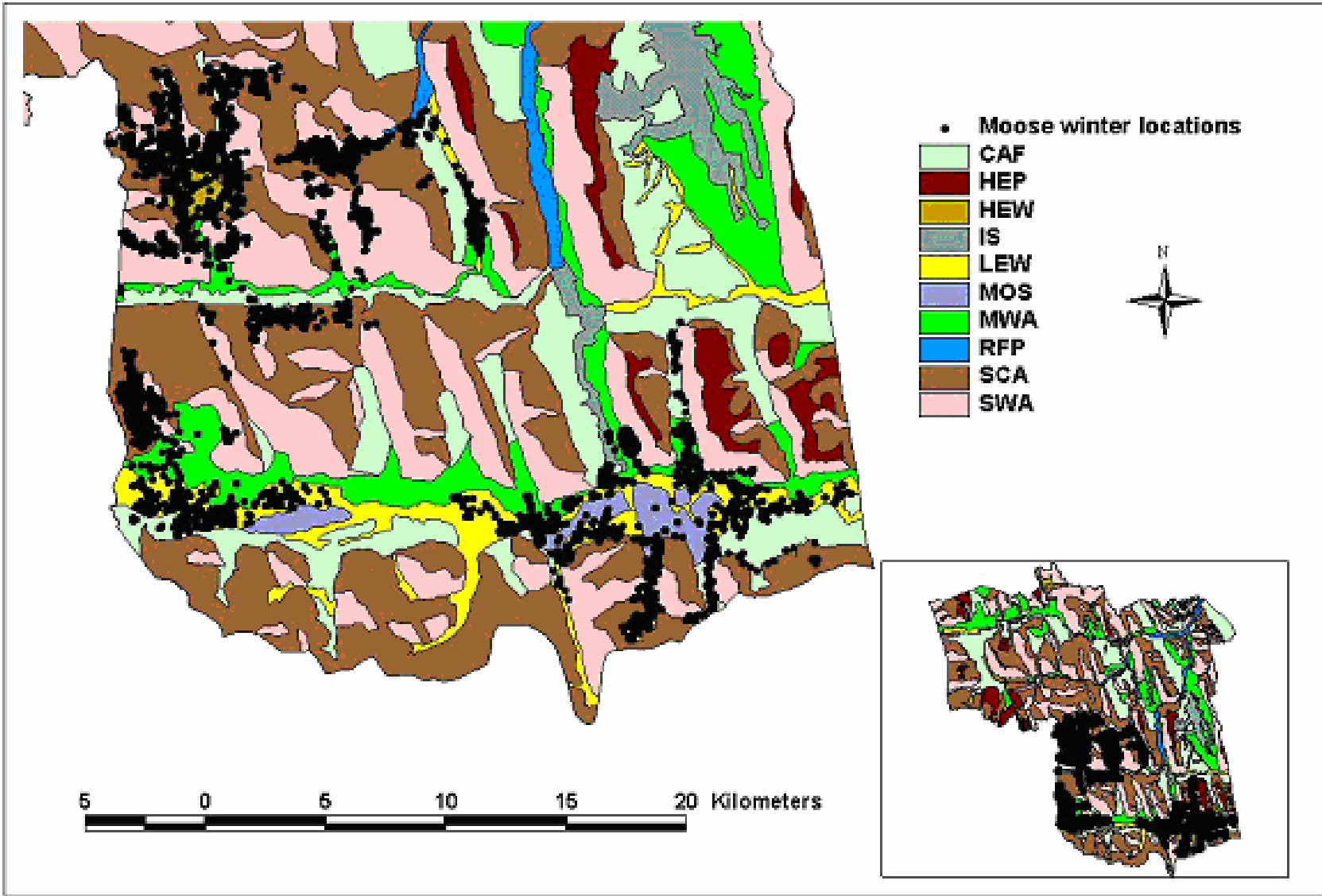| Pre-tenure zone | % of Area | # GPS Locations | % Use |
|---|---|---|---|
| CAF | 17.31 | 339 | 7.86 |
| HEW | 3.94 | 127 | 2.95 |
| HEP | 0.87 | 0 | 0.00 |
| IS | 1.71 | 4 | 0.09 |
| LEW | 3.46 | 700 | 16.23 |
| MOS | 0.84 | 110 | 2.55 |
| MWA | 11.64 | 274 | 6.35 |
| RFP | 1.65 | 3 | 0.07 |
| SCA | 31.92 | 1636 | 37.94 |
| SWA | 26.67 | 1119 | 25.95 |
| | | $n = 4312$ | |
| **FS Class** | **% of Area** | **# GPS Locations** | **% Use** |
| 1 | 1.84 | 370 | 8.55 |
| 2 | 9.50 | 926 | 21.39 |
| 3 | 22.63 | 1,264 | 29.20 |
| 4 | 24.45 | 952 | 21.99 |
| 5 | 23.93 | 662 | 15.29 |
| 6 | 17.65 | 155 | 3.58 |
| | | $n = 4,329$ | |

**Figure 21.** Winter GPS locations of radio-collared female <u>moose</u> (Nov 2003 – Mar 2004) in the southern Besa-Prophet Pre-tenure Planning Area, in relation to zones designated in the Besa-Prophet Pre-tenure Plan.
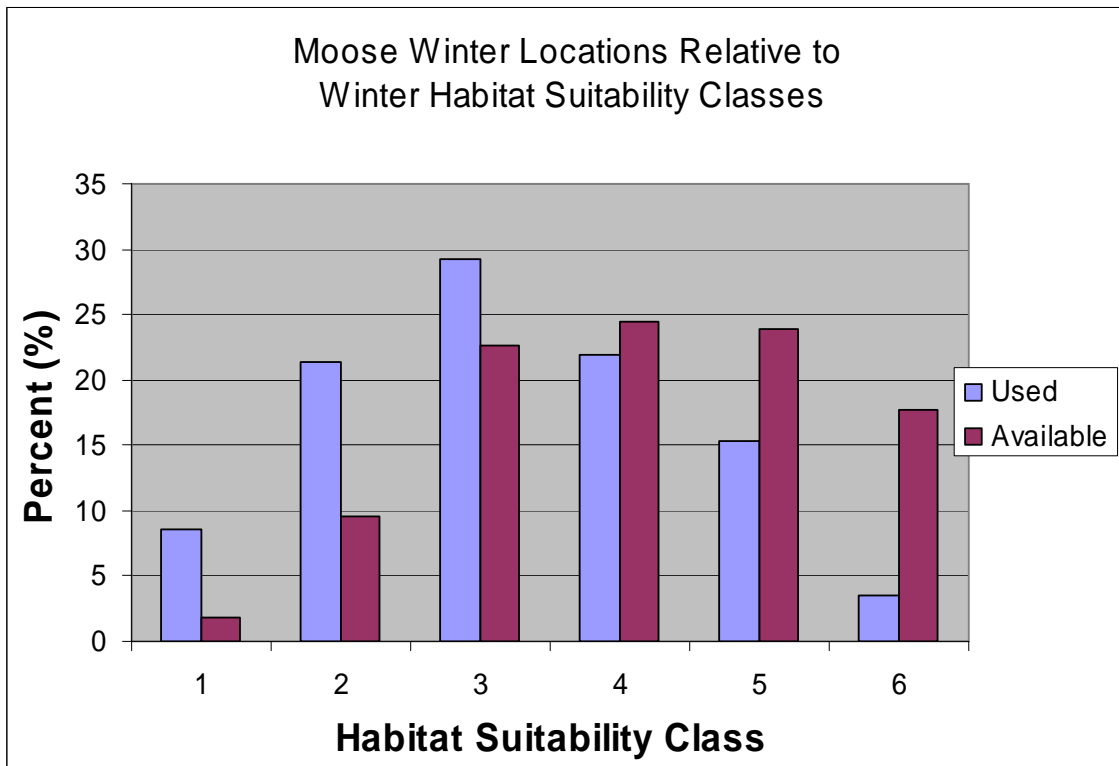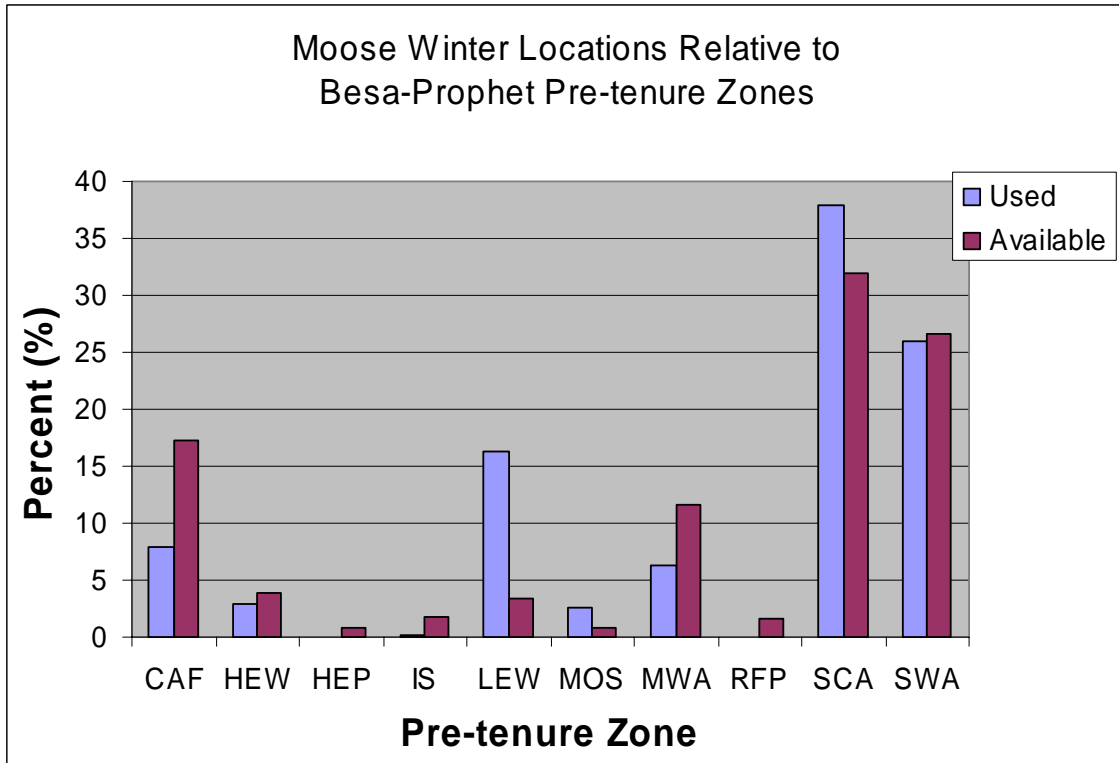
**Figure 22. Winter GPS locations of radio-collared female <u>moose</u> in relation to zones designated in the Besa-Prophet Pre-tenure Plan and availability of winter habitat suitability classes (developed by BC Ministry of Environment, Fort St John, BC).**

Across the Besa-Prophet, 67% of the area was categorized as relatively poor class 4-6 suitability for moose (Table 7, Fig. 23). In contrast, 59% of the locations for moose were in the areas with the highest suitability (classes 1-3) (Table 7, Fig. 22). This emphasizes the importance of the higher-class areas that occur on only 33% of the landscape. It also suggests that the evaluation used in the Ministry of Environment HSI modelling efforts reasonably reflects winter habitat values for moose. Slight differences in sample sizes between our GPS use locations relative to the pre-tenure biophysical zones and to habitat suitability classes occurred because of small differences in the boundaries of different map files.
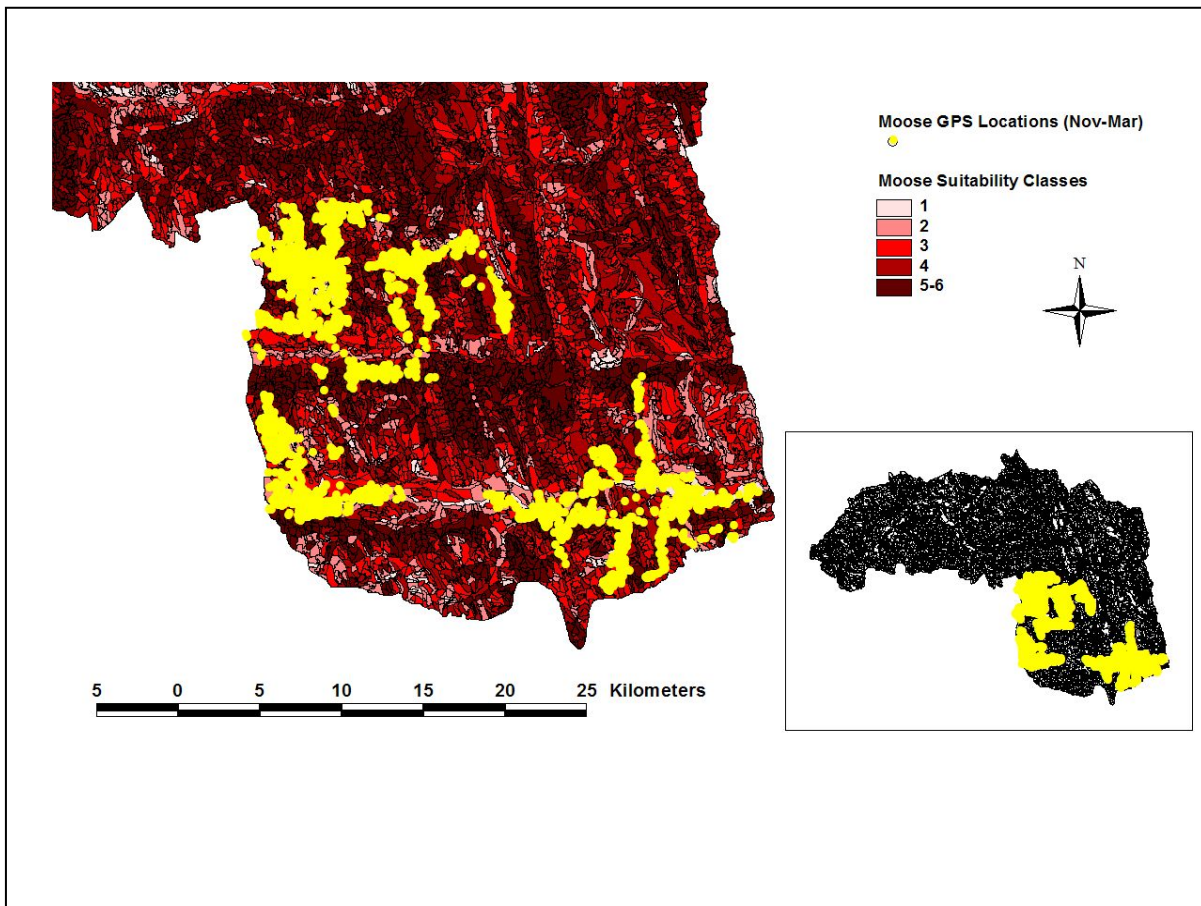


**Figure 23. Winter GPS locations of radio-collared female <u>moose</u> from November through March in the southern Besa-Prophet Pre-tenure Planning Area along Neves Creek and the Besa River in relation to winter habitat suitability classes (BC Ministry of Environment, Fort St John, BC).**

## Elk

Elk were overwhelmingly found on steep slopes with warm aspects (SWA) during winter, with some much lesser use of cool aspects (SCA) (Table 8, Fig. 24). These 2 pre-tenure zones included more than 95% of all elk locations even though they encompassed only 59% of the landscape. The SWA provides important winter habitat for elk (British Columbia Ministry of Sustainable Resource Management 2002).

Elk were observed in all 6 habitat suitability classes (Table 8, Figs. 25, 26), although as with moose, most locations were in the top 3 classes. Across the Besa-Prophet, 29% of the area was categorized in the top 3 habitat suitability classes for elk in winter, and more than half (58%) of the use locations for elk were in those classes. This suggests that HSI modelling efforts of the Ministry of Environment generally reflect winter habitat values for elk. However, the largest difference between elk use and availability of habitat suitability classes occurred in class 3, when the use locations were more than twice what might be expected based just on availability. Given that 88% of elk observations were consistently in the SWA, it would seem that HSI class 1 could be (and should be) fine-tuned to accommodate most elk locations. Our selection models indicated that elk select more than topographical features (as in the pre-tenure zones, Table 8) and therefore, there is the opportunity for a refined HSI classification that includes findings from this study.

**Table 8. Pre-tenure zones (excluding the Upper Prophet) and final habitat suitability (FS) classes as a percentage of the Besa-Prophet Pre-tenure Planning Area compared to GPS locations of collared female <u>elk</u> in winter (Jan – Mar 2005, Nov 2005 – Jan 2006).**

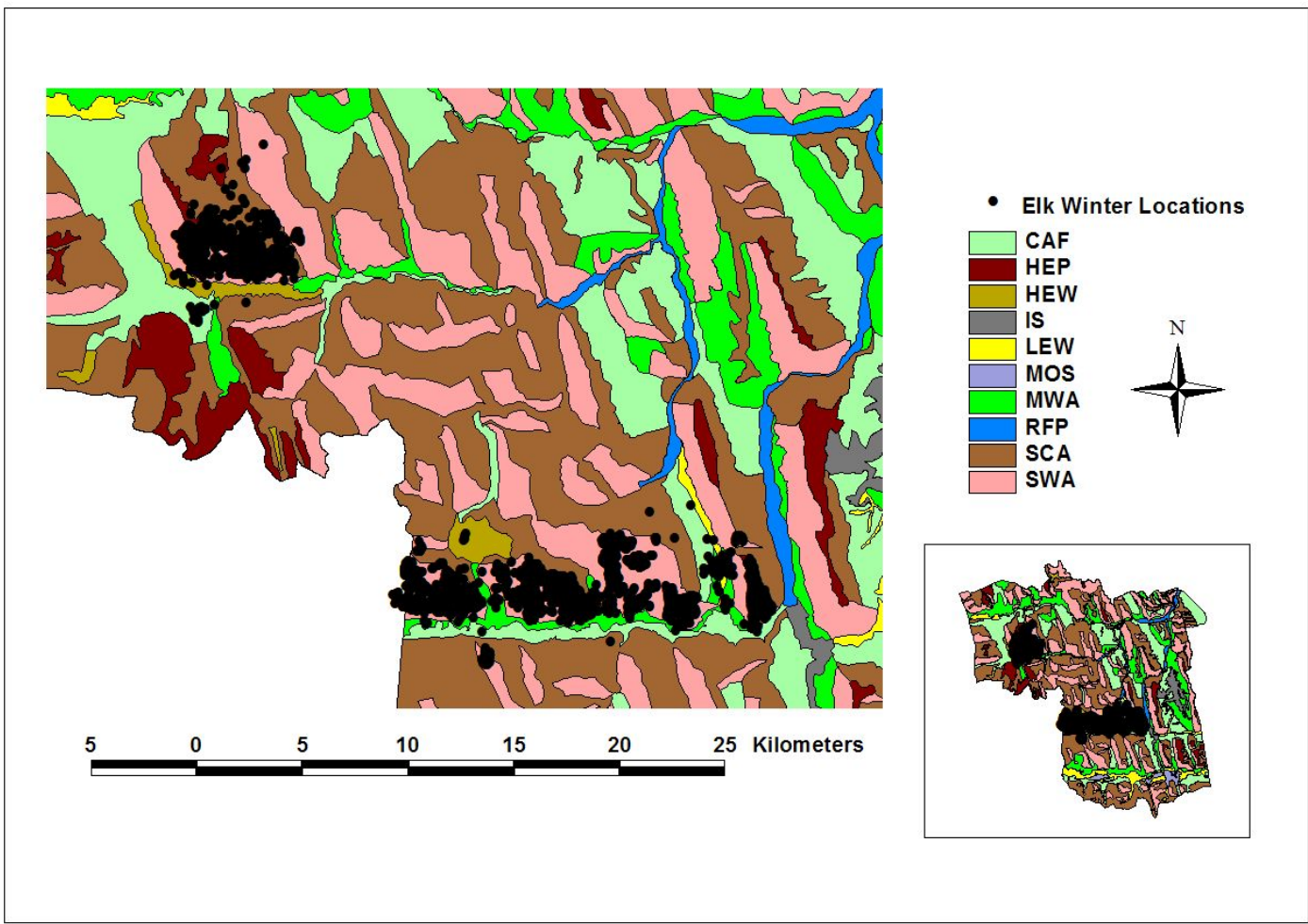| Pre-tenure zone | % of Area | # GPS Locations | % Use |
|---|---|---|---|
| CAF | 17.31 | 31 | 0.51 |
| HEW | 3.94 | 145 | 2.36 |
| HEP | 0.87 | 13 | 0.21 |
| IS | 1.71 | 0 | 0.00 |
| LEW | 3.46 | 13 | 0.21 |
| MOS | 0.84 | 0 | 0.00 |
| MWA | 11.64 | 66 | 1.08 |
| RFP | 1.65 | 0 | 0.00 |
| SCA | 31.92 | 495 | 8.07 |
| SWA | 26.67 | 5,369 | 87.56 |
| | | $n = 6,132$ | |
| **FS Class** | **% of Area** | **# GPS Locations** | **% Use** |
| 1 | 4.06 | 509 | 8.15 |
| 2 | 9.53 | 876 | 14.03 |
| 3 | 15.90 | 2,226 | 35.65 |
| 4 | 20.87 | 869 | 13.92 |
| 5 | 25.43 | 1,186 | 18.99 |
| 6 | 24.21 | 578 | 9.26 |
| | | $n = 6,244$ | |

**Figure 24. Winter GPS locations of radio-collared female <u>elk</u> (Jan – Mar 2005, Nov 2005 – Jan 2006) in the Besa-Prophet Pre-tenure Planning Area, in relation to zones designated in the Besa-Prophet Pre-tenure Plan.**
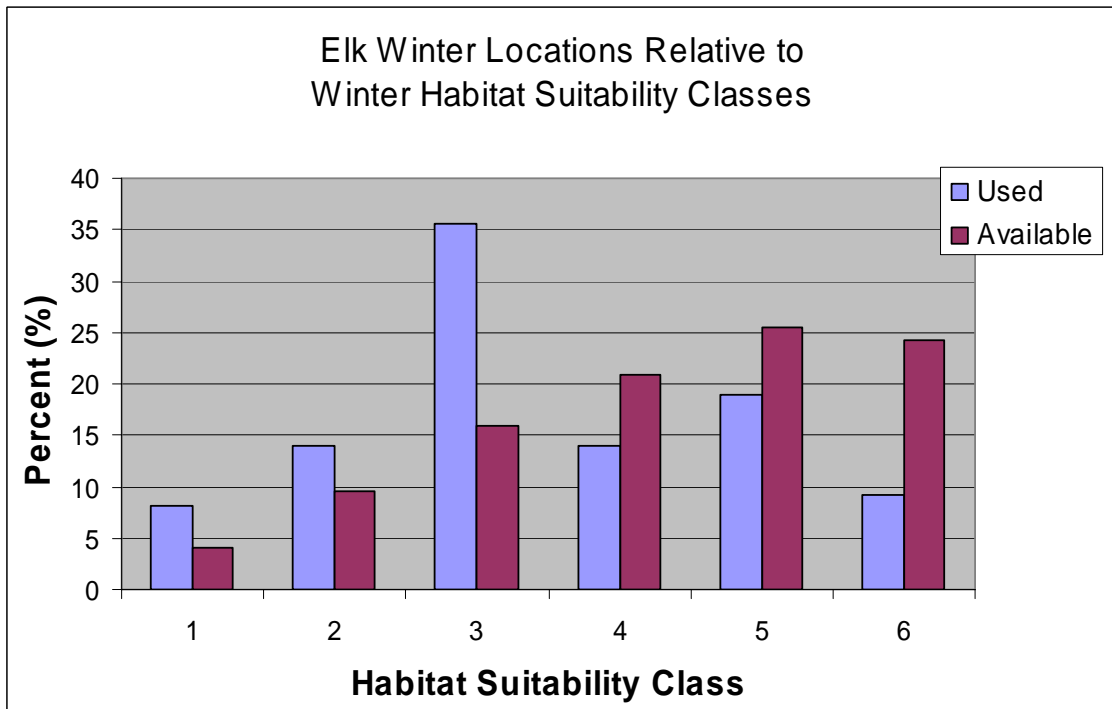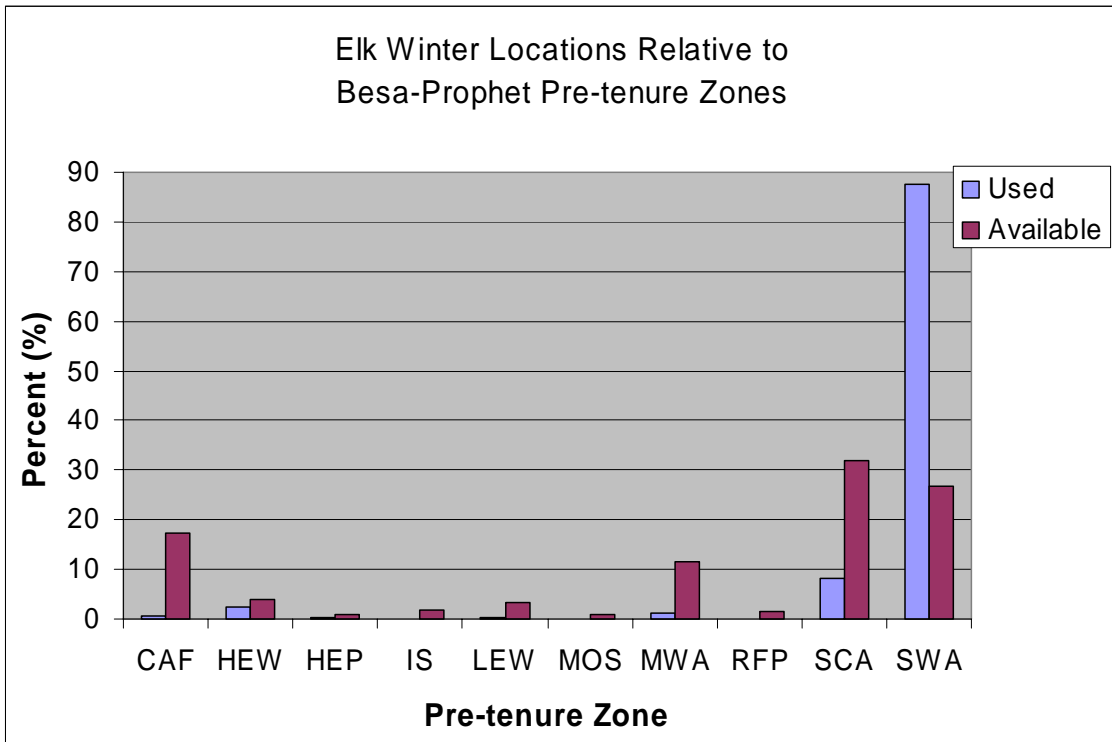
**Figure 25. Winter GPS locations of radio-collared female elk in relation to zones designated in the Besa-Prophet Pre-tenure Plan and availability of winter habitat suitability classes (developed by BC Ministry of Environment, Fort St John, BC).**
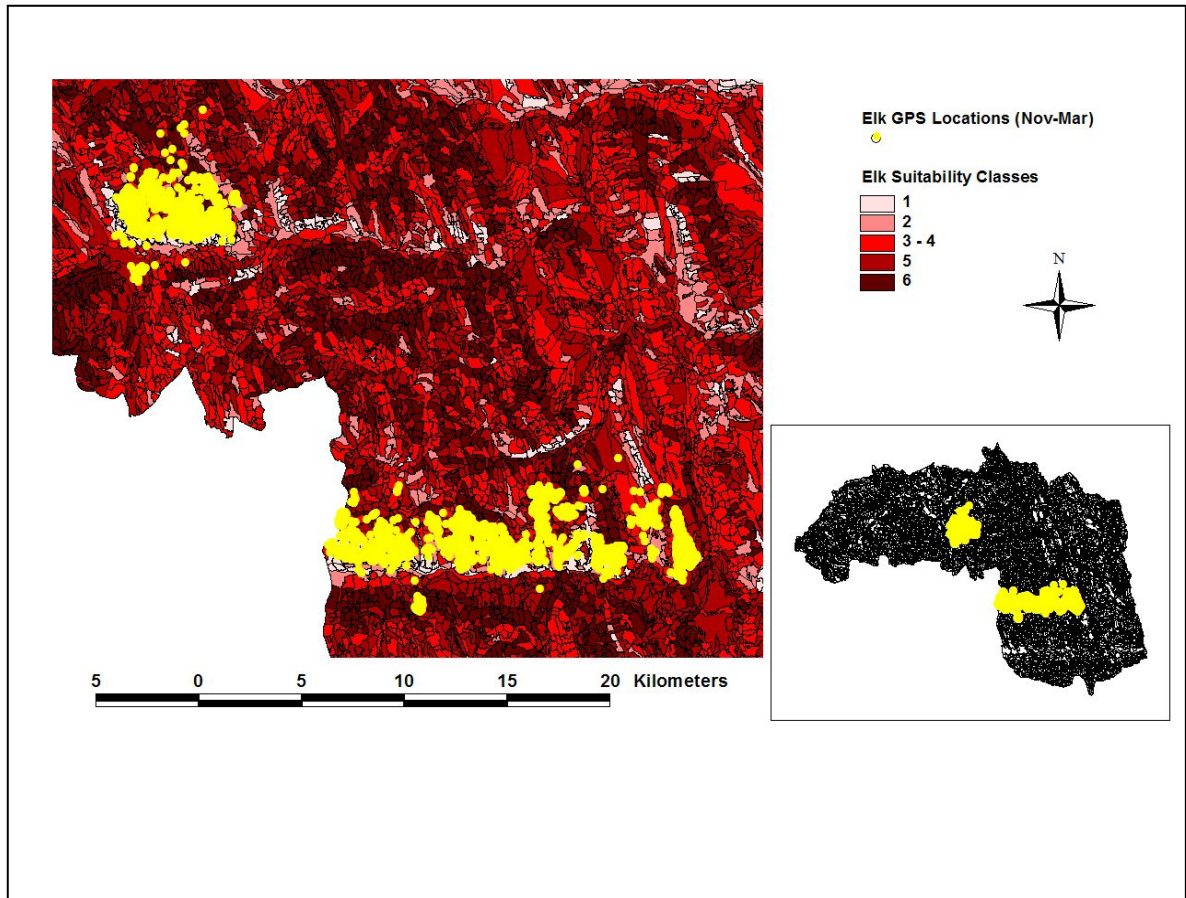
**Figure 26. Winter GPS locations of radio-collared female <u>elk</u> from November through March in the Besa-Prophet Pre-tenure Planning Area along the Besa River and Richards Creek in relation to winter habitat suitability classes (BC Ministry of Environment, Fort St John, BC).**

## *MANAGEMENT RECOMMENDATIONS*

Rarely is there the opportunity to quantify ecological relationships within relatively undisturbed ecosystems and to obtain baseline control data that can be used subsequently to monitor impacts. The general trend in many ecological studies has been to examine a system that has already been impacted to large extent by human activity and then attempt to make inferences about how the system has changed. In our study, the potential to make important contributions towards maintaining predator-prey ecosystems is significant, especially because there has been relatively little human interference in the Besa-Prophet region to date. Our data from the Besa-Prophet provide inputs to a management and conservation framework that is based on observed, natural ecosystem function. We believe that planning processes should include knowledge of ecosystem-level processes, and that the challenge will be to compile and use data obtained at different scales (e.g., in-depth biological knowledge obtained from

relatively small scales in studies such as ours, conservation area designs at larger scales, and cumulative impact frameworks). Sustainable management strategies for natural resources and effective planning processes in the Besa-Prophet region must include details from studies such as this research on the large-biomass ungulate species (moose and elk) to best operationalize activity on the ground while still maintaining ecological integrity.

Moose and elk are both very adaptable species that do well in diverse environments and they are keystone species that affect ecosystem processes. The Besa-Prophet is a highly heterogenous landscape that provides options to meet nutritional requirements and to allow trade-offs between forage and predation risk. Consequently, as in other diverse mountainous landscapes, animals may use several different strategies to arrive at the same endpoints: survival and successful reproduction. Our data provide some preliminary insights into habitat use and selection by moose and elk, but they are limited to small sample sizes and only one year of information for each species, and generate numerous follow-up questions. The fix-success rate of our GPS locations was lower for moose than elk, but information for both species may be biased slightly against more closed cover types that can inhibit successful transmission of data via satellites (Frair et al. 2004). The GPS information from our study is also limited to females. Both moose and elk show strong sexual segregation (e.g., Peek and Lovaas 1968, Miller and Litvaitis 1992), and females may be expected to use habitats differently than males across the study area (e.g., predation risk affects habitat selection by female elk more than male elk, Creel et al. 2005). Sizes of seasonal ranges may also differ between the sexes (e.g., female moose use larger areas in summer and smaller areas in winter than males, Dussault et al. 2005a). Even with such habitat options and constraints, and data limitations, our findings show similarities with other studies.

Moose, as with other species such as caribou (Rettie and Messier 2000) and grizzly bears (McLoughlin et al. 2002), may select habitats in a hierarchical fashion, which permits them to avoid the most limiting factor at large scales. For example, they may select home ranges on the landscape that minimize predation risk, particularly from wolves, and within those home ranges, select for high forage biomass. Dussault and others (2005b) found that moose in Quebec avoided areas with the lowest snowfall on the landscape, presumably to spatially segregate from wolves during winter. Studies in British Columbia with more topographical diversity, showed selection for low snow depths when traveling and for more open areas with high shrub cover for foraging (Poole and Stuart-Smith 2005, 2006). In the latter studies, the strongest single determinant of late-winter habitat use was decreasing elevation, which may be a surrogate for snow depth. Snow depth is one of the primary factors affecting late-winter distribution of moose populations (Peek 1997). For moose in the western interior mountainous regions, interactions between snow depths and predation risk may differ substantially from those in the east. Moose in the Besa-Prophet showed movements to lower elevations throughout the winter (Fig. 11), as observed in other interior mountainous areas (e.g., Pierce and Peek 1984, van Dyke et al. 1995), and they selected for vegetation classes with high available forage biomass (e.g., low shrubs, deciduous burns; Fig. 16). Predation risk was not a significant influence in our winter selection models. During calving, however, moose in the Besa-Prophet selected for locations that were lower in bear risk than what was available around them. Poole and others (2007) reported that moose in southern British Columbia showed 2 elevational strategies during calving related to risk. Climber moose moved up in elevation to areas with lower forage quality and quantity and farther from lower elevations with more grizzly bears). Non-climber moose calved at low elevations with much

higher forage values but potentially increased risk of predation. Given that grizzly bears in the Besa-Prophet tend to remain in higher areas during spring (Parker and Milakovic 2007), moose at lower elevations would avoid bear risk *and* have access to early green-up of shrub vegetation. This calving strategy, however, would come with the potential risk of wolf predation, given than wolves select for shrub vegetation in spring (Parker and Milakovic 2007). Our selection models indicated that by summer, moose locations were in areas of high wolf risk; correspondingly, our analyses of the food habits of wolves confirmed that a high portion of the diet was moose, of which ~60% were juveniles (Parker and Milakovic 2007).

Elk are generalist feeders that maximize their food intake through mechanisms of habitat selection rather than food selection (Irwin and Peek 1983). They typically select seasonal ranges based on forage biomass and forest cover in summer, and with additional snow constraints during winter (e.g., Anderson et al. 2005). Unlike studies in Alberta, Yellowstone, and the mid-western US, elk in the Besa-Prophet did not typically have larger range sizes in winter than summer (Table 3). This may indicate that snow is more limiting in our system, or that food is not limiting, particularly on the wind-blown south-facing slopes in the Besa-Prophet. The elk in our study did move to lower elevations during the winter as do elk in Yellowstone (Boyce et al. 2003), presumably to take advantage of increased food availability. Numerous other studies have addressed the role of predation in habitat selection by elk and have shown that elk respond to wolves by shifting habitats (e.g., Wolff and Van Horn 2003, Fortin et al. 2005, Mao et al. 2005). The presence of wolves increases the probability that elk use locations with more conifers, given that predation risk for elk is greater in open areas (Creel et al. 2005). In the central foothills of Alberta, for example, elk remain typically within 30 m of cover (Frair et al. 2005). How quickly elk respond to wolf presence is unknown, but it is usually within 1 day (Creel et al. 2005). Therefore, for elk in the Besa-Prophet, where habitats used by elk overlap to some extent those of another alternative relatively abundant prey species such as moose, habitat selection is consequently very dynamic. Interestingly, elk moved up in elevation to calve. The elk locations were in areas of relatively low vegetation biomass during calving and not in the highest quality vegetation in summer, which would presumably be selected to minimize predation risk. However, these locations were still close to high wolf risk during calving and high bear risk in summer. Bears in the Besa-Prophet do not tend to prey significantly on elk during spring or summer. The diets of wolves, however, include a large component of elk (as well as moose) in summer (Parker and Milakovic 2007).

Prescribed burning has commonly been used to maintain and improve wildlife habitat in the foothills of the Rocky Mountains, and major elk wintering areas are associated with these burns (e.g., Peck 1987, Peck and Peek 1991). Fires result in shrub and herb-dominated communities and increases in forage biomass, often with higher nutritional value. Intentional burning and its impacts on vegetation communities have been linked to the increase and expansion of elk herds in northeastern British Columbia (Luckhurst 1973, Silver 1976, Parminter 1983). In the Besa-Prophet, prescribed fire has been officially managed since the early 1980's (Table 5), although there also have been natural burns and locally initiated fires before and since that time. Anecdotal evidence suggests that elk populations are increasing and expanding (Greg Williams, local outfitter, personal communication). In our study we observed that moose also made use of the older deciduous burn vegetation (Figs. 9, 16). With the expansion of the prey base, and rapidly increasing elk populations in particular, increases in

wolf numbers should be expected to affect predator-prey dynamics. Prescribed burning also may be providing additional opportunities for grizzly bears that select for burned vegetation classes throughout the non-denning period (Parker and Milakovic 2007).

Densities of moose and elk populations in the Besa-Prophet are not well documented. Very rough estimates are approximately 2000 moose and 500 elk (J.P. Elliott, BC Ministry of Environment, Fort St John, personal communication). It is important to note that habitat use and selection will vary as a consequence of population density (Boyce et al. 2003). In follow-up studies in the Muswka-Kechika Management Area that continue to unravel the interactions among the large ungulate species, their predators, and habitat management, we recommend that population estimates and distributions are included. To truly understand patterns of habitat selection and increase our confidence in predicting patterns of use, it is also important to conduct analyses at multiple scales (e.g., Boyce et al. 2003). We recommend that future studies analyze animal responses to vegetation, topography, and predators to determine what factors are most important in selection of seasonal ranges on the landscape, as well as within those seasonal ranges.

We recommend the following to incorporate this research into management decision-making and to follow up with projects that expand on our research findings in the Besa-Prophet:

1)  Update the current Besa-Prophet Pre-tenure Plan. The Plan (British Columbia Ministry of Sustainable Resource Management 2004) allows for adaptive management and inclusion of new information. Our findings should be used to fine-tune the Plan if necessary. Inclusion of an appendix that provides recommended or suggested ways to minimize impacts on moose and elk would be helpful to commercial and recreational users of the area. This could be accommodated easily by adding an appendix of much of the information that was provided for each of the Planning Units in the original Besa-Prophet Pre-tenure Plan Phase I (British Columbia Ministry of Sustainable Resource Management 2002).

2)  Determine if there are distinct elevational differences in calving strategies between moose and elk. Data from our preliminary study showed that after late winter, female elk moved up in elevation to calve whereas moose did not, but this information may be confounded by yearly variation and small sample sizes. It seems unlikely that this elevation movement was in response to different snow depths or plant green-up between June 2003 (moose) and June 2005 (elk) because both moose and elk moved consistently down in elevation throughout the winter, suggestive of similar responses to snow and forage in both years. Elk returned to higher elevations to calve and moose did not.

3)  Determine if there are different movement strategies used by moose and whether these occur in relation to calving. The large movements observed by some of the collared moose may have occurred in animals without calves or those that lost calves.

4)  Define consequences of range burning. If prescribed burns are enabling increases in elk populations in the Besa-Prophet, there may be potential for competition between elk and Stone's sheep during some times of the year. There is also the potential that

with expanding elk populations, predator numbers also will increase.  If so, it is likely that wolves will expand into broader areas, potentially preying on other ungulates such as caribou and Stone's sheep more frequently.  Additional studies need to be specifically designed to determine how intensity, frequency, and locations of prescribed burns affect habitat use by ungulates (principally elk, moose, and Stone's sheep) and subsequently the focal predators (e.g., wolves and grizzly bears).

## *ACKNOWLEDGMENTS*

**Figure 27.  Authors Kathy Parker and Mike Gillingham, University of Northern British Columbia.**

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